Speaking Voice in Children and Adolescents: Normative Data and Associations with BMI, Tanner Stage, and Singing Activity

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Summary: Objectives: The aim of this study was to establish normative data concerning the speaking voice of children and adolescents for clinical diagnostics.

Study Design: Population-based mixed cross-sectional and longitudinal childhood cohort study.

Methods: Normative data measuring the speaking voice profile of 1352 male and 1274 female participants aged 6 to 17 years were collected. To evaluate the voice range, five different intensity levels as the quietest voicing speaking voice (Level I), conversational voice (Level II), classroom voice (Level III), shouting voice (Level IV), and again the quietest speaking voice (Level V) were investigated. Multivariable analyses were performed to describe the effects of body mass index, Tanner stage, and singing activity on the outcome variables.

Results: A clear distinction in frequencies and sound pressure levels between the five different voice levels can be found in both genders. In females the mean fundamental frequency of the conversational voice lowers from 223.3 to 205.8 Hz. In male participants it lowers from 223.3 to 102.3 Hz. The most substantial decrease in the fundamental frequency of the speaking voice in boys occurs at 13.5 years. Girls show an almost continuous decline in their fundamental frequency. Only the Tanner stage showed significant positive relationships with the grade of lowering of the fundamental frequency in both sexes.

Conclusions: It was shown that the investigation of the speaking voice using predefined intensity-levels represents a feasible examination for children and adolescents. This study provides reference data on the range and age-adjusted normative values of the speaking voice.

Key Words: Speaking voice−Voice change−Fundamental frequency−Adolescence−Pediatric voice.

INTRODUCTION

A healthy and reliable use of the voice becomes increasingly important during childhood and development for the individual to participate in social interactions and communication.[1,2] The detected increase in voice and speech disorders in children, especially in urban areas, leads to relevant effects on schooling and school performance.[3] Besides negative effects on communication, derogation of the voice can lead to contact disorders and speech anxiety or communication apprehension.[4,5] Therefore, the development of the speaking voice during childhood and adolescence is an important part of communication abilities and should be focused on by pediatricians and phoniatricians.

Basic parameters of the human voice are its frequency and intensity. The voice range profile (VRP) is a graphical representation of the vocal intensity range versus fundamental frequency (F0) and a central diagnostic tool for evaluating voice development disorders in children.[4,6] It can help to uncover the etiology and pathomechanism of voice disorders as well as to find the correct approach to voice therapy.[7]

In daily routine, the VRP is divided into singing and speaking VRP. Both measurements are essential in discriminating normal, pathological, and even supranormal voices (as, for instance, in subjects with increased singing activity). The evaluation and interpretation of the VRP are mainly achieved subjectively and also depend on the experience of the investigator and the methodological approach. The few studies on voice range in children concentrate on vocally trained children or try to determine normative data of the singing voice of untrained children. Normative data on the speaking voice of children is scarce and focused on frequency data without considering intensity. Previous studies are limited in their sample size or do not include a representative sample of the general population.[8−12] Parameters of the speaking voice do change substantially throughout

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Compliance with Ethical Standards

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Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants are in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards and under the supervision of the Ethics Committee of the University of Leipzig (Reg. No. 264-10-19042010).

Informed consent: Informed consent was obtained from all individual participants included in the study.

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adolescence. In addition, gender, height, and weight may affect voice parameters. The highest influence on the change of the individual voice is related to hormonal effects.[11,13–15] There is still little known about the effects of anthropometric parameters like body mass index (BMI) or singing activity on voice parameters, particularly during childhood and adolescence.[16,17] To gain insights into the physiology of the voice development and also to form a basis for the treatment of voice disorders in children, reliable normative data of singing and speaking voice parameters are required.

The present study reports, for the first time, on extensive data of voice parameters in a large population-based cohort of healthy children and adolescents in Germany. Besides confirming known gender and age effects, additional factors like BMI, Tanner stage, and singing activity using the KLASAK Classification[18] were related to the speaking voice profile.

MATERIALS AND METHODS

Study population

The collection of data was based on a specific voice assessment of the LIFE Child study, a large population-based cohort study in the area of Leipzig, Germany (clinical trial number NCT02550236). More than 4000 children and adolescents (LIFE Child HEALTH) and their families, as well as 750 pregnant women (LIFE Child BIRTH), have been recruited. Additionally, a subcohort of obese children and adolescents was enrolled to investigate the pathogenesis of obesity-related comorbidities (LIFE Child OBESITY). The investigation started in July 2011 and is ongoing. Strengths of the LIFE Child study are the possibility to survey different assessments and the close collaboration with the University of Leipzig and various research centers. Thereby, new insights about health and disease in today's youth could be gained.[19,20] The VRP was assessed on a subset of the participating children and their parents. In summary, we managed to investigate the voice parameters of 1,564 children and adolescents in the framework of the present study. Additionally, for 1,062 participating children, two to four follow-up examinations could be conducted, resulting in a total of 2,626 completed observations.

Ethics

The study was designed in accordance with following the Declaration of Helsinki[21] and under the supervision of the Ethics Committee of the University of Leipzig (Reg. No. 264-10-19042010). Each participant and the authorized representative were informed about the study program, the long-term use of data, potential risks of participation, and the right to withdraw from the study. Informed consent was obtained from all individual participants included in the study. In the rare cases of relevant incidental findings (eg, a new clinical diagnosis), these were reported to the families as well as their primary care physicians.

