Research Report JMST

Differences in Speech Characteristics among Frail, Pre-Frail, and Robust Older Adults in Korea

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Background As people age, changes in speech characteristics naturally occur. If differences in speech features exist between frail older adults and those experiencing healthy aging, speech assessment could become a valuable tool for monitoring frailty.

Purpose The purpose of this study was to investigate the differences in speech characteristics according to frailty in older adults.

Study design A cross-sectional design

Methods Forty-two individuals aged 65 and older were recruited from senior community centers. Frailty was assessed based on weight loss, self-reported exhaustion, low physical activity, slow gait speed, and weak grip strength, classifying participants into three groups: frail, pre-frail, and robust. Speech variables, including total speech duration, voiced and unvoiced duration, speech and articulation rates, mean syllable duration, and number of pauses during speech, were compared across the three groups.

Results Frail and pre-frail older adults exhibited significantly slower speech and articulation rates, taking longer to speak the same sentences compared to robust adults. Additionally, frail older adults showed a significantly longer mean syllable duration and more pauses during speech than their robust participants.

Conclusions These findings suggest that speech characteristics could be valuable indicators of frailty in older adults. Future large-scale studies should further explore the relationship between frailty and these speech features.

Key words Aging; Frailty; Older adults; Speech analysis.

J Musculoskelet Sci Technol
2024; 8(2): 134-140
Published Online
Dec 31, 2024
pISSN 2635-8573
eISSN 2635-8581

Article History
Received 22 Oct 2024
Revised 17 Nov 2024 (1st)
Revised 27 Nov 2024 (2nd)
Accepted 1 Dec 2024

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INTRODUCTION

South Korea is continuously experiencing an increase in its elderly population.[1] As people age, various physiological functions, including physical ability, cognition, and language, deteriorate even during the normal aging process. Frailty is a complex syndrome characterized by reduced metabolic reserves, making it harder to maintain balance and weakening the body's ability to withstand stress.[2] Frailty is also associated with various diseases, such as heart disease, falls, and dementia, which accelerate the decline in daily functioning, increase hospitalization rates, and raise mortality risks.[3,4] As a result, this leads to higher national healthcare costs and caregiving expenses, placing significant economic and social burdens on the country.[5]

Aging also affects the speech system.[6,7] Changes in speech characteristics include slower speaking and reading rates, specific articulatory difficulties, and reduced loudness and fluency.[6,8] Age-related speech changes are influenced by anatomical and physiological alterations in the speech mechanisms, such as the respiratory, laryngeal, and supralaryngeal systems.[7] Thoracic stiffness, reduced elastic recoil, and muscle weakness in the respiratory system limit airflow and reduce vital capacity, impairing the ability to articulate and phonate.[7] Additionally, ossification, calcification, and muscle atrophy in the larynx contribute to breathiness and reduced voice loudness in the elderly.[7,9] Furthermore, older adults consistently experience declines in cognitive functions such as semantic processing, lexical retrieval, and working memory, which lead to increased vocal reaction times and longer response durations during speech production.[10–12]

Voice assessment offers the advantage of being a non-invasive method that utilizes relatively inexpensive devices for evaluation. Voice analysis is not only used to assess speech-related disorders but also to evaluate neurocognitive and psychological impairments.[13–15] Previous studies have shown that speech measures, such as lexical-semantic and acoustic features, can differentiate cognitive impairment through brief audio recordings in the early stages of Alzheimer's disease[13] and acoustic speech features, such as the pause-to-word ratio, obtained through remote assessments, have also been linked to amyloid-beta pathology, an indicator of subtle cognitive deficits.[14] Furthermore, speech features such as articulation rate, speech rate, pause length, and formant values have been useful in detecting depression in both read and spontaneous speech.[15] Thus, the analysis of speech may serve as an important tool for screening both healthy and pathological conditions.

Frailty is associated not only with a decline in physical function but also with neurocognitive changes. If speech characteristics in frail older adults differ from those of healthy older adults, voice analysis could be a valuable tool for assessing frailty. Additionally, compared to traditional frailty assessment methods, such as physical performance tests or self-reported questionnaires, speech analysis is time-efficient, and can be performed remotely, making it a promising tool for early detection and continuous monitoring of frailty. Therefore, this study aims to examine speech characteristics among older adults classified as frail, pre-frail, and robust. This knowledge could enhance the assessment and monitoring of frailty in clinical practice, ultimately contributing to better healthcare outcomes for the elderly population.

