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ORIGINAL ARTICLE

Evaluation of rectus abdominis muscle strength and width of hernia defect in patients undergoing incisional hernia surgery

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Abstract

Background The aim of this study was to analyze the strength status of the rectus abdominis muscle in patients with incisional hernia and the relationship between the width of the hernia defect and the strength of the rectus abdominis muscle.

Methods This is a observational cohort study of patients with medial line incisional hernia (July–October 2022), classified as W2 according to the European Hernia Society (EHS). The data collected were demographic and clinical characteristics related to hernia, and measure of the rectus abdominis muscle strength using an isokinetic dynamometer and a strain gauge. We analyzed the relationship between hernia width and rectus abdominis muscle strength with correlation tests to adjustment by age, sex, BMI, and body composition.

Results A total of 40 patients (64% female) with a mean age of 57.62 years (SD 11) were enrolled in the study. The mean BMI was 29.18 (SD 5.06), with a mean percentage of fat mass of 37.8% (SD 8.47) and a mean percentage of muscle mass of 60.33% (SD 6.43). The maximum width of the hernia defect was 6.59 cm (SD 1.54). In the male group, the mean bending force moment (ISOK_PT) was 94.01 Nw m (SD 34.58), bending force moment relative to body weight (ISOK_PT_Weight) was 103.32 Nw m (SD 37.48), and peak force (PK_90) was 184.71 N (SD 47.01). In the female group, these values were 58.11 Nw m (SD 29.41), 66.48 Nw m (SD 32.44), and 152.50 N (SD 48.49), respectively. Statistically significant differences were observed in the relationship between the data obtained with the isokinetic dynamometer and sex ($p=0.002$), as well as between the data obtained with the isokinetic dynamometer and age ($p=0.006$). Patients in the 90th percentile (P90) of rectus abdominis muscle strength also had smaller hernia defect widths ($p=0.048$).

Conclusions In this study, age and sex were identified as the most statistically significant predictor variables for rectus abdominis muscle strength. The width of the hernia defect exhibited a trend towards statistical significance.

Keywords Isokinetic dynamometer · Strain gauge · Incisional hernia · Surgery · Rectus abdominis muscle strength

Introduction

Incisional hernia (IH) is a common condition worldwide. Its overall incidence is heterogeneous, although some publications report an overall incidence of IH up to 10% to 15% in patients with previous abdominal surgery [1]. Published rates of incidence in the literature have varied depending on the specific population they individually reference. This could be due to the existence of different surgical techniques for abdominal wall closure, different approaches (laparotomy vs. laparoscopy) and variability in comorbidities among patients [2]. However, some of the latest meta-analysis found that the rate of IH occurrence 2 years after the first surgery to be 12.8% (95% confidence interval [11.4;14.2]) [3]. When comparing laparoscopic and open surgery, IH incidence decreases from 10.1% to 4.3% in the first group [4].

Regarding surgical repair of this common condition, the best method of surgical repair for both preventing and treating incisional hernia has not been demonstrated and remains a common problem for surgeons throughout recent years.

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In this regard, the main goal and outcomes, measured and compared, have been the recurrence rates and comorbidity associated with the technique [2, 5–7]. In terms of functional outcomes, the effect of IH surgical repair on abdominal wall muscle function is unknown and the evidence in the literature is scarce. Only a few reports considered functional aspects of IH repair, and those methods varied from clinical examinations to quality of life (QoL) assessment scales, and specific instruments, such as dynamometers.

With respect to abdominal wall muscle function, some authors have reported on evaluation of the force that is generated by the contraction of the abdominal muscles. Previous studies have shown the importance of the mentioned muscular strength as a predictor of sport performance, functional capacity, and QoL [8–10]. In this regard, muscular strength has been evaluated with different tools such as a force platform, a hand-handle dynamometer and an isokinetic dynamometer [11–13]. The isokinetic dynamometer has been considered the gold standard for evaluating muscle strength, due to its ability to assess muscle function in different variables such as torque, power, and muscle endurance [14–16]. The validity and reliability of the isokinetic dynamometer have been reported in different muscle groups, such as knee extensors, hip flexors and trunk muscles [15–19]. However, the isokinetic dynamometer presents some limitations: expensive costs and difficult accessibility to use with routine patients in clinical practice.

