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Research Article

Investigation of the Relationship Between Functional Skills, Sensory Functions, and Anthropometric Properties of the Hand in Occupational Therapy Students Using Hierarchical Clustering Analysis

Ergoterapi Bölümü Öğrencilerinde Elin Fonksiyonel Becerileri, Duyumotor ve AntropometrikÖzellikleri Arasındaki İlişkilerin Hiyerarşik Küme Analizi Kullanılarak İncelenmesi

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ABSTRACT

Purpose: This study aims to examine the relationship between functional skills, sensorimotor, and anthropometric variables of the hand in health science students. **Material and Methods:** The study was carried out on 70 students (21.51± 1.59 years; 61 women, 9 men) from Biruni University. Upper extremity anthropometric measurements were taken from the students. Hand Dynamometer and Pinchmeter were used for hand grip strength, Purdue Pegboard Test for hand dexterity, Semmes-Weinstein Monofilament for two-point discrimination, and Vibration Perception Test were used for sensory functions. Hierarchical cluster analysis was employed to find the clustering trend of the variables. **Results:** At the end of the research, two main clusters were obtained, of which four sub-clusters belonging to the second one were identified. The main cluster I contains pinch, dipod, tripod, lateral grip force, Purdue pegboard dominant, non-dominant, both, and assembly. Main cluster II contains finger lengths, palmar length, hand grip, total upper extremity length, height, two-point discrimination, vibration, weight, BMI, monofilament, palmar width, segmental arm, forearm, and hand length. **Discussion:** As a result of the research, it was determined that pinch grip strength, dexterity, anthropometric and sensory characteristics were related to each other.

Keywords: Upper extremity anthropometry; Hand dexterity; Sensory assessment; Cluster analysis.

ÖZ

Amaç: Bu çalışmanın amacı, sağlık bilimleri öğrencilerinde elin fonksiyonel becerileri ile duyu-motor ve antropometrik değişkenleri arasındaki ilişkiyi incelemektir. **Gereç ve Yöntem:** Araştırma Biruni Üniversitesi'nden 70 öğrenci (21.51± 1.59 yıl; 61 kadın, 9 erkek) üzerinde gerçekleştirildi. Öğrencilerden üst ekstremite antropometrik ölçümleri alındı. El kavrama kuvveti için Jamar El Dinamometresi ve Pinchmetre, el becerisi için Purdue Pegboard Testi, duyusal beceriler için Semmes-Weinstein Monofilament, iki nokta ayırt etme ve titreşim algılama testi kullanıldı. Değişkenlerin kümelenme eğilimini bulmak için Hiyerarşik Küme Analizi kullanıldı. **Sonuçlar:** Araştırma sonunda iki ana küme ve II. ana küme'ye ait 4 alt küme elde edilmiştir. 1. Ana küme şunları içerir: Pinch, dipod, tripod, lateral kavrama kuvveti, Purdue Pegboard dominant, dominant olmayan, her ikisi ve montaj. II. ana küme şunları içerir: Parmak uzunlukları, palmar uzunluk, el kavrama kuvveti, toplam üst ekstremite uzunluğu, boy, iki nokta ayrımı, titreşim duyusu, kilo, BMI, dokunma duyusu, palmar genişlik, segmental kol, önkol ve el uzunluğu. **Tartışma:** Araştırma sonucunda çimdikleyici kavrama kuvveti, el becerisi, antropometrik ve duyusal özelliklerin birbiriyle ilişkili olduğu belirlendi.

Anahtar Kelimeler: Üst ekstremite antropometrisi; El becerisi; Duyusal değerlendirme; Küme analizi.

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The hand is the most important organ that enables people to take part in daily life and converts the information received from the brain into function. The main purpose of hand functions is the manipulation, stabilization, and grasping of objects (Sığırtmaç and Öksüz, 2021).

The activities of daily living (ADLs) is a term used to collectively describe fundamental skills required to independently care for oneself, such as eating, bathing, and mobility. ADL is used as an indicator of a person’s functional status (Reitz, Scaffa and Dorsey, 2020).

The grip strength of both hands plays an important role in ADL performance. Grasping skills are affected by factors such as age, sensory-perception-motor system, cognitive status, and musculoskeletal system (Sığırtmaç and Öksüz 2021; Lee, Wu, Chiang, et al., 2020).

