Importance of Intervertebral Disc Size in Low Back Pain

Zmago Turk, Dušan Čelan

Department of Medical Rehabilitation, Maribor Teaching Hospital, Maribor, Slovenia

Aim. To compare two anthropometrical methods for measuring the intervertebral disc size with computer tomography measurements and to develop a new anthropometrical method for calculating intervertebral disc area.

Methods. Intervertebral disc size was measured using computer tomography and two anthropometric methods (Colombini and modified Colombini) in a sample of 40 subjects. The new calculation for intervertebral disc size was developed and used in a sample of male bus drivers with (n=65) and without (n=30) anamnestic low back pain to assess clinical usefulness.

Results. The modified anthropometric method for intervertebral disc size assessment correctly predicted intervertebral disc size in 89% of the cases and the determination error was diminished to an average of 4.1% for level L-5-S-1 and 4.4% for level L-4-L-5. The average size of the intervertebral discs in 65 subjects with anamnestic lower back problems was significantly smaller than in the control group of 30 subjects having no such problems (p<0.001).

Conclusion. The use of the presented formulas for the calculation of the intervertebral disc in L-4-5 and L-5-S-1 areas from the data obtained by simple anthropometrical measurements is sufficiently reliable and accurate. The method is economical and harmless.

Key words: anthropometry; intervertebral disc; low back pain; measurement; occurrence; tomography, X-ray computed

One of the most common human problems – low back pain – has numerous causes, which can be exogenous and endogenous. Among endogenous causes, a potentially interesting area of research, involves the dimensions of spinal structures especially the intervertebral discs, whose degenerative changes are largely related to the origin of the problems.

In scientific literature, the anthropometric method of indirect calculation of disc size is not frequently mentioned (1-3). The anthropometric method of Colombini (1) involves anthropologic measurement of the intervertebral disc size using indirect methods for measuring individual parts of the body, which correlate with the intervertebral disc size. Prior to Colombini, only few similar studies are found in medical literature. Gilad and Nissan (4) assessed the geometric values of anthropometric dimensions of intervertebral and vertebral parameters. Schultz and Andersson (3) assessed the correlation between the disc size and the perfusion and nutrition of this region. Using computer tomography, Natarajan and Andersson (5) formed a three-dimensional model of the dynamic segment and thus calculated intervertebral disc size. They found that an endplate with insufficient blood supply was the basic cause of the occurrence of the degenerative process. Discreet peripheral fissures of the annulus fibrosus also accelerated the degenerative process.

The first anthropometric measurements were carried out by Matiegcka (6) as early as 1921. He drew up the first formula of anthropometric measurements, which was later used also by Colombini (1). In recent years, several important studies on the size of dynamic segment of vertebrae and intervertebral disc size were done by means of magnetic resonance imaging (7-10).

There are at least 4 basic methods used for measuring intervertebral disc size: the x-ray method, area measurement by computer tomography (6,11), nuclear magnetic resonance (7), and the anthropometric method (1).

In the x-ray method, the intervertebral disc surface is calculated from normal radiographs obtained by basic functional imaging of the lumbar spine, using the formula for the area of an ellipse (2,10,12). However, the method is not precise, particularly due to different radiology units and imaging methods, the distance of x-ray tubes, type of films, and various other circumstances (12).

With computer tomography we can calculate the area of the same segment by means of the geometric formula for an ellipse. Here the intervertebral disc shape is somewhat simplified as the lumbar intervertebral disc itself is not a perfect ellipse (10,12). Measuring the intervertebral disc area by the direct com-
puter tomography method is called the “region of interest” method. It is a direct method and can only be applied in accordance with this software option (12-14).

The same is true for the nuclear magnetic resonance examination, which is a slightly better method for the presentation of soft structures. From the practical point of view, the main negative characteristic of this examination is its availability.

A number of advanced examination methods exist to define the size of the intervertebral disc but these are costly, not easily available, and often harmful to health. All radiological investigations, computer tomography (11-14) as well as plain radiography (11,15), have a harmful effect on the human organism. As the anthropometric method according to Colombini is a completely non-aggressive method, we wished to establish whether it was sufficiently accurate to be used for measuring intervertebral disc size. By using this method we wanted to confirm the hypothesis that intervertebral disc size affects the incidence of lumbar syndrome – the most common disease of the locomotor system (16,17).