An alternative to the isokinetic dynamometer is the strain gauge, which is a low-cost and portable device. Various studies have used this method to assess different body muscles, for example, Needle et al. [20] used the strain gauge to measure the strength and stiffness in the plantar flexors of the ankle. Moreover, different conditions have also been assessed with this device. Machado Rodrigues et al. [21] reported the validity and reliability of the strain gauge to assess the strength of the quadriceps in patients with chronic obstructive pulmonary disease (COPD). However, to our knowledge, no study has used a strain gauge in patients with hernias. Therefore, the aim of our study was to analyze the strength of the rectus abdominis muscle in patients with incisional hernia and its relation with the width of the hernia defect.

Methods

An observational prospective study was performed, including a cohort of patients with incisional hernia (July–October 2022). The study population was recruited from the outpatient clinic (tertiary care hospital). All patients signed a specific informed consent form for participation in this research study, prior to assessment of abdominal wall function. Criteria for inclusion were: the diagnosis of IH of the midline, classified as W2 according to the European Hernia Society (EHS) classification (maximum hernia diameter between 4 and 10 cm), American Society of Anaesthesiologists score less than IV and patients undergoing hernia repair surgery at our Hospital.

Criteria for exclusion were: a diagnosis of IH classified as W1 or W3 according to the EHS (maximum hernia diameter less than 4 cm or more than 10 cm, respectively), lateral hernias and refusal to participate in the study.

Demographic and clinical characteristics such as age, sex, height, weight, BMI, body composition, and width of the hernia defect were collected. Body composition was calculated performing bioelectrical impedance analysis. Measurements for diagnosis and width of hernia defect were based on computed tomography (CT) imaging in all patients, and a radiological report was performed by a consultant radiologist.

The primary outcome was to assess the strength of the rectus abdominis muscle strength and to analyze its relationship with the clinical characteristics of the patients. To measure the strength of the abdominal wall, we used both an isokinetic dynamometer and a strain gauge.

Isokinetic dynamometer (Biodex System 4; Biodex Medical Systems. Shirley, NY: Biodex Corp®) (Fig. 1) and strain gauge (Chronojump. Barcelona, Spain: Boscosystem®)

Fig. 1 Patient's setting when measuring the rectus abdominis muscle strength using the isokinetic dynamometer (Biodex System 4; Biodex Medical Systems. Shirley, NY: Biodex Corp®)

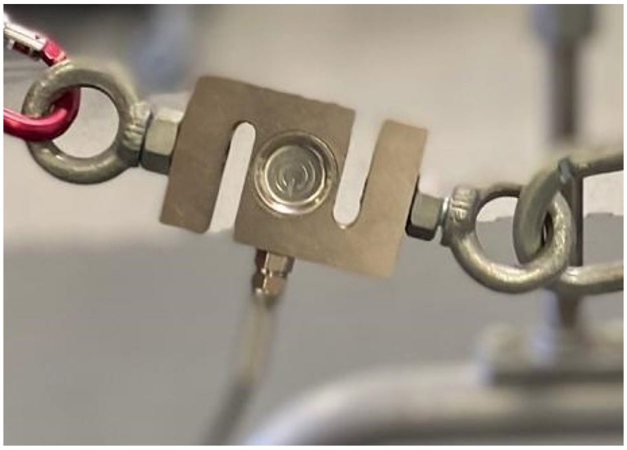

Fig. 2 Strain gauge (Chronojump. Barcelona, Spain: Boscosystem®)

Fig. 3 Patient's setting when measuring the rectus abdominis muscle strength using the strain gauge (Chronojump. Barcelona, Spain: Boscosystem®)

(Figs. 2, 3) were used to assess isometric rectus abdominis muscle strength.

Using the isokinetic dynamometer, each patient assumed a seated position with a hip-trunk angle of 90° and was secured with shoulder straps. Prior to testing, the range of motion for trunk flexion and extension was assessed for each participant. Three successive maximal isometric contractions, each lasting 5 s, were executed, with an inter-repetition rest period of 30 s.