Strength is one of the functions that affect grip. Many personal factors may affect the strength (Conforto, Samir, Chausse, et al., 2019; van der Looven, Deschrijver, Hermans, et al., 2021; Peters, van Nes, Vanhoutte, et al., 2011). Grip strength increases with age and reaches its highest level between 30-45 years of age, and then begins to decrease. A person's choice of work or leisure time activity also affects his/her grasping power (Martin, Ramsay, Hughes et al., 2015). Strong correlations are found between grip strength and anthropometric measurements (e.g., weight, height, hand length) (Zaccagni, Toselli, Bramanti, et al., 2020; Lopes, Grams, da Silva, et al. 2018).

Anthropometry is used in many fields such as ergonomics, product design, medicine, nutrition, and engineering (Dianat, Molenbroek and Castellucci, 2018). The use of hand anthropometry in the design of tasks related to the human hand is very important. The design of many products such as machine protection apparatus, hand tools, and luggage holders can be given as an example (Cakit, Durgun and Cetik, 2016). For this reason, as our research aims, it will be meaningful to reveal the relationship between anthropometry and the functionality of the hand.

To interact with the world, the primary way for a human is to use their hands. A child learns object manipulation motor skills through hands. A significant relationship between the functional skills of the hand and the performance of activities of daily living has been observed in studies conducted with different populations (Scherder, Dekker and Eggermont, 2008; James, Ziviani, Ware et al., 2015).

Different grip types are important for the functional independence of the person in different activities of daily living. In a previous study, the relationship between different grip types and functional independence in various ICF activities was examined; when compared to other grip types, pad-to-pad-pinch was observed to be the grip type most associated with the functional independence of the individual (Gracia-Ibáñez, Sancho-Bru and Vergara, 2018). The development of finger skills may be related to the capacity to use the central sensory input. Integration of sensory information is a critical component of motor control (Shurrab, Mandahawi and Sarder, 2017).

Integration of sensory and motor information is one step, among others, that underlies the successful production of goal-directed hand movements necessary for interacting with our environment. There are no studies found in the literature examining the relationship between sensorimotor skills, functional skills of the hand, and anthropometric variables in healthy young Turkish individuals.

Healthcare professionals often perform assessments and interventions with individuals who have difficulties with manual dexterity (Bleyenheuft, Wilmotte and Thonnard, 2010; Aranha, Saxena, Moitra et al., 2017). This study aims to examine the relationship between sensorimotor skills, functional skills of the hand, and anthropometric variables in health science students.

MATERIAL AND METHODS

Participants

The research was carried out on 70 occupational therapy students (21.51± 1.59 years; 61 women, 9 men) in the Biomechanics and Occupational Therapy Laboratories of Biruni University, Faculty of Health Sciences. Study data were collected between December 2021 and March 2022.

Inclusion criteria were being an occupation therapy university student and giving consent to the study. Exclusion criteria were having a neurological, neuromuscular, or musculoskeletal problem that would prevent participation in the study, and having an injury that would prevent participation in the study.

Data Collection Tools

Demographic Information Form: The form includes demographic information questions such as age, sex, which class the student is enrolled in, smoking status, dominant hand and personal, and family history of any chronic illnesses.

Anthropometric Measurements: Participants' height, weight, length of the upper extremity (distance from the acromion to fingertip), arm (distance from the acromion to the tip of the olecranon), forearm (distance from the tip of the olecranon to the styloid process of radius), hand (distance from the styloid process of radius to the fingertip), length of metacarpals and digits, and palmar width (distance between 2, 3, 4 and 5th metacarpal basis) were measured and recorded. Measurements were taken with a tape measure from both sides.

Hand Dynamometer: Jamar hand dynamometer is a measurement tool that is preferred as the "gold standard" for measuring maximal voluntary gripping force, and that can measure a maximum of 90 kg of grip force at 2 kg intervals. For the measurement, the participants' shoulder joints were in adduction and neutral position, the elbow in 90 degrees flexion, forearm and wrist in the neutral position. Participants were informed about the testing procedure. The adjustment of the dynamometer was made individually. Measurements were made three times and the average value of the measurements was recorded as kilogram-force (kg-f). These measurements are completed for participants' both hands (Peters et al., 2011).

