

Original Research Article

Effects of Age and Sex on the Anorectal Sensory Threshold to Electrical Stimulation: A Single-center Observational Study

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Abstract

Objectives: Anorectal sensation is an essential component for maintaining normal defecation and continence. This study aimed to investigate changes in anorectal sensation with age and sex using the anorectal sensory threshold to electrical stimulation in a large population with a broad age spectrum.

Methods: This study enrolled consecutive adult patients (20-89 years old) who underwent anorectal physiology tests to screen for functional or organic anorectal disease. Anorectal sensitivity was measured using an endoanal electrode with a 45-mm long bipolar needle. A constant electrical current was delivered to the lower end of the rectum and the anal canal. The minimum current in milliamperes at which the initial sensation was felt was defined as the sensory threshold.

Results: Overall, 888 patients were included in this study. The most frequent comorbidities were constipation and hemorrhoids. The median sensory threshold for all patients was 0.5 (interquartile range, 0.2-1.5) mA, and the overall sensory threshold was significantly higher in men than in women. The 95% confidence interval of the sensory threshold for men and women were 0.1-6.8 and 0.1-5.1 mA, respectively. The sensory threshold increased significantly with age in both sexes (men, $r = 0.384$; women, $r = 0.410$). There was no sex difference in the sensory threshold between ages 20 and 40 years; however, between ages 50 and 70 years, men had a higher sensory threshold than women.

Conclusions: The anorectal sensory threshold to electrical stimulation increased with age, and the influence of aging was more significant in men than in women.

Keywords

constipation, defecation, electric stimulation, fecal incontinence, rectal sensation, sensory thresholds

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Introduction

Constipation is one of the most prevalent disorders, and its chronic symptoms impair patients' quality of life and may increase the risk of death[1]. The prevalence of chronic constipation (CC) in the general population increases with age in both men and women. CC affects more women than men in their younger years, but this difference decreases

with age[2-4]. Madsen and Graff[5] reported that older individuals have slower colonic transit time than younger individuals, and that colonic transit time is not affected by sex. In contrast, Metcalf et al.[6] documented that the colonic transit times of healthy participants are longer in women than in men, but there was no difference between age groups. Therefore, it is unclear why the effects of aging on the prevalence of CC are more significant in men than in

women.

The anorectal sensation is a crucial component for maintaining normal defecation and continence. Anorectal hyposensitivity has been demonstrated in various anorectal disorders, such as dyssynergic defecation (DD), fecal incontinence (FI), fecal impaction, and overflow FI, which are highly prevalent in the elderly[7-9]. FI is more common in women than in men; however, men have an equal or greater prevalence in advanced years[10,11]. Therefore, we hypothesized that anorectal sensitivity decreased with age and this effect of aging was more severe in men.

The rectal sensation is conveyed via visceral afferents that ascend predominantly via parasympathetic pathways to reach the dorsal horn of the spinal cord[9,12,13]. In contrast, the sensory pathway from the anus is via the somatic nerves arising from the pudendal nerve[14,15]. However, the area from the lower third of the rectum to just above the dentate line (transition zone) is double innervated by the visceral afferents and pudendal nerves, and the transition zone is particularly rich in sensory organs and free nerve endings[14-16].

The rectal sensation is commonly assessed by simple volumetric distension using an intrarectal balloon[8,13,15], and anal sensation is measured by recording electrical stimulation thresholds[16-24]. Sensory assessment using balloon distension is easy and physiological; however, it does not always accurately reflect afferent nerve function. Technical factors, including the rate of inflation and intrinsic elasticity of the balloon, influence such distension volume techniques[19]. In patients with a megarectum or increased rectal compliance, mechanical distension of the balloon cannot correctly stimulate the rectal wall, resulting in extremely high thresholds[13]. In addition, axial extension into the sigmoid colon may occur during balloon distension[15].

Electrical stimulation is the most popular method for assessing anal sensation[20,21] and can also be used for rectal sensory testing to investigate visceral afferent function[18,19,21]. Electrical stimulation is less physiological; however, it can bypass mucosal receptors and activate the nerve directly, thus avoiding the confounding influences of rectal wall properties while providing a precise, reproducible stimulus[15,16]. A bipolar ring electrode mounted on the tip of a Foley catheter is often used for electrical stimulation[16-23]. Therefore, sensory thresholds can vary depending on the depth of the electrode from the anal verge. That is, the middle level of the anal canal has the lowest threshold, followed by the upper or lower part of the anal canal, and the rectal ampulla has the highest threshold[18,21,22]. Thus, the position of the electrode should be carefully set, particularly for the evaluation of anal canal sensation.

