Correlation between vocal tract length, body height, formant frequencies, and pitch frequency for the five Japanese vowels uttered by fifteen male speakers

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AIM OF OUR RESEARCH

1. To clarify the relationships of physical measures and acoustic parameters using a magnetic resonance imaging (MRI) database
   - Physical measures: vocal tract length (VTL) and body height
   - Acoustic parameters: pitch and formant frequencies
2. To verify whether the individual difference of formant frequencies is caused by the speakers' vocal tract length

MATERIALS AND METHODS

☐ATR vocal tract MRI data (released by ATR-Promotions)

Contents of the database

Speakers: 15 native Japanese adult male speakers

Speech materials: five Japanese vowels (/a/, /e/, /i/, /o/, /u/)

MRI data of the midsagittal plane obtained during speaking a vowel

Speech sounds recorded during the MRI scan

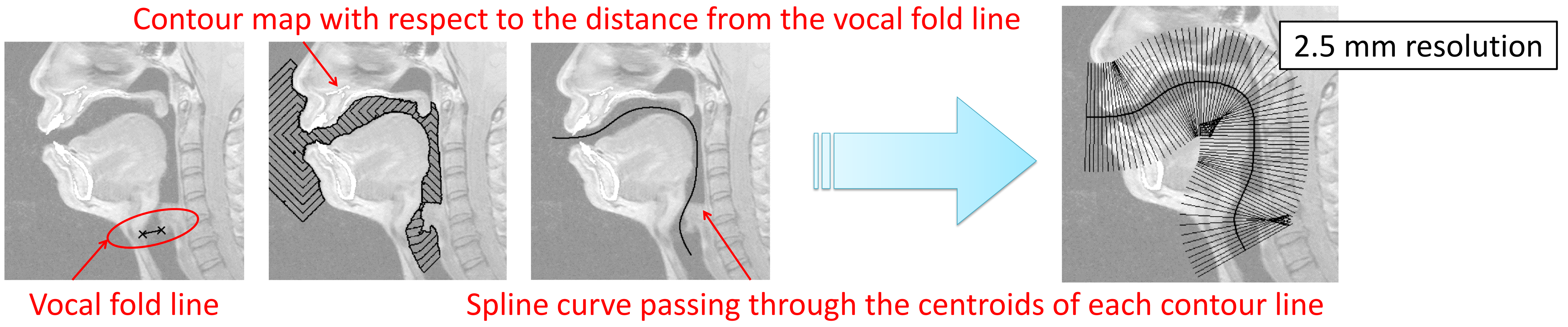
Vocal tract length extracted from the MRI data

Speakers' body heights (self-reported) and ages

☐Data acquisition methods

Vocal tract length

- The vocal tract length is defined by the glottis-to-lips length of the vocal tract midline with a 2.5 mm resolution obtained by the method proposed by Takemoto *et al.* (2006)



