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Variation of Torg-Pavlov ratio with age, gender, vertebral level, dural sac area, and ethnicity in lumbar magnetic resonance imaging

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ABSTRACT

Objectives: The objectives of the study were to provide normal values of the Torg-Pavlov ratio (TPR) of the lumbar spine in magnetic resonance imaging (MRI) for the Jordanian population and examine differences observed according to factors including age, gender, lumbar level, dural sac area, or ethnic group.

Material and Methods: Two hundred and eighteen lumbar MRIs from the Picture Archiving and Communication System were reviewed. These were collected from three main governmental hospitals, in North, Central, and South of Jordan. The mid-sagittal diameters of the vertebral body, spinal canal, and dural canal area were measured at all levels. Patients' gender and age were documented as well. Exclusion criteria were kyphoscoliosis alignments disorders, lumbar spinal canal compression regardless of the cause, vertebral bony disease (including fractures), and the presence of technical artifacts. Statistical analyses used descriptive and correlational methods. Comparisons were made between genders, age groups, lumbar level, dural sac area in the study population using independent t-test and one-way ANOVA tests, and between ethnicities by reviewing previous reports on subjects of different ethnicities.

Results: The mean TPR ratio for the study participants was 0.4502 ± 0.097 . The value of TPR was widest in the 20–29-year-old group at all vertebral levels and in both males and females. Females had a significantly wider TPR than males ($P = 0.003$) in all age groups. TPR differed significantly between the five vertebral levels ($P = 0.026$). The difference in TPR between age groups was not statistically significant. TPR showed a positive significant correlation with dural sac ($r = 0.203$, $P = 0.003$). Comparison with the previous literature demonstrated variation in the TPR where Jordanian population had a lower TPR in comparison with Negros and Caucasoids whereas similar to Koreans, especially in females.

Conclusion: There are significant differences in TPR according to gender, dural sac area, lumbar spinal level (except between L1 and L2), and ethnic group, but no significant difference with the age was found. The present study has identified normal values of Torg's ratio in the Jordanian population. Although the study may not be able to provide clear guidelines for use in clinical practice, it has still highlighted possible between countries variations and has identified differences in these values to different factors. Implications on clinical practice could be reflected on the diagnosis of lumbar spinal stenosis or on predicting the prognosis of lumbar spine injury.

Keywords: Torg-Pavlov ratio, Canal body ratio, Lumbar spine, Lumbar canal stenosis, Jordanian

INTRODUCTION

Torg-Pavlov ratio (TPR) or so called "Canal Body Ratio" CBR was first described in 1987 by Pavlov *et al.*, it represented the ratio between the sagittal diameter of the spinal canal and the

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sagittal diameter of the corresponding vertebral body and was first measured on lateral cervical spine X-ray. A ratio of $<0.7-0.8$ indicated a significant spinal stenosis with high risk of neurological injury.^[1]

The lumbar spinal canal stenosis is defined by the North American Spine Society guidelines as “buttock or lower extremity pain, which may occur with or without low back pain, associated with diminished space available for the neural and vascular elements in the lumbar spine.”^[2,3] They also state in their guidelines that “imaging is the key noninvasive test for lumbar spinal stenosis.” Although the previous definition covers both radiological and clinical sides, the radiological side remains unclear with no definite radiological criteria for stenosis.^[3]

Several radiological parameters have been proposed for the diagnosis of the spinal canal stenosis and ectasia, such as dural sac dimensions, mid-sagittal spinal canal, sagittal exit foramen, TPR, dural sac/spinal canal cross-sectional area, cross-sectional area of the right and left canals, depth of lateral recess, and lateral recess angle. However, it is reported that one of the preferred techniques is to measure TPR.^[4]

The TPR can be estimated not only by conventional X-ray but also using computerized tomography and magnetic resonance imaging (MRI). However, the ability to estimate both bony and soft-tissue structures in MRI made it the standard investigation tool for spinal canal assessment.^[5]

Till date, no study has been conducted on lumbar spine TPR in Jordanian population. Moreover, no study determined the variation of this ratio with five different factors all at once. Thus, this study may provide a reference value for TPR in the Jordanian population with multifactor variation. It is hoped that the findings will provide information for radiologists and surgeons and assist them in making an informed decision regarding the diagnosis of lumbar spinal canal stenosis.