Study design

In the framework of the LIFE Child study, every participant underwent an age-dependent determined investigation program. Information about the clinical history, clinical examinations, and a vast collection of diagnostic data were assembled. Additional computer-assisted personal interviews and self-administered questionnaires had to be completed by the children and by their parents.[19,20]

To ensure a high and stable quality of the registration of the voice parameters, a standard operating procedure was defined. The measurements were performed in a soundproof room. Ambient noise was not allowed to exceed 40 dB(A). The recommendations set by the Union of the European Phoniatricians[6] were obeyed. All measurements were done by trained investigators using the *DiVAS Software* (XION medical, Berlin, Germany).[6] Participants who suffered from chronic hoarseness or acute voice disorders were excluded from the study. The intensity and frequency of the speaking and singing voice were recorded using a self-calibrating USB-microphone-headset that was kept at a constant distance of 30 cm from the mouth of the participant. Starting with the registration of the speaking voice profile, children should count from 21 to 30 using their quietest voicing speaking voice (Level I), conversational voice (Level II), classroom voice (Level III), shouting voice (Level IV), and finally again their quietest speaking voice (Level V) in terms of a voice reset test. Thus, it was possible to register the total frequency and dynamic range of the speaking and the shouting voice.[7] Additionally, the investigator ranked the degree of motivation to the measurement of the children on a scale ranging from 1 (shows interest and intrinsic motivation) to 5 (no compliance).

BMI-standard deviation score (SDS), KLASAK Classification, and Tanner stage

The BMI was calculated using the body mass (kilogram) divided by the square of the body height (square meter). SDSs (z-scores) were obtained to account for a child's age and sex following the guidelines of the German Adiposity Society and Kromeyer-Hauschild 2001.[22] To verify the singing activity of the participants, the KLASAK Classification according to Fuchs et al[23] was used. The children were asked via a questionnaire about their degree of vocal strain and vocal training and whether they played a wind instrument. This classification system is a practical tool for evaluating singing activity and can be used at the level of a group comparison in scientific investigations. To consider the individual physical development of the children and adolescents, the Tanner scale (Tanner I-IV) according to Marshall and Tanner (as described in 1969 and 1970) was investigated as a composite of pubic hair and breast stage for girls and pubic hair and testis volume for boys.[18,24]

Statistical analysis

Statistical analyses were conducted using R version 3.2.3.[25] Stratified by sex, percentile curves of the voice frequency were estimated applying an LMS-type method implemented as a generalized additive model for location, scale, and shape. The method is recommended by the World Health Organization (WHO) for generating age-dependent reference values. It was used in the WHO multicenter growth study to establish the new international growth standard.[26,27]

Since the LIFE Child cohort has a longitudinal recruitment scheme, and as for some families more than one child was recruited, the data contain multiple measurements per child and measurements of siblings. In order to guarantee the independence of measurements, and still considering all observations, a resampling procedure was used in the estimation process. The estimation of percentiles as described above was repeated 1,000 times on distinct subsamples containing 500 independent observations each (one per family). A weighting ensured that each observation has the same probability of being chosen. The means of the estimated location, scale, and shape parameters conditional on age were used for the calculation of the final reference curves.

To assess the impact of the BMI SDS, Tanner stage, and KLASAK as independent variables on the pitch and sound pressure level of the voice, multilevel linear regression analyses were performed using function lmer from *the R package lme4* (version1.1.10, open source, authors: Douglas Bates, Martin Maechler, Ben Bolker, Steven Walker available from https://CRAN.R-project.org/package=lme4).[28] Multiple measurements of one child, as well as measurements from siblings, were accounted for using random intercepts term. All regression models were analyzed for both sexes individually. *P* values ≤0.05 were considered to indicate statistical significance.

RESULTS

Only data of children with all five measuring levels of the speaking voice profile were included. In total, 2,626 measurements of 1,352 male and 1,274 female participants could be registered. The age distribution was between 5.5 and 17.5 years. Due to the child development, we divided the cohort into three age groups ranging from 5.5 to 10.5 years of age, from 10.5 to 14.5 years of age, and from 14.5 to 17.5 years of age. Besides the fact that the oldest age cohort (between 14.5 and 17.5 years old) was slightly underrepresented, still, a representative amount for all three age groups could be included in the statistical analyses. More than 75% of the participating children showed a high or very high degree of motivation during the measurement. Only about 4% were skeptical or incompliant during the investigation. Motivation was slightly higher in younger children. The characteristics of the study population are shown in Table 1.

