Acta Scientiae et Intellectus
Volume: 11, No: 1,Year: 2025, pp.: 52-64
E-ISSN: **2519-1896**
URL: https://actaint.com/

# The Influence of the 2D:4D Finger Length Ratio on Swimming Performance

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Research Article
DOI: 10.5281/zenodo.17447131

*Received:* 22.05.2025 *Accepted: 20*.08.2025 *Published*: 25.08.2025

**Abstract**

This study aimed to investigate the influence of the 2D:4D finger length ratio on swimming performance. A total of 40 swimmers (19 males, 21 females) with a mean age of 12.85 participated in the research, selected from a swimming competition held in Çorum, Turkey. Participants' anthropometric characteristics, sports experience, and 2D:4D digit ratios were measured. Swimming performance was evaluated using 50 m and 100 m freestyle times. Finger lengths were measured with a digital caliper, and the 2D:4D ratio was calculated by dividing the length of the second finger by that of the fourth finger for each hand. Data were analyzed using independent samples t-tests and Pearson correlation. Results showed no statistically significant differences between genders in terms of height, weight, age, sports experience, finger lengths, or swimming performance ($p > 0.05$). Furthermore, no significant correlation was found between 2D:4D ratios and swimming performance. These findings suggest that the 2D:4D ratio is not a decisive predictor of performance in swimming, a closed-skill sport. This study contributes to the existing literature and highlights the need for broader research across various age groups and sports disciplines.

**Keywords:** 2D:4D Ratio, Swimming Performance, Finger Length

## INTRODUCTION

The differential exposure to testosterone and estrogen hormones during the prenatal period plays a critical role in determining the ratio between the lengths of the second (index) and fourth (ring) fingers, known as the 2D:4D ratio (Manning et al., 1998; Ceylan et al., 2022; Karaoğlan et al., 2025). This ratio is considered a biological indicator of the amount of androgen (testosterone) to which an individual is exposed in the womb. It has been reported that the mean 2D:4D ratio remains relatively stable throughout gestation and adulthood (Galis et al., 2010; Hollier et al., 2015). In general, males tend to have lower 2D:4D ratios than females—that is, their ring finger is typically longer relative to their index finger (Manning et al., 1998; Coates et al., 2009; Hönekopp & Watson, 2010). Moreover, significant differences among ethnic groups have been documented; for example, individuals of African descent generally have lower 2D:4D ratios compared to those of Caucasian ancestry (Manning et al., 2007). A large body of literature has demonstrated associations between the 2D:4D ratio and a range of physiological and psychological traits, including fertility, health, athletic ability, and aggression (Manning et al., 2001; Coates et al., 2009).

 

