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Anatomically high division of sciatic nerve and its clinical significance

Anatomski visoka podela sedalnog živca i njen klinički značaj

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Abstract

Background / Aim. The sciatic nerve (SN) is a mixed nerve formed in pelvis by joining of L4 - S3 anterior spinal nerve roots. SN can be under the pressure in different regions throughout its course. However, the most frequent site of impingement is under the *piriformis* muscle which causes the occurrence of *piriformis* syndrome. High division of SN has its relevance considering the fact that it leads to the compression of nerve resulting in *piriformis* syndrome. The aim of this study was to determine the connection between anatomical parameters of pelvis and high division of SN, which is considered to be one of the most common causes of *piriformis* syndrome in both genders. **Methods.** This study was conducted on 28 formalin fixed cadavers of both genders at the Institute of Anatomy, Faculty of Medicine, University of Belgrade (Belgrade, Serbia) and the Department of Anatomy, School of Medicine, University of St Andrews (St Andrews, United Kingdom). For the measuring of required dimensions, we used a ruler and a caliper. **Results.** A statistically significant difference in the values of bispinal and bituberal lines was observed. A high division of SN was found on 58.33% of the male cadavers and 80% of the female cadavers. A statistically significant difference in the mean value of the bituberal line between the male and female sex was also recognised. **Conclusion**. The connection between the anatomical parameters of the pelvis and the level of division of the SN is confirmed. Although on the basis of the results it could be assumed that people with smaller pelvic dimensions would have greater likelihood of developing a *piriformis* syndrome, the other factors, such as biomechanics related to a wider „Q angle" in women that could result in a higher incidence of *piriformis* syndrome, should also be considered.

Key words:
anatomy, regional; cadaver; piriformis muscle syndrome; sciatic nerve; sex characteristics.

Apstrakt

Uvod/Cilj. Sedalni živac (*n. ischiadicus*) je mešoviti živac koji nastaje u karlici od prednjih grana kičmenih (spinalnih) živaca od L4-S3. Tokom svog puta, n. *ischiadicus* može da bude podložan pritisku u različitim regionima, a naročito u predelu zgloba kuka od strane piriformnog mišića što prouzrokuje simptome piriformnog sindroma. Visoka podela nerva klinički je značajna zbog toga što ona najčešće ima za posledicu kompresiju nerva, odnosno piriformni sindrom. Cilj rada je bio ispitivanje povezanosti anatomskih parametara karlice sa visinom podele *n. ischiadicusa* kod oba pola, uz pretpostavku da ispitivani parametri utiču na samu podelu nerva koja se smatra jednim od glavnih uzročnika piriformnog sindroma. **Metode.** Studija je sprovedena na 28 formalinskih kadavera oba pola na Institutu za anatomiju Medicinskog fakulteta Univerziteta u Beogradu (Beoigrad, Srbija) i Institutu za anatomiju Medicinskog fakulteta Univerziteta u St Andrews-u (St Andrews, Velika Britanija). Za merenje parametara dimenzija karlice korišćeni su lenjir i kaliper **Rezultati.** Uočena je statistički značajna razlika u vrednosti bispinalne i bituberalne linije. Visoka podela je pronađena u 58.33% uzoraka muškog pola i 80% uzoraka ženskog pola. Takođe, ustanovljena je statistički značajna razlika u srednjoj vrednosti bituberalne linije između muškog i ženskog pola. **Zaključak.** Veza između anatomskih parametara karlice sa nivoom podele *n. ischiadicusa* je potvrđena. Iako bi se na osnovu rezultata moglo pretpostaviti da će osobe sa manjim dimenzijama karlice imati veću verovatnoću da se kod njih razvije piriformni sindrom, trebalo bi uzeti u obzir i druge faktore kao što je biomehanika koja je povezana sa širim uglom *m. quadriceps femoris-a* („Q angle") kod žena s posledičnom većom učestalošću piriformnog sindroma.

Ključne reči:
anatomija, regionalna; kadaver; n. ischiadicus; sindrom, piriformni; pol, karakteristike.

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Introduction

Sciatic nerve (SN) is the longest and the widest nerve of the human body. It is a mixed nerve formed in pelvis by joining of L4-S3 anterior spinal nerve roots. At the level of the sacroiliac joint, the SN can be almost 2 cm wide. The main reason for the high division of the SN is its size [1].