TABLE 1.
Characteristics of the Study Population

	Males			Females		
Age group	[5.5,10.5]	[10.5,14.5]	[14.5,17.5]	[5.5,10.5]	(10.5,14.5]	(14.5,17.5]
N	572	587	193	497	521	256
Age (standard deviation)	8.57 (1.22)	12.49 (1.14)	15.72 (0.79)	8.54 (1.22)	12.46 (1.19)	15.83 (0.79)
BMI-SDS (%)						
Thin	37 (6.5)	62 (10.6)	9 (4.7)	34 (6.9)	47 (9.1)	18 (7.1)
Normal	452 (79.6)	395 (67.6)	149 (77.2)	388 (78.9)	338 (65.3)	173 (68.4)
Overweight	30 (5.3)	49 (8.4)	14 (7.3)	26 (5.3)	64 (12.4)	18 (7.1)
Obese	49 (8.6)	78 (13.4)	21 (10.9)	44 (8.9)	69 (13.3)	44 (17.4)
Tanner (%)						
1	406 (89.6)	81 (21.4)	0 (0.0)	360 (80.2)	30 (6.6)	0 (0.0)
2	46 (10.2)	159 (42.0)	1 (1.5)	82 (18.3)	131 (28.7)	0 (0.0)
3	1 (0.2)	61 (16.1)	5 (7.5)	7 (1.6)	137 (30.0)	9 (4.0)
4	0 (0.0)	61 (16.1)	24 (35.8)	0 (0.0)	98 (21.4)	56 (25.0)
5	0 (0.0)	17 (4.5)	37 (55.2)	0 (0.0)	61 (13.3)	159 (71.0)
KLASAK						
Vocal strain (%)						
A	507 (92.3)	523 (94.4)	177 (95.2)	361 (76.8)	392 (79.2)	213 (85.5)
B	17 (3.1)	12 (2.2)	3 (1.6)	23 (4.9)	23 (4.6)	6 (2.4)
C	20 (3.6)	14 (2.5)	4 (2.2)	77 (16.4)	53 (10.7)	16 (6.4)
D	5 (0.9)	5 (0.9)	2 (1.1)	9 (1.9)	27 (5.5)	14 (5.6)
Vocal training (%)						
1	518 (95.6)	524 (95.3)	177 (96.2)	385 (84.1)	411 (84.6)	221 (88.8)
2	21 (3.9)	22 (4.0)	6 (3.3)	70 (15.3)	67 (13.8)	20 (8.0)
3	3 (0.6)	4 (0.7)	1 (0.5)	3 (0.7)	8 (1.6)	8 (3.2)
Wind instrument (%)						
Z	12 (2.2)	18 (3.2)	6 (3.2)	29 (6.1)	26 (5.2)	5 (2.0)
Motivation (%)						
1 very high	127 (25.8)	121 (24.6)	36 (20.2)	110 (26.3)	116 (26.1)	31 (13.8)
2 high	268 (54.4)	275 (55.9)	91 (51.1)	233 (55.7)	213 (47.9)	131 (58.5)
3 moderate	82 (16.6)	82 (16.7)	40 (22.5)	59 (14.1)	94 (21.1)	54 (24.1)
4 skeptical/restricted	13 (2.6)	13 (2.6)	11 (6.2)	16 (3.8)	19 (4.3)	7 (3.1)
5 incompliant	3 (0.6)	1 (0.2)	0 (0.0)	0 (0.0)	3 (0.7)	1 (0.4)

Regarding BMI-SDS, the 90th and 97th BMI percentiles are proposed as cutoff points for the definition of overweight and obesity. The third and the 10th BMI percentiles are proposed as cutoff points for the definition of thin.[22] The Tanner scale (Tanner I-IV) is classified according to Marshall and Tanner.[18,24] Analogous to the KLASAK Classification,[23] the vocal strain was divided into group A (only spontaneously), group B (occasionally—organized singing), group C (regular organized singing with concerts rehearsals/week + total time of concerts/year), and group D (regular organized singing with concerts rehearsals/week + total time of concerts/year = more than 6 hours = up to 6 hours). The vocal training is classified in group 1 (not at all), group 2 (in a large group—more than three persons), and group 3 (individual lessons or in a small group—up to three persons). An additional strain from playing a high-pressure wind instrument is classified with the letter Z.

Speaking voice profile

Figure 1 shows box plots of the five measured levels for the frequency and the sound pressure of the speaking voice for boys and girls separately. A clear distinction ($P \leq 0.05$) in frequencies and sound pressure levels between the five different voice levels (I-V) can be described for both genders. The comparison of the mean values of Levels I and V showed similar values.

The corresponding numerical summaries stratified by age group are listed in Table 2.

Effects of gender and age

The intensity parameters of the four different speaking levels showed very little variation across the three age groups. Besides the fact that the intensity of the shouting voice of the male participants was higher in all age groups than that of the female participants, it is remarkable that in the eldest age group, the male participants were able to speak with significantly lower intensity in their softest speaking voice (Level I) compared with the participants in other age groups. On the other hand, a significant change in the frequency can be described. Both sexes show almost equal values of the fundamental frequency on all speaking levels at a young age. Subsequently, the effects of adolescence can be seen in both genders. While females show a lowering of their fundamental frequency in their conversational voice by 17.5 Hz (about 1.4 semitones) from 223.3 (corresponds to A3) to 205.8 Hz (corresponds to G#3/A3), the male participants lower about 120 Hz (13.5 semitones) from 223.3 to 102.3 Hz (corresponds to G#2/A2) between ages 7 to 17 (see Figure 2). The graphic presentation of the fundamental frequency as a percentile curve attempts to define normative data for the speaking voice profile (see Figure 3).

Effects of voice change

When surveying the change in the fundamental frequency of the speaking voice in a monthly approach, the highest decrease occurs at 13.5 years for boys. Between the age of 13 and 14 years, a decrease of 2 Hz every month could be evaluated. In contrast, girls show an almost continuous decline in their fundamental frequency until 18 years (see Figure 4).

The mean values of the sound pressure levels of the female participants remain almost unchanged throughout adolescence. Because males, after voice change, can speak with a significantly lower intensity in their softest speaking voice (Level I), they achieve a wider vocal range.