The endoanal electrode we used for examination and treatment is equipped with a 45-mm long bipolar needle; therefore, there is no need for positioning, and the entire

anal canal and the lower end of the rectum can be reliably stimulated. This study aimed to measure the anorectal sensory threshold using the endoanal electrode in a large population with a broad age spectrum and to investigate the correlation between anorectal sensation and age and sex.

Methods

This study was a retrospective review of existing clinical data from the digital database of our hospital. All processes in this study were approved by the institutional review board of our hospital (approval code: K06-002). Anorectal sensory testing was performed as part of a standard anorectal investigation. Written informed consent was obtained from all patients.

This study enrolled consecutive adult patients (20-89 years old) who underwent anorectal physiology tests for screening of functional or organic anorectal diseases among those who visited our hospital due to constipation or various anorectal symptoms between January 2006 and December 2007. All patients underwent appropriate evaluations based on their presenting symptoms, including abdominal radiography, digital rectal examination, proctoscopy, colonoscopy, anorectal manometry, balloon expulsion test, endoanal ultrasound, and barium defecography. Exclusion criteria included a history of spinal injury, dementia, functional anorectal pain, perianal abscess, complete rectal prolapse, DD, FI, and previous anorectal surgery. Patients with cardiac pacemakers were also excluded because of contraindications to electrical stimulation.

Anorectal physiology testing

All anal physiology tests were performed with the patient in the left lateral position without bowel preparation. Anal manometry was performed using a one-channel microtip transducer mounted on a flexible catheter with a 5-mm diameter (P-1401; Star Medical Inc., Tokyo, Japan). The maximal resting pressure (MRP) was recorded using a rapid pull-through technique and defined as the highest resting pressure. Next, the maximal squeeze pressure (MSP), defined as the highest pressure above baseline at any level within the anal canal, was measured.

Subsequently, anorectal sensitivity was measured using a 55-mm long endoanal electrode with a 45-mm long bipolar needle (SBE-10; Star Medical Inc.) (Figure 1). The endoanal electrode was connected to a constant-current stimulator (SEN-3301; Nihon Kohden, Tokyo, Japan). The total length of the electrode was inserted into the anus, and a set constant electrical current (square-wave stimuli, 40 ms, 1 pulse per second) was delivered to the lower end of the rectum and anal canal. The initial stimulus was 0.1 mA, and the current was increased by increments of 0.1 mA until the patient was able to feel the stimulus, which was often per-

ceived as a pricking or tingling sensation. The minimum current in milliamperes at which the initial sensation was felt was defined as the anorectal electrical sensory threshold (AEST).

Outcome measures

We analyzed age-related changes and sex differences in MRP, MSP, and AEST. Furthermore, all patients were stratified into 10-year age groups, and sex differences in AEST in each age group were investigated.

Statistical methods

All statistical analyses were performed using the EZR software (version 1.11; Saitama Medical Center, Jichi Medical University, Saitama, Japan). Categorical variables are reported as frequency and percentage. Continuous variables are presented as mean and standard deviation. The contin-

gency tables were analyzed using the chi-square test. Sex differences in MRP and MSP were compared using an unpaired t-test. The AESTs are shown as medians and interquartile ranges. For the AEST, comparisons between groups were performed using the Mann-Whitney U test. Correlations between variables were assessed using the Pearson correlation coefficient for MRP and MSP and the Spearman correlation coefficient for AEST. A p-value <0.05 was considered statistically significant.

Results

A total of 888 patients who met the inclusion criteria were included in this study. The mean age of the patients was 55.0 ± 15.8 and 58.5 ± 16.6 years for men and women, respectively. The demographic information of the included patients is summarized in Table 1. There was no difference between the proportion of men and women in each age group, except those in their 30s and 80s. The most frequent comorbidities in the study population were constipation (41.4%) and hemorrhoids (37.6%). Among comorbidities, constipation was more common in women, whereas anal fistulas were more common in men. Significant differences in MRP and MSP were observed between men and women (Table 1).

