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MICHAELA RAČANSKÁ, LENKA VARGOVÁ, KATEŘINA VYMAZALOVÁ,
VERONIKA DZETKULIČOVÁ, LADISLAVA HORÁČKOVÁ

TARSAL COALITION IN SKELETAL REMAINS OF PAST CZECH POPULATIONS

ABSTRACT: The objective of our study is to estimate the frequency and types of the tarsal coalition in the populations of the Czech Lands, where this type of data is still missing. Examined skeletal collections belong to seven different sites and periods (from the Early Bronze Age through the Migration Period and Middle Ages until the 20th century). Tarsal coalition is hereditary abnormal bridging between two tarsal bones (mainly talus, calcaneus, and navicular) which would normally be separate bones. The bridging is caused by a type of connective tissue. Gross macroscopic analysis and comparison with clinical and archaeological literature were used to detect the signs of tarsal coalition. In some cases, the analysis was combined with the radiographic examination. A total of 267 individuals from the following locations were observed: Mikulovice, Kolín, Praha-Zličín, Sady-Špitálky, Trutmanice, Znojmo, and skeletons of recent cadavers from the Department of Anatomy, Faculty of Medicine, Masaryk University, Brno. Another 212 isolated tarsal bones from Brno ossuary material (dated to the 13th–18th century and currently deposited in the Department of Anatomy) were also studied. We estimated that the frequency of tarsal coalition (when individuals from all seven studied archaeological collections were pooled) was 5.6 %. The tarsal coalition frequencies for individual collections ranged between 2.3 % – 10.3 %. If the ossuary material was included in the total tarsal coalition frequency calculations (the number of individuals from the ossuary material was calculated as the minimum number of individuals), the tarsal coalition frequency was 6.1 %. In most of the cases, the calcaneonavicular coalition was detected. The findings may expand our overall understanding of tarsal coalition and stimulate further clinical research when looking for a causal link between tarsal coalition and orthopaedic diseases, such as painful, rigid flatfoot (fibular spastic flatfoot, tarsal synostosis, or dysostosis), and their possible secondary complications (intra-articular trauma, infection, arthropathy, osteonecrosis, neoplasm).

KEY WORDS: Tarsal coalition – Tarsal bones – Palaeopathology – Archaeological skeletal remains – Czech Lands

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INTRODUCTION

A tarsal coalition is an abnormal connection of two or more tarsal bones via connective tissues (Kulik, Clanton 1996). The bridging between bones could be provided via various types of connective tissue such as bone, cartilage, and ligaments. Tarsal coalition is a genetic disorder caused by impaired segmentation and differentiation of primitive mesenchyme during the embryogenesis of foot joints (Kulik, Clanton 1996, Dungl *et al.* 2005). Physiological human foot anatomy includes the following four joints between the talus, calcaneus, navicular, and cuboid bones: talocalcaneal, talocalcaneonavicular (named also only calcaneonavicular), calcaneocuboid, and, rarely, cuboideonavicular. Tarsal coalition can occur within these joints. Two of the most common tarsal coalition types (90 % of all types) are calcaneonavicular and talocalcaneal (*Figure 1*) (Herring 2019, Lemley *et al.* 2006).

The tarsal coalition was considered a rare form of harmless anatomical variation that was overlooked until the beginning of the 1930s (Andreasen 1968). However, further research observations suggested that the tarsal coalition might contribute to foot pain, leg muscle spasms, spastic or rigid flat foot condition, the valgus position of the foot, and movement limitation in the subtalar joint (Dungl *et al.* 2005). Based on the suggestions, the experts became interested in this morphologic abnormality. Cases of the tarsal coalition were described in palaeopathological literature by Angel (1971), Darton (2007), Dastugue and Metz (1977), Dinwiddy (2009), Silva (2005, 2011), Silva, Silva (2010) and Stloukal, Vyhnánek (1976). A limited number of studies present the frequency of tarsal coalition in populations based on the examination of complete osteological collections and cadaveric material. Among them are, for example, the research of Case, Burnett (2012), Cooperman *et al.* (2001), Rühli *et al.* (2003), and Vargová *et al.* (2016).

