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Evaluation of Hand Asymmetry in Relation to Hand Preference

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A B S T R A C T

We evaluated the asymmetric hand measurements in right- and left-handed individuals. 343 men and 290 women aged 18–42 years (22.11±2.07) participated in the study. There were no statistically significant differences when right–left differences in hand length, third finger length, palmar length, and the digit index value were evaluated according to hand preference and sex. Statistically significant differences were found for right–left differences in hand width, hand--shape index, and the palmar length/width according to hand preference. The strong left-handers, weak left-handers, and ambidextrous individuals in the study group all exhibited asymmetry favoring the left and were considered together. Similarly, the strong and weak right-handers exhibited asymmetry favoring the right hand and were considered together. The difference between these two groups was significant. When the data were evaluated according to sex, significant differences were found between the subgroups. In particular, right–left differences in the hand-shape index and palmar length/width values of the strong left-handers, weak left-handers, and ambidextrous individuals were found to be statistically significant according to sex; in contrast, the strong and weak right-handers showed no significant differences according to sex. These results suggest a relation of hand asymmetry to hand preference in a Turkish population.

Key words: *hand preference, Edinburgh Inventory, laterality, human*

Introduction

Complete body symmetry may be regarded as the norm in the animal kingdom, while asymmetry is said to be fairly rare in nature. Still, consistent right–left differences within an individual, termed handed asymmetry, are present in many vertebrates. Examples of this include the dextral looping of the heart during embryonic development, and the variations between the right and left lobes of the lungs. Moreover, minor limb asymmetry, which can be identified by careful anthropometry, is the norm in humans. In contrast, gross asymmetry, which is immediately detectable by the human eye, is rare[1].

Morphological asymmetry has traditionally been categorized into three types: fluctuating asymmetry (FA), directional asymmetry, and antisymmetry[2–6]. Directional asymmetry refers to the situation in which morphological asymmetry is consistently biased to the same side of the body in different individuals (e.g., the consistent asymmetry of the thoracic organs in humans); in antisymmetry, a trait is asymmetric in all individuals, but whether the left or right side is larger varies. In other words direction of asymmetry is random as seen in the major claws of lobsters and male fiddler crabs or the spiral orientation of palm-tree trunks. More than 450 species from 67 families in eight phyla exhibit antisymmetry[7]. FA refers to random bilateral deviations from normal symmetry, with the larger side and the magnitude of asymmetry varying among individuals. As most individuals are nearly symmetrical, a histogram of the left minus the right differences is normally distributed with a mean of zero[2,4–6]. FA reflects the inability of organisms to develop perfect symmetry[3,8]. In other words, FA reflects the magnitude of developmental instability/stability in an organism, which is the appearance of, or predisposition to, deviations from normal ontogeny[2,5,9–11]. Human examples of traits showing FA include the lengths of corresponding limbs or facial structures; however, anything that is normally considered identical on both sides of the body may exhibit FA[12]. Obviously, while the direction of a trait

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showing FA is random with regard to the population as a whole, any asymmetry in a given individual will be biased to one side or the other. More than one type of asymmetry can exist concurrently in the same population; however, characters exhibiting either directional asymmetry or antisymmetry should not be used for assessing FA[2–6].

The development of the right and left limbs depends on a similar morphogenesis for the right and left sides of the body and is a consequence of the development of mirror symmetry, the plane of the symmetry being the midline of the embryo. The limbs may be regarded as mirror images of each other with complete symmetry about the midline axis; thus, they are completely symmetrical. However, asymmetry in the limb bones is known to exist. Notably, the right humerus and forearm may be longer than the left; crossed asymmetry may occur, with the left femur being longer than the right. In addition, the upper limbs may display a greater degree of asymmetry than the lower limbs. The right upper limb is significantly longer (1–3%) and heavier (2–4%) than the left upper limb. The limb asymmetry is not only shown to be associated with certain musculoskeletal pathologies, but claimed to occur spontaneously without any pathological cause also. Besides certain investigations suggest a relationship between activity and bone growth, which may lead to limb asymmetry[1]. The hand is a developmentally complex structure with 19 pairs of metacarpals and phalanges in the right and left hands. Human hands are the result of a long evolutionary process and are embryologically distant from the midline of the developing body[3].