Scatter plots of age versus MRP and MSP by sex are shown in Figure 2, 3, respectively. Both MRP and MSP decreased significantly with age in both sexes. In contrast, AEST increased (thus decreasing sensitivity) significantly with age in both sexes (Figure 4). Both MRP and MSP were

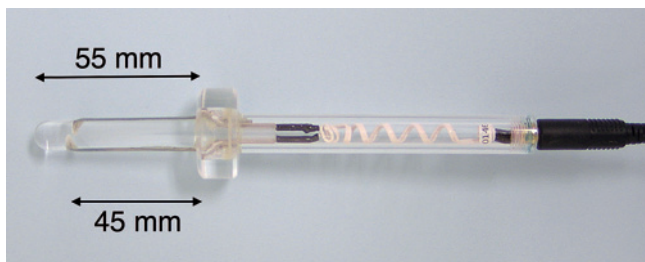


Figure 1. Endoanal electrode for electrical stimulation. The electrode is 55 mm long, 10 mm in diameter, mounted with a 45-mm long bipolar needle.

Table 1. Characteristics of the Study Population (n = 888).

Characteristics		Men n = 455	Women n = 433	p-value
Age (years)	20–29	30 (6.6)	32 (7.4)	0.641
	30–39	75 (16.5)	34 (7.9)	<0.001
	40–49	60 (13.2)	57 (13.2)	0.992
	50–59	90 (19.8)	85 (19.6)	0.955
	60–69	104 (22.9)	92 (21.2)	0.563
	70–79	83 (18.2)	95 (21.9)	0.169
	80–89	13 (2.9)	38 (8.8)	<0.001
Comorbidities	Constipation	164 (36.0)	204 (47.1)	<0.001
	Hemorrhoids	178 (39.1)	156 (36.0)	0.342
	Anal fistula	67 (14.7)	7 (1.6)	<0.001
	Anal skin tags	13 (2.9)	19 (4.4)	0.221
	Anal fissure	17 (3.7)	14 (3.2)	0.683
	Mucosal prolapse	4 (0.9)	12 (2.8)	0.062
	Anal dermatitis	6 (1.3)	5 (1.2)	0.825
	Others	6 (1.3)	16 (3.7)	0.023
Maximal resting pressure (mmHg)		62.1 ± 20.2	52.6 ± 20.6	<0.001
Maximal squeeze pressure (mmHg)		236.3 ± 79.8	139.8 ± 46.3	<0.001

Data are presented as numbers of participants with percentages in parentheses. Percentages may not sum up to 100 because of rounding.