Pinchmeter: A pinch meter was used to measure finger grip strength. Participants were seated in a chair with their feet flat on the floor, back against the backrest, shoulders in the neutral position, and elbows at 90 degrees. There was no support for the shoulder. The forearm and elbow were leaning on an armrest, and the wrist was in the neutral position. Three types of grips were evaluated with a pinch meter in the dominant and non-dominant hand: lateral grip strength with the end portions of the 1st and 2nd fingers, dipod grip strength with the tip of the 1st finger, and the lateral aspect of the 2nd finger, tripod grip strength with the tip portions of the 1st, 2nd and 3rd fingers. These tests were repeated three times. The average values in these three grip types were recorded as a kilogram-force (Martin et al., 2015; Shurrab et al., 2017).

Purdue Pegboard Test: This test was developed to measure manual dexterity using age-related normative data. The Purdue Pegboard Test involves a rectangular wooden surface. On this surface, there are two parallel lines consisting of twenty-five holes, one centimeter apart. In the upper part of the surface; there are four compartments with pins, sleeves, and washers. In this test, the aim is to place as many pins as possible into the holes within 30 seconds, first hands separately and then together at the same time; and then to place as many collars and washers as possible on the pins within 1 minute. The test was originally developed by Joseph Tiffin in 1948 to measure the manual dexterity of factory workers; then it was used in the field of rehabilitation and neurological evaluations (Stijic et al., 2023).

During the test, the participant sits in a comfortable position with the board in front of the surface and the partitions away from the participant. The participant should have been informed about the assessment and should have been allowed to practice beforehand. The person first places the pins from the nearby compartment with his dominant hand in a top-down direction, within 30 seconds. If one of the pins falls to the ground, the participant must reach for the next pin and not pick up the fallen pin. The non-dominant hand is then tested in the same way, and then this test is repeated using both hands at the same time (Figure 1). Finally, the number of pins, collars and washers that the person can string in one minute is observed and recorded in the same way (Lawson, 2019; Sığırtmaç and Öksüz, 2021).

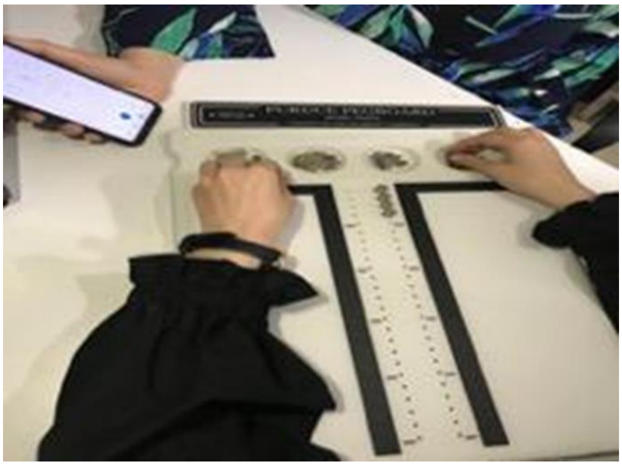

Figure 1. Purdue Pegboard Test

Semmes-Weinstein Monofilament Test: The Semmes-Weinstein Monofilament Test is a brief sensory evaluation test. The purpose of the test is to evaluate the patient's tactile sensation and detect conditions such as neuropathy, which involves nerve damage. It includes nylon filaments of the same length, gradually increasing in diameter. The patient's eyes should be closed while performing the assessment. The surface on which the filament will be applied is pressed and held for 1 second until the filament is bent. This application is done three times and it waits for 1 second after each application. The patient is informed to say "yes" whenever he/she felt the monofilament, and the responses obtained from the patient are recorded (Suda, Kawakami, Okuyama et al., 2021) (Figure 2).

Figure 2. Semmes-Weinstein Monofilament Test

Monofilaments are grouped and interpreted according to their thickness as follows: Normal: 1.65-2.83, decreased light touch sense: 3.22-3.61, decreased protective sensation: 3.84-4.31, loss of protective sensation: 4.56-6.45, only deep pressure: 6.65.

Two- Point Discrimination Test (TPD): Two-point discrimination is one of the tactile gnosis functions that gives information about the spatial sensitivity of the person. Two-point stimulation is the smallest distance perceived as two separate points on the skin. The discriminator is applied simultaneously to two points on the skin until it feels like a single point by the patient. It is recorded by taking “one” or “two" answers from the patient. Two-point discrimination test is frequently used to examine sensory disorders, and to evaluate the effectiveness of therapy. The two-point discrimination test is a low-cost, easy-to-use, and precise measurement tool. This test was previously used in the evaluation of healthy individuals (Wolny, Linek and Michalski, 2017).