Our study aimed to identify the validity of the following working hypotheses: 1) indirect determination of the area of the intervertebral discs L4-5 in L5-S1 by using anthropometrical measurements is sufficiently accurate; and 2) subjects with problems in the lower back also differ from the control group by the size of the area of the discs L4-5 in L5-S1.

Subjects and Methods

Subjects
The study was performed on 2 groups of subjects. At the first stage of the research, we compared the method of anthropometric determination of the area of the intervertebral discs L4-5 in L5-S1 by direct measurement with the computer tomography “region of interest” method, in 40 patients, all of them treated for lumbar syndrome at the Medical Rehabilitation Department of Maribor Teaching Hospital at the time of the study (between 1996 and 2000). The research included those patients who, owing to the nature of their illness, needed a diagnostic examination with computer tomography. These patients were not additionally exposed to harmful radiation for the sake of the research, and had been previously informed about their participation in the research and gave their consent. The group of 40 consecutive patients was made up of 19 men and 21 women. Their median age was 44 years (range 22-66). The median duration of lumbar syndrome was 6 years (range 1-40). The calculated median age at the onset of the lumbar syndrome was 35 years (range 15-57).

To confirm the second working hypothesis, we included 95 subjects. To reduce the variability of sample we decided to include only male subjects who suffered from similar stress at their working place – they were all bus drivers in urban and suburban transport employed at the Maribor’s public transport company “Certus.” The selection from the entire population of 300 bus drivers employed by “Certus” was made by an independent personnel officer who was not informed about low back pain troubles of subjects. He randomly chose available subjects who were willing to come to the examinations and measurements. Their median age was 41 years (range 25-54).

Methods

The original Colombini formulas (1) to calculate the area of the intervertebral discs (IVD) L4-5 and L5-S1 are as follows:

\[
\text{area IVD L4-5} = 0.0019 \times \text{SW} + 2.7 \text{ (cm^2)},
\]

\[
\text{area IVD L5-S1} = 0.0017 \times \text{SW} + 2.57 \text{ (cm^2)},
\]

where SW is bony structure weight

\[
\text{SW} = \text{AST} \times \text{h} \times 1.1 \text{ (cm^3)},
\]

where h – body height (cm) and

\[
\text{AST} = \frac{a + b + c + d}{4} \text{ (cm^2)},
\]

where a – wrist, b – elbow, c – knee, d – ankle joint diameters (cm).

Asterisk indicates original error in the Colombini formula – measurements of the surface size are expressed in cm² instead of cm³.

In computer tomography examinations, the “region of interest” method served as a reference method for measuring the area of the disc, because this software program can accurately determine the size of the surrounded area on the image of the disc cross-section.

The measurements were performed on L4-L5 (intervertebral disc between lumbal vertebra 4 and lumbal vertebra 5) and L5-S1 (disc between lumbal vertebra 5 and sacral vertebra 1).

In the second part of the study, 95 subjects were examined. They answered a specific question regarding their past problems with lower back (“Have you ever had low back pain in your life?”), which was followed by anthropometric measurements. Based on the presence of low back pain, two groups of bus drivers were formed: participants with the anamnesis of low back pain (n=65, 68.4%) and control group participants who have never had low back pain (n=30, 31.6%).