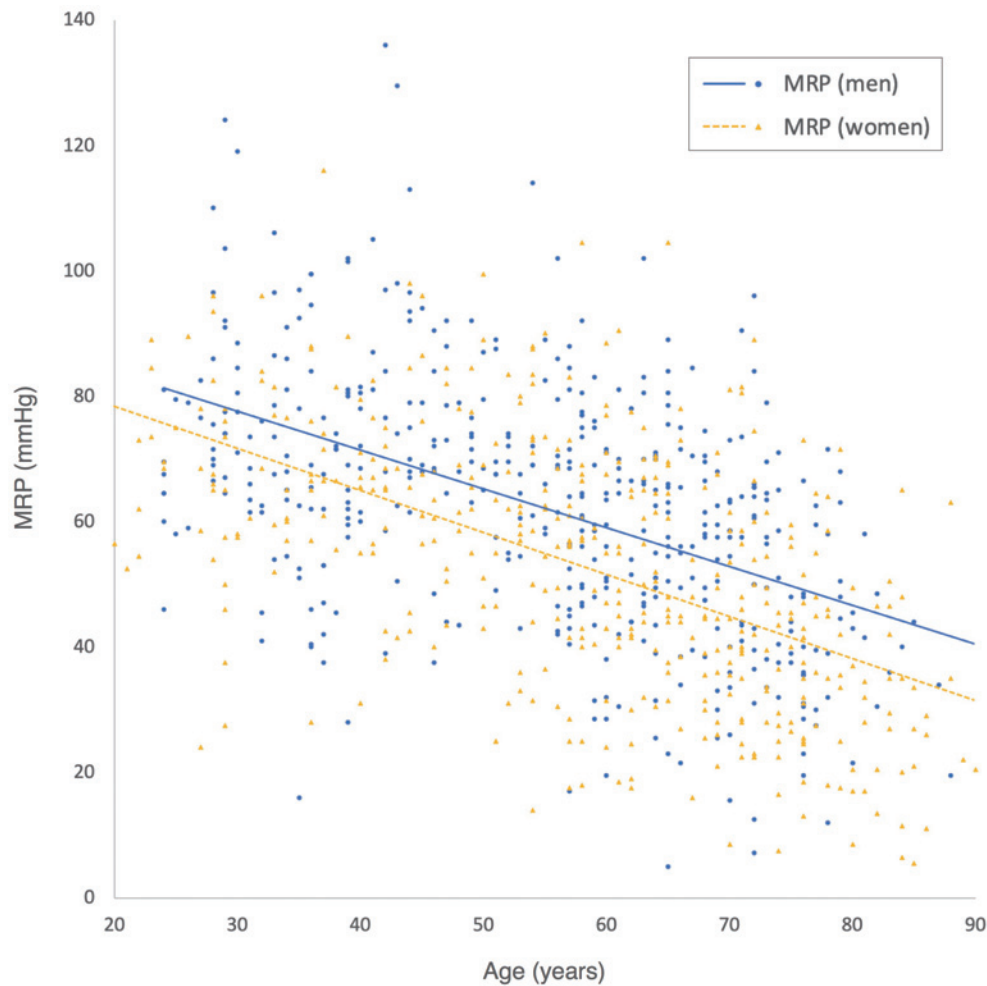


Figure 2. Regression analysis of the influence of age on MRP. MRP decreased significantly with age in both sexes (men, $r = -0.499$, $p < 0.001$; women, $r = -0.562$, $p < 0.001$). MRP, maximal resting pressure

normally distributed (Figure 2, 3); however, AEST was not normally distributed, with more small values and a few large ones (Figure 4). The median AEST for all patients was 0.5 (0.2-1.5) mA, and the overall AEST was significantly higher in men than in women (Table 2). The 95% confidence intervals of AEST were 0.1-6.8 and 0.1-5.1 mA for men and women, respectively. The median AEST measured in each age group for men and women is shown in Table 2, Figure 5. There was no sex difference in AEST in the age groups 20s-40s; however, from 50s to 70s, men had a higher AEST than women.

Discussion

In this retrospective study of 888 patients, we demonstrated that the anorectal sensory threshold to electrical stimulation increased with age, and that the influence of aging was more significant in men than in women.

In normal or asymptomatic participants, the median val-

ues of sensory thresholds to electrical stimulation range from 1.1 to 4.9 mA in the middle level of the anal canal[16-18,20-23] and from 12.3 to 17.9 mA in the rectum[18,19,21]. In the present study, sensory thresholds were measured using a long electrode that was inserted into the entire anal canal and the lower end of the rectum. Results showed a median value of 0.5 mA, the lowest value reported compared with previous studies. This suggests that the long electrode used in our research can adequately contact the anorectal mucosa and stimulate the nerves of the anal canal more effectively than that used in other studies. The long electrode we used also has the advantage of not requiring multiple measurements to identify the most sensitive location of the anal canal.

Currently, several studies have investigated the effects of age and sex on anal sphincter function. Most studies evaluating a large number of participants observed that the MRP and MSP decreased with age, and that the MRP and MSP were lower in women than in men[24-26]. These results are

