

An Assessment of the Relationship Between Ankle Joint Range of Motion and the Foot Function Index in Young Adults: A Single-Center Prospective Study

Genç Erişkin Bireylerde Ayak Bileği Eklem Hareket Açıklığı ile Ayak Fonksiyon İndeksi Arasındaki İlişkinin Değerlendirilmesi:

Tek Merkezli Prospektif Çalışma

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Abstract

Background: This study aims to present reference values for ankle joint range of motion in healthy young adults and to determine the correlation between these values.

Materials and Methods: The correlation between the range of motion of dorsiflexion, plantarflexion, inversion and eversion in both feet of each participant and their Foot Function Index (FFI) score was evaluated. In line with this, the variables were selected as right ankle dorsiflexion angle (RDF), left ankle dorsiflexion angle (LDF), right ankle plantar flexion angle (RPF), left ankle plantar flexion angle (LPF), right ankle inversion angle (RI), left ankle inversion angle (LI), right ankle eversion angle (RE), left ankle eversion angle (LE), right ankle FFI score (RFFIS), left ankle FFI score (LFFIS).

Results: The correlation between the range of motion of dorsiflexion, plantarflexion, inversion and eversion in both feet of each participant and their FFI score was evaluated. In line with this, the variables were selected as RDF, LDF, RPF, LPF, RI, LI, RE, LE, RFFIS, LFFIS.

Conclusions: The findings of this study indicate that there is no clear correlation between FFI scores and goniometric measurements for the ankle.

Keywords: Ankle biomechanics, Foot function index, Range of motion, Goniometer, Reference values

Öz

Amaç: Mevcut çalışmada sağlıklı gençlerde ayak bileği eklem hareket açıklığı referans değerlerinin sunulması ve bu değerler ile arasındaki korelasyonun tespiti amaçlanmıştır.

Materyal ve metod: Her katılımcının her iki ayağı için dorsi ve plantar fleksiyon, inversiyon ve eversiyon hareket açıklıkları ile FFI skoru arasındaki korelasyon değerlendirilmiştir. Buna göre değişkenler right ankle dorsiflexion angle (RDF), left ankle dorsiflexion angle (LDF), right ankle plantar flexion angle (RPF), left ankle plantar flexion angle (LPF), right ankle inversion angle (RI), left ankle inversion angle (LI), right ankle eversion angle (RE), left ankle eversion angle (LE), right ankle FFI score (RFFIS), left ankle FFI score (LFFIS) olarak belirlenmiştir.

Bulgular: Değişkenlerin istatistiksel analiz sonuçları sırasıyla erkek ve kadın olmak üzere; RDF için 23,9 (19,3-32,2) ve 27 (19,9-41,6), RPF için 45,4 (27,5-50,6) ve 44,5 (23,6-50,6), LPF için 45,2 (30,7-52,2) ve 44,5 (26,7-50,6), RI için 18 (13-28) ve 19 (12-33), LI için 17 (12-32) ve 19,5 (13-32), RE için 24 (13-36) ve 27,5 (18-48), LE için 27 (15-36) ve 27 (18-40) şeklindedir. Ortalama ve standart sapma değerleri sırasıyla LDF için 22,3±2,2 ve 23,2±4,1, RAFIS için 11,7±5,2 ve 12,7±4,5, LAFIS için 10,1±5,5 ve 10,3±4,7 olarak hesaplanmıştır.

Sonuç: Çalışma bulguları FFI skorları ile ayak bileğine ait gonyometrik ölçümler arasında net bir korelasyon olmadığı göstermektedir.