MATERIAL AND METHODS

This retrospective study was approved by the Institutional Ethics Committee, and the need for the patient's written consent was overlooked due to retrospective data collection and minimal risk. The total sample included 218 patients (113 males and 105 females) with age ranging between 23 and 86 years old.

Two hundred and eighteen MRI images (Siemens 1.5 Tesla Picture Archiving and Communication System [PACS]) that were scanned in the period between 2019 and 2021 in three governmental hospitals located in North, Central, and South of Jordan were reviewed by three trained observers under direct supervision of a neuroradiologist. Measurements were performed using (MPTronic medical software EZ.DICOM CD VIEWER version3 2.8.0).

Exclusion criteria included vertebral spine fractures, lumbar spinal canal lesions, vertebral bony lesions, kyphoscoliosis, and technical artifact.

The lumbar sagittal T2WI's was used to measure the mid-sagittal and mid-vertebral AP dimension of all lumbar vertebrae at the site of posterior basovertebral vein penetration and parallel to the axis of the vertebra (M), and the AP dimension of spinal canal (N) [Figure 1].

The dural sac area (E) was calculated using free hand drawings measurements of the previously mentioned viewing system in axial T2WI's [Figure 2].

The TPR (N/M) was calculated for each level and compared according to age, gender, vertebral level, and dural sac area. Ethnic differences were also examined by reviewing literature that included subjects of different ethnicities. Statistical analyses were conducted using SPSS v26. Descriptive analyses used means and standard deviation (SD) for the values of TPR (N/M) for age and gender categories at different vertebral levels. The differences in TPR (N/M) between genders, age groups, and vertebral levels were analyzed using one-way ANOVA test. Correlation tests were used to identify associations between TPR (N/M) and dural sac area (E). $P < 0.05$ was considered statistically significant.

RESULTS

The total number of patients' MRIs included in the study was 218 and consisted of 113 MRIs for males (51.8%) and 105 MRIs for females (48.2%).

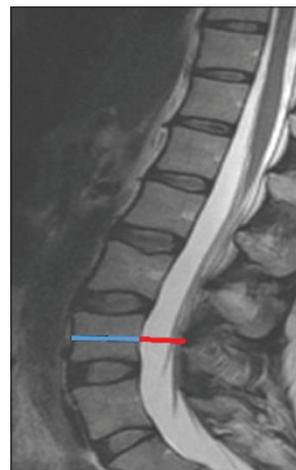


Figure 1: A 45 years old male who presented with low back pain, MRI Sagittal T2WI's. Measurements used for TPR: The blue line (M) represents the AP dimension of the vertebral body at L4 level. The red line (N) represents the AP dimension of the spiral canal at the same level.

The age of patients included ranged between 23 and 86 years old with the mean age being 52.23 ± 13.125 . The mean age for females was 52.08 ± 13.28 and 52.38 ± 13.04 for males with no significant difference between the two groups ($P = 0.865$).

The mean N/M ratio for the study participants was 0.4502 ± 0.097 . [Table 1] summarizes the findings of N/M ratios for different age categories. Dividing age groups into decades; the mean N/M's ratio for the 20–29 decade of life was the greatest with mean of 0.5101 ± 0.129 followed by age category of 60–69 with a mean N/M's ratio of 0.4658 ± 0.109 . The mean ratio for participants aged 30–39 years old was the least (0.4278 ± 0.427). In addition, the ratios for age groups of 40–49, 50–59, and >70 were found to be 0.449 ± 0.104 , 0.444 ± 0.083 , and 0.450 ± 0.099 , respectively.

[Figure 3] illustrates the variation in N/M with age groups where a drop in N/M occurs in the 30–39 years old age category.

