The Relationship Between Extremity Preferences and Medial Longitudinal Arch Collapse and Movements of the Ankle and Hallux

Ekstremite Taraf Tercihi ile Mediyal Longitudinal Ark Kollaps Seviyesi, Ayak Bileği ve Ayak Başparmağı Hareketleri Arasındaki İlişki

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ABSTRACT Objective: The aim of this study was investigate the effect of hemisphere preference on medial longitudinal arch collapse level and range of motion of ankle and hallux extension in both lower extremities and to determine whether there was a difference between the lower extremities. **Material and Methods:** The study was performed on 142 university students (male 77, female 65) aged between 18-27 (20.42 ± 1.441) years who agreed to participate. Participants completed two questionnaires questioning individual characteristics, and hand and foot preferences. Dorsiflexion and plantar flexion of both ankles and extension of both halluces were measured using a universal goniometer, and navicular drop (ND) in both feet using the "navicular drop test." **Resuts:** No statistically significant differences were determined between preferred and non-preferred sides in terms of plantar flexion of the ankle (PFA) and extension of the hallux (EH) (p> 0.05). However, the difference between preferred and non-preferred sides for dorsiflexion of the ankle (DFA) was significant in males and in the entire group. In addition, the difference in ND between preferred and non-preferred sides was also significant. Statistically significant positive and negative correlations were determined between preferred and non-preferred side measurements. **Conclusion:** Although there was no significant difference between the sides in any of the measurements among females, the differences in DFA values in males and in the entire group, and ND values in the entire group between preferred and non-prefered sides were significant. This suggested that hemisphere lateralization could be influential in the extremities. The data obtained in this study could not explain the extremity preferences. However, they suggested that extremity preference was not based on the functional differences and it did not cause any difference in the function.

Key Words: Hallux; ankle; lower extremity

ÖZET Amaç: Bu çalışmada hemisfer tercihinin her iki alt ekstremitedeki mediyal longitudinal ark çökme miktarına, ayak bileği eklem hareket açıklığına ve ayak başparmağı ekstansionuna etkisini ve alt ekstremiteler arasında fark oluşturup oluşturmadığını incelemeyi amaçlanmıştır. **Gereç ve Yöntemler:** Bu çalışma; katılmayı kabul eden 18-27 (20,42 ± 1.441) yaş arası 142 üniversite öğrencisi (erkek 77, kadın 65) ile yapılmıştır. Katılımcıların kişisel özellikleri ve el ile ayak tercihlerinin sorgulandığı iki ayrı anket formunu tamamlamışlardır. Üniversal goniometre kullanılarak her iki ayak bileğinin dorsifleksiyon ve plantar fleksiyonu ile her iki ayak başparmağının ekstensiyonu ve de her iki ayakta "navicular drop test" ile medial longitudinal arkın yükseklik farkı (ND) ölçümü yapıldı. **Bulgular:** Ayak bileği plantar fleksiyonu (PFA) ve ayak başparmak ekstansiyonu (EH) yönünden tercih edilen ile edilmeyen taraflar arasında istatistiksel olarak anlamlı fark bulunamadı (p> 0.05). Bununla birlikte tercih edilenle edilmeyen taraflar arasında erkek olgularda ve grubun tümünde ayak bileği dorsifleksiyonu (DFA) yönünden anlamlı fark mevcuttu. Ayrıca tercih edilenle edilmeyen taraf arasında ND yönünden de anlamlı fark mevcuttu. Tercih edilenle edilmeyen taraflardaki ölçümlerde istatistiksel açıdan anlamlı pozitif ve negatif korelasyonlar mevcuttu. **Sonuç:** Kadın bireylerdeki bütün ölçümlerde tercih edilen ile edilmeyen grup arasında fark yoktu. Fakat DFA değerleri yönünden erkek olgular ve tüm çalışma grubu olgularında ve ND değerleri yönünden ise tüm olgularda tercih edilen ve edilmeyen taraflar arasında anlamlı fark mevcuttu. Bu çalışmada ele edilen sonuçlar ekstremite tercih nedenlerini açıklamamıştır. Fakat ekstremite tercihinin fonksiyonların farklılığından kaynaklanmadığı gibi fonksiyon farklılığına da neden olmadığını düşündürmüştür.