Participants were seated comfortably and their upper extremities were stabilized. Two-point discrimination tests were applied to two different locations, namely the palmar side pulp of the distal phalanx of the second digit, and to the mid-medial ventral side of the forearm. The forearm was positioned in the supine position, the wrist was in the neutral position, the elbow was flexed 90 degrees, and the shoulder was in the neutral position. Three measurements were taken for each location with a 1-minute interval between each measurement. The average score, which represents the minimal distance that the patient was able to differentiate between one and two points, was calculated as the sum of those three measurements (Sheng, Blackford and Barcia, 2019) (Figure 3).

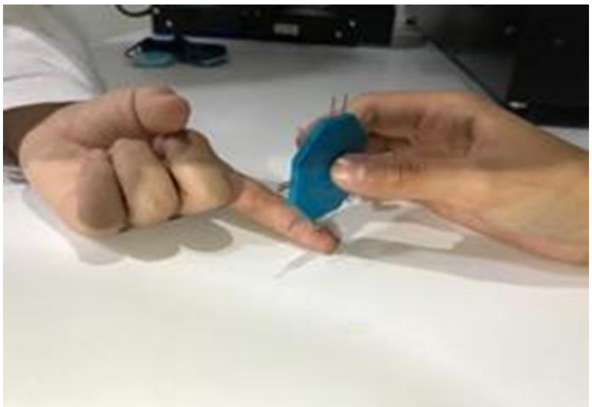

Figure 3. Two-point Discrimantion Test

Vibration Perception Test with Tuning Fork: 128-frequency standard tuning forks were used in the measurement of proprioception using vibration. After vibrating the tuning fork, it was placed on the dorsal of the distal interphalangeal joint of the 2nd finger, which was predetermined and marked. Patients were asked to start the stopwatch in their other hand as soon as they felt the vibration stop, and the tester stopped it when he/she feels the vibration stop. The time between was recorded in seconds. Measurements were repeated three times and the average was taken. Before each repetition, it was ensured that there was no residual vibration in the tuning fork. The forearm was maintained in a pronated position, the elbow joint was flexed at 90 degrees, and the shoulder joint was in a neutral position. Additionally, the upper extremity was stabilized by support from the table in front of the participant (Figure 4) (Lai, Ahmet, Bollineni, et al., 2014; Akseki, Erduran, Özarslan, et al., 2010).

Figure 4. Vibration Perception Test with Tuning Fork

Data analyses

Mean and standard deviation (SD) were calculated for continuous variables. The normality of the variables was analyzed via a Kolmogorov-Smirnov test. Hierarchical Cluster Analysis (CA) of modern multivariate statistical methods was employed to find the clustering tendency of the variables. The relationships between the variables were presented as a dendrogram that visually reveals the connection of those objects that seem to be similar. The dendrogram of the variables was found using the Common Linkage (between groups) and Ward's Hierarchical Clustering Model. The model decided upon should be the best according to the data structure and should minimize the variability within clusters and maximize the variability between clusters. Hierarchical Cluster Analysis can control the association between variables by using more variables collectively to investigate interactive outcomes and introduce clusters to determine the links between variables or to specify the conditions under which the association takes place. This gives a much richer and more realistic picture than looking at a single variable and provides a powerful test of significance compared to univariate methods. Thus, the method offers stronger results than the univariate methods. This can provide the investigator with a more powerful research statement (Demirel and Celik, 2017).

We conducted a power analysis using the GPower program. With a standard deviation of 0.05 and a power of 85%, taking into account the 0.412 r-value of the relationship between hand length and dipod grip strength variable it was found appropriate to include at least 66 participants in the study (Shurrab et al., 2017). Two-sided p values were considered statistically significant at $p \leq 0.05$. All statistical analyses were carried out by using R programming (version 3.6.2 (2019-12-12) – CRAN).

RESULTS

Table 1 describes the 70 participants who were included in this study. It is seen that the majority of the participants are women (87%), normal according to BMI (21.98±3.37 kg/m2), occupational therapy 2nd-year students (62%), right-handed (89%), and non-smokers (86%).

Table 2 shows the anthropometric measurements, and Table 3 presents grip strength and hand function values.

Table 1. Descriptive features of the participants.

