

Research Article

Examination of the coexistence of scoliosis and hallux valgus in females

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ABSTRACT

Objective: Both idiopathic scoliosis and hallux valgus are common in females, with risk factors including joint hypermobility, age, gender, hormonal factors, and family history. The aim of this study was to examine the frequency of co-occurrence of scoliosis and hallux valgus and the severity of these 2 conditions.

Methods: Evaluation was made of 497 females who female police candidates presented at the hospital to obtain a health report between January 1, 2023, and June 1, 2023 and met the study criteria. Cobb, kyphosis, hallux valgus, and intermetatarsal angles were measured from radiographs, and the data of height, weight, and body mass index (BMI) were recorded.

Results: Of the 497 participants, scoliosis was observed in 22.3% and hallux valgus in 74.8%. The rate of hallux valgus was found to be significantly higher in the group with scoliosis than in the group without ($P < .001$). Individuals with scoliosis had approximately 3 times higher odds of having hallux valgus compared to those without scoliosis (OR: 3.08; 95% CI: 1.66-5.72; $P < .05$). When the groups with and without scoliosis were compared, the females with scoliosis were determined to be significantly younger ($P = .007$). No significant difference was seen between scoliosis and height ($P = .766$). The weight and BMI values of the females with scoliosis were found to be significantly lower compared to those without ($P < .05$).

Conclusion: The study results showed that hallux valgus was determined in 88.3% of the females with scoliosis, which was significantly higher than the rate of 71% in those without ($P < .001$). No difference was seen between the scoliosis apex orientation and the hallux valgus side ($P = .511$), thus showing similar orientations of the scoliosis apex and hallux valgus side. There is a need for further studies to examine possible etiological causes in more detail.

Level of Evidence: Level III, Prognostic Study.

Introduction

Idiopathic scoliosis (IS) is characterized by lateral curvature of the spine accompanied by rotation of the vertebrae.¹ From a radiological perspective, scoliosis is defined as a curvature of at least 10° as determined by the Cobb technique on a standing X-ray.^{1,2} The diagnosis of IS is typically made by eliminating other known causes.³ Race, age, gender, low body mass index (BMI), late menarche, hormones, and family history are risk factors for IS.^{4,5} There are many studies in the literature on the prevalence of scoliosis in various sports, such as dance and ballet, gymnastics, swimming, and volleyball.⁶⁻⁸ In those studies, the prevalence of IS in female athletes has been found to be higher compared to control groups. These findings have increased interest in the idea that asymmetrical loading on the spine during the growth period may cause the development of scoliosis.⁹

A common deformity in women is hallux valgus, which is characterized by the big toe's lateral deviation from the first metatarsophalangeal joint.¹⁰ The etiology of hallux valgus includes gender, race, age, family history, shoe habits, BMI, length of the first metatarsus, flat feet, and ligament laxity.^{11,12} In a study by Hsu et al,¹³ an association between hallux valgus

and vertebral column diseases was shown. Hallux valgus has a high prevalence in the general population (19%), occurring 2-fold more in females than males.¹¹ Although both scoliosis and hallux valgus are commonly seen in females, their coexistence has not been extensively studied in homogeneous female populations. Female gender and joint hyperlaxity are among the known risk factors for both scoliosis and hallux valgus.^{6,12,14}

The aim of this study was to examine the frequency of concomitant scoliosis and hallux valgus and the severity of each condition.

Material and methods

In this study, female police candidates who presented between January 1, 2023 and June 1, 2023, to obtain a multidisciplinary health report for application to the police college were evaluated retrospectively. They were examined by 11 different departments (orthopedics and traumatology, internal medicine, obstetrics and gynecology, psychiatry, ophthalmology, otolaryngology, chest diseases, general surgery, neurology, cardiology, dermatology). The orthopedic qualifications required for police candidates, according to the legislation, being 18 years of age or older, are that

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the height should not be shorter than 162 cm, the BMI should be between 18 and 27, and there should be no spinal and/or extremity deformities and/or missing/excessive fingers (oligodactyly and polydactyly). At the same time, there should be no difference in limb length discrepancy.

