

# MODIFICATION OF THE SPINOPELVIC PARAMETERS WITH SURGICAL POSITIONING AND THE ROLE OF THE HIP

MODIFICAÇÃO DOS PARÂMETROS ESPINOPÉLVICOS COM O POSICIONAMENTO CIRÚRGICO E PAPEL DO QUADRIL

MODIFICACIÓN DE PARÁMETROS ESPINOPÉLVICOS CON EL POSICIONAMIENTO QUIRÚRGICO Y ROL DE LA CADERA

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## ABSTRACT

Post-operative lumbar pain is related to alterations in the sagittal and spinopelvic parameters. A lumbar fusion that fails to maintain, or that worsens the physiological lordosis alters the sagittal balance. Objective: To analyze spinopelvic variation in different surgical positions. Methods: A prospective, analytical and comparative study of spinograms, lumbosacral radiographs in the surgical position over a 4-pole quadratus lumborum, and lumbosacral radiographs with quadratus lumborum and support in the knees. A sample of 129 patients, of both sexes, aged between 18 and 60 years, and presenting with lower back pain. Lumbar Lordosis (LL), Pelvic Tilt (PT), Pelvic Incidence (PI) and Sacral Slope (SS) were measured. Results: PI was the most stable parameter. With quadratus lumborum, a slight increase in PT, a decrease in SS and a significant reduction in LL were found. With quadratus lumborum and support in the knees, a decrease in PT and a slight increase in SS were found, while the LL value remained similar to that of the spinogram. Conclusion: The intraoperative position with hip flexion of between 40° and 45° over quadratus lumborum reduced LL to 10.52° in men and 16.21° in women, increased PT, and decreased SS. The intraoperative position with hip flexion of between 0° and 10° showed the same values as the reference spinogram. **Level of Evidence II; Prospective comparative study.**

**Keywords:** Postural Balance; Lordosis; Patient Positioning.

## RESUMO

A dor lombar pós-operatória está relacionada a alterações nos parâmetros sagitais e espinopélvicos. Uma fusão lombar que não mantém ou piora a lordose fisiológica altera o equilíbrio sagital. Objetivo: Analisar a variação espinopélvica em diferentes posições cirúrgicas. Métodos: Estudo prospectivo, analítico e comparativo de espinogramas, radiografias lombossacrais na posição cirúrgica em um quadrado lombar de quatro pólos e radiografias lombossacrais com quadrado lombar e apoio para os joelhos. Foi feito um estudo com 129 pacientes, de ambos os sexos, entre 18 e 60 anos que apresentavam dor lombar. A lordose lombar (LL), a inclinação pélvica (PT), a incidência pélvica (PI) e a inclinação sacral (SS) foram medidas. Resultados: A PI foi o parâmetro mais estável. Com o quadrado lombar, um pequeno aumento na PT, uma diminuição na SS e uma redução significativa na LL foram observados. Com o quadrado lombar e o apoio para os joelhos, houve diminuição na PT e um leve aumento na SS, enquanto o valor da LL permaneceu semelhante ao valor do espinograma. Conclusão: A posição intraoperatória com flexão do quadril entre 40° e 45° no quadrado lombar reduziu a LL para 10,52° nos homens e 16,21° nas mulheres, aumentou a PT e diminuiu a SS. A posição intraoperatória com flexão do quadril entre 0° e 10° apresentou os mesmos valores do espinograma de referência. **Nível de Evidência II; Estudo prospectivo comparativo.**