Anahtar Kelimeler: Ayak başparmağı; ayak bileği; alt ekstremite

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Cerebral lateralization is defined as anatomical and functional differentiation between the right and left hemispheres of the brain. The requisite scientific approach represents the basis for identifying higher cerebral functions and impairments thereof. Cerebral and peripheral sensory-motor asymmetry in humans has been the subject of debate for more than a century.[1] The majority of researchers investigating anatomical asymmetry have looked at differences in the structures of the two hemispheres. They determined various differences in a number of structures between the hemispheres. However, the effects of these structural differences on the extremities have not been clearly established.[2-4]

It is known that one hemisphere is dominant over the other. It gives rise to the extremities on one half or side of the body being preferred in certain daily activities. The first and most dramatic evidence of functional asymmetry was obtained from observing the behavior of people with brain damage. Clinical research revealed that there were functional differences between the two sides of the brain, and that there were differences for normal people as well as for patients.[5] Therefore, examination of functional differences in the lower extremities in normal individuals may contribute to clinical assesements and diagnosis.

Research to date into cerebral dominance and extremity preference has investigated the upper extremities. Hand use is influenced by those people adopted as role models and the environment (custom/tradition and certain religious beliefs).[6] Various factors, including environmental, geographic, hormonal, genetic and level of cultural development, similar to the mechanisms behind hand use preferences have been proposed for lower extremity preference.[7] We think that, although the individual is unable to make an objective decision in hand preference, he or she can do so, without being influenced, in foot preference, as also in eye preference.[8] To put it another way, the lower extremities are under the control of the dominant hemisphere in a looser and uncontrolled manner. Hemisphere lateralization is perhaps more correlated with foot preference than other preferences.[9]

The foot and ankle are dynamic structures in which flexibility and stability are present together and they permit the weight of the body to be transmitted to the ground in a balanced manner.[10] Since the foot bears the weight of the body and makes contact with the environment, it is a structure in which overuse injuries are frequently seen. Medial arch height greater or less than normal is a significant risk factor for lower extremity overuse injuries. For example, a rigid foot with a high arch represents a risk for ankle injuries, stress fractures and anterior knee pain. A foot with a low arch, in contrast, represents a risk for medial tibial stress syndrome, knee pain and trauma in other structures in the medial part of the lower extremity.[11] We think that extremity preference may also have an influence on these risks and lower extremities possessing different functional capacities are of great importance for estimating injury risk.

The aim of this study was to analyze of the medial arch and the motion of the ankle and hallux, which play important roles in body stability and walking mechanics, and the transverse axis in both lower extremities separately. In this way, with the values obtained, the presence of certain changes conferring an advantage over others in the extremity under the control of the dominant hemisphere can be investigated and observed in terms of extremities' functional and structural differences.

MATERIAL AND METHODS

The study was performed with 142 (77 males, 65 females) university students aged between 18-27 (20.42 ± 1.441) years who agreed to participate. Written consents were obtained from the participants completing "Informed Consent" forms. Two questionnaires were administered, in which participants were asked about personal characteristics and hand-foot preferences. Researchers read and signed the "Helsinki Declaration," and the approval of the Ethics Board of the Karadeniz Technical University Faculty of Medicine was obtained prior to the commencement of the study. Dorsiflexion and plantar flexion of both ankles and range of both halluces' extension were measured using a universal goniometer. Navicular drop (ND) in both feet was measured using the "navicular drop test". The physiotherapist doing the measuring was held responsible for all measurements. Measurements were analyzed independently with the questionnaire in which hand-foot preferences were determined without a prior knowledge of individuals' hand-foot preferences.

MEASUREMENTS

Measurements were obtained by dorsiflexion of the ankle (DFA), plantar flexion of the ankle (PFA), extension of the hallux (EH) and "arch collapse (navicular drop)" level (ND) (navicular drop test).

