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Original Article

Anatomic, functional and cognitive asymmetries in monozygotic twins with discordant handedness

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Abstract. Discordant handedness was observed at a higher rate than expected in monozygotic (MZ) twins. This study was designed to investigate the degree of asymmetry in terms of anatomical, functional (motor) and cognitive (IQ and visual memory) features on 27 MZ twins for discordant handedness according to Edinburgh Handedness Inventory (EHI). There was statistically significant difference between EHI and Yetkin Laterality Questionnaire (YLQ). Ambidextrous were found lack of cerebral dominance. Both left and right handed subjects were found left hemisphere dominance. There was no significant difference in terms of anatomic or cognitive features between MZ twin members with discordant handedness.

Key words: Laterality, monozygotic twins, dominant hemisphere, anatomic symmetry, IQ

1. Introduction

Handedness is an easily observable feature for behavioral lateralization in humans. Left handedness incidence is about 8 percent in human population (1). Left-handedness in MZ (monozygotic) and DZ (dizygotic) twins and singletons frequencies are same. MZ twins have the same genotype thus they may be considerable for genetic analysis of handedness (2).

By the percentage of 20-25, discordant handedness in MZ twins (3) is greater than expected value (4). The reason of discordance for handedness in MZ twins may be explained by mirror-imaging or relatively late monozygotic twinning (4).

Geschwind et al. (5) reported that cerebral asymmetry is strongly correlated with handedness. The right handers have left brain dominance while left handers have, right (6). In human population, the dominance of left and right brain hemisphere is reported as 90-95% and 5-10%, respectively (7). According to Gurd et al, (8) differences observed between right-handers and left-handers on fine motor tasks can be associated with the functions of cerebral hemispheres. Additionally, Steinmetz's et al. (9) study showed the relationships between the lateralized structure and functions of the human brain. Similarly, Sommer (4) suggested that the cerebral hemispheres can also be considered as a paired organ. Fujinaga (10) additionally supported that brain hemispheres show left and right asymmetry like other paired organs.

According to Annett's (11) results, the differences in MZ twins are slightly larger than that of DZ twins in terms of handedness and cerebral asymmetry. Jancke and Steinmetz's (12) study showed that the degree of hand motor asymmetry in MZ twins is influenced by environmental factors, while hand motor skill is more likely to be determined by the genetic factors. Other asymmetry conditions were also investigated on MZ twins discordant for handedness; such as cerebral hemisphere specialization (13), hand preference and performance (8,12), language lateralization (4), verbal fluency and visuo-spatial attention (14).

It is still under investigation that whether the actual effect which determines hand preference is depending on genetic factors or is related with environmental factors (12). The aim of this study is to determine the asymmetric conditions of anatomic, cognitive and functional features in MZ twins, discordant for handedness.

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2. Material and Methods

2.1. Subjects

Twenty seven monozygotic twin pairs (thirteen twin pairs were female and fourteen were male) were included into this study. One member of twin had right hand preference (RH) while the other had non-right (left or mixed) hand preference according to Edinburgh Handedness Inventory (EHI). The non right handed MZ twins were composed of 16 left-handers and 11 mixed-handers. From all ages especially from primary school students, healthy volunteers were included into this study.

2.2. Assessing of hand preferences and laterality degrees

Handedness was assessed using the EHI (15). Body laterality degree was assessed by using YLQ, developed by Yetkin (16). The subjects' hand preferences were observed during performing the tasks (17). The columns of the each questionnaire were scored as "+10 (always right hand: AR-H)", "+5 (usually right hand: UR-H)", "zero point (either hand/or side: EH-S)", "-5 (usually left hand: UL-H)", and "-10 (always left hand: AL-H)". The laterality degrees were assessed by Geshwind scores (18). Our data on a subjects' body lateralization (YLQ) is according to the preferred hand/eye or foot for each of the following tasks:

1. Looking at a microscope (eye preference)
2. Thread the needle, The hand holding the thread (hand preference)
3. Shoot the ball (foot preference)
4. Take aim at (eye preference) and pull the trigger (hand preference)
5. Handshake and salutation (hand preference)
6. Sewing (hand preference)
7. Using hand saw (hand preference)
8. Using a hammer (hand preference)
9. Carrying a bag (hand preference)
10. Playing hopscotch (foot preference)

Hand and foot sizes (width and length), the height and head diameter were measured. For this purpose, anthropometric devices [mechanic and sensible electronic compass (±0.01 mm) and tape measure)] were used.