The SN exits the pelvic cavity wrapped with a single epineurium through the greater sciatic notch under the *piriformis* muscle. Most often, at the level of superior angle of popliteal cavity, the SN is divided into the terminal branches, medial tibial nerve and lateral common fibular nerve [2]. Once it enters gluteal region through the infrapirifom opening, it moves over the pelvitrochanteric muscles, covered with *gluteus maximus* muscle and soft tissue [3]. The SN then descends between tuberosity of ischium inside, and the greater trochanter of femur, which is outside. In the thigh, the SN is located posterior from the *adductor magnus* muscle and anterior from the long head of *biceps femoris* muscle[3]. In this area, the nerve is particularly vulnerable to injury during the administration of intramuscular injections [4]. Motor branches of the SN are responsible for the innervation of hip and knee joint, while the sensitive branches innervate almost the entire lower leg, with the exception of the anterior inner part of the lower leg and the medial edge of the foot [2]. By achieving a close relationship with the *piriformis* muscle, the SN in gluteal region can cause the occurrence of the "piriformis syndrome" [4]. Because of the common distal attachment with the *piriformis*, the muscle on the greater trochanter of femur, *obturator internus* muscle, as well as *superior* and *inferior gemellus* muscle, have the ability to compensate for the loss of its function [3].

According to the classification of Beaton and Anson [5], anatomical variations of the SN relative to the pelvitrochanteric *piriformis* muscle can be classified into several types: type 1 (undivided nerve below undivided muscle); type 2 (division of the nerve between and below undivided muscle); type 3 (division above and below undivided muscle); type 4 (undivided nerve between heads); type 5 (division between and above heads); type 6 (undivided nerve above undivided muscle) (Figure 1).

Babinski et al. [6] also described the new anatomical variation in which the common fibular nerve extends above and the tibial nerve below, relative to the *superior gemellus* muscle. All these classifications are important in surgery to determine the cause and location of nerve compression and the appropriate treatment. It is believed that divided *piriformis* muscle is an important cause of the piriform syndrome, because it contributes to the compression and irritation of the SN that runs between its fibers [2]. Besides the *piriformis* muscle, it is thought that nerve compression can also be performed by the *obturator internus* muscle (Figure 2), which belongs to the group of external rotators in hip joint, located below the SN [7]. The close contact between the tendon of the *obturator internus* muscle and SN causes similar symptoms, such as those occurring in the piriform syndrome [7].