Anahtar Kelimeler: Ayak bileği biyomekaniği, Ayak fonksiyon indeksi, Eklem hareket açıklığı, Gonyometre, Referans değerler

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Introduction

The feet, which transfers body weight to the ground and absorbs the reaction force from the ground, display a dynamic structure due to their biomechanical functions and a rigid structure due to their weight-bearing role. The biomechanical characteristics of the foot are underpinned by a complex anatomical structure supported by joint structures and muscles (1). Also, 25% of the bones are located in the foot (12). The kinetic connection between the leg and foot bones is established via the joints in the ankle (2,3). The foot and the ankle is comprised of 26 bones and 33 joints primarily formed by the talocalcaneal, tibiotalar, and talocalcaneonavicular joints. The anatomy of this joint is akin to a hinge comprised of multi-axial and simultaneous movements, designed for walking (3). It is also reported that the daily activities of a person, geographical and cultural differences, their age and sex influence the results of joint range of motion measurements (4,5). This influence demonstrates the need that the values for joint range of motion to be considered as reference must be specific to the population, sex and age (3-5). In addition, the range of motion of the ankle joint being within the reference values is a key factor in functional activities (6) and the control of balance and proprioception involving lower extremities (6,7). In line with this, it is believed that deviations from the reference values may result in unwanted and ineffective movements. Such movements affect the balance negatively and increase the risk of falling (8). Measuring joint range of motion provides valuable guidance for the identification and diagnosis, as well as the treatment process & planning of musculoskeletal disorders. For the purpose of measurement, the goniometer is largely preferred as it offers an inexpensive and reliable measurement method (4,9-11). Clinicians associate the decrease in joint range of motion with conditions such as osteoarthritis, hallux valgus, ankle sprains, micro traumas or muscle stiffness which affect the lower extremities (8-11). Foot pain, commonly experienced across a variety of age groups affect the quality of life negatively (11-15). Valid and reliable scales are required for the diagnosis and the monitoring of foot-related problems in both clinical practice and research. The Foot Function Index (FFI) developed by American Orthopaedic Foot & Ankle Society and adapted to various populations is one of such scales and is used widely (12-15). Used as a method to evaluate foot position by clinicians, the Index is adapted to a variety of cultures and is widely regarded as a quick, simple and reliable method. It consists of questions categorized under three main categories (pain, disability, and limitations) with each question rated on a scale from zero to ten. As these tests also include the results reported by patients,

they provide insights on patients' clinical condition and needs; guide treatment planning and enhance the communication between the clinician and the patient (12,13). The test has been validated for Turkish language and is written with a clear and easily understandable language designed to include a broad measurement range and reliable subscales (13,15). In line with the information provided, the primary aim of the study is to provide the reference values of ankle joint movement range in both healthy and sedentary young adults; and the secondary aim is to determine the correlation between these values and Foot Function Index.

Materials and Methods

The study is descriptive in nature and is conducted on healthy and sedentary students aged 18-22 enrolled in the Faculty of Medicine of Bolu Abant İzzet Baysal University. A total of 120 feet belonging to 30 females and 30 males in the study. The study was approved by the Clinical Research Ethics Committee of Bolu Abant İzzet Baysal University (approval no: 43, date: February 2, 2026) The research commenced after the approval of Clinical Research Ethics Committee numbered 2026/43. Individuals with a history of surgery, trauma or infection of the lower extremities; those who reported pain; those with a body mass index of 25 or higher and those who exercise regularly were excluded from the study. The participants were informed of the study and evaluated only after they have signed informed consent form. The participants' demographical information such as age, sex, height and weight were first recorded. The height and weights of the participants were calculated in line with the World Health Organization formula (2) and the ankle joint range of motions of those determined to be of normal weight was measured with a goniometer (16,18).

The participants were asked to perform dorsiflexion and plantar flexion and the inversion and eversion movements from the starting point to the furthest point possible. The range of motion was then measured with a goniometer (16). The assessment for dorsiflexion and plantar flexion was performed while the participants were lying on their back. The fixed point was designated as malleolus lateralis for the measurement; the fixed arm was placed on the lateral aspect of fibula, and the moving arm was placed on the lateral aspect of the fifth metatarsal bone. For the inversion and eversion assessments, the participants sat with their knees hanging down. The midpoint of the anterior aspect of the ankle was selected as the pivot point and the fixed arm was positioned along the midline of the leg, the moving arm followed the midline at the level of the second metatarsal bone (17,18).

