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Effects of Body Roundness Index on Spinal Anesthesia Block Characteristics

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Abstract: The body roundness index (BRI) concept assumes that the human body's shape is an ellipse, which combines height and waist circumference (WC). We aimed to investigate the effect of BRI on spinal anesthesia (SA) sensory levels and hypotension in patients undergoing elective surgery. In this observational study, we prospectively enrolled patients between 18-80 years old with the following characteristics: American Society of Anesthesiologists (ASA) physical status I-III, who underwent single-shot SA using 15 mg 0.5% hyperbaric bupivacaine at the L3–L4 intervertebral space for transurethral and lower limb surgery. The maximum sensory blockade level at the 15th and 30th min, block regression time to the L2 level, hypotension, and bradycardia occurrence were recorded. BRI, WC, and hip circumference (HC) were independent predictive factors for the maximum sensory blockade level at 15 min (OR=65.7 95% CI: 1.304-3310, p=0.036; OR=0.733 95% CI: 0.558-0.963, p=0.026; OR=1.065 95% CI: 1.001-1.133, p=0.047, respectively). Hypotension after SA was not associated with anthropometric variables. BRI can be a new practical tool to predict the increased cephalic spread of local anesthetic (LA) in patients undergoing SA.

Keywords: spinal anesthesia, body roundness index, hypotension, obesity, cephalic spread

Vücut Yuvarlaklık İndeksinin Spinal Anestezi Blok Karakteristik Özellikleri Üzerine Etkileri

Özet: Vücut yuvarlaklık indeksi (BRI), insan vücut şeklinin boy ve bel çevresini birleştiren bir elips olduğu varsayımına dayanır. Bu çalışmada, elektif cerrahi geçiren hastalarda BRI'nın spinal anestezi (SA) duyu seviyeleri ve hipotansiyon üzerine etkisini araştırmayı amaçladık. Bu gözlemsel çalışmada, transüretral ve alt ekstremite cerrahisi için L3-L4 intervertebral boşluktan, 15 mg %0.5 hiperbarik bupivakain kullanılarak, tek seferde spinal anestezi uygulanan, Amerikan anestezi derneğine (ASA) göre fiziksel durumu I-III olan 18-80 yaşındaki hastalar prospektif olarak kaydedildi. On beş ve 30. dakikalarda maksimum duyusal blokaj seviyesi, bloğun L2 seviyesine gerileme süresi, hipotansiyon, bradikardi oluşumu kaydedildi. BRI, bel ve kalça çevresi parametreleri 15. dakikada maksimum duyusal blokaj düzeyi için bağımsız predikte edici faktörler olarak bulundu (OR=65.7 %95 GA: 1.304-3310, p=0.036; OR=0.733 %95 CI: 0.558-0.963, p=0.026; OR=1.065 %95 CI: 1.001-1.133, p=0.047; sırasıyla). SA sonrası hipotansiyon gelişmesi ile antropometrik değişkenlerle ilişkili bulunmadı. BRI, SA uygulanan hastalarda lokal anesteziklerin artan sefalik yayılımını öngörmek için yeni bir pratik araç olarak kullanılabilir.

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Anahtar kelimeler: spinal anestezi, vücut yuvarlaklık indeksi, hipotansiyon, obezite, sefalik yayılım

INTRODUCTION

SA is a frequently used, simple, safe, and classical technique. It is crucial to obtain sufficient motor and sensory blockade to provide suitable surgical conditions in the patient under whom SA is applied. While a low spinal block may cause nausea due to surgical stimulation, a high cephalic spread may cause upper extremity weakness, shortness of breath, nausea, or anxiety. However, in SA, it is impossible to predict the cephalic spread of the LA drug injected into the cerebrospinal fluid (CSF). Therefore, factors affecting sensory loss associated with SA are still a current area of research (Logan et al., 1986). To date, studies investigated many factors potentially affect SA of cephalic spread levels (Pitkänen, 1987; Pitkänen et al., 1984; McCulloch et al., 1986; Greene, 1985; Stienstra et al., 1991; Liu et al., 2001). Two significant factors affecting cephalic spread, lumbosacral, are CSF volume and pressure (Carpenter et al., 1998; Hogan et al., 1996). However, this information has little practical value.

