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Variability of small bowel length: Correlation with height, waist circumference, and gender

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Abstract

First year medical students are always under impression that the small bowel length is almost 6 meters or more, as they have studied it in their textbooks; and when they try to measure, it does not always correspond with it. Knowledge of variable lengths of small bowel is important not just for an academic interest but it has implications in different surgical and other procedures related with small bowel length. In the present study, the height, waist circumference, and small bowel length was measured in 111 formalin-fixed cadavers (73 males and 38 females) from Indian population, and correlation of small bowel length to height, waist circumference and gender was searched, which showed small bowel length of 218-500 cm with a mean of 336.54 cm; the small bowel was significantly longer in males than that in females (($p<0.05$). Height and small bowel length showed moderately positive correlation with each other while waist circumference and small bowel length showed a strong positive reciprocal correlation. Linear regression analysis showed statistically significant relationship for both. Central obesity showed no correlation with small bowel length in males (R=0.049) and weak correlation in females (R=0.281). Small bowel length/height ratio as well as small bowel length/waist circumference ratio did not show statistically significant differences in either gender. Small bowel length in Indian population was found to be less than that reported in western studies or medical textbooks - a relevant finding - to be considered in application of different procedures and surgery of small intestine in Indian individuals.

Key words

Intestine, small bowel length, height, waist circumference, bariatric surgery, resection.

Introduction

Even though variability of small intestine has been known to researchers for many years, in traditional standard medical textbooks the small bowel length has been mentioned as around 6-7 meters (Williams and Warwick, 1980; Snell, 2012; Drake et al., 2015). First year medical students are always under impression that the small bowel length is almost 6 meters or more, and when they try to measure it the result does not always correspond with that expectation. In a research article of 1955, Underhill (1955) mentioned that the medical students had been unaware of such a deviation. This is also true even today.

The small bowel is a part of gastrointestinal tract from pyloric sphincter to the iliocecal junction, which comprises duodenum, jejunum and ileum. Duodenum is a

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fixed part with the length of 20-25 cm, while the remaining small bowel is free with total length of 3-7 meters in the living adults (Gabe, 2008). Research workers have considered many factors - like height, weight, obesity, age, gender etc. - that may have association with the variation in length of small bowel, but there is no uniformity of results in these studies (Guzman et al., 1977; Zhu et al., 2002; Hosseinpour and Behdad, 2008; Minko et al., 2014). In the present study the length of small bowel was measured in formalin-fixed adult cadavers of Indian origin. An attempt was made to correlate the small bowel length (SBL) with the height (H), waist circumference (WC) and sex of an individual. Knowledge of variable length of small bowel is not just for an academic interest but is important in massive resection of small bowel, intestinal bypass surgery, enteroscopy, magnetic resonance enterography, bariatric surgery or other types of surgery related to small bowel length. Studies of small bowel length (SBL) will provide a better approach for such procedures and surgery.

Materials and methods

The present study was conducted during a period of 7 years on 120 formalin-fixed cadavers in three medical colleges in Maharashtra State of India between 2010 and 2017. Out of the total 120 cadavers, 111 (73 males, 38 females) were included. The reasons for exclusion were history of surgery on gastrointestinal tract, resected bowel, subhepatic cecum and adhesions of small bowel. Parameters like age or ethnicity were not considered for correlation with SBL because the age group was between 60-80 years and all individuals in the present study were from the Maharashtra State, a state located in central India, which is supposed to have individuals that have a mixture of Indo-Aryan, Dravidian, and Mongolian ethnicities (Mujumder, 2001).

The measurement of small bowel length (SBL) was taken from duodenojejunal junction to ileocecal junction along the antimesenteric border immediately after removing the duodenum and jejunum, and *in situ* for the duodenum. Body height (H) was taken from cranial vertex to heel and waist circumference (WC) was taken at the level of umbilicus (WHO, 2008) by a flexible measuring tape. All the parameters were recorded in centimeters.

Individuals with central obesity were defined as males with WC $\geq$ 90 and females with WC $\geq$ 80 (Martin et al., 2003; Misra et al., 2006; Ahmad et al., 2016).

