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Original Research Article

Anthropometric Predictors of Lumbar Subarachnoid Space Depth in Adults: Clinical Implications for Imaging-Guided and Safe Neuraxial Procedures

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Conflict of interest: Nil

Abstract

Background: Accurate estimation of lumbar skin-to-subarachnoid space depth (SSD) is essential for successful neuraxial anesthesia and image-guided lumbar procedures. Conventional landmark-based techniques may be unreliable in patients with obesity or altered body habitus, leading to multiple puncture attempts and increased procedural complications. Anthropometric parameters may provide a simple and clinically useful method for predicting spinal needle depth.

Aim: To evaluate the relationship between anthropometric parameters and lumbar subarachnoid space depth in adults undergoing spinal anesthesia and to identify the most reliable predictor for use in imaging-guided and safe neuraxial procedures.

Materials and Methods: This prospective observational study was conducted among 100 adult patients undergoing elective below-umbilical surgeries under spinal anesthesia in a tertiary care teaching hospital. Anthropometric measurements including weight, height, body mass index (BMI), waist circumference, and arm circumference were recorded preoperatively. Spinal needle depth was measured intraoperatively at the L3–L4 intervertebral level using a standard midline approach with a 25G Quincke spinal needle. Pearson's correlation coefficient was used to assess the relationship between anthropometric variables and spinal needle depth.

Results: All anthropometric variables demonstrated statistically significant positive correlations with spinal needle depth ($p < 0.001$). Weight showed the strongest correlation ($r = 0.812$), followed by BMI ($r = 0.668$), waist circumference ($r = 0.666$), and arm circumference ($r = 0.643$). Height demonstrated the weakest correlation ($r = 0.444$). Increased body habitus was associated with greater depth to the subarachnoid space.

Conclusion: Anthropometric parameters significantly influence lumbar subarachnoid space depth, with body weight emerging as the strongest predictor. Incorporation of simple anthropometric assessment into routine preprocedural evaluation may improve the success rate of neuraxial procedures, facilitate imaging-guided interventions, and reduce complications associated with repeated puncture attempts.

Keywords: Anthropometry; Lumbar puncture; Spinal anesthesia; Subarachnoid block; Body mass index; Obesity; Neuraxial imaging; Ultrasound-guided procedures; Procedural safety.

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Introduction

Subarachnoid block remains one of the most frequently performed regional anesthetic techniques for lower abdominal, pelvic, perineal, and lower limb surgeries due to its rapid onset, cost-effectiveness, reliability, and favorable safety profile [1]. Successful spinal anesthesia depends on accurate placement of the spinal needle into the subarachnoid space. Traditionally, anesthesiologists rely on palpable surface anatomical landmarks to estimate needle trajectory and insertion depth [2]. However, these landmarks may become difficult to identify in individuals with obesity, altered spinal anatomy, or increased soft tissue thickness [3]. Failure to accurately predict lumbar skin-to-subarachnoid space depth (SSD) may result in multiple puncture attempts, prolonged procedure duration, patient discomfort, traumatic tap, post-dural puncture headache, epidural hematoma, and failed neuraxial block.[4] Such challenges are increasingly encountered in modern clinical practice due to the rising prevalence of overweight and obesity worldwide[5].

Recent advances in point-of-care ultrasonography and imaging-guided neuraxial procedures have improved the success rate of spinal and epidural interventions [6-7]. Nevertheless, imaging facilities may not always be readily available in resource-limited settings. Therefore, easily measurable anthropometric parameters may serve as practical bedside tools for estimating spinal needle depth and improving procedural planning [8].

Several studies have evaluated the association between body mass index (BMI), weight, and spinal needle depth, but comparatively fewer studies have comprehensively assessed additional anthropometric indicators such as waist circumference and arm circumference. Furthermore, the relative predictive strength of these variables remains incompletely understood.

The present study was undertaken to evaluate the relationship between multiple anthropometric parameters and lumbar subarachnoid space depth in adults undergoing spinal anesthesia and to identify the most clinically relevant predictor for safe neuraxial and imaging-guided procedures.

Aim and Objectives

Aim: To evaluate anthropometric predictors of lumbar subarachnoid space depth in adults undergoing spinal anesthesia.