METHOD

Participants

Our study recruited participants in Wonju-si, South Korea, from September to December 2023. Participants were selected through direct contact with senior community centers. The inclusion criteria required participants to have no speech or hearing impairments, be able to understand and speak Korean, and walk independently with or without assistive devices. Exclusion criteria included severe hearing or visual deficits, aphasia, neurological diseases, and upper or lower extremity fractures within the past year. Data on participants' gender and age were collected through interviews, while their height, weight, and cognitive function, assessed using the mini-mental state examination (MMSE), were evaluated by the examiner. Each participant received a detailed explanation of the study's purpose and procedures and provided written informed consent. This study was approved by the Ethics Committee of Sangji University.

Frailty assessment

Frailty was assessed based on the following five criteria: weight loss, self-reported exhaustion, low energy expenditure, slow gait speed, and weak grip strength, following the frailty assessment method proposed by Fried et al.[2,16] Weight loss was defined as a loss of ≥4.5 kg or ≥5% per year, as reported by the participants. Exhaustion was defined as self-reported feelings of exhaustion occurring 3–4 days per week or most of the time. Low energy expenditure was defined as <383 kcal per week for men and <270 kcal per week for women. Energy expenditure was calculated based on each individual's self-reported weekly activities using the short form of the Minnesota Leisure Time Physical Activity. Slow gait speed was defined as taking longer than a cutoff time to walk 4.57 m, based on gender and height. Weak grip strength was defined as a measurement lower than a cutoff value based on sex and body mass index, assessed using a hand-held dynamometer. Grip strength was measured in a sitting position with the arm parallel to the trunk, elbow flexed at 90 degrees, and forearm and wrist in a neutral position. Measurements were performed three times, and the average value was used. Participants meeting three or more of the five criteria were classified as frail, those with one or two criteria as pre-frail, and those with no criteria as the robust (not frail) group.[2,16]

Speech data collection and analysis

Voice data were collected using a Sony ICD-TX660 recorder. Participants were seated in front of a table, with the microphone positioned 15 centimeters from them. For the voice recording, two sentences were selected from the "Ga-eul (Autumn)" paragraph, which consists of 41 syllables in Korean. Participants were first asked to read the speech material aloud, after which the recording began. If the same syllable was repeated or misread three or more times during the recording, they were asked to read the text again. These sentences are widely used in clinical settings and studies on Korean speakers to analyze language characteristics.[17]

For the analysis of speech characteristics, the following variables were used: total speech duration, voiced and unvoiced time, speech rate, articulation rate, mean syllable duration, and the number of pauses.[18–20] Voiced and unvoiced time referred to the periodic (voiced) and aperiodic (unvoiced) time within the audio recordings. Speech rate was defined as the number of syllables produced per total duration.[19,20] Articulation rate was defined as the number of syllables produced per phonation time without pauses. Phonation time was defined as the sum of intrasyllable and intersyllable durations shorter than 250 ms.[19] Speech variables were extracted using Parselmouth and the Python (version 3.8) audio-processing libraries.[21]

Statistical analysis

Statistical analysis was conducted using SPSS version 27 (SPSS Inc., Chicago, IL, USA), with a significance level set at alpha <0.05. Descriptive analyses were conducted for all variables, and the normality of each variable was examined using the Kolmogorov-Smirnov test. To compare differences in speech data among the three groups (frail, pre-frail, and robust), one-way analysis of covariance (ANCOVA) with Bonferroni post-hoc analysis was performed, controlling for participants' age, gender, and MMSE scores. For the Bonferroni post-hoc analysis, the significance level was set at α=0.0167 (0.05/3).

RESULTS

For this study, interviews were conducted with 50 participants, and 42 individuals who met the inclusion criteria and agreed to participate were enrolled. Among the 50 participants, 8 were excluded: 3 had hearing or speech impairments, 2 reported difficulty with reading, and 3 either withdrew their consent during the study or faced challenges in completing the study. According to the frailty criteria, 14.29% (n=6) of participants were classified as frail, 57.14% (n=24) as pre-frail, and 28.57% (n=12) as robust. The characteristics of the participants are summarized in Table 1. There were no significant differences in gender ratio, age, weight, or body mass index. Additionally, the frail and pre-frail groups had shorter heights compared to the robust group (*p*=0.002 and *p*=0.003, respectively), and the frail group had lower cognition scores, as measured by the MMSE, compared to both the pre-frail and robust groups (*p*=0.010 and *p*<0.001, respectively).