**Descritores:** Equilíbrio Postural; Lordose; Posicionamento do Paciente.

## RESUMEN

El dolor lumbar postoperatorio está relacionado con alteraciones de los parámetros sagitales y espinopélvicos. Una fusión lumbar que no mantiene o empeora la lordosis fisiológica altera el balance sagital. Objetivo: Analizar la variación espinopélvica en diferentes posiciones quirúrgicas. Métodos: Estudio prospectivo, analítico, comparativo, de espinogramas, radiografías lumbosacras en posición quirúrgica sobre cuadrado lumbar de 4 postes y lumbosacra con cuadrado lumbar y soporte para las rodillas. Fue hecho un estudio con 129 pacientes, de ambos sexos, entre 18 y 60 años que presentaban dolor lumbar. Fueron medidas la lordosis lumbar (LL), la inclinación pélvica (PT), la incidencia pélvica (PI) y la inclinación sacral (SS). Resultados: La PI fue el parámetro más estable. Con el cuadrado lumbar, se observó pequeño aumento en la PT, una disminución en la SS y una reducción significativa en la LL. Con cuadrado lumbar y soporte para las rodillas hubo disminución en la PT y ligero aumento en la SS, mientras que el valor de la LL se mantuvo similar al valor del espinograma. Conclusión: La posición intraoperatoria con flexión de cadera entre 40° y 45° sobre el cuadrado lumbar, redujo la LL para 10,52° en hombres y 16,21° en mujeres, aumentó la PT y disminuyó la SS. La posición intraoperatoria con flexión de cadera entre 0° y 10° presentó los mismos valores del espinograma de referencia. **Nivel de Evidencia II. Estudio prospectivo comparativo.**

**Descriptores:** Balance Postural; Lordosis; Posicionamiento del Paciente.

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## INTRODUCTION

The spinal cord is the main axis for maintaining the correct standing position in humans, with Sagittal Balance (SB) being one of the most important factors. Lumbar degeneration results in a loss of lumbar lordosis, with the subsequent activation of compensatory mechanisms in order to maintain the capacity to walk, but which create greater muscular tension and stress on the static subsystems, causing them to become exhausted. Clinical consequences are lumbar pain and loss of quality of life.<sup>1-5</sup>

Postoperative lumbar pain is also closely related to alterations in sagittal parameters and spinopelvic angulation.<sup>6-8</sup>

In recent decades, the increase in vertebral instrumentations has led to a clear increase in the rate of instrumented lumbar arthrodesis. Current technology has brought several benefits for surgeons, although it has also led to the appearance of a greater incidence of flat back syndrome.

The term "flat back syndrome", also known as lumbar kyphosis, was initially described by Doherty (1973), based on a case of forward tilt of the core due to loss of normal lumbar lordosis. This can be caused by many factors, but the most common origin is iatrogenic, based on lumbar attachments in hypolordosis.<sup>9</sup>

Incorporating the spinopelvic parameters in the surgical planning is of great importance, and is considered essential for a good postoperative result.<sup>1-10</sup> It is well established that the spinal cord adapts itself to the pelvic parameters, hence the importance of a spinopelvic analysis.<sup>11</sup> A lumbar fusion that fails to maintain, or that worsens physiological lumbar lordosis results in accelerated wear on the adjacent musculature and loss of the sagittal balance.<sup>12</sup>

Many works have shown the importance of the study of spinal sagittal balance and spinopelvic angulation, not only in healthy individuals, but also in spinal cord surgery.<sup>6-7-13-14</sup>

The aim of this work is to analyze spinopelvic variation in different surgical positions.

## METHODS

Following approval by the Ethics Committee of Sanatorio Allende, we conducted a prospective, analytical and comparative study, with two independent observers, of spinograms in the standing position, lumbosacral radiographies simulating surgical position in ventral decubitus over a 4-pole quadratus lumborum (30 centimeters high) with hip flexion of between 40° to 45°, and lumbosacral radiography with quadratus lumborum with extra knee support (40 centimeters high) and hip flexion of between 0° and 10°. The sample consisted of 129 patients who presented with lower back pain between April 2017 and February 2018, at the Orthopedic and Trauma Service of our institution. All the patients who participated in the study signed an Informed Consent Form. The inclusion criteria were: patients who had previously presented with lower back pain in their first appointment, patients of both sexes, aged between 18 to 60 years. The exclusion criteria were: patients who had previously undergone spinal cord surgery and had chronic lumbar symptomatology or the existence of a structural pathology of the spinal cord. There was no conflict of interest in relation to this study.