For the strain gauge assessment, patients were seated with a hip-trunk angle of 90°, and a chest harness was applied. The strain gauge was affixed to the back of the harness. Similarly, to the isokinetic dynamometer protocol, three maximal isometric contractions, each spanning 5 s, were performed, with a 30-s rest period between repetitions. The positioning employed during testing with both devices effectively mitigated the contribution of the lateral abdominal wall muscles, thereby minimizing their impact on the recorded data.

Before initiating the tests, participants received instructions to rapidly flex their trunk and maintain the contraction while refraining from neck flexion. Verbal encouragement was consistently provided throughout the entire duration of the test to ensure maximal effort on the part of the participants.

After the test, data are processed by a software, concluding in these parameters: with the isokinetic dynamometer data recorded were bending force moment (ISOK_PT) and bending force moment relative to body weight (ISOK_PT_Weight) (Fig. 4). Data recorded with the strain gauge was the peak of force achieved (PK_90) (Fig. 5).

For statistical analysis, the qualitative variables were summarized as frequencies and proportions. The quantitative variables were summarized as their mean and standard deviation (SD), and variables that did not follow a normal distribution were expressed as the median and interquartile range (IQR). The Chi-square test or Fisher's exact test were used to determine the differences between categorical variables; the Student's t test or the ANOVA test were used to evaluate the differences between quantitative variables. The relationship between hernia defect width and rectus abdominis muscle strength was analyzed with linear regression tests with adjustment for age, sex, BMI, and body composition. A significant statistical difference was assumed if $p < 0.05$.

Data were processed and analyzed using the SPSS statistical software package (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp®).

Results

In the study, 40 patients were enrolled for analysis. From all the above, one of them was absent for the evaluation, so he was excluded from the study.

The group of patients was heterogeneous in terms of sex, with a certain majority of women (64%). The average age was 57.62 years. The mean BMI was 29.18, the mean percentage of fat mass was 37.8%, while the mean percentage of muscle mass was 60.33%. The mean width of the hernia defect was 6.59 cm (Table 1).

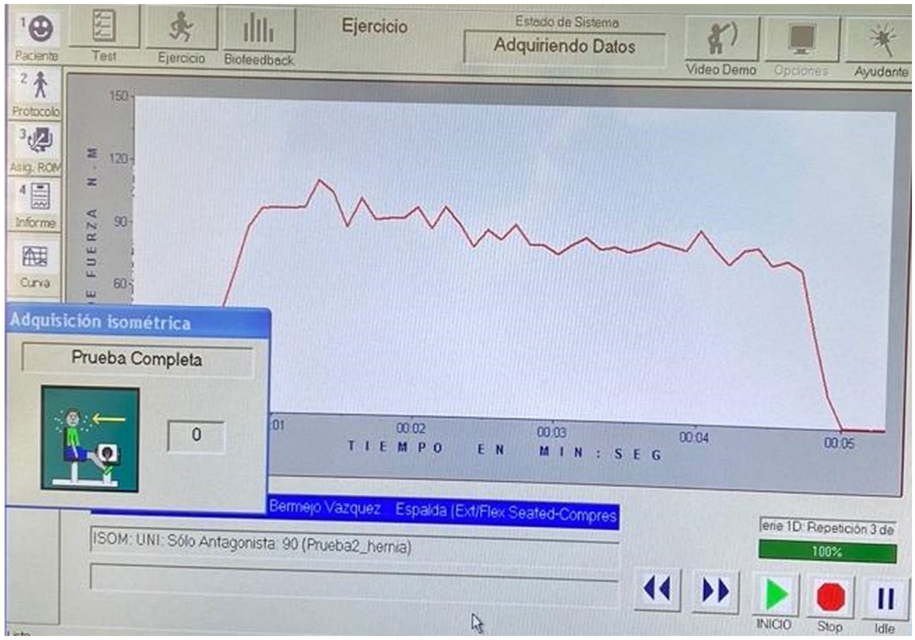

Fig. 4 Visual data obtained with the isokinetic dynamometer (Biodex System 4; Biodex Medical Systems. Shirley, NY: Biodex Corp®)

