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THE RELATIONSHIP BETWEEN HAND REACTION TIME AND JOINT POSITION SENSE IN HEALTHY YOUNG ADULTS

ODNOS MED REAKCIJSKIM ČASOM ROKE IN OBČUTKOM ZA POLOŽAJ SKLEPA PRI ZDRAVIH MLADIH ODRASLIH

ABSTRACT

In the context of motor function, the reaction time can be defined as the time between a given stimulus and the first muscle response to it. Factors affecting reaction time: Appropriate response, number of repetitions, the severity of stimulus, gender, dominant side, age, smoking and alcohol consumption and obesity have been reported. Proprioception can be another critical factor for reaction time since it provides and maintains the relevant body part a certain movement or position at the time appropriate to the stimulus. The purpose was this study to investigate the relationship between hand reaction time and joint position sense and factors affecting reaction time in healthy young adults.25 healthy individuals with a mean age of 26.7±4.9 years were included in the study. 16 of the participants were male and 9 were female, and their body mass index (BMI) mean 23.8±4.2 kg/m2. Reaction time was assessed by the Nelson Hand Reaction test and joint position sense were measured with a goniometer. The joint position sense for the wrist was made by repeating the target angle with active movement. Gender and the dominant side did not affect the reaction time ($p \geq 0.05$). The reaction time increased with increasing age ($p \leq 0.05$). The joint position sense of the left wrist was statistically significant in females and males ($p \leq 0.05$). The wrist joint position sense showed less deviation only in the wrist flexion movement in favour of the non-dominant side ($p \leq 0.05$). There was no relationship between wrist joint position sense and hand reaction time ($p \geq 0.05$).

Keywords: reaction time, joint position sense, proprioception, hand, wrist

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IZVLEČEK

V kontekstu motoričnih funkcij je reakcijski čas opredeljen kot čas med določenim dražljajem in prvim mišičnim odzivom nanj. Dejavniki, ki vplivajo na reakcijski čas so: primeren odziv, število ponovitev, resnost dražljaja, spol, dominantna stran, starost, kajenje, uživanje alkohola ter debelost. Propriocepcija je lahko še en odločilen dejavnik za reakcijski čas, saj zagotavlja in ohranja določen gib ali položaj ustreznega dela telesa v času, ki je primeren dražljaju. Namen te študije je bil raziskati povezavo med reakcijskim časom roke in zaznavanjem položaja sklepa ter dejavniki, ki vplivajo na reakcijski čas pri zdravih mladih odraslih. V študijo je bilo vključenih 25 zdravih posameznikov s povprečno starostjo 26.7 ± 4.9 leta. Med udeleženci je bilo 16 moških in 9 žensk, njihov indeks telesne mase (ITM) je bil povprečno 23.8±4.2 kg/m2. Reakcijski čas je bil ocenjen z Nelsonovim testom reakcije rok, občutek za položaj sklepov pa je bil izmerjen z goniometrom. Zaznavanje položaja sklepa za zapestje je bilo opravljeno s ponavljanjem ciljnega kota z aktivnim gibanjem. Spol in dominantna stran nista vplivala na reakcijski čas ($p \geq 0.05$). Reakcijski čas se je z naraščajočo starostjo povečeval ($p \leq 0.05$). Zaznavanje položaja sklepa za levo zapestje je bilo statistično pomembno pri ženskah in moških ($p \leq 0.05$). Pri zaznavanju položaja zapestnega sklepa je bilo manjše odstopanje le pri upogibu zapestja v korist nedominantne strani ($p \leq 0.05$). Med občutkom za položaj zapestnega sklepa in reakcijskim časom roke ni bilo povezave ($p \geq 0.05$).

Ključne besede: reakcijski čas, zaznavanje položaja sklepa, propriocepcija, roka, zapestje

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INTRODUCTION

Reaction time and joint position sense are both essential factors in neuromuscular performance and motor function. Reaction time is one of the indicators of healthy neuromuscular performance (Eckner et al., 2012). Within the context of motor function, reaction time refers to the duration between a specific stimulus and the initial muscular response it elicits. Reaction time plays a crucial role in daily life, requiring an intact sensory system, cognitive processing, and motor performance. Reaction time serves as a reliable indicator of an individual's sensorimotor coordination and performance (Balakrishnan et al., 2014). A prolonged reaction time indicates a decrease in performance (Shah et al., 2010).

Numerous factors have been identified as influencing reaction time, including but not limited to appropriate response, number of repetitions, stimulus severity, gender, dominant side, age, smoking and alcohol consumption, and obesity (Ampomah Brown et al., 2017a; R. K. Jha et al., 2020; Johari et al., 2018; Szabo et al., 2021).

The reaction time is influenced by the conduction of nerve impulses along both the afferent and efferent pathways, as well as the speed of information processing within the central neural circuits (Johari et al., 2018). Moreover, conscious and unconscious proprioception plays a crucial role in enabling the relevant body part to effectively and timely respond to the stimulus by providing and maintaining the appropriate movement or position. The central nervous system receives specialised proprioceptive information concerning the body's part position, as well as the length and tension of various muscles, through various mechanoreceptors located in joints and muscles. Among these receptors, Ruffini endings and Pacinian corpuscles, found in capsules and ligaments, are classified as dynamic receptors. Ruffini endings are responsive to both movement and position, while Pacinian corpuscles solely respond to movement by converting mechanical force into action potentials. Additionally, the Golgi tendon organ and muscle spindle, which are specific to muscles, contribute to the proprioceptive control of reflexes (Gilman, 2002).