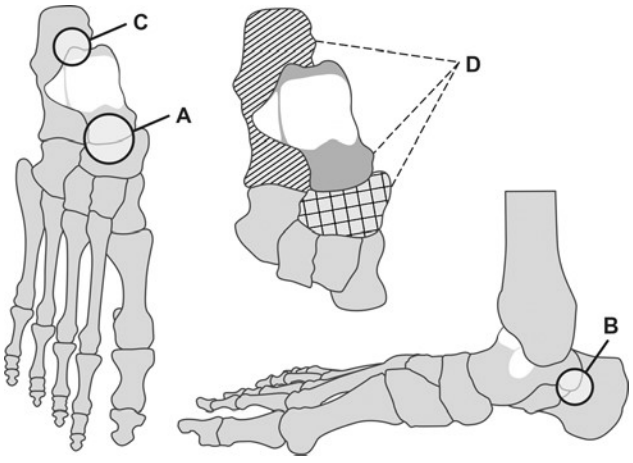

FIGURE 1: Diagram of tarsal coalition sites observed in this study. Diagram of tarsal coalition sites observed in this study. A, calcaneonavicular coalition; B, medial talocalcaneal coalition; C, posterior talocalcaneal coalition; D, marked bones are most often affected by tarsal coalitions (talus, calcaneus, navicular). Diagram: Jana Vachová.

Our research maps the frequencies and variation of expression of the tarsal coalition in Czech Lands from seven different sites and periods. The study aims to supplement and clarify current information about the tarsal coalition from the perspective of populations that occupied the territories of the Czech Lands.

MATERIALS

Seven osteological collections excavated in the current Czech Republic dated to various periods were examined to establish frequencies of tarsal coalition. Among the examined osteological collections were human remains from Únětice culture (Early Bronze Age) in Mikulovice (district Pardubice) and Kolín. The next collections were from a relatively extensive burial ground in Praha-Zličín dated to the Migration Period and from a burial ground associated with a sacral complex at the "Výšina svatého Metoděje" as a part of the locality "Sady-Špitálky" (Uherské Hradiště). Further studied archaeological osteological collection was from an extinct village of Trutmanice (Velké Pavlovice). More recent osteological collections that were examined came from mass burials of soldiers in Znojmo and osteological depository in the Department of Anatomy, Faculty of Medicine, Masaryk University in Brno. See *Figure 2* for the map of the archaeological sites and current locations in the context of the Czech Republic. *Table 1* shows dating of the locations and the number of individuals available for the analysis according to the locations.

Osteological collection from Mikulovice (Early Bronze Age, approx. 2200–1750 BC) contained skeletal remains of a typical population of farmers (Ernée *et al.* 2020). Almost half of the inhumations contained rich grave goods. Especially interesting finds were amber jewellery and other exotic items (Ernée *et al.* 2020). The type of grave goods suggests relatively active trade, increasing migration (Ernée *et al.* 2020).

Similarly to the Mikulovice site, the site from Kolín was dated to the Early Bronze Age (approx. 2200–1750

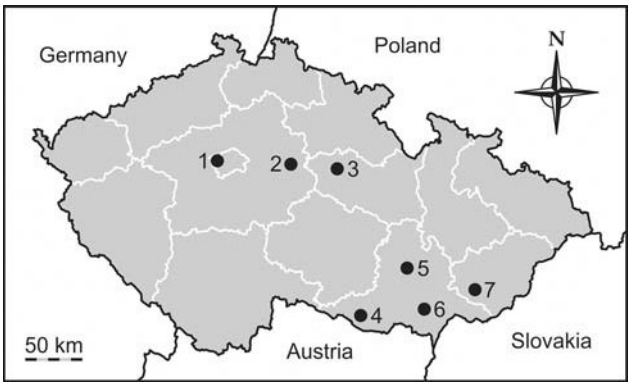

FIGURE 2: The map of the Czech Republic. The black dots show the original archaeological sites or current location (Brno) associated with the examined osteological collections. 1, Praha-Zličín; 2, Kolín; 3, Mikulovice (district Pardubice); 4, Znojmo; 5, Brno; 6, Trutmanice; 7, Sady-Špitálky (Uherské Hradiště).

