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Brief communication (Original)

Normative anatomy of the anal sphincter detected with 3D-endoanal ultrasonography

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Background: Understanding anal sphincter anatomy is crucial in management of anorectal disorders, including anorectal sepsis and fecal incontinence. Three-dimensional endoanal ultrasound (EAUS) provides better resolution of the tissue layers. Previous normative studies were obtained in Western populations.
Objective: We demonstrated the anal sphincter anatomy in normal East Asian subjects.
Methods: Forty-six healthy subjects without anorectal symptoms (M:F = 15:31, mean age ± SD = 47 ± 13 years) were enrolled. High-frequency (16 MHz) EAUS was performed with a mechanically rotated probe. Thickness and length of anal sphincter components were measured. Differences between sexes were assessed using a Student t test.
Results: We demonstrated 4 differentiable components: the anal sphincter; internal anal sphincter (IAS), subcutaneous external anal sphincter (Sc EAS), superficial external anal sphincter (Sp EAS), and puborectalis muscle (PRm). The mean length of anal sphincter components were obtained in mm (men vs. women), IAS (28.5 vs. 25.3, p = 0.03), Sc EAS (13.2 vs. 11.2, p = 0.005), Sp EAS (24.1 vs. 19.6, p = 0.0001), and PRm (12.4 vs. 12.2, p = 0.84). The anal canal was significantly longer in men (38.6 vs. 34.0, p = 0.007). The mean thickness for IAS (1.7 vs. 1.8, p = 0.095), Sc EAS (7.5 vs. 7.6, p = 0.587), Sp EAS (8.1 vs. 6.9, p = 0.001), and PRm (8.7 vs. 9.0, p = 0.605) were measured. The PRm was the thickest and the Sp EAS was the longest voluntary sphincter.
Conclusion: Normative details of anal sphincter components in an East Asian population are described. This data can be used for future consideration of diseased states.

Keywords: Anal sphincter anatomy, anal ultrasound, endoanal ultrasonography, normal anal sphincter anatomy, normative data, transanal ultrasound

Understanding anal sphincter anatomy is crucial for management of anorectal disorders including anorectal sepsis and fecal incontinence. In these conditions, normal anatomy of anal sphincters can be distorted or even disrupted. Three-dimension endoanal ultrasound (3D-EAUS) is useful for evaluation of the anal sphincter complex and the surrounding tissue plane with high accuracy. With multiplanar imaging, 3D-EAUS improves diagnostic confidence [1] and interobserver agreement [2]. Basic insight of normal endoanal sonographic features of anal sphincter will be useful for comparison of diseased and normal states.

Endoanal ultrasonography has been introduced to clinics since the 1980s. Previous studies have described techniques and features in both normal and diseased subjects. Most of these studies involve subjects from Western countries. There is still a lack of normative data in East Asian populations and whether there is a difference in anal sphincter characters between two populations was hitherto unknown.

We have introduced 3D-EAUS to King Chulalongkorn Memorial Hospital since 2009 for assessment of patients in the anorectal clinic. Thus, a prospective study of normal anal sphincter anatomy was warranted to serve as a baseline. This study aims to describe character of the anal sphincter of healthy East Asian subjects and establish normative data.

Materials and methods

Healthy subjects were enrolled through a questionnaire interview. The ratio of male to nulliparous female to multiparous female were planned to be 1:1:1. None had any history of anorectal

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disease or abnormal bowel symptoms related to constipation or fecal incontinence. None had previous anorectal or abdominal surgery other than a simple appendectomy. Informed consent was obtained prior to the study, and the Institutional Review Board of Faculty of Medicine, Chulalongkorn University, approved this study.

A three-dimensional EAUS study using a mechanically rotated probe (2050 Bruel and Kjaer Medical, Sanhoften, Denmark) was performed with the subject in a left lateral decubitus position. The scanner probe was inserted up to about 6 cm from the anal verge. The series of scans was obtained from the level of the pubococcygeus cranially down to the subcutaneous external sphincter caudally; using high-frequency transducer of 16 MHz. Images were saved for review. All subjects tolerated the procedure well without any complaint or complication.