Foot examinations were performed with the participants in a sitting position, with ankle and subtalar joints in the neutral position. Spinal deformities were screened with Adam's forward bending test. Cobb angle, kyphosis angle (KA), hallux valgus angle (HVA), and intermetatarsal angles (IMA) were measured by anterior-posterior (AP) weight-bearing foot radiographs, posteroanterior (PA), and lateral scoliosis ortho roentgenogram for patients with abnormalities detected in the examinations, with both weight bearing.

The relationship between scoliosis and hallux valgus was examined in females who presented at the hospital to obtain a health report.

The inclusion criteria were: (1) female gender; (2) age ≥ 18 years; (3) height ≥ 162 cm; (4) BMI between 18 and 27; (5) absence of spinal and/or extremity deformities; (6) no congenital anomalies such as oligodactyly or polydactyly; (7) no limb length discrepancy; and (8) applying for a health report to join the police force. The exclusion criteria were (1) pathology in other specialist examinations (diseases such as moderate to severe heart valve disease, chronic obstructive pulmonary disease, chronic hepatitis with hepatic dysfunction, nephrotic syndrome, type 1 diabetes mellitus, epilepsy, bipolar disorder, retinal pathology, vestibular dysfunction, chronic inflammatory skin diseases, and active or chronic viral infections are among the exclusion criteria.); (2) incomplete demographic data; (3) inappropriate radiographs; (4) previous foot surgery; (5) patients without skeletal maturity (skeletal maturation was assessed using Risser staging. Without Risser stage 5 were not included in the study).¹⁵ A total of 497 females who met the inclusion criteria were included in the study.

Radiographic measurements were performed using PA and lateral whole spine standing and weight-bearing bilateral AP foot X-rays. Measurements of the Cobb and KA (Figures 1 and 2, respectively) were performed on scoliosis radiographs, and measurements of the HVA and IMA were made on foot radiographs (Figure 3).

The level of curvature of patients with a Cobb angle of $\geq 10^\circ$, the apex of the curvature, and the orientation of the apex of the curvature were recorded. The thoracic KA was measured between T5 and T12 vertebrae in the sagittal plane.¹⁶ The radiographic evaluation of the hallux valgus was assessed using the HVA and the first IMA. A HVA $<15^\circ$ and a first IMA $<9^\circ$ were accepted as within the normal range. Hallux valgus classification was made using the Manchester scale, which is categorized into 4 groups: normal, mild, moderate, and severe.¹⁷

Radiographic evaluations were made by 2 separate orthopedic surgeons in a blinded fashion. The measurements were intra- and