BC). The population also used farming as their subsistence strategy, but their grave goods were poorer when compared to the sample from Mikulovice (Šumberová *et al.* 2010). There similarly were 82 individuals whose skeletal remains underwent palaeopathological analysis; however, only 77 individuals were in a good state of preservation for further analysis (data not published).

The collection from Praha-Zličín contained skeletal remains belonging to the Vinařice group dated to the early phase of the Migration Period (5th century). There were 173 graves uncovered, but the majority of the remains were in a fragmentary state of preservation (Vargová *et al.* 2016).

The burial ground from "Sady-Špitálky" (Uherské Hradiště) was dated to the Mladohradištní Period between the end of the 10th and 12th century (Galuška *et al.* 2008). Only the skeletal remains of 49 individuals with the highest level of preservation were selected for the palaeopathological analysis. The selection was aimed to examine possible familiar relationships between the buried individuals (for example, individuals buried at the same time in one grave) and to evaluate the individuals with presumed highest social status (based on the relative position of the graves and their rich grave goods) (Galuška, 1996).

There were 80 graves uncovered at the burial grounds near the church of the extinct village Trutmanice (Velké Pavlovice near Břeclav). The site was dated to the Late Middle Ages (between the 13th and 15th centuries). The individuals found in the graves belonged to a typical sample of village dwellers (Bíško *et al.* 2019).

In Znojmo, there were six mass graves uncovered, which contained the skeletal remains of 53 individuals. These were skeletal remains of soldiers who died during the Battle of Znojmo, which took place on the 10th and 11th of July 1809 (Kovárník *et al.* 2006).

The most extensive osteological collection investigated in this study is a part of the depository of the Department of Anatomy, Faculty of Medicine, Masaryk University in Brno. Tarsal bones in this collection originated from two sources. The first part of the collection originated from the skeletal remains of 40 individuals who donated their bodies to the

TABLE 1: Number of individuals available for the analysis according to the locations. Legend: TPA, total number of individuals used for palaeopathological analysis; F, female; M, male; NA, unidentified adults; SA, sub-adults; TBA, total number of individuals used for the analysis of tarsal coalition (where tarsal bones were available); AÚ, Department of Anatomy.

Collection	**Dating**	**Number of individuals**					
		TPA	F	M	NA	SA	**TBA**
Mikulovice	2200–1750 BC	106	35	34	0	37	**39**
Kolín	2200–1750 BC	77	19	10	27	21	**56**
Praha-Zličín	5th cent.	113	33	28	29	23	**43**
Sady-Špitálky	10th–12th cent.	49	13	25	0	11	**42**
Trutmanice	13th–15th cent.	149	24	32	23	70	**34**
Znojmo	19th cent.	53	1	47	5	0	**26**
AÚ	20th cent.	40	14	13	13	0	**27**

TABLE 2: Number of evaluated tarsal bones from ossuary collection deposited in the Department of Anatomy, Faculty of Medicine, Masaryk University, Brno.

Collection	Dating	Number of analysed tarsal bones						
		Total	Talus			Calcaneus		
			Total	Left	Right	Total	Left	Right
Ossuary collection	13th–18th cent.	212	93	49	44	119	62	57

TABLE 3: Summary of the studies containing the anthropological analyses of each of the osteological collections.

Collection	Anthropological analysis perfomed by
Mikulovice	Stránská *et al.* 2020
Kolín	Selected authors of this publication (data pending publication)
Praha-Zličín	Víšková *et al.* 2012
Sady-Špitálky	Šámalová 2000, Hájek 2000, Bortel 2001
Trutmanice	The authors of the current study using the methods of Knussmann (1988) and Stloukal *et al.* 1999
Znojmo	Kovárník *et al.* 2006

Department of Anatomy for scientific and educational purposes. The second part, which makes up the majority of this collection, includes isolated bones (tali and calcanei) from various Moravian ossuaries dated to the 13th–18th century (*Table 2*). The ossuaries emerged in the Middle Ages during plague epidemics as an emergency solution for cemeteries overwhelmed with the number of bodies. Graves were reused for multiple inhumations. Skeletal remains of earlier inhumations were exhumed and buried secondarily in shared underground crypts of churches and other buildings built for such purposes (Králíková 2007). Skeletal remains examined for this study came from the ossuary of Saint Jacob and Saint Thomas Church in Brno, from Hrádek u Znojma, and the pilgrimage church in Křtiny. The sex and age at death of the skeletal remains from this ossuary collection were unknown.

