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Clinical relevance of speaking voice intensity effects on acoustic jitter and shimmer in children between 5;0 and 9;11 years

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ABSTRACT

Background: Current voice assessment recommendations for dysphonic children comprise instrumental acoustic measurements of the perturbation parameters jitter and shimmer. In healthy adults and children changes in speaking voice sound pressure level (voice SPL) have significant confounding effects on both parameters. In adults these effects were considerably reduced in phonations with controlled voice SPL >80 dBA (10 cm distance). However, it is unclear if these findings apply to children and if children are able to control for their own voice intensity.

Objective: This cross-sectional single cohort study investigates voice SPL effects on jitter and shimmer in children between 5;0 and 9;11 years phonating at individually "medium" (modeling "comfortable" loudness of the usual clinical protocol), "soft" and "loud" voice and a prescribed intensity level of ">80 dBA" (10 cm distance, with visual control). Further both their ability to phonate at a prescribed voice intensity level and the effect on SPL related confounding effects were studied.

Subjects and methods: A total of 68 healthy children (39 f/29 m) aged 5;0 to 9;11 years were included. All phonated the vowel/a/for 5 s, three times at four defined voice intensity levels (soft/medium/loud/>80 dBA) each. Jitter (%), shimmer (%) and voice SPL (dBA) were determined using PRAAT. Voice intensity level effects were assessed by descriptive statistics, Analysis of Variance (ANOVA) and Linear Mixed Models (LMM).

Results: There were significant differences for jitter and shimmer between all voice tasks ($p < .01$). Jitter and shimmer were lowest and showed the smallest spread in controlled phonations ">80 dBA". 19 children below 7;0 years could not perform the voice tasks and were excluded from the study.

Conclusions: This practical study demonstrated a significant effect of voice loudness and task on jitter and shimmer in children. Since the observed confounding effects were large compared to treatment effects, jitter and shimmer may not be meaningful without adequate control of voice SPL. In phonations at ">80 dBA" (10 cm distance) voice SPL related effects were considerably reduced. However, this assessment protocol was suitable only for children above 7;0 years. Application of this task to future studies of dysphonic children may yield clinically valuable information.

1. Introduction

According to pediatric voice assessment guidelines a comprehensive clinical voice examination usually includes visual, perceptual, patient based subjective and instrumental acoustic assessment techniques [1,2]. Studies investigating the incidence of voice disorders during childhood report a prevalence from 6% to 38% [3]. This wide prevalence range highlights the complexity of pediatric voice diagnostics and the difficulties to determine vocal pathology in children. A voice disorder may compromise the general well-being, communication behavior and the social and academic development of a child [4]. Teachers and parents tend to judge the personality and cognitive abilities of a dysphonic child more negatively than of a normophonic child [5,6]. Therefore an early diagnosis and treatment of any voice disorder is key to avoiding considerable and probably even long lasting negative effects on the child's life.

Up to 20% of children below the age of 10 years may not tolerate invasive assessment procedures such as laryngostroboscopy

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[1,7–10]. Further in patients with muscle tension dysphonia, one of the most frequent diagnoses in children, laryngostroboscopy has limited validity to determine pathologic voice production patterns [11]. In these cases the clinical diagnosis and treatment decision depends on perceptual, subjective and instrumental acoustic assessment methods. Instrumental acoustic measurements allow an objective and non-invasive assessment of uninfluenced voice function by analyzing the vocal output. For this the patient's voice is recorded with a microphone, and acoustic analysis usually is done by a computer based software application. Even children of a very young age tolerate this procedure. Therefore instrumental acoustic assessments are considered as easily applicable in pediatric voice care [1]. The present work focuses on the acoustic perturbation parameters jitter and shimmer, indicating the irregularity of human voice pitch (jitter) and intensity (shimmer) respectively from one acoustic wave to the next.

The broad clinical application of jitter and shimmer is based on the hypothesis that the acoustic waveform represents the vibratory characteristics of the vocal folds. A variety of studies in children and adults show that vocal pathology and/or dysphonia are associated with increased jitter and shimmer [1,5,12–16]. Also, the onset of mutation in children was accompanied by increased acoustic voice perturbation [17]. It has been suggested, that jitter and shimmer may even indicate subtle changes in the vibratory properties of the vocal folds [16,18,19]. Based on this jitter and shimmer have been characterized as informative and clinically valuable parameters to determine pathology and mutation onset in childrens' voices [1,13].