In addition, the findings showed a significant difference between males and females ($P = 0.003$), where the mean segmental ratio in males was 0.43 (range: 0.22–0.930) and 0.47 (range, 0.29–0.69) in females.

[Table 2] shows a significant difference in the N/M ratio between L1 and L3 ($P = 0.022$), L1 and L4 ($P = 0.003$), and

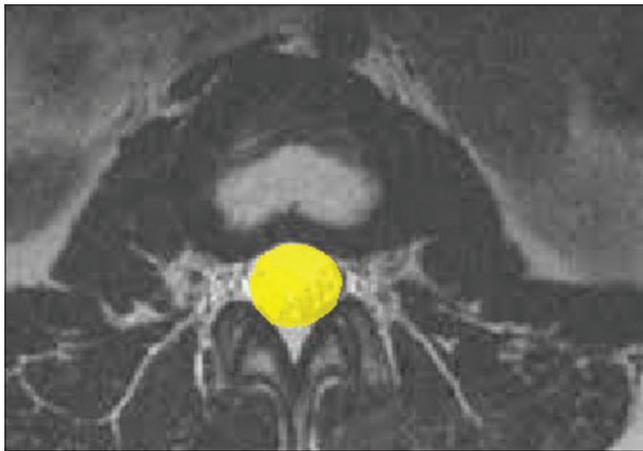


Figure 2: A 45 years old male presented with with low back pain. MRI axial T2WTs: The yellow circle represents the dural sac area (E).

L1 and L5 ($P = 0.009$). As for L2, no significant differences in the N/M ratio were found. For L3, the only significant difference in the N/M ratio was with L1. Likewise, L4 and L5 only showed significant differences with L1.

[Figure 4] illustrates the N/M ratio in different age groups and at five vertebral levels. The N/M ratio is found the highest in the 20–29 years old decade at all vertebral levels. The ratio then declines sharply in the age group of 30–39 years old at all levels. In the 40–49 decade of age, the N/M ratio increases for Levels 1, 2, 3, and 4. However, the ratio decreases at Level 5 for the same decade. For the 50–59 decade, the ratio declines at Levels 1, 2, and 3, while, it increases at Levels 4 and 5. In the 60–69 age group, the ratio shows increasing values at all levels except for Level 2. The ratio again decreases in the above 70-year-old group, except at Level 2 where we see an N/M increasing.

[Figure 5] illustrates that the N/M ratio is the highest in the age group 20–29 for both genders. It then behaves similarly in both genders in the age groups of 30–39, 40–49, and 60–69. However, in females of 50–59 age group, the N/M ratio increases while it decreases in males of the same age group. In addition, the ratio decreases more sharply and is much lower in males above 70 year -old than females. A variable of the interaction of age groups and gender was entered and examined using univariate ANOVA test to reflect whether the effect of age on the N/M ratio is influenced by the patient's gender. Findings show that N/M changes in similar age groups for both genders but these changes are not statistically significant ($F [5, 218] = 0.149, P = 0.980$).

A one-way ANOVA was performed to compare the effect of age on N/M ratio. The test revealed that there was not a statistically significant difference in N/M between at least two groups ($F [5, 212] = 1.299, P = 0.265$)

Regarding gender, one-way ANOVA test showed a significant difference in the N/M ratio between males and females included in the study($F [1, 216] = 9.023, P = 0.003$).

Finally, there was a statistically significant difference in N/M between five vertebral levels as determined by one-way ANOVA ($F [4, 213] 2.823, P = 0.026$).