Joint position sense is one of the components of conscious proprioception. Joint position sense plays a critical role in motor control, coordination, and balance (Aman et al., 2015; Proske & Gandevia, 2012). It enables individuals to perceive the position, direction, and velocity of their limbs and joints during movement, thereby facilitating precise movement control, accurate force generation, and the capacity to make necessary adjustments to maintain stability(Goble et al., 2011; Proske & Gandevia, 2012). Deficits in joint position sense can result in motor function impairments (Sainburg et al., 1993). Individuals with diminished proprioception may encounter challenges in tasks involving fine motor control or balance maintenance, such as navigating uneven surfaces or executing intricate manipulative actions (Goble et al., 2011; Sainburg et al., 1993). Proprioceptive training can be instrumental in improving joint position sense, thereby enhancing motor performance and reducing the risk of injuries (Aman et al., 2015).

While it is challenging to measure all aspects of proprioception objectively, the assessment of joint position sense offers valuable insights into proprioceptive capabilities (Han et al., 2016). Various methods exist for evaluating joint position sense, with one practical approach being the measurement of joint angles while actively or passively replicating a predetermined position. This method can be readily employed in everyday clinical settings (Düzgün et al., 2011). The accuracy of proprioception improves as the discrepancy between the repeated target angle and the predetermined angle decreases, indicating a higher quality of proprioceptive sense (Stanton R & Reaburn P, n.d.).

To summarise, both reaction time and joint position sense are fundamental aspects of neuromuscular performance and motor function (Hortobágyi et al., 2003). Reaction time governs the speed at which an individual can initiate a response to a stimulus, while joint position sense enables precise perception of limb and joint positioning. These factors can significantly improve motor control, coordination, and overall performance across various activities (Atan & Akyol, 2014a; Hrysomallis, 2011; Proske & Gandevia, 2012).

This study aimed to investigate the relationship between hand reaction time and joint position sense and factors affecting reaction time in healthy young adults.

METHODS

Participants

Twenty-five healthy individuals (female n=9, male n=16) from the university staff were included in the study. Informed consent was obtained from each participant, and the local ethics committee approved the study (IRB number: MU798.19).

Inclusion Criteria

- 18 - 40 years healthy individuals
- Healthy hearing and eye function

- No medical diagnosis by a medical doctor
- Participants who volunteered to participate in the study

Exclusion Criteria

- Neurologic, systemic, chronic diseases/disorders
- Upper extremity, spine or head trauma or surgery history
- Cognitive, and psychiatric disorders
- Elite or non-elite athletes
- Smokers
- Obese

Data collection

Gender, age, body mass index and dominant extremity were recorded for participants. Hand dominance was determined by asking the participants what hand was used in daily activities. Reaction time was assessed by Nelson Hand Reaction Test; joint position sense was assessed by a goniometer. Participants were asked not to take any alcohol 24 hours before measurements. A quiet environment was ensured during the measurements. All measurements were taken on the same day for each participant and by the same researcher. The tests were applied once to another researcher for observation and understanding by participants, but familiarisation was not used by the participants. Measurements were started with the Nelson Hand Reaction Test and then joint position sense. Measurements for the dominant and non-dominant sides were taken in random order. Randomisation was determined according to odd and even numbers at the end of their id number.

Nelson Hand Reaction Time Test: First, a practical demonstration was given to all the participants. The participant is to sit on the chair with their forearm and hand resting on the table so that the tips of the thumb and index finger are held in a ready-to-pinch position, about 3 or 4 inches beyond the table's edge. The assessor assures that the upper edge of the thumb and index finger are horizontal and holds the 30 cm ruler vertically in the air between the participant’s thumb and index finger, but not touching. A zero mark aligns with the participant’s fingers. The participant should indicate when they are ready. Then assessor releases the ruler without warning and lets it drop - the participant must catch it as quickly as possible as soon as they see it fall (Eckner et al., 2012; R. K. Jha et al., 2020; Kaluga et al., 2020). The number remaining on the upper edge of the thumb, where the participant caught the ruler, was read and recorded as the distance the ruler fell. This procedure was repeated five times, and the average score was taken.

The reaction time of the participant was determined by using this average in the formula below (James T Eckner, James K Richardson, Hogene Kim, David B Lipps, 2012):

Reaction Time = √2 x the distance the ruler fell (mm) / speed of gravity (980 s)

Assessment of Joint Position Sense: Wrist assessment was taken by repeating the predetermined target angle at which the hand was positioned with active movement. The participant sits on a chair and places his hand and forearm on a table in front of him. The participant positioned the hand at a particular target angle and was told to keep this position in memory, and then to move to the same position when commanded. After waiting 5 sec. at this certain angle, the neutral position is reached. Then, the participant was asked to move the wrist to the same position with his eyes closed, and the angle of the wrist was measured with a goniometer and recorded. After an initial trial, the test was repeated five times, measuring the difference from the target angle in each one, and taking the average of these five, and the amount of error as a degree was recorded. Measurements were taken in the flexion-extension and radial-ulnar deviation motion axes of the wrist. Target angles were; 30° for flexion-extension, 10° for radial deviation, and 10° for ulnar deviation.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 23.0 software (IBM Corp, Armonk, NY, USA). Descriptive data were presented in minimum, maximum, mean±standard deviation (SD) for numerical variables and in frequency for categorical variables. The normality was assessed by The Shapiro-Wilk normality test. The Spearman correlation coefficient was used since the distribution was not normal. Correlation between scales was interpreted as follows: r=0-0.19 a very weak correlation, r=0.20-0.39 weak correlation, r=0.40-0.59 moderate correlation, r=0.60-0.79 strong correlation and r=0.80-1 very strong correlation(Gravesande et al., 2019). The Mann-Whitney test was used for the comparison between the groups (depending on gender and hand side) since the data were not normally distributed. To compare the two groups on paired data, we used Wilcoxon signed rank test. The effect size measures were computed for each test and these values were interpreted by

Cohen's guideline (Cohen, 1988; Gignac and Szodorai, 2016). We assessed the statistical results for $\alpha = 0.05$ error level.