	Mean	Standard Deviation	Number	Percentage
Gender				
Female			61	87.14%
Male			9	12.86%
Height	165.65	7.45		
Weight	60.51	11.21		
BMI	21.98	3.37		
Occupational therapy 2nd year			43	62%
Occupational therapy 3rd year			15	5%
Occupational therapy 4th year			11	16%
Occupational therapy Postgraduate			1	1%
Smoking				
Yes			10	14%
No			60	86%
Dominant hand				
Right			62	89%
Left			8	11%

Table 2. Upper extremity anthropometrics

	Mean	Standard Deviation
Total Upper Extremity Length (cm)	72.07	3.87
Arm Length (cm)	34.58	2.86
Forearm Length (cm)	27.96	4.94
Hand Length (cm)	18.19	2.69
Palmar Length (cm)	17.53	1.70
Palmar Width (cm)	8.28	1.40
Thumb Length (cm)	6.49	0.61
2. Finger Length (cm)	7.08	0.56
3. Finger Length (cm)	7.75	0.48
4. Finger Length (cm)	7.02	0.57
5. Finger Length (cm)	5.87	0.49

Table 3. Hand strength and dexterity values

	Mean	Standard Deviation
Purdue Dominant Hand (sec.)	14.73	2.23
Purdue Non-dominant Hand (sec.)	12.77	2.10
Purdue Bilateral (sec.)	21.86	3.31
Purdue Assembly (sec.)	29.54	7.12
Pinchmeter Lateral Grasp Dominant Hand (kg.)	6.09	2.35
Pinchmeter Tripod Grasp Dominant Hand (kg.)	6.07	2.15
Pinchmeter Dipod Grasp Dominant Hand (kg.)	5.50	2.33
Pinchmeter Lateral Grasp Non-dominant Hand (kg.)	5.77	2.11
Pinchmeter Tripod Grasp Non-dominant Hand (kg.)	5.56	1.91
Pinchmeter Dipod Grasp Non-dominant Hand (kg.)	4.93	2.11
Jamar Dominant Hand (kg.)	27.38	7.02
Jamar Non-dominant Hand (kg.)	26.16	7.03
Tuning Fork Dominant Hand	3.48	4.38
Tuning Fork Non-dominant Hand	3.22	4.60
Semmes-Weinstein Monofilament Dominant Hand	2.44*	0.08**
Semmes-Weinstein Monofilament Non-dominant Hand	2.44*	0.04**
Two-Point Discrimination Dominant Hand Index Finger	3.19	1.31
Two-Point Discrimination Dominant Hand Forearm	13.54	1.63
Two-Point Discrimination Non-dominant Hand Index Finger	3.03	0.90
Two-Point Discrimination Non-dominant Hand Forearm	13.17	2.05

**For the Semmes-Weinstein Monofilament test, the median value is shown on the table*
***For the Semmes-Weinstein Monofilament test, the interquartile range is shown in the table*

Cluster: When the Cluster analysis was applied at the end of the research, two main clusters and 4 sub-clusters belonging to the main cluster II were obtained by using a dendrogram (Figure 5). Each cluster consists of variables related to each other.