The one-way ANCOVA, controlling for age, gender, and MMSE scores, revealed significant differences in total speech duration, voiced and unvoiced duration, speech rate, articulation rate, mean syllable duration, and the number of pauses among the frail, pre-frail, and robust groups (Table 2). The frail and pre-frail groups demonstrated significantly longer total speech durations (frail vs. robust; *p*<0.001, and pre-frail vs. robust; *p*=0.009, respectively), longer voiced durations (frail vs. robust; *p*=0.001 and pre-frail vs. robust; *p*=0.006, respectively), and longer mean syllable durations (frail vs. robust; *p*=0.001 and pre-frail vs. robust; *p*=0.006, respectively) compared with the robust group (Figure 1). The frail and pre-frail groups had significantly slower speech rates (frail vs. robust; *p*<0.001, and pre-frail vs. robust; *p*=0.001, respectively) and slower articulation rates (frail vs. robust; *p*=0.004 and pre-frail vs. robust; *p*=0.003, respectively) compared with the robust group (Figure 2). Lastly, frail older adults had significantly longer unvoiced durations (*p*=0.008) and a greater number of pauses compared to the robust group (*p*=0.015; Figure 3).

Table 1. Baseline characteristics of participants

Variables	Frail (n=6)	Pre-frail (n=24)	Robust (n=12)	*p*
Gender, No. (%) of females	5(83.3)	16(66.7)	6(50.0)	0.355
Age, years, mean±SD	83.83±5.81	83.58±5.72	80.67±8.05	0.413
Height, cm, mean±SD	151.92±7.06	155.94±6.37	164.25±7.53	0.001
Weight, kg, mean±SD	57.27±13.70	59.42±8.38	65.21±10.17	0.168
BMI, kg/m^2 mean±SD	24.52±3.91	24.43±2.99	24.18±3.32	0.968
MMSE, scores, mean±SD	23.33±3.44	26.38±1.97	28.08±1.62	<0.001

Abbreviations: BMI, body mass index; SD, standard deviation; MMSE, mini mental state examination.
The values for the frail, pre-frail, and robust groups are presented as mean±standard deviation.

Table 2. Differences in speech data among frail, pre-frail, and robust groups

Variables	Frail	Pre-frail	Robust	*p*
Total speech duration (s)	17.47±2.33	13.31±3.24	9.75±2.06	<0.001
Voice duration (s)	10.07±1.45	8.07±1.65	6.17±0.97	0.001
Unvoiced duration (s)	7.40±2.13	5.24±2.18	3.58±1.72	0.010
Speed rate (syl/s)	2.38±0.30	3.24±0.73	4.35±0.78	<0.001
Articulation rate (syl/s)	4.15±0.68	5.30±1.15	6.81±1.15	0.001
Mean syllable duration (s)	0.25±0.04	0.20±0.04	0.15±0.02	0.001
Number of pauses (No.)	17.83±3.82	13.75±4.85	10.75±3.77	0.017

Abbreviation: syl/s, syllables per second.
The values for the frail, pre-frail, and robust groups are presented as mean±standard deviation.