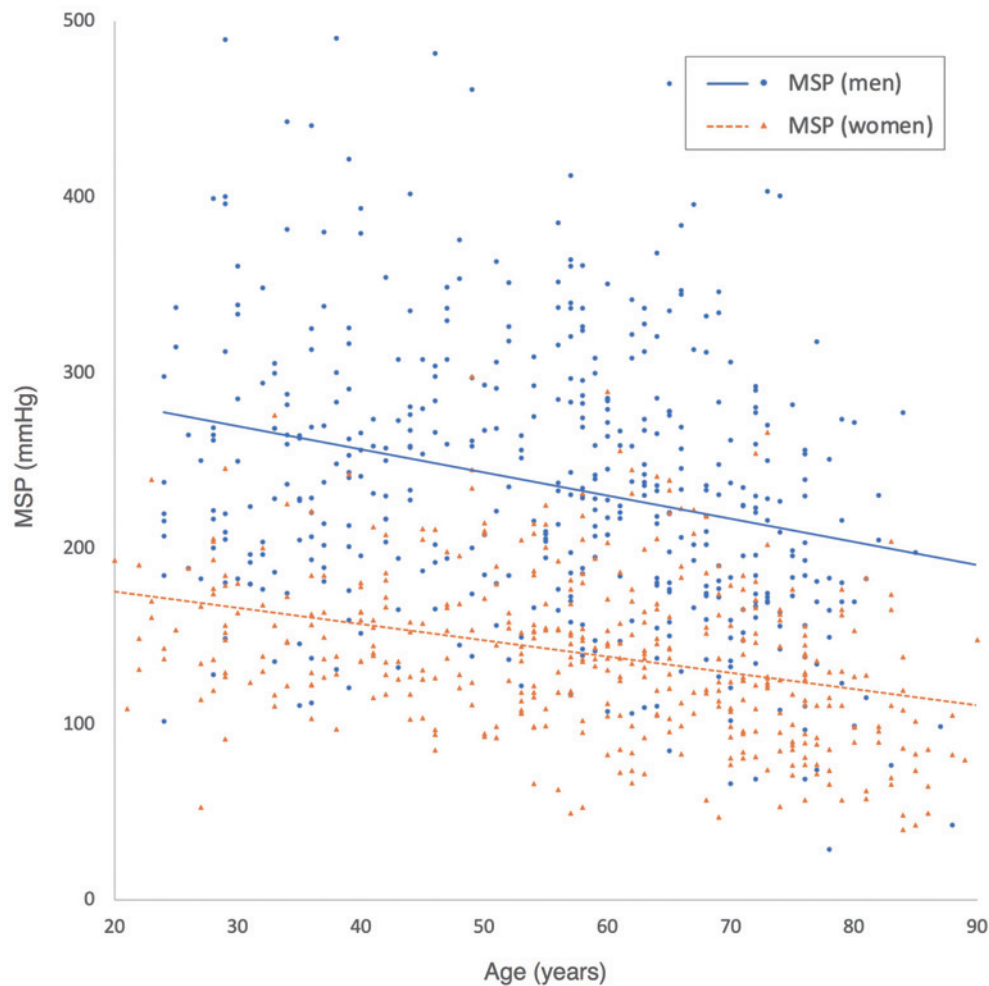


Figure 3. Regression analysis of the influence of age on MSP. MSP decreased significantly with age in both sexes (men, $r = -0.266$, $p < 0.001$; women, $r = -0.363$, $p < 0.001$). MSP, maximal squeeze pressure

in line with the results of our study, which included more than 400 patients of both sexes. The age-related decrease in MRP and MSP may be due to fibrosis of the internal anal sphincter muscle and decreased skeletal muscle mass, respectively[24,25].

Several studies have investigated the effects of aging on anorectal sensitivity, but the results are inconsistent. Roe et al.[17] measured anal sensory thresholds to electrical stimulation in normal participants and reported that there is no significant difference between participants aged <60 years ($n = 12$) and those aged >60 years ($n = 8$). In contrast, age-related deterioration of anal sensitivity was observed in all four studies that performed a regression analysis of the sensory threshold for electrical stimulation ($r = 0.22-0.42$)[16,20,23,24]. These results were confirmed by the regression analysis in the present study ($r = 0.384$ in men; $r = 0.410$ in women). Only one study examined age-related changes in rectal sensation with electrical stimulation. Jameson et al.[24] reported that the electrical sensory thresh-

old of the rectum significantly increases with aging ($r = 0.54$). Overall, these results suggest that deterioration in anorectal sensitivity correlates with aging. Age-related decline in anorectal sensitivity may be due to a decrease in the number of sensory neurons, alterations in peripheral and central autonomic nerve activity, and an increase in various neurological disorders in the elderly[24].

Very few studies have investigated sex differences in anorectal sensation. Of the nine studies investigating anal sensation in response to electrical stimulation[16-24], four studies involved only female participants, and only two studies examined sex differences in the sensory threshold[17,24]. Roe et al.[17] reported that there is no significant sex difference in the anal sensory threshold for electrical stimulation in healthy participants (15 women, 5 men). In contrast, Jameson et al.[24] found that men aged >50 years ($n = 23$) have higher sensory thresholds than women aged >50 years ($n = 13$) (7.3 mA vs. 5.7 mA). In the present study, we investigated a more significant number of participants, which