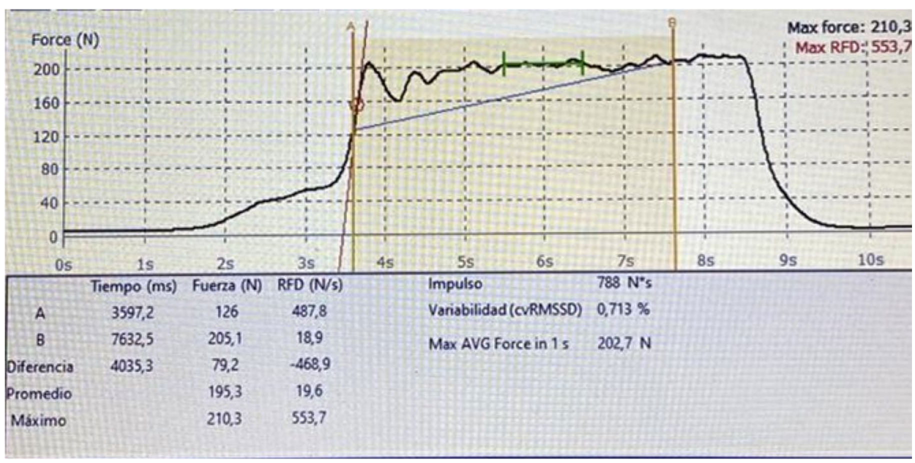

Fig. 5 Visual data obtained with the strain gauge (Chronojump. Barcelona, Spain: Boscosystem®)

Table 1 Demographic data

	N		Mean	Standard deviation (SD)
	Valid	Lost		
Age (years old)	39	1	57.62	11.00
Sex (0 = male, 1 = female)	39	1	64% female	–
Maximum diameter of hernia defect (cm)	39	1	6.59	1.54
BMI	39	1	29.18	5.06
% Fat mass	39	1	37.8	8.47
% Muscle mass	39	1	60.33	6.43

Table 2 shows rectus abdominis muscle strength data obtained using both isokinetic dynamometer and strain gauge. This is ISOK_PT, ISOK_PT_Weigh was obtained

Table 2 Trunk strength data using isokinetic dynamometer and strain gauge, grouped by sex

Sex	*N*	Mean	Standard deviation (SD)
ISOK_PT (Nw m)			
Male	14	94.01	34.58
Female	25	58.11	29.41
ISOK_PT_Weight (Nw m)			
Male	14	103.32	37.48
Female	25	66.48	32.44
PK_90 (N)			
Male	14	184.71	47.01
Female	25	152.50	48.49

Table 3 Comparison between trunk strength data obtained with isokinetic dynamometer and strain gauge and sex

	Signification	Mean difference	SD difference	IC 95%	
				Inferior	Superior
ISOK_PT (Nw m)	0.002	35.90	10.68	14.24	57.55
ISOK_PT_Weight (Nw m)	0.003	36.83	11.70	13.11	60.55
PK_90 (N)	0.052	32.21	16.01	−0.23	64.66

Table 4 Correlation between trunk strength and age

	Age	ISOK_PT (Nw m)	ISOK_PT_ Weight	PK_90
Age (years)				
Pearson correlation coefficient	1	−0.44	−0.210	−0.20
Signification		0.006	0.206	0.24
N	39	39	39	39

Table 5 Regression model that includes abdominal wall strength, hernia defect size, and demographic data

	Coeff	Standard error	Sig.	Exp(B)
Constant	−0.251	0.504	0.023	0.778
Sex	2.508	1.156	0.330	0.107
Age	2.056	2.598	0.530	1.158
BMI	0.300	0.458	0.754	1.020
Hernia defect size	0.053	0.100	0.079	0.896

Table 6 Mean comparison among patients belonging to P90 with respect to abdominal wall strength

P90	Mean	Stand. Dev.	*p*
Hernia defect size			
Yes	6.651	1.378	0.048
No	6.075	2.83	
Age			
Yes	58.49	11.06	0.146
No	50.00	7.87	
BMI			
Yes	29.12	5.14	0.752
No	30.80	7.28	

using both the isokinetic dynamometer; and PK_90, obtained using the strain gauge. All parameters related to rectus abdominis muscle strength were higher in the group of men, with a mean ISOK_PT of 94.01 Nw m (SD 34.58), mean ISOK_PT_Weight of 103.32 Nw m (SD 37.48) and a mean PK_90 of 184.71 N (SD 47.01).