Table 1: Mean N/M for each decade of life/age groups.

| Age categories (years) | Minimum | Maximum | Mean | Std. deviation | CI |
|------------------------|---------|---------|-------|----------------|-------------|
| 20–29 (n=10) | 0.28 | 0.75 | 0.510 | 0.129 | 0.417–0.602 |
| 30–39 (n=30) | 0.30 | 0.57 | 0.427 | 0.080 | 0.398–0.458 |
| 40–49 (n=51) | 0.24 | 0.69 | 0.449 | 0.104 | 0.420–0.497 |
| 50–59 (n=68) | 0.27 | 0.64 | 0.444 | 0.083 | 0.425–0.465 |
| 60–69 (n=32) | 0.33 | 0.93 | 0.465 | 0.109 | 0.426–0.505 |
| ≥70 (n=27) | 0.22 | 0.65 | 0.450 | 0.099 | 0.410–0.488 |
| Total (n=218) | 0.22 | 0.93 | 0.450 | 0.097 | 0.437–0.463 |

Table 2: Average (N/M) ratio at each vertebral level for each age category.

| Age categories (years) | L1 | L2 | L3 | L4 | L5 | Average (L1-L5) |
|------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-----------------|
| 20-29 | 0.6880±(0.27286) (0.43-1.41) | 0.5321±(0.07588) (0.40-0.61) | 0.4726±(0.05410) (0.38-0.57) | 0.4919±(0.07193) (0.37-0.62) | 0.5241±(0.12628) (0.28-0.75) | 0.510±0.129 |
| 30-39 | 0.5105±(0.08117) (0.33-0.69) | 0.4552±(0.07395) (0.30-0.61) | 0.4217±(0.07937) (0.30-0.58) | 0.4096±(0.08036) (0.24-0.54) | 0.4494±(0.10839) (0.24-0.81) | |
| 40-49 | 0.5232±(0.12199) (0.33-0.77) | 0.4818±(0.12413) (0.26-0.80) | 0.4375±(0.09911) (0.25-0.68) | 0.4175±(0.10540) (0.17-0.69) | 0.4402±(0.10419) (0.24-0.74) | |
| 50-59 | 0.5122±(0.08395) (0.26-0.65) | 0.4660±(0.09598) (0.24-0.86) | 0.4097±(0.08151) (0.18-0.61) | 0.4213±(0.08971) (0.26-0.64) | 0.4695±(0.12478) (0.27-0.93) | |
| 60-69 | 0.5189±(0.08854) (0.38-0.70) | 0.4524±(0.07747) (0.32-0.62) | 0.4367±(0.12583) (0.25-0.93) | 0.4441±(0.07890) (0.32-0.63) | 0.4742±(0.08689) (0.31-0.73) | |
| ≥70 | 0.5147±(0.11411) (0.16-0.71) | 0.4699±(0.10032) (0.23-0.62) | 0.4341±(0.08724) (0.22-0.62) | 0.4304±(0.10498) (0.24-0.67) | 0.4517±(0.09581) (0.31-0.65) | |

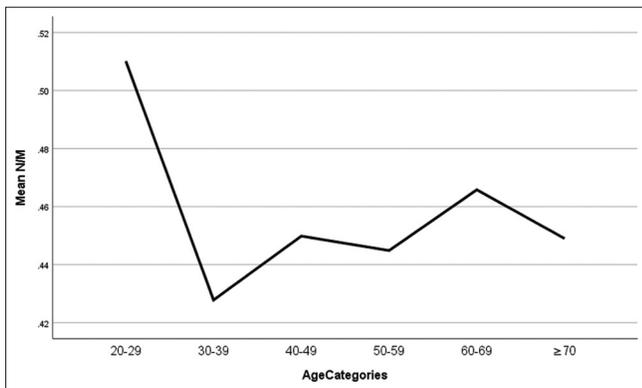


Figure 3: The mean Torg's ratio of different age groups.

