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RESEARCH ARTICLE

In Vivo Small Bowel Length is Longer than in Formalin-Fixed Cadavers

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Abstract

Background: Surgeons require accurate ranges of normal small bowel length (SBL) to benefit patients. The relationship between cadaveric SBL and *in vivo* human SBL is not known. We hypothesized that cadaveric SBL is significantly different compared to human SBL.

Methods: SBL was measured prospectively in 167 formalin-fixed cadavers; and studied in 118 without intestinal surgery. A standardized and reproducible method of small bowel measurement was utilized in both *in vivo* and cadaveric subjects. Small bowel was measured *in situ* from the Ligament of Treitz to the ileocecal valve. These measurements were compared to previously published cadaveric and *in vivo* human SBL data. The number of cadavers examined was larger than in other published studies; the number of *in vivo* subjects was also the highest yet reported.

Results: Formalin-fixed cadavers had significantly shorter SBL than living subjects- 366.1±82.7 vs 508.6±105.8 cm (mean + sd, $p < 0.0001$). The mean fresh cadaveric SBLs (592.8 cm) was longer in comparison to the formalin-fixed cadaver SBL (366 cm). In cadavers, univariate analysis showed that age (younger > older), height (taller > shorter), and gender (male > female) correlated with SBL ($p < 0.01$). In multivariate analysis, only height remained predictive of SBL ($p < 0.0001$). Torso length was positively correlated with SBL (cricoid to jugular notch, sternal angle, xiphoid, umbilicus, pubic tubercle), $p < 0.0001$ top = 0.005. Torso circumferences at the xiphoid-sternal angle, subcostal line, umbilicus, and iliac crest were all positively correlated with SBL ($p = 0.005$).

Conclusion: To date, this study remains the first to compare detailed physical measurements to SBL. *In vivo* SBL was significantly longer than formalin-fixed cadaver SBL. Height was a primary predictor of SBL. Cadaveric SBL measurements should not be used to estimate normative SBL data in living subjects.

Keywords

Small bowel, Small intestine, Length, Measurement, Anatomy, Short bowel syndrome, Cadaver, Human, Trauma

Abbreviations

SBL: Small Bowel Length

Introduction

The small intestine encompasses the majority of digestive and absorptive properties of the gastrointestinal system. Disease processes that disrupt small bowel length (SBL) and/or function hinder human growth and

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metabolism [1,2]. Physical and/or functional shortening of the small bowel may result in intestinal failure (characterized by inability to maintain fluid, electrolyte, micronutrient, and protein-energy balance). For this reason, understanding accurate SBL in living subjects is crucial. Currently, surgeons involved with trauma, intestinal ischemia, short bowel syndrome, inflammatory bowel disease, and intestine transplantation have limited literature resources defining small bowel length in live humans [3-5]. Treatment guidelines and reviews quote the normal SBL as 275 cm to 850 cm with a mean ± sd of 350 ± 60 cm [1-6].

Intestinal length has been of interest since antiquity. Because of religious prohibitions and other societal limitations, little reliable data was generated until the first comprehensive study on non-preserved human cadavers by Sir Frederick Treves [7]. With current living subject and cadaver studies, it is often difficult to determine the measurement and accuracy of the results from these reports; some (SBL) length data in textbooks were derived from fresh or formalin-fixed cadaver studies, many from India [7-11].

Currently, it is not known whether the length of the small bowel as measured in formalin-fixed cadavers is equivalent to that in living humans. In our earlier study, the small bowel length was measured in live patients intraoperatively and compared to previously published SBL in living human subjects [1]. The hypothesis was that SBL in cadavers was shorter than in the living. The current study is unique because it used a standard method to measure SBL in both formalin-fixed cadavers and living subjects yielding a contemporaneous comparison. In addition, we studied whether there was any correlation between SBL and height, gender, and other body measurements, since there has been continuing debate in the literature about this issue [7-9,12].

