THE EFFECT OF FOOT TYPE AND LATERALITY ON ANKLE SPRAIN IN ELITE FEMALE VOLLEYBALL ATHLETES

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Abstract:

Volleyball is a team game with a high incidence of ankle sprain. The purpose of our research was to investigate the ankle sprain history and incidence in elite female volleyball athletes according to the Root functional foot type and laterality. The additional aims were to investigate the foot type prevalence and the effect of age on ankle sprain incidence. Sixty-two elite female volleyball athletes (17-25 years, mean=20.7, SD=2.03) were investigated by an experienced rehabilitation physician for functional foot type according to Root, while the personal history of ankle sprain and laterality were estimated based on asking questions. The obtained data of ankle sprain cases in the subjects did not have the normal distribution (Kolmogorov-Smirnov, d=.26, p<.01). Also, the Spearman correlation and the Wilcoxon and Kruskall-Wallis tests were used to find out the significance of each case. Almost 68% of the subjects had a history of ankle sprain (1-13 cases per person, 2 cases on average). Ankle sprain has been confirmed as a very common injury in volleyball athletes. Spearman's correlation did not show the significance of age (Spearman's correlation, $r1$=-.1873; p<.05) in spite of the exclusion of three subjects with extremely high ankle sprain incidence (ASI) ($r2$=-.1656; p<.05). Laterality was not significant, either. (Wilcoxon test, p=.07). The findings supported previously described differences in the prevalence of various functional foot types – compensated rearfoot varus and flexible forefoot valgus were the most common ones (56.6% and 27.4%, respectively), compensated forefoot varus, rigid forefoot valgus and neutral foot were relatively rare (8.1%, 4.8% and 3.3%, respectively). Subjects with the two most common foot types had an obviously higher average incidence of ankle sprain (2.4 and 2.0, respectively) than the other ones (.8, .7 and .5, respectively), but without significance (Kruskall-Wallis, p=.44). The non-significance of foot type effect on ankle sprain frequency was questionable due to the very low prevalence or lack of other functional foot types with known empirical evidence of increased ankle sprain risk.

Key words: *ankle injury, Root model, biomechanics*

Introduction

Volleyball is a typical team game without a direct contact among the competitors. Nevertheless the players suffer from many injuries and other disorders of the movement system. Bahr and Bahr (1997) found the ankle to be the most commonly injured region, followed by the lower back, knee, shoulder and fingers. Agel, Palmieri-Smith, Dick, Wojtys, and Marshall (2007) confirmed the leading position of ankle sprain among the injuries in collegiate volleyball athletes as well as Augustsson, Augustsson, Thomee, and Svantesson (2006). Vorálek, Süss, and Parkanová (2007) found ankle sprain history in 62% and finger sprains in 64% of 42 elite female volleyball athletes aged 15-19 years (mean 16.3 years). A similar situation exists, e.g. in basketball athletes (Beynnon, Vacek, Murphy, Alosa, & Paller, 2005) or high jumpers (Langer & Langerová, 2008). Injury incidence is influenced by many factors, external (e.g. quality of floor and footwear, lighting of the hall, warming-up, load duration, etc.) and internal (e.g. quality of posture, muscle disbalance, fatigue, etc.). A particular review is offered by previously mentioned papers. We focused on two factors – laterality and foot type.

Mioduszewski, Szyszka, Adamczyk, and Wrobel (2008) found a higher incidence of ankle sprain in subjects with crossed laterality. We assumed different ankle sprain frequencies in the dominant/preferred and non-dominant/non--preferred foot because of its different tasks in the game and during practice sessions.

