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Araştırma Makalesi

Comparison of the Differences Between Dominant and Non-Dominant Upper Extremity Muscle Strength, Manual Dexterity and Joint Position Sense Between Genders in Healthy Young Adults

Sağlıklı Genç Erişkinlerde Cinsiyetler Arası Baskın ve Baskın Olmayan Üst Ekstremite Kas Kuvveti, Fonksiyon ve Eklem Pozisyon Hissi Arasındaki Farkların Karşılaştırılması

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ABSTRACT

Purpose: This study aims to compare hand grip strength (HGS), joint position sense (JPS), and manual dexterity between differences in dominant and non-dominant extremities according to gender. **Material and Methods:** Two hundred thirteen healthy young adults (107 males and 106 females) were included in the study. Participants' HGS was evaluated with the Jamar Dynamometer, shoulder JPS with the inclinometer, and upper extremity functional skill level with the Purdue Pegboard Test. **Results:** Grip strength and dexterity were statistically different between dominant and non-dominant extremities ($p<0.01$). In comparison by gender, the dominant and non-dominant hands of both males and females showed differences in HGS and dexterity ($p <0.01$), while there was no difference in JPS ($p>0.05$). There was a difference between HGS, dominant and non-dominant limbs, and males scored more than females in both hands ($p<0.01$). The hand functionality of females on both the dominant and non-dominant sides was higher than that of males ($p<0.01$). The difference results between dominant and non-dominant limb HGS ($p=0.638$), JPS ($p>0.05$), and manual dexterity ($p=0.463$) were similar between genders. **Conclusion:** Grip strength and manual dexterity vary between genders. Additionally, the results are more functional in the dominant extremity. It is important to consider gender and dominance for hand function rehabilitation.

Keywords: Dominance; Hand strength; Proprioception; Hand dexterity; Upper extremity.

ÖZ

Amaç: Bu çalışma, baskın ve baskın olmayan ekstremitelerdeki el kavrama kuvveti, eklem pozisyon hissi ve el becerisinin cinsiyete göre farklılıklarını karşılaştırmayı amaçlamaktadır. Gereç ve Yöntem: Çalışmaya 213 sağlıklı genç yetişkin (107 erkek ve 106 kadın) dahil edildi. Katılımcıların el kavrama kuvveti Jamar Dinamometresi, omuz eklem pozisyon hissi inklinometre ile ve üst ekstremite fonksiyonel beceri düzeyi Purdue Pegboard Testi ile değerlendirildi. **Bulgular:** Baskın ve baskın olmayan ekstremiteler arasında kavrama gücü ve el becerisi istatiksel olarak farklıydı ($p<0,01$). Cinsiyete göre karşılaştırıldığında hem erkek hem de kadınların baskın ve baskın olmayan elleri kavrama kuvveti ve el becerisi farklılıklar gösterirken ($p<0,01$), eklem pozisyon hissinde ise herhangi bir fark yoktu ($p>0,05$). Baskın ve baskın olmayan ekstremiteler arasında kavrama kuvvetinde fark vardı ve erkekler her iki elde de kadınlara göre daha fazla puan aldı ($p<0,01$). Kadınların hem baskın hem baskın olmayan taraftaki el fonksiyonelliği erkeklere göre daha yüksekti ($p<0,01$). Baskın ve baskın olmayan ekstremite kavrama kuvveti($p=0,638$), eklem pozisyon hissi ($p>0,05$) ve el becerisi ($p=0,463$) arasındaki fark sonuçları cinsiyetler arasında benzerdi. **Sonuç:** Kavrama kuvveti ve el becerisi cinsiyete göre farklılık göstermektedir. Ayrıca baskın ekstremitede sonuçlar daha fonksiyoneldir. El fonksiyon rehabilitasyonunda cinsiyet ve baskınlığın dikkate alınması önemlidir.

Anahtar Kelimeler: Baskınlık; El gücü; Propriyosepsiyon; El becerisi; Üst ekstremite.