Student's t-test for independent variables and Mann-Whitney U test were used to evaluate comparisons between males and females. Anova, Pearson's correlation coefficient and regression analysis were used to analyze differences and correlations regarding SBL, height and WC.

Results

The mean SBL in 111 individuals was found to be 336.54 cm, with a mean of 345.45 cm in males and 319.42 in females (Figure 1, Table 1). The difference was significant ($p<0.05$; Mann-Whitney U test after t-test). In males the maximum SBL was 500 cm, while it was 450 cm in females. The minimum SBL in males was 218 cm in males and 271 cm in females.

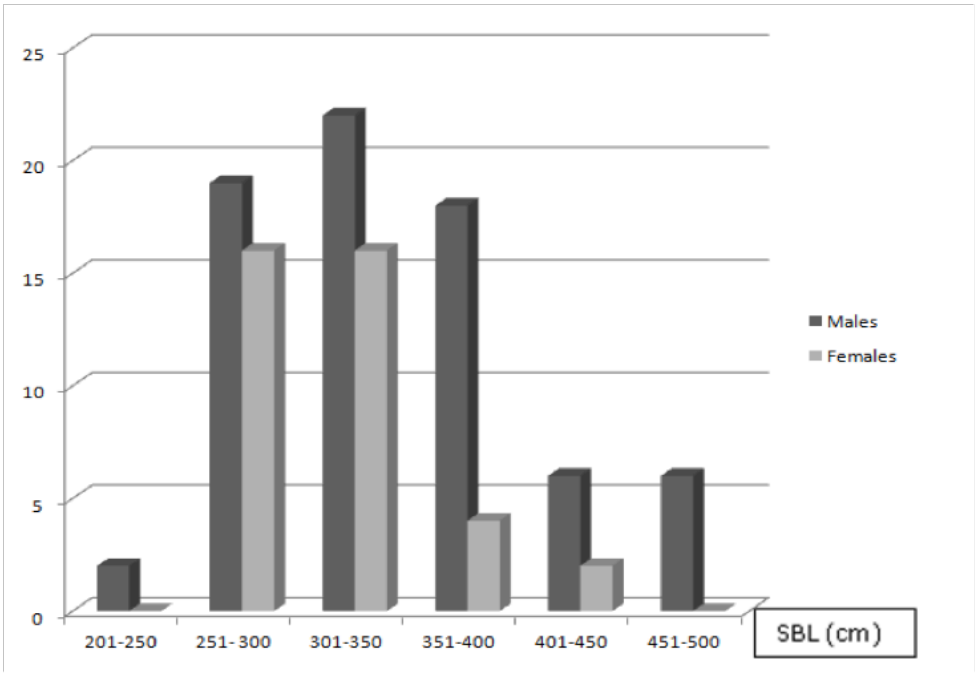

Figure 1. Comparison of SBL in males and females.

Table 1. SBL, SBL/H ratio and SBL/WC ratio in males and females.

Sex	SBL Mean (cm)	SBL/H	SBL/WC
Females (38)	319.42 ± 40.24	2.09±0.26	4.18±0.53
Males (73)	344.45 ± 63.20	2.07±0.36	4.28±0.61
p value	<0.05	not significant	not significant

Height and SBL showed a moderately positive reciprocal correlation with R= 0.329 (Figure 2, Table 2), while WC and SBL showed a strong positive reciprocal correlation with R=0.568 (Figure 3, Table 2). Regression analysis showed coefficients of 2.312 and 4.379 for height and WC respectively, which was statistically significant. However, in individuals with central obesity SBL showed no correlation with WC in males (R=0.049) and weak correlation in females (R=0.281).

SBL/Height ratio in males was 2.07 and in females 2.09, while SBL/WC ratio was 4.28 in males and 4.18 in females, both with no statistically significant difference (Table 1).