FFI is an assessment method consisting of 23 questions categorized under three subcategories, which are foot pain, disability and activity limitations, and features a broad scale ranging from 0 to 10 for all questions. The participants were asked to answer the Turkish version of the questions provided based on the past week. To calculate the index score, all answers were summed and the total was divided by the maximum score and the resulting number were multiplied by 100. The test results range between 0 and 100, and higher scores indicate increased pain and functional impairment for the foot.

In the study, the correlation between the range of motion for dorsiflexion, plantarflexion, inversion, and eversion in both feet of each participant and the FFI scores were evaluated. In line with this, the variables were selected as right ankle dorsiflexion angle (RDF), left ankle dorsiflexion angle (LDF), right ankle plantar flexion angle (RPF), left ankle plantar flexion angle (LPF), right ankle inversion angle (RI), left ankle inversion angle (LI), right ankle eversion angle (RE), left ankle eversion angle (LE), right ankle FFI score (RFFIS), left ankle FFI score (LFFIS). The statistical analyses of the variables, sex-based differences and correlations are presented.

Statistical Analyses

The statistical analyses were performed with the open-source RStudio software. A one-way analysis of variance was conducted for all variables. The normality of the resulting residual values were then assessed with the Anderson-Darling test. Logarithmic and square-root transformations were applied to variables that do not follow a normal distribution. Accordingly, while the LDF, RFFIS, and LFFIS variables displayed a normal distribution, the other variables did not. The relationship between the right-foot variables and RFFIS and the right-foot variables and LFFIS were evaluated with Pearson correlation test for variables displaying a normal distribution. For variables that did not show a normal distribution, Spearman rho correlation test was applied. In addition, the differences of variables between sexes were analyzed. For normally distributed variables, an Independent T Test; for variables that did not show a normal distribution, Mann Whitney U test was applied. The mean and standard deviation were calculated for normally distributed variables; for variables that do not follow a normal distribution, the median, minimum, and maximum values were calculated. The interquartile ranges and 95% confidence intervals for all variables were also provided.

