Abdominal wall deformities are very frequent and can be due to congenital or acquired etiology. Rectus abdominis diastasis occurs due to many factors that weaken the abdominal wall. The causes described in the etiopathogenesis of the phenomenon can be divided into congenital and/or acquired.

Major risk factors for the development of acquired rectus diastasis include conditions that increase intra-abdominal wall pressure such as obesity, pregnancy, abdominal surgeries and connective tissue disorders.

Large abdominal wall deformities and defects may be associated with problems such as low back pain, breathing disorders and also misperception of body image. Congenital defects are also associated with abdominal wall muscles hypoplasia as described in Cantrell’s pentalogy (thoracoabdominal syndrome), Beckwith-Wiedemann syndrome, Opitz syndrome, midline defect syndrome and plum belly syndrome; however, those require a complex abdominal wall reconstruction.

Excessive separation of the abdominal muscles may compromise the function of the abdominal wall and is noticed when the patient sits up during clinical examination. When a patient with rectus diastasis lifts his head and starts to sit, a fusiform bulging appears in the midline from the xiphoid to the umbilicus or pubis. This can also be confirmed with the Valsalva’s maneuver.

One of the most frequent deformities is the rectus abdominis diastasis after pregnancy, and treatment is performed by abdominoplasty, and the correction of the rectus diastasis is an important step of the procedure.
Although there is no specific definition, some authors define rectus muscle diastasis, when the distance between the medial aspect of the rectus muscle (the width of the linea alba) is greater than 2 cm.\cite{4,9} However, it is not a consensus because there is no objective data to define this value. Therefore, the aim of the present study is to evaluate the width of the linea alba in cadavers with no abdominal wall defects, in order to determine which measurements could be considered as normal.

**Materials and Methods**

After obtaining the informed consent from the relatives, fifty-three fresh adult cadavers were dissected at room temperature (22–25°C) at the Legal Medical Institute. Male cadavers were selected, regardless of race. Anthropometric data were recorded. Cadaver was placed supine and a xipho-pubic incision was made, including skin and subcutaneous, surrounding the umbilicus, down to fascia. A suprafascial undermining was performed, exposing the anterior lateral abdominal muscles (Figure 1).

The separation between the recti abdominis muscles was marked. Two reference levels were marked 3 cm superior (supraumbilical level) and 2 cm inferior (infraumbilical level) to umbilicus for to measure the distance between the medial aspect of the muscles.\cite{5} Measurements were performed with a digital pachymeter, by two examiners, and the mean value between them was considered. General data of the sample was displayed in the Table 1.

The width of the left rectus muscle was compared with the right side. The width of the linea alba obtained at the supraumbilical level was also compared to the infraumbilical pre-marked levels.

The t-test for two independent means was applied for statistical test, considering as significant where the considered p-value was less than 5%.

**Results**

The normality analysis of the sample revealed no significant variations. The length of the linea alba and rectus abdominis muscles were similar, with an average of 33.02 cm.

The mean value of the width of the right rectus muscle was 7.37 cm whereas the left was 6.84 cm. Although the right muscle was wider than the left when the values were compared, there was no statistically significant difference (p=0.479) (Figure 2).

The mean width of the linea alba was 2.17 cm at the supraumbilical level and 1.51 cm at the infraumbilical level. A statistically significant difference was found when these values were compared, demonstrating that the linea alba is wider at the supraumbilical level (p=0.034) (Figure 3).

**Discussion**

Rectus diastasis is a common deformity that may lead to an increase in the overall anterior projection of the abdominal wall, mainly observed at the profile position.\cite{9} This anatomic deformity can contribute to postural changes and low back pain, secondary to the alteration of the corporal gravity axis. It usually occurs due to weight variation, age, congenital condition and pregnancy.\cite{11,12}

Correction of this deformity is considered as an important step during abdominoplasty and lipoabdominoplasty.\cite{13} A special attention should be taken in the preoperative evaluation of the abdominal wall integrity when performing lipoabdominoplasty because of the risk of intestinal perforation during liposuction. Small hernias of 1 or 2 mm diameter may be found in the area of diastasis, especially in the supraumbilical area, what may facilitate the risk of cannula insertion in the abdominal cavity during liposuction.\cite{2}

The definition of rectus diastasis is quite heterogeneous and varies from any distance between the recti mus-

<table>
<thead>
<tr>
<th>Anthropometric data</th>
<th>Cadavers (n=53)</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>42.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.06</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.68</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.55</td>
</tr>
<tr>
<td>XP (cm)</td>
<td>33.02</td>
</tr>
<tr>
<td>CC (cm)</td>
<td>26.80</td>
</tr>
</tbody>
</table>

BMI: Body mass index; CC: distance between the iliac crests; XP: xiphopubic distance.

![Figure 1. Exposure of the anterior lateral abdominal muscles.](image1)

![Figure 2. (a) Comparative view between the right and left rectus muscles.](image2)

![Figure 3. Comparative view of the linea alba at the supraumbilical and infraumbilical levels.](image3)

![Table 1](table1)
Figure 2. Rectus abdominis muscle width on both sides (cm).