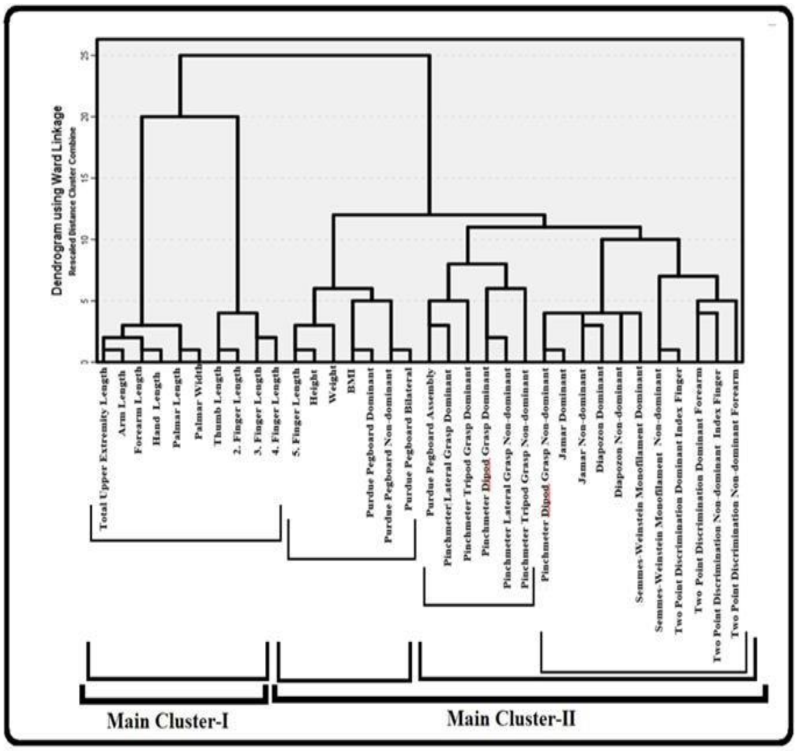

Figure 5. Dendrogram

The main cluster I contains; Dipod, tripod, and lateral grip force, Purdue pegboard dominant, non-dominant, both and assembly

The main cluster II contains; Finger lengths, palmar length, grip strength, total upper extremity length, height, two-point discrimination, vibration, weight, BMI, monofilament, palmar width, segmental arm, forearm and hand length.

The subcluster I contains; Finger 3-4 and palmar length, grip strength, total upper extremity, height.

The subcluster II contains; Two-point discrimination of forearm and fingers, diapason

The subcluster III contains; Finger 1-2-5 length, palmar width, arm, and forearm length

The subcluster IV contains; Weight, BMI, Monofilament, hand length.

DISCUSSION

Our research was designed to examine the relationship between sensorimotor, anthropometric, and functional features of the hand. It was shown that these functions are closely related to each other by using a Hierarchical Cluster Analysis Although the variables are clustered under two main clusters; there are 4 subclusters under Main Cluster II.

Main Cluster I has shown the relationship between the pinch grip pattern and the Purdue Pegboard test and Main Cluster II has revealed the relationships between anthropometric features of the hand and upper extremity, grip strength, and sensory parameters. The subclusters in the main cluster II showed us that the grip strength of the hand, sensory characteristics, and anthropometric characteristics are related to each other. Many movements of activities of daily living require object manipulation with a stable hand grip. Therefore, the decrease in grip strength causes functional loss.

By the findings from the Main Cluster II, it was concluded that palmar length, palmar width, finger lengths, BMI, and total upper extremity length were associated with hand grip strength. We also evaluated the sensation and functionality of the hand, and these variables were also associated with those values. The relationship between hand functionality and sensory characteristics is significant, and sensory problems can have a substantial impact on the recovery of hand function. Sensory impairments, such as reduced touch or vibration sensations, can affect the precision and accuracy of hand movements, making it more challenging to perform daily activities. Therefore, addressing sensory problems is crucial for enhancing hand functionality and promoting functional recovery. By incorporating interventions that target sensory deficits alongside motor rehabilitation, the potential for restoring hand function can be maximized. Thus, understanding and addressing the impact of sensory problems on hand functionality is essential for comprehensive rehabilitation strategies.

The pinch grip pattern is a type of grip needed for many professional performances. Too much pinch grip will not only increase occupational performance but also reduce the risk of injury (Sala, Lopomo, Romagnoli et al., 2022). It is seen that there is a relationship between pinch grip and Purdue Pegboard which is an important test in terms of reflecting fingertip grip in main cluster I. The relationship between the pinch grip pattern and the Purdue Pegboard Test in Cluster I may be due to the similarity in measuring hand skills. The pinch grip is important for professional performance, and a strong pinch grip can improve occupational performance and reduce the risk of injury. The Purdue Pegboard Test assesses finger grip and manipulation, reflecting fingertip grip abilities. Individuals with good pinch grip skills tend to perform better in the Purdue Pegboard Test, which measures similar hand skills. Overall, the relationship highlights the importance of hand dexterity and its impact on occupational performance.

In our study, findings in subcluster II show that the parameters of finger length, palmar width and upper extremity length are correlated with each other as expected. A study conducted on 46 university students in 2017 revealed that hand length and palmar width had a significant effect on pinch grip strength (Shurrab et al., 2017). Finger lengths were not calculated in that study. In our study, the relationship between total upper extremity length, finger length, palmar width and height, and hand grip strength is observed in subcluster I. By considering multiple variables related to hand structure and function, our study provides a more comprehensive understanding of the factors influencing hand grip strength.