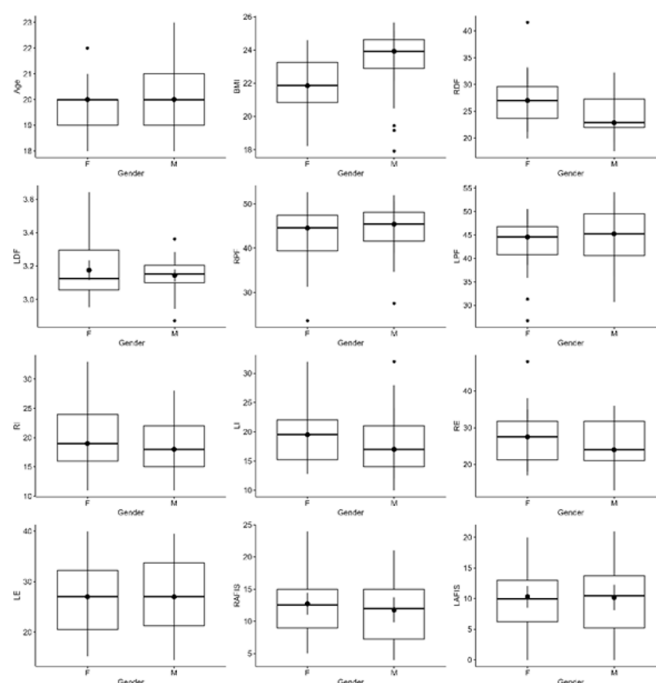
Results

For the age variable, the median was 20 (18-23) for males and 20 (18-22) for females; the interquartile range (Q1-Q3) was 19-21 and 19-20, respectively, and no statistically significant difference was found between the groups ($p=0.275$). The BMI values for males and females were 23.9 (17.9-24.9) and 21.8 (18.2-24.5), respectively; Q1-Q3 values were calculated as 22.8-24.6 and 20.8-23.2, respectively, and the difference was found to be statistically significant ($p=0.001$). While the mean RDF values were 23.9 (19.3-32.2) and 27 (19.9-41.6), respectively; the Q1-Q3 range was 22.0-27.2 and 23.6-29.5, and the difference between the groups was statistically significant ($p=0.024$). The RPF was found as 45.4 (27.5-50.6) and 44.5 (23.6-50.6), with Q1-Q3 values ranging from 41.5 to 48.0 and 39.3 to 47.4, respectively; no significant difference was observed between the groups ($p=0.355$). LPF was calculated as 45.2 (30.7-52.2) and 44.5 (26.7-50.6); the Q1-Q3 range was 40.5-49.5 and 40.8-46.7, respectively, and no significant difference was observed between the groups ($p=0.367$). The RI variable was found to be 18 (13-28) and 19 (12-33), and the Q1-Q3 values were calculated as 15-22 and 16-24, respectively; no statistically significant difference was found ($p=0.431$). The results for LI were 17 (12-32) and 19.5 (13-32), respectively; the Q1-Q3 ranges were 14-21 and 15.2-22, and no significant difference was observed between the groups ($p=0.203$). The results for the RE variable were 24 (13-36) and 27.5 (18-48), respectively, and the Q1-Q3 values were 21-31.7 and 21.2-31.7, with no statistically significant difference ($p=0.593$). The results for LE were measured as 27 (15-36) and 27 (18-40), respectively, and the Q1-Q3 range was 21.2-33.7 for males and 20.5-32.2 for females; no significant difference was found between the groups ($p=0.958$). The mean±standard deviation values for LDF were 22.3±2.2 in males and 23.2±4.1 in females, while the Q1-Q3 values were 21.2-23.6 and 20.2-25.9, respectively; no statistically significant difference was observed ($p=0.285$). The RFFIS score was 11.7±5.2 for males and 12.7±4.5 for females, with interquartile ranges of 7.2-15 and 9-15, respectively; no significant difference was observed ($p=0.448$). The values for the LFFIS variable were calculated as 10.1±5.5 and 10.3±4.7, respectively; the Q1-Q3 values were 5.2-13.7 and 6.2-13. No statistically significant difference was observed between groups for the LFFIS variable ($p=0.920$) (Table 1). The differences of variables between sexes are shown in Figure 1.

Table 1. Descriptive statistics for the variables, interquartile ranges, and p-values indicating differences between sexes

Variable	M	F	Q1-Q3		P value
			M	F	
Age	20.0 [18.0-23.0]	20.0 [18.0-22.0]	[19.0-21.0]	[19.0-20.0]	0.275 $\square$
BMI	23.9 [17.9-24.9]	21.8 [18.2-24.5]	[22.8-24.6]	[20.8-23.2]	0.001 $\square$
RDF	23.9 [19.3-32.2]	27.0 [19.9-41.6]	[22.0-27.2]	[23.6-29.5]	0.024 $\square$
RPF	45.4 [27.5-50.6]	44.5 [23.6-50.6]	[41.5-48.0]	[39.3-47.4]	0.355 $\square$
LPF	45.2 [30.7-52.2]	44.5 [26.7-50.6]	[40.5-49.5]	[40.8-46.7]	0.367 $\square$
RI	18.0 [13.0-28.0]	19.0 [12.0-33.0]	[15.0-22.0]	[16.0-24.0]	0.431 $\square$
LI	17.0 [12.0-32.0]	19.5 [13.0-32.0]	[14.0-21.0]	[15.2-22.0]	0.203 $\square$
RE	24.0 [13.0-36.0]	27.5 [18.0-48.0]	[21.0-31.7]	[21.2-31.7]	0.593 $\square$
LE	27.0 [15.0-36.0]	27.0 [18.0-40.0]	[21.2-33.7]	[20.5-32.2]	0.958 $\square$
LDF	22.3 $\pm$ 2.2	23.2 $\pm$ 4.1	[21.2-23.6]	[20.2-25.9]	0.285 $\neq$
RFFIS	11.7 $\pm$ 5.2	12.7 $\pm$ 4.5	[7.2-15.0]	[9.0-15.0]	0.448 $\neq$
LFFIS	10.1 $\pm$ 5.5	10.3 $\pm$ 4.7	[5.2-13.7]	[6.2-13.0]	0.920 $\neq$

