Research Square

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Anthropometric Predictors of Total Bowel Length in Metabolic and Bariatric Surgery: A Multicenter Cohort of 300 Patients

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Abstract

Introduction:

Total bowel length (TBL) shows marked inter-individual variability and may influence the functional impact of standard limb lengths in metabolic and bariatric surgery (MBS). This variability may influence weight-loss, metabolic outcomes and postoperative nutritional risk. To describe intraoperative TBL in patients undergoing laparoscopic MBS and evaluate anthropometric and clinical variables as predictors of TBL.

Methods

We conducted a multicenter retrospective analysis of prospectively maintained databases from three MBS centers in Portugal and Brazil. Adults undergoing primary laparoscopic bariatric procedures with intraoperative TBL measurement were included. TBL was measured from the ligament of Treitz to the ileocecal valve using graduated laparoscopic graspers and a non-tension running-bowel technique. Associations between TBL and clinical variables were assessed using bivariate analyses and multivariable linear regression.

Results

The study included 300 patients; mean age was 44.7 ± 11.2 years and 250 patients (83.3%) were female. Mean TBL was 638.5 ± 105.8 cm, with a wide range from 360 to 990 cm. In bivariate analyses, TBL was positively associated with age and height and negatively associated with weight, BMI and abdominal circumference. In multivariable models, height remained independently associated with longer TBL. BMI and abdominal circumference were independently associated with shorter TBL when analyzed in separate models.

Conclusion

TBL varies widely among MBS patients. Height was independently associated with longer TBL, whereas adiposity metrics were associated with shorter TBL. These findings support intra-operative bowel measurement to define strategies and optimize outcomes and reduce nutritional risk.

Key Points

• Total bowel length varied widely (360–990 cm) across 300 MBS patients.

• Taller patients had significantly longer total bowel length.

• Higher BMI and abdominal circumference were linked to shorter bowel length.

• Findings support intraoperative bowel measurement to tailor limb lengths.

Introduction

Bariatric and metabolic surgery (MBS) is the most effective long-term treatment for severe obesity and its metabolic comorbidities.[1] In the previously called mixed or malabsorptive procedures, an old classification, predefined limb lengths excluded a portion of small bowel from alimentary continuity; therefore, the relationship between limb lengths and total small bowel length is relevant to the absorptive capacity, nutritional risk[2] and to the metabolic impact.

The Total Bowel Length (TBL) shows marked inter-individual variability in living humans, with wide ranges reported across cohorts.[2] Moreover, the existing literature remains heterogeneous, particularly regarding measurement methodology, and no single standardized approach has been universally adopted.[2, 3, 4, 5] This variability becomes particularly important when surgeons apply standard limb lengths for procedures such as Roux-en-Y gastric bypass (RYGB), one anastomosis gastric bypass (OAGB), transit bipartition variants and duodenal switch derivatives, where the length of the common channel and the bypassed segments may influence both weight-loss, metabolic outcomes and postoperative nutritional risk.[2, 6]

A major challenge is that TBL measurement itself is method-sensitive. The degree of traction (stretched vs non-stretched bowel), timing during the operation, and the surgical approach (open vs laparoscopic) can meaningfully affect the measured length.[2] Moreover, laparoscopic measurement is vulnerable to inter-operator variability and may be inaccurate without robust standardization.[7–10] These methodological issues likely explain part of the inconsistency in published associations between TBL and anthropometric predictors. While some studies report correlations (often modest) with height and other measures, others conclude that clinical and anthropometric variables have limited practical predictive value for TBL, with multivariable models explaining only a small fraction of the observed variance.[2, 4, 5]

Despite these uncertainties, the clinical implications remain compelling. Nutritional complications after MBS, although multifactorial, are clinically relevant and require systematic prevention and management strategies.[6] Additionally, tailoring limb lengths relative to TBL has been proposed as a means to optimize the trade-off between effectiveness and nutritional safety, with early reports suggesting feasibility and potential benefit in selected settings.[11] Yet, multicenter real-world data describing TBL distributions measured during laparoscopic MBS, together with associations with anthropometrics and comorbidity profiles, remain scarce.

The aim of this study was to describe TBL in patients undergoing laparoscopic bariatric procedures. Our secondary aim was to evaluate the possible relationship between demographic, anthropometric and clinical factors and TBL.