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The hand is the most complex and unique musculoskeletal instrument in the human body. To meet the needs of daily living, the hand must have full function and sufficient strength (Bhat, Jindal and Acharya 2021). The hand's range of motion extends from fine motor movements to gross motor movements, which are necessary for many daily tasks and occur through the integration of the motor and sensory properties. Therefore, for a movement to be revealed, it must have muscular strength, joint position sensation, and function ability (Bhat, Jindal and Acharya 2021; Nicolay and Walker, 2005).

The grip is one of the hand functions that is crucial to the continuation of daily tasks (Nicolay and Walker, 2005). Age, body composition, body mass index (BMI), upper extremity function status, and laterality are among the physiological and psychological variables that impact it (Lee et al., 2012). Gender and age are the two key variables affecting hand grip strength (HGS), with gender accounting for most of the variability overall (Angst et al., 2010). Males' HGS values are higher than females' according to studies conducted worldwide (Amo-Setién et al., 2020; Nor Julahah J et al., 2020). The general rule states that the dominant hand (DH) is 10% stronger than the non-dominant hand (NDH). However, the 10% rule has not been verified despite numerous attempts to measure it (Armstrong and Oldham, 1999). Although it is stated that there is no observable difference in HGS value between DH and NDH, it is also shown that DH is stronger (Dağ and Erdoğan, 2020; Shrestha et al., 2023). The results of this situation are contradictory.

Proprioception is the sensory organization that combines afferent information from mechanoreceptors in the skin, muscles, ligaments, and tendons with visual and vestibular inputs in the central nervous system (Jerosch and Prymka, 1996). Proprioceptive skills are necessary for spatial orientation, movement, and interaction with the surroundings (Gay et al., 2010). Proprioceptive abilities are influenced by a variety of external circumstances. Previous studies have stated that proprioceptive variations may be affected by gender, limb dominance, and fatigue, but the results are not clear (Echalier et al., 2019; Lubiatowski et al., 2019). However, it is also suggested that males have better spatial skills than females (Pedersen et al., 1999). Additionally, it has been shown in various studies that the proprioceptive sense between dominant and non-dominant extremities may be similar or different (Ihalainen et al., 2016; Echalier et al., 2019; Lubiatowski et al., 2019). However, it needs to be investigated for clear results.

The capacity to make coordinated, fine movements of the hand is known as manual dexterity and is one of the essential components of hand functionality (Oxford Grice et al., 2003). Extensive research involving many populations has demonstrated a noteworthy correlation between the functional abilities of the hand and the execution of everyday tasks (James et al., 2015). Several variables, including age, gender, laterality, and cultural differences, can influence how well the hands do functional tasks in healthy persons without disabilities (Takla, Mahmoud and El-Latif 2018). Females may have an advantage in fine motor activities due to the average size of their fingers being smaller. The Purdue pegboard task provides significant experimental evidence supporting female's stronger fine motor skills (Tiffin and Asher, 1948; Wang et al., 2015). In contrast, some studies did not discover appreciable gender disparities regarding dexterity metrics (Takla, Mahmoud and El-Latif 2018; Rule et al., 2021).

A common practice in many therapy procedures is to compare the affected extremity's strength to either the unaffected extremity's strength or to normative data obtained from the same population. Nonetheless, this is beneficial when both extremities' pre-injury strength is comparable (Park and Son, 2022). According to available studies, the number of studies investigating manual skills, HGS, and JPS is limited. Also, it is noteworthy that there is a lack of studies examining gender-specific differences in results in dominant and non-dominant extremities. It is thought that examining this difference can be extremely useful in determining achievable goals for hand rehabilitation and in customizing care for different groups. We hypothesized that the difference between dominant and non-dominant extremity muscle strength, joint position sense, and manual dexterity varies according to gender. Therefore, this study aimed to compare the differences between hand grip strength, joint position sense, and dexterity of dominant and non-dominant upper extremities according to gender.