Effects of BMI-SDS, Tanner scale, and KLASAK Classification

As expected, Tanner stages have a definite effect on voice parameters. Progressing puberty leads to a lowering of the

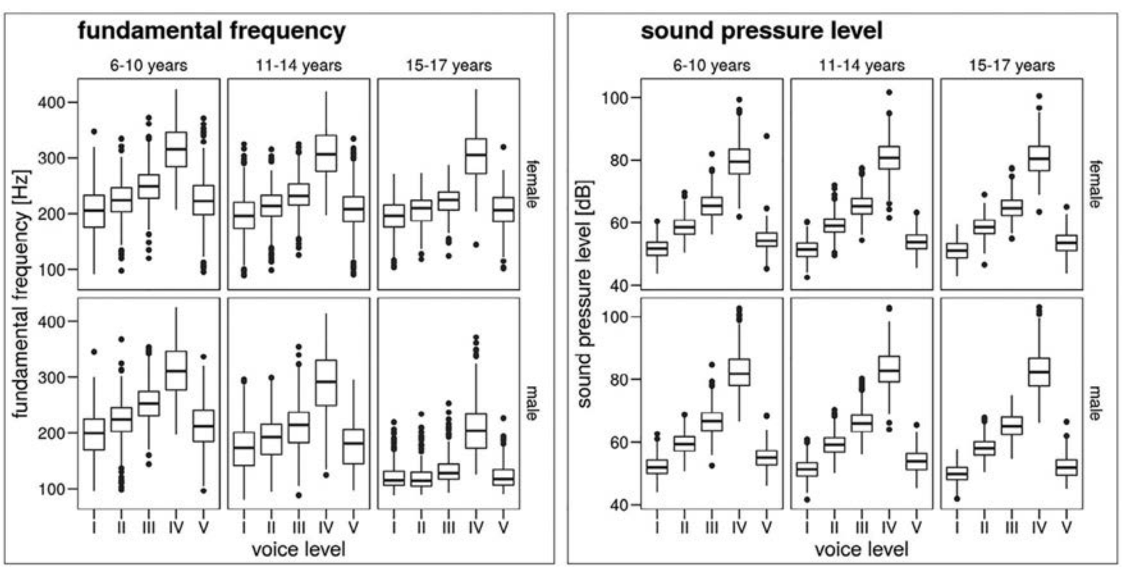

FIGURE 1. Association of gender with fundamental frequency and sound pressure level stratified by age group (5.5−10.5, 10.5−14.5, and 14.5−17.5 years of age) and five different levels of the speaking voice. Box plots are representing the median and the interquartile ranges for males and females (I: softest speaking voice; II: conversational voice; III: classroom voice; IV: shouting voice; V: quietest speaking voice in terms of a voice reset test).

TABLE 2.
Speaking Voice Parameters With Frequency and Sound Pressure Level Stratified by Gender and Age Group (5.5−10.5, 10.5−14.5, and 14.5−17.5 Years of Age) and Five Different Levels of the Speaking Voice; Mean Values and Standard Deviations for Males and Females (I: Softest Speaking Voice; II: Conversational Voice; III: Classroom Voice; IV: Shouting Voice; V: Quietest Speaking Voice in Terms of a Voice Reset Test)

	5.5−10.5 Years Mean (SD)	10.5−14.5 Years Mean (SD)	14.5−17.5 Years Mean (SD)
Males			
Frequency (Hertz)			
Level I	197.03 (39.23)	171.8 (40.03)	122.2 (24.11)
Level II	223.29 (34.75)	187.3 (40.72)	122.27 (25.83)
Level III	253.73 (34.38)	208.9 (45.4)	134.48 (28.09)
Level IV	311.8 (44.96)	287.22 (58.74)	207.51 (48.74)
Level V	211.98 (40.13)	178.15 (40.89)	124.32 (23.49)
SPL (Decibel)			
Level I	52.12 (3.09)	51.34 (3.19)	50.02 (3.19)
Level II	59.34 (3.3)	59.1 (3.31)	58.11 (3.58)
Level III	66.77 (4.29)	66.09 (4.1)	65.23 (4.21)
Level IV	82.51 (6.46)	83.45 (6.05)	82.72 (6.54)
Level V	55.1 (3.36)	53.83 (3.54)	52.2 (3.6)
Females			
Frequency (Hertz)			
Level I	204.47 (41.46)	195.54 (38.03)	194.05 (32.14)
Level II	223.27 (34.19)	213.53 (31.33)	205.77 (27.67)
Level III	250.3 (34.68)	232.99 (30.55)	222.54 (26.27)
Level IV	315.66 (42.59)	307.76 (44.39)	302.92 (44.35)
Level V	222.63 (43.92)	207.96 (37.76)	205.16 (33.25)
SPL (Decibel)			
Level I	51.77 (2.99)	51.42 (2.98)	51.1 (3.3)
Level II	58.62 (3.27)	59.13 (3.2)	58.58 (3.11)
Level III	65.54 (4.17)	65.42 (3.8)	64.85 (3.76)
Level IV	79.78 (5.59)	80.73 (5.38)	80.55 (5.52)
Level V	54.59 (3.61)	53.98 (3.37)	53.55 (3.63)

Abbreviations: SD, standard deviation; SPL, sound pressure level.