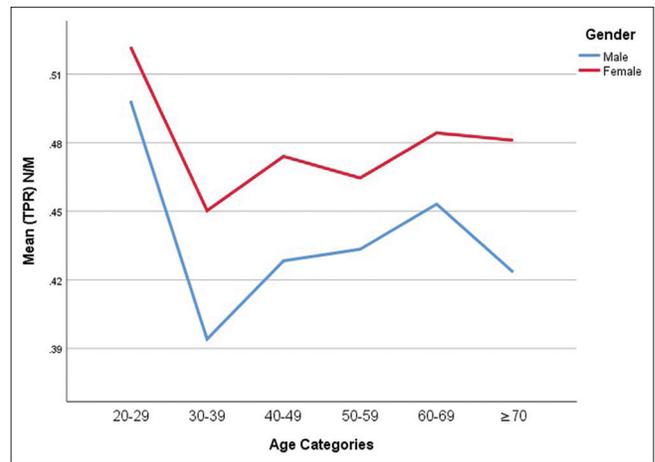


Figure 5: The mean Torg's ratio of different age groups in the two gender groups.

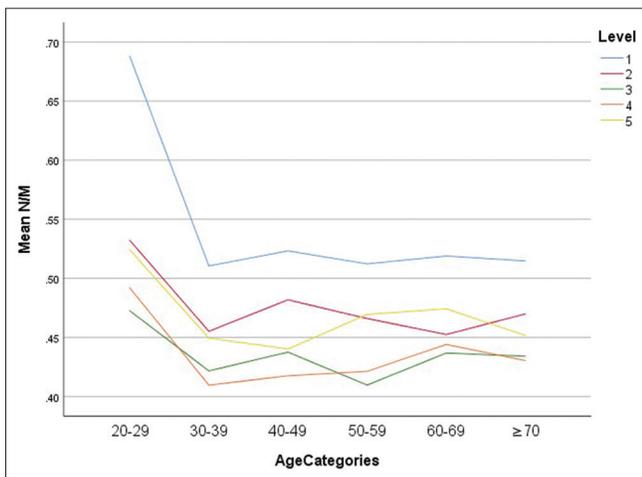


Figure 4: N/M ratio at different age groups and vertebral levels.

An LSD *post hoc* test for multiple comparisons revealed that the mean value of N/M was significantly different between Level 1 and Level 3 ($P = 0.022$ 95% C.I. = [0.0086, 0.1076]). A significant difference was found between Level 1 and Level 4 ($P = 0.003$ 95% C.I. = [0.0273, 0.1276]) and between Level

1 and Level 5 ($P = 0.009$ 95% C.I. = [0.0153, 0.1065]). While there was no statistically significant difference between Level 1 and Level 2 ($P = 0.161$).

Correlation test between dural sac area and TPR showed a positive significant correlation with $r = 0.203$ ($P = 0.003$).

An independent samples *t*-test was conducted to determine whether there is a difference in dural sac area between males and females. The results indicate a non-significant difference between males ($M = 1.7219$ and $SD = 0.59175$) and females ($M = 1.6567$, $SD = 0.45984$), ($t(216) = -1.3$, $P = 0.195$).

A correlation test was done to examine the relationship between age, N/M ratio, and dural sac area, where age was not significantly related to dural sac area ($P = 0.636$) while N/M ratio was significantly related to dural sac area ($P = 0.014$).

There was a statistically significant difference in the sac area between five vertebral levels as determined by one-way ANOVA ($F [4, 213] 3.419$, $P = 0.010$). An LSD *post hoc* test

for multiple comparisons revealed that the mean value of dural sac was significantly different which was found between Level 1 and Level 3 ($P = 0.020$ 95% C.I. = [0.0553–0.6296]). A significant difference was found between Level 1 and Level 4 ($P = 0.028$ 95% C.I. = [0.0362–0.6181]) and between Level 1 and Level 5 ($P = 0.002$ 95% C.I. = [0.1669–0.6960]). While there was no statistically significant difference between level 1 and level 2 ($P = 0.285$).

DISCUSSION

In our research, we estimated the relationship of TPR, as an indication for spinal canal stenosis, with different variables including age, gender, lumbar spine level, dural sac area, and ethnic groups as the following:

TRP with age

The TPR drops from its maximal value to the minimal value between the third and fourth decade of life, later, the values of TPR show a wavering rise, as shown in [Figure 3].

A one-way ANOVA test to compare the effect of age on TPR revealed that there was not a statistically significant difference ($F [5, 212] = 1.299, P = 0.265$).