It has been proposed that the 2D:4D ratio may be related to physical performance (Hönekopp & Schuster, 2010; Eklund et al., 2020). Research indicates that male athletes generally exhibit lower 2D:4D ratios than non-athletes (Manning et al., 2001; Bennett et al., 2010; Giffin et al., 2012; Adamczyk et al., 2021). Similarly, studies conducted on female athletes have identified differences in digit ratios when compared with control groups (Pokrywka et al., 2005; Giffin et al., 2012; Adamczyk et al., 2021). Among female athletes, the relationship between 2D:4D ratio and performance has been explored in alpine skiing (Manning et al., 2001), endurance running (Manning et al., 2007), fencing (Voracek et al., 2006), and rowing (Hull et al., 2015). Most of these studies have reported significant associations between digit ratio and athletic performance. Similarly, positive correlations between 2D:4D ratio and physical fitness (Hönekopp et al., 2006) or sporting talent (Paul et al., 2006) have been found among women participating in recreational physical activities. However, the meta-analysis conducted by Hönekopp and Schuster (2010) challenged the notion that the right-hand 2D:4D ratio is a stronger predictor of athletic ability, suggesting that this predictive value may vary depending on the sport (e.g., the right-hand ratio may be more influential in fencing). Consequently, some studies have examined both hands, while others have focused on the right hand alone or on the difference between the two hands (Bennett et al., 2010; Peeters et al., 2013; Wu et al., 2022). Recent studies have examined the association between 2D:4D ratio and sports that require both open skills and closed skills (Bennett et al., 2010; Lombardo & Otieno, 2021; Wu et al., 2022; da Silva Neto et al., 2025). In open-skill sports such as basketball, football, and rugby, moderate negative correlations have been reported between 2D:4D ratio and level of competitiveness (Nobari et al., 2021). Rahman and Sharma (2024) found that male basketball players competing at different levels (club, state, national, and international) displayed distinct mean 2D:4D ratios, with elite players having lower ratios. Similarly, Eklund et al. (2020) observed that among semi-professional female athletes, those with lower 2D:4D ratios demonstrated better match performance and were more likely to be included in the starting lineup. These findings suggest that the 2D:4D ratio may be associated with athletic performance and that prenatal androgen exposure could influence athletic potential. Nevertheless, most of the existing literature has focused on open-skill team sports, while closed-skill individual sports—particularly swimming—have received relatively limited attention. Swimming performance depends on factors such as coordination, endurance, technical efficiency, and neuromuscular control, which may be influenced by biological variations shaped by prenatal hormonal effects. Therefore, investigating the relationship between the 2D:4D digit ratio and

swimming performance offers an important research avenue for understanding the interaction between biological determinants and physical performance.

The aim of this study is to examine the relationship between the 2D:4D digit ratio and swimming performance. Specifically, it seeks to determine whether the amount of prenatal testosterone exposure (indicated by a lower 2D:4D ratio) is reflected in individuals' swimming performance. By contributing to the understanding of biological predictors of athletic performance, this study offers a novel perspective, particularly for closed-skill sports where environmental factors are more controllable. The findings may help inform athlete selection and talent identification processes by emphasizing the potential role of biological indicators. It is hypothesized that swimmers with lower 2D:4D ratios will exhibit higher swimming performance compared to those with higher ratios, a difference that may be linked to the possible effects of prenatal androgen exposure on motor skills and physical efficiency.

## MATERIALS AND METHODS

### Participants

The study included athletes who were actively engaged in swimming in the province of Çorum, Türkiye. Participants were selected from swimmers who took part in official swimming competitions organized in Çorum. All measurements were conducted prior to the competitions. Initially, anthropometric measurements were obtained from the participants, followed by the determination of finger lengths. After completing these measurements, the athletes participated in 50-meter and 100-meter freestyle swimming events, and their recorded race times were used as indicators of performance. A total of 40 swimmers (19 males and 21 females) voluntarily participated in the study (Figure 1). The participants' physical and demographic characteristics were as follows: mean height 162.85 ± 7.05 cm, body weight 57.77 ± 7.88 kg, mean age 12.85 ± 0.67 years, and mean sports experience 5.35 ± 1.26 years. The mean left-hand 2D:4D ratio was 1.06 ± 0.12, while the mean right-hand 2D:4D ratio was 1.25 ± 0.26.