Methods

Study design and setting

We conducted a multicenter retrospective analysis of prospectively maintained databases from three metabolic and bariatric surgery (MBS) centers in Portugal and Brazil (two centers in Portugal and one in Brazil). The study included patients undergoing laparoscopic bariatric surgery with TBL measurement between January 2022 and September 2025 at one Portuguese center and between May 2019 and February 2026 at the second Portuguese center and at the Brazilian center.

Inclusion/exclusion criteria

Eligible patients were adults (> 18 years old) undergoing primary laparoscopic bariatric procedures with intraoperative measurement of TBL. Patients were excluded if they had extensive intra-abdominal adhesions or a history of prior small bowel resection and/or did not have intraoperative TBL measurement recorded.

Ethics

This study was conducted in accordance with the Declaration of Helsinki and applicable data protection regulations. Given the retrospective nature of the study informed consent was waived. This was a non-interventional study, and no aspect of patient care or treatment was modified for the purpose of this analysis.

Surgical procedures

The following procedures were included: metabolic Roux-en-Y Gastric Bypass (mRYGB), Long Pouch Gastric Bypass (LPGB), One Anastomosis Gastric Bypass (OAGB), Single Anastomosis Duodeno-Ileal Bypass with Sleeve Gastrectomy (SADI-S), Transit Bipartition (TB) and One Anastomosis Transit Bipartition (OATB).

Intraoperative measurement of total small bowel length

TBL was defined as the length of jejunum and ileum between the ligament of Treitz and the ileocecal valve. Intraoperatively, TBL was measured using graduated laparoscopic graspers marked every 5 cm, employing a standardized “running bowel” technique without applying tension to the mesentery or bowel. Depending on the operative workflow and procedure performed, measurement was conducted in an antegrade (ligament of Treitz to ileocecal valve) or retrograde direction (ileocecal valve to ligament of Treitz), while targeting the same anatomical endpoints. At one participating center, intravenous

butylscopolamine was routinely administered at the beginning of the procedure before bowel measurement, as part of the local perioperative protocol.

Measurements were performed prior to any intestinal division or anastomosis. In each center, TBL was measured by the operating lead surgeon.

Variables and definitions

Collected variables included sex, age, country of birth, weight, height, body mass index (BMI), abdominal circumference, comorbidities (type 2 diabetes mellitus, hypertension, dyslipidemia), procedure type and TBL.

Comorbidities were defined based on preoperative clinical assessment and objective measurements and/or treatment: hypertension by measured blood pressure and/or antihypertensive therapy; dyslipidemia by lipid profile abnormalities and/or lipid-lowering therapy; and type 2 diabetes mellitus by HbA1c values and/or use of glucose-lowering medication.

Statistical analysis

Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as absolute and relative frequencies. Comparisons of means between two groups were performed using Student's t-test, and comparisons among three or more groups using analysis of variance (ANOVA), with Tukey's post-hoc test when appropriate. Comparisons of proportions were conducted using Pearson's chi-square test or Fisher's exact test, as appropriate. Associations between continuous variables were assessed using Pearson's correlation coefficient.

To adjust for potential confounding, multivariable linear regression was performed, reporting unstandardized regression coefficients (β) with 95% confidence intervals (95% CI). Multicollinearity was assessed using the variance inflation factor (VIF); VIF values greater than 5 were considered to be indicative of substantial multicollinearity. Because BMI and abdominal circumference showed high VIF, these variables were analyzed in separate regression models.

Statistical significance was set at a two-sided p-value < 0.05. Analyses were performed using SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA).

Results

The study included 300 participants, in whom demographic, anthropometric, clinical, and surgical characteristics were evaluated. The mean age was 44.7 ± 11.2 years, and 250 patients (83.3%) were female. Significant differences were observed between patients from Brazil and Portugal (Table 1). In the Brazilian cohort, the mean age was significantly higher than in the Portuguese cohort (52.2 ± 11.2 vs. 44.0 ± 11.0 years, $p < 0.001$), and the proportion of men was also significantly higher (64.0% vs. 12.4%, $p < 0.001$). Mean weight and BMI were significantly higher in Portugal ($p = 0.004$ and $p < 0.001$,

respectively), whereas height was significantly higher in Brazil ($p < 0.001$). Accordingly, higher BMI categories were more frequent in Portugal ($p < 0.001$). The prevalence of type 2 diabetes mellitus was significantly higher in Brazil ($p < 0.001$).