Materials and Methods

Population

Small bowel length was measured in 167 formalin-fixed human cadavers from three medical school anatomy labs to establish normal human cadaver ranges. Forty-nine subjects who had prior small intestinal surgery were excluded, leaving 118 cadavers with intact small bowel in the cohort. These measurements were compared to previously published *in vivo* human SBL data [11]. Additional external anatomic measurements were made to assess correlation with SBL. This study was approved by the Institutional Review Boards of each institution.

Literature review

A search through PubMed, MedLine, and Google Scholar was undertaken to review published English literature on cadaveric and *in vivo* SBL for comparison with the study data.

Investigational design

Human cadaveric data was obtained in three medical school anatomy laboratories in formalin-fixed, un-frozen bodies using the same method, as taught by the principle investigator and observed in random cadavers to assure consistency. When the abdominal cavity was opened, the small bowel length was measured *in situ* along the anti-mesenteric border using a 25-cm umbilical tape. It was measured once from the Ligament of Treitz to the ileocecal valve. The bowel was serially measured with segmental straightening but without undue stretching. The principal investigator had performed all *in vivo* measurements. Cadaveric and *in vivo* measurements were completed consistently and without significant longitudinal traction so that the data collected could be reliably compared.

The following additional parameters and measurements were collected from the cadavers: gender, height, evidence of previous surgery, abdominal wall thickness at the umbilicus, the distance from the cricoid to the jugular notch, sternal angle, xiphoid, umbilicus, and pubic tubercle, and the torso circumference at the xiphoid-sternal angle, the costal margin, the umbilicus and the iliac crest. Cadaver heights and weights were recorded, when possible. No medical records were available for these subjects. Cadavers with prior abdominal incisions and any evidence of small intestinal surgery were excluded from statistical analysis.

Comparison with *in vivo* data

New cadaveric data was compared to the earlier *in vivo* raw data in the report by Teitelbaum, et al. [11]. There were 287 de-identified subjects with *in vivo* SBL data available for comparison. This data had been collected during open laparotomies in living humans by the primary investigator using the same measurement technique, as previously described [11].

Statistical analysis

Statistical analysis was performed with the R v3.3.2 statistical software [13]. Analysis encompassed 118 cadavers, all numbered without relation to their cadaver identification number. Demographic characteristics including gender, age, and height were first compared in cadavers and living subjects. Fisher's exact test was used to determine gender; Welch's t-tests were used to compare groups on age and height. The total SBL was compared between the cadavers and the living subjects using nested generalized linear regression models. To examine whether age, height, gender, or a number of physical measurements might be related to small bowel length within the cadaver group, a series of analyses were conducted. First, correlations between age and total

Table 1: Age and height of the study cadavers and living subjects.

	Cadavers	Living subjects	P value
Number	118	287	
Age	79.9 (82) + 12.2	55.2 (56) + 15.8	P < 0.0001
Height	173.5 (174) + 12.0	168.9 (168) + 10.4	P = 0.0004

Mean (Median) ± Standard deviation.

Table 2: Total small bowel length of cadavers and living subjects.

	N	Min	1st Quartile	Median	Mean	3rd Quartile	Max	SD
Cadavers	118	199	312	368	366.1	413.8	603	82.7
Living Subjects	287	285	435	496	508.6	575	845	105.8

Min = Minimum; Max = Maximum, N = Number; SD = Standard deviation.