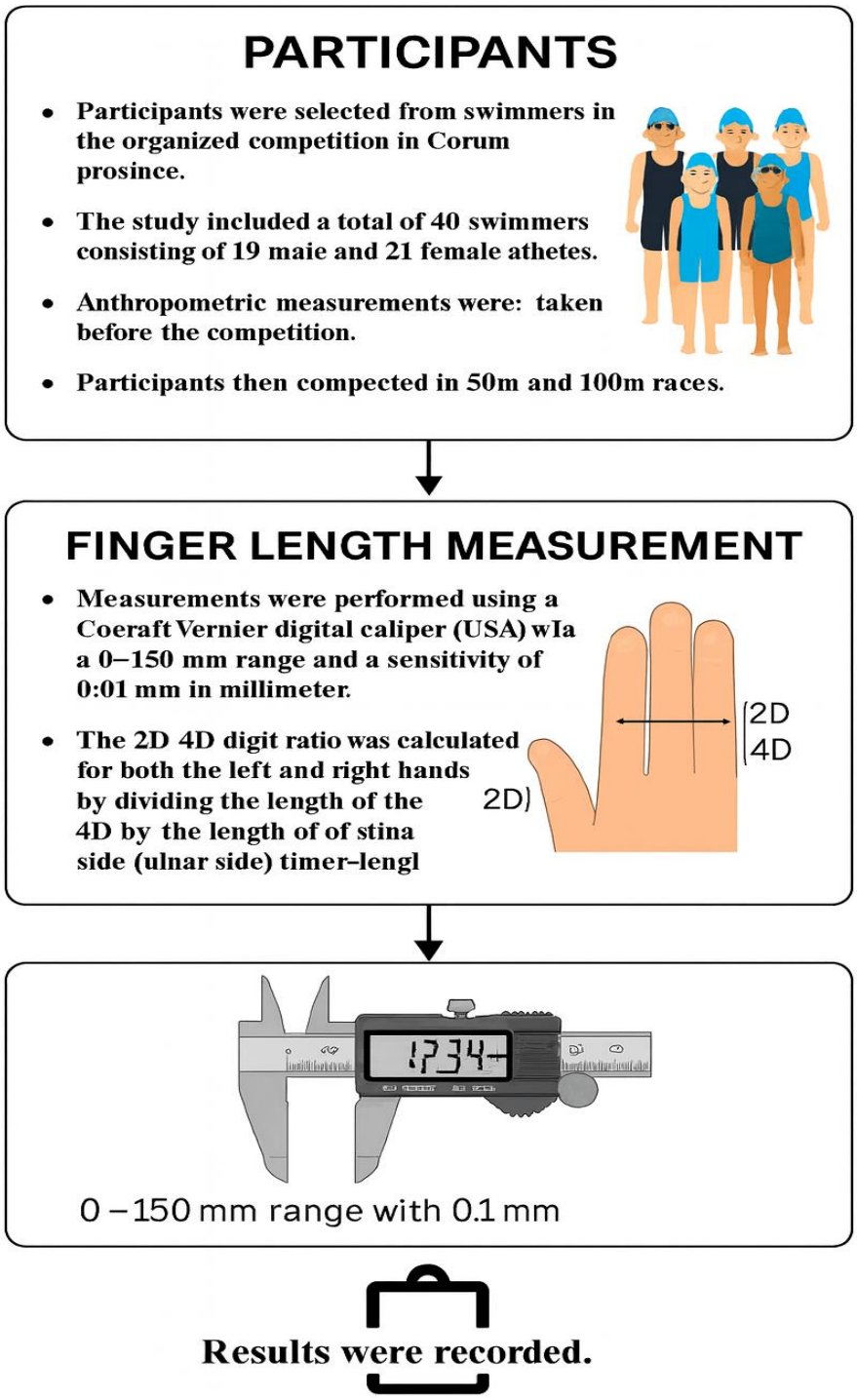


**Figure 1. Flowchart**

### Finger Length Measurement

To determine finger lengths, the second (2D) and fourth (4D) digits of both hands were measured in millimeters (mm) using a Vernier digital caliper (Cocraft, USA) with a measurement range of 0–150 mm and a precision of 0.01 mm (Figures 2–3). The measurement points were defined from the midpoint of the proximal crease of the proximal phalanx to the tip

of the distal phalanx. The 2D:4D ratio for each participant was calculated by dividing the length of the second digit (2D) by the length of the fourth digit (4D). All measurements were recorded in millimeters and later converted to centimeters (cm) for statistical analysis. To minimize measurement error, all measurements were conducted independently by the researchers using a double-blind–like procedure (Eklund et al., 2020).

