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EMERGING TECHNOLOGIES

Snoring intensity assessment with three different smartphones using the SnoreLab application in one participant

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Study Objectives: To compare the assessment of snoring using the SnoreLab application (app) using three different smartphones by one participant to validate SnoreLab as a method for collecting data for studies on the effectiveness of snoring treatment.

Methods: A person from the research group was monitored for 30 consecutive nights with the SnoreLab app using three different smartphones (Xiaomi MI8Pro, Samsung Galaxy Alpha, and BQ Aquaris V). The SnoreLab app instructions were strictly followed, and data were collected from the app.

Results: No significant differences were found in the measurements from the three smartphones in the time in bed, all snoring time, snoring percentage, and quiet time. BQ and Samsung smartphones determined significantly more light snoring time than did the Xiaomi smartphone. The Samsung smartphone assessed significantly less loud snoring time than did the Xiaomi smartphone and measured the shortest epic snoring time. The lowest Snore Score was calculated with the Samsung smartphone, the highest with the Xiaomi smartphone. Pearson's correlation coefficients demonstrated a relatively strong relationship between the Snore Score measured with the three smartphones.

Conclusions: Even though there was a relatively strong relationship between the Snore Score measured with the three smartphones by one participant, the observed differences make it difficult to use this index as a method of collecting data for studies on snoring treatment effectiveness when patients use different smartphones; however, the SnoreLab app may be handy to quantify treatment effectiveness for a specific patient, provided the patient always uses the same smartphone.

Keywords: snoring; SnoreLab app; application (app); smartphone; home monitoring

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Nowadays, about two billion people worldwide snore. Snoring is a sound caused by vibration of the soft palate and other airway structures when the air is partially blocked. Quantifying snoring, and finding its specific causes, is necessary to establish an effective treatment, so self-monitoring of snoring with a smartphone application can be useful.

Study Impact: The differences in the Snore Score measured using three smartphones by one participant make it difficult to use this index as a method of collecting data for studies on snoring treatment effectiveness in patients who use different smartphones; however, the SnoreLab application may be handy to quantify treatment effectiveness for a specific patient, provided that patient does not change the smartphone used.

INTRODUCTION

Nowadays, approximately 40% of men and 20% of women snore, which in absolute numbers involves about two billion people worldwide.[1] Snoring is a sound caused by vibration of the soft palate and other airway structures when the air is partially blocked and cannot move freely through the upper airway.[2–4] Primary snoring may be related to factors such as sex, age, body weight, sleeping position, allergies, common cold, alcohol, tobacco, medication consumption, and certain malocclusions.[2,5] Furthermore, snoring has been described as a risk factor for cardiovascular diseases[6,7] and as a sign of obstructive sleep apnea (OSA).[8] A positive correlation between snoring intensity and severity of OSA has been suggested[9]; however, not everyone who snores has OSA, and the snoring sound profile itself is not a good predictor of OSA presence or severity.[2] Despite these adverse effects, the most common patient motivation for asking for treatment is something like, "My snoring bothers my wife." Snoring often affects the quality of sleep of bed partners.[2,3,10]

Depending on where the upper airway block occurs, there are multiple techniques to reduce snoring, such as mandibular advancement devices, tongue retainers, nasal strips, nasal dilators, positional therapy, and antisnoring pillows.[11,12] Quantifying snoring, and finding its specific causes, is necessary to establish an effective treatment, so self-monitoring of snoring with a smartphone application (app) can be useful.[2,8]

SnoreLab (SnoreLab, London, United Kingdom) is an app that, through the built-in smartphone microphone, monitors the time in bed and the all snoring time, which is classified

Table 1—Characteristics of smartphones used in this study.

Brand	Model	Operative System
Samsung	Galaxy Alpha	Android 5.0.2 Lollipop
BQ	Aquaris V	Android 8 Oreo
Xiaomi	MI 8 Pro	Android 10

according to intensity as light, loud, and epic. Also, using a sophisticated algorithm, it calculates the Snore Score.[13] By quantifying the severity and duration of snoring, the SnoreLab app could also validate the effectiveness of the different treatments for a specific patient.[3]

The objective of this study was to compare the assessment of snoring with the SnoreLab app for one participant, using three different smartphones, to validate it as a method of collecting data for studies on snoring treatment effectiveness.

METHODS

A person from the research team (O.F.A.) monitored his sleep for 30 consecutive nights using the SnoreLab app on three different smartphones. The characteristics of the smartphones are shown in **Table 1**. According to the SnoreLab app instructions, all three smartphones were attached to external power all night. The app was activated, and the smartphones were placed face-down near the bed at arm's length away from the face with the device's microphones facing toward the sleeper.[13] They were placed next to each other, and on each night of testing, their position was alternatively exchanged.