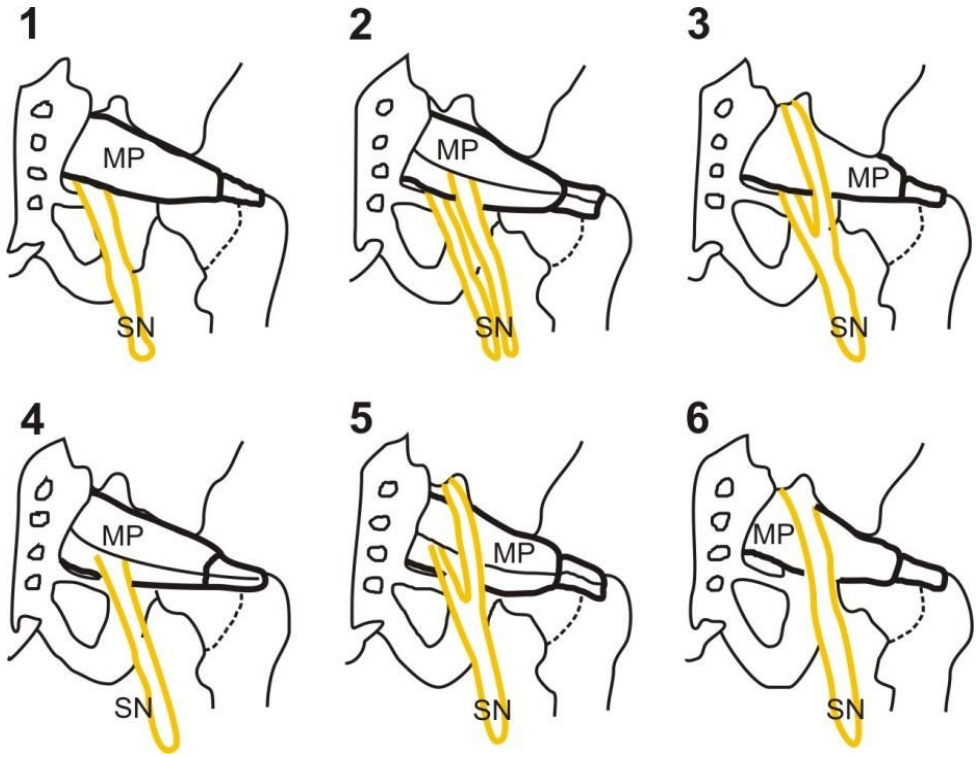

Fig. 1 - Anatomical variations of the sciatic nerve (SN) (Beaton's and Anson's classification [5]).
MP – muscle *piriformis*.
1) Undivided nerve below undivided muscle; 2) Division of nerve between and below undivided muscle; 3) Division above and below undivided muscle; 4) Undivided nerve between heads; 5) Division between and above heads; 6) Undivided nerve above undivided muscle.

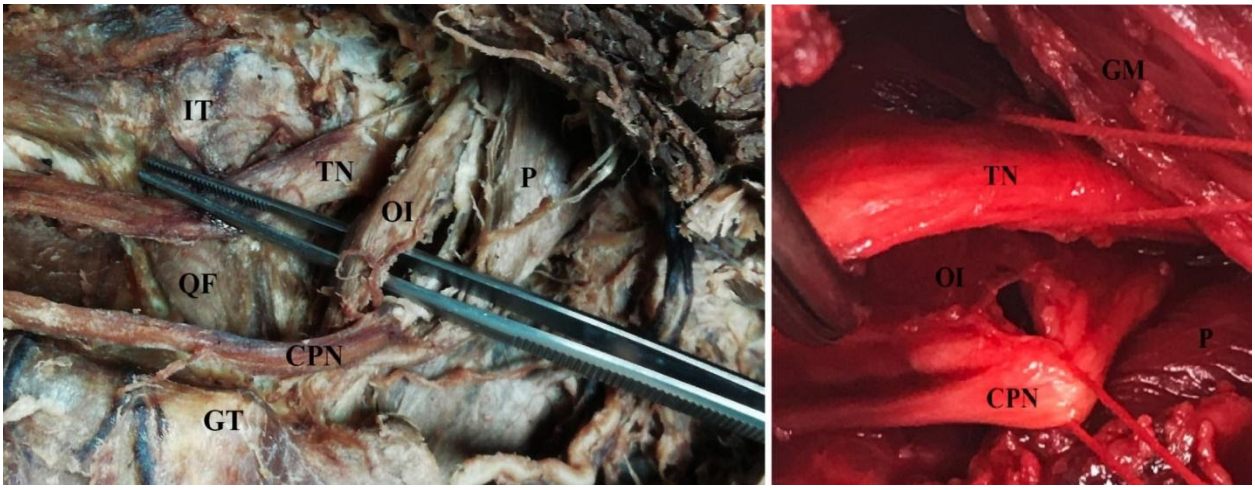

Fig. 2 - High division of the sciatic nerve, above the *obturator internus* muscle. The sciatic nerve exits in the pelvis from the infrapiriform portion of the greater sciatic *foramen* divided by attachment of the *obturator internus* muscle in the left gluteal region.
IT – tuberosity of ischium ; GT – great trochanter of femur; QF – *quadratus femoris* muscle; CPN – common peroneal (fibular) nerve; TN- tibial nerve; OI – *obturator internus* muscle; P- *piriformis* muscle, GM – *gluteus medius* muscle.

The aim of this study is to examine the relationship between the anatomical parameters of the bony pelvis and the height of SN division in both sexes, assuming that the analyzed parameters affect the SN division itself, which is considered to be one of the main causes of the piriform syndrome.

Methods

Our study was conducted at the Faculty of Medicine, University of Belgrade (Serbia) and School of Medicine, University of St Andrews (United Kingdom). The study was conducted on 28 cadavers, out of which 18 cadavers were male and 10 female, aged 74–86 years. These cadavers were embalmed and fixed with 10% formalin. We formed two study groups, which together comprised 56 lower extremities, with the aim of defining the high and low division of the SN. Distal attachment of the *piriformis* muscle on the greater *trochanter* of the femur was taken for boundary of division of the SN. All divisions above the distal attachment of the *piriformis* muscle are defined as high, while divisions below are defined as low. For the parameters of the bony pelvis dimensions, we took the distance between the right and left superior anterior iliac spine which we defined as a bispinal line, as well as the distance between two tuberosities of *ischium* that we defined as a bituberal line (Figure 3). For measuring of required dimensions, we used a ruler and a caliper.