A connection between the handedness of an individual and the lateralization of language has been observed, with right-handers demonstrating more complete lateralization than left-handers. Anatomical asymmetries of the cerebral hemispheres and of other body parts have also been demonstrated to be a function of the handedness of an individual[13]. Anthropometric studies comparing the two halves of the human body have found that the values obtained from the right half are different from those of the left[14–17]; however, the number of studies concerning hand asymmetry in relation to hand preference is limited. In this study we sought to evaluate the degree of asymmetry between the right and left hands of individuals with different hand preferences.

Subjects and Methods

Six hundred and thirty-three healthy individuals without chronic disease (343 men and 290 women) aged between 18 and 42 years (22.11±2.07) participated in the study. Informed consent was obtained from all participants, and the study was approved by the ethics committee of Karaelmas University, Zonguldak, Turkey. Hand preference was assessed for each subject using the Edinburgh Handedness Inventory[18], and the Geschwind Score (GS)[19] was calculated. Specifically, each participant was asked ten questions regarding his/her hand preferences for writing, drawing, throwing, jar opening, striking matches, and for using scissors, a toothbrush, a knife without a fork, and a spoon. GS was calculated as described previously[17,19,20].

A digital compass (Shan 150 mm) with a resolution of 0.01 mm was used for all hand anthropometric measurements. All measurements were performed by the same investigator (CB).

To determine intra-observer precision, three different widely used precision estimates were calculated: the technical error of measurement (TEM), the relative technical error of measurement (rTEM), and the coefficient of reliability (R)[21,23,24]. TEM was computed as the square root of the squared difference between two corresponding measurements divided by twice the sample size[22–24]. TEM is interpreted as the typical magnitude of error associated with a certain measurement and can be used to estimate intraobserver precision[22]. rTEM is calculated by dividing TEM for a given variable by the mean for that variable and multiplying the result by 100[22–24]. rTEM represents an estimate of error magnitude as a percentage of object size[22]. R can be calculated using TEM and ranges from 0 (not reliable) to 1 (complete reliability). R can be calculated using the following equation[21,23,24]: $R = 1 - [(TEM)^2/(SD)^2]$, where SD is the standard deviation of all measurements[23,24]. R represents the proportion of between-subject variance free from measurement error[21]. All computations regarding intra-observer precision were performed in Excel 2007.

The measurements were taken from the palmar side with the digits fully extended on a flat, hard surface and adducting from the second to the fifth digit while extending the thumb slightly.

For each hand, hand width, hand length, third digit length, and palmar length were measured as described by Pheasent[25]. Using these measurements, the shape index, which determines hand shape, the digit index, which determines grasping capability, and the palmar length/width ratio, which determines the palmar type without the digits, were calculated as follows.

- Palmar length: the distance between the midpoint of the distal wrist crease and the midpoint of the proximal digit crease, calculated by subtracting the length of the third digit from the total hand length[17,26].
- Shape index (length–width index, hand index): Hand width × 100/Hand length[17,27].
- Digit index (phalangeal index): Third digit length × 100/Hand length[17,27].
- Palmar length/width ratio: Palmar length/Palmar width (Palmar width = Hand width)[17,26].

The degree of asymmetry was determined by subtracting the values for the right hand from those of the left, with any value other than »0« indicating hand asymmetry[10,17]. If the value was positive, the asymmetry was said to favor the right hand, while a negative value indicated asymmetry that favored the left. The data were analyzed by univariate analysis of variance using SPSS for Windows, Release 11.01 (SPSS Inc., Chicago, IL, USA).

