Speaking Fundamental Frequency Changes in Women Over Time

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The purpose of this study was to examine the age-related differences in speaking fundamental frequencies (SF$_0$) of women, in order to determine the effects of normal aging on SF$_0$ of the speakers' voices. The study compared the SF$_0$ characteristics of a group of 8 women with the SF$_0$ characteristics of the same speakers 25 years later. The results not only confirmed the reported trend outlined by the majority of available reports regarding
SF₀ changes in women but also demonstrated a significant decrease in SF₀ of women speakers as they age. The findings of the study have provided preliminary normative data for female elderly speakers' SF₀ changes that are largely absent from the current literature.

**Key Words:** women, aging, SF₀

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**Introduction**

With the dramatic increase in the elderly populations in many regions of the world, especially in the developed countries in the past decades, it is important to understand the normal changes of speakers' voices due to the gradual decline in bodily function throughout the course of life. Many elderly people report vocal changes and difficulties as they undergo the aging process. Understanding the normal aging process and its effects will allow for better diagnosis of true problems and application for more appropriate treatments of communication disorders in this population (Mueller, 1991). Factors such as heredity (Bourliere, 1970), lifestyle and diet (Bourliere, 1970; Fritsch, McClenond, Smyth, et al., 2007); and excercise (devries, 1974; Mittlestaedt, Hinton, Rana, et al., 2005; Shepard & Sidney, 1979; Spiridušo, 1980; Xue & Mueller, 1997) have been reported to affect general physical changes associated with the aging process. Several recent lines of research have implied that physical training may be of significance in the prevention and/or rehabilitation of age-related voice changes (Ramig, 1983; Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987; Xue & Mueller, 1997). However, the actual effects of physical activity on the acoustic characteristics of the aging voice still remain largely assumptive. As aging is such a multifactorial process, differential senile involuntional changes in the laryngeal mechanisms of individuals may well account for the significant differences in vocal acoustics between persons of the same chronologic age (Chodzko-Zajko & Ringel, 1987).