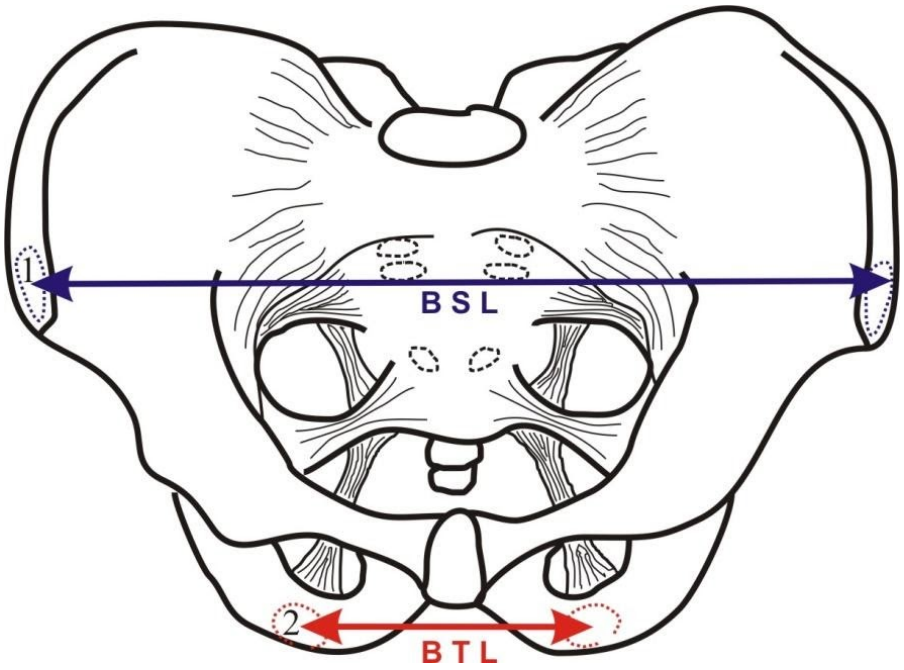

Fig. 3 –Anatomical parameters of the pelvis.
1 – superior anterior iliac spine; 2 – tuberosity of ischium; BSL – bispinal line; BTL – bituberal line.

Statistical data processing was performed in SPSS 11.0 using the Mann-Whitney *U* test, with an accepted level of statistical significance was $p < 0.05$, and $p < 0.001$ for highly statistically significant result.

Results

The results of our research are presented in Tables 1 and 2. We analyzed 56 lower extremities of 36 male and 20 female cadavers.

Table 1

Pelvic parameters of cadavers analyzed

Parameters	Mean ± SD
High division of SN (67.86%)	
bispinal line (cm)	24.38 ± 1.69*
bituberal line (cm)	14.56 ± 1.05*
Low division of SN (32.14%)	
bispinal line (cm)	30.01 ± 2.27
bituberal line (cm)	16.38 ± 0.25

SN – sciatic nerve; SD – standard deviation. *statistically significant difference versus low division of SN (p< 0.05).

Table 2

Pelvic parameters in cadavers with high division of SN

Parameters	Mean ± SD
High division of SN in male (58.33%)	
bispinal line (cm)	24.75 ± 2.36
bituberal line (cm)	15.38 ± 0.63
High division of SN in female (80%)	
bispinal line (cm)	24.00 ± 0.82
bituberal line (cm)	13.75 ± 0.65*

SN – sciatic nerve; SD – standard deviation. *statistically significant difference in decrease of length of bituberal line in female (p< 0.05).

High and low division of the SN were found in 38 (67.86%) and 18 (32.14%) of total sample, respectively. The high division of the SN was found in 21/36 (58.33%) of the male specimens and 16/20 (80%) of the female specimens. The mean values of the length of bispinal line on the total cadaver sample with the high and low division of the SN were 24.38 ± 1.69 and 30.01 ± 2.27, respectively. Comparing the two formed groups (with the high and low division of the SN), we demonstrated a statistically significant difference of mean value of the bispinal line between high and low divisions ($p = 0.003$ and $p < 0.05$, respectively). The mean values of the length of bituberal line in cadavers with the high and low division of the SN were 14.56 ± 1.05 and 16.38 ± 0.25 ($p = 0.004$ and $p < 0.05$, respectively). The mean values of the length of bispinal line in the male and female cadaveric groups with the high division of the SN were 24.75 ± 2.36 and 24.00 ± 0.82, without statistical significance ($p = 0.88$ and $p > 0.05$, respectively). Mean value of the bituberal line in the male cadaveric group was 15.38 ± 0.63, while the same parameter in the female cadaveric group was 13.75 ± 0.65 showing statistically significant diference between two groups ($p = 0.028$ and $p < 0.05$, respectively).