The more common surgical procedures in Portugal were OAGB and OATB and in Brazil, the most common surgical procedure was TB (45.1% and 32.3% vs 76.0%, $p < 0.001$).

Table 1
Demographic, anthropometric, clinical, and surgical characteristics of participants (n = 300).

Variable	Total	Portugal	Brazil	p
	n = 300 (100%)	n = 275 (91.7%)	n = 25 (8.3%)	
Age (years), mean ± SD	44.7 ± 11.2	44.0 ± 11.0	52.2 ± 11.2	< 0.001
Sex, n (%)				< 0.001
Male	50 (16.7)	34 (12.4)	16 (64.0)	
Female	250 (83.3)	241 (87.6)	9 (36.0)	
Anthropometrics, mean ± SD				
Weight (kg)	118.1 ± 26.4	119.4 ± 26.3	103.6 ± 22.7	0.004
Height (m)	1.64 ± 0.09	1.64 ± 0.09	1.70 ± 0.10	< 0.001
BMI (kg/m²)	43.7 ± 8.7	44.4 ± 8.4	35.7 ± 7.9	< 0.001
Abdominal circumference (cm)	125.8 ± 17.2 (n = 176)	125.7 ± 17.2 (n = 172)	128.8 ± 23.2 (n = 4)	0.728
BMI category, n (%)				< 0.001
30–39	119 (39.7)	98 (35.6)	21 (84.0)*	
40–49	104 (34.7)	102 (37.1)*	2 (8.0)	
≥50	77 (25.7)	75 (27.3)*	2 (8.0)	
Abdominal circumference category, n (%)				1.000
Appropriate for BMI	43 (24.4)	42 (24.4)	1 (25.0)	
Elevated for BMI	133 (75.6)	130 (75.6)	3 (75.0)	
Comorbidities, n (%)				
Hypertension	99 (33.0)	86 (31.3)	13 (52.0)	0.059
Dyslipidemia	98 (32.7)	90 (32.7)	8 (32.0)	1.000
Type 2 diabetes	56 (18.7)	36 (13.1)	20 (80.0)	< 0.001
Procedures, n (%)				< 0.001

Variable	Total n = 300 (100%)	Portugal n = 275 (91.7%)	Brazil n = 25 (8.3%)	p
mRYGB	15 (5.0)	15 (5.5)	0 (0.0)	
LPGB	12 (4.0)	11 (4.0)	1 (4.0)	
OAGB	127 (42.3)	124 (45.1)*	3 (12.0)	
SADI-S	34 (11.3)	33 (12.0)	1 (4.0)	
TB	22 (7.3)	3 (1.1)	19 (76.0)*	
OATB	90 (30.0)	89 (32.3)*	1 (4.0)	

* Statistically significant association by adjusted residuals at a 5% significance level.

Furthermore, the correlation of TBL and the categorical variables were evaluated (Table 2). Bivariate analyses were performed to assess correlations between TBL and continuous variables (Table 3). Overall, greater total bowel length was significantly observed among patients with BMI 30–49 kg/m² ($p < 0.001$).

Table 2
Total bowel length (centimeters) in the overall sample and by categorical variables (n = 300).

Variable	Mean	Median	Minimum	Maximum	SD	p
Overall sample	638.5	630	360	990	105.8	—
Country of birth						0.063
Portugal	635.1	630	360	990	106.2	
Brazil	676.2	710	500	850	94.8	
Sex						0.176
Male	657.0	680	360	850	107.4	
Female	634.8	630	370	990	105.3	
BMI category						< 0.001
30–39	668.6	680	370	990	107.2	
40–49	638.7	630	400	950	106.3	
≥50	591.8	600	360	800	85.2	
Abdominal circumference category						0.058
Appropriate for BMI	679.0	680	370	990	113.5	
Elevated for BMI	644.6	630	360	930	99.0	
Type 2 diabetes						0.270
Yes	652.6	655	460	850	100.6	
No	635.3	630	360	990	106.9	
Hypertension						0.105
Yes	652.6	650	360	900	104.8	
No	631.6	620	370	990	105.8	
Dyslipidemia						0.903
Yes	639.6	620	450	990	103.1	
No	638.0	635	360	990	107.3	

 Within BMI categories, values sharing the same superscript letter do not differ by Tukey's test at a 5% significance level.

