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Objective Analysis of Vocal Warm-Up with Special Reference to Ergonomic Factors

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Summary: Vocal warm-up was studied in terms of changes in voice parameters during a 45-minute vocal loading session in the morning. The voices of a randomly chosen group of 40 female and 40 male young students were loaded by having them read a novel aloud. The exposure groups (5 females and 5 males per cell) consisted of eight combinations of the following factors: (1) low (25 ± 5%) or high (65 ± 5%) relative humidity of ambient air; (2) low [< 65 dB(SPL)] or high [> 65 dB(SPL)] speech output level during vocal loading; (3) sitting or standing posture during vocal loading. Two sets of voice samples were recorded: a resting sample before the loading session and a loading sample after the loading session. The material recorded consisted of /pa:ppa/ words produced normally, as softly and as loudly as possible in this order by all subjects. The long /a/ vowel of the test word was inverse-filtered to obtain the glottal flow waveform. Time domain parameters of the glottal flow [open quotient (OQ), closing quotient (CQ), speed quotient (SQ), fundamental frequency (F_0)], amplitude domain parameters of the glottal flow [glottal flow (f_{AC}) and its logarithm, minimum of the first derivative of the glottal flow (d_{peak}) and its logarithm, amplitude quotient (AQ), and a new parameter, CQAQ], intraoral pressure (p), and sound pressure level (SPL) values of the phonations were analyzed. Voice range profiles (VRP) and the singer's formant (g/G, a/A, c1/c, e1/e, g1/g for females/males) of the loud phonation were also measured. Statistically significant differences between the preloading and postloading samples could be seen in many parameters, but the differences depended on gender and the type of phonation. In females the values of CQ, AQ, and CQAQ decreased and the values of SQ and p increased in normal phonations; the values of f_{AC}, d_{peak}, and SPL increased in soft phonations; the values of AQ and CQAQ decreased in loud phonations; the harmonic energy in the singer's formant region increased significantly at every pitch. In males the values of OQ and AQ de-

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creased and the values of d_{peak}, F_0, p, and SPL increased in normal phonations; the values of f_{AC} and p increased in soft phonations. The changes could be interpreted as signs of a shift toward hyperfunctional voice production. Low humidity was associated with more hyperfunctional changes than high humidity. High output was associated with more hyperfunctional changes than low output. Sitting position was associated with an increasing trend at both margins of male VRP, whereas the case was the opposite for standing position. **Key words:** Warm-up effect—Voice—Relative humidity of air—Ergonomics.

INTRODUCTION

Vocal loading is defined as prolonged use of the voice. Vocal warm-up (WU) can be described as "an initial period of rapid vocal change"[1] that takes place during vocal loading. In general, it is believed that after WU voice use becomes easier and smoother. The phenomenon can be seen during vocal loading in both speech[1–3] and singing.[4] Empirically, WU can also be achieved by specific vocal exercises, which are considered to be an important part of preparation not only for singing but also for speaking performances.[5,6]

As to the physiological mechanisms underlying the subjective experiences on vocal WU, there is very little specific knowledge. An attempt to understand its background was made by Elliot et al.[6] However, the method used (measurement of phonatory threshold pressure) failed to show any systematic changes and the interindividual variation was large. The authors rejected the hypothesis that viscoelastic changes of the vocal muscle would be responsible for the phenomenon. However, it is not clear how the pretest voice use was controlled, and it is possible that the baseline level was not the same for all subjects. On the basis of our earlier studies on vocal loading, the choice of the reference level, that is, the pretest state of voice, considerably affects the outcome.[7–10]

As Neils and Yairi[11] pointed out, a large number of normal subjects would be required to improve our understanding of WU due to the marked intersubject variation. To overcome this problem, a relatively large number of subjects (40 female and 40 male students) were recruited for our study. The collection of speech samples started in the morning, that is, the baseline represents vocal quality prior to any significant voice use. The present study was launched because several parameters of the glottal flow [fundamental frequency (F_0), intraoral pressure, sound pressure level (SPL), glottal flow, negative peak amplitude of the differentiated glottal flow (d_{peak}), open quotient (OQ), speed quotient (SQ), and closing quotient (CQ)] did not change monotonously in a day-long loading experiment in our earlier studies.[7–10] Instead, these parameters revealed nonlinearity, with marked changes after the first 45-minute loading session as well as after the lunch break. The present study focused on the changes occurring during the first loading session in the morning rather than on general loading changes. All the data were reanalyzed, and new, previously unpublished results were included.

It was assumed that the changes (see above) occurring during the first vocal loading session in the morning would be mostly caused by the WU effect. This assumption seems tenable for five reasons: (1) The biggest changes in the objective voice parameter values took place during the first 45-minute loading session.[7–10] No such major changes were seen in the voice samples obtained later during the day. This finding is consistent with the definition of vocal WU as an initial period of rapid vocal change (see above). (2) In the previous studies, the vocal loading time needed for subjective vocal WU effects to take place has varied between 5 and 45 minutes.[1–3] Based on these observations, 45 minutes should be a sufficient loading time for the WU phenomenon to appear. (3) According to the earlier studies, the positive effects of WU last for much longer than 45 minutes when the loading is continued.[1,3] Therefore, it was unlikely that marked negative effects would occur during the first 45 minutes of loading. (4) Vocal fatigue was not likely to take place during the first loading session in the morning, because the loading task (reading a novel) was not considered especially strenuous by the subjects; actually, subjective signs of vocal fatigue occurred later during the test day