We assumed the effect of foot type, too. Magee (1992) as well as Michaud (1997a) consider Root´s functional foot types as a specific injury factor for the foot, leg and lower back. Merton L. Root introduced his foot typology some decades ago, creatively bringing together his ideas and clinical outcomes with the ones of his forerunners and colleagues. He stated the basic "intrinsic" foot deformities and developed an understanding as to how these foot types affect the foot's function (Lee, 2001). One of his primary purposes was to introduce distinct, consistent and accurate terminology (Root, Orien, Weed, & Hughes, 1971). His foot type definitions were based primarily on structural findings in physical examinations, but his strong accent on related foot biomechanics allows us to call his system "functional". The Root system evolved over time, as described very profoundly by Lee (2001) and different variations of it emerged, as well as the alternative concepts and systems of Root students and followers. Within a Root biomechanics framework we can, today, describe these basic foot types: *neutral foot* (*NF*), when the axis of the shank's lower third continues as the heel axis and the forefoot plantar plane is parallel to the heel plantar plane; *rearfoot varus* (*RFvar*), when the heel axis is inverted in relationship to the axis of the shank's lower third; *forefoot varus* (*FFvar*), when the forefoot plantar plane is inverted with regard to the heel plantar plane; *forefoot valgus* (*FFvalg*), when the forefoot plantar plane is everted with regard to the heel plantar plane. Types *RFvar* and *FFvar* could be compensated (*RFvarC* and *FFvarC*, respectively) or non-compensated (*RFvarN* and *FFvarN*, respectively). Type *FFvalg* could be flexible or rigid (*FFvalgF* and *FFvalgR*, respectively). Detailed descriptions were given, for example, by McPoil and Brocato (1990), Magee (1992), Valmassy (1996), Sutherland (1996) or Michaud (1997a) in their works, including examination methods.

The purpose of our research was to investigate the history and incidence of ankle sprain in elite female volleyball athletes according to functional foot type and laterality. The additional aims were to investigate the foot type prevalence and the effect of age on ankle sprain incidence.

Methods

Sample

The original tested group consisted of 65 elite female volleyball athletes from the Czech Republic and Slovakia aged 17-34 years. Before statistical testing we removed 3 subjects older than 30 years to achieve a more compact group according to age. So, we obtained a research group of 62 elite female volleyball athletes aged 17-25 years (mean=20.7, SD=2.03).

Data collection

Ankle sprain (AS) as well as injuries, surgery and pain in lower extremities and the other parts of the movement system were targeted while collecting personal history data. The findings were written down onto a prepared form.

The movement of the spiking arm was estimated by asking questions. The propulsion foot in the vertical spike jump was not estimated unambiguously because of the subjects' confusing answers and the lack of clear standardized methodology (Vařeka & Šiška, 2005). According to the empirical evidence of one of the authors who is an experienced coach and theorist in the field of elite volleyball athletes, the propulsion foot in the vertical spike jump is ipsilateral to the spiking arm, almost without exception, so the propulsion foot was estimated in this way.

The foot type was determined on the barefoot subject laying pronated on a table with the distal third of her leg over the table edge. The non-examined foot was bent at the knee and rotated at the hip, so the ankle lay in the popliteal groove of the examined knee. The examiner gripped the head of the 5th metatarsal between the thumb and forefinger of his ipsilateral hand, subsequently gripping the

navicular between the thumb and forefinger of his contra-lateral hand. Then the examiner moved the foot into a neutral subtalar position (NSP), where he felt the navicular symmetrically under his thumb and forefinger. While in NSP, the examiner pushed the lateral forefoot slightly dorsally to stabilize the transversotarsal joint. In this foot position, the examiner lined up the heel axis with the axis of the shank's lower third, as well as the forefoot plantar plane with the heel plantar plane, to estimate the basic functional foot types according to Root.

Data analysis

The obtained data of ankle sprain cases in the subjects did not have the normal distribution (Kolmogorov-Smirnov, d=.26, p<.01), so we used non-parametric tests – Spearman's correlation for the effect of age, the Wilcoxon test for the effect of laterality and the Kruskall-Wallis test for the effect of foot type. Statistical significance was estimated at the level of p<.05. Software Statistica, Cz release 6 (StatSoft, 2001) was used.

Results

General anthropometric data

General anthropometric data are presented in Table 1. Each of sixty-two elite female volleyball athletes had a typical body composition, an average height of 165-194 cm (mean=180.4, SD=6.18), and their body mass was between 58-87 kg (mean=71.1, SD=6.18), Body Mass Index (BMI) was 18.6–26.9 (mean=21.8, SD=1.78).

Table 1. General anthropometric data

	AGE (years)	HEIGHT (cm)	MASS (kg)	BMI
M	20.7	180.4	71.1	21.8
SD	2.03	6.18	7.35	1.78
Minimum	17	165	58	18.6
Maximum	25	194	89	26.9

Legend: M – mean, SD – standard deviation, BMI – Body Mass Index

Ankle sprain and age

The ankle sprain incidence (ASI), respectively the number of cases, according to age is presented in Table 2. Twenty subjects (32.3%) did not have any history of ankle sprain, eighteen subjects (29%) had one case of ankle sprain each, seven subjects (11.3%) had two sprains each, six subjects (9.7%) had three injuries each, three subjects (4.8%) had four injuries each, and four subjects (6.5%) had six ankle sprains each. The remaining four subjects had five cases of ankle sprain, ten, twelve and thirteen, respectively.