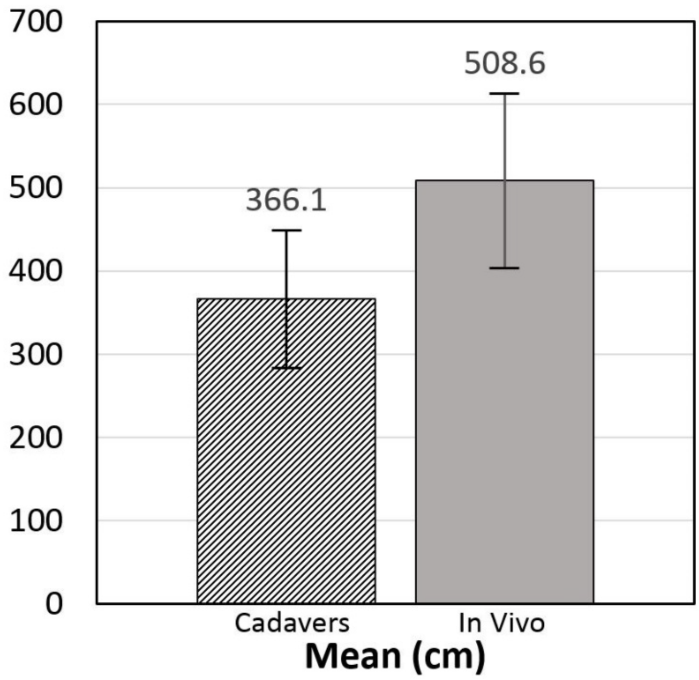

Figure 1: Mean SBL in formalin-fixed cadavers compared with *in vivo* subjects (n = 118 cadavers and 287 *in vivo*)-p < 0.0001. Normal small bowel length (SBL) means/ranges have been established. SBL was significantly longer in live subjects versus formalin-fixed cadavers. This finding is important for the transplant surgeon for small bowel transplantation, and other gastrointestinal surgical decisions.

length, as well as height and total length were calculated and tested against zero. Similarly, correlations between the series of physical measurements and total length were calculated and tested against zero. A Welch's t-test was performed to determine if there were differences between genders. Lastly, nested linear models were constructed using age, height, and gender; the models were compared using Likelihood ratio tests.

Results

Cadaver *vs.* Living subjects

Table 1 provides the summary age and height of the cadavers and living subjects in this study. The cadaver group included 57 (48%) women and 61 (52%) men. Age was available in 40% (47 of 118) of the cadavers. Ages ranged from 53 to 102 years, with a median age of 82 years. All but one of the cadavers had height information. Heights ranged from 145 cm to 199 cm, with a median of 174 cm. The *in vivo* group included 143 (50%) women and 144 (50%) men. Ages ranged from 14 to 95 years, with a median age of 56 years. Heights ranged from 138 cm to 196 cm, with a median of 168 cm. Comparisons of the two groups on basic demographics revealed no significant difference in gender (p = 0.83), but the cadavers were both older (p < 0.0001) and taller (p < 0.001).

For this reason, generalized linear models were used to examine the relationship between groupings (cadaver *vs.* living subjects) and total SBL, controlling for age and height. Nested models showed that cadavers have significantly shorter small bowel length than the living subjects (p < 0.0001), even when controlling for age and height (Table 2 and Figure 1).

Table 3: Summary statistics of all additional cadaver measurements (centimeters).

	N	Min	1st Quartile	Median	Mean	3rd Quartile	Max	SD
Thickness								
Abdominal wall	55	0.5	1.1	1.9	2.0	2.3	5.6	1.0
Circumferences								
At xiphoid-sternal angle	109	67.8	84	95.6	95.2	103.0	147.4	14.8
At subcostal line	109	67.5	87.3	95.0	96.0	104.0	163.6	15.0
At umbilicus	109	68.0	87.5	97.0	97.7	107.0	176.8	16.9
At iliac crest	109	69.5	88.0	98.0	100.1	110.0	177.0	16.9
Lengths								
Cricoid to jugular notch	110	3.0	4.5	5.0	5.2	6.0	9.0	1.0
Cricoid to sternal angle	108	5.5	9.4	10.0	10.2	11.0	14.0	1.5
Cricoid to xiphoid	113	12.6	22.6	24.8	24.3	26.5	33.0	3.7
Cricoid to umbilicus	113	26.0	41.0	43.5	43.5	46.0	59.0	4.6
Cricoid to pubic tubercle	114	49.6	59.0	62.0	62.0	65.0	76.0	4.9
Total small bowel length	118	199.0	312.0	368.0	366.1	413.8	603.0	82.7

Min = Minimum; Max = Maximum; N = Number; SD = Standard deviation.