2.3. Assessment of intelligence quotient (IQ) degree

IQ degree was assessed using Cattell ''Culture Free'' Test (19) and administered to 13 aged and over subjects.

2.4. Assessment of dominant hemisphere

The management of dominant hemisphere was assessed using Alder's (20) test and the test was administered to 11 aged and over subjects. The obtained result was assessed 1-9 score range (Figure 1).

2.5. Determination of the subjects' visual memory status

Visual memory status was assessed using 15 words. These words showed for 40 seconds and then the subjects were asked to write the remembered words in another 40 seconds.

2.6. Statistical analysis

Descriptive statistics for studied variables (characteristics) were presented as mean, standard deviation, minimum and maximum values. Paired t tests were used to compare MZ twin members. Pearson correlation analysis was carried out to examine linear relationships among the variables. Statistical significance levels were considered as 5% and SPSS (ver. 13) statistical program was used for all statistical computations.

3. Results

The difference between handedness average of MZ twin members was statistically significant ($p<0.01$). The highest correlation was found as 100% in terms of visual memory while the lowest correlation is found as 14% in terms of management of dominant hemisphere between MZ twin members. However, there was no statistically significant difference among other investigated features (Table 1).

Anatomical features were highly correlated with each other (Table 2). According to YLQ, there was significant negative correlation between MZ twin members in terms of body lateralization and the correlation coefficient was -69.9% ($p<0.01$, Table 2). Likewise, correlations among lengths and all measured anatomical features were statistically significant ($p<0.01$,

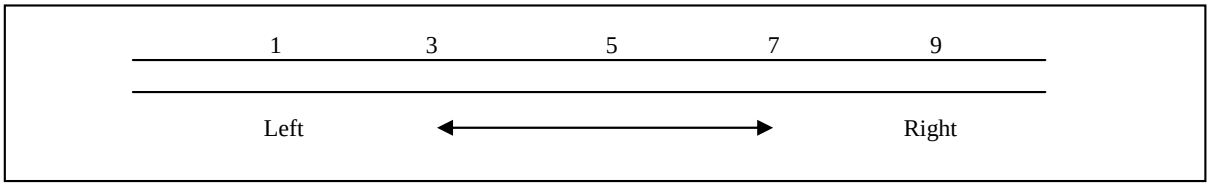

Fig. 1. Hemisphere management rating scale

Table 1. Paired comparison test results and correlation coefficients for MZ twins

	Mean	N	Std. Deviation	Difference	p	Correlation
Handedness EHI	-45.93	27	49.847	-125.556	.000	-.255
Handedness EHI	79.63	27	27.384			
Lateralization YLQ	5.23	22	61.808	-27.273	.263	-.699**
Lateralization YLQ	32.50	22	58.833			
Management of dominant hemisphere	4.8250	12	.45143	.12083	.465	.141
Management of dominant hemisphere	4.7042	12	.38895			
Visual memory	3.75(a)	4	1.708	.000	1.000	1.000
Visual memory	3.75(a)	4	1.708			
IQ	78.33	3	15.373	.000	1.000	.995**
IQ	78.33	3	4.619			
Length	133.09	23	15.681	.087	.927	.958**
Length	133.00	23	14.774			
Head diameter	51.31	23	2.147	-.117	.690	.762**
Head diameter	51.43	23	1.713			
Length of right hand	14.6352	23	1.91812	.11652	.670	.752**
Length of right hand	14.5187	23	1.71560			
Width of right hand	6.3357	23	.87694	.11000	.169	.908**
Width of right hand	6.23	23	.739			
Length of left hand	14.4822	23	1.66698	-.00043	.997	.936**
Length of left hand	14.4826	23	1.76963			
Width of left hand	6.35	23	.760	.127	.073	.906**
Width of left hand	6.23	23	.733			
Length of right foot	19.0043	23	2.44388	-.02522	.899	.923**
Length of right foot	19.0296	23	2.26466			
Width of right foot	7.060	23	1.0012	.2526	.024	.892**
Width of right foot	6.807	23	1.1076			
Length of left foot	18.99	23	2.440	-.17217	.441	.902**
Length of left foot	19.1600	23	2.21316			
Width of left foot	6.8378	23	.87801	.17043	.064	.884**

Table 2). Furthermore, the correlation coefficient between length and head diameter was significant (45.3%, $p<0.05$, Table 2).