### Radiological Studies

This work was conducted in the Diagnostic Imaging Service, which was given an explanatory protocol that included the inclusion and exclusion criteria and the rules to follow in order to simulate intraoperative positions. The imaging studies used for the analysis were: spinogram in the standing position (side projection) (Figure 1), lumbosacral radiography (side) in the surgical position with quadratus lumborum (hip flexion) (Figure 2) and lumbosacral radiography (side) in the surgical position with additional support in the knees (extended hip) (Figure 3).

The variables analyzed were as follows:

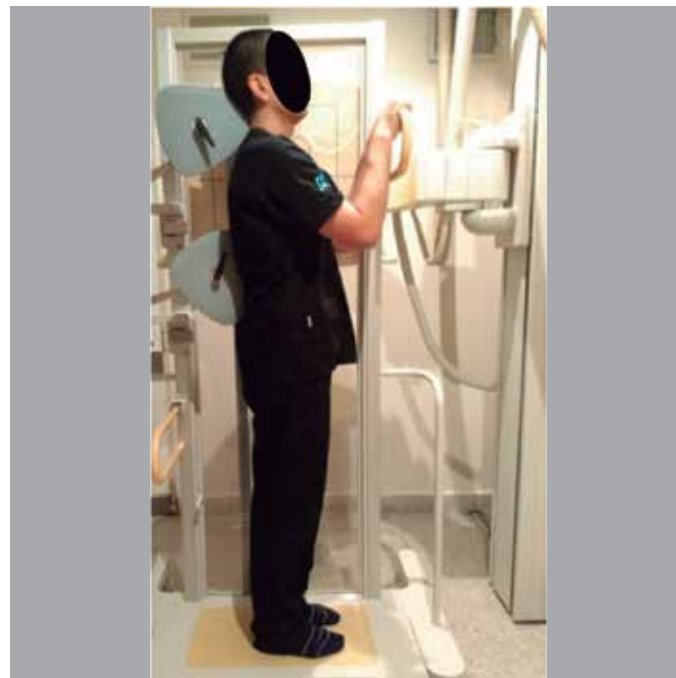


Figure 1. Spinogram in the standing position (side projection).



Figure 2. Lumbosacral radiography in surgical position over 4-pole quadratus lumborum.



Figure 3. Lumbosacral radiography in the surgical position with 4-pole quadratus lumborum with extended hips.

### Lumbar Lordosis (LL)

Physiological lumbar lordosis is an important parameter that must be considered in spinal cord surgeries, as it maintains normal sagittal balance and is related to Pelvic Incidence.

This ratio can be used to determine the ideal LL in a given patient using the following formula  $LL = PI \pm 10^\circ$ .<sup>15</sup>

### Pelvic Parameters

In the side projection, the three parameters that determine pelvic configuration were measured. First, Pelvic Incidence (PI), which

determines the width of the pelvis using an anatomically fixed angle, which is specific to each individual and does not vary after adolescence. Second, Pelvic Tilt (PT), which shows the rotation of the pelvis around the femoral heads: in retroversion, PT increases, while in anteversion, PT decreases, and lastly, Sacral Slope (SS), which is a compensatory angle of PT and is characterized by the position of the base of the sacrum (S1).

Mathematically, the pelvic parameters are expressed by the expression  $PI = PT + SS$ . These four parameters were measured in each patient, with the aid of the software program SurgiMap. Figure 4 shows how they were measured and how the observations of each indicator were obtained. This measurement software can be applied not only in research but also in clinical fields. Its high reliability was recently demonstrated; consequently, it can be incorporated as a tool for sophisticated sagittal alignment.<sup>16</sup>

**RESULTS**

The patient's average age was comparable for both sexes ( $p=0.949$ ), with average ages (standard deviations) of 31.7 (9.4) years for men and 31.5 (9.9) for women. This was not associated with the lumbopelvic parameters evaluated (PT,  $p=0.356$ ; IP,  $p=0.401$ ; LL,  $p=0.694$ ; SS,  $p=0.791$ ), in any of the rehearsed positions. The estimated rates of correlation were below 0.18 in all cases, except for the position that included the surgical quadratus, in which a slight tendency towards lordosis (LL,  $r=0.24$ ,  $p=0.091$ ) was observed. However, noticeable differences were found between sexes in the measured parameters in the side spinogram. Table 1 presents the statistical summaries for each characteristic under the reference position (spinogram) and by sex, reflecting values that are significantly greater for lumbar lordosis and sacral slope in women, apart from the smaller value obtained for pelvic tilt when being compared to the other parameters at a general level (both sexes).