Results for variables that did not have a normal distribution are presented as the median [minimum-maximum], while results for normally distributed variables are presented as the mean $\pm$ standard deviation. The p-value column on the far right shows the p-value from the Mann-Whitney U test for variables that do not follow a normal distribution, and the p-value from the independent t-test for variables that do follow a normal distribution. $\square$: p-value from the Mann-Whitney U Test. $\neq$: p-value from the Independent T-Test. BMI: Body mass index, RDF: Right ankle dorsiflexion angle, LDF: Left ankle dorsiflexion angle, RPF: Right ankle plantar flexion angle, LPF: Left ankle plantar flexion angle, RI: Right ankle inversion angle, LI: Left ankle inversion angle, RE: Right ankle eversion angle, LE: Left ankle eversion angle, RFFIS: Right ankle AFI score, LFFIS: Left ankle AFI score

**Figure 1.** Box-and-whisker plots of variations in variables between sexes

Body mass index, RDF: Right ankle dorsiflexion angle, LDF: Left ankle dorsiflexion angle, RPF: Right ankle plantar flexion angle, LPF: Left ankle plantar flexion angle, RI: Right ankle inversion angle, LI: Left ankle inversion angle, RE: Right ankle eversion angle, LE: Left ankle eversion angle, RFFIS: Right ankle AFI score, LFFIS: Left ankle AFI score

A positive correlation was found between LAFIS and LDF ($r=0.31$) on the assessment of correlation results on the left side measurements. A weak negative correlation was found between LAFIS and LPF ($r=-0.29$). Overall, the most notable findings are the strong negative correlations between LPF-LI ($r=-0.66$) and LI-LE ($r=-0.60$) variable pairs and the moderate positive correlation between LPF-LE ($r=0.60$) variables. On the right-side correlation analysis results, it was observed that RAFIS variable does not correlate with other measurements, hinting that it varies

independently from the other right-side parameters. Overall, it is seen that some of the right side anatomical measurements display a combined change, particularly that the RI variable is associated with both RDF ($r=0.65$) and RE ($r=-0.60$) while RAFIS measurement has no association with the other parameters. These findings suggest that right side measurements does not display a homogeneous structure and that some morphometric parameters may represent different biomechanical or anatomical components (Figure 2).