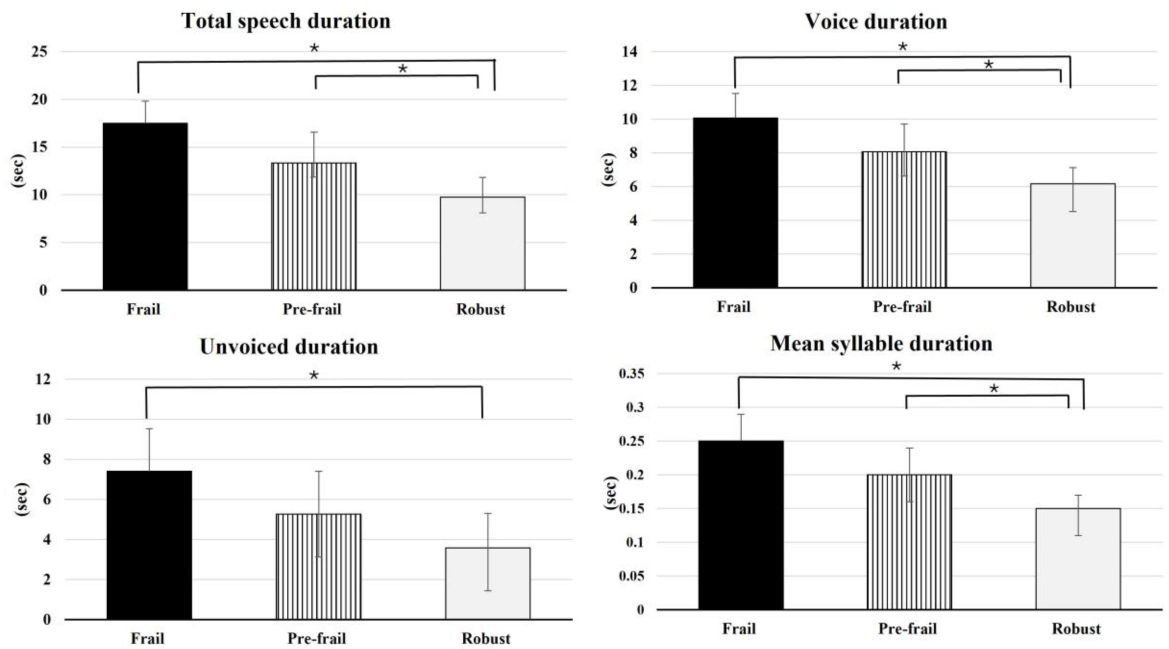

Figure 1. Comparison of total speech duration, voiced and unvoiced duration, and mean syllable duration across groups with post-hoc analysis. * $p<0.0167$. Values are presented as mean±standard deviation.

DISCUSSION

This study examined the speech characteristics of older adults according to their frailty status. The results indicated that both the frail and pre-frail elderly groups took longer to speak and had slower speech rates compared to the robust group. Additionally, the frail and pre-frail groups exhibited longer mean syllable durations and more pauses than the robust group. Thus, we suggest that monitoring speech characteristics could assist in the assessment of frail older adults.

Speech analysis using voice recording devices has been employed to evaluate the pathological changes associated in clinical and experimental settings.[6,22–24] This study highlights the importance of speech characteristics, including slow speech and articulation rates, longer syllable durations, and increased pauses, which should be considered when analyzing the characteristics of frail older adults. These differences in speech characteristics may reflect underlying physiological and cognitive changes that affect speech production in older adults with frailty. Based on our findings, future research should investigate whether frail elderly individuals can be predicted and differentiated through the analysis of speech characteristics in a controlled, large-scale

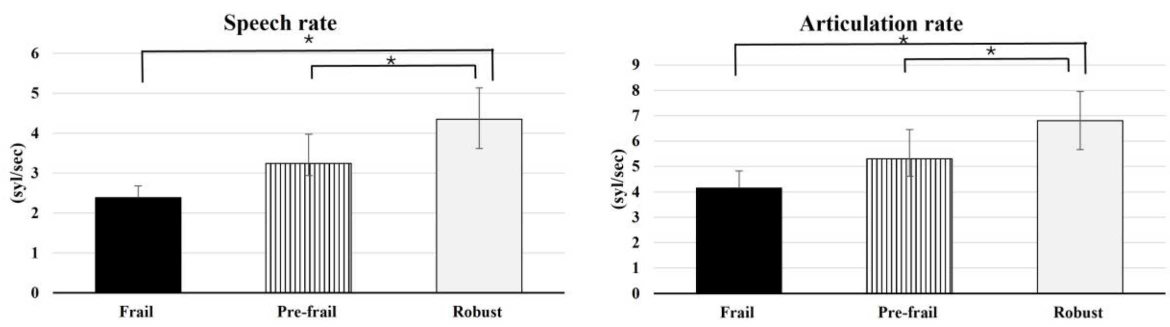

Figure 2. Comparison of speech and articulation rates across groups with post-hoc analysis. * $p<0.0167$. Values are presented as mean±standard deviation.

