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ORIGINAL COMMUNICATION

The Torg Ratio of C3–C7 in African Americans and European Americans: A Skeletal Study

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The ratio between the sagittal diameter of the spinal canal and the sagittal diameter of the vertebral body, known as the "Torg ratio", is often used to test for spinal canal narrowing. Here, we investigate this ratio in a large population, consisting of two ethnicities, both sexes and three age groups. Measurements were taken on the dry cervical verterbrae (C3–C7) of 277 individuals using a digital apparatus allowing for the recording of 3D coordinates of a set of landmarks on the vertebral body. Vertebral body and vertebral foramen lengths were compared across the different subgroups. Vertebral body and vertebral foramen lengths differ significantly between males and females and between African Americans and European Americans. With age, the vertebral body length increases while the foramen length does not undergo significant changes. These anatomical differences are reflected in differences in the Torg ratio calculated for the different subgroups. In conclusion, our findings suggest that a hard cutoff on the Torg ratio used to define a pathological narrowing of the cervical spine should be adapted to the population the patients come from. Clin. Anat. 32:84–89, 2019.

Key words: Torg–Pavlov ratio; cervical spine; spinal stenosis; vertebral body; vertebral foramen

INTRODUCTION

The "Torg–Pavlov" ratio, or "Torg ratio", is the ratio between the sagittal diameter of the spinal canal and the sagittal diameter of the vertebral body. This ratio was first proposed by Torg et al. (1986) as an indicator for spinal canal narrowing. When the ratio drops below .80, clinical symptoms may appear, such as cervical myelopathy (Epstein et al., 1979; Payne and Spillance, 1957) or neurapraxia (Torg et al., 1996). Likewise, the Torg ratio may be used to identify patients at risk for acute spinal cord injury following a minor trauma to the cervical spine and to predict the neurological outcomes (Song et al., 2009; Wick et al., 1999). The normal and pathological ranges of this ratio have been assessed using a variety of methods, including lateral radiographs (Boijsen, 1954; Burrows, 1963; Epstein et al., 1979; Eismont et al., 1984; Pavlov et al., 1987; Herzog et al., 1991), computed tomography (CT) scans (Matsuura et al., 1989; Stanley et al., 1986) and magnetic resonance imaging (MRI) (Tierney et al., 2002;

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TABLE 1. Demographic Characteristics of the Study Population

Ethnic group	African Americans (*N* = 146)						European Americans (*N* = 131)					
Sex	Females (*N* = 69)			Males (*N* = 77)			Females (*N* = 65)			Males (*N* = 66)		
Age group	Young	Middle	Old	Young	Middle	Old	Young	Middle	Old	Young	Middle	Old
N=[a]	23	25	21	25	25	27	21	20	24	21	23	22

[a]Young (20–39 years old), Middle (40–59 years old) and Old (over 60 years of age).

Lamothe et al., 2011; Aebli et al., 2013). Using such techniques, ranges of Torg ratios have been determined for different populations, among which are Japanese (Murone, 1974; Hashimoto and Tak, 1977; Ogino et al., 1983; Hayashi et al., 1987), Indians (Bhalla et al., 1977; Gupta et al., 1982), European Americans, African Americans (Lamothe et al., 2011; Tatarek, 2005) and Chinese (Chen et al., 1994; Lim and Wong, 2004). In addition, they have been assessed for different age groups (Aebli et al., 2013; Tierney et al., 2002) and different clinical groups, i.e., symptomatic vs. nonsymptomatic (Pollard and Apple, 2003; Jackson et al., 2004; Fisher et al., 2005; Hagen et al., 2005; Song et al., 2009).

The current study aims to determine the Torg ratio for vertebrae in the cervical spine (C3–C7) in a large population and reveal its association with sex, age and ethnicity.

MATERIALS AND METHODS

Direct measurements of cervical vertebral bodies and foraminae were taken on nonpathological human skeletal remains from the Hamman-Todd Osteological Collection (Cleveland Museum of Natural History). A total of 277 individuals were included in the study. The skeletons originate from African American or European American males and females, which were assigned into three age cohorts: 20–39; 40–59 and over 60 years of age (Table 1). A total of 1385 cervical vertebrae from C3 through C7 were measured.