In bivariate analyses (Table 3), TBL was positively associated with age ($p = 0.049$) and height ($p = 0.001$) and negatively associated with weight ($p = 0.010$), BMI ($p < 0.001$), and abdominal circumference ($p = 0.026$).

Table 3
Association between small bowel length and continuous variables in the overall sample (n = 300).

Total bowel length versus	Pearson correlation coefficient	p-value
Age	0.114	**0.049**
Weight	-0.149	**0.010**
Height	0.187	**0.001**
BMI	-0.267	**< 0.001**
Abdominal circumference	-0.168	**0.026**

Two multivariable models were fitted to address multicollinearity between BMI and abdominal circumference, because abdominal circumference was available in only 176 participants (Table 4). Model 1 included age, sex, height, BMI, country of birth, and hypertension. Model 2 included the same variables, replacing BMI with abdominal circumference. In both models, height was independently associated with small bowel length. For each additional centimeter of height, mean TBL increased by 2.49 cm (Model 1) and 2.42 cm (Model 2). In Model 1, BMI was independently associated with small bowel length, with a mean decrease of 2.68 cm per 1 kg/m² increase in BMI. In Model 2, abdominal circumference was independently associated with small bowel length, with a mean decrease of 1.15 cm per 1 cm increase.

Table 4
Multivariable linear regression analyses of factors independently associated with TBL.

Variables	Model 1 (n = 300) β (95% CI)	p	Model 2 (n = 176) β (95% CI)	p
Age (years)	0.57 (-0.64 to 1.78)	0.354	0.47 (-1.09 to 2.04)	0.550
Male sex	16.6 (-17.3 to 50.6)	0.336	16.1 (-78.8 to 46.7)	0.897
Height (cm)	2.49 (0.69 to 4.28)	**0.007**	2.42 (0.11 to 4.82)	**0.049**
BMI (kg/m²)	-2.68 (-4.17 to -1.20)	**< 0.001**	—	—
Country of birth (Portugal)	-4.43 (-51.9 to 43.0)	0.854	-6.73 (-109 to 96.2)	0.897
Hypertension	15.4 (-11.0 to 41.8)	0.252	15.2 (-19.9 to 50.3)	0.394
Abdominal circumference (cm)	—	—	-1.15 (-2.11 to -0.19)	**0.020**

The regression findings were supported by a graphical exploration of continuous associations. In scatterplots of total bowel length against BMI and abdominal circumference (Figs. 1 and 2), higher adiposity metrics were associated with shorter bowel length, with a clear negative linear trend across the study population. Conversely, height showed a positive association with bowel length (Fig. 3), consistent with body size, a related anatomical variation. Given the correlation between BMI and abdominal circumference, these variables were evaluated in separate multivariable models; nevertheless, the direction of effects observed in the figures was concordant with the adjusted analyses.

Discussion

The main findings of our study were inter-individual variability in TBL, height was consistently and independently associated with longer TBL, whereas BMI and abdominal circumference were inversely associated with TBL. Significant demographic and clinical differences were also observed between the Portuguese and Brazilian cohorts: patients from Brazil were older, more frequently male, taller and had a higher prevalence of type 2 diabetes, whereas patients from Portugal had higher mean weight and BMI. The distribution of surgical procedures also differed between countries, with OAGB and OATB being more frequent in Portugal and TB being more frequent in Brazil. These findings reinforce that TBL should be interpreted in the context of patient characteristics, population differences, and surgical practice.

Bekheit et al. (2020)[5] studied 606 individuals and reported small bowel lengths between 2.5 and 13 meters, illustrating the wide anatomical variability in living humans. A key explanation for discrepancies across studies is methodological heterogeneity, particularly the tension applied to the bowel and the approach used (laparoscopic vs open). Tacchino et al. (2015)[2] showed that measured length differs substantially between “stretched” and “non-stretched” measurements, and that laparoscopic measurements can systematically differ from laparotomy, emphasizing the need to specify technique and interpret values within that context.