Data Analysis

Student t-test, linear correlation, and Lin’s concordance correlation coefficient were used to compare Colombini and our formula with the computer tomography “region of interest” method, as a reference method. Bland and Altman plot was used for graphical presentation (18). The influence of each anthropometric parameter on the calculated area of IVD was assessed using Pearson correlation coefficient. Formula correction was done using Cronbach’s α coefficient. The IVD area between the groups with and without low back pain problems was compared using a Student t-test. All data were analyzed with SPSS statistical package program version 8.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Comparison between CT “Region of Interest” Method and Colombini Formula

The data showed normal distribution, so that parametric tests were used for comparison. Linear correlation comparison showed good correlation for measurements on both levels with the following results: IVD L4-L5: \( r = 0.891, p < 0.001 \); IVD L5-S1: \( r = 0.879, p < 0.001 \). However, there were statistically significant differences between the two measurements (\( p < 0.001 \)) (Table 1). In addition, Bland and Altman plot showed a negative difference between computer tomography “region of interest” method and Colombini method, indicating higher values for the size of the intervertebral disc when using Colombini method. The average difference for IVD L4-L5 was

<table>
<thead>
<tr>
<th>Intervertebral disc (cm²)</th>
<th>CT ROI</th>
<th>Colombini</th>
<th>Absolute difference (cm²)</th>
<th>Relative difference (%)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>L4-L5</td>
<td>17.96±2.40</td>
<td>22.02±2.98</td>
<td>4.05±1.40</td>
<td>22.74±7.1</td>
<td>-18.36</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L5-S1</td>
<td>16.88±2.06</td>
<td>19.85±2.66</td>
<td>2.97±1.32</td>
<td>17.6±7.2</td>
<td>-14.21</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Framed-test.
4.05 cm² and for IVD L5-S1 2.97 cm² (Fig. 1). The comparison of both methods using Lin’s concordance correlation coefficient suggested only moderate correlation between the two methods (IVD L4-L5/c114c = 0.4072; IVD L5-S1/c114c = 0.4745).

The analysis showed that the values of anthropometrical areas were greater than those from computer tomography in all patients and that the difference included some constant values. Thus, the indirect assessment of intervertebral disc area proved to be reliable, but the real intervertebral disc areas of the sample were somewhat smaller than in the study by Colombini et al (1). Assuming that both values of disc areas, anthropometrical and computer tomography, were consistent but that there was a constant difference which systematically augmented anthropometrical values, we decided to use linear regression to get the proper curve fitting.

Modified Formula for Calculating Intervertebral Disc Area

Individual anthropometric parameters of Colombini were compared with the computer tomography “region of interest” reference method. Colombini considered body height and the diameters of the right wrist, elbow, knee, and ankle as anthropometric parameters.

There are 5 elements in basic Colombini formula (1) and theoretically 4 of them – the diameter of elbow, wrist, knee, and ankle – should have an absolutely equal influence on or association with the intervertebral disc size. A survey of Pearson correlation coefficients between individual elements for the calculation of the anthropometric area of both intervertebral discs and their actual areas according to the computer tomography method (Table 2) showed that the diameter of the ankle had a relatively lower correlation than the other measurements.

It is not sufficient for the elements to be in high correlation to compose a consistent measure, as they may correlate in completely different space and time. They must, however, correlate congruently. A spurious correlation may arise from the failure to control either of the confounding relationships (19). We assumed that the items on the scale had to be positively correlated with each other as well because they measured a common entity.

Table 2. Correlation between the area of intervertebral discs (IVD) L4-L5/L5-S1 determined by computer tomography “region of interest” method and anthropometric parameters

<table>
<thead>
<tr>
<th>Anthropometric parameters</th>
<th>Area of IVD L4-L5</th>
<th>Area of IVD L5-S1</th>
<th>correlation p</th>
<th>correlation p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body height</td>
<td>0.742</td>
<td>0.670</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body weight</td>
<td>0.497</td>
<td>0.371</td>
<td>&lt;0.001</td>
<td>0.019</td>
</tr>
<tr>
<td>Wrist circumference</td>
<td>0.679</td>
<td>0.643</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Wrist diameter</td>
<td>0.761</td>
<td>0.754</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Elbow diameter</td>
<td>0.818</td>
<td>0.730</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Knee diameter</td>
<td>0.713</td>
<td>0.689</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ankle diameter</td>
<td>0.547</td>
<td>0.526</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Cronbach’s alpha indicates the extent of reliability between the items, following the assumption that they measure a single uni-dimensional latent construct. The alpha of a scale should be greater than 0.70 for the items to be used together as a scale (20). The alpha for the total scale may also be computed assuming that the item under examination is deleted. If the alpha increases over the current total alpha scale when an item is deleted, then the rule of thumb is to delete the item unless it is theoretically necessary for the analysis. Individual items on Colombini’s scale lowered the reliability of the scale. The first Colombini’s scale showed an alpha of 0.30. Recalculated for our sample, 2 items (body height and ankle diameter) were not correlated to the other measurement so that summarizing the items would not be appropriate. After eliminating these 2 from the measure, the reliability of the scale increased to 0.84. The presumption that it sufficed to take 2 elements less into account...
proved to be well grounded. By decreasing the elements in Average Square Thickness (see original Colombini’s formula), the new formula even gained in correlation with reference measurements of areas on computer tomography.