TPR with gender

The TPR values in females are higher for each age group in comparison to the male gender group, the wavering appearance of the graph for both genders is almost similar except for 50–59 age group, where TPR increases in females, while it decreases in males for the same age group [Figure 5].

The one-way ANOVA test showed a significant difference in TPR between both genders included in the study ($F [1, 216] = 9.023, P = 0.003$).

TPR showed a significant difference between males and females ($P = 0.003$), where the mean segmental ratio in males was 0.43 (range: 0.22–0.930) and 0.47 (range, 0.29–0.69) in females.

TPR with different lumbar levels

The TPR is maximum in 20–29 years old at all vertebral levels; however, there is no specific character for the behavior of the graph for each lumbar level in different age groups [Figure 4].

There was a statistically significant difference between five vertebral levels as determined by one-way ANOVA test ($F [4, 213] 2.823, P = 0.026$). An LSD *post hoc* test for multiple comparisons revealed that the mean value of TPR was significantly different between L1 and (L3/L4/L5), but with no significance difference between L1 and L2.

Table 3 : ANOVA test for differences in N/M according to gender, age groups, and vertebral level.

| Variable | F-value | P-value |
|------------------------|---------|---------|
| Gender | 9.023 | 0.003 |
| Age categories (years) | 1.299 | 0.265 |
| Vertebral level | 2.823 | 0.026 |

Table 4: Correlation between Torg’s ratio (N/M) and dural sac area (E).

| Variable | Mean | SD | r | P-value |
|----------|--------|---------|-------|---------|
| N/M | 0.4502 | 0.09702 | 0.203 | 0.003 |
| E | 1.7122 | 0.56575 | | |

Table 5: ANOVA test for differences in area according to gender, age groups, and vertebral level.

| Variable | F-value | P-value |
|------------------------|---------|---------|
| Gender | 1.69 | 0.195 |
| Age categories (years) | 0.355 | 0.879 |
| Vertebral level | 3.419 | 0.01 |

A significant difference was found between Level 1 and Level 3 ($P = 0.022$ 95% C.I. = [0.0086, 0.1076]). In addition, a significant difference between Level 1 and Level 4 ($P = 0.003$ 95% C.I. = [0.0273, 0.1276]) and between Level 1 and Level 5 ($P = 0.009$ 95% C.I. = [0.0153, 0.1065]). While there was no statistically significant difference between Level 1 and Level 2 ($P = 0.161$).

TPR with dural sac area

There was a positive significant correlation between the dural sac area and TPR indicating that TPR is a reliable measurement for spinal canal stenosis. However, the dural sac was not significantly changed by age or gender, though it changed with lumbar spine level except for the first two levels which is similar to that of TPR.

TPR with ethnic group

We compared our results with Zulu Negros, Sotho Negros, Caucasoid,^[7] and Korean^[6] population. Our values were the lowest in comparison with Negros and Caucasoid and almost similar to Koreans, especially for the female gender.

There are several causes for spinal canal stenosis, the most common cause being degenerative disk disease including disk herniation, facet joint degenerative hypertrophic changes, synovial cyst, ligamentum flavum hypertrophy, spondylolisthesis, posterior longitudinal ligament calcification, and osseous osteophyte.^[8,9] Other causes such as space occupying lesion and congenital causes are also documented.^[8,10]

Table 6: Comparison of TPR of different ethnics group.