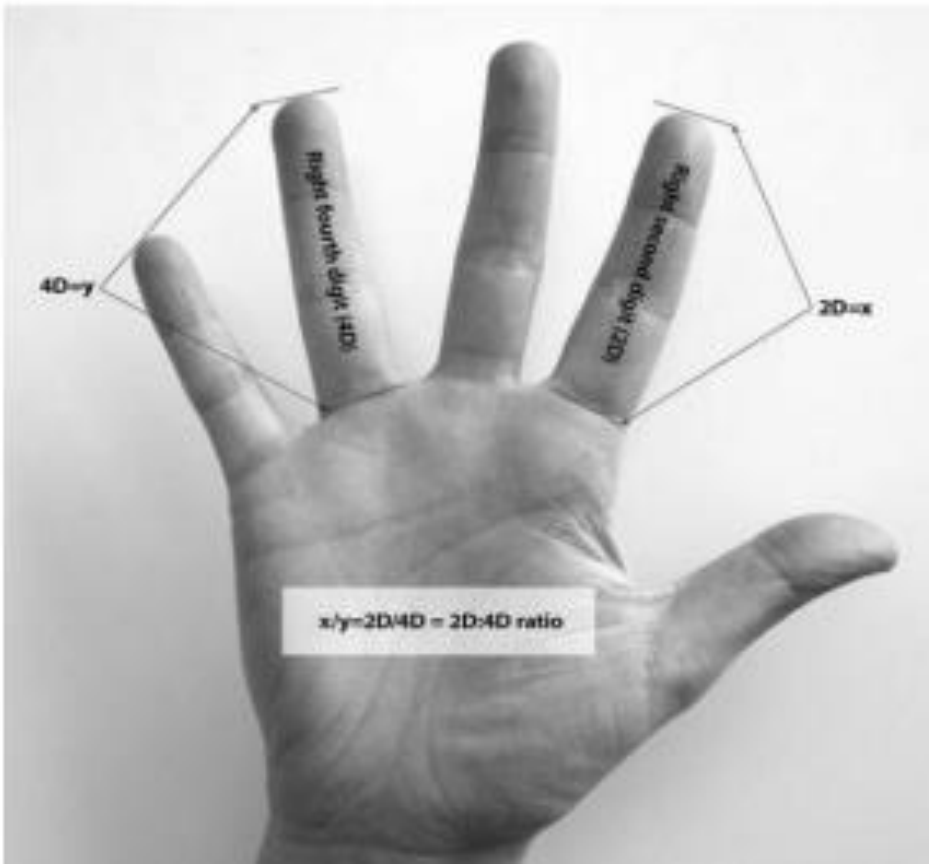


**Figure 2. Measurement and calculation of the second and fourth digit (2D:4D) ratio (Eklund et al., 2020).**

**Figure 3. Digital Caliper**

## DATA ANALYSIS

The data obtained within the scope of the study were analyzed using descriptive statistics (arithmetic mean and standard deviation) and comparative analyses. An independent samples t-test was performed to determine gender-based differences. Mean and standard deviation values were calculated for participants' age, height, body weight, sports experience, finger lengths (2D and 4D), and 2D:4D ratios. A significance level of $p<0.05$ was adopted for all statistical analyses. In addition, Pearson's correlation analysis was conducted to examine the possible effects of 2D:4D digit ratios on sports experience and swimming performance. All analyses were performed using the SPSS 25.0 statistical software (IBM, USA).

## RESULTS

A total of 40 swimmers participated in the study, consisting of 19 males and 21 females. The mean height of the participants was 162.85 ± 7.05 cm, mean body weight 57.77 ± 7.88 kg, mean age 12.85 ± 0.67 years, and mean sports experience 5.35 ± 1.26 years. The mean left-hand 2D:4D ratio was 1.06 ± 0.12, whereas the mean right-hand 2D:4D ratio was 1.25 ± 0.26.