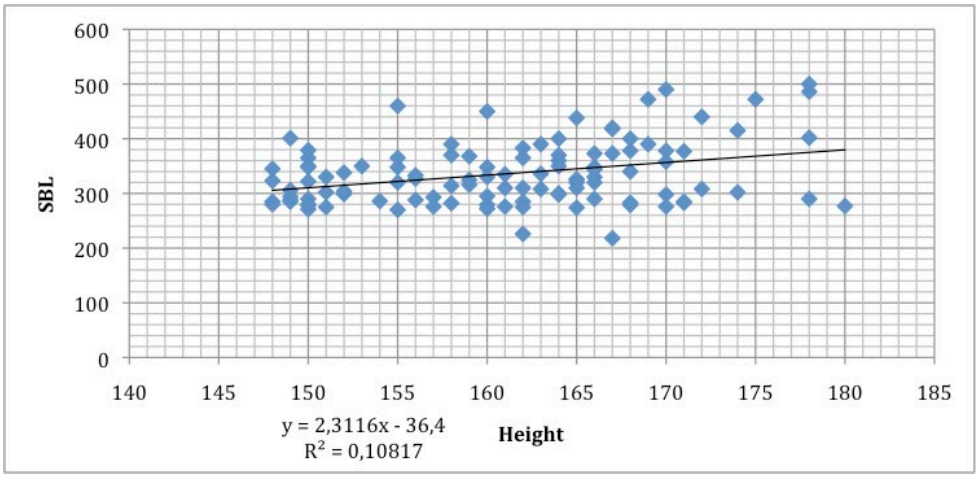

Figure 2. Correlation of height with small bowel length (SBL).

Table 2. Correlation of SBL with Height (H) and waist circumference (WC).

		H	WC
SBL	Pearson Correlation	0.329	0.568
	p-value	<0.05	<0.05
	N	111	111

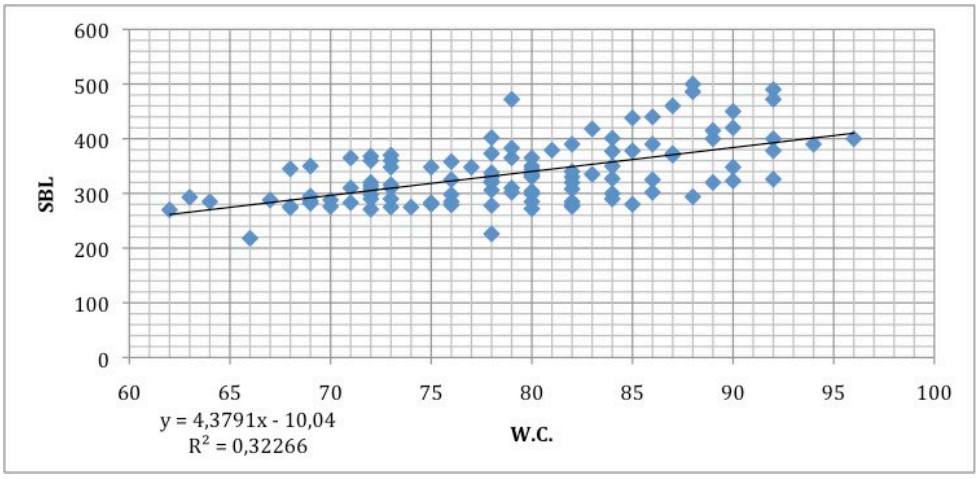

Figure 3. Correlation of waist circumference (WC) with small bowel length (SBL).

Discussion

Gray's Anatomy, 40th edition, mentions small bowel length of 3-7 meters with an average of 5 meters in living adults (Gabe, 2008). Most of the European or American studies also showed average SBL to be around 6 meters or more e.g. 575 cm (Weaver et al., 1991), 609.6 cm (Underhill, 1955), 630-1510 cm (Raines et al., 2015), 632.5 ± 88.9 (Hosseinpour and Behdad, 2008), 690.1 ± 93.7 cm, 795 ± 129 cm (Hounnou et al., 2005), 1193 cm (Tacchino 2015). These studies showed a wide range of variation in SBL length from a minimum of 201 cm to a maximum of 1510 cm, with a mean around 600 cm (Reiquam et al., 1965; Raines et al., 2015; Tacchino 2015). Such wide variations do not match with the description given in the standard textbooks. In the present study, we did not come across any measurement of small bowel length of more than 5 meters. Another study in Indian population also showed the SBL to be not more than 500 cm (Jadhav et al., 2015). The SBL in Indian population is less in comparison with the textbook figures as well as with the values of SBL mentioned in western studies. The present study in Indian population showed an SBL in the range of 218-500 cm, with an average of 336.54 cm.