Cadaver data

Initial correlations and t-tests within the cadaver group indicated an inverse relationship between age and total SBL (Pearson's = -0.40; p = 0.006), and a direct relationship between height and total SBL (Pearson's = 0.42; p < 0.0001). Gender and total SBL were also related (t-test; p < 0.0001). Older people had shorter SBL; taller people had longer SBL; and men had longer SBL than women.

When multiple regression models were considered, the only variable that remained significantly correlated with SBL was height (p < 0.0001). Once height was controlled for, age (p = 0.51) and gender (p = 0.21) were no longer significantly related to total SBL. Age and height were negatively correlated (Pearson's correlation coefficient = -0.51; p = 0.001) and men were taller than women (t-test; p < 0.0001).

Table 2 shows SBL measured in 118 formalin-fixed human cadavers and 287 living subjects.

Many of the physical measurements were positively correlated with total SBL in cadavers (Table 3). Except for the abdominal wall thickness, the correlation between the SBL and circumference and bowel length at different levels was statistically significant (Table 4). These included measurements of length from the cricoid to the jugular notch, angle, xiphoid, umbilicus, pubic tubercle (p < 0.0001 top = 0.005). In addition, torso circumferences at the xiphoid-sternal angle, subcostal line, umbilicus, and iliac crest were also positively correlated with SBL (p < 0.0001 to p = 0.005).

Table 4: Pearson correlation coefficient between physical measurements and total small bowel length.

	Pearson correlation coefficient	p-value
Thickness		
Abdominal wall thickness	0.25	0.07
Circumference		
At xiphoid-sternal angle	0.34	0.0003
At subcostal line	0.39	< 0.0001
At umbilicus	0.33	0.0005
At iliac crest	0.26	0.007
At crico-jugular notch	0.26	0.007
Length		
Cricoid to sternal angle	0.22	0.02
Cricoid to xiphoid	0.35	0.0002
Cricoid to umbilicus	0.29	0.002
Cricoid to pubic tubercle	0.41	< 0.0001

Cadaver and *in vivo* SBL literature reports

The published studies were from Sweden, Italy, United States of America, United Kingdom, Thailand, Turkey, and France. Table 5 depicts the data available in the English literature for 7 reports of fresh cadaver small bowel measurement (1885-2012) for comparison with the present study [4,7-10,14,15]. The mean fresh cadaver SBL measurements ranged from 364 to 699 cm in contrast to measurement (mean 366.1 cm) done on the formalin-fixed cadavers in this report. There were 9 reports on *in vivo* SBL lengths (1974-2013) shown in Table 6 [9,11,16-23]. Table 7 depicts the SBL measuring process reported for the cadavers and intraoperative patients [4,7-11,14-23]. All SBL measurements were taken from the Ligament of Treitz to the ileocecal valve, except for Underhill [8] who included the pylorus in the measurement of the SBL. A variety of implements were used for measurement. Statements were made by most authors that the bowel was not intentionally stretched during the

Table 5: Cadaver SBL measurements in the literature.

	Total						Male					Female					
Author	**Age (Years)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Height (cm)**	**Age (Years)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Age (Years)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Comments**
Treves* [7]	--	100	699	539	932	--	20-50	--	686	472	970	--	--	711	605	894	No correlation (age, height, or weight)
Dreike* [15]	--	50	579	381	936	--	--	27	632	422	1013	--	23	526	340	859	--
Bryant* [14]	--	160	625	305	864	--	--	27	663	457	813	--	17	587	406	762	No correlation (age)
Underhill* [8]	27-91	100	615	412	751	--	27-91	65	637	488	785	38-85	35	592	335	716	SBL correlated with height
Hounnou, et al. [10]	76 ± 12 (33-100)	200	634.9	280	1000	164 ± 9 (140-185)	74 ± 12	100	643.9	365	1000	78 ± 12	100	573.8	280	840	SBL correlated with height
Hosseinpour, et al. [9]	--	30	632.5	543.6	721.4	--	--	--	--	--	--	--	--	--	--	--	No correlation (age, height or weight)
Gondolesi, et al. [5]	24 (17-40)	8	364	290	469	161 ± 8.8	20 (17-23)	5	388	315	469	30 (20-40)	3	324	290	360	No correlation (age, height or weight)
Present study 2019	79.9 ± 12.2	118	366.1	199	603	173.5 ± 12.0	75.9 ± 12.6 (53-95)	61	395.1	215	603	83.7 ± 10.7 (56-102)	57	335	199	550	SBL correlated (height)