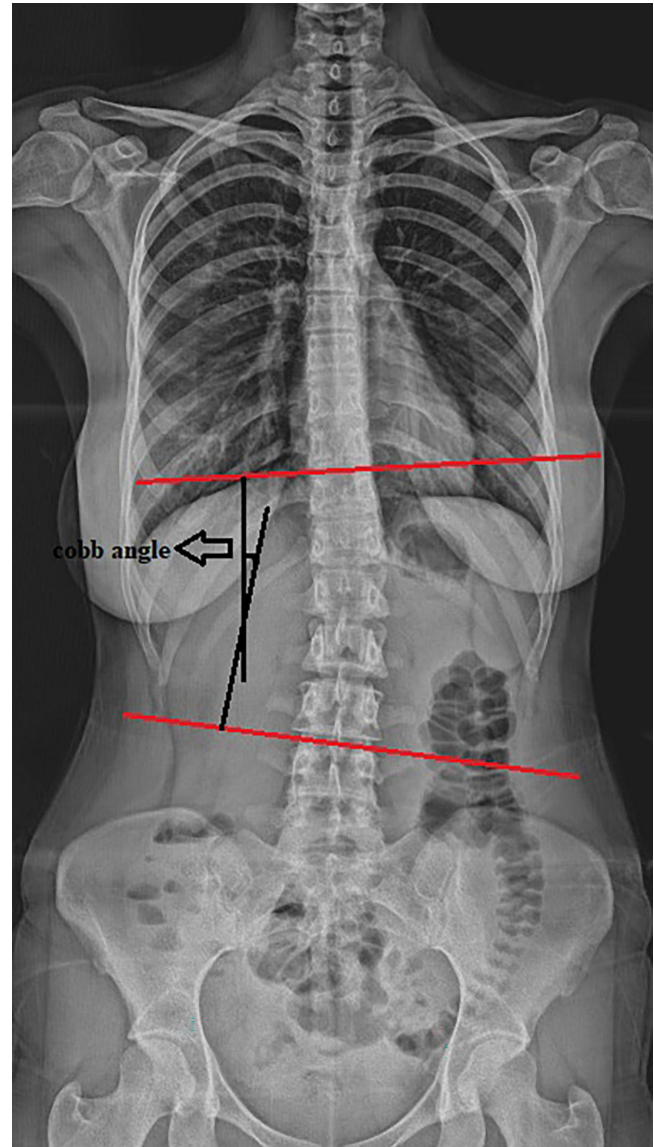


Figure 1. Cobb angle formed by the lines drawn between the end vertebrae of the curvature of the deformity.³³ The apex of the thoracic curves is located between the T2 vertebra and the T11/T12 disc. Thoracolumbar curves are characterized by an apex located between the T12 and L1 vertebrae, while lumbar curves feature an apex ranging from L1/L2 to L4.³⁴

interobserver compatible. The height, weight, BMI, and other specialist doctor examination findings of the patients were recorded in the hospital system.

This study was approved by the institutional ethics committee of Kastamonu University, (decision/protocol number: 2024-KAEK-3 date: January 17, 2024). Written informed consent was obtained from all participants included in the study.

Data obtained in the study were analyzed statistically using Statistical Package for the Social Sciences version 23.0 software. To assess intra- and interobserver reliability, 2 orthopedic surgeons independently measured the CA, KA, HVA, and IMA in 30 randomly selected subjects. Each observer repeated the measurements after a 2-week interval. Intra- and interobserver agreement was evaluated using the intraclass correlation coefficient (ICC), based on a 2-way random-effects model with absolute agreement. In the statistical

HIGHLIGHTS

- The study found that the incidence of scoliosis and hallux valgus coexistence in women was higher than that in the general population, and the rates were similar to studies conducted on female athletes.
- It has been determined that the incidence of hallux valgus in women with scoliosis is significantly higher than that in women without scoliosis.
- It is thought that spinal deformity may be responsible for the development of hallux valgus on the side where the scoliosis apex is located.

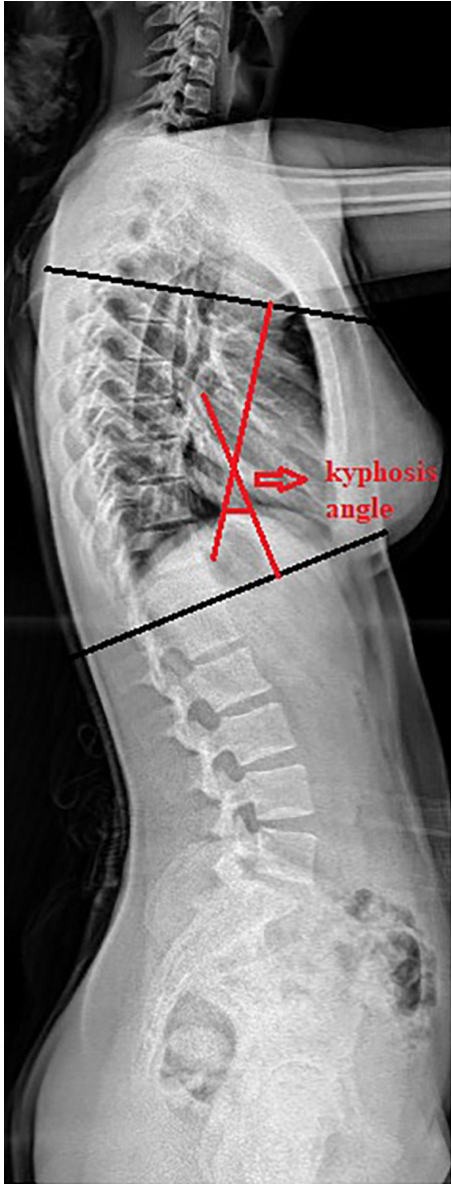


Figure 2. Kyphosis angle measured between the upper endplate of T5 and the lower endplate of T12 on the lateral radiograph.¹⁶ A kyphosis angle of $<10^\circ$ is considered hypokyphosis, a kyphosis angle $>40^\circ$ is considered hyperkyphosis, and an angle between 10° and 40° is considered normal.³⁵