To complement this, Figure 5 illustrates the empirical distribution for each variable used in the reference evaluation (spinogram), compared to the two innovated positions (with quadratus lumborum and additional support in the knees), and shows the lack of adhesion among the three series and in each parameter. This lack of adhesion, as mentioned previously, was closely associated with sex ( $p$ -global value 0.0107), as can be seen in Tables 2 and 3, with distinctive features in the female group.

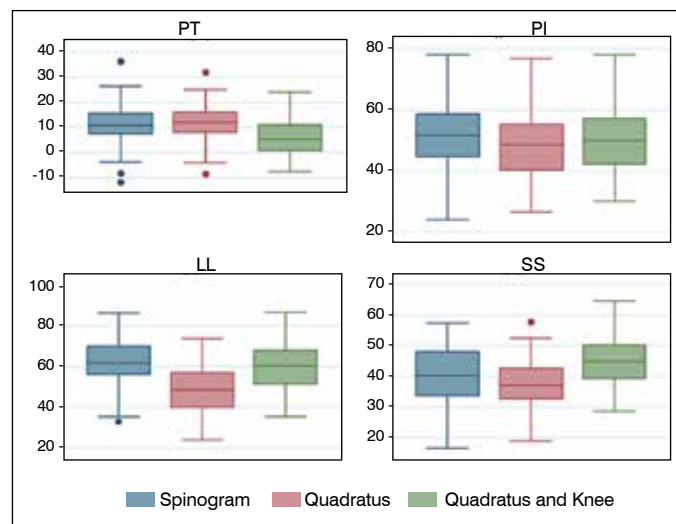
Pelvic incidence, a parameter considered an invariant quality of each individual, was measured and also mathematically calculated by adding PT and SS. In the adopted positions (spinogram, with quadratus lumborum and quadratus lumborum plus support in the

knees), the pelvic incidence calculated by both procedures was statistically similar, with estimated correlations of 0.983, 0.998 and 0.997, respectively, indicating a highly satisfactory pairing. This is illustrated in Figures 6 (spinogram) and 7 (quadratus lumborum), by means of scatter diagrams showing the PI measurements performed, and the calculations produced by summation.

As described earlier, the consistency among the measures

**Table 1.** Descriptive statistics of lumbar pelvic parameters (spinogram) for both sexes.

Sex	Variable	Average	Margin of error	IC 95%	p-value
Male	Pelvic Tilt	14.04	1.14	[11.73, 16.36]	0.004
	Pelvic Incidence	50.88	1.85	[47.14, 54.63]	0.827
	Lordosis	58.77	1.95	[54.80, 62.77]	0.016
	Sacral Slope	37.19	1.52	[34.13, 40.26]	0.0017
Female	Pelvic Tilt	7.93	1.19	[5.50, 10.34]	
	Pelvic Incidence	51.41	1.52	[48.33, 54.49]	
	Lordosis	65.06	1.62	[61.77, 68.37]	
	Sacral Slope	43.59	1.24	[41.06, 46.11]	



**Figure 5.** Box diagram of pelvic tilt (Pt), pelvic incidence (PI), lordosis (LL) and sacral slope (SS) obtained in the positions: reference (spinogram, blue), with quadratus lumborum (red) and with the addition of support in knees (green).