RESULTS

Sixteen males and nine females were included in the study. The mean age was 26.7±4.9 years (min-max: 18-36), mean BMI was 23.8±4.2 kg/m2 (min.-max: 18.3-35.2). No significant difference was observed in the mean ages between males and females in the comparison. The dominant hand was the right side in twenty-three participants and the left side in two participants.

Participants` amount of error in joint position sense (degree) and hand reaction time (mm/sec) showed in Table 1. Based on the data presented in Table 1, a comparison between the right wrist and left wrist groups was conducted for various parameters. The error in ulnar deviation (°) for the right wrist was found 2.80 (0,00 - 7,33). In contrast, the error in ulnar deviation for the left wrist was 3.64 (0,00 - 12,33). The p-value associated with this comparison was 0.32. Measurements were compared based on the right and left wrist sides and following results were found: For the error in radial deviation (°), the right wrist group had a mean of 2.13 (0,00-10,67). In the left wrist group, the mean was 1.70 (0,00-5,67). The p-value for this comparison was 0.77. Regarding the error in flexion (°), the right wrist group exhibited a mean of 2.84 (0,33 -12,33), In contrast, the left wrist group had a mean of 1.80 (0,00 -13,33). The p-value associated with this comparison was **0.00**, indicating a statistically significant difference. For the error in extension (°), the right wrist group had a a mean of 3.22 (0,33-10,67). The left wrist group showed a mean of 4.60 (0,33-17,33). The p-value for this comparison was 0.24. Regarding reaction time, the right wrist group had a range of a mean of 0.18 (0,053-0,390). The left wrist group had a range of, a mean of 0.17 (0,075-0,346). The p-value associated with this comparison was 0.46.

Table 1. Comparison of the groups based on right or left hand side.

Parameters	**Right wrist**		**Left wrist**			
	Min - Max	**Mean-SD**	**Min - Max**	**Mean - SD**	**P value**	**ES**
Error in ulnar deviation (°)	0,00 - 7,33	2,80	0,00 - 12,33	3,64	0,32	0,20 (small)
Error in radial deviation (°)	0,00 - 10,67	2,13	0,00 - 5,67	1,70	0,77	0,06 (small)
Error in flexion (°)	0,33 - 12,33	2,84	0,00 - 13,33	1,80	**0,00**	0,61 (large)
Error in extension (°)	0,33 - 10,67	3,22	0,33 - 17,33	4,60	0,24	0,24 (small)
Reaction time (s)	0,053-0,390	0,18	0,075-0,346	0,17	0,46	0,15 (small)

Wilcoxon signed rank test was applied. Min: minimum, Max: maximum, SD: standard deviation, ES: Effect size. [0.10- 0.30) (small effect), [0.30-0.50) (moderate effect) and >=0.5 (large effect).

The relationships between hand reaction time and error in joint position sense showed in Table 2. Based on the data presented in Table 2, the results indicate the relationship between right hand reaction time and the error in ulnar deviation of the right wrist, with a p-value of 0.142 and an r-value of 0.302. Additionally, the relationship between right hand reaction time and the error in flexion of the right wrist shows a p-value of 0.093 and an r-value of 0.343. Similarly, the relationship between right hand reaction time and the error in extension of the right wrist exhibits a p-value of 0.177 and an r-value of 0.279. Regarding the left hand, the relationship between left hand reaction time and the error in ulnar deviation of the left wrist demonstrates a p-value of 0.625 and an r-value of 0.103. Furthermore, the relationship between left hand reaction time and the error in radial deviation of the left wrist presents a p-value of 0.718 and an r-value of 0.076. Additionally, the relationship between left hand reaction time and the error in flexion of the left wrist exhibits a p-value of 0.636 and an r-value of 0.099. Finally, the relationship between left hand reaction time and the error in extension of the left wrist shows a p-value of 0.089 and an r-value of 0.348.

Table 2. The relationships between hand reaction time and error in joint position sense.

Parameters	**P value**	**r**	**ES**
Right hand reaction time - Error in ulnar deviation of right wrist	0,142	0,302	0,302 (Moderate)
Right hand reaction time - Error in radial deviation of right wrist	0,142	0,302	0,302 (Moderate)
Right hand reaction time - Error in flexion of right wrist	0,093	0,343	0,343 (Moderate)
Right hand reaction time - Error in extansion of right wrist	0,177	0,279	0,279 (Moderate)
Left hand reaction time - Error in ulnar deviation of left wrist	0,625	0,103	0,103 (Small)
Left hand reaction time - Error in radial deviation of left wrist	0,718	0,076	0,076 (No effect)
Left hand reaction time - Error in flexion of left wrist	0,636	0,099	0,099 (No effect)
Left hand reaction time - Error in extansion of left wrist	0,089	0,348	0,348 (Moderate)

r: Spearman correlation coefficient ES: Effect size [0.10- 0.30) (small effect), [0.30-0.50) (moderate effect) and >=0.5 (large effect). The values less than the lower point is interpreted as “no effect”.