The length of anal sphincter components was measured in sagittal view (anterior and posterior parts) and coronal view (left and right lateral parts) as can be seen in **Figures 1 and 2**. The thickness of anal sphincter components was measured in cross-sectional view at the 3, 6, 9, and 12 o'clock positions (**Figure 3**). Each measurement was repeated 5 times.

Details of the anal sphincter character were described as mean ± SD. Differences between sexes were analyzed using Student's *t* test. A $p < 0.05$ was considered statistically significant.

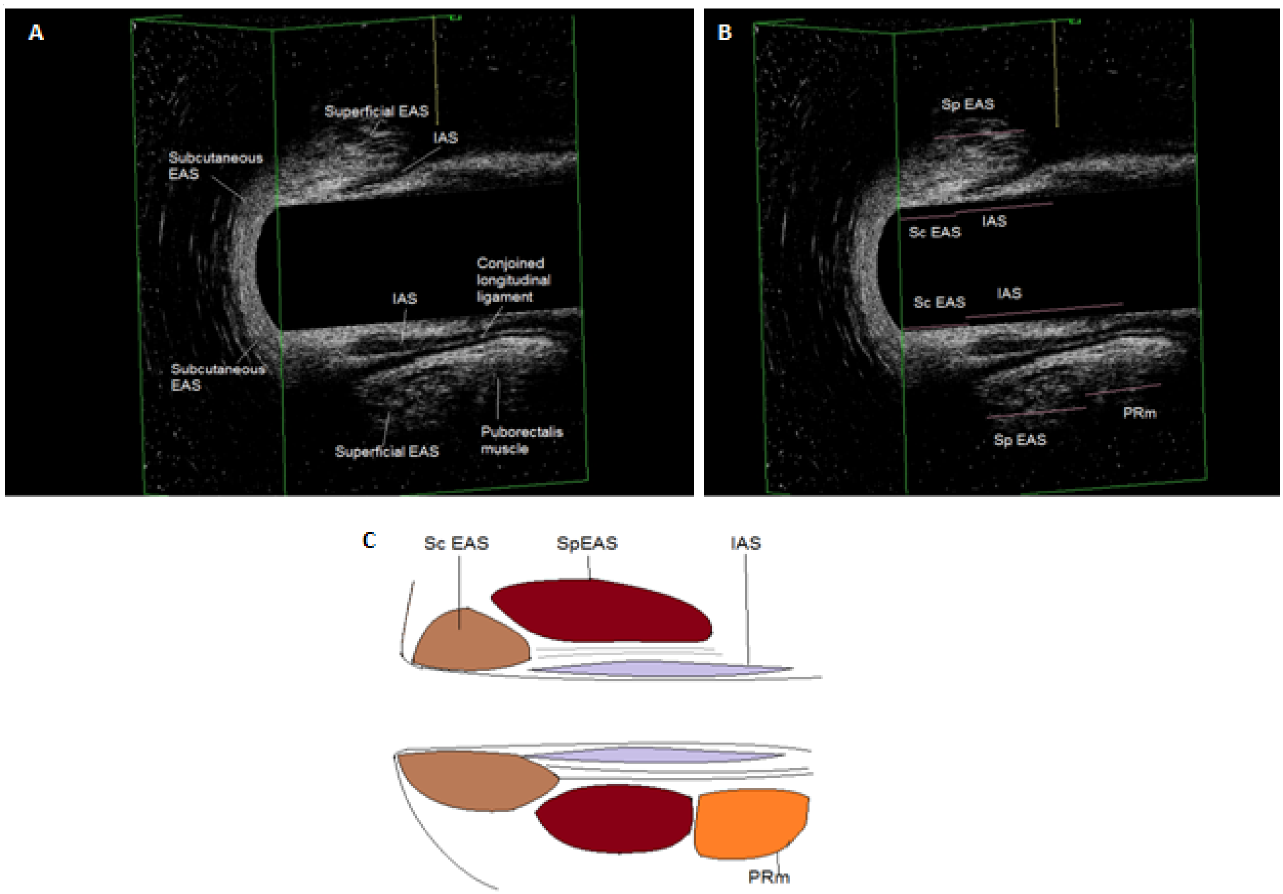

Figure 1. **A:** Sagittal view of anal sphincter components, **B:** Measurement of anal sphincter length, anterior and posterior positions, **C:** Schematic view of sagittal view of anal sphincter components. EAS = external anal sphincter, IAS = internal anal sphincter, Sc EAS = subcutaneous external anal sphincter, Sp EAS = superficial external anal sphincter, PRm = Puborectalis muscle