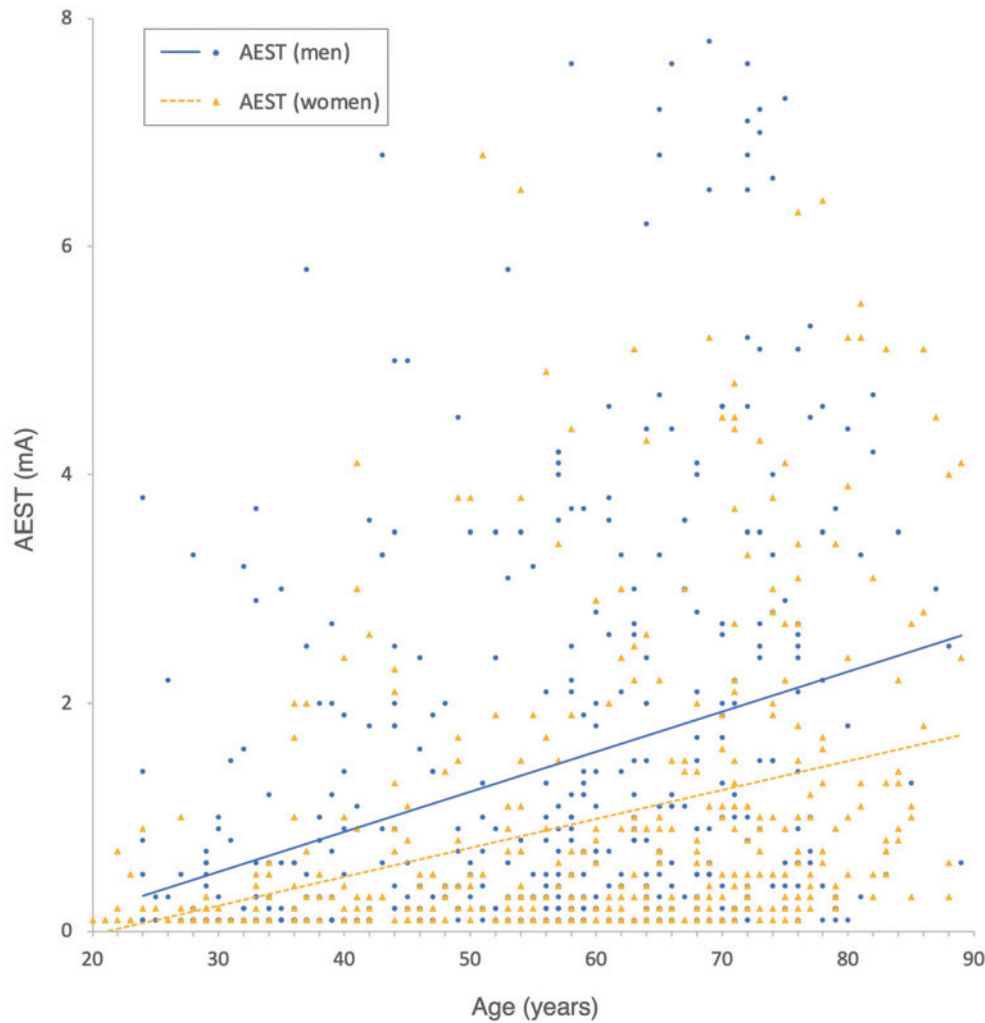


Figure 4. Regression analysis of the influence of age on AEST. AEST increased significantly with age in both sexes (men, $r = 0.384$, $p < 0.001$; women, $r = 0.410$, $p < 0.001$). AEST, anorectal electrical sensory threshold

Table 2. AEST in Each Age Group for Men and Women (n = 888).

Age	AEST		p-value
	Men	Women	
20–29	0.2 (0.1–0.6)	0.2 (0.1–0.2)	0.280
30–39	0.2 (0.1–0.7)	0.2 (0.1–0.5)	0.959
40–49	0.4 (0.2–1.8)	0.3 (0.1–0.9)	0.081
50–59	0.5 (0.2–1.3)	0.3 (0.1–0.7)	0.008
60–69	0.9 (0.4–2.6)	0.3 (0.2–0.9)	<0.001
70–79	1.5 (0.4–3.5)	0.8 (0.3–1.9)	0.006
80–89	2.5 (0.6–3.9)	1.4 (0.7–3.7)	0.178
Total	0.6 (0.2–2.0)	0.4 (0.2–1.1)	<0.001

AEST, anorectal electrical sensory threshold

Data are medians with interquartile ranges in parentheses.