As the age of the participants increased, the reaction times increased. There was no relationship between hand reaction time and the dominant hand (Table 3). Based on the data presented in Table 3 following several relationships were examined. Age and Left hand reaction time: A statistically significant relationship was observed, with a p-value of 0.021 and an r-value of 0.460*. These findings indicate a moderate positive correlation between age and left hand reaction time. Age and Right hand reaction time: Another significant relationship was found, with a p-value of 0.048 and an r-value of 0.399*. This suggests a moderate positive correlation between age and right hand reaction time. Dominant hand and Left hand reaction time: No significant relationship was detected, as evidenced by a p-value of 0.627 and an r-value of -0.102. Consequently, no apparent correlation exists between dominant hand and left hand reaction time. Dominant hand and Right hand reaction time: Similarly, no significant relationship was observed, with a p-value of 0.149 and an r-value of -0.297. Hence, no substantial correlation exists between dominant hand and right hand reaction time.

Table 3. The relationships between age, dominant hand and hand reaction time.

Parameters	**P value**	**r**	**ES**
Age - Left hand reaction time	**0,021**	0,460	0,460 (Moderate)
Age - Right hand reaction time	**0,048**	0,399	0,399 (Moderate)
Dominant hand - Left hand reaction time	0,627	-0,102	0,102 (Small)
Dominant hand - Right hand reaction time	0,149	-0,297	0,297 (Small)

Spearman correlation coeffients were calculated. ES: Effect size [0.10-0.30) (small effect), [0.30-0.50) (moderate effect) and >=0.5 (large effect). The values less than the lower point is interpreted as “no effect”.

Table 4 provides a comparison of the groups based on gender. The mean age ± standard deviation (SD) for female participants was 27.66 ± 6.89, while for male participants it was 26.18 ± 3.64. However, the p-value associated with this comparison was 0.56, indicating that there was no significant difference in age between female and male participants. In terms of BMI, the mean BMI ± SD for female participants was 21.56 ± 4.53, whereas for male participants it was 25.19 ± 3.56. The comparison of BMI between the genders yielded a significant p-value of 0.01, indicating that there was a statistically significant difference in BMI between female and male participants. Concerning the error in joint position sense in flexion of a left wrist, there was a statistically significant difference between males and females.

The mean error in ulnar deviation of the right wrist (°) ± standard deviation (SD) for female participants was 2.88 ± 2.48, while for male participants it was 2.75 ± 2.07. However, the p-value associated with this comparison was 0.98, indicating that there was no significant difference in the error in ulnar deviation between female and male participants. Similarly, the mean error in radial deviation of the right wrist (°) ± standard deviation (SD) for female participants was 1.81 ± 1.72, whereas for male participants it was 2.31 ± 3.03. The p-value associated with this comparison was 0.84, indicating that there was no significant difference in the error in radial deviation between female and male participants.

Additionally, the mean error in flexion of the right wrist (°) ± standard deviation (SD) for female participants was 2.66 ± 1.50, whereas for male participants it was 2.93 ± 2.89. The p-value associated with this comparison was 0.67, indicating that there was no significant difference in the error in flexion between female and male participants. The mean error in extension of the right wrist (°) ± standard deviation (SD) for female participants was 3.59 ± 2.40, whereas for male participants it was 3.02 ± 2.73. The p-value associated with this comparison was 0.53, indicating that there was no significant difference in the error in extension between female and male participants.

The mean error in ulnar deviation of the left wrist (°) ± standard deviation (SD) for female participants was 2.81 ± 2.70, whereas for male participants it was 4.10 ± 3.51. The p-value associated with this comparison was 0.43, indicating that there was no significant difference in the error in ulnar deviation between female and male participants. The mean error in radial deviation of the left wrist (°) ± standard deviation (SD) for female participants was 1.37 ± 1.06, whereas for male participants it was 1.89 ± 1.86. The p-value associated with this comparison was 0.73, indicating that there was no significant difference in the error in radial deviation between female and male participants.

The mean error in flexion of the left wrist (°) ± standard deviation (SD) for female participants was 2.00 ± 0.94, whereas for male participants it was 1.68 ± 3.19. The p-value associated with this comparison was 0.02, indicating that there was a statistically significant difference in the error in flexion between female and male participants. The mean error in extension of left wrist (°) ± standard deviation (SD) for female participants was 3.88 ± 2.97, whereas for male participants it was 5.00 ± 4.86. The p-value associated with this comparison was 0.78, indicating that there was no significant difference in the left wrist extension deviation between female and male participants.

The mean right hand reaction time (mm/sn) ± standard deviation (SD) for female participants was 0.22 ± 0.11, whereas for male participants it was 0.16 ± 0.07. The p-value associated with this comparison was 0.09, indicating that there was no significant difference in the right hand reaction time between female and male participants, although the p-value approaches the significance threshold. The mean left hand reaction time (mm/sn) ± standard deviation (SD) for female participants was 0.21 ± 0.10, whereas for male participants it was 0.15 ± 0.04. The p-value associated with this comparison was 0.27, indicating that there was no significant difference in the left hand reaction time between female and male participants.

Table 4. Comparison of the groups based on gender.