analyses of the study, numerical data were presented as mean and standard deviation values for descriptive statistics, and categorical data were stated as number (n) and percentage (%). The distribution of age, Cobb angle, height, weight, and BMI data was examined using the Skewness test and histogram graphics. Numerical data related to scoliosis and hallux valgus were analyzed using the Student's *t*-test and the Mann-Whitney *U* test. The Chi-square test was employed to examine the associations between scoliosis and hallux valgus characteristics and the data of height, weight, and BMI. A value of $P < .05$ was accepted as statistically significant.

To evaluate the association between scoliosis and HV, the prevalence of HV in individuals with and without scoliosis was compared, and the odds ratio (OR) with a 95% CI was calculated. Additionally, a binary logistic regression analysis was performed to identify independent predictors of scoliosis. The dependent variable was defined as the presence or absence of scoliosis, and independent variables

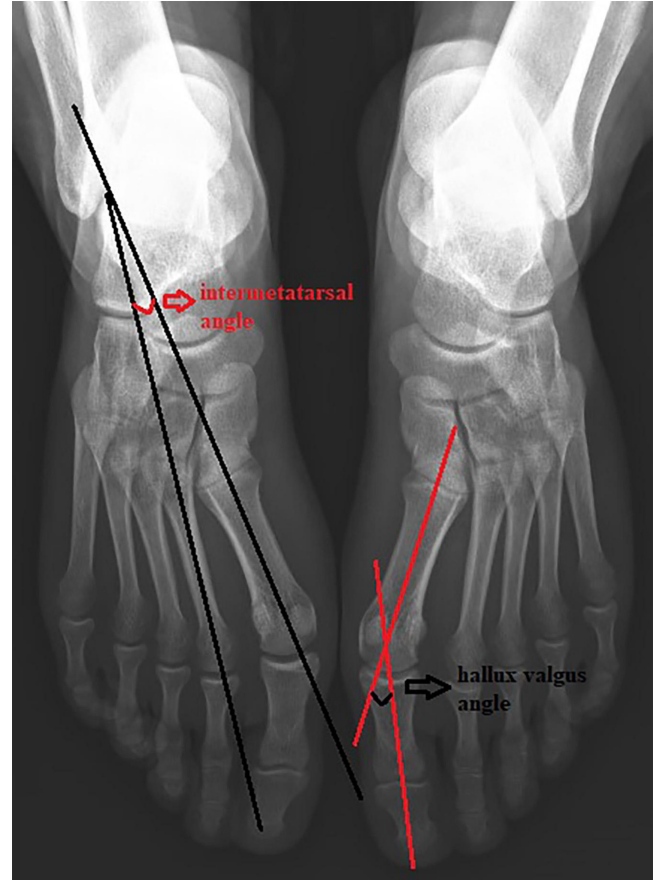


Figure 3. Measurement of the hallux valgus angle between the axis of the metatarsal bone and the proximal phalanx of the great toe.³⁶ The intermetatarsal angle is determined by measuring the angle between the long axis of the shafts of the first and second metatarsal bones on anteroposterior foot radiographs.³⁶ Hallux valgus can be categorized as mild, moderate, or severe. A mild hallux valgus deformity is defined as having a hallux valgus angle of $<20^\circ$ and a first intermetatarsal angle of $\leq 11^\circ$. A moderate deformity is defined as a hallux valgus angle of 20° - 40° and a first intermetatarsal angle $<16^\circ$. Severe deformity is characterized by a hallux valgus angle $>40^\circ$ and a first intermetatarsal angle of $\geq 16^\circ$.¹⁷

included age, height, weight, and BMI. Model fit was assessed using the Hosmer-Lemeshow test, and the overall significance of the model was evaluated with the Omnibus tests of model coefficients.