Results

TEM, rTEM and R for all parameters measured are presented in Table 1. For all of the parameters measured the TEM values were between 1.02–2.11 mm. The rTEM values were between 1.05% and 1.63%. R values of all the parameters were close to 1 suggesting that most of the variation for the parameters within the sample was due to factors other than measurement error. These results suggest that acceptable degree of intra-observer precision was obtained for the hand anthropometric measurements.

TABLE 1
PRECISION ESTIMATES CALCULATED FOR HAND ANTHROPOMETRIC MEASUREMENTS (n=36)

Parameters	TEM (mm)	rTEM (%)	R
Right hand length	2.11	1.16	0.96
Right hand width	1.18	1.47	0.95
Right 3rd digit length	1.13	1.45	0.93
Right palmar length	1.66	1.60	0.95
Left hand length	1.90	1.05	0.97
Left hand width	1.02	1.25	0.97
Left 3rd digit length	1.28	1.63	0.93
Left palmar length	1.46	1.41	0.96

One hundred and thirteen of the participants were strong right-handers (53 male, 60 female), 388 were weak right-handers (200 male, 188 female), 33 were ambidextrous (25 male, 8 female), 68 were weak left-handers (44 male, 24 female), and 31 were strong left-handers (21 male, 10 female). The hand anthropometric measurements from the different hand preference groups of each gender are shown in Table 2.

No statistically significant differences were observed between the subgroups when right–left differences in hand length, third finger length, palmar length, and the digit index value were considered according to hand preference and sex ($p>0.05$). The only significant interaction we detected was for right–left differences in palmar

TABLE 2
HAND ANTHROPOMETRIC MEASUREMENTS FOR DIFFERENT HAND PREFERENCE GROUPS OF BOTH SEXES

Gender	Parameters	Strong Right Hander	Weak Right Hander	Ambidextrous	Weak Left Hander	Strong Left Hander
Male (N=343)	Right hand length (mm)	186.99±8.78	187.46±9.05	188.65±8.79	188.15±9.68	187.36±9.12
	Right hand width (mm)	84.36±6.23	84.72±4.18	85.54±4.13	84.22±4.58	84.18±4.47
	Right 3rd digit length (mm)	79.70±4.94	80.72±4.62	81.15±4.93	79.81±4.61	80.52±4.80
	Right palmar length (mm)	107.29±5.07	106.75±5.68	107.50±5.15	108.34±5.86	106.84±5.80
	Right shape index	45.11±2.28	45.26±2.50	45.41±2.57	44.80±1.89	44.99±2.56
	Right digit index	42.61±1.31	43.06±1.33	43.00±1.32	42.42±1.06	42.98±1.42
	Right palmar length/width ratio	1.28±0.07	1.26±0,08	1.26±0.07	1.29±0.07	1.27±0.08
	Left hand length (mm)	187.27±9.81	188.73±9.36	187.32±7.95	186.61±9.27	186.48±9.96
	Left hand width (mm)	83.62±6.01	84.41±4.23	86.54±4.50	85.76±4.99	85.50±4.46
	Left 3rd digit length (mm)	80.14±5.24	81.07±5.08	81.09±5.29	79.70±5.10	80.12±4.83
	Left palmar length (mm)	107.12±5.60	107.65±5.47	106.23±4.14	106.91±5.59	106.36±6.68
	Left shape index	44.67±2.34	44.79±2.47	46.23±2.17	45.99±2.18	45.92±2.54
	Left digit index	42.78±1.25	42.95±1.28	43.26±1.51	42.70±1.44	42.97±1.52
	Left palmar length/width ratio	1.28±0.08	1.28±0.07	1.23±0.05	1.25±0.07	1.25±0.09
Female (N=290)	Right hand length (mm)	171.65±8.02	171.65±7.89	173.17±7.23	173.14±7.37	170.78±8.09
	Right hand width (mm)	75.46±3.15	75.65±4.06	74.08±2.68	75.21±3.18	75.17±3.22
	Right 3rd digit length (mm)	74.54±4.11	74.06±4.02	75.32±2.17	74.92±3.27	74.46±4.96
	Right palmar length (mm)	97.11±5.43	97.58±4.98	97.85±5.92	98.23±5.45	96.32±3.94
	Right shape index	44.02±2.02	44.11±2.25	42.79±0.85	43.47±1.62	44.04±1.37
	Right digit index	43.44±1.58	43.15±1.25	43.53±1.31	43.29±1.38	43.57±1.26
	Right palmar length/width ratio	1.29±0.08	1.29±0.08	1.32±0.04	1.31±0.07	1.28±0.05
	Left hand length (mm)	171.15±7.71	171.59±8.50	173.93±8.33	173.43±7.53	171.52±8.09
	Left hand width (mm)	74.39±3.12	74.78±4.09	74.26±3.69	75.99±3.83	76.01±3.07
	Left 3rd digit length (mm)	74.27±4.20	74.16±4.17	75.44±2.82	74.78±3.66	74.64±4.38
	Left palmar length (mm)	96.88±4.99	97.43±5.44	98.50±6.17	98.66±5.13	96.88±4.84
	Left shape index	43.52±2.15	43.63±2.27	42.71±1.12	43.83±1.75	44.37±2.01
	Left digit index	43.39±1.51	43.22±1.31	43.40±1.17	42.12±1.28	43.51±1.29
	Left palmar length/width ratio	1.30±0.08	1.31±0.08	1.33±0.05	1.30±0.07	1.28±0.07