SBL = Small bowel length; Min = Minimum; Max = Maximum; *SBL reported in cm. Total SBL, Min and Max are averages of the Male & Female values in the publications. All converted to cm from feet and inches. Data presented as mean or mean ± sd; yrs = years.

Table 6: *In Vivo* intraoperative SBL measurements in the literature.

	Total						Male					Female					
Author	**Age (yrs)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Height (cm)**	**Age (yrs)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Age (yrs)**	**#**	**SBL Mean (cm)**	**SBL Min (cm)**	**SBL Max (cm)**	**Comments**
Backman^^, et al. [16] Obese	--	56	824	--	--	M 179 ± 1.7 F 168 ± 1.0	38 ± 1.6	13	824 ± 34	630	1022	38 ± 1.8	43	734 ± 12	575	870	Longer SBL in the obese
Backman^^, et al. [16] Controls	--	32	698	--	--	M 175 ± 1.9 F 164 ± 1.1	58 ± 3.5	12	698 ± 32	500	846	50 ± 3.4	20	616 ± 19	400	784	Shorter SBL in controls
Guzman, et al. [18] Obese	35 ± 9.4	272	512 ± 95.4	--	--	--	--	--	562 ± 103	--	--	--	--	502 ± 90	--	--	Height not recorded; correlated with sex
Guzman, et al. [18] Non-obese	43 ± 10	121	525 ± 91.1	--	--	--	--	--	530 ± 85	--	--	--	--	507 ± 102	--	--	Height not recorded; correlated with sex
Nordgren, et al. [21]	--	77	564 ± 111	360	1090	--	--	40	591 ± 119	380	1090	--	37	534 ± 90	360	740	Control group-correlated with height
Glehen, et al. [17]	60.3	92	566	350	826	166	--	51	588	350	756	--	41	539	406	826	Control group-correlated with height
Hosseinpour, et al. [9]	20-43	100	460	285	620	--	--	54	452 ± 79	--	--	--	46	468 ± 80	--	--	No correlation (age, height or weight)
Karagül, et al. [19]	35.4 ± 13 (19-67)	28	580 ± 103	400	817	169 ± 12 (147-186)	--	--	--	--	--	--	--	--	--	--	16 healthy; 12 liver disease
Lohsiriwat, et al. [20]	60 (28-88)	48	428 ± 105	169	745	160.3 ± 8.4 (138-175)	--	27	468 ± 105	322	745	--	21	376 ± 81	169	476	Thai population; no correlation (age, height or weight)
Raines, et al. [22]	--	91	998.5	630	1510	166.8 ± 10.2	--	51	--	--	--	--	40	--	--	--	Linear correlation with height
Tacchino, et al. [23]	37.7 (15.4-68.1)	443	690 ± 93.7	350	1050	M 173 ± 8.2 F 161 ± 6.9 (143-187)	--	101	729 ± 89	--	--	--	342	678 ± 92	--	--	Correlated with height, only
Teitelbaum, et al. [11]	55 (20-86)	240	506 ± 105	285	845	169 (138-196)	--	113	533			--	127	482			Height predictive of SBL
Present study 2019	55.2 ± 15.8	287	508.6	285	845	168.9 ± 10.4	55.4 ± 15.8 (20-87)	144	531.7 ± 105.7	300	845	55.1 ± 15.8 (14-95)	143	485.4 ± 1.1	285	800	Height predictive of SBL

SBL = Small bowel length; Min = Minimum; Max = Maximum; Data presented as mean or mean ± sd; yrs = years; ^^ Height varied between 151 and 189 cm for both groups.

measurement process. Underhill and Hounnou, et al. [10] removed the bowel from the abdominal cavity measurement, introducing another confounding variable. Measurements were made along the antimesenteric border of the SB in the majority of studies. The number of cases ranged from 8 to 443 measured with tape, suture or ruler (SBL 428-824 cm). The longest SBL was reported in the study by Raines, et al. where a rigid 10 cm ruler was used (mean 998.5 cm) [23].