Measurements were performed using a Microscribe-3D apparatus (Immersion, San Jose, CA), to record three-dimensional coordinates for landmarks on the vertebrae. The measured vertebrae were held in place using a custom-made apparatus designed to ensure a constant orientation. The position resolution and accuracy of the apparatus, as defined by the manufacturer, are .13 and .43 mm (mean values), respectively. Two measurements were recorded: (1) the vertebral body length at the superior discal surface (SVBL), defined as the projected distance between the anterior–superior border and the posterior–superior border of the vertebral body; and (2) the superior vertebral foramen length (SVFL), defined as the distance between the anterior–superior border of the spinous process and the posterior–superior border of the vertebral body (Fig. 1). Both measurements were taken on the midsagittal plane on the anterior–posterior dimension.

Descriptive statistics were carried out for both measurements. A *t* test was used to determine whether the Torg ratio differs significantly between males and females, between young and old individuals and between African Americans and European Americans. A three-way ANOVA was used to check for an interaction effect between the three-independent variables (sex, age and ethnicity) on the Torg ratio. The level of significance was set at .05.

Intraclass correlations were computed to determine the intra- and intertester reliabilities, by comparing the results of repeated measurements taken on 15 randomly chosen individuals. One of the authors (DE) carried out the measurements three times with an interval of 3–5 days, in order to determine the intratester reliability of the measurements. Intertester reliability was assessed by comparing the measurements of three of us (DE, YM, IH), who carried out the measurements within an hour of one another. All testers were blinded to previous results. The validity of the measurements was assessed by comparing measurements carried out using a caliper directly on the dried bones to those obtained by the Microscribe-3D apparatus.

RESULTS

Reliability of Measurements

Inter and intratester reliabilities were high for all coordinates, ranging from $r = .7$ to $r = .99$, regardless of the measured point (anatomical landmark) and the time interval between measurements. The measurements carried out using the Microscribe 3D apparatus were similar to those obtained using a digital caliper.

Vertebral Body Dimensions and Torg Ratio

Vertebral body length. Regardless of ethnicity, the cervical vertebral bodies, at any vertebral level, are significantly longer in males compared to females.

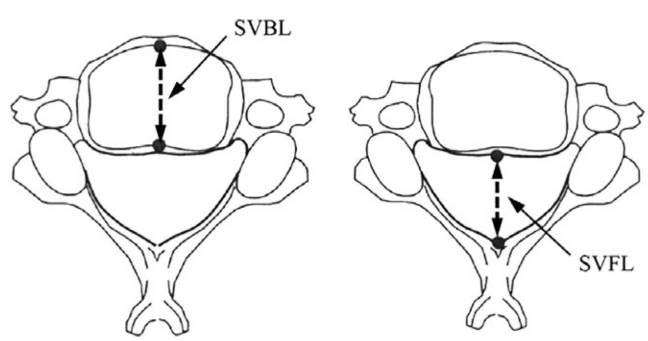

Fig. 1. Illustrations and definitions of the measurements taken in this study: superior vertebral body length (SVBL, left) and superior vertebral foramen length (SVFL, right).

TABLE 2. Superior Vertebral Body Length (SVBL) and Superior Vertebral Foramen Length (SVFL) by Ethnicity and Sex (All Ages Combined)

	All individuals N = 277		African American females N = 69		European American females N = 65		African American males N = 77		European-American males N = 66		Interaction between sex and ethnic group
Vertebra	Mean (mm.)	SD	Mean (mm.)	SD	Mean (mm.)	SD	Mean (mm.)	SD	Mean (mm.)	SD	P
Superior vertebral body length (SVBL)											
C3	13.46	2.32	13.14	1.70	11.72	1.62	15.15	2.18	13.51	2.29	.633
C4	13.91	2.31	13.40	2.18	12.26	1.74	15.22	2.05	14.53	2.08	.356
C5	14.02	2.64	13.71	2.39	12.57	1.91	15.32	2.80	14.23	2.57	.946
C6	14.90	2.90	14.24	2.89	13.93	2.44	15.82	2.78	15.48	3.06	.466
C7	15.30	2.76	14.37	2.69	14.37	2.33	16.30	2.59	16.03	2.84	.729
Superior vertebral foramen length (SVFL)											
C3	14.70	1.83	14.01	1.45	14.78	1.81	14.44	1.75	15.63	1.94	.314
C4	13.98	1.81	13.30	1.88	13.91	1.76	14.23	1.77	14.48	1.63	.390
C5	14.32	1.68	13.58	1.62	14.05	1.49	14.41	1.68	15.25	1.50	.340
C6	14.38	1.76	13.89	1.66	13.93	1.63	14.64	1.58	15.06	1.94	.346
C7	14.59	2.02	14.10	2.26	14.07	1.68	14.66	2.03	15.51	1.71	.162

African Americans have significantly longer cervical vertebral bodies than European Americans (Table 2). For both ethnicities and both sexes, cervical vertebral bodies become longer with age.