The effect of obesity on SA is controversial, and previous studies on this topic reported conflicting results (McCulloch et al., 1986; Carvalho et al., 2011). Considering the effect of body measurements on the spine as one or two dimensions can be a meaningful explanation for these conflicting results. In 2013, Thomas and colleagues defined the BRI, a new anthropometric index calculated using height, weight, WC, and HC (Thomas et al., 2013). They used BRI to estimate the percentage of body fat and evaluate health status (Thomas et al., 2013). Although BRI is an independent risk factor associated with the maximum level of sensory block in pregnant women undergoing SA for cesarean section, it is still unknown whether BRI is related to the spinal blockade's increased level in the general population (Kozanhan et al., 2020). Therefore, we aimed to research the relationship between BRI and the cephalicspread of SA and hypotension in patients scheduled for transurethral and lower limb surgery.

MATERIALS and METHODS

The Karatay University Ethics Committee (No. 2018/011) approved this single-center, prospective, and observational study, conducted at the Konya Education and Research Hospital, Turkey. The study followed the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion Criteria

We enrolled American Society of Anesthesiologists (ASA) physical status I-III adult patients who underwent single-shot SA in the sitting position using 15 mg bupivacaine at the L3-L4 intervertebral level for transurethral and lower limb surgery.

Exclusion Criteria

Patients with deformities in the spinal column or a history of previous spinal surgery, failure of SA or a need for additional intraoperative analgesia, heart disease, mental illnesses, and undergoing emergency surgery were not in the study.

Design of the Study

Participants' weight (kilograms), height (meters), WC, and HC were measured in the ward before SA. Body mass index (BMI) was calculated by dividing body weight by the square of height in meters (kg/m^2). BRI was calculated according to a standardized formula defined by Thomas et al. (Thomas et al., 2013). SA was performed by an experienced anesthesiologist blinded to the participant's anthropometric measurements. All patients received 8 ml/kg isotonic saline during the first 10 minutes of SA. All patients were in the supine position throughout the surgery, and all assessments were

performed in the supine position. During the surgery, the sensory blockade level was assessed every 2 min until 15 min after SA induction—every 5 min for another 15 min in midclavicular lines by a pinprick. The level of SA at 15 minutes after intrathecal injection was the maximum sensory blockade level. The time to reach the maximum sensory block level and peak sensory block degree at 30 min were also recorded. After the surgery, the sensory blockade degree was evaluated every 5 minutes until regression to the L2 level. Blood pressure and heart rate (HR) were recorded at 5-min intervals after intrathecal injection during the surgery. Hypotension was described as a decrease in systolic (SAP) of ≥20% of the baseline value or to <90 mmHg and was treated with intravenous ephedrine (5-10 mg). Bradycardia was defined as a decrease in HR <60 beats/min and was treated with IV atropine 0.5 mg.

Sample Size Calculation

Pilot study data from 35 patients were used for sample size analysis. According to the maximum sensorial block level at the 15th minute, patients were divided into two groups: T4 and above and below T4. Based on the mean BRI value in the groups, Cohen's d effect size was 0.580 in the t-test model in the independent groups. At least 175 patients were needed to have a power of at least 95%, with a two-sided α error of 5%, and a 10% dropout rate.