MEASUREMENT OF DORSIFLEXION (DFA) AND PLANTAR FLEXION OF THE ANKLE (PFA)

Measurements were performed in a sitting position at a height at which the feet did not touch the floor, and with the hip and knee joints flexed at 90°. Active ankle dorsiflexion and plantar flexion were requested. Neutral ankle position was taken as a 90° perpendicular angle between the 5th metatarsal bone and the fibula. The point indicated by the goniometer center on the joint is known as the pivot point. The pivot point for the ankle was the lateral malleolus. The fixed arm of the universal goniometer used was held parallel to the long axis of the fibula, while the mobile arm was positioned in such a way as to follow the long axis of the 5th metatarsal bone. No foot inversion or eversion was permitted during measurement. Participants were asked to move their ankles a few times in the desired direction before measurement commenced. The value at movement completion was recorded. Measurements were taken three times and the values recorded. The same measurement was then performed for the other ankle.[12]

MEASUREMENT OF EXTENSION OF THE HALLUX (EH)

Measurement was performed with the foot on a hard surface in an upright standing position (in such a way as to measure body weight standing up). Subjects were allowed to hold onto a bar on the side in order to maintain balance. The pivot point in this measurement was the medial of the base of the first metatarsal bone. Measurement was performed with the fixed arm parallel to the ground and the mobile arm following the hallux. Subjects were asked to bring the hallux to extension. Once the subject had fully understood this movement, the researcher stood to the medial of the toe concerned for measurement to take place. The value at the final point when the subject brought the hallux to extension was measured. Values for both halluces were measured and recorded three times.[13]

MEASUREMENT OF NAVICULAR DROP (ND)

ND measurement was performed with body weight either being transmitted or not being transmitted to the foot to be measured, using the "Navicular Drop Test" in both cases.[13-16]At measurement in which weight was not transmitted, patients were seated in such a way that the height of both knees in 900 flexion could be adjusted, with both feet touching the ground and the ankle in neutral position. In both feet, the highest point of the medial arch was determined with a line parallel to the ground passing through the most concave part of the navicular. The distance between the line determined and the floor was measured with a digital compass and the values recorded as mm. In the measurement in which body weight was transferred, participants stood on one leg on a hard and level floor, holding onto a bar to maintain balance, and the distance between the line determined and the floor was again measured, for both feet, using a digital compass. These measurements were conducted three times for each foot. Values were recorded as milimeters. With these measurements, the height from the floor of the medial longitudinal arch while bearing body weight and when not bearing it was determined.

DETERMINATION OF PREFERRED AND NON-PREFERRED SIDE

Individuals' preferred and non-preferred sides were determined from the results of the hand and foot preference questionnaire administered to participants whose measurements were recorded. Annett's criteria were employed in that part of the questionnaire concerning hand preferences.[17,18] Participants were asked which upper extremity they preferred when writing, throwing something, peeling fruit, striking a match, hammering a nail, brushing their teeth, using scissors, threading a needle, dusting, playing table tennis, dealing playing cards, or putting on an item of clothing with a front zipper. In determining foot preferences, participants were asked which extremity they preferred for kicking a stationary ball and playing "seksek" (a traditional Turkish game resembling hopscotch).[19-24] Hand preference was taken as the basis for the determination of hemisphere dominance, and those of the initial 161 participants who preferred right hand and right foot or right hand and both feet were determined as preferring the right side. Those who preferred left hand and foot and left hand and both feet were determined as preferring the left side. Eleven subjects were determined to have left side, in other words right hemisphere dominance, and 131 to have right side, or left hemisphere dominance. Nineteen individuals with diagonal hand-foot preference or equal preference for both hands were excluded from analysis. The measurements were divided into two groups "preferred" and "non-Preferred."

EXCLUSION CRITERIA

1- Answering "NO" to the first question ("have you ever had a headache?") posed in order to determine honesty in answering the questionnaire determining hemisphere lateralization,

2- Expressing, in the determination of hand and foot preferences

i- A preference for both hands equally or,

ii- Diagonal hand-foot preferences (right hand/left foot, left hand/right foot),

3- A history of anomalies, trauma/traffic accidents or surgery affecting the lower extremities, all regarded as exclusion criteria.

DATA ANALYSIS

Statistical analyses of the measurements were performed using SPSS 13.0. Arithmetic means and standard deviations were determined. Normally distributed data were analyzed using Kolmogorov-Smirnov test, the t test for dependent sample test, and Pearson analysis was performed for correlations.

RESULTS

No significant differences were determined between preferred and non-preferred sides in females in terms of the measurements performed. DFA was greater on the non-preferred side in males and in whole group (p_{male}=0.007*, p< 0.05, and p_{total}=0.016*, p< 0.05 respectively). Medial longitudinal arch drop level (ND) was greater on the preferred side in whole group only (p_{total}=0.018*, p< 0.05). (Table1) There were positive and negative correlations between measurements (Table 2).