Results

Evaluation was made of 497 female participants with a mean age of 19.1 ± 1.2 years (range 17-24 years) and a mean height of 167.4 ± 3.7 cm. Scoliosis was determined in 111 (22.3%) females. The mean Cobb angle value was found to be 12.9, with a minimum 10 and a maximum 23 degrees. Right-sided curvature was determined in the majority of those with curvature ($n=72$, 64.9%), and hallux valgus was found in 372 (74.8%), with a bilateral rate of 49.2%. Other sociodemographic data, as well as scoliosis and hallux valgus-related data, are presented in Tables 1 and 2.

The hallux valgus characteristics of the participants were examined according to scoliosis status. In the group with scoliosis, hallux valgus was observed at a rate of 88.3% (63.9% mild, 34% moderate, 2.1% severe), and in the group without scoliosis, hallux valgus was observed at a rate of 71% (74.3% mild, 25.7% moderate). There was determined to be a statistically significantly higher rate of hallux valgus in those with scoliosis ($P < .001$) (Table 3). No significant

Table 1. Numerical Sociodemographic Data and Cobb Angle Data

	Mean	Median	Minimum	Maximum	Standard Deviation
Age (years)	19.1	19	17	24	1.2
Cobb (°)	12.9	12	10	23	3.1
Height (cm)	167.4	166.9	162.1	184.1	3.7
Weight (kg)	60.2	60	48.1	81.5	6.5
BMI (kg/m ²)	21.4	21.2	18	26.9	2.0

difference was observed between the orientation of the curvature in scoliosis and the orientation of hallux valgus ($P=.511$).

When the groups with and without scoliosis were compared, the age of patients with scoliosis was seen to be significantly younger ($P=.007$). There was no significant difference in height according to the presence of scoliosis ($P=.766$). The weight and BMI values of those with scoliosis were found to be significantly lower ($P < .05$) (Table 4).

Intraobserver reliability was excellent for all measurements, with ICC values as follows: CA (ICC=0.93), KA (ICC=0.91), HVA (ICC=0.94), and IMA (ICC=0.90). Interobserver reliability was also excellent: CA (ICC=0.89), KA (ICC=0.87), HVA (ICC=0.91), and IMA (ICC=0.88). These results indicate high consistency between and within observers for all radiographic measurements.

The analysis revealed that the prevalence of hallux valgus was significantly higher in individuals with scoliosis compared to those without scoliosis (OR=3.081; 95% CI: 1.659-5.722; $P < .05$).

According to the binary logistic regression analysis, the overall model was statistically significant (Omnibus chi-square=14.462; $df=4$; $P=.006$), with a Nagelkerke R^2 value of 0.044, indicating modest explanatory power.

Table 2. Scoliosis and Hallux Valgus–Related Data

		n	%
Scoliosis	Yes	111	22.3
	No	386	77.7
Scoliosis apex	Right	72	64.9
	Left	39	35.1
Kyphosis T5-12	0-10: hypokyphosis	1	0.2
	10-40: normal	470	94.6
	>40: hyperkyphosis	26	5.2
Apex of curvature	Thoracic	40	36
	Thoracolumbar	61	55
	Lumbar	10	9
HV	Yes	372	74.8
	No	125	25.2
HV laterality	Right	153	41.1
	Left	36	9.7
	Bilateral	183	49.2
HV grade	Mild	261	71.5
	Moderate	102	28
	Severe	2	0.5
Right foot HV	Normal	161	32.4
	Mild	233	46.9
	Moderate	101	20.3
	Severe	2	0.4
Left foot HV	Normal	279	56.2
	Mild	183	36.8
	Moderate	35	7
	Severe	0	0

HV, hallux valgus.

Among the variables evaluated, only age was found to be independently associated with scoliosis (OR=1.278; 95% CI: 1.043-1.566; $P=.018$).

Height, weight, and BMI were not identified as significant predictors ($P > .05$).