Statistical Analysis

SPSS version 22.0 was used for the statistical analysis (IBM). Continuous variables were provided as the mean and standard deviation (SD), and comparisons were made using the independent samples Student's t-test if the variables followed a normal distribution as determined by the Kolmogorov–Smirnov test. When the data did not follow a normal distribution, Mann–Whitney U-test was used to evaluate the data, and its median (inter-quartile range) was provided. The "Pearson Chi-square and Fisher's Exact tests" were used in performing comparisons between categorical variables reported as numbers and percentages. The area under the curve (AUC) from a receiver operating characteristic (ROC) analysis was used to determine the best BRI cut-off points, as it maximizes the test's sensitivity and specificity. The difference between the BRI ≥ 5.11 and BRI <5.11 groups was analyzed using a t-test for independent samples. Multiple logistic regression analysis examined the association between BRI, BMI, weight, WC, HC, and T4, the maximum sensory block level. A p-value <0.05 was the threshold for the statistical significance.

RESULTS

Two hundred patients were first evaluated for eligibility in this study; however, 25 of them had at least one of the following reasons: a history of prior spinal surgery (n=7), skin rash at the site of the injection (n=1), antiplatelet agent application (n=8), and patients with no neuraxial block (n=9). The remaining 175 patients' data were analyzed. Table 1 contains the data on the patient's demographic and anthropometric information and the outcomes of SA. The mean age of the participants was 51.2 ± 18.8 years. The mean BMI and the mean BRI were 28.7 ± 5.99 kg/m^2 and 5.20 ± 1.40, respectively.

Table 1. Clinic, laboratory and demographic features of patients (n=175).

Characteristics		**Mean and standart deviation or median (interquartile range) or number (%)**
Age (year)		51.2 ± 18.8
Gender	Man	116 (66.3 %)
	Woman	59 (33.7 %)
Weight (kg)		81 ± 16
Height (cm)		168.2 ± 8.76
BMI (kg/m^2)		28.7 ± 5.99

Waist Circumference (cm)		97.5 ± 16.2
Hip Circumference (cm)		102 ± 13
Body Roundness Index (BRI)		5.20 ± 1.40
ASA	1	75 (42.9 %)
	2	66 (37.7 %)
	3	34 (19.4 %)
Surgical type	Urology	60 (34.3 %)
	General surgery	26 (14.9%)
	Orthopedics	89 (50.9 %)
Surgery time (min)		50.3 ± 24.5
Sensorial Block at 15 min	Th10	30 (1.1 %)
	Th9	12 (6.9 %)
	Th8	22 (12.6 %)
	Th7	17 (9.7 %)
	Th6	29 (16.6 %)
	Th5	30 (17.1 %)
	Th4	41 (23.4 %)
	Th3	20 (11.4 %)
	Th2	1 (0.6 %)
	Th1	1 (0.6 %)
Sensorial Block At 30 min	Th10	1 (0.6 %)
	Th9	3 (1.7 %)
	Th8	20 (11.4 %)
	Th7	21 (12 %)
	Th6	29 (16.6 %)
	Th5	31 (17.7 %)
	Th4	46 (26.3 %)
	Th3	22 (12.6 %)
	Th2	1 (0.6 %)
	Th1	1 (0.6 %)
Peak sensorial block level at 15 min. (range)		Th 5 (3)
Peak sensorial block level at 30 min. (range)		Th 5 (3)
Time to achieve maximum sensorial block level (min)		13.64 ± 6.11
Time to regression sensorial block to L2 level (min)		58.9 ± 16.8
Bradycardia, n (%)		7 (4 %)
Hypotension, n (%)		26 (14.9 %)
Ephedrine, n (%)		24 (13.7 %)
Nausea, n (%)		3 (1.7 %)
Shivering, n (%)		7 (4 %)

Data are mean and standart deviation, median (interquartile range) or number (%).
Th: Thoracic vertebrae, L:Lumbar vertebrae, BMI: Body mass index, ASA: American Society of Anesthesiologists.

The optimal cut-off value of 5.11 for BRI was obtained from the ROC analysis, calculating the area under the curve levels of BRI in predicting obesity (Table 2, Fig. 1).

Table 2. Cut-off, sensitivity, specificity and area under curve levels of BRI in predicting obesity.