However, correlation between hand preference (EHI) and management of dominant hemisphere was not statistically significant. In the same way, there was further no statistically significant correlation among the body lateralization (YLQ) and management of dominant hemisphere.

There was no statistically significant difference among left-handed, right handed and mixed-handed subjects for management of dominant hemispheres (Table 3). For left and right handed MZ twins, management of dominant hemisphere averages were 4.68 and 4.74, respectively. Similarly, for mixed handed subjects, management of dominant hemisphere average was 5.00.

4. Discussion

In this study, 27 MZ twin pairs found discordant for hand preference according to EHI. 5 twins of them were strongly lateralized and exhibited 100% discordance for handedness (one member was 100% left-handed while the other had 100% right hand preference degree). In addition, 19 twins of them were found discordant for hand, eye and foot preferences (body lateralization) according to YLQ. Two twins of them were strongly lateralized and exhibited 100% discordance (one member had 100% right body lateralization while the other had 100% left body lateralization) for body lateralization.

The difference between the handedness averages of MZ twins was found statistically significant ($p< 0.01$). Nevertheless, the reason of the discordance was excluded from this study. However, mirror reflection evocative symptoms were encountered in some visually discordant for MZ twins. In other discordant twins, the reason of the discordance was suggested as an epigenetic difference.

Gurd et al. (8) indicated that the right-handers showed more strongly lateralization degree than their left-handed twin member, likewise left-handers also showed large variation in their

Table 2. Pearson correlation coefficient among the studied variables

	HND1	HND2	LAT1	LAT 2	MDH 1	MDH 2	Length 1	Length 2	HDI1	HDI2	LRH1	LRH2	WRH1	WRH2	LLH1	LLH2	WLH1	WLH2	LRF1	LRF2	WRF1	WRF2	LLF1	LLF2	WLF1	WLF2
HND1	1																									
HND2	-.255	1																								
LAT1	.379	.037	1																							
LAT2	.141	.042	-.699**	1																						
MDH1	.239	.045	.488	-.230	1																					
MDH2	-.010	.225	.096	.295	.141	1																				
Length1	-.238	.225	.055	-.032	.239	.497	1																			
Length2	-.233	.288	.072	-.045	.170	.448	.958**	1																		
HDI1	-.235	.376	.017	-.105	-.122	-.005	.626**	.573**	1																	
HDI2	-.097	.111	.204	-.283	-.208	-.130	.453*	.484*	.762**	1																
LRH1	-.081	.364	.306	-.064	.402	.296	.783**	.769**	.378	.283	1															
LRH2	-.196	.180	.196	-.135	.217	.363	.914**	.935**	.591**	.571**	.752**	1														
WRH1	-.085	.345	.165	-.076	.509	.198	.749**	.752**	.496*	.303	.712**	.747**	1													
WRH2	-.181	.374	.160	-.160	.311	.246	.776**	.817**	.502*	.378	.751**	.826**	.908**	1												
LLH1	-.253	.218	.068	-.065	.103	.420	.922**	.910**	.624**	.509*	.742**	.951**	.786**	.859**	1											
LLH2	-.172	.363	.204	-.104	.264	.471	.905**	.931**	.595**	.547**	.828**	.957**	.791**	.865**	.936**	1										
WLH	-.101	.261	.086	.016	.266	.582*	.800**	.792**	.463*	.259	.709**	.748**	.904**	.883**	.845**	.800**	1									
WLH	-.068	.258	.200	-.142	.170	.388	.730**	.762**	.580**	.426*	.627**	.791**	.886**	.894**	.839**	.812**	.906**	1								
LRF	-.132	.237	.091	-.019	.108	.414	.892**	.835**	.580**	.367	.733**	.849**	.784**	.822**	.928**	.839**	.870**	.792**	1							
LRF	-.106	.236	.120	-.059	-.119	.339	.847**	.857**	.493*	.367	.713**	.857**	.748**	.809**	.893**	.842**	.839**	.809**	.923**	1						
WRF	-.212	.279	-.038	-.004	.203	.396	.864**	.842**	.553**	.293	.634**	.814**	.838**	.838**	.895**	.814**	.897**	.816**	.928**	.909**	1					
WRF	-.148	.269	.076	-.142	-.028	.348	.711**	.762**	.358	.223	.559**	.685**	.753**	.800**	.751**	.710**	.854**	.774**	.800**	.889**	.892**	1				
LLF	-.131	.229	.053	.021	.068	.369	.905**	.849**	.537**	.315	.695**	.836**	.772**	.781**	.894**	.802**	.833**	.737**	.964**	.913**	.929**	.795**	1			
LLF	-.180	.345	.160	-.125	-.014	.372	.868**	.897**	.544**	.402	.733**	.888**	.756**	.838**	.903**	.887**	.821**	.810**	.915**	.971**	.911**	.892**	.902**	1		
WLF	-.254	.288	.030	-.106	.023	.237	.783**	.780**	.671**	.509*	.530**	.787**	.844**	.840**	.854**	.781**	.871**	.873**	.870**	.829**	.905**	.842**	.839**	.847**	1	
WLF	-.173	.462*	.062	-.082	.143	.448	.727**	.797**	.456*	.303	.580**	.739**	.840**	.895**	.798**	.804**	.887**	.858**	.798**	.817**	.888**	.894**	.780**	.860**	.884**	1