MATERIAL AND METHOD

Study Design

This study was planned as a cross-sectional observational study. This research was conducted at Karabuk University Physiotherapy and Rehabilitation Application and Research Center between November 2023-March 2024. A total of 213 young individuals participated in the study. Individuals between the ages of 18-25 who volunteered to participate in the study were included. Exclusions from the study included patients with a history of trauma within the previous year (fracture, dislocation), cancer, sports participation or other activities requiring bilateral movement (knitting, sports, music, etc.), a diagnosis of any neurological or orthopedic condition that could impair hand-eye coordination, muscle strength below a

value of 3 when assessed as motor, Botox injections within the previous six months, and upper extremity surgery. The University Ethics Committee approved the study (No: 2023/1479) and was conducted by the Declaration of Helsinki. Before participating in the study, the purpose of the study was explained to the participants and their consent was obtained. Submitted to Clinical Trial number: NCT06269887.

The demographic information of the individuals was determined. Then, hand preference, grip muscle strength, dexterity, and proprioception were evaluated.

Outcome Measures

Hand Preference

The Edinburgh Handedness Questionnaire, developed by Oldfield (1971), questions individuals' hand use in daily activities. Individuals are asked questions about hand use during ten activities (such as writing, brushing teeth, and using scissors). Depending on the answer given by the individuals, the box under the right or left hand is checked. Scores are calculated separately for the right and left hands, with each answer receiving 1 point. Calculations are made according to the Geschwind Scoring based on the answers given by individuals. The final total score is between 100 and -100. Individuals who score more than 40 points are right-hand; Individuals in this score range from 40 to -40 inclusive are recorded as ambidextrous (those who actively use both hands), and individuals with scores of -40 points and below are left-handed. Additionally, the Turkish validity and reliability of this questionnaire have been reported as excellent (Atasavun Uysal et al., 2019).

Grip Strength

Hand grip strength was measured by Jamar Dynamometer. The American Association of Hand Therapists standard posture was used to test hand grip strength. The patient is asked to stand with feet flat on the floor, arms unsupported, shoulders in neutral rotation, elbows bent to a 90-degree angle, and forearm and wrist fixed in a neutral position. The patient was asked to squeeze the device as hard as possible for five seconds each. The measurement was repeated three times, and the average was recorded (Halpern and Fernandez, 1996; Haidar et al., 2004).

Joint Position Sense

Proprioception was assessed by a joint position sense (JPS) test using a digital dynamometer. The test was performed at 90 degrees for shoulder flexion and abduction. Participants were instructed to sit upright in a chair with their feet flat on the floor, their hips and knees bent at exactly 90 degrees, and their backs unsupported. The participant's upper extremities were positioned in the sagittal plane for arm flexion movement and in the scapular plane for abduction movement. During the test, the individuals' arms were placed in a 90-degree shoulder flexion and abduction position, and they were asked to maintain this position for 5 seconds. They were then asked to repeat the same movement with closed eyes actively. The test was performed three times, and the angle of deviation was recorded (Ünlüer et al., 2019).

Manual Dexterity

The Purdue Pegboard Test (PPT) was used to evaluate the functional skill levels of the upper extremities. PPT consists of five subtests: dominant (D) hand, non-dominant (ND) hand, both (B) hands, dominant + non-dominant + both (D + ND + B) hands and assembly subtest (Tiffin and Asher, 1948; Yancosek and Howell, 2009). D and ND subtests were used in this study. The subject was instructed to start with a verbal signal, and time was measured with a stopwatch. In the D and ND hand subtests, participants were asked to fill as many holes as possible with needles within thirty seconds. The number of pins placed on the board within the allowed time represents the results of the D and ND hand subtests. With the results obtained, the difference between D's and ND's hands was calculated and compared according to gender (Stijic et al., 2023).