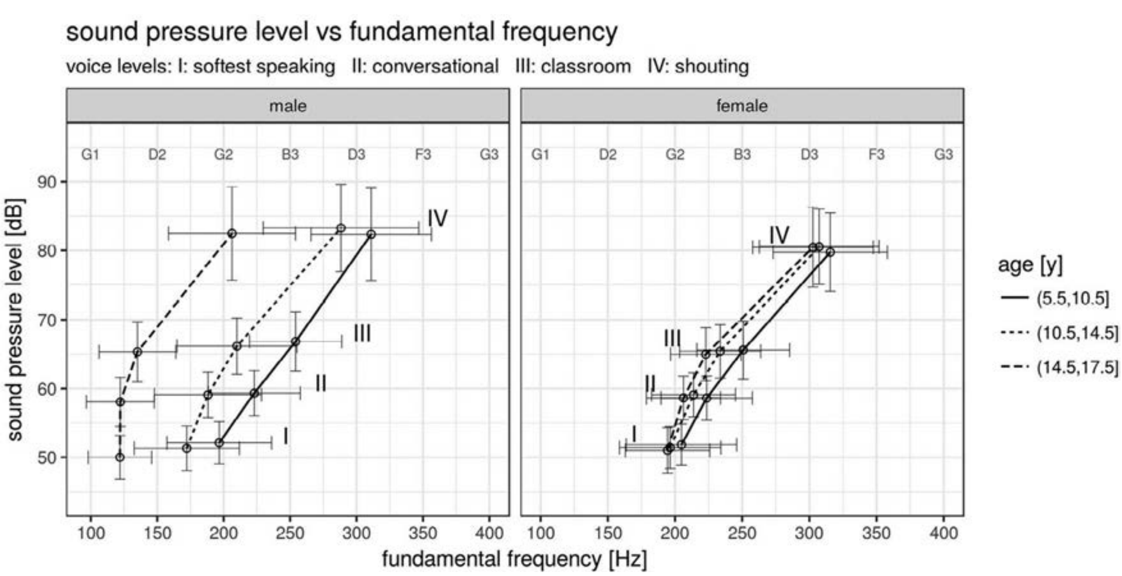

FIGURE 2. Association of age with fundamental frequency and sound pressure level stratified by gender. Mean values and standard deviations of male and female participants. While the intensity parameters stay almost stable, both genders show a lowering of the fundamental frequency during aging (I: softest speaking voice; II: conversational voice; III: classroom voice; IV: shouting voice).