METHODS

Standard anthropological analysis of the osteological material was used to gain primary demographic data (sex and age at death estimation) about the analysed population samples. Summary of the studies containing the anthropological analyses of each of the osteological collections can be found in *Table 3*.

Palaeopathological analysis of the osteological collections consisted of detailed macroscopic examination supplemented by a radiological analysis in specific cases. The tarsal coalition was diagnosed based on the criteria by Case, Burnett (2012), Chapman (2007), and Dungl *et al.* (2005).

Due to the state of skeletal preservation in the majority of the samples, we studied only selected types of the tarsal coalition – the tarsal coalition in the hindfoot (mainly between the talus and calcaneus – talocalcaneal tarsal coalition, and the calcaneus and navicular bone – calcaneonavicular tarsal coalition) (*Figure 1*). The diagnosis was determined using the macroscopic examination.

In cases of calcaneonavicular coalition, a slightly medially inclined atypical contact surface was observed at the calcaneus near the anterior talar articular surface to connect with a corresponding contact surface at the navicular bone (*Figure 3*). Both contact surfaces matched in shape and size. They were irregular and covered with a layer of compact bone containing a large number of pores that communicated with the trabecular bone.

If this type of atypical contact surface was detected on the tarsal bones in a studied skeleton, the head of the talus was inclined more medially in contrast to the norm, while the navicular axis was shifted laterally

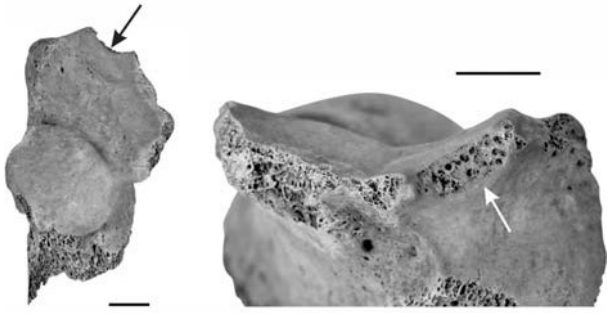

FIGURE 3: Fragment of the left calcaneus with an atypical contact surface (shown with arrows) for the calcaneonavicular coalition. The scale corresponds to 1 cm. Photo: Jana Vachová.

FIGURE 4: Left talus of an adult individual from the ossuary collection with an atypical contact surface (shown with arrows) for the posterior talocalcaneal coalition. The scale corresponds to 1 cm. Photo: Jana Vachová.

towards the calcaneus when the foot was in the anatomical position (Mosca, Bevan 2012).

Talocalcaneal coalition characteristically occurs on the medial side of the subtalar joint. Although tarsal coalition between the calcaneus and talus may occur in three joint facets, the middle facet is most commonly involved (Mosca, Bevan 2012). We mainly detected posterior talocalcaneal coalition (*Figure 4*).

The frequency of tarsal coalition cases present in each of the osteological collections was recorded based on the number of individuals with preserved talus and calcaneus. The frequency of the tarsal coalition was calculated as the number of individuals with uni or bilateral occurrence of tarsal coalition divided by the total number of individuals with preserved relevant tarsal bones multiplied by 100. Bilateral incidence of the tarsal coalition was also assessed for each of the osteological collections. Furthermore, the differences between males and females in the frequency of tarsal coalition were examined in this sample.