**Table 1. Participants' characteristics by gender**

| Variable | Gender | n | Mean ± Std. Deviation |
|---|---|---|---|
| Height (cm) | Male | 19 | 165.88 ± 7.13 |
| | Female | 21 | 160.36 ± 6.21 |
| Body Weight (kg) | Male | 19 | 61.66 ± 8.33 |
| | Female | 21 | 54.59 ± 6.15 |
| Age (years) | Male | 19 | 13.00 ± 0.70 |
| | Female | 21 | 12.72 ± 0.64 |

When the participants' demographic characteristics were examined by gender, the mean height of male participants was 165.88 ± 7.13 cm, while that of female participants was 160.36 ± 6.21 cm. The mean body weight of males was 61.66 ± 8.33 kg, whereas females had a mean of 54.59 ± 6.15 kg. Regarding age, the average was 13.00 ± 0.70 years for males and 12.72 ± 0.64 years for females. These findings indicate minor differences between groups in terms of height, body weight, and age.

**Table 2. Comparison of sports experience, performance, finger lengths, and 2d:4d ratios by gender**

| Variables | Gender | n | Mean ± Std. Deviation | t | p |
|---|---|---|---|---|---|
| Sports Experience (years) | Male | 19 | 6.33 ± 1.58 | -0.052 | 0.959 |
| | Female | 21 | 6.36 ± 1.02 | | |
| 50 m Freestyle (s) | Male | 19 | 31.55 ± 3.04 | 0.085 | 0.933 |
| | Female | 21 | 31.45 ± 2.25 | | |
| 100 m Freestyle (s) | Male | 19 | 70.66 ± 11.90 | 0.126 | 0.901 |
| | Female | 21 | 70.09 ± 8.52 | | |
| Left 2D (cm) | Male | 19 | 5.80 ± 0.40 | 0.359 | 0.724 |
| | Female | 21 | 5.73 ± 0.46 | | |

| | | | | | |
|---|---|---|---|---|---|
| Left 4D (cm) | Male | 19 | 5.47 ± 0.34 | 0.701 | 0.492 |
| | Female | 21 | 5.38 ± 0.24 | | |
| Right 2D (cm) | Male | 19 | 6.71 ± 0.98 | 0.289 | 0.776 |
| | Female | 21 | 6.57 ± 1.05 | | |
| Right 4D (cm) | Male | 19 | 5.40 ± 0.45 | 0.660 | 0.518 |
| | Female | 21 | 5.29 ± 0.32 | | |
| Left Ratio (2D/4D) | Male | 19 | 1.06 ± 0.13 | -0.033 | 0.974 |
| | Female | 21 | 1.06 ± 0.12 | | |
| Right Ratio (2D/4D) | Male | 19 | 1.26 ± 0.27 | 0.052 | 0.959 |
| | Female | 21 | 1.25 ± 0.26 | | |

When participants' sports experience, swimming performance (50 m and 100 m freestyle), finger lengths, and 2D:4D ratios were compared by gender, no statistically significant differences were found between male and female groups across any variables ($p > 0.05$). The mean sports experience of males was 6.33 ± 1.58 years, while that of females was 6.36 ± 1.02 years. The 50-meter freestyle performance was 31.55 ± 3.04 seconds for males and 31.45 ± 2.25 seconds for females; for the 100-meter freestyle, the mean times were 70.66 ± 11.90 seconds and 70.09 ± 8.52 seconds, respectively. Similarly, there were no significant gender differences in left and right hand second (2D) and fourth (4D) digit lengths or in the 2D:4D ratios. These findings suggest that the motor and biometric variables evaluated in the study were not influenced by gender.