The Spearman's correlation did not show significance (Spearman's correlation, *r*1=-.1873; p<.05) in spite of the exclusion of three subjects, each of whom had an extremely high ASI (*r*2=-.1656; p<.05). Paradoxically, the highest ASI on average was in the lowest age category, but that category contained two subjects only (Figure 1).

Ankle sprain and laterality

Sixty subjects (96.8%) were right-arm spiking, only two subjects (3.2%) were left-arm spiking. These two left-arm spiking subjects did not have any history of ankle sprain. All the one hundred and twenty-six cases of ankle sprains happened to the right-arm spiking subjects – seventy left-sided

Table 2. Ankle sprain incidence according to age

age	n	Incidence of ankle sprain										P	M
		0	1	2	3	4	5	6	10	12	13		
17	2	0	1	0	0	0	0	0	0	0	1	100.0%	7.0
18	6	1	1	3	1	0	0	0	0	0	0	83.3%	1.7
19	11	1	5	1	2	0	0	1	1	0	0	90.9%	2.6
20	12	3	6	0	1	0	1	1	0	0	0	75.0%	1.7
21	13	7	1	2	0	2	0	1	0	0	0	46.2%	1.5
22	5	3	1	0	1	0	0	0	0	0	0	40.0%	.8
23	7	4	1	1	0	0	0	0	0	1	0	42.9%	2.1
24	2	1	1	0	0	0	0	0	0	0	0	50.0%	.5
25	4	0	1	0	1	1	0	1	0	0	0	100.0%	3.5
S/M	62	20	18	7	6	3	1	4	1	1	1	67.%	2.0
Spearman		*r*1=-.1873 *r*2=-.1656 p<.05											

Legend: n – number of subjects; P – percentage of subjects with a history of ankle sprain; M – cases of ankle sprain on average; S/M – sum or mean; *r*1 – Spearman's correlation between age and ankle sprain incidence in all the subjects; *r*2 – Spearman's correlation between age and ankle sprain incidence with the exclusion of three subjects with extremely high ankle sprain incidence

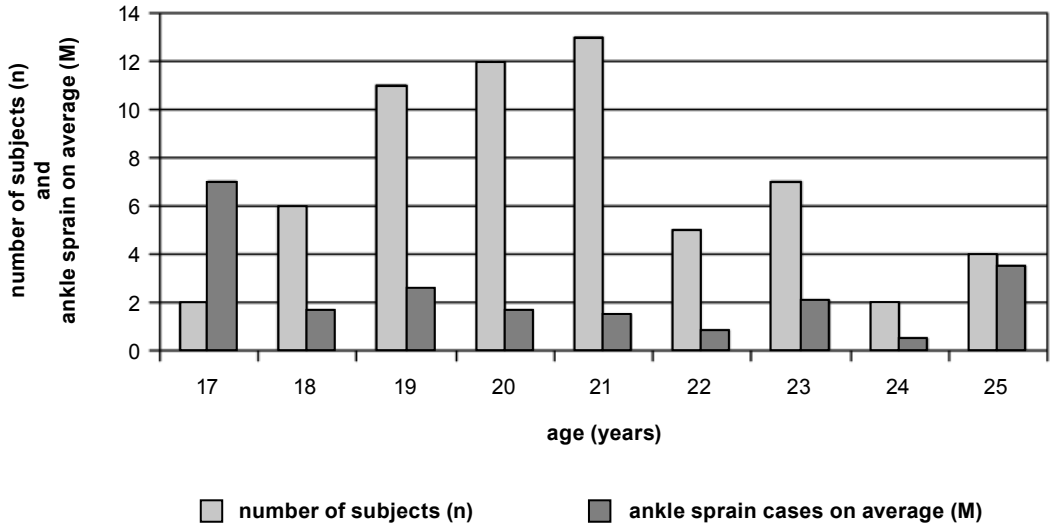

Figure 1. Ankle sprain cases on average according to age

ankle sprains (55.5%) and fifty-six right-sided ones (44.4%), the difference was not significant (Wilcoxon test, p=.07).