The findings from the ossuary collection curated by the Department of Anatomy were interpreted differently due to different sample characters (isolated bones instead of sets of skeletal remains belonging to a specific individual). Left and right talus and calcaneus were examined separately, as the pairing was impossible in the ossuaries´ osteological collection. The frequency of tarsal coalition for each bone type and side was calculated as the number of detected tarsal coalitions divided by the number of present bone types for the given side multiplied by 100. The frequency of the tarsal coalition in the ossuary collection was calculated as the total number of detected tarsal coalitions divided by the total number of examined bones from the ossuary collection multiplied by 100. Unilateral or bilateral frequency of the tarsal coalition was not assessed in the ossuary sample. The differences in the frequency of tarsal coalition between males and females were also not examined in this sample, as based on the sex estimation method by Novotný (Novotný, Malinovský 1985), the majority of the isolated bones were categorised as "unidentified sex".

The total tarsal coalition frequency of the examined sample was calculated as the number of detected unilateral (where possible to establish) cases of tarsal coalition divided by the total number of individuals (the number of individuals from the ossuary material was calculated as the minimum number of individuals) multiplied by 100. The minimum number of individuals was calculated as the most abundant tarsal bone type (left calcaneus, *Table 2*).

Microsoft Office 365 Excel 2016 was used to calculate the percentages of tarsal coalition cases. Frequencies of the tarsal coalition were compared between the different population samples using the Pearson Chi-square test in Tibco Statistica ver. 13.5 (Tulsa, USA). All the statistical tests were conducted at the level $\alpha = 0.05$.

RESULTS

Differential diagnosis

In differential diagnosis, it was necessary to distinguish between tarsal coalitions and the presence of fractures. Both conditions are characterised by their specific location of the lesion, the characteristic change in the shape of the bone, or the presence of

corresponding contact surfaces between the neighbouring tarsal bones in the case of tarsal coalitions. Unclear findings, such as significant bone damage, were excluded from the overall evaluation.

Furthermore, it was necessary to determine whether the tarsal coalition was an isolated deviation or one of the symptoms of a general congenital malformation. According to scientific literature, Apert syndrome, Pfeiffer syndrome (Žižka 1994), or Nievergelt-Pearlman syndrome (Dungl *et al.* 2005) would be considered as the general congenital malformations that could cause tarsal-coalition-like symptoms. No other pathological changes corresponding to the mentioned syndromes were observed in skeletal remains from burial grounds and cadavers examined in this study. For isolated tarsal bones from Moravian ossuaries, the possibility of the individuals suffering from any of the mentioned syndromes could not be ruled out, as it was impossible to study the entire skeleton in detail.

Tarsal coalition frequencies

The first group of bones examined for the presence of tarsal coalition were skeletal remains from archaeological burial grounds. Archaeological research made it possible to estimate the number of studied individuals more accurately in this sample, and thus the frequency of tarsal coalition in studied populations. Tarsal coalitions observed on recent skeletal remains from donated bodies with known sex and age at death were also included in this first group of the studied material. The results of this part of the study are shown in *Table 4* and *Figure 5*.

A total of 267 individuals from various historical periods were evaluated. The tarsal coalition was

TABLE 4: Incidence of the tarsal coalition in seven osteological collections from different historical localities. Legend: M, male; F, female; TC, tarsal coalition; (+) presence of TC; (-) absence of TC; 0, not possible to evaluate; N: number of individuals (adult and juvenile) where the tarsal bones were present; AÚ, Department of Anatomy, osteological collection of bodies donated for educational and research purposes.

Collections	Burial no. (object)	Sex	TC left	TC right	%	N
Mikulovice	10	M	-	+	10.3	39
	12	F	+	+		
	29	F	0	+		
	49	M	+	+		
Kolín	3690	F	+	+	5.4	56
	4348	M	+	-		
	1039	F	-	+		
Praha-Zličín	530/19	F	+	0	2.3	43
Sady-Špitálky	168/59	F	+	+	2.4	42
Trutmanice	802	M	+	+	8.8	34
	807	M	+	0		
	860	M	0	+		
Znojmo	5/8	M	0	+	7.7	26
	5/10	M	+	+		
AÚ	20/49	F	+	+	3.7	27

TABLE 5: Comparison of p-values when comparing tarsal coalition frequencies between the osteological collections examined in this study. Legend: AÚ, Department of Anatomy; level of statistical significance $p < 0.05$.