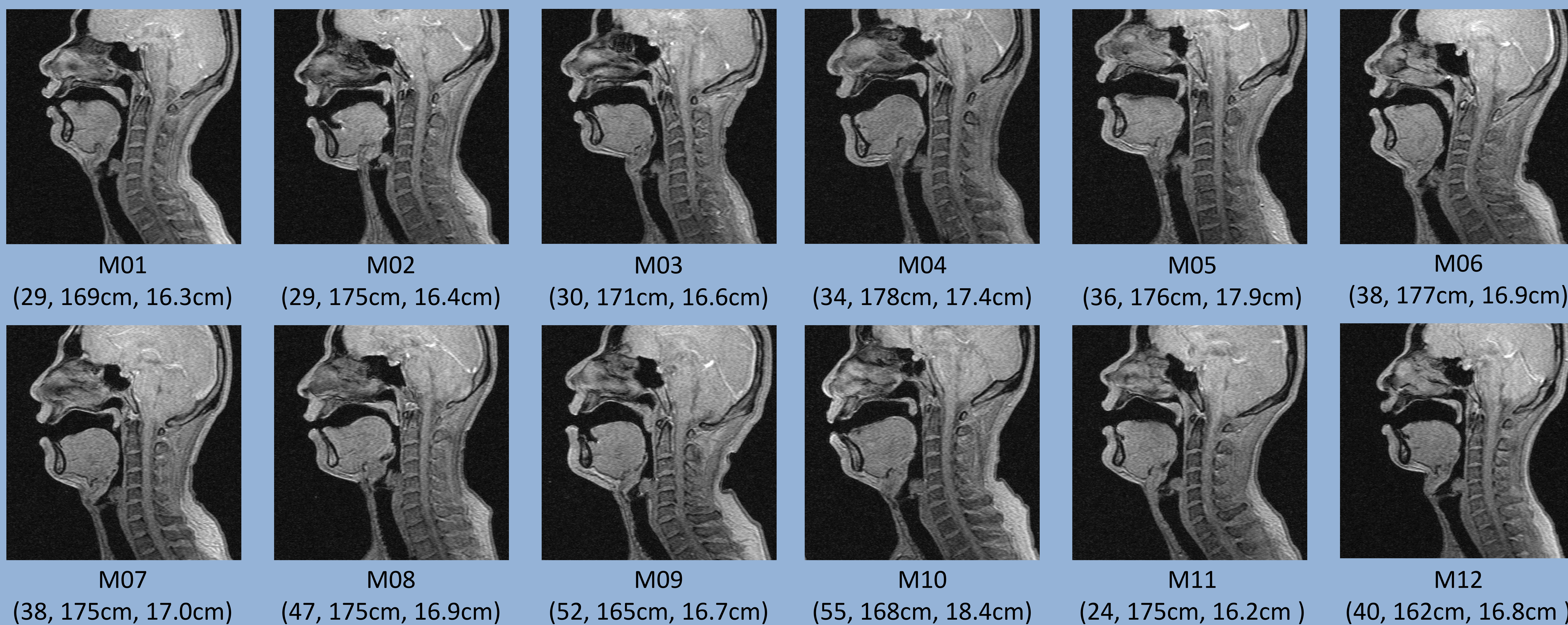
Formant frequencies

- The F1 - F4 were measured from the log spectral envelopes of the vowel segments calculated by the unbiased log spectral estimation (Imai & Furuichi 1987) and averaged with respect to the frames (frame length: 64ms, frame period: 16ms, order of the cepstrum: 60, number of iterations: 3)

Pitch frequencies

- The pitch frequency was extracted using the Pitch Contour function of WaveSurfer with its default parameters (frame length: 7.5ms, frame period: 10ms)

RESULTS



	Range	Mean	S.D.
Age	24 - 55	37	9
Body height	162 - 184	173	6
VTL	15.3 – 19.3	17.0	0.8

Figure 1: *MR images of each speaker during uttering the vowel /a/. The speakers' age, body height, and vocal tract length which averaged five vowels are showed under their images. The table on the bottom-right corner indicates the range, mean, and standard deviation of speakers' age, body height, and vocal tract length.*

Table 1: *Correlation coefficient (r) between vocal tract length and formant frequencies.*

	/a/	/e/	/i/	/o/	/u/
F1	-.16	-.65	-.27	-.48	-.46
F2	-.15	-.56	-.07	-.50	.05
F3	-.21	-.43	-.20	-.41	.22
F4	-.24	-.58	.38	-.28	.23