Ankle sprain and functional foot type according to Root

Table 3 presents the percentage of subjects with specific foot type as well as the percentage of subjects with ankle sprain history and ankle sprain incidence per person on average within these foot types. Subjects with *RFvarC* or *FFvalgF* had ankle sprain history (ASH) in 71.4% and 70.6%, respectively. On the other hand, 40% of the subjects with *FFvarC* had ASH. Subjects with *RFvarC* or *FFvalgF* had a higher ASI on average than subjects with *FFvarC* (mean=2.4, 2.0 and .8, respectively).

Table 4 presents non-significant differences in ASI among the three most common foot types in our study group - *RFvarC*, *FFvalgF* and *FFvarC* (Kruskall-Wallis, p=.44). The number of subjects with the rigid forefoot valgus (*FFvalgR*) or neutral foot type (*NF*) was so low (n=3 and 2, respectively) that we could not take them into account.

Table 3. Ankle sprain and foot type

	n	P1	nS	P2	tS	M
RFvarC	35	***56.5%***	*25*	***71.4%***	85	**2.4**
FFvalgF	17	***27.4%***	*12*	***70.6%***	34	**2.0**
FFvarC	5	***8.1%***	*2*	***40.0%***	4	**.8**
FFvalgR	3	***4.8%***	*2*	***66.7%***	2	**.7**
NF	2	***3.2%***	*1*	***50.0%***	1	**.5**

Legend: n – number of subjects; P1 – percentage of subjects with specific foot type; nS – number of subjects with ASH; P2 – percentage of subjects with ASH; tS – ankle sprain incidence; M – ankle sprain incidence per person on average; RFvarC – rearfoot varus compensated; FFvarC – forefoot varus compensated; FFvalgF – forefoot valgus flexible; FFvalgR – forefoot valgus rigid; NF – neutral foot

Table 4. Significance of the differences in ankle sprain incidences among the foot types

	n	Kruskal-Wallis test	
		H	p
RFvarC	27		
FFvalgF	17	1.64	.44
FFvarC	5		

Legend: H – Kruskal-Wallis test characteristic; p – significance; for the other abbreviations see Table 3

Prevailing foot type

The prevailing functional foot type was *RFvarC*, found in 56.5% of the subjects, *FFvalg* was the second (27.4% of the subjects) and prevailed in the forefoot region. The prevalence of the other ones was very low or none (Table 3).

Discussion and conclusions

We found one hundred and twenty-six ankle sprain cases in sixty-two young elite female volleyball athletes, so our results supported the previous findings of high ASI in that population.

In spite of our expectations we did not find any significant effect of age. The age of the subject is not an optimal parameter by itself, whereas the actual length of their sport career should be a better indicator. Nevertheless, virtually all professional volleyball athletes had the same sport history, because they started their intensive training at the age of 10 or 11 years and continued without a significant

pause. According to the empirical evidence of one of the authors, who is an experienced coach and theorist in elite volleyball athletes, we can presume the linearity between the age of the subjects and the length of their sport career.

Two left-arm spiking subjects did not have any ASH. In sixty right-arm spiking subjects we found 55.5% (n=70) left-sided ankle sprains and 44.4% (n=56) right-sided ones – the difference was non-significant. We assume that these right--arm spiking subjects preferred the ipsilateral foot for propulsion in the vertical spike jump as mentioned above (see the section on Methods). In the case that we assume ipsilaterality between the spiking arm and the propulsion foot in the vertical spike jump, the non-preferred "breaking" left foot had a non-significantly higher risk of ankle sprain. Mioduszewski et al. (2008) found 56% (n=29) right--sided ankle sprains and 44% (n=23) left-sided ones in fifty-two subjects and the subjects with crossed lateralization suffered more severe damage. We did not take into account the severity of ankle sprain or cross-laterality in our study.

Compensated rearfoot varus (*FFvarC*) and flexible forefoot valgus (*FFvalgF*) were the most common functional foot types (56.5% and 27.4%, respectively) in our group. McPoil, Knecht and Schuit (1988) found RFvar in 83.6% of fifty-nine symptom-free young women (18-30 years), but the research of Garbalosa, McClure, Catlin, and Wooden (1994) showed more frequent *FFvar* (87.67%) than *FFvalg* (8.75%) in one hundred and twenty healthy men and women without significant differences between the men and women.