There was a negative correlation between PFA and EH angles for the preferred side in females (p_{female}= 0.028 ; r= -0.273), however there were no similar significant correlations in males. There was a significant correlation between DFA and EH angles in females and in all participants (p_{female}= 0.0001; r= 0.481, and p_{total}= 0.0001; r= 0.367, respectively) (Table 2). A significant negative correlation existed between ND and EH in all subjects (p= 0.017; r= -0.200) (Table 1).

TABLE 1: Statistical comparison of preferred and non-preferred side DFA and PFA angles in females and males.

Sex		N	Preferred Mean ± SD	Non-Preferred Mean ± SD	p
Female	PFA	65	60.66 ± 7.30	61.30 ± 7.16	0.172
	DFA	65	18.68 ± 7.07	19.02 ± 6.67	0.521
	EH	65	25.17 ± 8.47	24.55 ± 7.138	0.476
	ND	65	6.13 ± 2.98	5.39 ± 3.43	0.067
Male	PFA	77	56.76 ± 7.04	56.63 ± 7.22	0.835
	DFA	77	15.27 ± 6.05	16.53 ± 6.01	0.007*
	EH	77	22.87 ± 9.84	21.49 ± 9.12	0.072
	ND	77	7.75 ± 3.04	7.33 ± 3.42	0.109
Total	PFA	142	58.54 ± 7.39	58.77 ± 7.54	0.577
	DFA	142	16.83 ± 6.54	17.67 ± 6.61	0.016*
	EH	142	23.92 ± 9.28	22.89 ± 8.38	0.072
	ND	142	7.01 ± 3.11	6.44 ± 3.55	0.018*

* p values are statistically significant.
PFA: Plantar flexion of the ankle,
DFA: Dorsiflexion of the ankle,
EH: Hallux extension,
ND: Navicular drop.

TABLE 2: Correlations between preferred and non-preferred sides by gender and among all measurements.

Side	Sex		N	r	p
Preferred					
	Female	PFA/EH	65	-0.27	0.028
		DFA/EH	65	0.48	<0.005
		DFA/ND	65	0.18	0.178
		PAF/ND	65	0.08	0.516
		EH/ND	65	-0.16	0.197
	Male	PFA/EH	77	0.13	0.260
		DFA/EH	77	0.25*	0.290
		DFA/ND	77	0.00	0.978
		PFA/ND	77	0.012	0.919
		EH/ND	77	-0.185	0.107
	Total	PFA/EH	142	-0.008	0.921
		DFA/EH	142	0.37*	<0.0005*
		DFA/ND	142	-0.14	0.087
		PFA/ND	142	-0.03	0.746
		EH/ND	142	0.20*	0.017*
Non- Preferred					
	Female	PFA/EH	65	- 0.17	0.181
		DFA/EH	65	0.36*	<0.0005*
		EH/ND	65	-0.03	0.821
		PFA/ND	65	-0.05	0.717
		DFA/ND	65	-0.27*	0.029*
	Male	PFA/EH	77	0.28*	0.013*
		DFA/EH	77	0.29*	0.011*
		EH/ND	77	-0.25*	0.028*
		PFA/ND	77	-0.05	0.664
		DFA/ND	77	-0.06	0.586
	Total	PFA/EH	142	0.15	0.070
		DFA/EH	142	0.33*	<0.0005*
		EH/ND	142	-0.20*	0.016*
		PFA/ND	142	-0.13	0.126
		DFA/ND	142	-0.21*	0.013*

* p values are statistically significant.
PFA: Plantar flexion of the ankle,
DFA: Dorsiflexion of the ankle,
EH: Hallux extension,
ND: Navicular drop.

There was a significant correlation between DFA and EH angles on the non-preferred side in males and females and in all subjects. (p_{female}= 0.004; r= 0.356, p_{male}= 0.011; r= 0.287, and p_{total}= 0.0001; r= 0.334, respectively) There was a significant correlation between PFA and EH angles in males (p_{male}= 0.013; r= 0.281), but not in females. A significant correlation existed between DFA and ND in females and in the entire group (p_{female}= 0.029; r= -0.271, and p= 0.013; r= -0.208, respectively), though not in males. PFA angles had no effect on ND in males or females. There was a significant correlation between ND and EH in males and in the entire group (p_{male}= 0.028; r= -0.251, and p_{total}= 0.016; r=- 0.202, respectively) (Table 2).