Parameters	**Female (n=9) Mean ± SD**	**Male (n=16) Mean ± SD**	**P value**	**ES**
Age	27,66±6,89	26,18±3,64	0,60	0,01 (No effect)
BMI	21,56±4,53	25,19±3,56	**0,01**	0,04 (No effect)
Error in ulnar deviation of right wrist (°)	2,88±2,48	2,75±2,07	0,98	0,09 (No effect)
Error in radial deviation of right wrist (°)	1,81±1,72	2,31±3,03	0,84	0,13 (Small)
Error in flexion of right wrist (°)	2,66±1,50	2,93±2,89	0,67	-0,16 (Small)
Error in extansion of right wrist (°)	3,59±2,40	3,02±2,73	0,53	0,07 (No effect)
Error in ulnar deviation of left wrist (°)	2,81±2,70	4,10±3,51	0,43	0,45 (Moderate)
Error in radial deviation of left wrist (°)	1,37±1,06	1,89±1,86	0,73	0,06 (No effect)
Error in flexion of left wrist (°)	2,00±0,94	1,68±3,19	**0,02**	0,33 (Moderate)
Sol el bileği ekstansiyon sapma miktarı (°)	3,88±2,97	5,00±4,86	0,78	0,22 (Small)
Right hand reaction time (mm/sn)	0,22±0,11	0,16±0,07	0,09	0,01 (No effect)
Left hand reaction time (mm/sn)	0,21±0,10	0,15±0,04	0,27	0,04 (No effect)

Mann-Whitney U test was employed. ES: Effect size [0.10-0.30) (small effect), [0.30-0.50) (moderate effect) and >=0.5 (large effect). The values less than the lower point is interpreted as "no effect".

DISCUSSION AND CONCLUSION

The objective of this study was to examine the relationship between hand reaction time and joint position sense, as well as to identify the determinants influencing reaction time in a sample of healthy young adults.

Hence, this study aimed to explore the association between reaction time and joint position sense, yet no statistically significant correlation was observed. Nevertheless, it is important to acknowledge that the limited sample size in our study may have contributed to this outcome as a potential limitation.

Reaction time has gained substantial recognition in recent decades as a valuable measure for assessing neuropsychological functions, motor cognitive processing, and executive attention (Ampomah Brown et al., 2017b; Deary & Der, 2005; Lipps et al., 2011a; Szabo et al., 2021). During the occurrence of a specific stimulus, accurate proprioceptive information plays a vital role in facilitating an appropriate reaction. Proprioception, an indispensable sensory modality, enables the body to perceive and respond to various movements or positions in response to external stimuli. Surprisingly, the literature has largely overlooked the association between reaction time and joint position sense, which is a fundamental component of proprioceptive senses.

Given that various factors, such as age, sex, hand dominance, visual focus, practice, fatigue, fasting, breathing patterns, personality traits, physical activity, and intelligence, can influence the average human reaction time, it is crucial to measure and explore the relationship between reaction time and these parameters. Understanding these associations can provide valuable insights into the multifaceted nature of reaction time and its variability among individuals (Baayen & Milin, 2010). In addition, understanding the impact of these factors on treatment responses in rehabilitation or performance in sports education, as well as ensuring the necessary approaches in intervention strategies, holds significance in daily practice.

Consistent with existing literature, our findings revealed a linear correlation between age and reaction time, which has been reported by many authors (Adamo et al., 2007; Deary & Der, 2005; Goble, Coxon, et al., 2009; Goble, Noble, et al., 2009). As participants' age increased, their reaction times demonstrated a corresponding increase. Furthermore, studies focusing on hand dominance have consistently demonstrated that the reaction time of the non-dominant hand is significantly higher (slower) compared to that of the dominant hand(Chouamo et al., n.d.). Based on this, we believe that the development of training strategies aimed at improving reaction time on the non-dominant side, particularly in sports involving both upper extremities, can be beneficial for sports performance, as well as work performance for related occupational activities.

In our study, we observed that the dominant side did not have a significant impact on reaction time. While previous research has demonstrated faster reaction times in males compared to females for verbal or visual stimuli, the gender difference in hand reaction time has been inconsistent (Ampomah Brown et al., 2017a; R. Jha et al., 2020; Lipps et al., 2011a; Roivainen, 2011). However, in our study, we did not find a gender-related difference in reaction time. It appears that further investigation into the role of gender is necessary for future studies. Furthermore, when examining the joint position sense, we found that the amount of error during left wrist flexion was higher in females compared to males. This disparity may be attributed to the fact that two male participants in our study were left-handed, whereas there were no left-handed individuals in the female group.

Interestingly, recent studies indicate that healthy younger adults possess the capability to prepare accurate responses faster than their voluntary reaction times suggest, resulting in an apparent delay of approximately 80-100ms before responding (Haith et al., 2016). Investigating the relationship between age and movement preparation, initiation, and the delay between them, Hardwick et al. discovered that the slower reaction times observed in healthy older adults cannot be attributed to increased hesitancy to respond (Hardwick et al., 2022). Instead, these findings suggest that age-related changes in brain structure and function lead to alterations in stimulus processing and movement preparation, providing an explanation for the slower reaction times observed in older individuals.

While there is limited literature specifically focusing on hand reaction time in healthy subjects, research on reaction time in general suggests that athletes and individuals with motor expertise tend to have faster hand reaction times compared to non-athletes or individuals with less motor training (Yau Meng Kuan et al., 2018). Several studies have investigated the relationship between expertise and hand reaction time in athletes (Heppe et al., 2016; Yau Meng Kuan et al., 2018). These studies have generally found that elite athletes tend to have faster hand reaction times compared to non-athletes or lower-level athletes. This finding suggests that sports training and experience can improve hand reaction time.