Researchers have measured the SBL either in living, during laparotomy or by radiology or magnetic resonance imaging (Guzman et al., 1977; Fanucci et al.,1984; Hosseinpour and Behdad, 2008; Sinha et al., 2014; Raines et al., 2015; Tacchino, 2015), in brain dead (Gondolesi, 2012; Sinha et al., 2014; Tacchino, 2015), in cadavers which are not formalin-fixed (Underhill, 1955; Martin et al., 2003; Misra et al., 2006), or in formalin-fixed cadavers (Minko et al., 2014; Jadhav et al., 2015). It was reported that the bowel is longer in cadavers than the living due to decrease in the muscle tone after death (Gad, Gad 2007; Richards, 2018); however; Smyth (1988) found no significant increase in bowel length after death. In formalin-fixed cadavers, there is shrinkage due to hardening and dehydration of tissue (Coleman and Kogan, 1998; Clarke et al., 2014; Tran et al., 2015). The variable results may be due the measurements taken in different situations. However, as there is a wide variation in the small bowel length in living adults (Gabe, 2008), the same will be reflected during measurements in any particular situation mentioned above. In the present study, measurements of small bowel were taken in formalin-fixed cadavers.

There is no uniformity of results regarding the factors influencing SBL; however, height seems to be a relevant factor, as the higher bodies may need longer bowels.

However, some researchers found weak or no relationship of height with the SBL (Hosseinpour and Behdad, 2008; Minko et al, 2014) and some showed a decrease in SBL/height ratio as the age increases (in infants 4.24, in adults 2.12), as the bowel length does not significantly change after birth (Gondolesi et al., 2012). Some studies showed a significant height – SBL correlation (Raines et al., 2015; Tacchino, 2015; Ahmad et al., 2016). Mean SBL/height ratio in the present study was 2.09, and there was positive correlation between height and SBL.

Normal waist circumference in Indian males and females is 78 cm and 72 cm respectively. Higher WC (90 cm and more in males and 80 cm and more in females) indicates central obesity/abdominal obesity (Martin et al., 2003; Misra et al., 2006; Ahmad et al., 2016). There are studies showing strong positive correlation as well as no correlation between weight and SBL (Guzman et al, 1977; Zhu et al., 2001; Hounnou et al., 2002; Tacchino, 2015). One study mentions that jejunal length can be a

good predictor of weight (Tacchino, 2015). The present study tried to search the relation between WC (normal values) and SBL, and we found a positive correlation but only in subjects without central obesity. Regression analysis showed statistically significant coefficients for both height and WC.

Small bowel length is not just an issue of academic discussion. It is of concern for surgeons especially in the procedure of massive resection of small bowel, where large amount of the small bowel is to be resected and can lead to short bowel syndrome. It is reported that short bowel syndrome can occur following resection of small bowel if the remaining portion is less than 2 meters or 50% of the original length (Shonyo and Jackson, 1950; Robinson and Wilmore, 2001). If the original length of small bowel is around 3-4 meters, are there more chances of short bowel syndrome in massive resection? Same concern is shown by Tacchino in his research article (Tacchino, 2015). Knowledge of variable length of small bowel is important for intestinal bypass surgery, enteroscopy, magnetic resonance enterography, bariatric surgery and any surgery related to small bowel length (Gondolesi et al., 2012; Tacchino, 2015). Bowel length conditions its capacity to absorb micronutrients as well as its caloric absorptive capacity. The relationship between different bowel limb lengths and SBL is valuable for the success of bariatric surgery, which needs an accurate evaluation before surgery. The bypass done in bariatric surgery mimics resection of a major portion of proximal bowel (Tacchino, 2015). Studies of SBL will provide a better insight in above mentioned procedures and surgery, this study in particular for Indian population.

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The authors have no conflict of interests to declare.

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