DISCUSSION

The left cerebral hemisphere controls the right hand, and the right hemisphere controls the left hand. The left cerebral hemisphere is dominant in right-handed, and the right hemisphere in left-handed. For that reason, it may be said that the superiority of the left hand over the right hand in left-handed people is due to the right cerebral hemisphere and that of the right hand over the left hand in right-handed people is due to the left hemisphere.[25] No significant difference was determined in this study in terms of DFA, PFA, ND or EH on the preferred or non-preferred sides in males or females. Similarly, van der Harst et al. determined no difference between dominant and non-dominant sides as a result of kinetic and kinematic analysis of both legs.[26] In agreement with the results of our study, Zifchock et al. determined no significant difference between preferred and non-preferred side in terms of arch height and rigidity.[27] Rigidity was significantly greater in subjects with a high navicular drop.[27]

Pang et al. compared preferred and non-preferred side Achilles tendon performance and thickness and their results support ours. They determined that preference had no effect on Achilles tendon thickness and performance.[28] Holmes et al. analyzed the isokinetic strengths of quadriceps muscle and hamstring group muscles in high school students. They determined no difference between preferred and non-preferred sides in males or females.[29] Similarly, Maupas et al. determined that dominance had no effect on muscle strength.[30] Madigan et al. compared individuals' step speeds on the preferred and non-preferred sides and found no difference between them.[31]

In contrast, Rahnama et al. analyzed knee flexor and extensor muscle strengths and flexibility in 41 footballers in order to compare flexibility and strength on the preferred and non-preferred sides.[19] Strength in the knee flexors was greater on the preferred side. The fact that no difference in flexibility and extension force was determined between the preferred and non-preferred sides may give rise to the conclusion that other specific muscle groups need to be investigated more actively in extremity preference. The study stated that some muscles on the preferred side were used more actively as individuals select the lower extremity. This suggests a difference between movement extension in specific directions in the joints where the muscles pass through on the preferred and non-preferred sides. No measurement of muscle power was performed in our study, however. We think that such measurements may comprise the next stage of this research. It is also noteworthy that in males and all subjects, levels of DFA were higher on the non-preferred side yet ND was greater in the preferred side in the entire group.

Macedo et al. measured all the upper and lower extremity joints, apart from those analyzed in our study, in individuals aged 18-59 years, and determined that some joint extensions were greater on the preferred side and that others were greater on the non-preferred side.[32] We did not obtain similar results in our study. Macedo et al. also compared the lower extremities in terms of active and passive joint extension. In ankle passive joint extension, dorsiflexion was greater on the preferred side and plantar flexion on the non-preferred side. In active movement, plantar flexion was greater on the non-preferred side.[32] In our study, in contrast, DFA was greater on the non-preferred side in males and in the entire group.

In contrast to Macedo et al.'s study in which differences between the sexes were not investigated, in our study in which joint movements were actively analyzed, ND values were significantly higher in both the preferred and non-preferred sides in males compared to females.[32] In addition, the ages of the individuals comprising our study group were closer to one another, while their study was performed on subjects with a wider age range.

Valderrabano et al. similarly performed measurements of joint extension, muscle strength, sport status and calf circumference in middle-aged subjects with the aim of determining the correlation between lower extremity preference and muscle power. Calf circumference was greater on the preferred side, together with plantar flexion and dorsiflexion muscle power. That study also showed that the effect of extremity preference on the muscles measured favored the preferred side.[33] In our study, on the other hand, DFA favored the non-preferred side in males and in the entire group. We think that more objective results can be obtained with further research.

CONCLUSION

In conclusion, we suppose that extremity preference has no effect on level of medial arch collapse and range of motion of ankle and hallux extension in both lower extremities. Medial arch collapse in the preferred lower extremity is not advantaged over the non-preferred side in terms of range of motion of ankle and hallux extension. In addition, further research into extremity preference and functions will make it possible to say more about whether extremities are preferred because of the advantages they possess (muscle strength, endurance, flexibility, joint extension, coordination etc.) or whether they acquire certain distinctive characteristics as a result of cerebral dominance.

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