	Mikulovice	Kolín	Praha-Zličín	Sady-Špitálky	Trutmanice	Znojmo	AÚ	Ossuaries
Mikulovice	×	0.37	0.13	0.14	0.84	0.73	0.32	0.32
Kolín	0.37	×	0.44	0.46	0.52	0.68	0.74	0.56
Praha-Zličín	0.13	0.44	×	0.99	0.20	0.29	0.73	0.21
Sady-Špitálky	0.14	0.46	0.99	×	0.21	0.30	0.74	0.22
Trutmanice	0.84	0.52	0.20	0.21	×	0.88	0.42	0.90
Znojmo	0.73	0.68	0.29	0.30	0.88	×	0.53	0.95
AÚ	0.32	0.74	0.73	0.74	0.42	0.53	×	0.45
Ossuaries	0.71	0.56	0.21	0.22	0.90	0.95	0.45	×

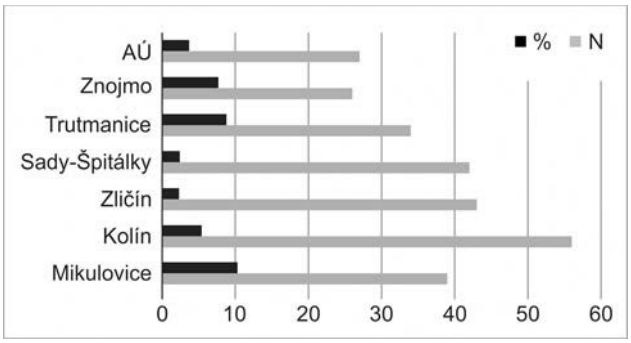

FIGURE 5: Percentage of tarsal coalition cases observed in the total number (N) of evaluated individuals from osteological collections. AÚ: Department of Anatomy, osteological collection of bodies donated for educational and research purposes.

observed in 5.6 % of all evaluated cases in these osteological collections. Tarsal coalitions were observed on skeletal remains from all observed historical periods (prehistory to modern times). The calcaneonavicular coalition was the most commonly observed (93 %) in our sample. For example, *Figure 6* shows the tarsal coalition observed in tarsal bones from Praha-Zličín from the Migration Period.

The highest frequency of tarsal coalition (10.3 %) was observed in the sample from Mikulovice (Early Bronze Age). The lowest frequency of tarsal coalition (2.3 %) was observed in the group from Zličín (5th century). However, Pearson's Chi-square test did not show a statistical difference in the incidence of the tarsal coalition in any of the osteological collections when comparing all of them or in a pair-wise comparison (*Table 5*).

TABLE 6: Detected suspected tarsal coalitions in ossuary material deposited in Department of Anatomy, Faculty of Medicine, Masaryk University, Brno. Legend: TC, tarsal coalition; Total, total number of examined tarsal bones.

Bone	TC	TC %	Total
right calcaneus	4	7.2	57
left calcaneus	5	8.1	62
right talus	0	0	44
left talus	4	8.2	49

The second group of bones examined for the presence of tarsal coalition were isolated tarsal bones (tali and calcanei) from the ossuary collection. The tarsal bones of the right and left sides were evaluated separately. Findings of tarsal coalition frequencies for each bone are shown in *Table 6*.

The frequency of tarsal coalition in the ossuary collection was 6.1 %. As can be seen from the above results, 6.1 % falls into the range of tarsal coalition frequencies from the rest of examined osteological collections (2.3 % – 10.3 %). The slight difference is not statistically significant.

FIGURE 6: A, Calcaneonavicular coalition (shown with the black arrow) on the left tarsal bones of a 45–50year-old-female from Praha-Zličín (5th century, grave No. 530/19). B, Radiograph shows a round protrusion of the calcaneus with the atypical contact surface in contact with the navicular bone referred to as the anteater nose sign (shown with the white arrow) (Chapman 2007). C, Supero-anterior view of the calcaneonavicular coalition. The scale corresponds to 5 cm; the dimension is the same for all figure parts. Photo edited by Jana Vachová. A and B were reproduced with permission by Vargová *et al.,* 2016 and the main editor of the *Interdisciplinaria archaeologica*, Figure 12 p. 24.

