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Speech during light physical activity: Effect on F0 and intensity

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Physical activity triggers physiological changes in the body that also affect systems involved in speech production. The most widely reported effect is an increase in F0, but the mechanism is not fully understood: since most studies employ vigorous exercise, it is not clear whether this is due to increased airflow or a general increase in muscle activation. The present study investigates light vs. moderate exercise, thereby aiming to tease apart the effects of higher respiratory drive from those of simple body movement. Changes to F0, intensity and their correlation are assessed.

1. Introduction

F0 has been found to increase during aerobic activity [e.g., 1, 2], but the mechanism is not clear. One explanation is increased respiratory drive: deeper, more frequent breaths increase subglottal pressure (P_{sub}) and, in turn, F0 [3]. Increased P_{sub} has also been found to correlate with increased intensity [4]. In this scenario, F0 and intensity would increase during moderate physical activity (65% max. heart rate). Another explanation is an increase in overall muscle tension, also affecting the laryngeal muscles. Here, light activity (35% max. heart rate) would already increase F0 but not necessarily intensity.

To date, most studies have looked at vigorous exercise, which conflates the effects of muscle activation and increased respiratory drive. The current study extends our previous work on spontaneous speech [5] using read speech. We also investigate light vs. moderate exercise to tease apart the effects of general muscle activation from those of increased respiration. In an initial step, we analyze changes in F0, intensity and their correlation at different levels of physical activity.

2. Method

As part of a larger project, acoustic, motion capture and respiratory data are being collected

from adult female speakers of German (here, $N=13$). Speakers read a paragraph (126 words) aloud prior to experiment, then three times per condition: 1) sitting (control); 2) light cycling; 3) moderate cycling. Cycling level was based on heart rate (Karvonen formula) and monitored in real time. Exit surveys indicated that speakers perceived the low-intensity condition as “very light activity” (Borg Scale: 10) [6]. Speech parameters were obtained with Praat [7] scripts to detect voicing (autocorrelation; pitch floor/ceiling: 120/400 Hz) and to extract mean F0 and intensity for each voiced section (15,678 observations). Mean differences were assessed with a one-way ANOVA and post hoc Tukey test in R (Version 3.6.0.). Data were then z-transformed to account for speaker variability, and regression lines were fitted to display the relationship between F0 and intensity.

3. Preliminary results

Mean F0 and intensity increased significantly with exercise (LIGHT: 12 Hz, 1 dB; MODERATE: 27 Hz, 4 dB). The strength of correlation also increased with exercise, displayed with a linear regression in figure 1. The Pearson correlation coefficient also indicated an increase (CONTROL: $r = 0.31$; LIGHT: $r = 0.41$; MODERATE: $r = 0.47$).

But there were considerable speaker differences: 5 speakers showed no change in correlation

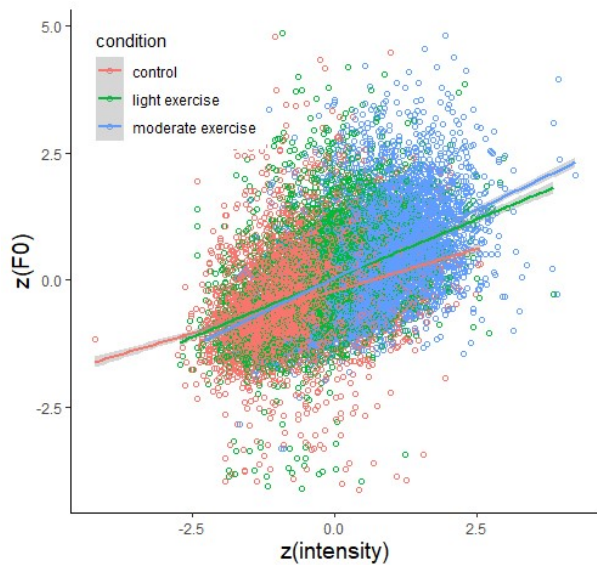


Fig. 1. F0 and intensity pooled across speakers. Values were normalized to z-scores before averaging.

strength, 5 speakers showed greater correlation during activity, and 3 speakers showed greater correlation in MODERATE only. Figure 2 displays examples of the two main observed patterns.

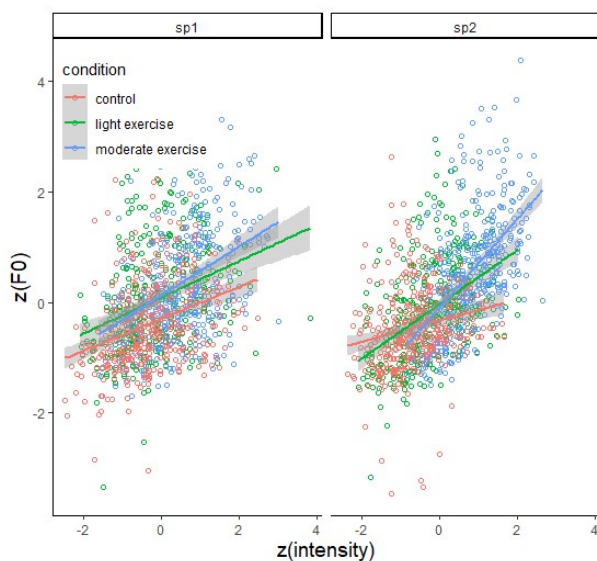


Fig. 2. Speaker differences in F0–intensity correlation: little change (sp1: CON: $r = 0.34$; LIGHT: $r = 0.32$; MOD: $r = 0.38$) and increase as physical activity intensifies (sp2: CON: $r = 0.21$; LIGHT: $r = 0.45$; MOD: $r = 0.57$).

4. Discussion

Overall, light exercise was associated with a very small increase in mean F0 and intensity, and moderate exercise with a small increase in F0 and moderate increase in intensity. This could indicate that subglottal pressure is the main driver of F0 and intensity, but the group mean

obscures considerable interspeaker variability: half of speakers show increased F0 with no increase in intensity during light activity, and even during moderate activity F0-increases vary from 5 to 50 Hz. Though rarely addressed, speaker differences of similar scope have been reported [8]. Further, F0 has been found to be independent of Psub at low intensities [9]. Taken together, these findings indicate that the relationship between Psub, F0 and intensity is not straightforward, and that interspeaker differences are not trivial. Future analyses will further investigate speaker differences by assessing the extent to which physical activity affected breath cycles and voice quality.

5. References

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