Vertebral foramen length. cervical vertebral foramen length is significantly greater in males compared to females. In most vertebrae (C3, C4 and C5) it is significantly greater in European Americans than in African Americans (Table 2). No significant changes in vertebral foramen length with age were found.

Figure 2 demonstrates the changes in vertebral foramen and vertebral body lengths with age, as exemplified in vertebra C6. While the vertebral body length alters significantly with age, the changes in the vertebral foramen are not significant.

Torg ratio. The prevalence of Torg ratio <.80 tends to be greater in males than females, yet this difference is only significant at the level of C3. At the levels of C3–C5, the prevalence of a low Torg ratio is significantly higher in African American individuals than in European Americans (Table 3). Lastly, the prevalence of a low Torg ratio is significantly higher in the old age group at all cervical vertebral levels except C3 (Table 4).

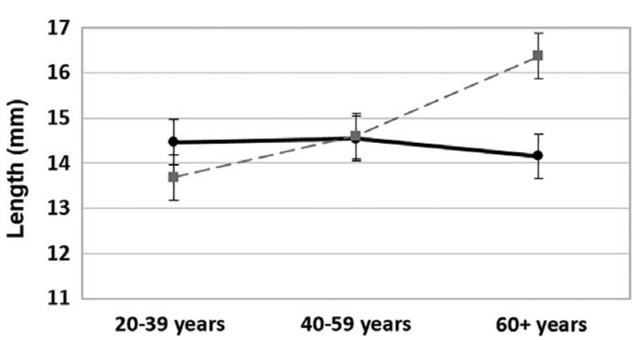

Fig. 2. Superior vertebral body length (gray dashed line) and superior vertebral foramen length (black continuous line) in the C6 vertebra in three age groups.

Tables 5–7 show the mean Torg ratio by sex, ethnic origin and age group. Males manifest significantly smaller mean Torg ratios than females in vertebrae C3 and C4. The mean Torg ratio in African Americans is significantly smaller in all vertebrae except C6 than European Americans (Table 5). Finally, at all cervical levels, the mean Torg ratio is significantly smaller in individuals of the older age group (Table 6). We note that no significant interaction between sex, ethnicity and age was found in regard to the mean Torg ratio (Table 7).

DISCUSSION

Torg Ratio in Relation to Cervical Vertebral Body and Canal Length

The results of this study show that cervical vertebra body length is greater in African Americans compared to European Americans, independent of sex, coinciding with similar findings reported in previous studies (Gupta et al., 1982; Taitz, 1996 Tatarek, 2005). Moreover, in all cervical vertebrae, the anterior–posterior foramen diameter was greater in Europeans Americans compared to African Americans (significant for C3, C4 and C5) independent of sex, supporting previous studies with similar observations (Taitz, 1996; Tatarek, 2005). These two findings suggest that a criterion using a hard cutoff for cervical stenosis (i.e., Torg ratio of <.80) is not applicable to all populations. More so, as the vertebral body's sagittal diameter has already been shown to be age-dependent, mainly due to its anterior expansion with age (Ezra et al., 2017), and no significant differences were found in vertebral foramen length with age (regardless of sex and ethnicity) in the current study (an observation supported by Lee et al., 1994; although see Tanaka, 1984 and Humphreys et al., 1998 for different findings), a Torg ratio criterion for spinal stenosis should also be corrected for age.

TABLE 3. Prevalence of Individuals with Torg Ratio <.80 by Sex and Ethnicity

Vertebra	Males (N = 143)		Females (N = 134)		
	N	(%)	N	(%)	P
C3	21	14.7	8	6.0	**.018**
C4	23	16.1	17	12.7	.421
C5	20	14.0	16	11.9	.613
C6	29	20.3	20	14.9	.243
C7	31	21.7	29	21.6	.994
	African Americans (N = 146)		European Americans (N = 131)		
C3	22	15.1	7	5.3	**.008**
C4	27	18.5	13	9.9	**.043**
C5	28	19.2	8	6.1	**.001**
C6	29	19.9	20	15.3	.317
C7	35	24.0	25	19.1	.424

TABLE 4. Prevalence of Individuals with Torg Ratio <.80 in Three Age Groups: Young (20–39 Years Old), Middle (40–59 Years Old) and Old (Over 60 Years of Age)