| | | | L1 | L2 | L3 | L4 | L5 |
|--------------------------|--------|-------|------|------|------|------|------|
| Korean | Male | Canal | 15.4 | 14.3 | 13.6 | 14 | 14.6 |
| | | Body | 29.1 | 30.8 | 32.3 | 33.7 | 33.2 |
| | | Ratio | 0.53 | 0.46 | 0.42 | 0.42 | 0.44 |
| | Female | Canal | 15.5 | 14.8 | 14.1 | 14 | 14.1 |
| | | Body | 27.6 | 29 | 31 | 32 | 32.4 |
| | | Ratio | 0.56 | 0.51 | 0.45 | 0.44 | 0.44 |
| Caucasoid | Male | Canal | 18 | 17 | 16 | 16 | 18 |
| | | Body | 31 | 32 | 33 | 34 | 33 |
| | | Ratio | 0.58 | 0.53 | 0.48 | 0.47 | 0.54 |
| | Female | Canal | 18 | 17 | 17 | 16 | 18 |
| | | Body | 27 | 27 | 29 | 29 | 30 |
| | | Ratio | 0.66 | 0.62 | 0.58 | 0.55 | 0.6 |
| Zulu Negroid | Male | Canal | 16 | 15 | 15 | 15 | 16 |
| | | Body | 28 | 30 | 32 | 33 | 32 |
| | | Ratio | 0.57 | 0.5 | 0.46 | 0.45 | 0.5 |
| | Female | Canal | 17 | 16 | 15 | 16 | 16 |
| | | Body | 25 | 26 | 28 | 30 | 31 |
| | | Ratio | 0.68 | 0.61 | 0.53 | 0.53 | 0.51 |
| Sotho Negroid | Male | Canal | 16 | 15 | 14 | 15 | 16 |
| | | Body | 27 | 29 | 31 | 32 | 33 |
| | | Ratio | 0.59 | 0.51 | 0.45 | 0.46 | 0.48 |
| | Female | Canal | 16 | 16 | 15 | 15 | 16 |
| | | Body | 25 | 26 | 28 | 30 | 31 |
| | | Ratio | 0.64 | 0.61 | 0.53 | 0.5 | 0.51 |
| Jordanian (Our study) | Male | Canal | 14.2 | 13.1 | 12.5 | 13.1 | 13.8 |
| | | Body | 30 | 31 | 31.7 | 32.5 | 30.4 |
| | | Ratio | 0.47 | 0.42 | 0.39 | 0.4 | 0.45 |
| | Female | Canal | 14.8 | 14 | 13.2 | 13.1 | 12.9 |
| | | Body | 26.4 | 27.6 | 29.1 | 29.8 | 28.4 |
| | | Ratio | 0.56 | 0.51 | 0.45 | 0.44 | 0.45 |

TPR: Torg-Pavlov ratio

The neurosurgeons usually would go for the surgical intervention for cases where medical treatment of claudication pain failed (pain killer, nerve block, physiotherapy...etc.) and where moderate-to-severe spinal canal stenosis is evident on the radiological imaging.^[9,10] The findings of this study suggest that the radiological evidence of abnormal TPR can be considered a criterion for the diagnosis of spinal canal stenosis and, therefore, may be of clinical value in cases where decision-making of surgical intervention is required. Our findings may also help neurosurgeons to choose between minimally invasive procedures for mild cases to more advanced procedures for severe cases; such as laminectomy with facetectomy and spinal fixation.^[11]

In terms of implications for the future research, it is recommended that further research can focus on the radiological diagnosis of spinal canal stenosis and whether radiological evidence can be accurately detected among clinically diagnosed cases. Moreover, advanced statistical approaches can be used to determine possible cutoffs

of abnormal TRP examined with relation to different neurological findings, ethnicities, age groups, gender, or lumbar level.

Limitations of this study were mainly related to the absence of reliable computerized clinical neurological data of the patients on PACS, especially in peripheral hospitals in Jordan. This made it difficult to perform a case-control study. Instead, following a retrospective observational design in this study may have prevented the generation of evidence for a definitive causal relationship between the severity of clinical symptoms and TPR.

CONCLUSION

There is a significant relationship between TPR with multiple variables; gender, dural sac area, lumbar spinal level (except between L1 and L2), and ethnic group, but no significant difference with age indicating that TPR could be a reliable method for estimating and predicting the radiological diagnosis of spinal canal stenosis. However, different values for both genders, different lumbar levels, and ethnics group should be taken into consideration.

Declaration of patient consent

Patients' consent not required as patients' identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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