On The Utility of a Single-Breath Counting Task for the Remote Digital Assessment of Respiratory Function in ALS

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Introduction and Objectives. Amyotrophic Lateral Sclerosis (ALS) is a progressive neurodegenerative disease, characterized by degeneration of lower and upper motor neurons. Early detection of respiratory decline is crucial for optimal symptom management for people with ALS (Hardiman 2011). Respiratory function is commonly evaluated with a spirometer, both in clinic and remote (Baroi et al. 2018). However, such tests need the help of a caregiver in most cases (Tattersall et al. 2022) and can be difficult to execute for people with faciobulbar weakness (Lechtzin et al. 2018).

The demand for low-burden objective digital biomarkers is high, both to enhance clinical trials and to improve patient monitoring. It has been shown that forced vital capacity can be estimated from speech acoustics, specifically from sustained vowel phonation (Stegmann et al. 2021; Tabor Gray et al. 2023). In this work, we explore single breath counting (SBC) as an alternative assessment of respiratory function. SBC is a more ecologically valid assessment of daily function compared to the artificial nature of the sustained vowel phonation test, because it involves natural speech articulation. Previous research on SBC in clinical settings has shown that the duration correlates with standard pulmonary and respiratory measurements (Bartfield et al. 1994; Ali et al. 2011). In this work, we assess the feasibility of transferring this task into a self-driven remote assessment, which is based on a web based dialog system.

Methods. A web based dialog system (Ramanarayanan et al. 2023) was used to collect speech recordings from participants. For the SBC task, participants were instructed to take a deep breath and count up from one until they run out of breath. Additionally, participants filled out the ALS functional rating scale - revised (ALSFRS-R) (Cedarbaum et al. 1999). The ALSFRS-R consists of 12 questions that capture functional impairment in four domains. Each question can have a score between 0 and 4, where 4 indicates full function. We used the respiratory sub score (three questions about dyspnea, orthopnea, and respiratory insufficiency; range from 0 to 12) to investigate the correlation between SBC duration and respiratory function. The SBC duration was computed automatically for every sample using Praat (Boersma 2001). We computed two metrics: *speaking duration* (including silences within the utterance), and *articulation duration* (excluding silences, i.e. the duration of all speech events concatenated). We have shown previously that robust automatic articulation boundary detection is feasible in this remote setting where participants use their own devices (Liscombe et al. 2022). We report Spearman correlation between SBC duration and the ALSFRS-R respiratory sub score. Additionally, a non-parametric Kruskal-Wallis test was done on a cross-sectional subset of the data to test whether SBC duration differs statistically between participants with a respiratory score of 12 (*RES_12*) and participants with a score below 12 (*RES<12*). For this, every participant's first sample was considered.

Data and Demographics. Recordings from 96 people with ALS (46 females, mean age (SD): 62.1 (8.9) years) were collected between 2021-12-02 and 2024-02-01 in collaboration with EverythingALS and the Peter Cohen Foundation[1]. The study protocol was granted exempt status by an external Institutional Review Board[2]. The total number of sessions in the dataset is 1,153 (54.6% with a respiratory sub score of 12, see Fig. 1a).

Results. The Spearman correlation coefficient between respiratory sub score and SBC duration was 0.43 ($p < 0.0001$) for *speaking duration* and 0.44 ($p < 0.0001$) for *articulation duration* when considering all samples, and 0.37 ($p < 0.0001$) for *speaking duration* and 0.38 ($p < 0.0001$) for *articulation duration* for the *RES<12* group. Figure 1b shows the relationship between SBC duration and the respiratory sub score. SBC *articulation duration* was significantly different between the two groups *RES_12* and *RES<12* at $p < 0.05$. The effect size in terms of Glass' delta was moderate (-0.46), indicating a shorter mean duration in the *RES<12* cohort.

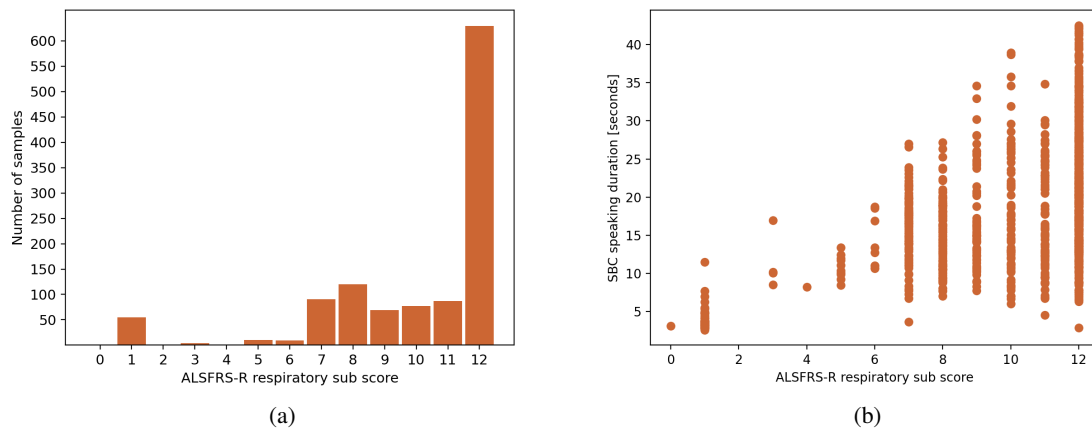[1]`https://www.everythingals.org/research`
[2]`https://www.advarra.com/`

Figure 1: (a) Distribution of ALSFRS-R respiratory sub score. The *RES<12* group has a median score of 8.0 with a standard deviation of 2.8. (b) Relationship between SBC duration and respiratory sub score.

Discussion. We examined the feasibility of administering the SBC task within a web based remote speech assessment and its utility to capture information on respiratory function. We have shown that the SBC duration has a moderate correlation with the self-reported ALSFRS-R respiratory sub score. The correlation is higher at the lower end of the distribution (score of 6 and below), whereas we observed large variation in SBC duration in samples with higher respiratory scores.

An important observation during the study was that participants performed the task in different ways; some counted at a fast pace, while others counted slow with distinct pauses between numbers. This emphasizes the importance of clear and unambiguous instructions in such a self-driven assessment. Another caveat is the use of the self reported ALSFRS-R respiratory sub score as a proxy for respiratory function. Future work should involve spirometry measurements as ground-truth. Lastly, we acknowledge the fact that pure correlation with the ALSFRS-R respiratory sub score can be misleading in individual cases, as we observed participants with a constant respiratory sub score for whom the SBC duration decreased over time. This suggests the possibility of detecting changes early, before they are reflected in the ALSFRS-R responses.

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