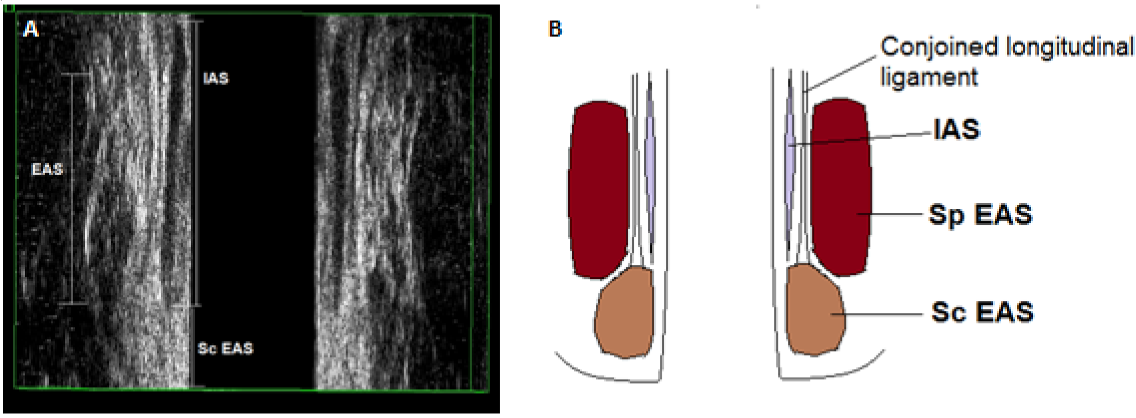

Figure 2. **A:** Coronal view of anal sphincter components, **B:** Schematic view of coronal view of anal sphincter complex. Sc EAS = subcutaneous EAS, EAS = external anal sphincter (include superficial EAS and Puborectalis muscle due to indistinguishable), IAS = internal anal sphincter

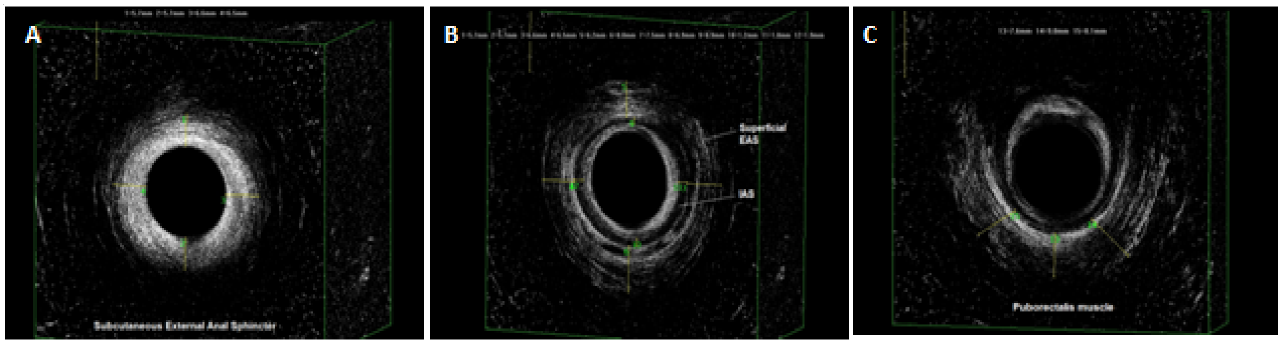

Figure 3. Cross-sectional view and measurement of thickness of anal sphincter components at 3 levels of the anal canal. **A:** Lower anal canal; subcutaneous external anal sphincter, **B:** Middle anal canal; superficial external anal sphincter and internal anal sphincter, **C:** Upper anal canal; puborectalis muscle

Results

Forty-six subjects (M:F 15:31, mean age ± SD, 47 ± 13 years) were enrolled. In the female group, there were 7 nulliparous, 7 with previous cesarean section (without previous vaginal delivery) and 17 with previous vaginal delivery. Thus, the ratio of male: nulliparous female: cesarean section: vaginal delivery was 1:0.5:0.5:1. For the group with previous vaginal delivery, median number of children was 1 (range 1–5). There were 8 subjects with difficult vaginal delivery (one or more of the following; prolonged labor, birth weight of more than 3,500 g, assisted instrumentation). **Table 1** shows body weight and height of subjects. There was no anal sphincter defect detected in this study. Thickness and length of anal sphincters were shown in **Tables 1 and 2**.