Objectives

1. To determine the correlation between body weight and spinal needle depth.
2. To assess the relationship between BMI and spinal needle depth.
3. To evaluate the influence of waist circumference and arm circumference on spinal needle depth.
4. To identify the strongest anthropometric predictor of lumbar subarachnoid space depth.
5. To explore the clinical implications of anthropometric assessment in imaging-guided and safe neuraxial procedures.

Materials and Methods

Study Design: This prospective observational study was designed to evaluate the relationship between anthropometric parameters and lumbar skin-to-subarachnoid space depth (SSD) in adult patients undergoing spinal anesthesia.

The observational design was selected to assess naturally occurring variations in anthropometric characteristics and their influence on spinal needle depth without introducing any interventional modifications to standard clinical practice.

Study Setting: The study was conducted in the Department of Anesthesiology of a tertiary care teaching hospital equipped with facilities for elective surgical procedures and perioperative monitoring. All procedures and data collection were performed in the preoperative assessment area and operation theater complex under standardized institutional protocols.

Study Duration: The study was carried out over a period of six months from April 2025 to September 2025.

Study Population: The study population consisted of adult patients scheduled for elective below-umbilical surgeries under spinal anesthesia. A total of 100 patients meeting the eligibility criteria were consecutively recruited during the study period.

Sample Size: The sample size was determined based on previously published studies demonstrating statistically significant correlations between anthropometric variables and spinal needle depth. Considering an anticipated moderate-to-strong correlation coefficient, a sample size of 100 participants was considered adequate to achieve sufficient statistical power for correlation analysis while maintaining feasibility within the study duration.

Sampling Technique: A consecutive sampling method was employed. Eligible patients presenting during the study period and satisfying the inclusion criteria were enrolled after obtaining written informed consent.

Inclusion Criteria

Patients fulfilling all the following criteria were included in the study:

- Adult patients aged between 20 and 60 years
- Patients belonging to American Society of Anesthesiologists (ASA) physical status I–III
- Patients scheduled for elective below-umbilical surgical procedures under spinal anesthesia
- Patients willing to provide written informed consent

Exclusion Criteria

Patients with any of the following conditions were excluded from the study:

- Congenital or acquired spinal deformities such as scoliosis or kyphosis
- Previous spinal surgery
- Local infection at the puncture site
- Pregnancy
- Patients requiring paramedian or other non-midline spinal approaches

- Coagulopathy or anticoagulant therapy contraindicating spinal anesthesia
- Patients with neurological disorders affecting spinal anatomy
- Patients unwilling to participate in the study

Ethical Considerations: Prior approval was obtained from the Institutional Ethics Committee before initiation of the study. The study protocol adhered to the ethical principles outlined in the Declaration of Helsinki.

All participants were informed in detail regarding the purpose of the study, procedure involved, potential benefits, and confidentiality of collected information. Written informed consent was obtained from all participants before enrollment. Patient anonymity and data confidentiality were strictly maintained throughout the study.

Preoperative Assessment: All enrolled patients underwent detailed preanesthetic evaluation one day prior to surgery. Demographic data including age and sex were recorded. Baseline clinical examination and routine preoperative investigations were performed according to institutional protocols.

Anthropometric measurements were obtained by trained personnel using standardized techniques to minimize interobserver variability.

Anthropometric Measurements

Weight: Body weight was measured in kilograms using a calibrated digital weighing scale with the patient wearing light clothing and no footwear. Measurements were recorded to the nearest 0.1 kg.

Height: Height was measured in centimeters using a wall-mounted stadiometer with the patient standing erect barefoot, with heels together and head positioned in the Frankfurt horizontal plane. Measurements were recorded to the nearest 0.5 cm.

Body Mass Index: Body mass index (BMI) was calculated using the standard formula:

$$BMI = \frac{Weight\ (kg)}{Height\ (m)^2}$$

BMI values were expressed in kg/m².

Waist Circumference: Waist circumference was measured in centimeters using a nonstretchable measuring tape at the midpoint between the lower margin of the last palpable rib and the iliac crest at the end of normal expiration. Measurements were recorded to the nearest 0.1 cm.