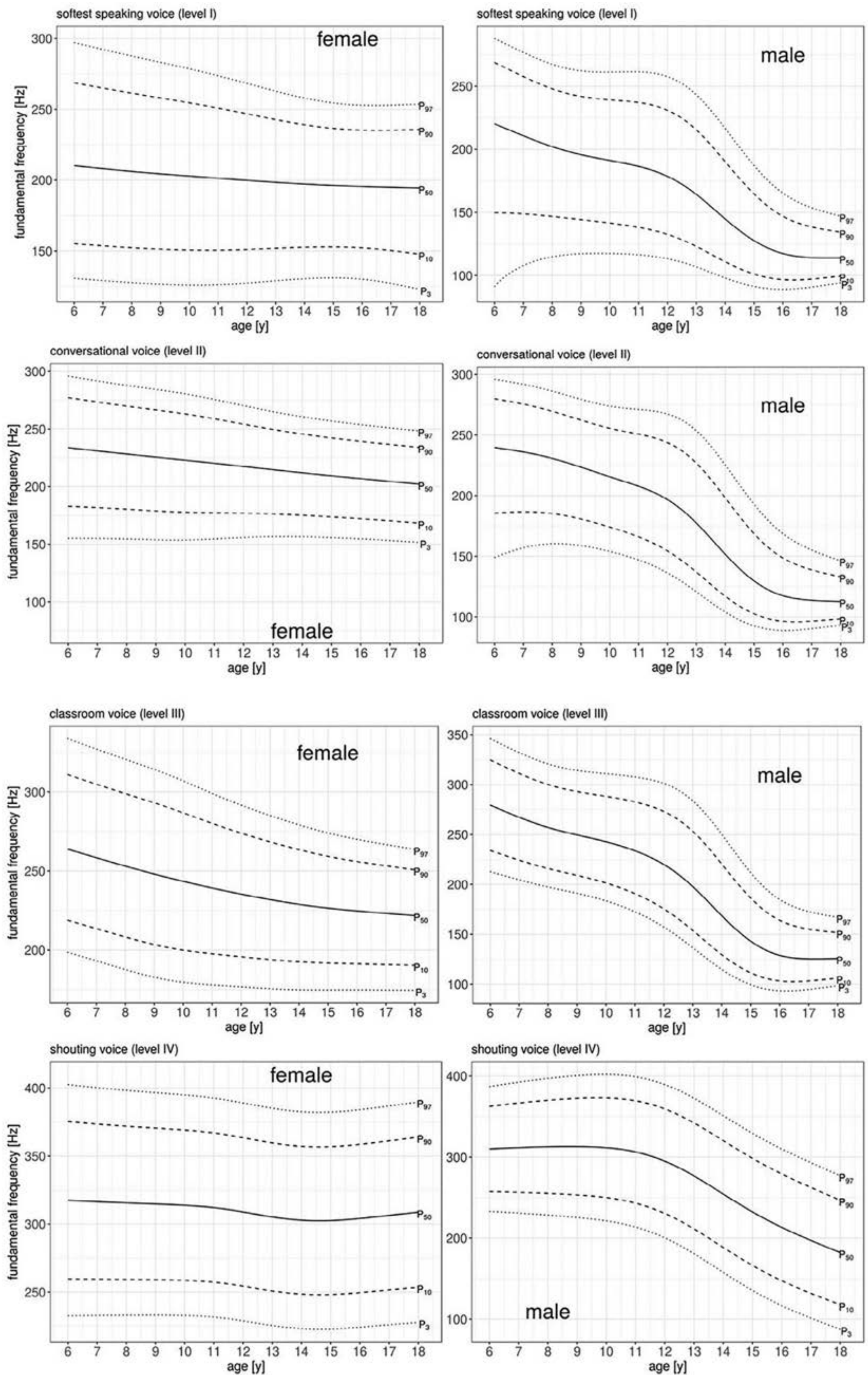

FIGURE 3. Relation between age and fundamental frequency for the speaking voice in four different voice levels divided between genders as depicted in percentile curves (I: softest speaking voice; II: conversational voice; III: classroom voice; IV: shouting voice).

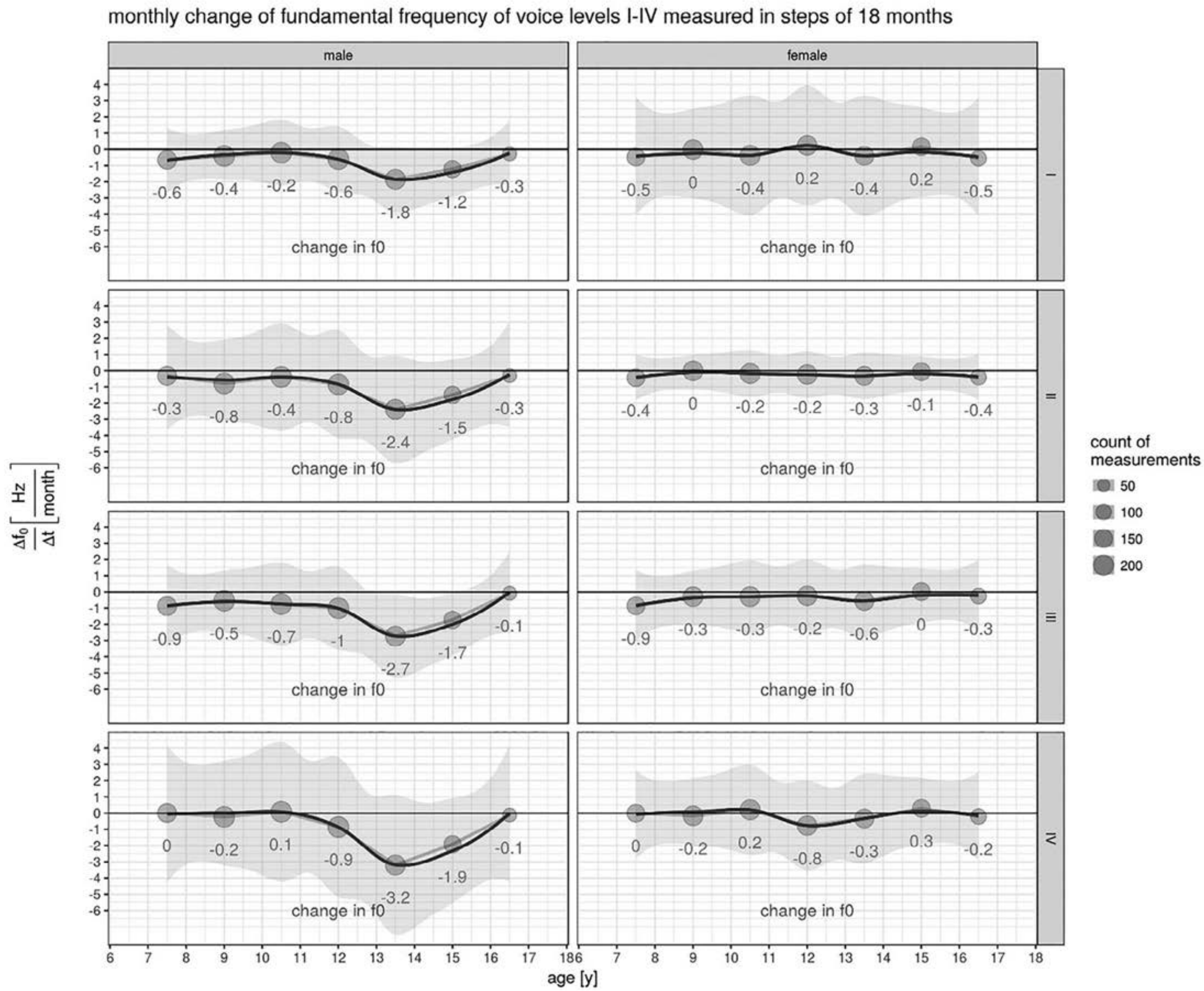

FIGURE 4. Mean monthly change rates in the fundamental frequency of all measured four different voice levels stratified by gender (I: softest speaking voice; II: conversational voice; III: classroom voice; IV: shouting voice).

voice in both males and females. Besides the specified effects of aging on the lowering of the fundamental frequency for both sexes, male children with Tanner stages 4 and 5 can speak about 2 dB lower in their softest speaking voice (Level I). All other parameters did not show significant correlations with the frequency or intensity of the different voice levels.