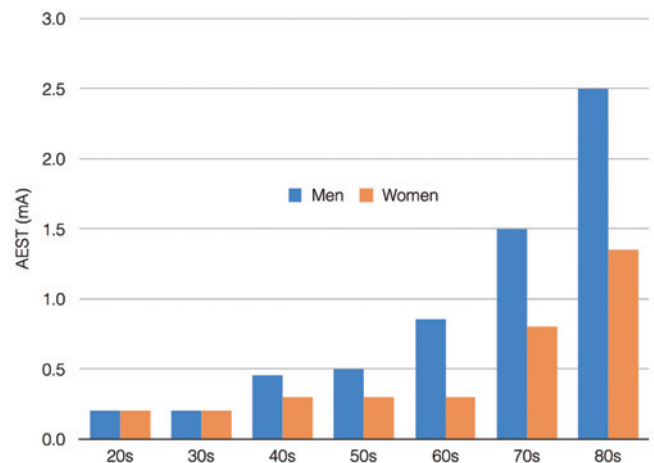


Figure 5. Median AEST for each age group of men and women. There was no sex difference in AEST in ages 20–40 years, but in ages 50–70 years, men had higher AEST than women. AEST, anorectal electrical sensory threshold

enabled a regression analysis of the data. Consequently, we found significantly higher AEST in men than in women. For

rectal sensitivity, Gundling et al.[25] examined the perception threshold for balloon distension in 146 asymptomatic participants, with a median age of 64 (range 22-90) years, and showed a significantly higher threshold in men (median volume 30 ml in men and 20 ml in women).

However, the cause of a higher anorectal sensory threshold in men has not been explored. Prolonged pudendal nerve terminal motor latencies (PNTMLs) have been reported to be associated with significantly decreased anal resting and squeeze pressures[27]. In addition, PNTMLs increase with age in both men and women[24], but no correlation between prolonged PNTML and decreased anorectal sensation has been observed[16,20]. Thus, it is unclear why the age-related decline in anorectal sensation is milder in women than in men. Sun and Read[26] advocated that a low sensory threshold in women may help compensate for the weakness of anal sphincters.

Men were found to have more functional defecation disorders, such as DD and FI, mainly supported by the evidence of less anorectal sensation. Sun and Read[26] reported that men have weaker recto-anal inhibitory reflexes to rectal balloon distension than women, resulting in higher residual anal pressure during rectal evacuation. This means that the anal canal cannot be relaxed during defecation, leading to inadequate rectal emptying[28]. A recent cross-sectional study of patients with FI showed that men were more likely to report coexisting constipation than women (42% vs. 30%)[29]. Townsend et al.[30] investigated the differences in pathophysiological mechanisms of FI between sexes and reported that, in males, anal sphincter dysfunction is uncommon (male, 37% vs. female, 77%), whereas impaired rectal sensation (male, 24% vs. female, 7%) and functional disturbances of evacuation (male, 36% vs. female, 13%) are more common than in women.

This study is limited by its retrospective design and the heterogeneity of the study population. Anorectal physiology data were collected from symptomatic patients rather than normal subjects. In addition, we did not assess the impact of their comorbidities on anorectal sensation. However, most of the comorbidities were constipation and hemorrhoids, which are common in the general population undergoing anorectal physiology tests. Therefore, the results of the present study could be readily applied to clinical practice.

In conclusion, our data suggest that anorectal sensitivity decreases with aging in both sexes, and that among the elderly, men have significantly lower sensitivity than women. These alterations that occur with aging and the observed sex differences may explain the increased prevalence of CC or FI in older men. Therefore, these physiological features can impact treatment strategies. Sensory training, such as bio-feedback, electrical stimulation, or sacral neuromodulation to treat CC or FI, may benefit older men more than women.

Conflicts of Interest

There are no conflicts of interest.

Author Contributions

Tatsuya Abe contributed to the concept and design and data acquisition and analysis and drafted and revised the manuscript; Masao Kunimoto, Yoshikazu Hachiro, Shigenori Ota, Kei Ohara, Mitsuhiro Inagaki, and Masanori Murakami contributed to data acquisition, revised the manuscript, and approved the final version.

Approval by Institutional Review Board (IRB)

This research was approved by the institutional review board of Kunimoto Hospital (approval code: K06-002).

Disclaimer

Tatsuya Abe is one of the Associate Editors of Journal of the Anus, Rectum and Colon and on the journal's Editorial Board. He was not involved in the editorial evaluation or decision to accept this article for publication at all.

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