Sample size

The number of individuals to participate in the study was determined by comparing the dominant and non-dominant hand grip strength differences between genders obtained from the pilot study with the G power (Heinrich Heine University of Düsseldorf, Düsseldorf, Germany) program. 194 individuals, including at least 92 individuals in both groups, were determined for 80% power, effect size (d)=0.406, and α=0.05 margin of error. Considering that there may be data loss in the research, at least 212 people are required to participate for the 10% cut-off point.

Statistical Analysis

SPSS 25 (Statistical Package for Social Sciences) program was used to analyze. The normal distribution was evaluated using the Shapiro-Wilk test and histogram graph. Mean and standard deviations were given for quantitative variables that showed normal distribution, and median, minimum, and maximum values were given for quantitative variables that did not normal distribution. Categorical data were presented as numbers and percentages. Students' t-tests and Mann-Whitney U tests were used to compare genders, and the Chi-square test was used to compare qualitative data. Statistical significance was evaluated at $p<0.05$ level.

RESULTS

A total of 215 healthy individuals were screened, and two individuals were excluded from the study because they did not want to participate. The study was completed with a total of 213 healthy individuals. A total of 106 (49.7%) female and 107 (50.3%) male participated in the study. The demographic characteristics of the participants in the study are given in Table 1 (Table 1).

There was no difference between genders regarding hand preference in total score and classification (p>0.05). When compared according to gender, D and ND HGS was statistically different (p<0.01, Table 2). However, there was no significant difference between D and ND HGS between genders (p=0.638). In addition, females had statistically higher manual dexterity on both the D and ND sides than males (p<0.01, Table 2).

JPS results for deviation angles showed no statistical difference between D and ND side flexion and abduction deviation angles between genders (p>0.05, Table 3). Additionally, D and ND flexion and abduction angular differences were similar between genders (p>0.05).

Table 1. Demographic characteristic of participants

	Female (n=106)	**Male (n=107)**	**Total (n=213)**	**p**
	X±SD Med (Min-Max)	**X±SD Med (Min-Max)**	**X±SD Med (Min-Max)**	
Age, years	21 (18-26)	21 (18-25)	21 (18-26)	0.664
Height, cm	162.54±5.04	177.80±6.43	170.20±9.57	**<0.01**
Weight, kg	56 (42-95)	74 (50-129)	65 (42-129)	**<0.01**
BMI, kg/m²	21.51 (16.14-37.58)	23.05 (16.98-42.61)	22.34 (16.14-42.61)	**<0.01**
Underweight	17 (16%)	6 (5.6%)	23 (10.8%)	**0.020**
Normal	71 (67%)	68 (63.6%)	139 (65.3%)	
Overweight	13 (12.3%)	25 (23.4%)	38 (17.8%)	
Obese	5 (4.7%)	8 (7.5%)	13 (6.1%)	
Dominant Hand				
Right	97 (91.5%)	98 (91.6%)	195 (91.5%)	0.983
Left	9 (8.5%)	9 (8.4)	18 (8.5%)	

Table 2. Comparison of HGS, manual dexterity, and handedness preference between dominant and non-dominant sides according to gender

	Female (n=106)	**Male (n=107)**	**Total (n=213)**	**p**
	X±SD Med (Min-Max)	**X±SD Med (Min-Max)**	**X±SD Med (Min-Max)**	
EHPQ-Total	85 ((-100)-100)	85 ((-100)-100)	85 ((-100)-100)	0.321
EHPQ classification n (%)				
Strong Left Hand	5 (4.7%)	5 (4.7%)	10 (4.7%)	0.649
Weak Left Hand	3 (2.8%)	4 (3.7%)	7 (3.3%)	
Ambidextrous	0	0	0	
Weak Right Hand	35 (33.0%)	27 (25.2%)	62 (29.1%)	
Strong Right Hand	63 (59.4%)	71 (66.4%)	134 (62.9%)	
Handgrip Strength				
Dominant hand	25.3 (16.3-39.3)	44.3 (24.7-77.3)	33.3 (16.3-77.3)	**<0.01**
Non dominant hand	22.85 (15.3-55)	42.91 (20.7-66.3)	30.7 (15.3-66.3)	**<0.01**
Difference	2.3 ((-31).0-7.7)	2.6 ((-11.0)-11.6)	2.3 ((-31)-11.6)	0.638
Purdue Pegboard Test				
Dominant hand	15 (10-20)	14 (10-19)	14 (10-20)	**<0.01**
Non dominant hand	14 (8-19)	13 (7-17)	13 (7-19)	**<0.01**
Difference	1 ((-4)-6)	1 ((-5)-5)	1 ((-5)-6)	0.463