length. The presence of an interaction effect implies that the effect of sex on right–left differences in palmar length varies as a function of hand preference. The right–left difference in palmar length tended to be symmetric in females, whereas left-handed males exhibited asymmetry favoring the right hand and right-handed males tended to show asymmetry favoring the left. Statistically significant differences were detected between the subgroups for right–left differences in hand width, shape index, and the palmar length/width value according to hand preference ($p<0.001$). The strong left-handers, weak left-handers, and ambidextrous individuals all showed asymmetry favoring the left hand; thus, they were considered together as a group. In contrast, the strong and weak right--handers had asymmetry favoring the right hand, and they too were considered together as a group. The difference between these two groups was significant. When the values were evaluated according to sex, the differences between the subgroups were significant ($p<0.05$). In particular, right–left differences in the shape index and palmar length/width value of the strong left-handers, weak left-handers, and ambidextrous individuals were found to be statistically significant according to sex, whereas no significant differences were found for the strong and weak right-handers according to sex (Tables 3 and 4).

When the shape index values were evaluated, no difference was found between the strong and weak right-handers according to sex; each group exhibited asymmetry favoring the right side when compared to the left--handers and ambidextrous individuals. The left-handed and ambidextrous males tended to have asymmetry favoring the left when the shape index was considered, while the left-handed and ambidextrous females tended to show symmetry.

When the palmar length/width values were evaluated, no difference was observed between the strong and weak right-handers according to sex; each group had asymmetry favoring the left side when compared to the left-handers and ambidextrous individuals. The left-handed males and ambidextrous males tended to have asymmetry favoring the right when the palmar length/width values were considered, while the left-handed and ambidextrous females tended to exhibit symmetry (Tables 3 and 4).

Discussion and Conclusion

There are various studies concerning the anthropometric measurements of the body[28,,29,30]. Dimensions of the hands are amongst the parameters evaluated in those studies. In the studies of Srhoj et al.[28], Cavala et al.[29] morphological characteristics of handball players including hand length and width were evaluated. Barut et al. evaluated hand dimensions in basketball, volleyball and handball players[30]. Buffa et al. evaluated palmar length and lengths of fingers according to gender and hand preference[31]. However none of those studies took into account hand asymmetry.