Sonographically, anal sphincter complex is comprised of 4 parts: the internal anal sphincter, subcutaneous external sphincter, superficial external anal sphincter, and puborectalis muscle (**Figures 1 and 2**).

The internal anal sphincter (IAS) was seen as a thickened hypoechoic circular tube that continues from the inner circular muscular layer of rectum above. It ends in the lower part of mid-anal canal above the subcutaneous external anal sphincter (Sc EAS).

The external anal sphincter (EAS) was previously described has having three parts: deep, superficial, and subcutaneous [3]. In this study, we found two ultrasonographically differentiable parts. The lowest bright hyperechoic ring below the termination of IAS is the subcutaneous external anal sphincter (Sc EAS). Above that level, the heterogenous echoic ring that surrounds IAS just outer to conjoined longitudinal ligament is defined here as superficial external anal sphincter (Sp EAS). These components can be consistently differentiated in all subjects.

Table 1. Lengths of anal sphincter complex components (mm, mean ± SD)

	Male (n = 15)	Female (n = 31)	Total	*p*
Age (years)	44.8 ± 14.3	47.4 ± 12.4	47 ± 13	0.536
Body weight (kg)	67.3 ± 9.9	56.3 ± 10.6	59.9 ± 11.4	0.002
Height (cm)	165.5 ± 6.8	154.5 ± 7.2	157.5 ± 9.1	0.0001
IAS—anterior	27.2 ± 4.7	19.4 ± 5.0	21.9 ± 6.1	0.0001
IAS—posterior	27.8 ± 4.5	23.6 ± 5.2	25.0 ± 5.3	0.01
IAS—left	29.4 ± 4.7	29.5 ± 5.0	29.5±4.9	0.95
IAS—right	29.4 ± 4.6	28.8 ± 5.1	29.0 ± 4.9	0.72
IAS—mean	**28.5 ± 4.5**	**25.3 ± 4.4**	**26.3 ± 4.6**	**0.03**
Sc EAS—anterior	12.3 ± 2.9	10.7 ± 1.6	11.2 ± 2.2	0.017
Sc EAS—posterior	14.9 ± 3.1	12.4 ± 2.1	13.2 ± 2.7	0.002
Sc EAS—left	12.5 ± 3.9	10.4 ± 1.7	11.1 ± 2.78	0.014
Sc EAS—right	13.2 ± 3.9	11.4 ± 1.9	12.0 ± 2.80	0.047
Sc EAS—mean	**13.2 ± 3.3**	**11.2 ± 1.3**	**11.9 ± 2.32**	**0.005**
Sp EAS—anterior	21.7 ± 4.0	15.7 ± 2.7	17.6 ± 4.2	0.0001
Sp EAS—posterior	19.2 ± 5.3	14.3 ± 2.7	15.9 ± 4.4	0.0001
Sp EAS—left*	28.0 ± 5.4	24.3 ± 4.9	25.5 ± 5.3	0.027
Sp EAS—right*	27.7 ± 5.5	24.0 ± 4.8	25.2 ± 5.3	0.026
Sp EAS—mean	**24.1 ± 4.7**	**19.6 ± 3.1**	**21.1 ± 4.3**	**0.0001**
PRm—posterior	**12.4 ± 3.6**	**12.2 ± 2.8**	**12.2 ± 3.1**	**0.84**
Anal canal—anterior	35.9 ± 8.4	27.7 ± 5.4	30.4 ± 7.5	0.0001
Anal canal—posterior	38.3 ± 6.5	34.77 ± 5.0	35.9 ± 5.7	0.045
Anal canal—left	39.9 ± 6.4	36.2 ± 4.6	37.4 ± 5.5	0.031
Anal canal—right	40.4 ± 6.3	37.2 ± 4.6	38.2 ± 5.4	0.06
Anal canal—mean	**38.6 ± 6.6**	**34.0 ± 4.3**	**35.5 ± 5.6**	**0.007**

* These might include the length of PRm (see text). IAS = internal anal sphincter, Sc EAS = subcutaneous external anal sphincter, Sp EAS = superficial external anal sphincter, PRm = Puborectalis muscle.