**Table 3. Correlation between finger ratio, sports experience, and swimming distance**

| Variables | Sports Experience | 50 m Freestyle | 100 m Freestyle |
|---|---|---|---|
| **2D:4D Ratio (Left)** | | | |
| ***r*** | -0.056 | -0.127 | -0.026 |
| ***p*** | 0.816 | 0.593 | 0.913 |
| ***n*** | 40 | 40 | 40 |
| **2D:4D Ratio (Right)** | | | |
| ***r*** | -0.069 | -0.108 | -0.005 |
| ***p*** | 0.774 | 0.652 | 0.983 |
| ***n*** | 40 | 40 | 40 |

When the relationships between the participants' left- and right-hand 2D:4D ratios and their sports experience, 50 m, and 100 m freestyle performance were examined, no significant correlations were found among any of the variable pairs ($p > 0.05$). These findings indicate that digit ratios do not appear to be a determining factor for sports experience or swimming performance.

## DISCUSSION AND CONCLUSION

In this study, the effect of the 2D:4D digit ratio on swimming performance was examined. Participants' anthropometric characteristics, sports experience, finger lengths, and swimming performances were compared by gender, and the relationships between the 2D:4D ratio and swimming performance were analyzed. The findings revealed that gender differences were not statistically significant and that there was no significant relationship between digit

ratio and swimming performance. These results support the notion that biological and hormonal characteristics in developing athletes may not yet be fully differentiated.

Small differences were observed between males and females in terms of height, body weight, and age; males were on average taller and heavier than females. However, these differences were not statistically significant (Table 1). This finding indicates that physical developmental differences between genders remain limited during childhood and early adolescence (Malina et al., 2004; Rey-Guerra et al., 2023; Long et al., 2024). Additionally, the fact that both male and female swimmers participating in official competitions in Çorum had similar training backgrounds may have contributed to the absence of significant gender-based differences. Similar reports in the literature suggest that anthropometric variables have a limited impact on performance among athletes of comparable age groups (Lesinski et al., 2020; Saal et al., 2022; Larkin et al., 2023).

No significant gender differences were found in sports experience, 50 m and 100 m freestyle performance, left and right hand 2D and 4D finger lengths, or 2D:4D ratios (Table 2). This finding contrasts with the results of Manning et al. (1998; 2001), who reported that male athletes generally exhibit lower 2D:4D ratios. However, those studies were primarily conducted on adult and elite-level athletes, whereas the present research examined developing athletes with a mean age of 12.85 years. Within this age range, it is possible that hormonal influences have not yet been fully reflected in digit ratios (Kobus et al., 2021; Sitek et al., 2022). Consistent with this interpretation, the meta-analysis by Hönekopp and Schuster (2010) indicated that the predictive value of the 2D:4D ratio for athletic performance may vary depending on sport type, age group, and gender.

Furthermore, studies conducted on individuals with congenital adrenal hyperplasia have shown lower right- and left-hand 2D:4D ratios in both females and males, but without significant gender differences (Nave et al., 2020; Richards et al., 2020; Ernsten et al., 2023). These findings suggest that biological differences do not always translate directly into performance outcomes. Similarly, research on the relationship between 2D:4D ratio and endurance performance has yielded conflicting results (Eklund et al., 2020; Gower et al., 2025). Gower et al. (2025) reported that a lower 2D:4D ratio in males was associated with higher endurance parameters, while Manning et al. (2007) also found that endurance runners with lower ratios demonstrated better endurance capacity. Conversely, Ceylan et al. (2022) reported no significant effect of the 2D:4D ratio on aerobic performance among basketball players. The

current study supports this view by suggesting that in closed-skill sports such as swimming, the predictive value of the 2D:4D ratio may be relatively limited.

The correlation analysis results revealed no significant relationships between left- or right-hand 2D:4D ratios and sports experience, 50 m, or 100 m freestyle performance (Table 3). This finding diverges from the negative correlations observed in open-skill sports such as basketball and football by Manning et al. (1998; 2001) and Hönekopp and Schuster (2010). In swimming, which is a closed-skill sport, the relatively controlled environmental factors may reduce the influence of biological determinants such as the 2D:4D ratio (Wu et al., 2022). Moreover, the homogeneity in training level and technical proficiency among swimmers may also explain the absence of significant correlations.