Laparoscopic measurement is also prone to inter-operator variability. Gazer et al. (2017)[7] showed that laparoscopic bowel length assessment is inaccurate and variable, underscoring the need for a reproducible standardized technique. In an ex vivo experiment with marked graspers, Slagter et al. (2022)[8] quantified intra- and inter-individual variability among surgeons and trainees, supporting that operator and method contribute meaningfully to dispersion in TBL values. Instrument marking improves precision in laparoscopic length estimation.[10] Collectively, these studies emphasize that methodological factors must be considered when comparing TBL across cohorts and interpreting correlations with patient characteristics.[2, 8, 9, 10]

In our study, TBL was measured using graduated laparoscopic graspers (5-cm markings), employing a running-bowel technique without applying tension and prior to any intestinal division. This standardized intent should improve internal comparability. Nonetheless, measurements were performed by the lead surgeon at each center, which reflects real-world practice but may still introduce center effects related to subtle differences in handling or interpretation of “no tension”.[2, 7, 8]

Across available evidence, height is the most consistently reported anthropometric correlate of TBL. Tacchino et al. (2015)[2] found that, in multivariable models including sex, age, height, and weight, height was the only independent predictor of small bowel length, though the explained variance was modest. Teitelbaum et al. similarly reported that demographic predictors explain only a limited proportion of TBL variation.[4] In a large bariatric cohort, Karimi Behnagh et al. (2024)[3] reported only weak associations and highlighted that anthropometric models explain only a small proportion of TBL variability, with height being the most reproducible. Our findings are consistent with this evidence: height remained independently associated with TBL in both models, supporting that body size contributes to anatomical bowel length while simple anthropometric models cannot fully explain the substantial interindividual variability.

Population differences may also contribute to variation in reported bowel length.[12] Khake et al. (2019)[13], in an anatomical study in an Indian population, found mean small bowel lengths lower than those in many Western series, suggesting ethnicity and population characteristics should be considered when interpreting TBL. Previous Brazilian studies further illustrate this heterogeneity. Nassif et al. (2009)[14] evaluated 30 patients undergoing MBS, measuring the small bowel from the duodenojejunal flexure to the ileocecal junction with a 10-cm marked clamp under minimal tension, reporting a mean of 528.7 cm and no correlation between BMI and TBL. This contrasts with our inverse BMI–TBL association and may reflect differences in sample size, population, technique and methodology. More recently, Daronch et al. (2015)[15] reported a mean TBL of 5.02 m in patients undergoing Fobi-Capella surgery and a directly proportional relationship between small bowel length and weight loss. Although not establishing causality, these findings support the hypothesis that individual bowel length may contribute to variability in bariatric outcomes.

Finally, pharmacological and anesthetic factors may also influence bowel tone and motility during intraoperative measurement. At one participating center, intravenous butylscopolamine was routinely administered at the beginning of the procedure according to local protocol. Although this may theoretically influence motility, measurements were performed using a standardized non-tension running-bowel technique, and this factor should be considered when comparing results across studies.

The most clinically important implication of TBL variability is that fixed (“standard”) limb lengths can represent very different fractions of total absorptive capacity across individuals. Tacchino et al. (2015)[2] noted that a meaningful proportion of patients may have relatively short TBL and therefore be at risk of nutritional consequences when undergoing procedures that exclude long segments, particularly malabsorptive and revisional operations. Conversely, in patients with very long TBL, the same fixed limb lengths represent a smaller excluded fraction, potentially reducing malabsorptive effect and durability where limb lengths are central to efficacy.[2, 12] Tailoring limb lengths relative to TBL has been proposed to balance efficacy and nutritional safety; Komaei et al. (2019)[11] reported preliminary results suggesting that tailoring biliopancreatic limb length to a fraction of TBL may reduce nutritional deficiencies while maintaining weight loss compared with a fixed limb length.

Key limitations of this study include the retrospective design, exclusion of patients without recorded TBL (selection bias) and the absence of formal inter-operator reliability assessment, which is particularly relevant given documented measurement variability in laparoscopic settings. Additionally, we did not assess postoperative nutritional or weight-loss outcomes in relation to TBL, precluding direct conclusions about clinical endpoints. Strengths of this study include a multicenter bariatric cohort, standardized anatomical endpoints (ligament of Treitz to ileocecal valve), measurement performed prior to intestinal division, and the use of marked instruments with a running-bowel approach.