However, in adults and children the reliability and usefulness of jitter and shimmer measurements has been questioned for a number of reasons [20–22]: both parameters are significantly influenced by technical confounding factors such as microphone quality, the analysis software type or background noise. The analysis system and program may affect mean shimmer and jitter by factors ranging from 1.2 to 3.1 [23]. Also the type of the analyzed voice signal determines the exactness and clinical usefulness of acoustic measurements. Several authors have argued that perturbation parameters are not meaningful in severely irregular voices, since jitter and shimmer depend on correct recognition of fundamental frequency and voice SPL [20,21,23–25]. However even under adequate measurement conditions both jitter and shimmer vary considerably within healthy adults and children during a day [26,27]. A practical reason for this might be how patients are instructed during acoustic assessments [22]. According to current guidelines, patients are usually asked to phonate at "comfortable loudness and pitch" [1]. Under this assessment protocol, adults have substantial interindividual differences in speaking voice SPL, which significantly influence jitter and shimmer [28–30]. A statistical analysis of data by means of eta-squared in phonations at individually "normal" voice loudness showed that 62% of shimmer variance and 24% of jitter variance could be explained by changes in voice SPL. The effect sizes of vowel, gender and fundamental frequency (F_0) were considerably smaller ranging from 0% to 4% [28]. Therefore the reliability of jitter and shimmer measurements in adults could be considerably improved with adequate control of voice SPL [22,28].

Children also vary substantially in their speaking voice intensity, when asked to phonate at "comfortable" loudness [31]. Further a study by Glaze et al. showed, that voice intensity differences have significant effects on both jitter and shimmer in children [32]. However it has not been investigated, how these confounding effects may be sufficiently controlled for in clinical practice. Preliminary findings in healthy adults suggest, that the effects due to differences in speaking voice SPL may be considerably reduced, when patients are asked to phonate at a minimum of 80 dBA (measured at 10 cm distance) [30,33]. However these findings may not apply to children, since vocal fold length and microstructure change with age. Currently it is not fully established, how these developmental changes affect the vibratory properties of the vocal folds and hence jitter and shimmer [6]. Also, from a practical point of view, it is unclear if children are able to phonate at a prescribed voice intensity level. Specifically younger children may be unable to control for their own voice SPL, since their conceptual skills and physical abilities are not fully developed [34]. To the best of our knowledge these issues have not been investigated in children to date, and therefore will be key aims of the present study.

1.1. Study aims

The aims of the present study in children between 5;0 and 9;11 years were to characterize the effects of voice intensity changes on jitter and shimmer in a variety of voice tasks. Specifically it was tested if children of this age group are able to phonate at a prescribed voice intensity level of "$>$80 dBA", and if this minimizes confounding effects due to differences in voice SPL.

2. Materials and methods

2.1. Population studied

A total of 87 children aged between 5;0 and 9;11 years, 47 girls and 40 boys, were recruited to the present cross-sectional cohort study. Of these, 19 children were not able to perform the voice tasks and were excluded. Please refer for further details about the specific exclusion reasons to Section 3. All children were students of three schools and kindergartens in Zurich, Switzerland. This study was approved by the responsible ethical review board under reference number KEK-ZH-Nr. 2010-0305/2.

2.2. Recruiting process and exclusion criteria

Prior to the study information packages were send out to all parents of students between 5;0 and 9;11 years of age. All packages included detailed study information, an informed consent form and a participant questionnaire assessing the eligibility of children for the study. 142 parents returned the informed consent and questionnaires. Oral consent was obtained from all children on the assessment day.

Children were excluded from the study if they met one or more of the following criteria:

- previous formal voice training or therapy;
- acute infection of the ears, nose and throat or allergic reaction on the recording day;
- a medical condition or medication that might affect normal voice function;
- surgery in the torso, head and neck region or intubation for any intervention within the last 18 months;
- inability to say the vowel/a/for 5 s in three auditively discernible loudness levels ("soft", "medium", "loud" voice) and at a minimum of 80 dBA (measured at 10 cm distance) after a maximum training phase of 5 minutes;
- perceptual voice pathology, indicated by a mean of $\geq$1 in any GRBAS scale characteristic as assessed by the study examiner and a speech pathologist [35].

2.3. Recording and analysis technique

All voice recordings were made at the children's school or kindergarten during break time in a quiet room with ambient noise