Careful measurement of several bilateral traits in humans has revealed many differences. However, the asymmetries found in humans are often very small and subtle. Perfect symmetry of bilateral traits is said to represent ideal development, while asymmetry represents an inexact presentation of developmental design[5]. Of the param-

TABLE 3
DEGREE OF ASYMMETRY ACCORDING TO HAND PREFERENCE IN BOTH SEXES

Gender	Parameters	Degree of Asymmetry Mean ± SD				
		Strong Right Hander	Weak Right Hander	Ambidextrous	Weak Left Hander	Strong Left Hander
Male (N=343)	Hand length (mm)	–0.28±3.75	–1.26±5.89	1.33±3.87	1.55±4.09	0.88±4.54
	Hand width (mm)	0.73±2.03	0.31±2.23	–0.99±2.76	–1.54±1.91	–1.32±2.80
	3rd digit length (mm)	–0.45±1.80	–0.36±3.60	0.05±2.06	0.11±2.37	0.40±2.01
	Palmar length (mm)	0.17±2.96	–0.90±3.24	1.27±2.76	1.43±3.03	0.48±3.44
	Shape index	0.44±1.44	0.47±1.70	–0.82±1.77	–1.19±1.24	–0.93±1.61
	Digit index	–0.18±0.78	0.11±0.95	–0.26±0.75	–0.28±0.94	0.006±0.82
	Palmar length/width ratio	–0.01±0.05	–0.02±0.05	0.03±0.06	0.04±0.04	0.03±0.05
Female (N=290)	Hand length	0.50±5.68	0.06±4.56	–0.76±2.05	–0.29±3.51	–0.74±3.18
	Hand width	1.07±2.17	0.87±1.95	–0.18±2.37	–0.77±1.98	–0.84±1.77
	3rd digit length	0.27±1.85	–0.09±2.28	–0.12±1.19	0.14±1.55	–0.17±1.89
	Palmar length	0.23±5.27	0.15±3.51	–0.64±2.11	–0.43±3.24	–0.56±1.90
	Shape index	0.50±1.85	0.49±1.56	0.09±1.32	–0.36±1.30	–0.32±1.06
	Digit index	0.04±1.56	–0.07±1.07	0.13±0.75	0.16±0.99	0.07±0.61
	Palmar length/width ratio	–0.02±0.08	–0.01±0.06	–0.006±0.04	0.007±0.05	0.007±0.04

TABLE 4
RESULTS OF UNIVARIATE ANALYSIS OF VARIANCE

Parameters	Sex		Hand preference		Interaction	
	F	p	F	p	F	p
Hand length (mm)	1.141	p>0.05	1.219	p>0.05	2.232	p>0.05
Hand width (mm)	4.539	p=0.034	15.099	p<0.001	0.135	p>0.05
3rd digit length (mm)	0.024	p>0.05	0.335	p>0.05	0.440	p>0.05
Palmar length (mm)	2.671	p>0.05	1.344	p>0.05	3.502	p<0.01
Shape index	5.384	p=0.021	11.819	p<0.001	1.351	p>0.05
Digit index	1.930	p>0.05	0.225	p>0.05	2.020	p>0.05
Palmar length/width ratio	6.664	p=0.010	8.597	p<0.001	2.038	p>0.05

eters used in the literature to evaluate asymmetry, hand -width and finger-length are common[6,17]. Ozener evaluated the asymmetry of the body in laborers in detail, thus evaluating the asymmetry of the hand[32]. However he did not take into account the hand preference.

Hebbal and Mysorekar stated that right-handed females had significantly longer palms than left-handed females, whereas left-handed females had significantly longer and wider left palms than right-handed females[33]. Based on their results, it may be said that right-handed females show asymmetry in palm length favoring the right while left-handed females show asymmetry in palm length and width favoring the left. Similarly, for both right- and left-handed males, it is possible to define »symmetry« for palm length and width. Hebbal and Mysorekar also stated that in both sexes, when anthropometric parameters were considered, the right-handers showed right upper limb dominance while the left-handers showed left upper limb dominance[33]. However, they did not note the degree of hand preference as in our study. Here, females tended to show asymmetry for palmar length in all subgroups, while left-handed males had asymmetry favoring the right and right-handed males tended to show asymmetry favoring the left. When hand width was considered, the strong left-handers, weak left--handers, and ambidextrous individuals had asymmetry favoring the left, whereas the strong and weak right-handers had asymmetry favoring the right. Thus, our results are in accordance with those of Hebbal and Mysorekar[33].