Michaud (1997b) pointed out the variations of *FFvar* occurrence 9-90% depending on the examination method, respectively on the examiner. Kidd (1997) even completely deprecated the *FFvar* as a clinical entity. Nevertheless, forefoot varosity is taken into account, henceforth. Cobb and Tis (2004) found decreased antero-dorsal stability in subjects with forefoot varosity. Buchanan and Davis (2005) validated the occurrence of rearfoot eversion in standing subjects with forefoot varosity. Powers, Maffuci and Hampton (1995) validated the affinity between forefoot varosity and patellofemoral pain. Gross et al. (2007) validated the affinity between forefoot varosity and ipsilateral coxalgia.

Vařeka and Vařeková (2008) found *FFvalg* and *RFvar* (36.9% and 32.6%, respectively) to be significantly more frequent than *FFvar* and *NF* type (15.6% and 14.9%, respectively) in one hundred and forty-one women (17-85 years, mean=58.8, SD=12). Subtypes *FFvalgF* and *RFvarC* were not significantly relatively more frequent (18.4% and 14.9%, respectively).

In our study, relatively high ASI has been found in the most common foot types – *RFvarC* (56.6%) and *FFvalgF* (27.4%). The relatively low ASI in the other foot types was questionable because of its relatively low prevalence in our group. Three subjects with *RFvarC* had extremely high ASI (10, 12 or 13 cases of ankle sprain, respectively).

The literature review of Morrison and Kaminski (2007) disputed the effect of foot characteristics on ankle sprain risk and the necessity of more reliable measurement techniques in gait analysis, respectively the motion of foot segments was pointed out. Another literature review of Beynnon, Murphy, and Alosa (2002) provided conclusions similar to those of Morrison and Kaminski (2007) but another paper of Beynnon, Renström, Alosa, Baumhauer, and Vacek (2001) mentioned a greater risk of ankle sprain in women with increased tibial varum and calcaneal eversion range of motion. These characteristics agree with the rearfoot varus foot type, because rearfoot varus is accepted as a sum of the tibial and subtalar varus. Another paper of Beynnon, Vacek, Murphy, Alosa, and Paller (2005) reported significantly greater risk of ankle sprain in female than in male basketball athletes. Willems, Witvrouw, Delbaere, De Cock, and De Clercq (2004) used the pressure plate method and observed the increased risk of ankle sprain in subjects with the following characteristics: a laterally situated centre of pressure at the initial contact, increased and prolonged periods of heel pronation, delayed resupination and roll off passing laterally from the hallux. This characteristic could be related to rearfoot varus, but could be more pronounced in forefoot varus in fact.

A rearfoot varus pathomechanical state implicates an excessively quick rearfoot resupination in the early propulsion phase, locking the transversotarsal joint, which ensures the foot rigidity necessary for foot function as a lever of the triceps muscle. This extremely quick resupination appears because of the previously exaggerated rearfoot pronation at the start of the stance phase, just after the heel strike, which is actually a principle of compensation in *RFvar* ensuring full contact between the foot sole and the ground. The treatment would consist of reducing the need for compensation by medial rearfoot posting. This type of posting could be seen as a standard design in some sport footwear, e.g. running shoes, etc. But an inadequate medial rearfoot posting could increase the risk of ankle sprain at the start of stance phase when the appropriate rearfoot pronation is necessary, together with knee flexion and extensor muscles eccentric contraction, to absorb the impact of a heel strike.

In our study the second highest ASI on average has been found in the subjects with *FFvalgF*. According to Michaud (1997a) there are three subtypes of *FFvalgF*. The exaggerated supination in the early propulsion phase, similarly to the previously mentioned *RFvarC*, happens in one of them. There are various modalities of treatment

posting, but in general every post should be individually adjusted to the subject. The routine usage of one footwear type or prefabricated post without a careful examination by an experienced specialist could lead to the invocation and/or aggravation of symptoms.

According to the empirical evidence, the rigid forefoot valgus (*FFvalgR*), non-compensated rearfoot varus (*RFvarN*) and non-compensated forefoot varus (*FFvarN*) have the highest tendency to occur in ankle sprain incidents (Valmassy, 1996). But in our group of elite female volleyball athletes, we found only 3 subjects with *FFvalgR* (4.8%) and we did not detect any subject with *RFvarN* and *FFvarN*. Vařeka and Vařeková (2008) found only 9.9% of their subjects to have *FFvarR*, whereas there were 7.1% subjects with *RFvarN* and 2.8% subjects with *FFvarN* in the group of one hundred and forty-one women (17-85 years, mean=58.8). This low incidence or lack of these foot types in elite volleyball athletes might be attributed to the fact that having a foot type most prone to ankle sprain prevented them naturally from becoming elite volleyball athletes. In any case the lack of these foot types in our group kept us from a clear assessment of the effect of functional foot type according to Root on the ankle sprain risk.