Conclusions

TBL varies considerably among bariatric patients. In this study, taller individuals were found to have a longer TBL, whereas increasing adiposity was found to be independently associated with a shorter TBL. These findings reinforce the idea that standardized intestinal limb lengths represent different proportions of the total absorptive bowel. Therefore, TBL should be measured in order to implement strategies that can reduce the risk of nutritional complications in patients with a shorter bowel length, and to prevent suboptimal weight loss or metabolic outcomes in patients with a longer bowel length. Further prospective studies with standardized TBL measurement and post-operative outcome assessment are required to determine whether measuring TBL improves long-term safety and efficacy.

Declarations

Conflicts of Interest: The authors declare no conflict of interest.

Author Contributions: All authors contributed to the study conception and design, methodology, and formal analysis. The first author prepared the original draft. All authors contributed to review and editing, and all authors read and approved the final version of the manuscript.

Funding: None.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This was a retrospective, non-interventional multicenter study using routinely collected clinical data; no aspect of patient care or treatment was modified for the purpose of this analysis. For this type of study formal consent is not required.

Informed Consent: Given the retrospective nature of the study, informed consent was waived by the appropriate ethics committee. No identifying information about individual participants is included in this article.

Data Availability: The datasets generated and analyzed during the current study are not publicly available due to privacy restrictions concerning patient data, but are available from the corresponding author on

reasonable request.