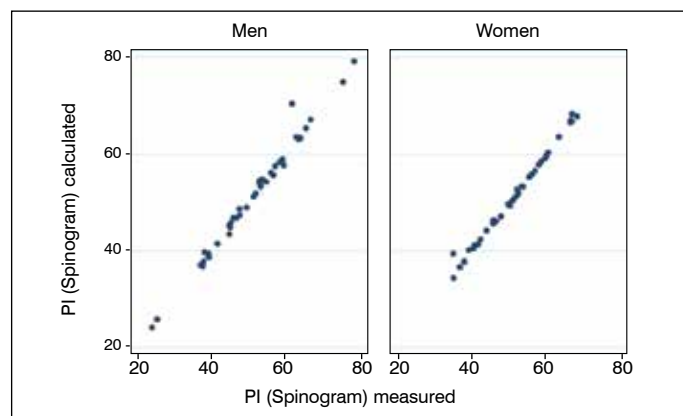
**Figure 4.** Measuring the spinopelvic parameters in SurgiMap of spinogram and the two rehearsed positions.

**Table 2.** Descriptive statistics of lumbar pelvic parameters obtained under assisted position with quadratus lumborum, by sex.

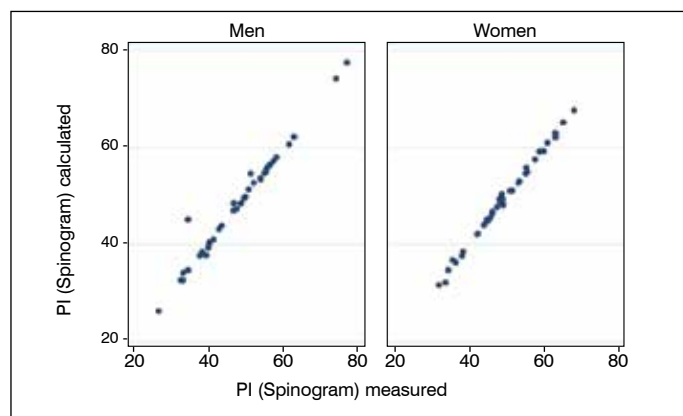
Sex	Variable	Average	Standard deviation	Minimum	Maximum
Male	Pelvic Tilt	1275	6.88	-1.2	32
	Pelvic Incidence	47.99	11.04	26.6	77
	Lordosis	48.25	10.2	28	66.4
	Sacral Slope	35.67	8	19	57.7
Female	Pelvic Tilt	10.70	7.25	-8.7	25
	Pelvic Incidence	48.88	9.09	31.8	68
	Lordosis	49.31	10.13	24.11	73.8
	Sacral Slope	38.29	7.46	22.1	52.6

**Table 3.** Descriptive statistics of lumbar pelvic parameters obtained in patients under assisted position with quadratus lumborum and support in knees, by sex.

Sex	Variable	Average	Standard deviation	Minimum	Maximum
Male	Pelvic Tilt	7.14	7.60	-5	23.9
	Pelvic Incidence	49.87	11.85	30.2	78.2
	Lordosis	58.88	11.47	35.4	80.6
	Sacral Slope	42.86	8.65	28.7	64.7
Female	Pelvic Tilt	4.52	6.11	-7.8	13.7
	Pelvic Incidence	50.66	8.85	35.5	67
	Lordosis	61.82	10.22	43.1	86.4
	Sacral Slope	46.21	7.34	32.7	60.5



**Figure 6.** Scatter diagram comparing the values for pelvic incidence measured in the spinogram, with and without the addition of PT and SS.



**Figure 7.** Scatter diagram comparing the values for pelvic incidence measured under assisted position with quadratus lumborum, with and without the addition of PT and SS.

obtained from the three positions depended largely on the patient's sex, and not on the patient's age. This is why the following description is only related to that biological factor. This adhesion was not proportional, but has a particular behavior for each sex. In order to obtain reference values and predictions by sex, several regression models were performed. Intercepts and linear coefficients of those models were estimated to describe the relationship between pelvic parameters, considering the different positions, and using the spinogram as a baseline.