Characteristic	**Cut-off**	**Specifity (%)**	**Sensitivity (%)**	**AUC (95%CI)**	**P value**
Body Roundness Index (BRI)	5.11	81%	88%	0.907 (0.864-0.951)	**<0.001**

Values of $p < 0.05$ was marked bold.

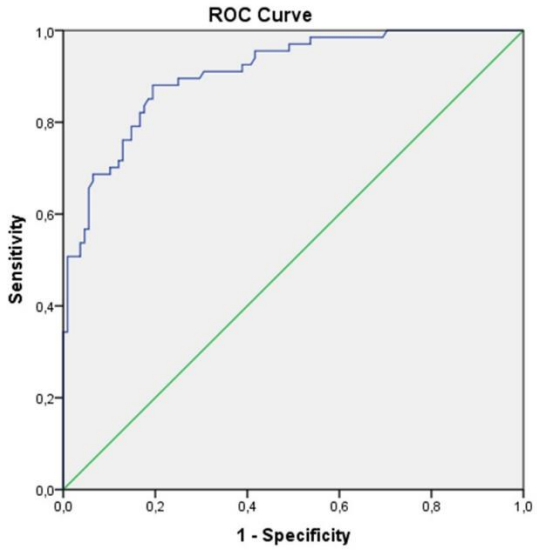

Figure 1. ROC curve of BRI in patients.

The demographic and anthropometric data of the participants and the outcomes of the spinal block were compared for the groups regarding BRI (BRI <5.11 and BRI ≥ 5.11) (Table 3). Our results revealed that the time needed to obtain the maximal sensory block level and the maximum sensory block level at 15 and 30 min were similar in the groups (p=0.362, p=0.075, and p=0.087, respectively). However, the time required to regress to the L2 level was significantly longer in the BRI≥ 5.11 group than in the BRI < 5.11 group (p=0.034). Additionally, hypotension and ephedrine consumption were significantly higher in the BRI≥ 5.11 group than in the BRI < 5.11 group (p=0.037 and p=0.028). We did not observe differences in the incidence of bradycardia among the groups.

Table 3. Clinic, laboratory and demographic features in BRI ≥ 5.11and BRI < 5.11 groups.

Characteristics		**BRI< 5.11 (n=95)**	**BRI ≥ 5.11 (n=80)**	**p value**
Age (year)		43.9 ± 19.4	59.8 ± 14.1	**<0.001**
Gender	Man	81 (85.3 %)	35 (43.7 %)	**<0.001**
	Woman	14 (14.7 %)	45 (56.3 %)	
Weight (kg)		74.2 ± 12.4	89.1 ± 16	**<0.001**
Height (cm)		172 ± 8	164 ± 7.5	**<0.001**
BMI (kg/m²)		25 ± 3.23	33.2 ± 5.49	**<0.001**
Waist Circumference (cm)		86.5 ± 9.9	110.5 ± 11.9	**<0.001**
Hip Circumference (cm)		93.9 ± 8.2	111.7 ± 10.9	**<0.001**
ASA	1	60 (63.2 %)	15 (18.8 %)	**<0.001**
	2	26 (27.4 %)	40 (50 %)	
	3	9 (9.5 %)	25 (31.2 %)	
Surgery time (min)		50.8 ± 26.1	49.7 ± 22.8	0.758
Peak sensorial block level at 15 min. (range)		Th 6 (3)	Th 5 (2)	0.075
Peak sensorial block level at 30 min.(range)		Th 5 (3)	Th 5 (2)	0.087
Time to achieve maximum sensorial block level (min)		13.3 ± 5.96	14.1 ± 6.29	0.362
Time to regression sensorial block to T10 level (min)		56.4 ± 16.7	62.8 ± 16.6	**0.034**
Bradycardia		4 (4.2 %)	3 (3.8 %)	1
Hypotension		7 (8.8 %)	19 (20 %)	**0.037**
Ephedrine		6 (7.5 %)	18 (18.9 %)	**0.028**
Nausea		1 (1.1 %)	2 (2.5 %)	0.593
Shivering		6 (6.3 %)	1 (1.3 %)	0.127

Data are mean and standart deviation, median (interquartile range) or number (%). Th: Thoracic vertebrae, BMI: Body mass index, ASA: American Society of Anesthesiologists. Values of p < 0.05 was marked bold.