The total tarsal coalition frequency of the examined sample (ossuary collection combined with other osteological collections) was also 6.1 %. The minimum number of individuals for the ossuary collection used for this calculation was 62. When comparing the frequency of tarsal coalition in all osteological collections together, the p-value was p = 0.63.

Regarding the type of tarsal coalition in the ossuary collection, the calcaneonavicular coalition was observed more frequently (in nine cases – five on the left side and four on the right side). Signs of the talocalcaneal coalition were observed less often (in four cases on the left side).

Tarsal coalition laterality and sex differences

No statistically significant differences between the unilateral and bilateral incidence of the tarsal coalition were observed in the first group of examined bones (sets of skeletal remains from the non-ossuary osteological collections). The incidence of the bilateral tarsal coalition was observed in 47 % of cases (7 out of 15) for the second group of examined bones (ossuary collection) (*Table 4*).

No significant differences were observed in the incidence of the tarsal coalition between the sexes. The slightly higher incidence of the tarsal coalition in males, i. e. 57 % (8; N = 15), was not statistically significant compared to 43 % (7; N = 15) in females.

DISCUSSION

Tarsal coalition frequencies

The first group of examined bones (sets of skeletal remains from the non-ossuary osteological collections) were compared with other published studies about the incidence of the tarsal coalition in osteological collections (for example, Case, Burnett 2012, Leonard 1974). In scientific literature, data on the total frequency of tarsal coalition in various populations differ in some cases (Mosca, Bevan 2012). Recent clinical trials estimate the frequency around 1–2 % (Case, Burnett 2012). According to cadaver studies reported by Rühli *et al.* (2003), the prevalence of calcaneonavicular coalition is 7 %, and the prevalence of all types of tarsal coalition together is up to 12.9 %. It is important to note that a higher prevalence of tarsal coalition was detected in a sample of cadaveric material (12.9 %), which also contained soft tissues besides the skeletal tissues (Rühli *et al.* 2003). Clinical studies suggest a lower incidence of tarsal coalition and report it to be between 1–2 % in the general human population (Kulik, Clanton 1996, Newman, Newberg 2000, Plotkin 1996, Stormont, Peterson 1983, Vincent 1998). Nevertheless, according to Rühli *et al.* (2003), these clinical studies disregard the asymptomatic coalitions, so the true incidence of the tarsal coalition would be probably much higher. Furthermore, Case and Burnett (2012) also argue that many estimations of tarsal coalition incidence are based on clinical samples that utilize radiographic examination of patients with foot pain (peroneal spasm, flat foot), which can also bias the results as the asymptomatic cases are not included in such studies.

Tarsal coalition laterality, type, and sex differences

Similarly to other studies, there was no difference between the unilateral and bilateral incidence of the tarsal coalition observed in the first group of examined bones (sets of skeletal remains from the non-ossuary osteological collections) (Bohne 2001, Cooperman *et al.* 2001, Kulik, Clanton 1996, Newman, Newberg 2000). The incidence of the bilateral tarsal coalition was observed in 7 out of 15 cases for the second group of examined bones (ossuary collection). The results could be underestimated as, in some cases, it was not possible to observe the presence or absence of tarsal coalition bilaterally due to the poor state of preservation or due to the complete absence of relevant bones from the set of skeletal remains.

The calcaneonavicular coalition was the most commonly observed in our sample. Case and Burnett (2012) noted significant geographical differences in tarsal coalition types and frequencies. According to their research, calcaneonavicular coalitions are most common in the European population. At the same time, they are rarely observed in the African population (for example, in the medieval Danish population, the frequency of tarsal coalition is 2.2 %, whilst in the modern South African population, only 0.2 %). South Africans exhibited significantly higher tarsal coalitions in the midfoot, with the naviculocuneiform I coalition (1.0 %) as the most common type. Contrary to this, no tarsal coalitions in the midfoot were found among the Euro-Americans or medieval Danes (Case, Burnett 2012). The talocalcaneal coalition is often reported to be the second most common type of tarsal coalition in European populations, this was documented in clinical (Brtková, Jiříčková 2012, Stormont, Peterson 1983), cadaveric (Case, Burnett 2012, Pfitzner 1896, Rühli *et al.* 2003), and archaeological samples (Case, Burnett 2012). Our results fully correspond to that.