Table 4 shows the estimated coefficients for each sex. It can be observed that for each parameter, the y-intercepts (expressed as subscript 1 and 2 for the relation with quadratus lumborum and quadratus lumborum plus support in the knees, respectively) interpreted as discharges in absolute terms in relation to the reference value (spinogram), are significantly different between sexes. For example, the model between PT (quadratus lumborum) and PT (spinogram) is estimated as

$$PT_1 = A_1 + B_1.PT \text{ (spinogram)}$$

$$= 2.80 + 0.71.PT(\text{spinogram}),$$

indicating that for each unit of increase in PT (spinogram), the PT to be obtained in an assisted position with quadratus lumborum does not increase in the same proportion, but increases by 0.70 compared to the former, with a discharge of 2.80. This means that the lack of adherence between both measurements could not be described as a small degree of change, but maintains a model of linear regression with positive and significant slope. These models obtained for each parameter were all significant and depended on sex (except for PI), with more extreme (and significant) estimates in lordosis and sacral slope. The exhaustive analysis of these estimates would indicate the existence of alterations to the parameters in the first and second positions, incorporating quadratus lumborum and support, and the reference values could only be recovered via the spinogram through those functional ratios. Figures 4-8 illustrate, for some of the parameters, the satisfying performance of these predictive models.

In practical terms, for both sexes, the ratio PT (quadratus lumborum):PT (spinogram) was 1.38, this ratio being arrived at by averaging 0.91 for men and 1.85 for women (opposite ratio). When the position with support in the knees is considered, the ratio PT(C+R):PT was 0.32 for men and 0.48 for women.

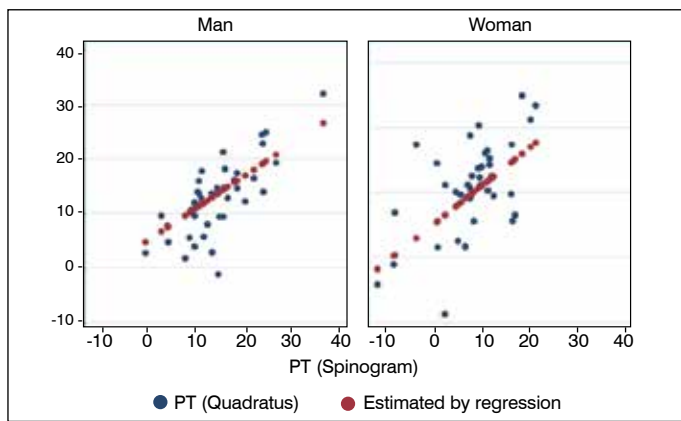
For pelvic incidence (quadratus lumborum), this ratio was estimated at 0.95, and with support in the knees, 0.98, this being the most stable parameter of the studies carried out in this work. For lordosis, these ratios were also significantly different from 1: under the quadratus lumborum position: 0.83 and 0.71 for men and women, respectively, and with the addition of support in the knees: 1.06 and 0.95 for men and women, respectively. This behavior was similar

**Table 4.** Values and estimates of the coefficients of the linear regression model (y-intercept and slope) for each pelvic parameter and for both sexes, considering a spinogram as reference (independent variable) and quadratus lumborum (1) and quadratus lumborum with support in the knee (2) as a variable answer (to be predicted or dependent).