Further multiple logistic regression analysis determined the relationship between the anthropometric variables and maximum sensory block level (<T4) and hypotension. The BRI, WC and HC were independently associated with maximum sensory block level (OR=65.7 95% CI: 1.304-3310, p=0.036; OR=0.733 95% CI: 0.558-0.963, p=0.026; OR=1.065 95% CI: 1.001-1.133, p=0.047, respectively) (Table 4).

Table 4. Univariate and multivariate regression analyses of different variables of associated with maximum sensory block level and hypotension in patients.

Characteristics	Maximum sensorial block level at 15 min (≥Th 4)				Hypotension	
	Univariate		Multivariate		Univariate	
	OR (95% CI)	P value	OR (95% CI)	p value	OR (95% CI)	p value
Age (year)	0.990 (0.974-1.006)	0.216	-	-	1.006 (0.984-1.029)	0.581
Gender	1.509 (0.791-2.879)	0.212	-	-	0.543 (0.206-1.436)	0.219
Weight (kg)	1.031 (1.011-1.053)	**0.003**	1.364 (0.995-1.871)	0.054	0.990 (0.964-1.017)	0.466
Height (cm)	0.993 (0.959-1.029)	0.714	-	-	1.028(0.980-1.078)	0.260
BMI (kg/m^2)	1.088 (1.031-1.148)	**0.002**	0.452 (0.191-1.069)	0.071	0.953 (0.883-1.028)	0.214
Body Roundness Index	1.349(1.075-1.692)	**0.010**	65.7 (1.304-3310)	**0.036**	0.859 (0.627-1.178)	0.345
Waist Circumference (cm)	1.029 (1.009-1.050)	**0.005**	0.733 (0.558-0.963)	**0.026**	0.994 (0.969-1.021)	0.677
Hip Circumference (cm)	1.049 (1.022-1.077)	**<0.001**	1.065 (1.001-1.133)	**0.047**	0.992 (0.960-1.025)	0.627

Th: Thoracic vertebrae, BMI: Body mass index. Values of $p < 0.05$ was marked bold.

DISCUSSION and CONCLUSION

In the present prospective observational study, increased BRI, WC, and HC levels had an association with a higher sensory blockade level at 15 min after SA. In the group of patients with BRI≥ 5.11, the sensory 'block regression to the L2 level was prolonged, and ephedrine consumption was also higher. However, no association was present between hypotension following SA and any anthropometric variables.

Obesity, an increasing public health problem worldwide, can be classified into two groups: abdominal and peripheral obesity (Patel et al., 2013). BMI indicates general obesity; however, regional differences in body fat ratio are not taken into account in BMI calculation. Moreover, although BMI and WC are the most used anthropometric indicators, they cannot comprehensively distinguish visceral adipose accumulation, particularly for non-obese individuals with normal BMI and WC. On the other hand, BRI reflects both visceral adipose tissue and body adipose percentage; therefore, it can assess health status (Rico-Martín et al., 2020).

BRI values range from 1 to 16, and generally, more elliptical individuals tend to have larger values (Thomas et al., 2013; Chang et al., 2015). One possible mechanism of our results may be related to decreased CSF volume within the patient group with BRI≥ 5.11. CSF volume is lower in obese patients due to increased intra-abdominal pressure or epidural adipose tissue (Hogan et al., 1996; Taivainen et al., 1990; Robinson, 1949). In a patient with a large BRI, elevated intra-abdominal pressure due to increased abdominal adipose content may obstruct the inferior vena cava, increase blood flow from the lumbar vertebral plexus, and result in enlargement in the extradural veins. If an extradural vein is enlarged, a decrease in CSF volume is generally anticipated. Then, if the same volume of LA is injected in a patient with a lower CSF volume, a higher cephalic spread of LA should be expected. Even though

we did not assess the CSF volume, this mechanism may have caused more cephalic spread and prolonged regression of the level of the spinal block observed in this study. The demonstration of increased diffusion of radiopaque material in CSF due to abdominal compression seen with myelography is in line with this mechanism (Barclay et al., 1948).