The distinction of children's singing activity, including voice strain, voice training, and practicing woodwind or brass-instrument playing, was done according to the KLASAK Classification of Fuchs et al.[23] Due to the fact that the majority of the participants did not have higher vocal strain or regular vocal training, we classify all participating children into two groups: one group without vocal experience and no vocal training (KLASAK A and B) and another group with vocal experience and higher vocal strain or individual vocal training (KLASAK C and D). Only 3.9% of the male children showed a higher vocal strain regarding a regular singing activity. Only 4.5% of all male children had individual or group singing lessons. In the female children, 16.1% participate in regular singing activities in which 14.8% receive particular support for their singing capability.

There is no apparent effect of the KLASAK characteristics on the speaking voice parameters. The analysis of a possible influence of the singing activity on the speaking voice parameters depicts that girls with regular singing activity achieve on average a wider voice range of one semitone when adjusted for pubertal stage. Figures 5 and 6 show regression analyses on associations of the fundamental frequency and the intensity of the conversational voice and the shouting voice with the KLASAK characteristics, Tanner stages, and the BMI-SDS categories in a linear regression model.

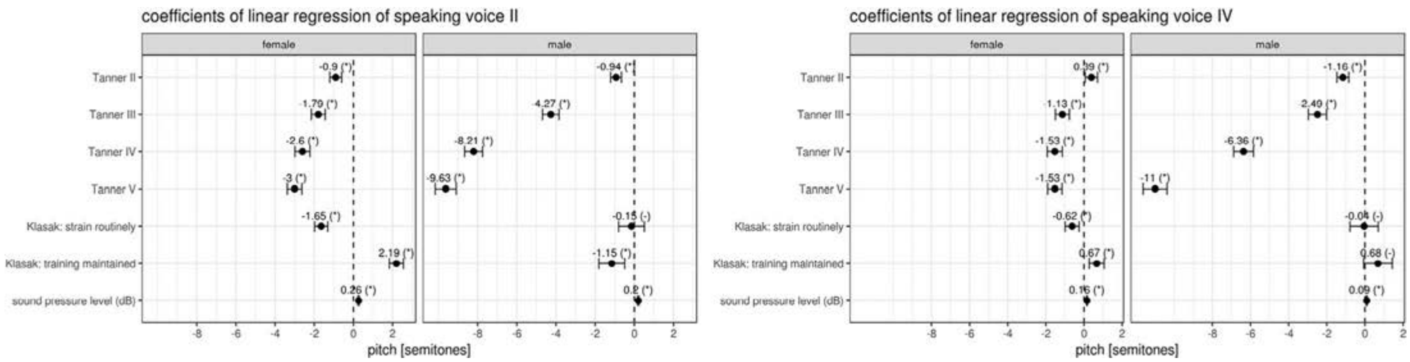

FIGURE 5. Illustration of the coefficient of multilevel linear regression of the fundamental frequency measured in semitones for the conversational voice (II) and the shouting voice (IV) stratified by gender on the Tanner stage and the KLASAK Classification. Error bars indicate the 95% confidence interval. A line crossing point zero on the x-axis indicates that no statistical significance is given. A clear significant association was only seen for the Tanner stages.

DISCUSSION

The purpose of the present study was to examine voice parameters in children and adolescents using the speaking voice profile. The possibility to collect a surpassing quantity of voice parameters led to the demand to generate normative data for the speaking voice profile in this age group. One of the main acoustic parameters examined in children is the fundamental frequency of the habitual pitch by telling a short story or sustaining the vowel /a/ for several seconds.[12,28−31] In order to determine the voice range of the children, we used the speaking voice profile in terms of counting from 21 to 30 in four different voice levels. Barsties[32] showed the effects of different tasks on the determination of the fundamental speaking frequency. For example, reading passages and sustaining vowels seem not to be appropriate methods to describe the fundamental frequency as they do not represent conversational speech accurately. This finding is clinically important as it indicates that the same task should be used to monitor changes in the voice over time in relationship to surgical or behavioral interventions. Barsties figured out that to determine the speaking fundamental frequency,[32] a continuous speech should be used. The same results were presented by Baker et al, who delineated that the manner in which tasks are elicited does significantly influence the fundamental frequency values in young children.[31] Our rationale to measure the speaking voice in four predefined intensity levels was to examine the speaking voice ranges and its dynamics. Similar considerations were done by Hacki and Heitmüller, who investigated the voice development before voice change by examining the intensity and pitch of the habitual and shouting voice.[29] Secondary, all age groups should be capable of passing the examination sufficiently.

Our analyses show a clear differentiation in the frequency and intensity of the five predefined intensity levels, illustrating a feasible and reliable examination of the speaking voice for all age groups. The resulting percentile curves (see Figure 3) show the age effect in both genders. If we, based on a pediatric approach, consider the range between the 10th (10.) and the 90th (90.) percentile as an acceptable variation, the fundamental frequency of the speaking voice can differ up to 100 Hz in every age group. These results confirm findings by Baker et al or by Linders et al, who described a range of the fundamental frequency between 182 and 331 Hz in girls and from 205 to 293 Hz in boys.[30,31,33]

In our study sample between 5.5 and 10.5 years of age, the gender-specific values of the fundamental frequencies of the