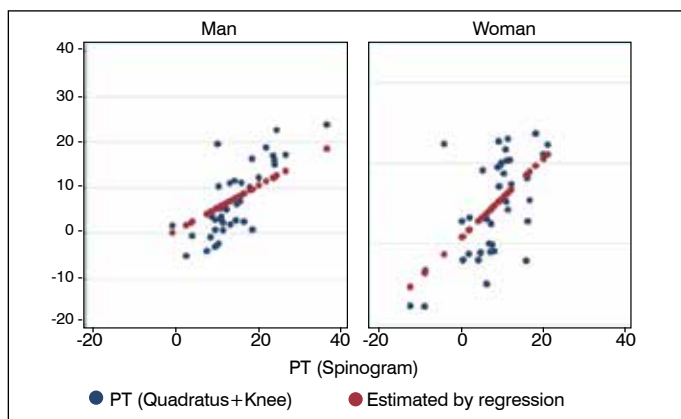
Sex	Variable	Degree	p-value
Male	Pelvic Tilt	$A_1=2.80, B_1=0.71$	<0.001, <0.001
		$A_2=-8.8, B_2=0.82$	0.011, <0.001
	Pelvic Incidence <sup>§</sup>	$A_1=3.33, B_1=0.88$	0.001, 0.114
		$A_2=3.57, B_2=0.92$	0.101, 0.001
Lordosis	$A_1=13.11, B_1=0.60$	0.021, <0.001	
	$A_2=13.34, B_2=0.79$	0.001, 0.032	
Female	Sacral Slope <sup>§§</sup>	$A_1=11.91, B_1=0.64$	<0.001, 0.02
		$A_1=6.31, B_1=0.55$	<0.001, <0.001
	Pelvic Tilt	$A_2=0.60, B_2=0.49$	0.61, 0.001
		Lordosis	$A_1=8.56, B_1=0.63$
$A_2=19.82, B_2=0.60$	<0.001, <0.001		
Sacral Slope <sup>§§</sup>	$A_1=15.12, B_1=0.53$	<0.001, 0.013	

<sup>§</sup>There was no difference between sexes. A single pair of coefficients is shown for both sexes. <sup>§§</sup>Similar degrees of the positions with quadratus lumborum, with respect to the spinogram.

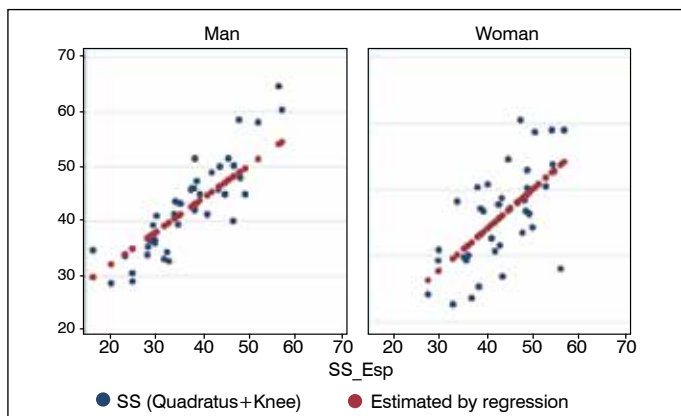




**Figure 8.** Scatter diagram comparing the values for pelvic tilt (PT) under the assisted position with quadratus lumborum, and the spinogram, for each sex.



**Figure 9.** Scatter diagram comparing the values for pelvic tilt under the assisted position with quadratus lumborum and with support in the knees, and the spinogram, for each sex.

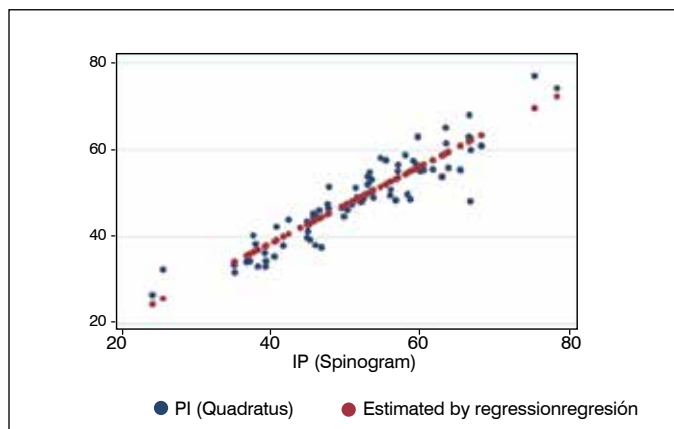


**Figure 10.** Scatter diagram comparing the values for sacral slope under the assisted position and with support in the knees and the spinogram, for each sex.

for the evaluation of sacral slope, with 0.98 and 0.89 (quadratus lumborum), 1.12 and 1.07 (quadratus lumborum plus support) for men and women, respectively.