Most of the available literature on aging voice focus on the acoustic, physiologic, and perceptual characteristics of the speakers' voices. The stereotypic aged voice is characterized by altered pitch, tremulousness, weakness, hoarseness, and lack of intensity (Mueller, 1985; Xue & Mueller, 1997; Xue & Deliyski, 2001). Some acoustic parameters were found to be contributing to such perception of aged voice. For instance, in terms of F₀ standard deviations, previous studies (Brown, Morris, & Michel, 1990; Linville, 1988; Linville & Korabic, 1987; Xue & Deliyski, 2001) indicate that elderly speakers demonstrated significantly higher F₀ SD levels and higher levels of intraspeaker variability than young speakers. The higher roughness of the voice is also acoustically correlated with higher jitter and shimmer (Linville, 1988; Linville & Fisher, 1985). Increased jitter and shimmer with age have been observed in both sexes (Linville & Fisher, 1985; Mysak, 1959; Wilcox & Horri, 1980; Xue & Delynski, 2001; Xue & Mueller, 1997). Limited studies indicate that in general, older speakers in poor physical condition had greater spectral noise than older speakers in good physical conditions or than younger speakers regardless of physical condition (Ramig 1983; Xue & Mueller, 1997). The finding well indicates that not all persons undergo changes in their body physiology at the same rate, although these age-related changes in body physiology are important contributors to changes in certain voice characteristics (Ramig & Ringel, 1983).
A large number of studies have been carried out to investigate $F_0$ changes as a function of vocal aging. For instance, "there appears to be at least a trend for pitch to increase slightly in males and to decrease somewhat more prominently in females as a function of normal aging" (Higgins & Saxman, 1991; Mueller, 1991; Pegoraro-Krook, 1988; Russell, Penny, & Pemberton, 1995; Xue & Mueller, 1997). However, the results, as well as the methods used to obtain these acoustic results, have varied widely. Some studies have used different methodologies, such as cross-sectional designs versus longitudinal designs, whereas others differ by the acoustic measures used, such as a sustained vowel versus $SF_0$. Russell, Penny, and Pemberton (1995) reported a dramatic decrease in $SF_0$ for six women who were recorded when they were young women, then recorded again 36 years later. The mean $SF_0$ of these six subjects, when measured as young women in 1945 was 229.0 Hz (SD: 12.3 Hz). When the subjects were measured again in 1993 (48 years later), the mean $SF_0$ decreased to 181.2 Hz (SD: 17.5 Hz). Other studies found the female $SF_0$ to decrease only slightly (Mueller, 1991). Mueller (1991) reported female $F_0$ from sustained vowel production instead of continuous speech, using a cross-sectional research design. Two hundred and twenty-seven elderly subjects (both male and female) between the ages of 60 to 90 years were tested to find $F_0$ on sustained vowels. The results of the female elderly population were compared to results obtained from a middle-aged group of women. The difference in $F_0$ seems to follow the same trend as the findings of Russell, Penny, and Pemberton (1995), with a decrease in $F_0$ observed with an increase in age. However, the differences in the magnitude of $F_0$ changes in women speakers between the two studies could be due to several factors. First, the differing research design could be a reason for the different findings, because with the longitudinal study, the same groups of people participated as the subjects. In Mueller's (1991) cross-sectional design, the groups studied were actually different groups of people; therefore, the elderly population could have had different $F_0$ during their middle-aged years of life than the middle-aged group of people who participated in the study. Second, given the much more rapid changes of vocal folds adductions and abductions needed for constant pitch adjustment for intonation contours, the $SF_0$ changes from connected speech as investigated by Russell, Penny, and Pemberton (1995) may further reveal the subtleties and dynamics of the speakers' vocal functions that sustained vowel phonations may be insufficient to demonstrate. Therefore, continuous speech, instead of single vowel phonations, was used in this study to obtain the $SF_0$ of the female speakers as a function of aging. It is very important for the clinicians to have objective and reliable acoustic norms for the voices of the seniors so that they could make appropriate therapeutic decisions when they treat patients with vocal complaints due to the aging processes. Therefore, the purposes of this study were to investigate the changes in females' $SF_0$'s over time, by using the longitudinal model. The hypothesis was that the $SF_0$ in women would decrease significantly as a function of age. The findings of the study would not only contribute to the current literature of speaking $F_0$ changes as a function of aging, but also confirm the magnitude of such changes as reported in previous literature.

**Method and Results**

**Subjects**

The subjects were eight females, ranging in age from 26 years to 38 years, when their voices were initially recorded. The same eight females were recorded again, approximately 25 years later. The subjects' ages are presented in Table 1. All of the women were native speakers of American English. The women's general physical health was assessed as healthy by the investigators. All of the subjects were in the entertainment busi-
ness 25 years ago, and still remained in the entertainment business when the study was conducted.

**Procedure**

Each of the eight female speakers was videotaped during an interview at a young age, then interviewed and videotaped again at an older age approximately 25 years later (see Table 1). The subjects were speaking for interviews when all of the recordings were made. Each subject was seated directly across from the interviewee during their interview. The tapes of the interviews were recorded on TDK Revue Premium Quality T-120 VHS tapes on Standard Play (SP) speed using a Magnavox VCR. All the female speakers appeared to speak casually in calm and conversational voices during all the recordings.