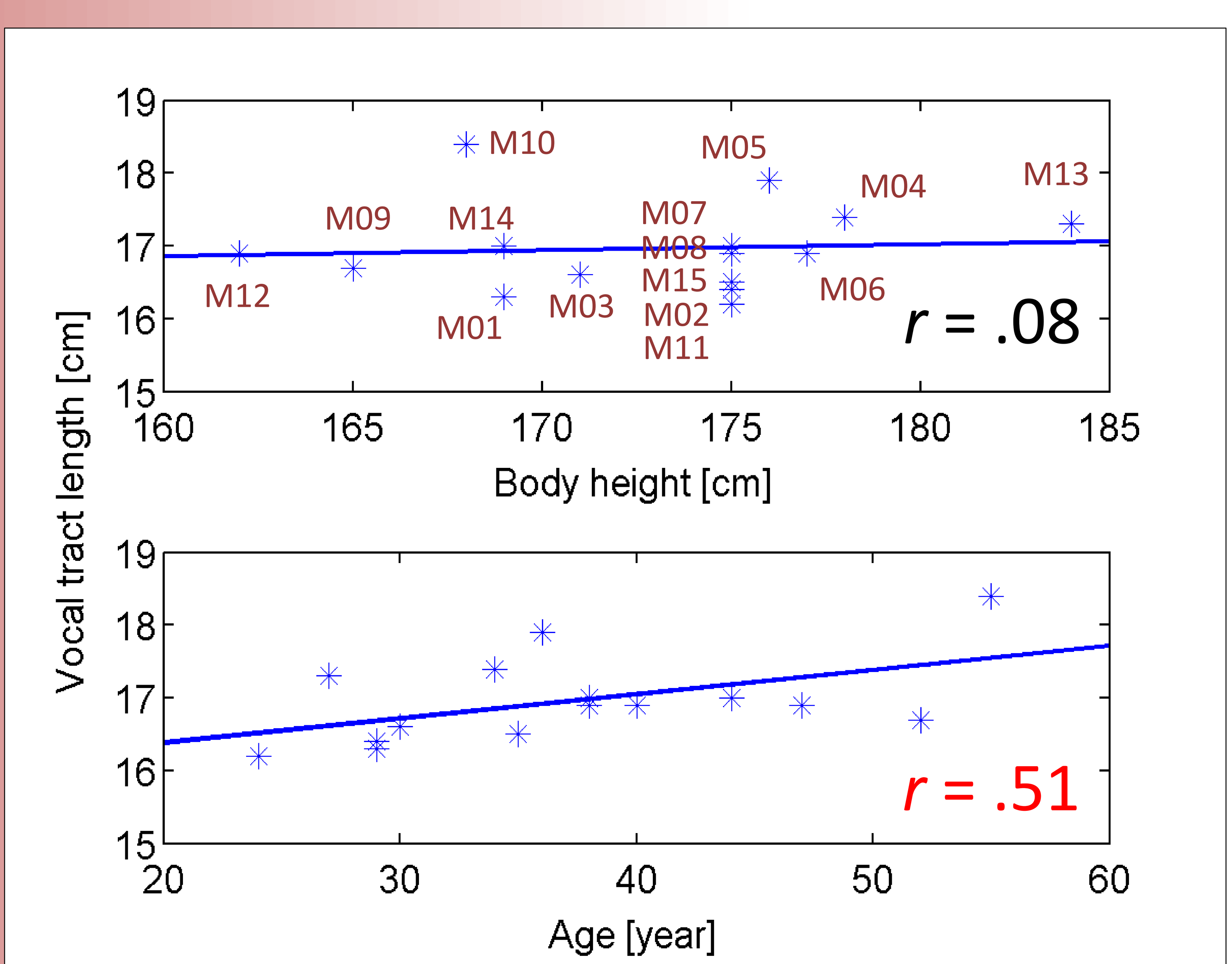


Figure 2: *Upper panel: correlation between mean vocal tract length and body height. Lower panel: correlation between vocal tract length and age.*