Ankle sprain has been confirmed as a very common injury in volleyball athletes. The compensated rearfoot varus and flexible forefoot valgus were the most common foot types. The findings showed the differences in the prevalence of various functional foot types as described previously. The age or footedness derived from the spiking arm did not have any significant effect on ankle sprain incidence in the subjects. The subjects with the compensated rearfoot varus and flexible forefoot valgus, the most frequent foot types, had a higher relative incidence of ankle sprain than the other types, but not significantly. The result was unclear due to very low prevalence or lack of the subjects with other functional foot types. Nevertheless, the application of some appropriate sport footwear and/or individually adjusted insoles and/or posts based on a particular examination is recommended.

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UTJECAJ FUNKCIONALNOG TIPA STOPALA I LATERALNOSTI NA UGANUĆE GLEŽNJA KOD VRHUNSKIH ODBOJKAŠICA

Odbojka je ekipni sport s velikom učestalošću uganuća gležnja. je Cilj ovog istraživanja bio istražiti povijest i frekvenciju uganuća gležnja na uzorku vrhunskih odbojkašica prema funkcionalnom tipu stopala i lateralnosti (prevladavanja uganuća desnog ili lijevoga gležnja), definiranoga prema Rootovoj klasifikaciji. Parcijalni ciljevi bili su istražiti javljaju li se uganuća gležnja više kod pojedinih funkcionalnih tipova stopala i utječe li dob ispitanica na incidenciju ozljede. Uzorak ispitanika od 62 vrhunske odbojkašice, u dobi između 17 i 25 godina (20,7±2,03) pregledao je iskusni fizijatar e da bi odredio funkcionalni tip stopala prema Rootovoj klasifikaciji, dok je osobna povijest uganuća gležnja i lateralnost svake ispitanice procijenjena na temelju upitnika. Dobiveni rezultati nisu bili normalno distribuirani u promatranom uzorku ispitanika. Za utvrđivanje statističke značajnosti svakog pojedinačnog slučaja koristili smo Spearmanovu korelaciju te Wilcoxonov i Kruskall-Wallisov test. Gotovo 68% ispitanika doživjelo je uganuće gležnja (1-13 slučajeva po ispitaniku, 2 uganuća prosječno). Spearmanova korelacija nije pokazala statističku značajnost razlika u frekvenciji uganuća po dobi ($r1=-0,1873$; $p<0,05$) ispitanica, unatoč tomu što su izuzete tri ispitanice s vrlo visokim brojem uganuća ($r2=-0,1656$; $p<0,05$). Lateralnost također nije bila statistički značajna (Wilcoxonov test $p=0,07$). Rezultati ovog istraživanja potvrdili su već opisane razlike u prevladavanju različitih funkcionalnih tipova stopala – kompenzirajući *varus* stražnjeg dijela stopala i fleksibilni *valgus* prednjeg dijela stopala bili su tipovi stopala kod kojih su se uganuća događala najčešće (56,6%, odnosno 27,4%), dok su se kompenzacijski *varus* prednjeg dijela stopala, tvrdi *valgus* prednjeg dijela stopala i neutralno stopalo relativno rijetko ozljeđivali (8,1%, 4,8% i 3,3%). Ispitanice s tipovima stopala koji su se najčešće ozljeđivali imali su veći prosjek incidencija uganuća gležnja (2,4, odnosno 2,0) u odnosu prema ostalim tipovima stopala (0,8, 0,7, odnosno 0,5), ali bez statističke značajnosti utvrđene Kruskall-Wallisovim testom ($p=0,44$). Nepostojanje statistički značajne razlike u incidenciji uganuća gležnja kod različitih funkcionalnih tipova stopala je upitna, vjerojatno zbog vrlo niskog broja prevladavajućih tipova stopala ili nedostatka ostalih tipova stopala, budući da su nam već poznati empirijski dokazi o povećanom riziku uganuća gležnja kod određenog funkcionalnog tipa stopala, što u ovom radu nije eksperimentalno potvrđeno.

Ključne riječi: *ozljeda gležnja, Rootov model, biomehanika, sportska obuća, individualizacija*