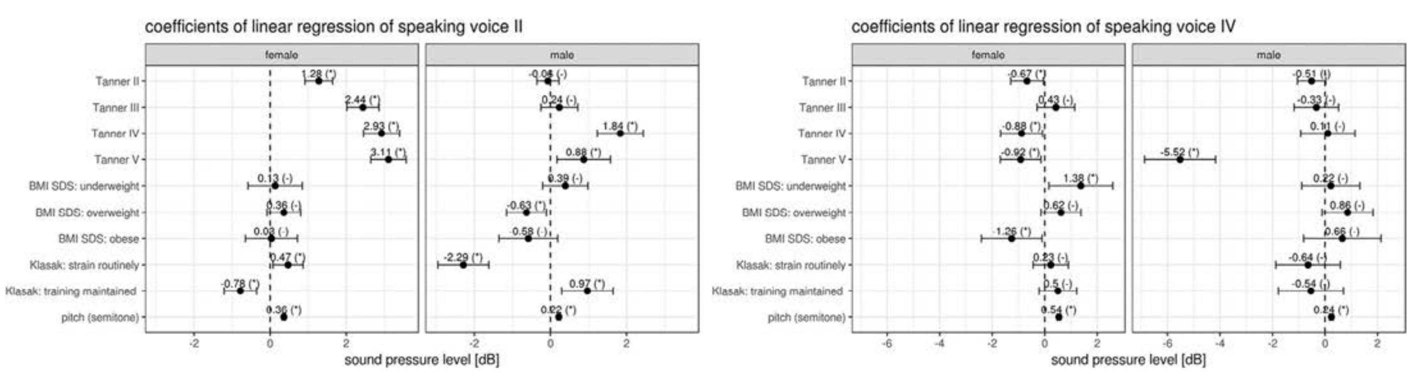

FIGURE 6. Illustration of the coefficient of multilevel linear regression of the intensity measured in decibels of the speaking voice for the conversational voice (II) and the shouting voice (IV) stratified by gender on BMI-SDS, the Tanner stage, and the KLASAK Classification. Error bars indicate the 95% confidence interval. A line crossing point zero on the x-axis indicates that no statistical significance is given. A clear significant association was only seen for the Tanner stages.

different voice intensities are comparable. The mean values of the conversational voice (Level II—223.3 Hz) and the classroom voice (Level III—252 Hz) in this age group slightly differ from other published data. While results published by Hacki et al[7] or Nicollas et al[34] show higher values for the fundamental frequency, other authors find similar or even lower values.[30,35] However, for a comparison of the data, the effect of different recording devices has to be considered.

The major change in speaking voice occurs during puberty. Puberty usually starts between the age of 8 and 15 years. During puberty, the female voice usually drops about 2.5 semitones, while the male voice drops approximately one octave.[36] In our cohort the major change in the fundamental frequency occurs between 13 and 14 years in boys, while the female participants showed a continuous decrease. This finding is in line with the work from Infusino et al,[37] who analyzed children's voices using a cepstral analysis of continuous speech samples and described a decreasing linear correlation with age with no critical points of the fundamental frequency data for female participants. Regarding the voice change in boys, our results underline findings from Hollien,[38] who stated a mean age of about 13.4 years at the onset of adolescent voice change in boys, and concluded that for most boys, the adolescent voice change occurs between the ages of 12 and 15 years. Looking at the median decline of the fundamental frequency over all age groups, boys show already at the age of 8 a significant lowering of their voice compared with the girls. Taken together, in the period between 7 and 17 years, the fundamental frequency of the conversational voice lowers about 1.8 semitones for girls and 12.5 semitones for boys. This finding confirms previous results found in literature.[38,39] Hacki and Heitmüller, and Fuchs et al declared prepuberty with a decrease in the mean fundamental frequency of about 6 to 12 months before the voice change.[29,40] Considering our data we can confirm this statement as we see a first significant decline in the fundamental frequency at the age of 12 years. Besides the finding that for both genders the sound pressure levels showed a clear differentiation between the five intensity levels (I-V), a notable fact is that the values of intensity of the shouting voice in boys were higher in all age groups. The remaining intensity levels showed almost comparable data for both genders. Comparing the data with results from Berg et al,[41] who investigated the speaking voice profile of adults, almost no substantial differences throughout the lifetime can be found. Taking into account that acoustic parameters represent physiological status, these normative acoustic values might be beneficial in differentiating normal from abnormal phonation.

It is known that frequent singing during voice change can affect the physiological development of the voice, whereas children with an average level of vocal strain usually pass through this period without severe problems.[40] On the other hand, choristers with a regular high vocal strain show a lower incidence of voice disorder and higher vocal skills.[41–43] In our cohort, the influence of the vocal strain or voice training on the speaking voice seems to be negligible. Yet further research on the influence of the KLASAK on the singing voice may differ from these results. Another notable fact is that 19.45% of the participants were overweight or obese. This overrepresentation of obese children can be explained by the inclusion of the voice data of the LIFE Child OBESITY subcohort in our statistical analysis. Regarding a possible influence of the BMI as another covariate on the voice range, no critical effects could be detected. These data are in line with previous studies that found no correlation between BMI and the fundamental frequency.[17,43,44]

CONCLUSION

The present study described for the first time the intensity and fundamental frequency of the speaking voice in an outreached cohort of young children and adolescents. The investigation of predefined intensity levels of the speaking voice appeared to be a feasible and reliable examination in all included ages. Therefore, our data allow a valid estimation of the reference range of parameters of the speaking voice. Beyond the effect of growth, the other surveyed parameters like BMI and the singing activity do not seem to have a relevant influence on the speaking voice. While revealing the relevant changes of voice parameters throughout aging, the presented data can help to distinguish between normal and pathologic alterations of the speaking voice and lead to an earlier therapeutic intervention in case of necessity.

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