Studies examining hand reaction time in athletes have also explored the effects of age and gender (Atan & Akyol, 2014b; Lipps et al., 2011b). While findings are not consistent across all studies, some research suggests that hand reaction time tends to decline with increasing age in athletes, while others have not found significant age-related differences (Badau et al., 2018; Gursoy et al., 2017). Regarding gender differences, limited research suggests that males may have faster hand reaction times compared to females, but further investigation is necessary to establish conclusive evidence (Hodgkins, 1963; Lipps et al., 2011b).

In our study, we observed that the joint position sense of the wrist exhibited minimal deviation, specifically in wrist flexion movement, favoring the non-dominant hand side. In a similar vein, Schmidt et al. reported that their study in healthy individuals also found a reduced amount of error favoring the non-dominant side (Schmidt et al., 2013). The authors suggested that motor learning and repetition play a role in decreasing errors in joint position sense. In our study, the assessment of joint position sense involved measuring randomly however most of the participants` randomisation order was the right hand first and then the left hand using a goniometer. Each hand was measured five times. This order of measurement may have facilitated better focus and learning specifically for the left side, potentially resulting in a lower average error for the non-dominant side. Consequently, this randomisation method and result of it for ordering of measurements represents an important limitation of our study. Obtaining more reliable results could have been achieved by re-evaluating the same participants on a different day, in a different order for the right and left-hand side.

Studies conducted on healthy individuals have consistently demonstrated a gradual decline in position sense as age advances throughout adulthood. This decline in proprioceptive acuity serves as an important factor to consider when assessing motor function in older populations (Herter et al., 2014; Kalisch et al., 2012).

Additionally, a positive correlation has been established between proprioceptive accuracy and sport achievement among elite athletes. This highlights the significance of proprioception in optimising athletic performance (Han et al., 2015). Moreover, research has revealed a positive relationship between enhanced proprioceptive accuracy in the elbow joint and improved throwing performance in sports such as basketball and darts. This suggests that precise joint position sense contributes to skillful execution in these activities. (Feng et al., 2020)

Furthermore, one study found a significant correlation between wrist-joint position sense and free-throw success rate, indicating a moderately strong relationship. A moderate correlation was observed between elbow-joint position sense and free-throw success rate. Notably, individuals with the highest proprioceptive performance in both joint positions tended to be the most successful shooters. These findings emphasise the relevance of proprioceptive abilities in achieving accurate free-throw performance which is also closely related to hand reaction. (Feng et al., 2020).

Taken together, these findings suggest that perceiving the position of distal joints in the throwing upper limb contributes, at least partially, to successful free-throw performance among players. From a motor-control perspective, this implies that basketball players rely on proprioception and hand reaction to effectively coordinate compensatory movements between the joints of their free-throwing arm. From a practical standpoint, these findings underscore the potential for developing targeted training techniques aimed at enhancing free-throw efficiency through proprioceptive interventions (Sevrez & Bourdin, 2015).

Hand joint position sense assessment has clinical relevance in various contexts, including rehabilitation and the evaluation of sensorimotor deficits. Assessing hand joint position sense can aid in diagnosing and monitoring conditions that affect proprioception, such as peripheral neuropathy, stroke, or musculoskeletal injuries.

The relationship between hand joint position sense and hand reaction time in healthy subjects is an area that has received relatively less attention in the literature. However, it is reasonable to speculate that individuals with better proprioceptive acuity and awareness of hand joint positions may have an advantage in terms of faster hand reaction times which can be very important for sport performance. Further research is needed to elucidate this relationship more comprehensively.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Adamo, D. E., Martin, B. J., & Brown, S. H. (2007). Age-Related Differences in Upper Limb Proprioceptive Acuity. *Perceptual and Motor Skills*, *104*(3_suppl), 1297–1309. https://doi.org/10.2466/pms.104.4.1297-1309

Aman, J. E., Elangovan, N., Yeh, I. L., & Konczak, J. (2015). The effectiveness of proprioceptive training for improving motor function: A systematic review. *Frontiers in Human Neuroscience*, *8*(JAN). https://doi.org/10.3389/fnhum.2014.01075

Ampomah Brown, A., Derkyi-Kwarteng, L., K Ackom, C., Addae, E., Newton, F., Amoah, D., & Nartey Bleman, D. (2017a). Simple reaction time: how it relates to body mass index (BMI), gender and handedness in Ghanaian students. *Journal of Thee Medical Sciences (Berkala Ilmu Kedokteran)*, *49*(01), 1–7. https://doi.org/10.19106/jmedsci004901201701

Ampomah Brown, A., Derkyi-Kwarteng, L., K Ackom, C., Addae, E., Newton, F., Amoah, D., & Nartey Bleman, D. (2017b). Simple reaction time: how it relates to body mass index (BMI), gender and handedness in Ghanaian students. *Journal of Thee Medical Sciences (Berkala Ilmu Kedokteran)*, *49*(01), 1–7. https://doi.org/10.19106/jmedsci004901201701

Atan, T., & Akyol, P. (2014a). Reaction Times of Different Branch Athletes and Correlation between Reaction Time Parameters. *Procedia - Social and Behavioral Sciences*, *116*, 2886–2889. https://doi.org/10.1016/j.sbspro.2014.01.674

Atan, T., & Akyol, P. (2014b). Reaction Times of Different Branch Athletes and Correlation between Reaction Time Parameters. *Procedia - Social and Behavioral Sciences*, *116*, 2886–2889. https://doi.org/10.1016/j.sbspro.2014.01.674

Baayen, R. H., & Milin, P. (2010). Analyzing reaction times. *International Journal of P Sychological Research*, *3*(2), 12–28.