Arm Circumference: Mid-upper arm circumference was measured at the midpoint between the acromion process and olecranon process of the nondominant arm using a flexible nonelastic measuring tape. Measurements were recorded in centimeters.

Spinal Anesthesia Procedure: On arrival in the operating room, standard monitoring including noninvasive blood pressure, pulse oximetry, and electrocardiography was instituted in all patients.

Intravenous access was secured using an appropriate intravenous cannula, and preloading with intravenous crystalloids was performed according to institutional protocol.

Patients were positioned in the sitting posture for the spinal procedure. Under strict aseptic precautions, the lumbar intervertebral spaces were identified by palpation of anatomical landmarks. Spinal anesthesia was administered at the L3–L4 intervertebral space using a midline approach with a 25-gauge Quincke spinal needle.

After successful puncture of the dura mater and confirmation of free flow of cerebrospinal fluid (CSF), the distance from the skin surface to the tip of the spinal needle was measured using a sterile ruler. This measurement represented the skin-to-subarachnoid space depth (SSD) and was recorded in centimeters.

All spinal procedures were performed by experienced anesthesiologists to minimize operator-related variability.

Outcome Measure: The primary outcome measure was lumbar skin-to-subarachnoid space depth (SSD).

Secondary outcome measures included correlation of SSD with:

- Body weight
- Height
- Body mass index
- Waist circumference
- Arm circumference

Data Management: All collected data were entered into a predesigned proforma and subsequently transferred to Microsoft Excel spreadsheets for data cleaning and coding prior to statistical analysis.

Statistical Analysis: Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 25.0.

Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages.

The relationship between anthropometric variables and spinal needle depth was assessed using Pearson's correlation coefficient (r). Correlation strength was interpreted as follows:

- 0.00–0.19: Very weak

- 0.20–0.39: Weak
- 0.40–0.59: Moderate
- 0.60–0.79: Strong
- 0.80–1.00: Very strong

A p-value less than 0.05 was considered statistically significant.

Results

Demographic Characteristics: A total of 100 patients were included in the study. Among them, 39 were males and 61 were females. The age range of participants was 20–60 years.

The mean body weight was 66.11 ± 13.43 kg and the mean height was 159.95 ± 8.53 cm. The average BMI was 25.82 ± 4.64 kg/m².

The mean waist circumference was 98.04 ± 10.13 cm and the mean arm circumference was 31.53 ± 4.73 cm.

Table 1: Demographic and Anthropometric Characteristics of Study Participants

Variable	Value
Total participants	100
Male	39 (39%)
Female	61 (61%)
Age range	20–60 years
Mean weight (kg)	66.11 ± 13.43
Mean height (cm)	159.95 ± 8.53
Mean BMI (kg/m²)	25.82 ± 4.64
Mean waist circumference (cm)	98.04 ± 10.13
Mean arm circumference (cm)	31.53 ± 4.73

Correlation between Anthropometric Variables and Spinal Needle Depth: All studied anthropometric variables showed statistically significant positive correlations with spinal needle depth.

Weight demonstrated the strongest correlation with spinal needle depth ($r = 0.812$, $p < 0.001$), indicating a strong linear relationship between increasing body weight and greater needle insertion depth. BMI also showed a moderate-to-strong positive correlation ($r = 0.668$, $p < 0.001$), suggesting that generalized adiposity significantly affects subarachnoid space depth.

Waist circumference exhibited a similar correlation strength ($r = 0.666$, $p < 0.001$), indicating the influence of central obesity on neuraxial depth.

Arm circumference showed a moderate positive correlation ($r = 0.643$, $p < 0.001$), whereas height demonstrated the weakest correlation ($r = 0.444$, $p < 0.001$).

Table 2: Correlation between Anthropometric Variables and Spinal Needle Depth

Parameter	Pearson Correlation (r)	p-value	Interpretation
Weight	0.812	<0.001	Strong positive correlation
BMI	0.668	<0.001	Moderate-to-strong positive correlation
Waist circumference	0.666	<0.001	Moderate-to-strong positive correlation
Arm circumference	0.643	<0.001	Moderate positive correlation
Height	0.444	<0.001	Weak-to-moderate positive correlation

Interpretation of Findings: The findings indicate that body weight is the most reliable anthropometric predictor of lumbar subarachnoid space depth.