**Data Analysis**

The recordings of each subject were transferred from the videotapes to the CSL 4500 (Kay Elemetrics). Each recording was segmented to obtain several 15-sec recordings of each speaker at each of the two ages. In order to maximally reduce the possible CSL program errors of mis-tracking the $S_F_0$, cautions were taken to edit out any significant "jumps" and/or "troughs" by visually monitoring the $S_F_0$ autotracing screen of the program. Any speech segments with significant pauses (>500 msec) were removed from the selection pool of samples. With regards to their perceptual judgment of each speaker's typical vocal functions, the investigators also reached consensus in choosing one 15-sec recording of each speakers' "typical" speech samples at each of the two ages. Thus, there were 16 total samples (eight female speakers at both a younger and older age). These samples were then analyzed with the CSL 4500 for abstracting $S_F_0$. Once the results were obtained, a paired $t$-test was performed with SPSS (10.1) set at 0.05 to test whether the differences between the two age sets were statistically significant.

**Speaking Fundamental Frequency**

The $S_F_0$, measured in Hz, for each sample in each of the two age groups, is shown in Figure 1. Except for $S_1$, each subject showed a decrease in $S_F_0$ at the older age when compared to her own voice recorded at a younger age. The younger group had a mean $S_F_0$ of 219.3 Hz (SD: 25.6 Hz) and the older group had a mean $S_F_0$ of 196.5 Hz (SD: 29.3 Hz). The average difference between the two groups was 22.8 Hz. This difference was found to be statistically significant (paired $t$-test, $p < 0.05$).

**Discussion**

The results of this study demonstrate a significant decrease in $S_F_0$ with aging in female speakers. These results are consistent with similar studies by Russell, Penny, and Pemberton (1995), and Mueller (1991). Russell, Penny, and Pemberton (1995) found a decrease in $S_F_0$ in a longitudinal study involving six women in Australia. However, that study did not reveal a statistically sig-

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**Table 1.** Ages of the Female Speakers When Their Voices Were Recorded and Analyzed
significant difference, probably due to a small sample size. In a cross-section study, Mueller (1991) showed a decrease in the sustained SF₀ of older female speakers compared to the younger group. The present study took advantage of the longitudinal data available from a group of female speakers and demonstrated the significant decrease in the SF₀ with aging in female speakers.

The findings of this study demonstrate that SF₀ changes could be a fairly common vocal aging phenomenon among women. It is very important for practicing speech-language pathologists, especially those who work with seniors for voice disorders, to be aware of such changes so that normal aging processes are not interpreted as potential vocal pathologies. The study also provides the speech pathologists with a preliminary norm for the SF₀ changes in elderly women, which is very valuable given that the norms of such changes are virtually unavailable. Another clinical implication from this study is that preventing SF₀ decreases could be one of the effective therapeutic modalities in the reduction of perceptual aging voices in elderly women.

This study further refers to the intriguing correlation between the normal aging voice characteristics (like the SF₀ decreases) with the anatomic and physiologic deteriorations underlying such changes. To date, few studies have addressed the existence of possible relationships between biological factors and the rate and extent of age-related changes in laryngeal performance. Laryngeal control is known to be dependent on a delicate balance of pulmonary, laryngeal, articulatory, and other resonator factors, which in turn are dependent on the structural and functional integrity of the neural, endocrine, skeletal, and muscular systems (Ringel & Chodzko-Zajko, 1987). Individual differences in physiologic integrity have been shown to influence the amount of vocal change observed in elderly speakers. The decrease in SF₀ found in this study could be due to several factors related to physical, emotional and lifestyle factors, which differ in every person. Some of these factors could include muscle atrophy, hormones, stress, or other irritants such as smoking or drinking alcohol (Mueller, 1991). It is important not only to identify these changes as investigated in this research, but also to identify the causes for these changes to better understand the aging voice. Future studies should consider further investigations of the intrinsic relationships between the speakers’ physiologic status and their phonatory and auditory performances, and future research protocols.
should include comprehensive physiologic and biochemical evaluations along with voice acoustic and auditory assessments for the investigator to establish some "biological markers" of the aging voices. Although the longitudinal nature of the present study has contributed to the normative base on the senescent changes of women voices, the number of subjects involved in this study was still quite small. Future studies should also investigate the trajectories of SFo changes in the male cohorts over time.

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References