Table 2. Thickness of anal sphincter complex components (mm, mean ± SD)

Components	Male (n = 15)	Female (n = 31)	Total	*p*
IAS—mean	1.7 ± 0.4	1.8 ± 0.3	1.8 ± 0.3	0.095
Sc EAS—mean	7.5 ± 0.6	7.6 ± 0.6	7.5 ± 0.6	0.587
Sp EAS—mean	8.1 ± 1.3	6.9 ± 0.9	7.3 ± 1.1	0.001
PRm—mean	8.7 ± 1.3	9.0 ± 1.5	8.9 ± 1.4	0.605

The uppermost level of the anal canal is the U-shaped puborectalis muscle (PRm) which continues superolaterally with the V-shaped pubococcygeus muscle.

Internal anal sphincter

The mean length of the IAS was 28.5 mm in men and 25.3 mm in women (p = 0.03). In women, the IAS was shortest anteriorly. The mean thickness of IAS was 1.7 mm in men and 1.8 mm in women (0 = 0.095).

External anal sphincter

The mean length of the Sc EAS was 13.2 mm in men and 11.2 mm in women (p = 0.005). Sc EAS tends to be shortest in the anterior part. For Sp EAS, the mean length was 24.1 mm in men and 19.6 mm in women (p = 0.587). The length of this muscle on lateral sides seems overstated. This is because of a technical inability to separate definitely the Sc EAS from the PRm in the coronal view. Thus, the length of both was combined into the measurement (**Figure 2**). Women had a significantly shorter Sc EAS and Sp EAS compared with men in all directions ($p < 0.05$).

The mean thickness of Sc EAS was 7.5 mm in men and 7.6 mm in women ($p = 0.587$). The mean thickness of the Sp EAS was 8.1 mm in men and 6.9 mm in women ($p = 0.001$). Compared with men, women had a significantly thinner Sp EAS in all directions. The anterior part of the Sp EAS is the thinnest area in both sexes.

Puborectalis muscle

The length of the PRm was measured at the posterior midline (**Figure 1**). It was 12.4 mm in men and 12.2 mm in women ($p = 0.84$). The thickness of the PRm was measured at the bottom of the U shape (6 o'clock position, **Figure 3C**). It was 8.7 mm in men and 9.0 cm in women ($p = 0.605$).

When the entire anal sphincter components were measured, the mean length of the anal canal was 38.6 mm in men and 34.0 mm in women ($p < 0.007$). The anterior part of the anal canal was the shortest area because of the lack of PRm in the upper anal canal. Women had a significantly shorter anal canal than men did, especially in the anterior part.

Discussion

EAUS is a useful tool for the assessment of patients with anorectal disorders including fecal incontinence and anorectal sepsis [4-6, 15, 16]. Technically, it is simple, minimally invasive, and well tolerated [4, 12, 16]. It is the most reliable test for delineation of anatomical defects of the external and internal anal sphincters [4, 5]. Three-dimensional EAUS offers a longitudinal perspective of the anal canal and with a multi-planar function. Thus, it helps decrease operator dependency [2] and provides better differentiation of each anal sphincter component. Using a transducer probe at 16 MHz, which is a higher frequency than what was previously used (7 and 10 MHz), anal sphincter components are clearly defined. Basic knowledge of the normal sonographic character of the anal sphincter components is important for comparison and recognition of disease states.

Previous studies had reported findings in healthy volunteers using classical two- or three-dimensional EAUS [7-9]. However, there was no report regarding the normative value for East Asian populations. We present here details of anal sphincter components detected with 3D-EAUS in healthy East Asian subjects. We found that there were 4 distinguishable components: IAS, Sc EAS, Sp EAS, and PRm. We could not differentiate the deep portion of the EAS, which may the result of its fusion or intimate relationship with the PRm [6].