We excluded calculating bony structure weight from the original Colombini’s formula and thus shortened Colombini’s original formula.

The new ASTTURK was calculated according to the formula:

$$\text{ASTTURK} = \left(\frac{a+b+c}{3}\right)^2 \text{ (cm}^2\text{)}$$

where a, b, c are diameters of 3 large joints: elbow, wrist, and knee, measured in cm.

The adequacy of the newly composed measure was tested on the basis of known areas in 40 subjects.

The results of the mathematical calculations which took into consideration the best possible correlation between the obtained values and the area of the intervertebral disc (IVD) measured by computer tomography “region of interest” gave the following formulas for calculating the disc areas:

- Area of IVD L4-L5 = 0.29 × ASTTURK + 2.11 (cm²)
- Area of IVD L5-S1 = 0.25 × ASTTURK + 3.55 (cm²)

The units for measuring surface are now accurate (cm²).

Comparison between CT “Region of Interest” and Turk Formula

Since the data showed normal distribution parametric tests were used for comparison. Linear correlation comparison showed good correlation for measurements on both levels with the following results: IVD L4-L5: r = 0.891, p < 0.001; IVD L5-S1: r = 0.879, p < 0.001. On the other hand, when using a Student t-test, there was no statistically significant difference between these two measurement tools (p > 0.05) (Table 3).

Bland and Altman plot of computer tomography “region of interest” method, and Turk method indicated good agreement, with a higher accuracy in the area of small intervertebral disc as compared to the larger areas of the intervertebral disc – the average difference was smaller than 0.01 cm² for both IVD levels (Fig. 2). Percentage presentation showed that 95% of all values collected using the Turk method differed from the mean of both methods for less than 11% (Fig. 3). Comparison using Lin’s concordance correlation coefficient indicated excellent agreement between these two methods (IVD L4-L5: ρc = 0.8854; IVD L5-S1: ρc = 0.8718).

Testing New Formula on Human Subjects

In the second part of the research we analyzed the sizes of the observed intervertebral discs in a sample of 95 subjects.

The individuals without low back pain complaints had significantly bigger intervertebral disc

| Table 3. Intervertebral disc L4-L5 and L5-S1 area determination differences (mean ± standard deviation) between computer tomography “region of interest” (CT ROI) measurement and Turk calculation |
|-----------------|-------------|-----------------|-----------------|-----------------|-----------------|
| Intervertebral disc (cm²) | CT ROI | Turk | Absolute difference (cm²) | Relative difference (%) | t* | p |
| L4-L5 | 17.96±2.40 | 17.96±2.67 | 0.76±0.77 | 4.1±3.7 | 0.004 | 0.997 |
| L5-S1 | 16.88±2.06 | 16.87±2.43 | 0.75±0.62 | 4.4±3.3 | 0.081 | 0.936 |