Several studies have suggested that the relationship between the 2D:4D ratio and exercise performance may be linked to $VO_2$max levels (Nobari et al., 2021; Parpa et al., 2024; Gower et al., 2025). Hill et al. (2012), in their study of physically active boys, reported that lower right- and left-hand 2D:4D ratios were associated with higher $VO_2$max values. Conversely, Peeters et al. (2013), who examined young females, and Nobari et al. (2021), who studied male adolescents, found no significant relationship between $VO_2$max and the 2D:4D ratio. Similarly, Çetinkaya et al. (2024) also reported no significant association between the 2D:4D ratio and athletic performance, noting that this variable may vary depending on sport type and age group. Hönekopp et al. (2006) emphasized that while the 2D:4D ratio showed a positive correlation with physical fitness in some sports, no meaningful relationship was found in others. This suggests that digit ratio may not serve as an equally decisive indicator across all athletic disciplines.

## CONCLUSION

In conclusion, this study demonstrates that the 2D:4D digit ratio is not a determining factor for swimming performance. The findings align with previous literature suggesting that the influence of digit ratio on athletic performance may vary depending on sport discipline, age, gender, and level of competition. Moreover, the incomplete maturation of the hormonal system in developing athletes may limit the manifestation of a digit ratio–performance relationship. Future longitudinal studies should jointly examine different age groups, hormonal indicators, and training levels to provide a clearer understanding of the validity of the 2D:4D ratio as a potential biological performance marker.

## RECOMMENDATIONS

Future research should incorporate multiple age groups, sport types, and hormonal variables to more comprehensively explore the possible influence of the 2D:4D digit ratio on athletic performance. Longitudinal studies conducted before and after puberty may better clarify the developmental dynamics of the digit ratio–performance relationship.

It is recommended that biological markers such as the 2D:4D ratio not be used as sole determinants in talent identification or performance evaluation. Instead, these indicators should be considered holistically, alongside factors such as training history, technical skill, motivation, and psychosocial variables. Such an integrated approach would contribute to a more equitable and scientifically grounded assessment of individual differences among athletes.

## LIMITATIONS OF THE STUDY

This study has several limitations. First, the sample consisted solely of swimmers aged 11–13 years from a single province, which restricts the generalizability of the findings. Second, the biological maturity levels of the participants were not assessed; only chronological age was considered. Finger length measurements were obtained manually, without the use of digital scanning tools, which may have introduced measurement error. Lastly, swimming performance was evaluated only based on the 50-meter freestyle event, and other variables that could influence performance—such as technical proficiency, endurance, or psychological factors—were not taken into account.

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| ***CONTRIBUTION RATE*** | ***EXPLANATION*** | ***CONTRIBUTORS*** |
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| *Idea or Notion* | *Form the research hypothesis or idea* | Esin Çağla Çağlar |
| *Design* | *To design the method and research design.* | Esin Çağla Çağlar |
| *Literature Review* | *Review the literature required for the study* | Esin Çağla Çağlar |
| *Data Collecting and Processing* | *Collecting, organizing and reporting data* | Esin Çağla Çağlar |

| | | |
|---|---|---|
| *Discussion and Commentary* | *Evaluation of the obtained finding* | Esin Çağla Çağlar |

***Statement of Support and Acknowledgment***

*No contribution and/or support was received during the writing process of this study.*

***Statement of Conflict***

*Researchers do not have any personal or financial conflicts of interest with other people and institutions related to the research.*

***Statement of Ethics Committee***

*This study was reviewed and approved by the Non-Interventional Research Ethics Committee of Hitit University (Decision No: 2024-27, Meeting Date: 25.12.2024).*