The length of the IAS and Sp EAS was longer on the lateral side than on the anterior or posterior sides as consistent with a previous report [9]. This may be the result of fixation of the lateral part of the upper anal canal to the pelvic side wall. For Sp EAS, there is no clear separation plane between Sp EAS and PRm on the lateral sides. Thus, the length of these two muscles was combined on the lateral sides. The length of the anal sphincter components: IAS, Sc EAS, Sp EAs, and anal canal was significantly greater in men compared with women, except for the PRm. This is also consistent with previous reports [9, 10].

Anteriorly, the anal canal is shorter. Sc EAS length comprised at least one-third (36.7%) of the anal canal length. Thus, division of this part such as in fistulotomy can lead to significant loss of anal sphincter mass. Data regarding length and thickness of anal sphincter components from previous study is shown in **Tables 3 and 4**, respectively.

The thickness of IAS had been shown to increase with age [7, 11], which is the same trend in this study. There was no difference in IAS thickness between sexes. EAS thickness was reported between 4–10 mm [7, 11, 13, 14]. Our data was not completely similar to previous study. This may be because of the difference in race or the difference in the instrument and measurement technique. We did not assess the difference between nulliparous and parous women. This is because we wanted to present normative data that can be generalized to the general population of women.

Conclusion

We present details of length and thickness of anal sphincter portions in healthy subjects using 3D-EAUS. Our data are not completely similar to previous studies. This basic information will serve as normative data to guide diagnosis and treatment of disorders involving anal sphincter. By measuring each component separately, individualized treatment may be planned.

Acknowledgements

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Table 3. Length of anal sphincter components

	Internal Anal Sphincter												Puborectalis muscle		
	Anterior			Posterior			Lateral			Mean			Posterior		
	M	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***
Knowles et al. [7]	29.0	25.0	0.042	28.0	25.0	0.061	–	–	=						
Regadas et al. [10]	27.5	20.7	0.004	35.6	30.2	<0.001	35.8	33.8	NS						
William et al. [9]	x	x	x	x	x	x	x	x	x	34.4	33.2	0.72	23.9	27.1	0.49
This study	27.2	19.4	0.0001	27.8	23.6	0.0001	29.4	29.2	NS	28.5	25.3	0.03	12.4	12.2	0.84

	External Anal Sphincter									Anal canal Total		
	Anterior			Posterior			Lateral					
	M	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***
Knowles et al. [7]	25.0	16.0	<0.0001							36.0	34.0	0.24
Regadas et al. [10]	34.2	22.0	<0.001	36.6	32.0	0.002	39.5	36.8	NS	37.9	36.0	0.036
William et al. [9]	30.1	15.6	<0.001	29.3	16.4	0.002	31.6	19.5	<0.001	50.2	42.2	0.019
This study	34.0	26.4	<0.05*	46.5	38.9	<0.05*	40.7	35.0	<0.05*	38.6	34.0	0.007

* Anterior length of EAS is the sum of Sc EAS and Sp EAS, posterior length of EAS is the sum of Sc EAS, Sp EAS and PRm and lateral length of anal canal is the sum of Sc EAS and Sp EAS.

Table 4. Thickness of anal sphincter components

	Internal anal sphincter											
	Anterior			Posterior			Lateral			Mean		
	M	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***	**M**	**F**	***p***
Regadas et al. [10]	1.9	1.2	0.013	1.9	1.8	NS						
Burnette et al. [11]							2.8	2.8	–			
Knowles et al. [7]										2.1	2.2	NS
Papachrysostomou et al. [12]										2.0	2.1	NS
This study	1.6	1.6	0.712	1.4	1.6	0.083	1.8	2.1	NS*	1.7	1.8	0.095

	External anal sphincter		
	M	**F**	***p***
Knowles et al. [7]	6.2	6.6	NS
Gregory et al. [13]	–	5.7	NS
Burnette et al. [11]	–	6.0	NS
Papachrysostomou et al. [12]	8.7	7.5	<0.02
This study Sc EAS	7.5	7.6	0.587
This study Sp EAS	8.1	6.9	0.001

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