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Figures

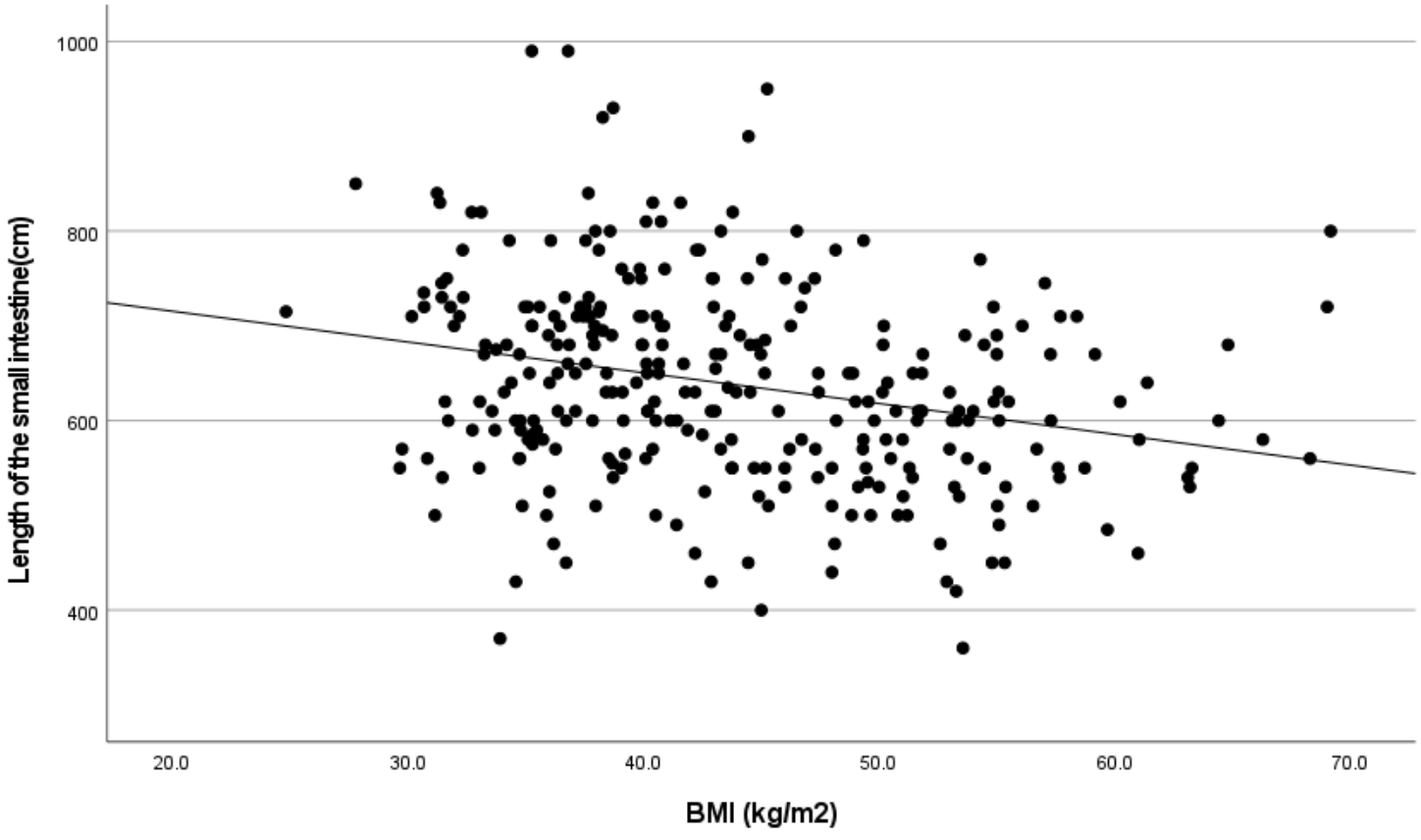


Figure 1

Association between BMI and TBL in the overall study population.

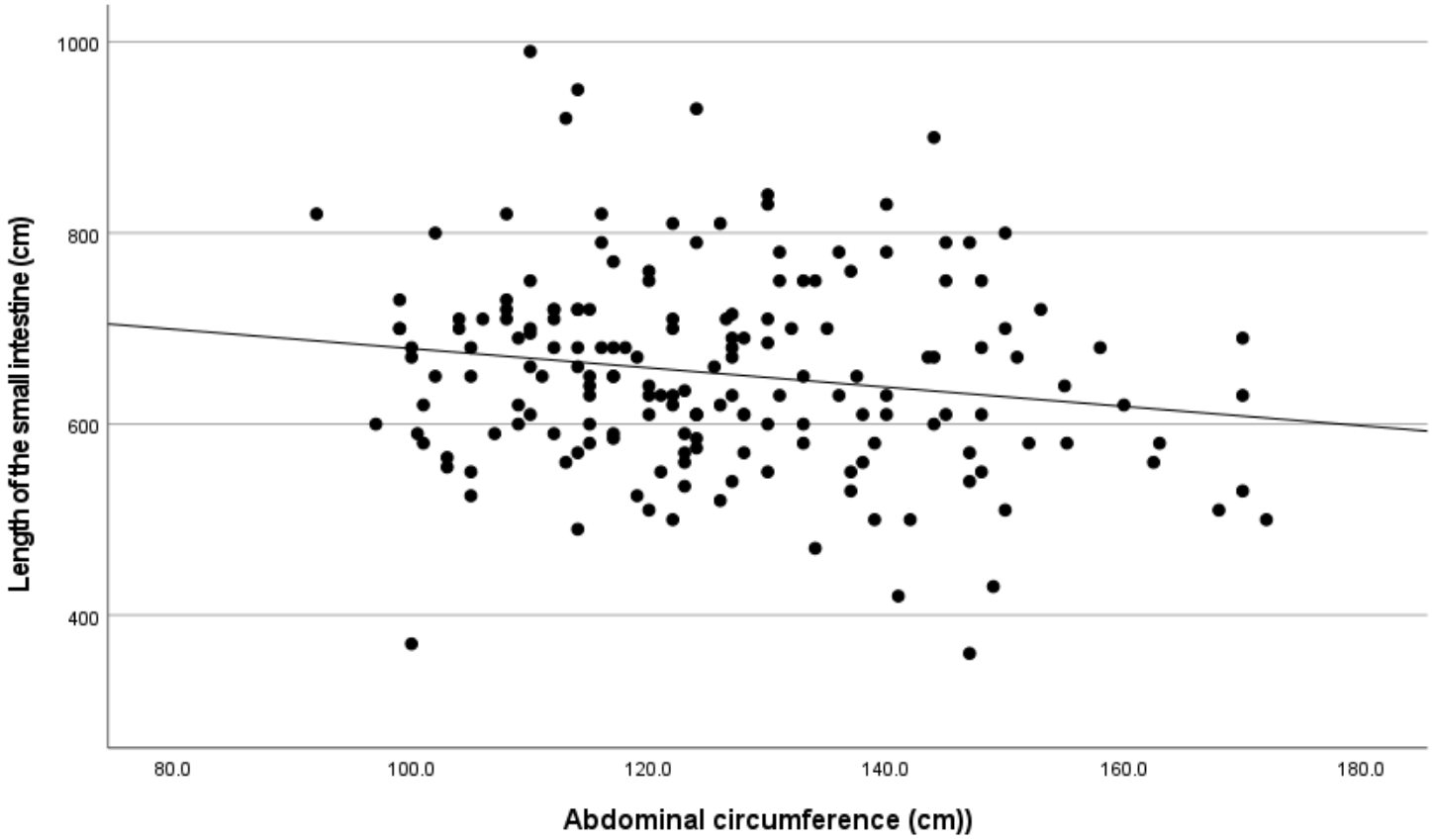


Figure 2

Association between abdominal circumference and TBL in the overall study population.