Table 3. Comparison of JPS between dominant and non-dominant sides according to gender

	Female (n=106)	Male (n=107)	Total (n=213)	p
	X±SD Med (Min-Max)	X±SD Med (Min-Max)	X±SD Med (Min-Max)	
Proprioception 90° shoulder flexion				
Dominant	0.7 (0-3.3)	0.5 (0-3.6)	0.7 (0-3.6)	0.640
Non dominant	0.8 (0-6)	0.9 (0.1-3.7)	0.9 (0-6)	0.568
Difference	0.58 (0-5.5)	0.5 (0-3.6)	0.5 (0-5.5)	0.743
Proprioception 90° shoulder abduction				
Dominant	0.55 (0-5.0)	0.5 (0-4)	0.5 (0-5)	0.287
Non dominant	0.9 (0-5.7)	0.9 (0-5.3)	0.9 (0-5.7)	0.571
Difference	0.6 (0-4.3)	0.7 (0-2.3)	0.64 (0-4.3)	0.953

DISCUSSION

This study aimed to compare the differences between hand grip strength, joint position sense, and dexterity of dominant and non-dominant upper extremities according to gender. Accordingly, the study showed that males had greater grip muscle strength while females had better dexterity. However, the difference in grip strength and dexterity test between dominant and non-dominant extremities was similar between groups. The dominant hand had approximately 8.4% greater grasping ability, JPS flexion nearly 28.6%, abduction about 80%, and dexterity about 7.7% better than the non-dominant hand after the dominant and non-dominant hands were controlled for all individuals.

According to the general rule of thumb, the dominant hand is thought to be 5–10% stronger than the non-dominant hand (Lee and Hwang, 2019). Adam et al. (1998) report that, on the dominant hand, there is a spread recruitment pattern. In the non-dominant hand, motor units have a more significant recruitment percentage at lower absolute force levels. In a study, Park and Son (2022) discovered that the dominant hand was approximately 8.1% stronger than the non-dominant hand. Demiroğlu et al. (2017) found that the dominant grip strength was 8-9% in females and 5-7% in men. Although it is slightly different from the 8% grip ability rate in this study, the common point is that the grip strength of the dominant hand is higher and is close to the generally applied 10% rule. This may be explained by males having more muscle and less fat mass. Additionally, the fact that males engage in activities that require more strength supports the results.

In a study by Yim, Cho and Lee (2003), the Jebsen-Taylor Hand Function Test, the O'Conner Finger Dexterity Test, and the PPT were used to compare the dominant and non-dominant hands to examine variations in hand function based on the dominant hand. Typically, the dominant hand performs better functions than the non-dominant hand. In tests where the non-dominant hand performed better than the dominant hand, the ability to use the non-dominant hand was also excellent when the left hand was employed as the dominant hand. This situation led to improved results for hand function measurements. Based on this, various studies and methods were suggested to promote using both hands, even when the right hand is the dominant hand. However, the previous study included older adults, and right and left hands were not evaluated separately (Yim, Cho and Lee, 2003). In our study, the dominant hand was found to have a higher function than the non-dominant hand, which is consistent with earlier research. Gender differences in performance on fine motor function tests have also been proposed, although no firm conclusions have been reached. According to certain research, adult females performed much better than males in the grooved pegboard test (Wang et al., 2015). Additionally, females performed better than males in our study on the dominant and non-dominant hand subtests of the PPT. These results align with earlier research showing that females perform better on the Purdue Pegboard and other manual dexterity tests (Lawrence et al., 2014). In addition, research on sex differences in fine motor tasks suggests that females may benefit from having smaller fingers on average than males (Halpern, 2001). However, it was recommended that the performance of both males and females declines at a similar rate with age (van Wijk and Meintjes, 2015). Park and Son (2022) compared the dexterity ratios (non-dominant hand/dominant hand) and difference values (dominant hand-non-dominant hand) between dominant and non-dominant hands