Figure 3. Comparison between the width of the linea alba at the supra and infraumbilical levels.
cles\cite{2} to values greater than 1–3 cm above the umbilicus, and 1–1.5 cm below the umbilicus.\cite{3,4,6,9} Therefore, there is no well-defined pattern to determine what is a normal or abnormal width between recti muscles. There is not a reference that defines rectus diastasis. In this way the diagnosis of diastasis is usually made by the experience of the professional who examines. Therefore, despite the use of ultrasound\cite{4} or computerized tomography,\cite{6} which requires a relative learning curve.

The use of cadavers to evaluate the abdominal wall is well established in the literature.\cite{5} In most studies that described and evaluated rectus diastasis, patients were not homogeneous, adding some bias to the study, such as previous pregnancy, especially because of the almost totality of the evaluated sample was female gender.\cite{1,2,3,6,9} Pregnancy may expand the abdominal wall as a whole or more specifically in the area of the linea alba, thus promoting diastasis. Diastasis secondary to pregnancy will depend on the individual’s genetic condition and weight gain. Rodrigues et al.\cite{4} has shown that an increase in intraabdominal pressure after plication of the anterior rectus sheath is not directly related to the width of diastasis. This study demonstrated that the genetic structure of the aponeurosis is more important than the rectus diastasis itself when competency of the abdominal wall is considered. The width of the diastasis of the rectus is probably due to the loosening of the aponeurosis and, in this case, the patient will have a less intense impact on intra-abdominal pressure after the plication of the anterior rectus sheath. In the present study, the authors have chosen to evaluate only male cadavers, with normal BMI and without abdominal scars or other alteration/abnormality in the abdominal wall. This aspect was considered precisely to avoid bias in relation to the female gender due to the possibility of previous pregnancies.

The use of a paquimeter/caliper for this kind of study is well described in the literature,\cite{2,3} with measurements taken by two observers. The average values of the width of the rectus abdominis muscles were 7.37 cm on the right and 6.64 cm on the left side did not show statistically significant difference when compared. Despite this little difference was found, no information about this tendency was found in the literature review. However, it is possible that it has a direct correlation with congenital or acquired asymmetries that can occur due to postural vices observed in the clinical practice. It may also be related to the fact that the majority of the specimens are right-handed, who use most of the time the right side of the body when doing movements, with a consequent hypertrophy of the right rectus muscle.

Corvino et al.\cite{15} evaluated rectus diastasis in 92 women by ultrasound and found rectus diastasis in 82 patients; from these, 5 were nulliparous. The authors proposed a classification of rectus diastasis in five patterns when the most frequent (59%) was Type 1 (rectus diastasis above the umbilicus). In the present study, comparisons of the mean distances between the medial margins of the rectus muscles at the supra and infraumbilical levels, showed statistically significant difference, with greater values at the supraumbilical area, similarly to the Type 1 pattern. These data did not corroborate to the findings presented by Mendes et al.\cite{2} who compared rectus diastasis by measuring preoperative and intraoperative values by ultrasound and found no statistical difference between the supra and infraumbilical levels. Similarly, Rett et al.\cite{10} evaluated rectus diastasis in primiparous and multiparous women, by clinical exam (palpation) and the use of a paquimeter. They did not find significant differences between supra and infraumbilical levels. It is well known that the increase of the intra-abdominal pressure during pregnancy may promote a distension of the linea alba and even affect the integrity of the abdominal wall. However, despite these changes on the structure of the abdominal muscles during pregnancy, they still maintain their function.\cite{15} This fact could explain the findings of the present study (using male cadavers) and others that evaluated women with previous history of pregnancy.

This research evaluated male cadavers, without age and biotypes restriction, making the results relevant and useful in clinical practice on different areas such as plastic surgery, general surgery and physical therapy. It was also demonstrated the importance of the normal anatomy of the rectus abdominis muscle and linea alba, making the diagnosis of diastasis and myoaponeurotic distension in male patients easier. This study has some limitations, as cadaver is not a dynamic model. Although the number of studied specimens (n=53) was large, a greater sample might be necessary in order to determine the normal separation between the recti muscles. In the same way, a more representative group with different genders, ages, and ethnicity would be interesting to determine the range of values of the width of the linea alba to be considered as normal.

Conclusion

The width of the linea alba in male cadavers is significantly wider at the supraumbilical level as compared to the infraumbilical level. The right rectus abdominis muscle has shown to be wider than the left one.
Acknowledgments
The authors would like to express their sincere gratitude to the donors and their families.

Conflict of Interest
The authors declare that they have no conflict of interest.

Author Contributions
MVJB: conceptualization, methodology, formal analysis and investigation, writing manuscript, review and editing, supervision; AdLD: writing manuscript, review and editing; IB: writing manuscript, review and editing; IPBJ: writing manuscript, review and editing; FXN: conceptualization, methodology; LMF: conceptualization, formal analysis and investigation. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics Approval
This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board (number 084-13).

Funding
There were no external funding bodies involved in this investigation.

References

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Conflict of interest statement: No conflicts declared.

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