The baricity of an LA agent is a significant factor in determining spread within the CSF. McCulloch et al. investigated the cephalic spread of SA in obese patients with isobaric bupivacaine. They found a positive correlation between the height of the spinal block and obesity (McCulloch et al., 1986). However, isobaric LA was associated with increased variability at the block level (McCulloch et al., 1986; Carpenter et al., 1998). Carvalho et al. assessed whether obese parturients require less spinal LA for cesarean delivery. They reported that hyperbaric bupivacaine's median dose for successful anesthesia in morbidly obese parturients was similar to that in nonobese parturients (Carvalho et al., 2011). This study evaluated clinical results using hyperbaric Marcaine due to its frequent preference in our clinical practice in our hospital. Clinical outcomes with hypobaric LA need to be investigated.

The effect of obesity on SA outcomes is still controversial, and there is no clear clarity on how to adjust LA doses in obese patients. However, if SA lasts for shorter, the operation time causes anesthesia failure. In contrast, SA that extends beyond the operation time may cause bladder dysfunction and discomfort in patients and extended hospital stays. We observed a longer regression time in the sensory block in the BRI≥ 5.11 patient group. However, patients were not evaluated for bladder dysfunction or time to discharge. Taivainen et al. compared obese patients with normal BMI using 3 ml of plain 0.5% bupivacaine for SA and reported more extensive cephalad spread of sensory block in patients with increased BMI than in patients with normal BMI (Taivainen et al., 1990). Similarly, Pitkänen found that with 3 ml of isobaric bupivacaine, patients with above-normal BMI had a higher cephalad spread of anesthesia. Additionally, with hyperbaric bupivacaine, shorter individuals developed higher levels of anesthesia (Pitkänen, 1987). This study assessed the sensory blockage levels, hypotension, and block regression time in patients administered a fixed dose of LA. Future studies should re-evaluate clinical results with different doses of LA, and create practical dosage formulas for dose adjustment in patients with high BRI values.

Although BRI's predictive value in maximum sensory block levels after SA in patients undergoing cesarean section was investigated, the present study is the first to evaluate this in a nonobstetric population (Kozanhan et al., 2020). The cut-off value we reached for BRI in this study coincides with the cut-off value previously determined in the Turkish population (Solak et al., 2018). The BRI has shown promising results for clinical use, but future studies should investigate the optimal cut-off value for each population of different ethnicities and races.

There are several limitations to this study. First, we cannot conclude with certainty that a higher BRI directly affects the outcome of SA related to a smaller CSF volume; hence, we did not assess the CSF volume. Second, defining the location of the interspinous space with USG minimizes the number of attempts and is beneficial for a successful spinal block with fewer side effects. However, the interspinous interval was determined by traditional methods because our current conditions were not suitable. In this study, although the sex and age distribution was predominantly female and over middle age, they did not affect the multivariate analysis. However, future studies should have a more homogeneous population.

In conclusion, BRI can be used as a new practical index to evaluate the increased cephalic spread of LAs in patients undergoing SA.

Conflict of Interest: There is no conflict of interest among the authors.

REFERENCES

Barclay, D. L., Renegar, O. J., & Nelson Jr, E. W. (1968). The influence of inferior vena cava compression on the level of spinal anesthesia. *American Journal of Obstetrics and Gynecology, 101,* 792-800.

Carpenter, R. L., Hogan, Q. H., Liu, S. S., Crane, B., & Moore, J. (1998). Lumbosacral cerebrospinal fluid volume is the primary determinant of sensory block extent and duration during spinal anesthesia. *Anesthesiology, 89,* 24-29.