The values of the following variables given by the SnoreLab app were recorded: time in bed; all snoring time; snoring percentage; percentage of quiet time; percentage of time in which snoring was light, loud, and epic; and the Snore Score index. *Time in bed* meant the time from when the device started recording (after 20 minutes of pressing the start button) until the application was turned off. *All snoring time* denoted the time the smartphone detected snoring, and the *snoring percentage* represented the percentage of the night in which snoring was distinguished. *Quiet time* was the time no snoring was identified. According to intensity, snoring was classified as *light* (unlikely to disturb a bed partner), *loud* (likely to disturb a bed partner, similar in volume to quiet talking), and *epic* (likely to disturb a bed partner, similar in volume to a normal conversation or greater). All percentages of quiet, light, loud, and epic snoring time were transformed in minutes for further analysis. *Snore Score* represented, as claimed by SnoreLab company, a unique measurement of snoring intensity calculated with the average volume and the total duration of suspected snoring episodes during a night. A higher Snore Score indicated louder or more frequent snoring.[13]

Statistical analysis

Normal distribution of collected data and homogeneity of the variances were verified through the Shapiro-Wilk test and the Levene test, respectively. Subsequently, the statistical significance of differences noticed in the data collected was checked with an analysis of variance. Thenceforth, Fischer's least significant difference was used to determine significant differences among the studied groups. Afterward, Pearson's correlation coefficient between the Snore Scores obtained from the different smartphones was determined. Statistical significance was set at .05.

RESULTS

The means and the standard deviations of the variables studied with the three different smartphones are shown in **Table 2**, together with their statistical significance.

No differences were found in the measurements of the three smartphones in the time in bed, all snoring time, snoring percentage, and quiet time. BQ and Samsung smartphones determined significantly more light snoring time than did the Xiaomi smartphone. The Samsung smartphone assessed significantly less loud snoring time than did the Xiaomi smartphone, and it also measured the shortest epic snoring time. The lowest Snore Score was calculated with the Samsung smartphone and the highest with the Xiaomi smartphone.

Pearson's correlation coefficients calculated when comparing the Snore Scores between Xiaomi and BQ equaled 0.9, Xiaomi and Samsung 0.90, and Samsung and BQ 0.90. All coefficients demonstrated a relatively strong relationship.

DISCUSSION

The SnoreLab app is a top-rated app that tracks duration and snoring intensity. It is available for IOS and Android. It is rated with 4.7 of 5 stars according to more than 10,000 user ratings.[14] The SnoreLab app company claims that it is intended only for informational purposes and not for collecting data for studies on snoring treatment effectiveness[14]; however, comparison of the snoring before and after application of any sort of treatment could be a useful tool for clinicians.[3] The SnoreLab app company also claims that the measured results may be influenced by microphone sensitivity, noise interference, and device placement,[14] so all these parameters, but not the microphone sensitivity, were controlled throughout all the study.

Many times, it is the bed partner who quantifies snoring.[10] For patients who sleep alone, such as singles, this app may be especially useful[10] because it allows assessment of snoring that does not bother anyone but may suggest the presence of associated pathology or a cardiovascular risk factor.[6–8] By default, the SnoreLab app records 20 snoring samples per night, although it can optionally be programmed to record throughout the night. Subsequently, if any suspicious characters in the snoring record were assessed, other tests, such as polysomnography or a complete sleep study, could be indicated to discard OSA.[2,8] For a National Health System, the SnoreLab app could become a valuable screening tool for OSA.

Three different smartphones were used in this study. These smartphones could simulate either the phones that someone could acquire and use for about 5 years or the different types of

Table 2—Variables studied with three different smartphones.

	BQ	Samsung	Xiomi	*P* Value*
Time in bed	429 ± 50.12	429 ± 50.24	429 ± 50.30	1
All snoring time	162.53 ± 40.17	155 ± 33.62	147.70 ± 34.73	.29
Snoring percentage	40.20 ± 10.10	38.30 ± 8.80	36.47 ± 8.11	.28
Quiet	94.97 ± 14.72	93.42 ± 12.28	91.49 ± 13.45	.61
Light	42.21 ± 22.32	42.66 ± 21.83	24.06 ± 10.48	<.01 (1–3, 2–3)
Loud	20.82 ± 10.13	18.64 ± 9.66	25.81 ± 12.19	.03 (2–3)
Epic	4.48 ± 4.90	0.78 ± 1.76	6.29 ± 5.30	<.01 (1–2, 2–3)
Snore Score	41.70 ± 11.50	35.47 ± 8.41	55.77 ± 13.63	<.01 (1–2, 1-3, 2-3)

Values are presented as mean ± SD. *P** column indicates analysis of variance (least-squares difference results < 0.05). Time in bed; all snoring time; quiet, light, loud, and epic time measured in minutes (min).

phones that could be used by people who do not change phones frequently. They were of various brands and with varying versions of the upgrade of the same operating system. A limitation of this study is that only smartphones with Android operating systems were used because it was intended not to introduce a potential flaw using another operating system, such as iOS; however, published literature reports good results when measuring snoring in an in vitro setting with iPhone (4 and 5 models) and iPad (mini and second generation).[10] When measuring in a real setting, as we did in this study, the performance of the iOS operating devices was different, depending on the smartphone and the app used. They did not assess the SnoreLab app.[10]

The 30 measurements performed in this study were always carried out under the same conditions, in the same room, in a quiet residential area, with the wife as a bed partner. Some factors may have affected the snoring intensity, such as exercising before going to bed, having a copious dinner, and drinking alcoholic beverages during or after dinner, which can explain the variability of the obtained results; however, possible snoring of the bed partner, extraneous noises, and factors that might have influenced the snoring intensity affected all three smartphone measurements. The detected differences in snoring intensity influenced the real measure of snoring intensity but did not affect the objectives of this manuscript. Nevertheless, instead, it reinforced it by making the measurements more real. The smartphone's position could affect the sensitivity of the built-in microphone,[3] so the location was alternatively exchanged every night.