When comparing means for trunk strength data using the Student t test, we found statistical differences in the relationship between data obtained using the isokinetic dynamometer (ISOK_PT and ISOK_PT_Weight) and sex. However, when the relation analyzed was between the data obtained with the strain gauge (PK_90) and the sex, we did not find statistical significance, although we found a certain tendency to statistical significance ($p=0.052$), as shown in Table 3.

Table 4 shows the relationship between ISOK_PT, ISOK_PT_Weight, PK_90 and age. We found statistical differences between ISOK_PT and age ($p=0.006$). No statistical differences were found between ISOK_PT_Weight and age ($p=0.206$), nor between PK_90 and age ($p=0.239$).

Regarding the assessment of rectus abdominis muscle strength (ISOK_PT, ISOK_PT_Weight and PK_90) and hernia defect width, we did not find statistical differences. However, when this relationship was analyzed using regression analysis adjusting data by sex and BMI, we found a trend toward statistical significance ($p=0.079$), as shown in Table 5.

In our analysis, we also found that the group of patients in the 90th percentile (P90) of rectus abdominis muscle strength also had smaller hernia defect widths. This is shown in Table 6.

Discussion

Over the past few decades, surgeons have tried to assess the best technique for incisional hernia repair. In this regard, different factors related to the characteristics of the patient: the type of previous surgery and the type of hernia repair have been studied. In this study, we tried to assess the status of the abdominal wall in patients with incisional hernia and the relationship between the strength of the abdominal wall and the diameter of the hernia defect.

In our group of study, 64% of the patients were female (25 females vs 14 males) which lead us to think of female sex as a risk factor for incisional hernia. In addition to that, after analyzing our data, we found statistical differences in the relationship between abdominal wall strength and sex, concluding that in our group, males tend to have a stronger rectus abdominis muscle compared to females.

When we compared these results to the evidence in the literature, we found other studies that claim the same assumption. For example, Parker et al. [22] carried out a meta-analysis in which they identified some predictors for ventral hernia recurrence. They found female sex, among others, as a risk factor for ventral hernia recurrence.

Considering that we found a statistically significant relationship between female sex and weaker rectus abdominis muscle, this could lead us to think about a weak rectus abdominis muscle as a risk factor for presenting incisional hernia, although further studies should be carried out to confirm this assumption.

Gignoux et al. [23] also found that the majority of patients in their group of population studied (55%) were female, which are similar findings to our own.

However, the role of female sex as a risk factor for incisional hernia is controversial. Some studies have not found significant differences (Bosanquet et al. [3] only found significant differences in univariate analysis) in incisional hernia rates depending on sex [3, 24], and yet others found male sex as a risk factor for incisional hernia [25, 26].

These different results could be explained due to the samples in some of these studies being smaller, the fact that they were carried out quite a few years ago, and the possibility that incisional hernia rates based on sex could have changed since then. Despite this, we think that further studies should be performed to clarify the role of sex in incisional hernia recurrence.

After analyzing our data, we found a statistically significant tendency in the relationship between hernia defect width and rectus abdominis muscle strength. We also found that patients with stronger rectus abdominis muscle (grouped in the 90th percentile of rectus abdominis muscle strength measured with the isokinetic dynamometer and strain gauge) had a shorter width of hernia defects. This suggests a negative association between these two variables.

Strigård et al. [27] also found an inverse correlation between abdominal wall muscle strength (measured with the same isokinetic dynamometer model used in our study) and hernia defect size although they were unable to assess the point at which this relationship begins to apply since all patients included in their study were diagnosed with a W3 hernia according to the EHS (maximum hernia diameter greater than 10 cm), and patients with smaller areas were not included.