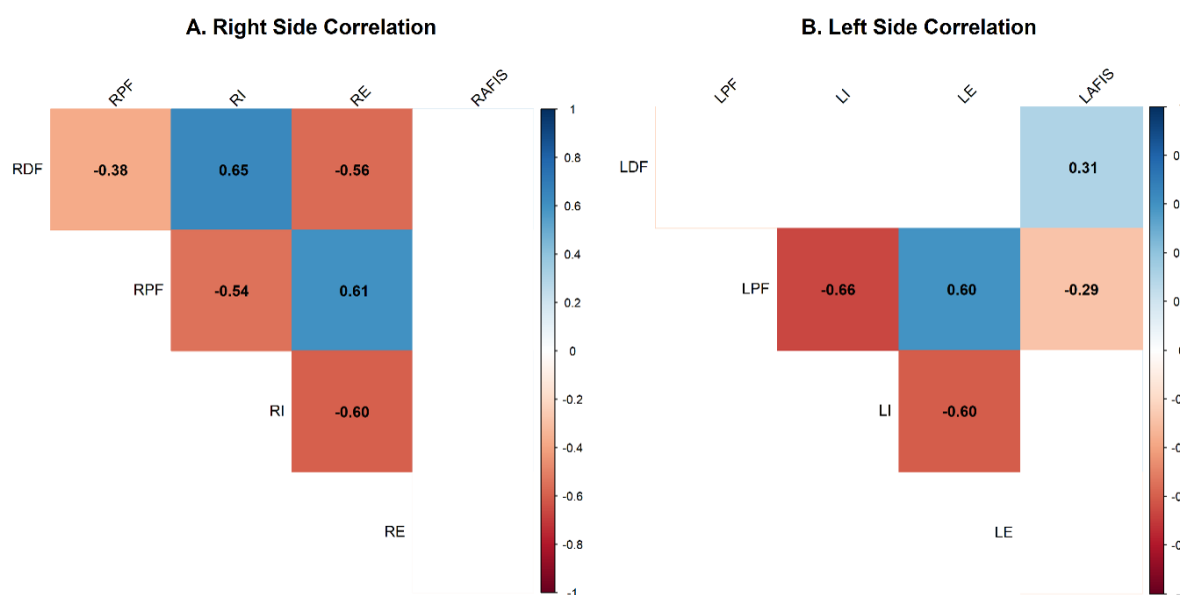


Figure 2. Correlation chart showing the right and left relationships of variables. The numbers in the boxes indicate the correlation coefficients Body mass index, RDF: Right ankle dorsiflexion angle, LDF: Left ankle dorsiflexion angle, RPF: Right ankle plantar flexion angle, LPF: Left ankle plantar flexion angle, RI: Right ankle inversion angle, LI: Left ankle inversion angle, RE: Right ankle eversion angle, LE: Left ankle eversion angle, RFFIS: Right ankle AFI score, LFFIS: Left ankle AFI score

Discussion

This study presents the results of goniometer measurements of range of motion of ankle joints in a healthy adult Turkish population while also taking into account the differences between sexes. In addition, the FFI score results of healthy adults are presented, and it is emphasized that no significant correlation was observed between the range of motion and PPI score. To the best of researchers' knowledge, this study is the first study on the subject. When considering other studies on joint range of motion, it is noteworthy that the goniometric measurements of the ankle in the present study are similar to those reported in the literature (2,4,6,7,10,18).

In a study where the correlation between the BMI of healthy

young adults and navicular drop, it is observed that no statistically significant difference was observed between both sexes. The negative effect of abnormalities in the anatomical structure of the foot arch on flexibility and balance was also emphasized in the study. Similar to the present study, it can be argued that the difference between sexes may not be significant at younger ages (2). In a study examining the effects of vibration-rolling as a myofascial release tool on exercise performance, the sample group consisted of young adults. The study focused on the relationship between vibration-rolling and a number of parameters such as range of motion of the ankle, proprioception, muscle strength and agility. While the results of the study indicate that static stretching before exercise is effective in improving the range of motion of dorsiflexion and plantar flexion; it is also

found that the range of motion values presented in the study are similar to those presented in this study (4). In another study focusing on the correlation between the range of motion of the ankle, muscle strength and balance of healthy young adults, the range of dorsiflexion movement was evaluated with the forward reach test, and the muscle strength was measured with a dynamometer. The study findings indicate a negative correlation between the range of motion in dorsiflexion and balance while no significant correlation was found for dynamic balance. Similar to the present study, it can be stated that the correlation between joint range of motion and other foot-related variables is not significant (6). In the study evaluating the range of motion of the ankle and lower extremity muscle strength via regression analysis, the static balance was also assessed via the postural sway method. The study findings indicate a significant relationship between the static balance and the range of motion of the plantar flexion joint; and the range of motion was found to be similar to those reported in this study (7). In a study examining the correlation between muscle strength in the foot and ankle and the angle of dorsiflexion, it was found that the strength of the dorsiflexor muscles in the ankle and the big toe showed a significant correlation with joint range of motion. The study findings, similar to those in the current study, provided reference values for healthy adults, and it was observed that both sets of results are closely aligned (10). Similarly, in a study examining the relationship between the ankle, the toe muscle strength and stability in healthy young adults, anthropometric measurements of the foot and advanced functional stability index was calculated. Findings of the study indicate a significant relationship between the score and the flexor muscle strength. The study also notes that relationship between the other variables and the score was not statistically significant (20). In a study designed to evaluate the validity and reliability of a mobile app by measuring the movement in the ankle and the big toe movement via the app, measurements were obtained both in-person and via telemedicine. The results indicate that as the difference in angular values of measured joints were less than 1.5 degrees, both methods could be preferred. Also, as the study was conducted with healthy subjects, similar mean values were observed (18).