Discussion

There are various studies in the literature on scoliosis, foot deformities, and plantar pressure relationships.^{18,19} It is thought that sagittal and coronal spine deformities may cause a change in the center of gravity, causing pathology in the entire lower extremity on the side of the deformity.¹⁹ The results of this study demonstrated that the incidence of scoliosis and hallux valgus coexistence in females was higher than that in the general population, and the rates were seen to be similar to those reported in studies conducted on female athletes.^{6,20} It was also determined that the incidence of hallux valgus in females with scoliosis was significantly higher than that in females without scoliosis.

In a previous study by Steinberg et al.,²¹ 39.7% of young female dancers with hallux valgus were also determined to have scoliosis, consistent with other reports in the literature. However, in that study, the prevalence of scoliosis in those with hallux valgus was examined rather than the prevalence of hallux valgus in those with scoliosis. In another study by Steinberg et al.,⁶ the morphological characteristics of young female dancers were examined, and it was reported that hallux valgus was seen in 69.3% of dancers with scoliosis, which was a significantly higher rate than for dancers without scoliosis. Very few studies in the literature have examined the relationship between scoliosis and hallux valgus. Some studies have suggested that hallux valgus in the lower extremities can lead to misalignment of the axial skeleton.^{6,21} However, these studies do not include any comparisons of the orientation of the scoliosis apex and the side affected by hallux valgus. In the current study, when the side of the scoliosis apex was compared with the side of the hallux valgus, no significant difference

Table 3. Evaluation of Scoliosis and Hallux Valgus

		Scoliosis				<i>P</i>
		Yes		No		
		n	%	n	%	
HV	Yes	98	88.3	274	71	<.001
	No	13	11.7	112	29	
HV laterality	Right	40	40.8	113	41.3	.008
	Left	2	2.1	34	12.4	
	Bilateral	56	57.2	127	46.3	
HV grade	Mild	62	63.9	199	74.3	.015
	Moderate	33	34	69	25.7	
	Severe	2	2.1	0	0	
Kyphosis T5-12	0-10: hypokyphosis	1	0.9	0	0	.072
	10-40: normal	107	96.4	363	94	
	>40: hyperkyphosis	3	2.7	23	6	
HV, hallux valgus.						

HV, hallux valgus.

Table 4. Evaluation of Age, Height, Weight, and BMI with Scoliosis

	Scoliosis				<i>P</i>
	Yes (n = 111)		No (n = 386)		
	Mean	Standard Deviation	Mean	Standard Deviation	
Age (years)	18.9	1.1	19.2	1.2	.007
Height (cm)	167.5	3.5	167.5	3.8	.766
Weight (kg)	58.9	5.2	60.7	6.8	.014
BMI (kg/m ²)	20.9	1.7	21.6	2.1	.007
BMI, body mass index.					

BMI, body mass index.

was found in terms of the curvature orientation and the side affected by the hallux valgus ($P=.511$). The hallux valgus side and the apex orientation of scoliosis were found to be similar. This finding suggests that spinal deformity may be responsible for the development of hallux valgus on the side where the apex is located. Szulc et al¹⁸ demonstrated that girls with right-sided idiopathic thoracic scoliosis exhibited increased pressure dampening in the hallux and the convex anterior region of the foot compared to the control group. Hengsomboon et al²² identified alterations in all lower limb muscle strength, with the exception of the hip flexor and foot plantar muscle groups, in patients with adolescent IS. At the same time, in the study conducted by Catan et al¹⁹ in patients with IS, they found a significant increase in plantar pressure in the foot on the same side as the curvature apex direction of scoliosis and in the load on the first and fifth metatarsals compared to the control group. Further prospective studies with detailed postural and gait analyses may help clarify the potential biomechanical linkage between spinal curvature direction and hallux valgus side. Although previous studies have shown that joint hypermobility is among the risk factors for IS and hallux valgus,^{23,24} there are no studies on the frequency of hallux valgus in scoliosis patients with joint hypermobility. Since joint hypermobility is also a disorder related to connective tissue,²⁵ the coexistence of scoliosis and hallux valgus may be more common in elastic patients. The 3-fold increase in hallux valgus in scoliosis can be attributed to biomechanical changes resulting from connective tissue. This situation is seen to be a possible development between spinal alignment and foot deformities.