according to gender; both the ratio and difference values of dexterity were not different between male and female. The result of the research is parallel to our study. The fact that the difference between dominant and non-dominant hands is similar for both genders shows that the non-dominant hand is less functional for both males and females. Considering this difference during the hand rehabilitation process and including it in the clinic monitoring process may be effective in choosing a more appropriate rehabilitation.

Proprioception is an essential sensory parameter for the organization of limb movements. In this way, the distribution and timing of force and movement are ensured. Therefore, controlling and maintaining position sense is important (Kumar et al., 2012; Lephart et al., 1994). However, the effect of this condition on dominant and non-dominant extremities has not been adequately investigated. A study by Kumar et al. (2012) reported little change in joint position sense throughout the shoulder rotational range of motion in healthy adults, with no change between dominant and non-dominant shoulders. Similarly, another study showed that proprioception was unrelated to shoulder dominance (Lephart et al., 1994). This study observed no difference between dominant and non-dominant shoulder proprioception sensations. The difference in gross and fine motor activities between extremities may be related to the position sense of the distal joints.

In the literature, the number of studies examining the relationship between gender and shoulder proprioception is limited, and the results are contradictory. In a study conducted in this context, Pedersen et al. (1999), showed that female's kinesthesia is less sensitive than men's. However, according to Björklund et al. (2000), no change in the degree of deviation in shoulder joint position angle was found between males and females before and after muscle fatigue. Emery and Côté (2012) repeated a similar result showing that gender did not affect shoulder joint position sense during muscle fatigue. Additionally, some studies show that males have a better sense of proprioception than females (Dallinga et al., 2016; Sell et al., 2018). However, it has been noted that gender differences may exist in the directionality properties of position sense, with females often exhibiting a different repositioning error in front of and below the target. The sense of proprioception between genders is generally related to the sense of proprioception of the knee and ankle joint in sports branches where anterior cruciate ligament injuries are common. Therefore, it has been reported that the injury process and proprioception may be related to gender (Dallinga et al., 2016; Sell et al., 2018). Similar to many studies in literature, this study showed no difference between genders regarding position sense. This may be associated with the high sensory awareness of young individuals. Although, we thought that another reason why no difference was found in proprioception between genders in this study is that proprioception was evaluated only with joint position sense. Therefore, maintaining proprioceptive sensory awareness is important for both genders to avoid injuries or organize movements.

This study has several limitations. Since age groups affect grip strength, studies with larger sample sizes and including other age groups are needed. Additionally, only the shoulder was measured for proprioception in the upper extremity. Studies involving elbow and hand joints are important for rehabilitation planning. More research is needed to understand the differences between genders in proprioception better.

In conclusion, this study revealed differences between the D and ND hands in all examined items except JPS and gender differences in HGS and dexterity, excluding JPS. These findings suggest that, when establishing rehabilitation objectives for hand function, the damaged side's recovery aim should be determined by dominance and gender, and the target value can be approximated using the function of the uninjured hand.

Ethics Approval

The study was approved by the Non-Interventional Ethics Committee of Karabuk University (Decision no: 2023/1479)

Authorship Contributions

Metehan Yana: Conceptualization, Methodology, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Supervision. Dalal Bouta: Investigation, Data curation, Writing - Original Draft. Musa Güneş: Formal Analysis, Data curation, Supervision, Writing - Original Draft, Writing - Review & Editing. Writing - Original Draft, Writing - Review & Editing.

Conflict of Interest

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

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