Discussion

The SN represents the nerve which is due to anatomical characteristics particularly susceptible to various forms of injury [3]. The neuropathy of this nerve is one of the most common diseases of lower extremities [3]. The SN may be susceptible to the pressure in different regions, but it most commonly occurs in the area of hip joint by the *piriformis* muscle, causing the symptoms of "piriformis syndrome" in patients [4]. The "piriformis syndrome" is characterized by severe pain in the gluteal region, lower part of back, and worsening of symptoms due to prolonged sitting [9]. The reason of the "piriformis syndrome" can be caused by impaired anatomical structures during growth and development, as well as congenital anomalies [4]. In the study [4], the researches analyzed topographic characteristics on fetuses that are thought to vary during the fetal development of the organs. When they followed distances between the infrapiriform opening and individual anatomical structures on the hip bone, it was observed that distances increased with age. However, it was not possible to make the correlation between nerve thickness in the level of the infrapiriform opening and age, which is explained by the faster development of the musculoskeletal system versus nervous system [4]. It was also noted that the distance between tuberosity of the *ischium* and SN, as well as the distance between the greater trochanter of the femur and SN at the point where the SN transitions from the gluteal region into the posterior femoral compartment, remained unchanged relative to age [4]. The significance of these results is the fact that the SN position in relation to the femur and pelvic bone does not change depending on age [4]. The high division of the SN is clinically significant because it most often results as nerve compression which is the cause of "piriformis syndrome" [2]. In our study, we followed the relationship between the high and low division of the SN and pelvic parameters (bispinal and bituberal line). Division of the SN into the end branches at a higher level than usual can happen anywhere in a thigh or pelvis and it is a relatively common phenomenon [3]. This was confirmed by our results which showed that in 67.86% of the total sample, the SN was highly divided above the distal attachment of the *piriformis* muscle on the greater trochanter of femur, which we have designated as the criterion for determining the level of the division. Analyzing the pelvic parameters of cadavers with the high division of the SN, it can be observed that the mean value of both parameters, bispinal line (24.38 ± 1.69) and bituberal line (14.56 ± 1.05) is less than mean value of bispinal line (30.01 ± 2.27) and bituberal line (16.38 ± 0.25) obtained in cadavers with the low division of the SN, which proved to be statistically significant ($p < 0.05$). Further analyzing the obtained results by gender, we got the result indicating statistically significant ($p < 0.05$) decrease in the length of bituberal line in the female cadavers. These results indicate the relationship between the anatomical parameters of the pelvis and the level of SN division, so that the high division is associated with smaller pelvic dimensions. It could be assumed that, due to frequent high division, the person with the smaller size of the pelvis will have a higher probability to develop "piriformis

syndrome". However, other factors, such as biomechanics, should be considered. The "piriformis syndrome" is up to six times more common in women than in men, due to the biomechanics which is associated with a wider angle *m. quadriceps femoris* ("Q angle") in women [8]. Our results may indicate the cause of the "piriformis syndrome", primarily in individuals of the female population, because the conducted cadaveric study showed a more frequent high division of the SN in women (80% of the total sample), with a statistically significant difference in the length of bituberal line, which is certainly smaller in females. The results of one study showed the relationship between the anatomical structures of the hip bone and SN, first in the anatomical position, and then in the positions which are simulating the *piriformis* muscle elongation test (such as 60° flexion, 30° adduction and 10° medial rotation in the hip joint) [10]. In the mentioned study, the results showed that during biomechanics stretching tests the infrapiriform opening becomes closer to the spine of *ischium* and the angle between transversal plane and the SN becomes larger, so that it makes the SN more susceptible to being „stuck".

Conclusion

The results of our study show that there is a relationship between the anatomical parameters of the bony pelvis with the SN division level. A high division of the SN is associated with the smaller length of bispinal and bituberal line in both sexes. In females, there is a more frequent high division of the SN and statistically significant difference in the length of bituberal line, which is smaller.

Although the results would suggest that people with smaller pelvic dimensions are more likely to develop the "piriformis syndrome", other factors, such as biomechanics, associated with the wider "Q angle" in women, result in a higher incidence of this syndrome.

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