*Paired t-test.
the basis of high correlation coefficients, but not sufficiently precise: it gave larger values: 22.7% at L4-L5 and 17.6% at L5-S1 than computer tomography measurements. For this reason we revised Colombini’s formulas to find a possibility to correct the precision of the calculation. We made a graphic comparison of the distribution of the areas measured by the anthropometric and reference methods and found that it was possible to make adjustments for the anthropometric calculation of the areas, which would be closer to the actual areas measured with the computer tomography ‘region of interest’ method. With the reliability test for two scale compositions, we established that the elements of ankle diameter and height had a lower correlation than the other factors. By exclusion of these two elements, the new Average Square Thickness formula gained in correlation with reference measurements of the areas on computer tomography. Thus the original Colombini formula was shortened, practically meaning that fewer anthropometric measurements were performed. In contrast to Gilad and Nissan (4) who calculated and measured intervertebral disc size on a survey radiograph, compared it with the anthropometric characteristics of the subject (height, weight), and found no significant correlation; we found good correlation for several anthropometric parameters. The results of our study confirmed Scoles et al (21) cadaver measurements of vertebral sizes, which established that the segment between vertebrae 4 and 5 was the largest in the lumbar spine.

Comparison of mean values between our method and computer tomography “region of interest” method showed an average of 4% differences (4.1% for IVD L4-L5 and 4.4% for IVD L5-S1). On the other hand, statistical analysis, using Bland and Altman plot, showed that 95% of all values collected using Turk method differed from the mean of both methods for less than 11%, indicating that using Turk method for measuring the size of the intervertebral disc is clinically acceptable. The new formulas were considered a reliable substitution for the costly and potentially harmful computer tomography investigation.

These new formulas were used in further investigation of low back pain. The second part of our study, performed on a limited sample of male respondents with similar work load, showed that subjects with anamnestic problems in the lower back had statistically significant smaller areas of intervertebral disc L4-L5 and L5-S1 than subjects having no such problems. This finding supports the study of Eriksson et al (12) who compared the incidence of lumbar syndrome with anthropologic parameters of athletes, attempting to find a connection between intervertebral

**Table 4.** Mean and standard deviation values of intervertebral disc L4-L5 and L5-S1 areas in a group of 65 subjects with anamnesis of low back pain (LBP group) and group of 30 subjects without these troubles (control group)

<table>
<thead>
<tr>
<th>Intervertebral disc (cm²)</th>
<th>LBP group</th>
<th>Control group</th>
<th>t*</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>L4-L5</td>
<td>18.59±1.38</td>
<td>20.79±1.95</td>
<td>-6.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L5-S1</td>
<td>17.40±1.17</td>
<td>19.26±1.65</td>
<td>-6.31</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Paired t-test.

Discussion

The method for determining disc size must be scientifically reliable and it should not be harmful or too costly.

When we compared the values of intervertebral disc areas obtained by computer tomography “region of interest” method with the anthropometric method and formulas suggested by Colombini et al (1), the method proved to be fairly reliable, particularly on

![Corrected Bland and Altman plot – comparison of Turk and computer tomography “region of interest” (CT ROI) method in the size of the intervertebral disc area (IVD) L4-L5 (A) and L5-S1 (B) (ordinate axis: percentage of the differences; units: mm²). Percentage presentation of both figures showed that 95% of all values collected using the Turk method differed from the mean of both methods for less than 11%, for both measured intervertebral disc areas.](image)
disc size and low back pain. They realized that the incidence of lumbar syndrome was lower in corpulent athletes. Body weight did not affect the incidence of pain. A study by Boots et al (8-10) found that the discs with degenerative changes had a statistically significantly smaller area, particularly a smaller volume which is in agreement with our findings. The most common assumption is that the size of the intervertebral disc represents one of the risk factors for the occurrence of lower back pain (22).

One of the questions asked in this study was whether intervertebral disc size affected the occurrence of lumbar syndrome. From the biomechanical point of view, if an intervertebral disc with a smaller area is exposed to movement and forces, the pressure on each cm² of disc is higher and disc degeneration can be expect sooner than usual (10).

In conclusion, the proposed formulas for determining disc size could be used as a preventive measure in all cases in which the overloading of the lumbar and sacral spine is expected (children, sportsmen, manual workers, and soldiers). The method is non-aggressive, absolutely harmless, and very economical. Anthropometric measurement may be important, because our study had identified the link between the size of the area of the intervertebral discs L4-L5 and L5-S1 and the presence of problems with the lower back in a sample of subjects. Further epidemiological research on a larger scale is needed to confirm this relation.

References