Carvalho, B., Collins, J., Drover, D. R., Ralls, L. A., & Riley, E. T. (2011). ED (50) and ED (95) of intrathecal bupivacaine in morbidly obese patients undergoing cesarean delivery. *Anesthesiology, 114,* 529-535.

Chang, Y., Guo, X., Chen, Y., Guo, L., Li, Z., Yu, S. … Sun, Y. (2015). A body shape index and body roundness index: two new body indices to identify diabetes mellitus among rural populations in northeast China. *BMC Public health, 15,* Article 794.

Greene, N. M. (1985). Distribution of local anesthetic solutions within the subarachnoid space. *Anesthesia and Analgesia, 64,* 715-730.

Hogan, Q. H., Prost, R., Kulier, A., Taylor, M. L., Liu, S., & Mark, L. (1996). Magnetic resonance imaging of cerebrospinal fluid volume and the influence of body habitus and abdominal pressure. *Anesthesiology, 84,* 1341-1349.

Kozanhan, B., Bardak, O., Tutar, M. S., Ozler, S., Yildiz, M., & Solak, I. (2020). The influence of body roundness ındex on sensorial block level of spinal anaesthesia for elective caesarean section: An observational study. *Journal of Obstetrics and Gynaecology, 40,* 772-778.

Liu, S. S., & McDonald, S. B. (2001). Current issues in spinal anesthesia. *Anesthesiology, 94,* 888-906.

Logan, M. R., McClure, J. H., & Wildsmith, J. A. (1986). Plain bupivacaine: an unpredictable spinal anaesthetic agent. *British Journal of Anaesthesia*, *58*, 292-296.

McCulloch, W. J., & Littlewood, D. G. (1986). Influence of obesity on spinal analgesia with isobaric 0.5 % bupivacaine. *British Journal of Anaesthesia, 58,* 610-614.

Patel, A. V., Hildebrand, J. S., & Gapstur, S. M. (2014). Body mass index and all-cause mortality in a large prospective cohort of white and black U.S. Adults. *PLoS One, 9,* Article e109153.

Pitkänen, M. T. (1987). Body mass and spread of spinal anesthesia with bupivacaine. *Anesthesia and Analgesia, 66*, 127-131.

Pitkänen, M., Haapaniemi, L., Tuominen, M., & Rosenberg, P. H. (1984). Influence of age on spinal anaesthesia with isobararic 0.5 % bupivacaine. *British Journal of Anaesthesia, 56,* 279-284.

Rico-Martín, S., Calderón-García, J. F., Rey, P. S., Franco-Antonio, C., Alvarez, M. M., & Muñoz-Torrero, J. F. S. (2020). Effectiveness of body roundness index in predicting metabolic syndrome: A systematic review and meta-analysis. *Obesity Reviews, 21,* Article e13023.

Robinson, L. S. (1949). The collateral circulation following ligation of the inferior vena cava; injection studies instillborn infants. *Surgery, 25,* 329-347.

Solak, I., Guney, I., Cihan, F. G., Mercan, S., & Eryilmaz, M. A. (2018). Evaluation of a body shape index and body roundness index, two new anthropometric indices, in obese individuals. *Acta Medica, 34*, 1545-1550.

Stienstra, R., & Greene, N. M. (1991). Factors affecting the subarachnoid spread of local anesthetic solutions. *Regional Anesthesia and Pain Medicine, 16,* 1-6.

Taivainen, T., Tuominen, M., & Rosenberg, P. H. (1990). Influence of obesity on the spread of spinal analgesia after injection of plain 0.5% bupivacaine at the L3-4 or L4-5 interspace. *British Journal of Anaesthesia, 64*, 542-546.

Thomas, D. M., Bredlau, C., Bosy-Westphal, A., Mueller, M., Shen, W., Gallagher, D. … Heymsfield, S. B. (2013). Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. *Obesity, 21,* 2264–2271.