Badau, D., Baydil, B., & Badau, A. (2018). Differences among three measures of reaction time based on hand laterality in individual sports. *Sports*, *6*(2). https://doi.org/10.3390/sports6020045

Balakrishnan, G., Uppinakudru, G., Girwar Singh, G., Bangera, S., Dutt Raghavendra, A., & Thangavel, D. (2014). A Comparative Study on Visual Choice Reaction Time for Different Colors in Females. *Neurology Research International*, *2014*. https://doi.org/10.1155/2014/301473

Chouamo, A. K., Griego, S., Susana, F., & Lopez, M. (n.d.). *The Journal of Science and Medicine Reaction time and hand dominance*. https://doi.org/10.37714/josam.v2i4.66

Deary, I. J., & Der, G. (2005). Reaction time, age, and cognitive ability: Longitudinal findings from age 16 to 63 years in representative population samples. *Aging, Neuropsychology, and Cognition*, *12*(2), 187–215. https://doi.org/10.1080/13825580590969235

Düzgün, İ., Yakut, A. Y., Baltacı, G., Uygur, F., Şimşek, I., Doç İrem Düzgün Gazi Üniversitesi, Y., Bilimleri Fakültesi, S., & ve Rehabilitasyon Bölümü, F. (2011). Sağlıklı bireylerde açı tekrarlama testi ile omuz pozisyon hissinin değerlendirilmesi: bir pilot çalışma. In *Fizyoterapi Rehabilitasyon* (Vol. 22, Issue 3). www.fizyoterapirehabilitasyon.org

Eckner, J. T., Richardson, J. K., Kim, H., Lipps, D. B., & Ashton-Miller, J. A. (2012). A novel clinical test of recognition reaction time in healthy adults. *Psychological Assessment*, *24*(1), 249–254. https://doi.org/10.1037/a0025042

Feng, J., Hung, T. M., Huang, R., Hou, S., & Ren, J. (2020). Role of Proprioception in Slow and Rapid Movements. *Perceptual and Motor Skills*, *127*(2), 281–298. https://doi.org/10.1177/0031512519895632

Gilman, S. (2002). Joint position sense and vibration sense: Anatomical organisation and assessment. In *Journal of Neurology Neurosurgery and Psychiatry* (Vol. 73, Issue 5, pp. 473–477). BMJ Publishing Group. https://doi.org/10.1136/jnnp.73.5.473

Goble, D. J., Coxon, J. P., van Impe, A., Geurts, M., Doumas, M., Wenderoth, N., & Swinnen, S. P. (2011). Brain activity during ankle proprioceptive stimulation predicts balance performance in young and older adults. *Journal of Neuroscience*, *31*(45), 16344–16352. https://doi.org/10.1523/JNEUROSCI.4159-11.2011

Goble, D. J., Coxon, J. P., Wenderoth, N., van Impe, A., & Swinnen, S. P. (2009). Proprioceptive sensibility in the elderly: Degeneration, functional consequences and plastic-adaptive processes. *Neuroscience & Biobehavioral Reviews*, *33*(3), 271–278. https://doi.org/10.1016/J.NEUBIOREV.2008.08.012

Goble, D. J., Noble, B. C., & Brown, S. H. (2009). Proprioceptive target matching asymmetries in left-handed individuals. *Experimental Brain Research*, *197*(4), 403–408. https://doi.org/10.1007/s00221-009-1922-2

Gravesande, J., Richardson, J., Griffith, L., & Scott, F. (2019). Test-retest reliability, internal consistency, construct validity and factor structure of a falls risk perception questionnaire in older adults with type 2 diabetes mellitus: a prospective cohort study. *Archives of Physiotherapy*, *9*(1), 1–11. https://doi.org/10.1186/s40945-019-0065-4

Gursoy, R., Sadr, Y., & Ozan, M. (2017). An Examination of Hand Preferences, Reaction Times and Some Power Parameters of Athletes in Short Track and Curling Branches. *Advances in Physical Education*, *07*(02), 156–167. https://doi.org/10.4236/ape.2017.72014

Haith, A. M., Pakpoor, J., & Krakauer, J. W. (2016). Independence of movement preparation and movement initiation. *Journal of Neuroscience*, *36*(10), 3007–3015. https://doi.org/10.1523/JNEUROSCI.3245-15.2016

Han, J., Waddington, G., Adams, R., Anson, J., & Liu, Y. (2016). Assessing proprioception: A critical review of methods. In *Journal of Sport and Health Science* (Vol. 5, Issue 1, pp. 80–90). Elsevier B.V. https://doi.org/10.1016/j.jshs.2014.10.004

Han, J., Waddington, G., Anson, J., & Adams, R. (2015). Level of competitive success achieved by elite athletes and multi-joint proprioceptive ability. *Journal of Science and Medicine in Sport*, *18*(1), 77–81. https://doi.org/10.1016/j.jsams.2013.11.013

Hardwick, R. M., Forrence, A. D., Gabriela Costello, M., Zackowski, K., & Haith, A. M. (2022). Age-related increases in reaction time result from slower preparation, not delayed initiation. *Journal of Neurophysiology*, *128*(3), 582–592. https://doi.org/10.1152/jn.00072.2022

Heppe, H., Kohler, A., Fleddermann, M. T., & Zentgraf, K. (2016). The relationship between expertise in sports, visuospatial, and basic cognitive skills. *Frontiers in Psychology*, *7*(JUN). https://doi.org/10.3389/fpsyg.2016.00904