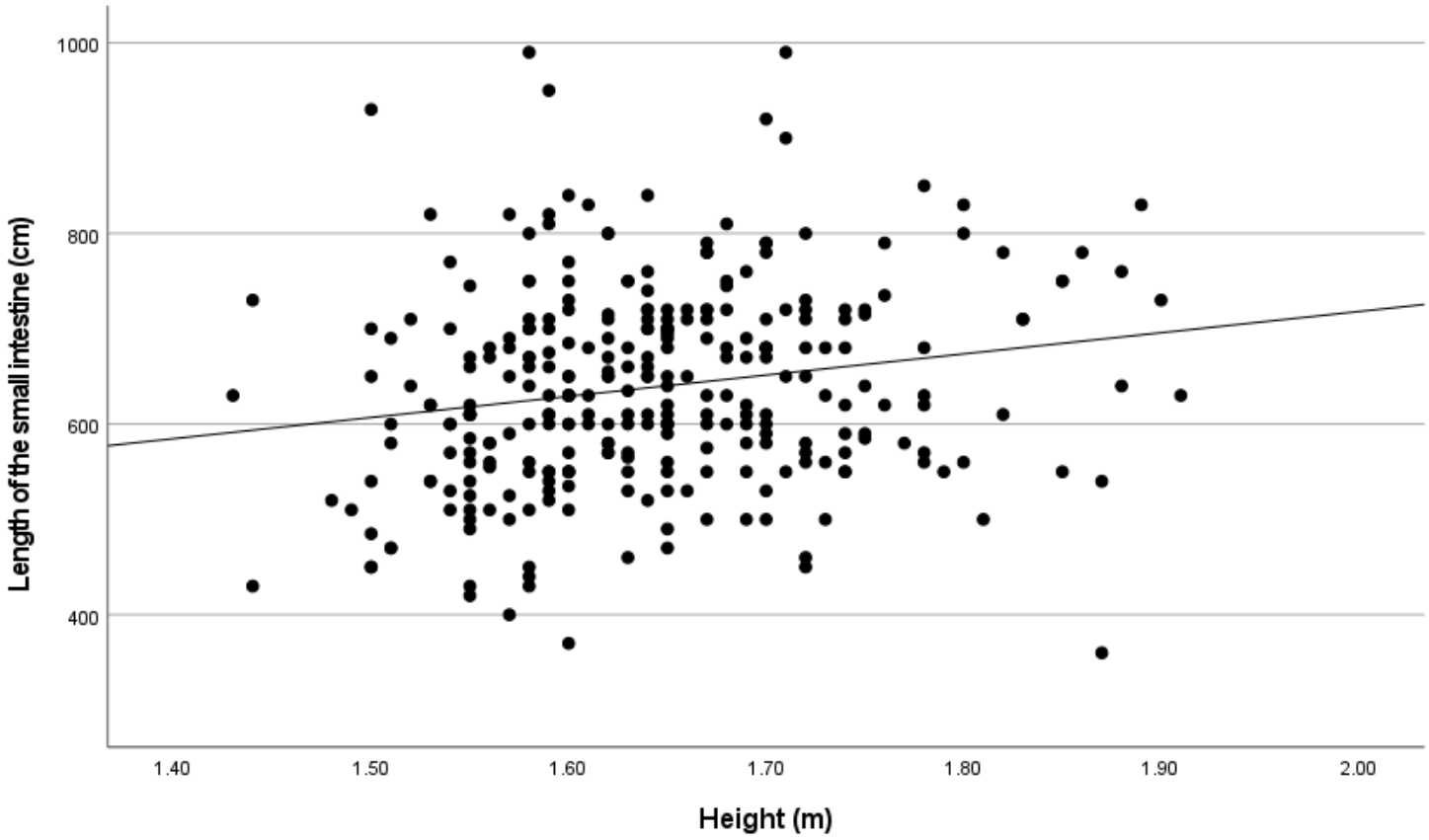


Figure 3

Association between height and TBL in the overall study population.