Scoliosis prevalence studies in the literature have reported rates ranging between 0.47% and 23.8%.^{6,26-28} Since scoliosis is seen at a higher rate in females than in males, the prevalence of scoliosis in studies of only female populations is higher than that in studies conducted in male and female populations (male-to-female ratio 1 : 11).²⁹ The current study only included females, and scoliosis prevalence (22.3%) was found to be higher than that of the general population. However, this prevalence rate seems to be compatible with the rates of previous studies that have included only females and athletes.^{6,20}

Many studies in the literature have investigated the relationship between scoliosis, weight, and BMI. Watanabe and Clark found significant associations between scoliosis and low BMI. The current study results on this point are supported by the literature ($P<.05$).^{30,31} Although the participants with scoliosis in the current study were significantly younger, a significant connection could not be established because all the participants were young adults ($P=.006$).

In a meta-analysis of the prevalence of hallux valgus, Cai et al¹¹ reported the prevalence to be 19%. Moreover, hallux valgus was seen at a higher frequency in females than in males (23.74% vs. 11.43%). The prevalence of hallux valgus varies according to various factors, including age, gender, and race/ethnicity.^{11,32} In a study

of the prevalence of hallux valgus, Şaylı et al³² evaluated 2662 individuals in Türkiye and found that 59% of women had the condition, and of these, bilateral hallux valgus was present in 90.6% of cases. Within the same study, the Manchester scale was used to assess the extent of deformity, revealing rates of mild, moderate, and severe deformity at 72.1%, 17.6%, and 5.8%, respectively. In the current study, hallux valgus was determined at a prevalence of 74.8%, with 49.2% being bilateral. The severity of the deformity was rated as mild, moderate, and severe at rates of 71.5%, 28%, and 0.5%, respectively. Previous studies have reported that exercises performed by athletes expose the joints to high loads and tension.^{11,21} This excessive mechanical load affects the bone growth plates, thereby contributing to the development of anatomical deformities along the joints of the spine and distal lower extremities. The mechanism that causes deformity in the spine and extremities can initiate the development of deformity in the metatarsophalangeal joint, such as hallux valgus.^{11,21,32}

One of the limitations of this study was the inclusion of female participants. Although a homogeneous group was created by evaluating only female participants, it does not show the population prevalence of hallux valgus and scoliosis because male participants were not included. Family history and age of menarche, which have an impact on the development of scoliosis and hallux valgus, were unknown, and joint hypermobility was not evaluated. An important limitation of this study is that joint hypermobility, a well-known common risk factor for both scoliosis and hallux valgus, was not assessed. Although the study focused on the association of scoliosis and hallux valgus, hypermobility may play an important etiological role and was included in a prospective study for a more comprehensive understanding. The results of this study showed that hallux valgus was present in 88.3% of the females with scoliosis and in 71% of those without. The rate of hallux valgus was found to be significantly higher in the females with scoliosis ($P<.001$). No significant difference was determined between the scoliosis apex orientation and the hallux valgus side ($P=.511$), meaning that the scoliosis apex and hallux valgus orientations were similar. Future studies are needed to examine possible etiological causes in more detail.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of the University of Kastamonu (Approval no: 2024-KAEK-3; Date: 17/01/2024).

Informed Consent: Written informed consent was obtained from the patients/patient who agreed to participate in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.A.S. K.K.; Design – M.A.S., K.K.; Supervision – M.A.S., R.T.; Resources – F.U., M.T.; Materials – K.K., R.T.; Data Collection and/or Processing – F.U., M.T.; Analysis and/or Interpretation – M.A.S., R.T.; Literature Search – M.A.S., F.U.; Writing – M.A.S., M.Ç.; Critical Review – M.T., M.Ç.

Declaration of Interests: Mert Çiftedemir is an Associate Editor at Acta Orthopaedica et Traumatologica Turcica/Orthopaedica et Traumatologica Turcica, however; his involvement in the peer-review process was solely as an author. The other authors have no conflict of interest to declare.

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