There was a higher incidence of tarsal coalitions in males than in females. A higher incidence in males

could be expected due to the better preservation of robust male skeletons in the studied populations. In addition, there was one osteological collection where only male tarsal bones were examined, namely the skeletons of soldiers from the Battle of Znojmo (Kovárník *et al.* 2006). Other osteoarchaeological studies also suggested an increased incidence of the tarsal coalition in male samples (Calder, Calder 1977). However, most of these conclusions are based on a minimal number of cases. Furthermore, some studies obtained different results. For example, Rühli *et al.* (2003) suggested that the tarsal coalition condition is more frequent in females based on a study of a recent cadaveric sample. In clinical studies, there is a slight male prevalence of the condition (Bohne 2001, Newman, Newberg 2000).

Minor differences in tarsal coalition frequencies and their frequencies in uni/bilaterality are present when comparing the results of the present communication with similar publications, and when comparing the frequency of tarsal coalition between the osteological collections of past Czech populations. Different factors can cause the differences. Above all, evaluating the tarsal coalition in skeletal remains depends on its preservation. The highest frequency of occurrence was recorded in the osteological collection from Mikulovice, which was relatively well preserved compared to other archaeological osteological collections. Furthermore, evidence confirms the familial predisposition of tarsal coalition incidence (Cvrček *et al.* 2021). Genetic influence in tarsal coalitions is well known (Leonard 1974, Wray, Herndon 1963). Tarsal coalitions are unifactorial autosomal dominant disorders with nearly complete penetrance (Leonard 1974, Mosier, Asher 1984) and numerous reports associate them with other congenital disorders (Geelhoed *et al.* 1969, Grogan *et al.* 1994, Takakura *et al.* 1991).

At this point, it is not possible to describe the familial relationships in the examined populations objectively. An extensive genetic study of the skeletal remains of the inhabitants of Mikulovice is underway. Similar projects are being prepared to focus on the skeletal remains of Kolín and Trutmanice, which may help partially clarify the differences in tarsal coalition frequencies in the future.

CONCLUSION

The study focused on evaluating one of the congenital bone disorders – an abnormal connection between the tarsal bones (tarsal coalition), in various samples from past Czech populations. This defect was observed in skeletal remains coming from seven different sites and periods (from the Early Bronze Age through the Migration Period and Middle Ages until the 20th century). The frequency of tarsal coalition in skeletal material ranged between 2.3 % and 10.3 %. In most cases, it was the calcaneonavicular type of tarsal coalition, which corresponds with the observations made in other European populations. The frequency of tarsal coalition in the current study does not statistically differ when comparing osteological collections from past Czech populations who lived in various historical periods. There are no differences in the frequency of tarsal coalition between sexes or between sides in the present study. Although our results only allow a speculative comparison with earlier studies on different populations, the findings may expand our overall understanding of tarsal coalitions. The findings could support future clinical research where the clinicians could look for a causal link between tarsal coalition and orthopaedic diseases.

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Michaela Račanská
Lenka Vargová
Kateřina Vymazalová
Veronika Dzetkuličová*
Research Group of Medical Anthropology and Clinical Anatomy
Department of Anatomy, Faculty of Medicine
Masaryk University,
Kamenice 3, 625 00 Brno
Czech Republic
E-mail: michaela.racanska@med.muni.cz
E-mail: vargova@med.muni.cz
E-mail: vymazalova@med.muni.cz
E-mail: veronika.dzetkulicova@med.muni.cz

Horáčková Ladislava
Department of Kinesiology, Faculty of Sports Studies
Masaryk University, Kamenice 5, 625 00 Brno
Czech Republic
E-mail: lhorac@fsps.muni.cz

*Corresponding author.