In a study investigating the effect of ankle joint range of motion on jumping performance with and without arm swing among female volleyball players, the research began with the hypothesis that ankle flexibility influences jumping performance. The study concluded that there is a significant relationship between ankle joint range of motion and flexibility. The results particularly

emphasized the need to improve dorsiflexion for better jumping performance (21). In a study examining the effects of chronic ankle sprains on pain, movement, proprioception and balance, athletes were included and separated into two groups based on their ankle sprain history. Healthy athletes without lower extremity injuries constituted the control group for the study. No statistically significant differences were found between the groups in the assessment of joint range of motion measured using a goniometer, and the ankle goniometric values were found to be similar to those in the present study (22). In a comparative study where foot and ankle joint movements of dancers and non-dancers were evaluated, the range of motion of the joint was measured via radiographs. While the dancers demonstrated lower dorsiflexion and higher plantar flexion, the non-dancers demonstrated similar mean values to this study. In addition, it was argued that the difference between two groups was not caused by a single joint but all the joints involved in the movement (7). In a study evaluating the correlation between the dorsiflexion angle and landing positions of the ankles of football players, mobile phones were utilized. Significant correlations were found between landing errors and dorsiflexion angles, and it was concluded that decreases in dorsiflexion movement would set the stage for incorrect movements (23). In a study examining the range of motion of the ankle and surrounding joints following total ankle arthroplasty, differences between fixed and mobile-bearing prosthetics were investigated. Plantar and dorsiflexion movements were assessed via radiography one and two years post-surgery. While no significant differences in range of motion were observed between fixed and mobile bearing varieties, the findings were less pronounced than those in the current study. This difference may be due to the fact that the sample group in the current study consisted of healthy individuals (24). In a study examining dorsiflexion and foot posture in individuals with and without plantar heel pain, body mass index was matched for both groups. The results showed no significant difference between the groups in terms of foot posture and joint range of motion, while dorsiflexion values were found to be similar to those in the present study (25). In a study investigating the effect of body mass index on pes planus, balance, and pain levels, the sample group comprised sedentary individuals, akin to the present study. It was reported in the study that a correlation was observed between body mass index and foot parameters among participants identified as sedentary according to the International Physical Activity Questionnaire (26). In a study examining the relationship between the morphological characteristics of the foot, foot pain and functional limitations, FFI was also administered and difference between sexes were considered. The findings reveal

higher rates of pain and functional limitations in females and the study defends that foot morphology and sex influence the foot pain (14). In a descriptive study where the differences in the foot posture index between the right and left feet were examined, the sample size consisted of healthy adults. The asymmetry differences reported as findings of the study are consistent with those of this study (16). In a study evaluating the plantar and dorsiflexion joint angle of the ankle and lower extremity alignment, the angles formed at the hip during plantar and dorsiflexion movement were examined. Similar to this study, the study was conducted with healthy individuals and sex differences were taken into account, reached similar findings and defends that the same kinematic parameters should also be compared with patient groups (27).

Conclusion

The study was designed to present the results of standard goniometer measurements of the range of motion for plantar and dorsal flexion, inversion, and eversion of the ankle in healthy young adults and to evaluate their correlation with the FFI. To the best of researchers' knowledge, the present study is the first study on the subject, and the analyses of the findings show no statistically significant differences between joint range of motion and FFI scores. The researchers believe that the reference values presented for healthy individuals may prove valuable for future studies and clinical sciences.

AI Usage Information: No artificial intelligence was used.

Ethical Approval: The study was approved by the Clinical Research Ethics Committee of Bolu Abant İzzet Baysal University (approval no: 43, date: February 2, 2026).

Author Contributions:

Concept: M.K., G.R., A.R., I.K.

Design: M.K., G.R.

Data Collection or Processing: G.R.

Analysis or Interpretation: A.R.

Literature Search: M.K., G.R., A.R., I.K.

Writing: M.K., G.R., A.R., I.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

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