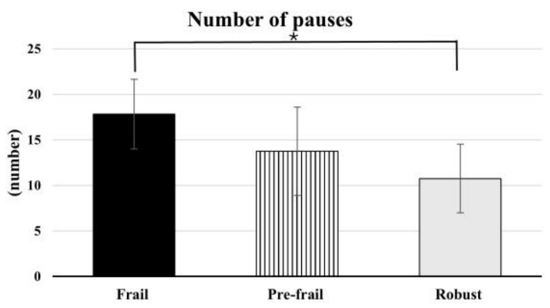

Figure 3. Comparison of the number of pauses across groups with post-hoc analysis. * $p<0.0167$. Values are presented as mean±standard deviation.

study of older adults.

Frailty affects overall physical health and is also associated with declines in the functions of the respiratory and laryngeal systems necessary for speech production. With aging, changes in lung function, such as reduced respiratory muscle strength and endurance, along with airflow limitations due to increased thoracic stiffness, can lead to difficulty in exhalation.[25,26] Consequently, this results in a reduction in overall speech rate and an increase in the frequency of pauses during speech. Furthermore, age-related changes in the larynx, such as bowed vocal fold margins and insufficient glottal closure due to atrophy of the thyroarytenoid muscle, can negatively impact speech production.[27,28] In this study, the significantly slower speech and articulation rates, along with more pauses, in frail and pre-frail older adults may reflect reduced respiratory and laryngeal functions compared to robust older adults.

Our research found that frail elderly individuals had a slower articulation rate and longer mean syllable duration compared to the robust group. A slower articulation rate in frail and pre-frail older adults indicates that they take longer to phonate while reading the same sentence aloud compared to healthy older adults. This slow articulation rate may result from slower speech motor control, which encompasses cognitive, linguistic, and motor workloads.[10,11] Previous study using magnetic resonance imaging demonstrated age-related changes in movement timing in cortical and subcortical regions associated with speech, suggesting that motor control timing declines with age.[10] This change may reflect difficulties in motor planning or control for speaking in frail older adults compared to robust older adults. Additionally, older adults with cognitive impairment often exhibit longer phonation times, more pauses in speech, and lower speech rates.[20,29] Although this study controlled for cognitive differences using MMSE scores as covariates among the groups, the frail group demonstrated lower cognitive state compared to the robust group. Thus, the decreased articulation rate and increased duration of speech sounds during syllables may reflect difficulties in word retrieval and declines in cognitive control functions related to speech production.

This study has some limitations. The relatively small sample size in this study limits the generalizability of the findings, highlighting the need for larger samples to provide more robust evidence. Another limitation is that participants' education levels were not considered when evaluating speech characteristics. Education level influences age-related cognitive decline; higher education is associated with better performance on verbal fluency tests.[30] Although the participants in this study had no difficulties reading and speaking in Korean, future studies should control for education level to help differentiate speech characteristics in older adults according to their frailty status, thereby excluding cognitive differences attributable to educational attainment. Lastly, the participants were recruited from a specific region in South Korea, and speech characteristics can be influenced by regional differences.[31] Therefore, to generalize these findings regarding the speech characteristics of older adults in Korea, it is essential to conduct studies involving elderly individuals from diverse regions.

CONCLUSION

This study demonstrated that differences in speech characteristics among older adults are based on their frailty status. By analyzing speech and articulation rates, syllable durations, and pause times, we found that frail and pre-frail older adults exhibit significant differences in their speech characteristics compared to robust individuals. This study serves as a preliminary exploration into the use of speech data in older adults, providing a foundation for future research aimed at classifying frailty through speech assessment.

Key Points

Question Speech characteristics could be considered indicators of frailty in the elderly.

Findings Frail older adults exhibited slower speech and articulation rates, longer syllable durations, and increased pauses compared to robust older adults.

Meaning Speech analysis could be a useful, non-invasive tool for assessing frailty in clinical settings.

Article information

Conflict of Interest Disclosures: None.
Funding/Support: This work was supported by Sangji University Research Fund, 2022.
Acknowledgment: None.
Ethic Approval: Institutional Review Board of Sangji University (Approval number: IRB 2023-110).

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Project administration: BI Yang, MS Park, SH Kim.
Interpretation of data: KN Park, SH Kim.
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Funding acquisition: BI Yang, MS Park, SH Kim.
Writing–review&editing: KN Park, SH Kim.

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