In another study, the lateral, dipod, and tripod grip strengths, BMI, and hand lengths of the subjects were calculated as in our study. The mean age was 21.1, the weight was 65.7, the height was 170.5 cm, the BMI was 22.3 kg/m2, the average hand length was 17.5 cm, and the palmar width was 7.7 cm. In this study, the maximum voluntary contraction of both hands was also measured. Hand length is 18.6 cm in men, and 16.4 cm in women; palmar width is 8.3 cm in males, and 7.1 cm in females. It is seen that these obtained values are similar to the findings of our study. As a result of the research, it was found that gender, hand length, palmar width, and pinch grip strength increased the maximum voluntary contraction of the hand (Shurrab et al., 2017). The similarity in the calculated grip strengths, BMI, hand lengths, and other measurements between the mentioned study and our research indicates a consistent pattern across different populations. The fact that both studies report comparable values suggests that these anthropometric characteristics are relatively consistent across different samples. Furthermore, the findings of the other study align with our research, emphasizing the impact of gender, hand length, palmar width, and pinch grip strength on the maximum voluntary contraction of the hand. These similarities in results across studies contribute to the growing body of evidence supporting the influence of these factors on hand functionality. Overall, the agreement between the two studies strengthens the validity and generalizability of the findings regarding the relationship between anthropometric measurements and hand strength. The findings highlight the role of hand morphology and physical characteristics in hand function.

Hand grip strength is of great importance in terms of performance in many sports such as basketball and baseball. Studies have shown that athletes with longer and larger hands have greater grip strength (Chahal and Kumar, 2014; Fallahi and Jadidian, 2011). Similar results of the relationship in Subcluster I were also seen in a study conducted in 2010. In this study, it was revealed that the anthropometric characteristics of the hand and grip strength are determinative in terms of functionality (Koley, Singh and Kaur, 2010). In conclusion, the relationship between hand grip strength and hand size is a significant factor that can impact sports performance. Athletes with longer and larger hands generally exhibit greater grip strength, reflecting the importance of hand size about athletic abilities. Variations in hand size can affect athletes' hand function and overall performance.

In our study, finger lengths, palmar width, and forearm length variables are included in Subcluster III. Considering the other subclusters in the Main Cluster II, we can easily conclude that hand length and hand width are related to grip strength. In a study on basketball players aged 10-16; age, height, weight, hand length, and hand width were calculated and hand grip strength was evaluated. Consistent with the results of our research, it was concluded that there is a relationship between hand width and grip strength (Chahal and Kumar, 2014). Overall, the collective evidence from our study and that study on basketball players supports the notion that hand width, along with other hand morphology factors, influences grip strength. Understanding these associations can have practical implications for athletic performance and training, especially in sports that require strong grip capabilities.

Manual dexterity is a crucial skill for various daily activities and professional performance, relying on precise control of fine and gross motor skills. Our research reveals that manual dexterity is influenced not only by anthropometric characteristics but also by sensory factors. While previous studies have acknowledged the significance of anthropometric features alone, they fail to provide a comprehensive explanation of hand functionality. For instance, a study on dental students demonstrated that anthropometric characteristics such as hand length and palmar width had small yet significant effects on dexterity performance, with individuals possessing smaller hands exhibiting better performance (Cakit et al., 2016). However, these studies did not include evaluations of sensory abilities. In contrast, our study takes a step further by incorporating sensory assessments, thereby offering a more holistic understanding of the factors contributing to manual dexterity. By considering both sensory and anthropometric characteristics, we provide a richer perspective on hand functionality. Our findings contribute to the existing literature by highlighting the interplay between sensory and anthropometric factors and their combined influence on manual dexterity. The inclusion of sensory evaluations in our study allows for a more nuanced exploration of hand functionality, ultimately enhancing our comprehension of the intricate relationship between sensory abilities and manual dexterity.

In our study, the relationship between manual dexterity and TPD, light touch, and vibration senses in main cluster II is striking. In addition, the relationship between hand length, and light touch sense is also important in subcluster IV. Hand length, as an anthropometric characteristic, can influence tactile sensation and the ability to perceive light touch. This finding suggests that individuals with longer hands may exhibit differences in their light touch sensory perception compared to those with shorter hands. In this sense, the evaluation of different senses and the anthropometric measurements have enriched our research.