Vertebra	Young (N = 90)		Middle (N = 93)		Old (N = 94)		
	N	(%)	N	(%)	N	(%)	P
C3	8	8.9	8	8.6	13	13.8	.424
C4	9	10.0	8	8.6	23	24.5	**.003**
C5	6	6.7	7	7.5	23	24.5	**.0001**
C6	7	7.8	14	15.1	28	29.8	**.0001**
C7	10	11.1	19	20.4	31	33.0	**.001**

Torg Ratio by Sex, Ethnicity and Age

The mean Torg ratio is greater in females than in males (significant for C3–C4), in European Americans compared to African Americans (C6 excluded), and in young individuals compared to old individuals. These findings further emphasize that the cutoff to define a pathological Torg ratio should be established for each subgroup separately.

The vertebrae most prone to spinal stenosis, assuming the definition based on a Torg ratio of <.80, are C6 and C7, regardless of the sex of the individual. Pathological ratios are more common in males compared to females (significant for C3) and in African Americans compared to European Americans (significant for C3–C5). The prevalence of Torg <.80 is significantly higher in older individuals in all vertebrae except C3. This, however, does not necessarily imply a greater risk for spinal stenosis, as the changes is mainly in the sagittal diameter of the vertebral bodies, whereas the diameter of the canal remains constant.

Strengths and Limitations of this Study

The discrepancies in our results compared to previous radiology-based studies (Tanaka, 1984; Humphreys et al., 1998) can be explained in several ways. First, differences in sample size and composition may affect the results of population-based studies. Many radiological studies are based on limited amount of observations and do not include intermediate variables in their analyses, such as sex, age and ethnicity. Secondly, the types of measurements carried out varies as well. We note that our study was

TABLE 5. Mean Torg Ratio by Sex and Ethnicity

Vertebra	Males (N = 143)		Females (N = 134)		
	Mean	SD	Mean	SD	P
C3	1.078	.284	1.188	.291	**.001**
C4	.993	.225	1.102	.279	**.001**
C5	1.041	.268	1.086	.284	.174
C6	.994	.308	1.031	.272	.320
C7	.965	.237	.995	.224	.313
	African Americans (N = 146)		European Americans (N = 131)		
C3	1.031	.216	1.245	.325	**.0001**
C4	.997	.210	1.097	.294	**.0001**
C5	.999	.227	1.134	.280	**.0001**
C6	.988	.240	1.039	.339	.161
C7	.952	.209	1.010	.250	**.041**

TABLE 6. Mean Torg Ratio in Three Age Groups: Young (20–39 Years Old), Middle (40–59 Years Old) and Old (Over 60 Years of Age)

	Young (*N* = 90)		Middle (*N* = 93)		Old (*N* = 94)		
Vertebra	Mean	SD	Mean	SD	Mean	SD	*P*
C3	1.181	.311	1.138	.291	1.077	.267	**.0001**
C4	1.126	.296	1.060	.230	.952	.213	**.0001**
C5	1.142	.226	1.084	.259	.966	.231	**.0001**
C6	1.095	.285	1.035	.297	.910	.263	**.0001**
C7	1.040	.231	1.000	.231	.901	.232	**.0001**

TABLE 7. Mean Torg Ratio by Ethnicity and Sex (All Ages Combined)

	All individuals *N* = 277		African American Females *N* = 69		European American Females *N* = 65		African American Males *N* = 77		European American Males *N* = 66		Interaction between sex and ethnicity
Vertebra	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	*P*
C3	1.131	.292	1.091	.218	1.293	.324	.977	.200	1.198	.321	.781
C4	1.045	.258	1.036	.232	1.171	.308	.963	.183	1.028	.263	.240
C5	1.063	.262	1.028	.245	1.149	.251	.973	.209	1.120	.306	.670
C6	1.012	.291	1.021	.261	1.042	.285	.958	.216	1.035	.877	.424
C7	.979	.231	.977	.197	1.014	.249	.929	.218	1.006	.250	.464

carried out with 3D digitizer directly on dry vertebrae, allowing for accurate measurements of the bony spine. Nevertheless, such as approach does not enable an evaluation of the sclerosis of the ligamentum flavum.

CONCLUSION

In conclusion, the popularity of the Torg ratio as a measure for spinal canal narrowing derives from its simplicity. Nevertheless, this criterion should not be used indiscriminately, as it varies with sex, age and ethnicity.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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