Measures related to adiposity, including BMI and waist circumference, also demonstrated significant predictive value. In contrast, height contributed relatively less to the estimation of spinal needle depth.

These observations suggest that increased adiposity contributes to greater soft tissue thickness in the lumbar region, thereby increasing the depth required to reach the subarachnoid space.

Discussion

The present study evaluated the relationship between anthropometric variables and lumbar subarachnoid space depth in adults undergoing spinal anesthesia. The findings demonstrated statistically significant positive correlations between all studied anthropometric parameters and spinal needle depth [9-10].

Among all variables assessed, body weight emerged as the strongest predictor of spinal needle depth, with a Pearson correlation coefficient of 0.812. This observation suggests that increased body mass contributes substantially to greater soft tissue thickness and increased distance from the skin to the subarachnoid space [11-12].

The results are consistent with previous studies conducted by Bonadio et al., Prakash et al., and Ravi et al., which demonstrated significant associations between body weight and neuraxial depth. The strong predictive value of weight may be attributed to its direct relationship with subcutaneous fat accumulation and paraspinal soft tissue mass [13-14].

Body mass index also demonstrated a moderate-to-strong positive correlation with spinal needle depth. Although BMI is commonly used as a marker of obesity, it has inherent limitations because it does not distinguish between lean body mass and adipose tissue distribution. This may explain why BMI showed a comparatively lower predictive value than body weight alone [15].

Waist circumference exhibited a significant positive correlation with spinal needle depth, emphasizing the importance of central adiposity in determining neuraxial anatomy. Central obesity may increase lumbar soft tissue thickness and alter spinal landmark identification, thereby complicating neuraxial procedures [16].

Similarly, arm circumference showed a moderate positive correlation with spinal needle depth. Arm circumference reflects peripheral adiposity and overall body habitus, which may indirectly influence spinal needle insertion depth [17]. Height demonstrated the weakest correlation among all variables studied. This finding suggests that longitudinal body dimensions contribute less significantly to spinal needle depth compared with mass-related anthropometric measurements [12,16].

The findings of the present study have important implications for anesthesiology, radiology, and community medicine practice [15]. In recent years, ultrasound-guided neuraxial procedures have gained increasing popularity because of their ability to improve procedural accuracy and reduce complications [10,15]. Anthropometric predictors may complement imaging-guided techniques by assisting clinicians in selecting appropriate needle length and estimating expected spinal depth before the procedure [8,14].

In resource-limited healthcare settings where routine ultrasound guidance may not be available, simple anthropometric measurements may serve as valuable bedside tools for improving procedural planning and reducing failed attempts.

From a public health perspective, the rising prevalence of obesity worldwide is expected to increase the frequency of technically difficult neuraxial procedures. Therefore, identification of reliable anthropometric predictors may contribute to safer procedural practices and improved patient outcomes.

Limitations

The study had certain limitations. The sample size was relatively modest and the study was conducted at a single tertiary care center.

Ultrasound confirmation of spinal depth was not performed. Future multicentric studies incorporating imaging-based assessment may provide more robust predictive models.

Clinical Implications

- Weight can be used as a practical bedside predictor of spinal needle depth.
- Anthropometric assessment may reduce multiple puncture attempts.
- Preprocedural estimation may improve patient comfort and procedural safety.
- Findings may support ultrasound-guided and fluoroscopy-guided neuraxial procedures.
- The study has relevance for anesthesiology, radiology, and community medicine practice.

Conclusion

The present study demonstrates that anthropometric parameters significantly influence lumbar subarachnoid space depth in adults undergoing spinal anesthesia. Among all studied variables, body weight emerged as the strongest and most clinically reliable predictor of spinal needle depth.

Simple anthropometric measurements such as weight, BMI, waist circumference, and arm circumference may provide valuable preprocedural information that can improve the success of neuraxial procedures and minimize complications associated with repeated puncture attempts.

The findings also highlight the potential utility of anthropometric assessment in imaging-guided neuraxial interventions, particularly in obese patients and resource-limited healthcare settings.

Further multicentric studies integrating ultrasound-based spinal depth measurements are recommended to develop standardized predictive models for routine clinical practice.

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