In a study conducted in 2020, two-point discrimination and manual skills of individuals whose average age was similar to that of our study were evaluated. A positive correlation was found between TPD and manual dexterity. The index finger TPD value was found to be 3.2 mm. This value was 3.18 in our research, which is quite close. In the same study, the mean dexterity score of the right hand was 15.5 and that of the left hand was 13.67. The mean dexterity score of both hands was 11.52. The mean dexterity score for the assembly was found to be 30.71. In our study, the dominant hand score was found as 14.73, the non-dominant hand score was found as 12.77, both hand's score was 21.85, and the assembly score was 29.54. In general, it is seen that the values are similar in these studies (Aysha and Smitha, 2020). Regarding the manual dexterity scores, both studies indicate relatively comparable results. While there might be some slight variations in the specific scores, the general trend is similar. In both studies, higher scores were observed for the assembly task, indicating better dexterity in performing complex tasks that require fine motor skills and coordination. Additionally, the dominant hand scores were generally higher than the non-dominant hand scores, which is expected due to the preferential use and better control of the dominant hand. Finally, these findings contribute to the existing body of knowledge and provide further evidence for the importance of TPD and its correlation with manual dexterity. The consistency in results adds confidence to the conclusions drawn from your study and further validates the relationships between these variables.

In our study, a significant relationship was observed between hand grip strength and light touch sensations in Main Cluster II. A relationship similar to the relationship between grip and light touch sensation in healthy individuals, which we stated in our results, was also reported in a recent study in patients with type 2 diabetes. In this study, physical examination and electrodiagnostic tests were performed on a total of 161 type 2 diabetes patients, and each participant's grip, pinch strength, light touch sensations, and manual dexterity were measured. Significant correlations were found between weak hand skills and grip, pinch, and mild tactile senses of participants with diabetic polyneuropathy. It was noteworthy that similar relationships were found in the results of healthy or neurologically affected individuals. Remarkably the relationship between hand grip strength and light touch sensation that we obtained in the healthy population was similar to the results of individuals with neurological impairment (Zhang, Liu, Jia, et al., 2021). The convergence of findings from your study and the study involving individuals with type 2 diabetes supports the notion that grip strength and light touch sensation are closely related and can be affected by neurological conditions. These insights contribute to our understanding of the complex interplay between motor and sensory functions and their clinical implications.

When we examine the previous studies on this subject in the literature, the anthropometric characteristics of individuals are examined and their relationship with hand grip strength, hand functionality, and hand skills are explained. Most studies did not include sensory evaluations. However, what we do with our hands is both a very important function of the nervous system and a unique feature that distinguishes humans from many other species. While evaluating this complex structure, many different features should be considered together. In our research, we evaluated the hand from many different aspects such as sensory, motor, anthropometry, and function. Using Hierarchical Cluster Analysis, which is an advanced statistical method, the interrelationship of sensorimotor, anthropometric, and functional features of the hand is revealed in a very understandable way. The results of this study, in which we examined the healthy human hand, can be a reference in terms of easier interpretation of pathomechanics. We think that our research will guide many clinicians who apply preventive rehabilitation approaches about which variables are important to include when creating assessment and intervention programs.

Besides, manual skills are an important part of their professional life for healthcare professionals. They perform interventions for the development of these skills for the individuals they work with, therefore therapists' manual skills should be at a sufficient level while performing these interventions. Our research will also support their knowledge of this issue.

One-third of hand injuries are due to work accidents. The inclusion of biomechanical analyses in occupational evaluations and the early evaluation of young adults in terms of grip strength can perhaps be considered a preventive strategy to prevent possible injuries. It can be seen that Main Cluster I has features that can be changed and improved, such as pinch grip strength and dexterity. By these findings, strategies can be developed for the development of fine grasping power and hand skills, so that the therapist does not experience difficulties while performing their profession in the future.

Our limitations are that we did not take upper extremity circumference measurements and we did not measure kinematics in the grip position. We plan and aim to obtain more objective data by using computerized motion analysis in our future studies. In addition, similar studies can be planned for children, adolescents, and adults in different age ranges and comparisons can be made.

Ethical Approval

The current study was approved by the Ethics Committee of the Biruni University on 18/11/2021 with the number 2021/61-5. All participants provided consent to be included in this study.

Authors' Contribution

BÖ, RA: Conceptualization, review and editing, supervision; BÖ, RA, EA: Conceptualization, investigation, Writing–Original Draft; BÖ: Review and editing, supervision; YÇ: Methodology, statistical analysis; BÖ, RA, EA: Investigation, review and editing.

Conflicts of Interest

The authors have indicated they have no potential conflicts of interest to disclose.

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