*: p<0.05 **: p<0.01 ;

HND: Handedness. MDH: Management of Dominant Hemisphere. HDI: Head diameter.LRH: Length of right hand. WRH: Width of right hand. LLH: Length of left hand. WLH: Width of left hand. LRF: Length of right foot. WRF: Width of right foot. LLF: Length of left foot. WLF: Width of left foot.

laterality scores according to the hand and foot preference. The similar results were found in our study. In our study, the right-handers showed more strongly lateralization degree then their non-right handed sister/brother. The non-right-handers consist of 16 left-hander and 11 mixed-hander. As compared to right-handed members, there was greater variation in non-right handed twins.

Gurd et al. (8) also indicated that there was no performance difference between right and left handed MZ twin members. In this study there was no statistically significant difference between non-right and right-handed twin members for cognitive functions (IQ, visual memory).

However the highest correlation was found for visual memory among MZ twin members. The results cannot be generalized since there was only 4 twins in visual memory testing group. The second highest correlation was found as 99.5% for IQ value of MZ twins. Similarly, only 3 twins were in this group. Interclass correlations within twin pairs for anatomic asymmetry were not significant. These results revealed that in handedness discordant of MZ twin members, management of dominant hemisphere and anatomical features were more likely to be determined by genome while the hand preference by non-genetic factors.

According to YLQ, there was a negative and statistically significant correlation (-69.9%, $p<0.01$) between MZ twin members (Table 2).

Field (21), defined the hemisphere dominance as the brain hemisphere which has or develops a special responsibility for language. There was no statistically significant difference between handedness and management of dominant hemispheres (Table 3). The average of management of dominant hemisphere was found as 4.68 in left-handers. This indicates left brain dominance. Therefore the relationship between handedness and hemisphere dominance cannot be observed in left handed MZ twin members. The right-handers management of dominant hemisphere average was 4.74. This result revealed that right-handers have left brain hemisphere dominance. Management of dominant hemisphere was found as 5.00 in ambidextrous subjects. Our results were supported by Corballis et al. (22)'s findings.

Clark et al. (23) observed that there was no discrepancy among MZ twins with discordant handedness and MZ twins with concordant handedness for measured intelligence.

Khosravizadeh and Teimournezhad (24) reported that there was no difference between the left and right-handed individuals in terms of their IQ. Similarly, there was no statistically significant difference between right-handed and non-right-handed twin members for average value of IQ.

Table 3. Management of dominant hemispheres value for handedness

	N	Mean	Std. Dev.	Min.	Max.	p
Left-handers	8	4.6838	.39946	3.88	5.08	
Mixed handers	4	5.0000	.34689	4.59	5.38	0.465
Right handers	12	4.7400	.45068	4.08	5.60	
Total	24	4.7646	.41668	3.88	5.60	

In conclusion, there was no statistically significant difference between right and non-right handed twins in terms of IQ. The results revealed that the hand preference was strongly lateralized while eye preference and foot preference were not. There was considerable variation for eye and foot preference among MZ twins.

Left handers were found as left hemisphere dominant. Ambidextrous subjects were found lack of hemisphere dominance. The right handed subjects were found left hemisphere dominance. Despite the cerebral dominance dissimilarity, there was no statistically significant difference in terms of IQ among left, right and mixed handed members. However, it was suggested that wider group studies should be conducted in the future research.

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