Discussion

This study indicated that when SBL was measured in the same consistent manner, the small bowel was shorter in formalin-fixed cadavers compared to living subjects and to previously published fresh cadavers. The present study also confirmed the findings by Gondolesi, et al. [4] in the *in vivo* SBL measurement; that data, however, was based on only 8 cadavers who were donors for intestinal transplantation.

Although there were correlations between cadaveric SBL and many other measurements such as torso circumference and various longitudinal subject lengths, overall height was the best predictor of SBL. Underhill [8] and Gondolesi, et al. [4] also found a positive correlation with height.

Similarly, this correlation with height was found in our *in vivo* study subjects [11]. Literature on correlations between SBL and other body measurements is mixed. Underhill [8] found that intestinal length was correlated with height but independent of age, as we did. However, Hounnou, et al. [10] found body weight was significantly correlated with SBL. Tacchino, et al. [23] analyzed the relationship of SBL to obesity and did not find it significant. Earlier reports found no correlation with age, height, or weight [7-9,14].

In an interesting study, Gondolesi, et al. [4] evaluated the ratio of small bowel length to body surface area (BSA) in children. There were 2 groups: Group 1 (number = 5) with a height of < 70 cm with an age of 0.58 ± 0.21 years; and Group 2 (number = 5) with a height of > 70 cm --- < 150 cm and an age of 5.6 ±

Table 7: SBL Measurement Process in Cadavers and *in vivo* Subjects.

Author	Total SBL (Mean cm)	Formalin-Fixed/ Fresh	Tape/Ruler	Mesenteric/Antimesenteric Border
Cadaver				
Treves* [7]	699	Fresh (12-24 hours)	NA	NA
Dreike* [15]	579	Fresh	NA	NA
Bryant* [14]	625	Fresh	NA	NA
Underhill*^ [8]	615	Fresh (5-72 hours)	30 cm ruler	NA
Hounnou^, et al. [10]	635	Fresh (5-72 hours)	Tape	Antimesenteric
Hosseinpour, et al. [9]	633	Fresh	5 m hard non-elastic tape	NA
Gondolesi, et al. [5]	364	Fresh donors	Umbilical tape (80 cm)	Antimesenteric
Present Study 2019	366	Formalin fixed	Umbilical	Antimesenteric
in vivo				
Backman, et al. [16]	698 control; 824 obese	Intraoperative	White cotton band	Midway between antimesenteric & mesenteric
Glehen, et al. [17]	566	Intraoperative	Tape	Antimesenteric
Guzman, et al. [18]	525 control; 512 obese	Intraoperative	Tape	Antimesenteric
Nordgren, et al. [21]	564	Intraoperative	100 cm heavy silk suture	Midway between Antimesenteric & mesenteric
Hosseinpour [9]	460	Intraoperative	5 m hard non-elastic tape	NA
Karagül, et al. [19]	580	Intraoperative	70 cm nylon tape + ruler	Antimesenteric
Lohsiriwat, et al. [20]	428	Intraoperative	Tape	Antimesenteric
Raines, et al. [22]	999	Intraoperative	10 cm flexible ruler	Antimesenteric
Tacchino, et al. [23]	690	Intraoperative	100 cm heavy silk suture	Midway between antimesenteric & mesenteric
Teitelbaum, et al. [11]	506	Intraoperative	25 cm umbilical tape	Antimesenteric
Present Study 2019	509	Intraoperative	25 cm umbilical tape	Antimesenteric

SBL = Small bowel length; *SBL reported in cm; Total SBLs are averages of the male and female values in the publications. All converted to cm from feet and inches. ^Intestine removed prior to measurement; NA = Not available.