Herter, T. M., Scott, S. H., & Dukelow, S. P. (2014). *Systematic changes in position sense accompany normal aging across adulthood*. http://www.jneuroengrehab.com/content/11/1/43

Hodgkins, J. (1963). Reaction time and speed of movement in males and females of various ages. *Research Quarterly of the American Association for Health, Physical Education and Recreation*, *34*(3), 335–343. https://doi.org/10.1080/10671188.1963.10613242

Hortobágyi, T., Mizelle, C., Beam, S., & Devita, P. (2003). *Old Adults Perform Activities of Daily Living Near Their Maximal Capabilities*. https://academic.oup.com/biomedgerontology/article/58/5/M453/536222

Hrysomallis, C. (2011). Balance Ability and Athletic Performance. *Sports Medicine 2011; 41 (3): 221-232*, *41*(3), 221–232.

James T Eckner, James K Richardson, Hogene Kim, David B Lipps, J. A. A.-M. (2012). A Novel Clinical Test of Recognition Reaction Time in Healthy Adults. *Psychological Assessment*, *24*(1).

Jha, R. K., Thapa, S., Kasti, R., & Nepal, O. (2020). Influence of Body Mass Index, Handedness and Gender on Ruler Drop Method Reaction Time among Adults. *Journal of Nepal Health Research Council*, *18*(1), 108–111. https://doi.org/10.33314/jnhrc.v18i1.2545

Jha, R., Thapa, S., Kasti, R., & Nepal, O. (2020). Influence of Body Mass Index, Handedness and Gender on Ruler Drop Method Reaction Time among Adults. *Journal of Nepal Health Research Council*, *Vol. 18 No. 1*, 108–119. https://doi.org/10.33314/jnhrc.v18i1.2545

Johari, K., den Ouden, D. B., & Behroozmand, R. (2018). Effects of aging on temporal predictive mechanisms of speech and hand motor reaction time. *Aging Clinical and Experimental Research*, *30*(10), 1195–1202. https://doi.org/10.1007/s40520-018-0902-4

Kalisch, T., Kattenstroth, J. C., Kowalewski, R., Tegenthoff, M., & Dinse, H. R. (2012). Age-related changes in the joint position sense of the human hand. *Clinical Interventions in Aging*, *7*, 499–507. https://doi.org/10.2147/CIA.S37573

Kaluga, E., Straburzynska-Lupa, A., & Rostkowska, E. (2020). Hand-eye coordination, movement reaction time and hand tactile sensitivity depending on the practiced sports discipline. *The Journal of Sports Medicine and Physical Fitness*, *60*(1), 17—25. https://doi.org/10.23736/s0022-4707.19.09726-3

Lipps, D. B., Galecki, A. T., & Ashton-Miller, J. A. (2011a). On the implications of a sex difference in the reaction times of sprinters at the Beijing Olympics. *PLoS ONE*, *6*(10). https://doi.org/10.1371/journal.pone.0026141

Lipps, D. B., Galecki, A. T., & Ashton-Miller, J. A. (2011b). On the implications of a sex difference in the reaction times of sprinters at the Beijing Olympics. *PLoS ONE*, *6*(10). https://doi.org/10.1371/journal.pone.0026141

Proske, U., & Gandevia, S. C. (2012). The Proprioceptive Senses: Their Roles in Signaling Body Shape, Body Position and Movement, and Muscle Force. *Physiol Rev*, *92*, 1651–1697. https://doi.org/10.1152/physrev.00048.2011.-This

Roivainen, E. (2011). Gender differences in processing speed: A review of recent research. *Learning and Individual Differences*, *21*(2), 145–149. https://doi.org/10.1016/j.lindif.2010.11.021

Sainburg, R. L., Poizner, H., & Ghez, C. (1993). Loss of Proprioception Produces Deficits in Interjoint Coordination. In *JOURNALOF NEUROPHYSIOLOGY* (Vol. 70, Issue 5). www.physiology.org/journal/jn

Schmidt, L., Depper, L., & Kerkhoff, G. (2013). Effects of age, sex and arm on the precision of arm position sense - Left-arm superiority in healthy right-handers. *Frontiers in Human Neuroscience*, *7*(DEC). https://doi.org/10.3389/fnhum.2013.00915

Sevrez, V., & Bourdin, C. (2015). On the Role of Proprioception in Making Free Throws in Basketball. *Research Quarterly for Exercise and Sport*, *86*(3), 274–280. https://doi.org/10.1080/02701367.2015.1012578

Shah, C., Gokhale, P. A., & Mehta, H. B. (2010). Effect of Mobile Use on Reaction Time. In *Al Ameen J Med Sci* (Vol. 3, Issue 2).

Stanton R, & Reaburn P. (n.d.). *The effect of short-term Swiss ball training on core stability and proprioception.* https://doi.org/10.1016/j.jbmt.2013.09.014.

Szabo, D. A., Neagu, N., Teodorescu, S., Panait, C. M., & Sopa, I. S. (2021). Study on the influence of proprioceptive control versus visual control on reaction speed, hand coordination, and lower limb balance in young students 14–15 years old. *International Journal of Environmental Research and Public Health*, *18*(19). https://doi.org/10.3390/ijerph181910356

Yau Meng Kuan, Nurul Atikah Zuhairi, Faudziah Abd Manan, Victor Feizal Knight, & Rokiah Omar. (2018). Visual reaction time and visual anticipation time between athletes and nonathletes. In *Article in Malaysian Journal of Public Health Medicine*. https://www.researchgate.net/publication/324441797