Another limitation of this research is that no control was used, so it was impossible to determine which smartphone was more precise for assessing snoring intensity. Stippig and coworkers demonstrated that in a controlled setting, with no noise but a controlled, recorded snoring sound, all devices used correctly assessed the intensity of snoring. It was when using the recorded snoring sound in a real setting that more considerable variations among measuring devices were assessed.[10] In our study, no control was used because the objective of the study was to determine whether there were differences between the snoring intensity measurements performed by three different smartphones, not to assess the most accurate way to measure snoring intensity.

The results obtained showed no differences in the measurement of time in bed, in which the built-in microphone is not used, confirming the correct data collection. Those variables are recorded through the smartphone timer, which is universal in all smartphones. The SnoreLab app company does not provide any information about the frequency range at which snoring is detected; however, this study confirmed that the threshold the SnoreLab app uses to detect snoring was compatible with all built-in smartphone microphones used in this study because the all snoring time measurements were similar.

The SnoreLab app does not allow adjusting the sensitivity of the built-in smartphone microphone. The company claims that the app has been carefully calibrated to work in the bedroom environment when positioned as specified.[13] The company does not provide the used frequencies or intensities to classify the snoring in light, loud, or epic. The results obtained in this study showed that the SnoreLab app classifies the intensity of light, loud, and especially epic snoring differently, depending on the smartphone used. It also affected the Snore Score, which is calculated using an algorithm not explained by the company that depends on the intensity and duration of snoring. The intensity measured by the three smartphones was relatively strongly related, suggesting a different sensitivity of the built-in microphones when determining the snoring intensity, as previously described.[8,10] A limitation of this study is that it is not possible to determine whether smartphones of the same brand, and even the same model, would measure snoring intensity the same way because only one unit of every smartphone was used. Perhaps different releases of the same model could have different built-in microphones, which could affect the intensity detection. In the same way, different models of different brands could have the same built-in microphone so that intensity readings could be comparable. Further investigation assessing the type of built-in microphone installed in each tested unit could be fascinating.

The different, but strongly correlated, Snore Score measured with the three different smartphones could be explained by the different sensitivity of the microphones that classified the intensity in a constant way. The fact that the Snore Score is calculated with the intensity and duration of the snoring detected by the smartphone, which differs with the smartphone used, provides an absolute variant value of Snore Score. These

differences in the Snore Score measured with the three smartphones, together with the poor transparency of the algorithm, make it difficult to use this index to collect data for studies on snoring treatment effectiveness when patients use different smartphones. The Snore Score could be valid to study the effectiveness of an intervention to reduce snoring intensity or frequency in a particular patient by studying the variation in a specific patient who always uses the same smartphone. Perhaps to study patients who use different smartphones, the Snore Score could be valid if the Snore Score variation were used (final Snore Score minus initial Snore Score), but further investigation is needed. It would also be challenging to determine the Snore Score of each brand and model of smartphone, which could identify patients who should undergo a more precise assessment. This information could be integrated into the SnoreLab app, which would become a screening device for both clinicians and patients.

Several types of treatment act on different areas of the upper airway.[11,12] It is essential to act on the structure that partially blocks the air, thus causing snoring. We believe the SnoreLab app is handy and may be useful in quantifying treatment effectiveness in a specific patient,[3] provided the patient always uses the same smartphone.

ABBREVIATIONS

app, application
OSA, obstructive sleep apnea

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DISCLOSURE STATEMENT

All authors have seen and approved the manuscript. The authors report no conflicts of interest.

EDITOR'S NOTE

The Emerging Technologies section focuses on new tools and techniques of potential utility in the diagnosis and management of any and all sleep disorders. The technologies may not yet be marketed and indeed may exist only in prototype form. Some preliminary evidence of efficacy must be available, which can consist of small pilot studies or even data from animal studies, but definitive evidence of efficacy will not be required, and the submissions will be reviewed according to this standard. The intent is to alert readers of the *Journal of Clinical Sleep Medicine* of promising technology that is in early stages of development. With this information, the reader may wish to (1) contact the author(s) to offer assistance in more definitive studies of the technology; (2) use the ideas underlying the technology to develop novel approaches of their own (with due respect for any patent issues); and (3) focus on subsequent publications involving the technology to determine when and if it is suitable for application to their own clinical practice. The *Journal of Clinical Sleep Medicine* and the American Academy of Sleep Medicine expressly do not endorse or represent that any of the technology described in the Emerging Technologies section has proven efficacy or effectiveness in the treatment of human disease nor that any required regulatory approval has been obtained.