2.51 years. They found that SBL did not increase with growth, and so the SBL/height ratio decreased with growth, concluding that SBL was fairly constant after childhood. In agreement with this study, age was not significant when height was included in the model in our study.

Study strengths

A strength of this study is that a standardized and reproducible method of small bowel measurement was utilized in both *in vivo* and cadaveric subjects. Additionally, the number of cadavers examined was larger than in other published studies; the number of *in vivo* subjects was also the highest yet reported.

The results of this investigation indicate that the SBL is shorter in formalin-fixed cadavers compared to living subjects. This is supported by Table 7, where the average of the fresh cadaveric SBLs (592.8 cm) is longer in comparison to the formalin-fixed cadaver SBL (366 cm). To date, this study remains the first to compare detailed physical measurements to SBL (Table 3 and Table 4). These anthropometric indices in these two tables are directly associated with height, therefore, it makes sense they are significant correlators with SBL. Future studies may focus on whether individual anthropometric indices independently correlate with SBL in both cadaveric and *in vivo* subjects.

There are many artifacts that may affect SBL other than the reported elements, temperature, and opioids, such as the formalin-fixation process, genetics, chronic diseases, and nutritional status before death [9,24]. Crohn's disease was considered an independent risk factor for shortened small bowel in two studies [18,19]. To our knowledge, none of the subjects in this study had Crohn's disease. Earlier reports described a loss of muscular tonicity after death resulting in increased length [8,12] while another study [24] described an intestinal retraction phenomenon that resulted after surgical intestinal resection. The retraction phenomenon did not occur in cadavers, but rather in colorectal resection specimens from live patients [24]. It is possible that the small bowel in fresh cadavers is significantly longer with relaxation of the smooth muscle and that this is reversed by the formalin-fixation process. Goldstein, et al. [24] noted that in surgical colorectal specimens, there was a 40% reduction of length in formalin-fixed tissue compared to the prior *in vivo* lengths. This may explain why the mean SBL in the formalin-fixed cadavers in the current study was only 63% as long as the SBL in *in vivo* subjects (mean 366.1 *vs.* 508.6 cm). In contrast, fresh cadaver SBLs in the literature were longer compared to the *in vivo* and the formalin-fixed SBL measurements in this study. Overall, our *in vivo* SBL lengths were consistent with the SBL lengths reported in the literature (Table 6).

Study limitations

Limitations of this study primarily include the wide variation in age. In addition, although we recognize a larger study population would improve the power, our study remains the largest analysis of a cadaveric population to date. In our data, 60% of the cadavers did not have an age recorded, and so the mean and median ages listed may not be accurate. Perhaps with a larger cohort, age may be correlated with SBL. Many intestinal and abdominal disorders may have an effect on small bowel length; these could not be identified from the cadavers. The circumference measurements may be associated with weight, but it was not possible to get accurate cadaver weights and body mass index (BMI).

It is essential for the clinician to have a good understanding of normal small bowel length and ranges since this has implications in many clinical situations such as trauma, small bowel transplantation, intestinal bypass, Roux-en-y reconstruction, small bowel Crohn's disease, intestinal ischemia, and short bowel syndrome. With the current trend of utilizing living donor small bowel transplant (LR-SBTx) of the terminal ileum, it is important to have accurately estimated donor SBL so that the donors can retain the recommended 60% of their SBL for survival and freedom from post-donation intestinal complications [25]. To reduce error in SBL length measurement, a recommendation from an *in vivo* healthy liver donor study was to perform several measurements on stretched compared to non-stretched bowel [26]. Trauma and Gastrointestinal surgeons should be vigilant in preserving small bowel, especially in patients with shorter than average height. Fresh or formalin-fixed cadaveric SBL data do not provide good estimates of SBL in living human subjects.

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