**DISCUSSION**

Spinopelvic sagittal balance, and in particular, lumbar lordosis, must be maintained through correct intraoperative positioning; otherwise, changes will occur that will result in a reduction in lumbar lordosis and a positive balance at the postoperative sagittal level. This positive balance has been reported in the literature as



**Figure 11.** Scatter diagram comparing the values for pelvic incidence under the assisted position with quadratus lumborum, and the spinogram, for both sexes.

the beginning of lumbar pain.<sup>17</sup> When planning a lumbar fusion, positions should be used that maintain this spinopelvic physiological balance.

Therefore, two surgical positions were tested in this work, taking the spinogram in the standing position as reference. Significant differences were found when the surgical position with 4-pole quadratus lumborum was simulated (hip flexion between 40° to 45°), with a slight increase in PT, a decrease in SS and a significant reduction in LL. In the simulation of the surgical position with quadratus lumborum and additional support in the knees (hip flexion 0° to 10°), less accentuated differences were found, with a reduction in PT and a slight increase in SS, while the value of LL remained similar to that of the spinogram. This last position was the one that was most similar to reference values. This work contributes valuable additional information for future practice, as it obtains and estimates models that can be used for predictive purposes to analyze changes that would be obtained in different clinical situations in relation to the reference values obtained from the spinogram.

Many authors have carried out research on normal physiological lordosis. Anderson and Cols showed average lumbar lordosis from L1 of 59.8. Other authors such as Tan and Cols, obtained an average of 55.6° and a range of 38° to 70°.

Our results demonstrate an average lordosis of 58.77° in men and 65.06° in women for the spinogram in the standing position.<sup>18,19</sup> LL was the most variable parameter found in women, but did not vary significantly with age. Some publications state that the degenerative process reduces this variability. PI was the most stable parameter found in different clinical trials, with average values of 50.88° and 51.41° for men and women, respectively, which is in agreement with the literature.<sup>20,21</sup>

There have been some studies on the behavior of lumbar lordosis in instrumented surgeries. Works such as those of Guanciale's et al. and Stephens et al. show a variation in lumbar lordosis between the Jackson and the Andrews positions (hip flexion between 60° and 90°), which explains the importance of hips at the moment of surgical positioning.<sup>22,23</sup> Different works compare the variation in lordosis using four different surgical supports, but none of the analyses examines the change in pelvic parameters as separate from lumbar lordosis, in simulated surgical positions in relation to the reference spinogram.

Our predictive model of adjustable parameters with surgical decubitus could be of great use for preoperative planning especially in deformity pathologies, in which the priority is to restore the sagittal balance.

A weakness of our work is its relatively small sample and the age of the patients, who were mainly young. This is because at older ages, the degenerative process may influence the degree of variation in the studied parameters.

## CONCLUSION

The intraoperative position with hip flexion between 40° and 45° over four-pole quadratus lumborum used in spinal cord surgeries not only reduces lumbar lordosis to 10.52° in men and 16.21° in women, but also modifies pelvic parameters, with a slight increase in PT and a decrease in SS, compared to the spinogram in the standing position. But the intraoperative position with hip flexion between

0° and 10° shows the same values as the reference spinogram.

We believe that a precise knowledge of these changes is very important when planning the surgical strategy.

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All authors declare no potential conflict of interest related to this article.

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**CONTRIBUTION OF THE AUTHORS:** Each author made significant individual contributions to this manuscript. CM (0000-0001-6444-9921)\* and DO (0000-0003-0988-305X)\* were the main contributors to the writing, design and discussion of the results of the manuscript. These two authors, together with AG (0000-0002-9480-2906)\* and RC (0000-0001-9176-074X)\*, contributed to the acquisition, analysis and interpretation of the data. ON (0000-0001-7461-3879)\* and GJ (0000-0002-8887-8947)\* contributed to the review and approval of the final version of the work. All authors carried out the bibliographic research and contributed to the intellectual concept of the study. \*ORCID (Open Researcher and Contributor ID).

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