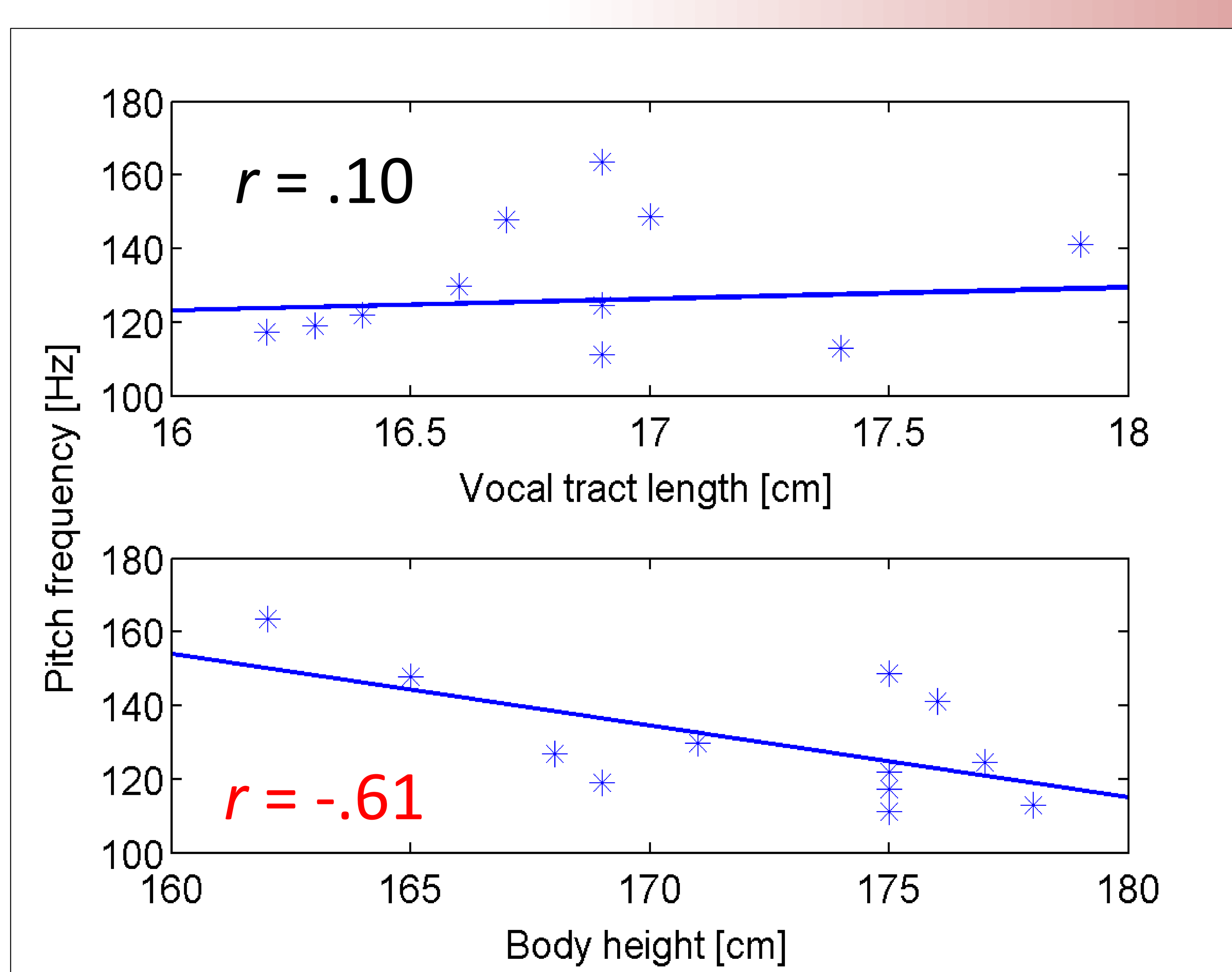


Figure 3: *Upper panel: correlation between mean vocal tract length and pitch frequency. Lower panel: correlation between body height and pitch frequency.*

DISCUSSION

- ☐ There is no correlation between VTL and body height (r = .08)
  - ➢ Fitch and Giedd (1999) indicated that correlation coefficient between them is .92.
  - ➢ Participants' ages is 2 to 24 in their study, but is 24 to 55 in our study.
  - ➢ In the former range, the vocal tract shape is strongly changed with growth. In our range, speech apparatus is already fully developed.

- ☐ There are negative correlations between VTL during uttering the vowel /e/ and its formant frequencies (except for F3)
  - ➢ In the production of /e/, there is no strong constriction in the vocal tract. Thus the vocal tract shape of /e/ is closest to a uniform tube among the Japanese vowels.
  - ➢ For the other vowels, the position and the cross-sectional area at the constriction much affect formant frequencies.

- ☐ There is a positive correlation between VTL and age (r = .51)
  - ➢ The larynx is lowered with increasing age, especially for elderly people.

- ☐ There is a negative correlation between the pitch frequency and body height (r = -.61)
  - ➢ This suggests that the length of the vocal fold may track the body height, even for a fully developed, adult population.

CONCLUSION & FUTURE WORKS

- ☐ Conclution
  - ✓ Individual differences in the formant frequencies, which contribute to voice characteristics, might not to be mainly caused by differences in the VTL within the adult male group.
  - ✓ One of the dominant factors causing speaker-to-speaker differences in the formant frequencies is the length of the vocal tract for the vowel /e/.
  - ✓ The age could be one of the factors for variability of the VTL even for adults.

- ☐ Future works
  - ➢ To reinforce the results obtained in this study by increasing the number of speakers.
  - ➢ To investigate the correlation between the physical and acoustic factors for adult female speakers.

Acknowledgements

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