In our study, statistical differences were found between the strength of the rectus abdominis muscle measured with the isokinetic dynamometer (ISOK_PT) and the age, with an inverse relationship between them, the oldest patients being those with the weaker rectus abdominis muscle.

Regarding age, most of the evidence we found in the literature agrees with the consideration of older age as a risk factor for ventral hernia recurrence [23, 25, 26]. As we mentioned before with respect to sex, since we found a statistically significant relationship between older age and a weaker rectus abdominis muscle, we could consider a weak rectus abdominis muscle as a risk factor for the occurrence of incisional hernia.

In contrast, the analysis Parker et al. [22] carried out suggests that age above 65 years is a protective factor for the occurrence of incisional hernia, although they did not find strong statistical differences in incisional hernia rates relative to age.

In this study, we found an inverse relationship between age and rectus abdominis muscle strength, and between maximum hernia width and rectus abdominis muscle strength. We also found that female sex correlates with weaker rectus abdominis muscle.

Although Strigård et al. [27] also found an inverse correlation between hernia defect size and abdominal wall muscle strength, they did not find any correlation regarding age and sex to abdominal wall muscle function.

Both of our sample's sizes were similar (40 patients our own vs 52 patients Strigård's), but the main difference lies in the characteristics of the hernia: our patients were classified as W2 according to the EHS, while theirs were classified as W3. This could explain differences between our results.

Only hernias classified as W2 according to EHS were include in order to avoid bias secondary to small hernias impact on abdominal wall strength. Furthermore, during the recruiting time of our study, we found a very small number of patients with hernia width over 10 cm. We decided not to include them in order to obtain a more homogeneous sample.

Evidence in the literature about the effect of incisional hernia repair on muscle strength in the abdominal wall is scarce. Some studies in the literature try to evaluate this effect using QoL assessment scales. Licari et al. [28] evaluate the improvement in the QoL of patients after surgical repair of incisional hernias using different QoL assessment scales, such as performance-oriented mobility assessment (POMA) scale, short-form (36) Health Survey (SF-36 test), among others. They found an overall improvement in QoL of patients with incisional hernia after its surgical repair.

Some other studies have used the different dynamometers to assess abdominal wall muscle function and to evaluate how it improves after surgical repair of the incisional hernia. Jensen et al. [29] found the dynamometer to be a reliable method to measure abdominal wall muscle function.

Other groups of researchers tried to assess this effect using different physical examination tests. Parker et al. [30] proposed this method to evaluate the abdominal wall muscle function and its improvement after surgical repair of incisional hernias.

In this regard, we find the use of biomechanical tools, such as an isokinetic dynamometer and strain gauge, the best method to evaluate abdominal wall muscle strength. We believe this assumption since this method allows us to obtain objective data on abdominal wall muscle function and strength, which cannot be obtained by QoL assessment scales.

Using biomechanical tools also allows us to obtain data with no interobserver variability, and is possible by simply using physical exam tests. We believe that further studies should analyze the impact of surgical repair of incisional hernia on the muscle strength and function of the abdominal wall, and these studies should be carried out with the use of biomechanical tools, such as the isokinetic dynamometer.

In our study, we observed a statistically significant relationship between the size of the hernia defect and the strength of the abdominal wall, indicating that smaller hernias might be associated with stronger abdominal walls. This finding suggests that the extent of the hernia defect plays a role in determining the abdominal wall strength.

In addition, we identified age and sex as significant predictors of abdominal wall strength. Females and older patients were found to have weaker abdominal walls. These factors should be taken into consideration when evaluating abdominal wall function and planning surgical interventions for incisional hernias. However, further studies are needed to explore the complex relationship among the size of the hernia defect, age, sex, and abdominal wall strength. Investigating these variables in larger and more diverse populations would provide a more comprehensive understanding of the factors influencing abdominal wall strength in patients with incisional hernias. Such studies could contribute to the development of tailored treatment strategies and improve patient outcomes.

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Declarations

Conflict of interest The authors declare that there is no conflict of interest in this article.

Ethical approval The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Regional Ethics Committee of biomedical research.

Human and animal rights All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standerds.

Informed consent Informed consent was obtained from all patients who agreed to participate in the study.

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