Of the parameters considered by Manning and Pickup, asymmetry for third digit length was not statistically significant[34]. Our results for third finger length are in accordance with those of Manning and Pickup[29], as we found no statistically significant differences between the subgroups when right–left differences in third finger length were evaluated according to hand preference and sex (p>0.05, Tables 3 and 4).

Laubach and McConville reported a statistically significant difference between right and left hand width values, with the left side being wider, while no statistically significant difference was reported between right and left hand length values[15]. These results seem to support ours, as we found no significant difference in hand length according to sex and hand preference, and a significant difference in hand width was detected between the subgroups with the strong left-handers, weak left-handers, and ambidextrous individuals showing asymmetry favoring the left, and the strong and weak right-handers showing asymmetry favoring the right.

In the study by Means and Walters, they stated that right-handed males had longer right hands than left hands while non-right-handed males had longer left hands than right hands[13]. Similarly, they reported that right-handed females had longer left than right hands and non-right--handed females had longer right than left hands. These results are not in accordance with those from our study, as we did not find any significant difference between the subgroups in terms of hand length asymmetry.

Kulaksiz and Gozil reported that a significant difference existed between males and females in terms of third finger length asymmetry, with males favoring the left side and females favoring the right; however, no statistically significant differences between males and females were reported for hand width, hand length, shape index, finger index, and palmar length/width ratio asymmetry[17]. Significant differences were also reported between hand preference subgroups for hand width, shape index, and palmar length/width ratio asymmetries, with strong right-handers, weak right-handers, and ambidextrous individuals showing asymmetries favoring the right side and strong and weak left-handers giving the opposite results[17]. These findings seem to be in accordance with those of our study, except that in our study, the ambidextrous individuals showed asymmetries similar to those of the strong and weak left-handers.

Our results suggest that hand width, shape index, and the palmar length/width ratio are most influenced by hand preference and gender. The ambidextrous individuals in our study exhibited asymmetries similar to those of the strong and weak left-handers in that they favored the left side for each of the aforementioned parameters. Moreover, a gender difference was observed for shape index and palmar length/width for the strong and weak left-handers and ambidextrous individuals.

These findings strengthen our understanding of hand asymmetry in relation to hand preference in a Turkish population; however, additional studies with larger groups will be necessary to more thoroughly evaluate the influence of hand preference.

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PROCJENA ASIMETRIJE RUKU U ODNOSU NA PREFERENCIJU RUKU

SAŽETAK

Procijenili smo mjere asimetrije ruku kod ljevorukih i desnorukih pojedinaca. U istraživanju su sudjelovala 343 muškarca i 290 žena u dobi od 18 do 42 godine (22,11±2,07). Nema statistički značajne razlike između lijeve i desne ruke s obzirom na spol u duljini ruke, duljini trećeg prsta, palmarnoj duljini i indeks vrijednosti duljine prsta. Statistički značajna razlika pokazala se s obzirom na odnos lijeve i desne ruke u širini ruke, indeksu oblika ruke, i plamarnoj duljini i širini. Izraziti ljevoruki, slabije ljevoruki i ambideksteri su pokazali asimetriju favorizirajući lijevu ruku i sačinjavali su prvu grupu ispitanika. Slično, izrazito desnoruki i slabiji desnoruki pokazali su asimetriju favorizirajući desnu ruku i sačinjavali su drugu grupu ispitanika. Razlika između ove dvije grupe bila je značajna. Kada su podaci bili analizirani s obzirom na spol, pokazale su se značajne razlike u ovim podgrupama. Posebno, razlike lijeve i desne ruke u indeksu oblika ruke i vrijednostima palmarne duljine i širine kod izrazito ljevorukih, slabije ljevorukih i ambidekstera bile su značajne s obzirom na spol. Ovi rezultati sugeriraju odnos asimetrije ruku i favoriziranja ruke u turskoj populaciji.