Can Smartphones with External Microphones Be Used in Place of Sound Level Meters?

Harkomal Gill[1], Amardeep Kambo[2], Fred Shaw[3]

1 Lead Author, B. Tech Student, School of Health Science, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G 3H2
2 Supervisor, School of Health Science, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G 3H2
3 Contributor, School of Health Science, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G 3H2

Abstract

Background

Sound and noise are two sides of the same coin, around us during our daily lives. Excessive noise is listed as a public health concern and is one of the most common environmental and occupational exposures. Many municipalities in BC enacted Bylaws to regulate noise, which are enforced by Bylaw Officers and Environmental Health Officers (EHOs).

Noise complaints are addressed by conducting measurements with approved and standardized Commercial Sound Level Meters (SLMs). Smartphone technology has progressed rapidly in the past decade, including the use of external microphones. Studies have been conducted on their use, however, the effects of their use have yet to be fully assessed.

Methods

A sound measurement experiment was conducted at the Environmental Health Lab (SW1-1230) at the BCIT Burnaby Campus. Noise was generated via a laptop application and projected through a Bluetooth speaker. The smartphone, smartphone + external microphone, and Type 2 SLM were placed on tripods at equal height and distance away from the noise source. Sound measurements were recorded and tallied at 50 readings per sound level group (62.5 dB, 70 dB, and 80 dB).

Results

All three sound measurement setups were significantly different from each other, except for the 70 dB variation from reference sound level group. The variation of the Smartphone + External Microphone setup from the reference sound level ranged from [0.22 ± 0.06 dB] to [0.412 ± 0.08 dB], which was well within the allowable standard error of ± 2.6 dB for Type 2 SLMs.

Conclusion

The results of the study show that all three sound measurement setups were significantly different from each other, except for the 70 dB variation group. The least deviation from the reference sound level was noticed in the Smartphone with External microphone at 70dB [0.22 ± 0.06 dB], which suggests that external microphone usage may be equivalent to Type 2 Commercial SLMs. External microphones may be used to conduct preliminary investigations by EHOs or Strata building managers. Although smartphone technology is rapidly advancing, further research is required to solidify the accuracy and precision of external microphones.

Keywords: *Smartphones, External Microphones, Sound Level Meters, SLMs, Smartphone Applications, Apps, Sound Measurement, Noise*

Introduction

Noise is all around us during our daily lives. It can take on multiple forms, such as the vibrations of vocal cords creating speech. Excessive noise is listed as a public health concern and is one of the most common environmental and occupational exposures. Studies have shown that it may lead to poorer health outcomes, such as: cardiovascular disease, hypertension, and insomnia. (1,2)

Many municipalities in the Province of British Columbia (BC) have enacted Bylaws to regulate noise with the aim of controlling excessive noise. The City of Burnaby requires noise levels to conform to Bylaw No. 7332, titled *Burnaby Noise or Sound Abatement Bylaw 1979.* (3)

Law enforcement officers, such as Environmental Health Officers (EHOs), Bylaw Officers, and Peace Officers use commercial Sound Level Meters (SLMs) to measure noise levels.

The study by Hong et al (2017) focussed on sound measurements using a smartphone with an internal microphone via a commercial SLM. (4) This study further provided a suggestion of reviewing the use of smartphone with external microphones for sound measurements.

Literature Review

Sound and Noise

Sound is a physical property present in our everyday lives. Sound is what we hear, whereas noise is sound that is unwanted by the listener. (5)

Sound is produced by vibrations through a medium, or substance in which sound travels, and is transmitted by our ears. Our brains process the information and we interpret it as the sounds we hear in our lives, such as the chirping of birds. (5) The change in compression or decompression of the air translates to the velocity, or speed, of the sound. (5)

Sound Pressure Levels are difficult to interpret, therefore, we use a scale known as Decibels (dB). A 10 dB increase means the sound has multiplied by a factor of 10. (5)

Types of Sound or Noise

There are many diverse types of sound or noise. Burnaby's Noise Bylaw defines two types of sound or noise, continuous and non-continuous. (3) Continuous sound or continuous noise is defined as any sound or noise continuing for a period(s) totalling more than three minutes in a 15 minute interval while non-continuous sound or noise is defined as lasting for less than three minutes. (3)

According to the Canadian Centre of Occupational Health and Safety (CCOHS), if there is a mix of quiet and noisy during specified periods, then the sound or noise is intermittent. (5) Impulse is another type described as a harsh noise or sound lasting one second or less. Examples of impulse noise include the sound of a gun or a punch press in a manufacturing plant.

SLMs

According to the City of Burnaby's Bylaw, an SLM means a device that the American National Standards Institute (ANSI). ANSI provides standard specifications for SLMs. There are three types of SLMs specified by the standard, type 0, 1, and 2. (6) Type 0 SLMs are denoted as laboratory equipment and are used as a reference standard for measuring sound during calibration. (6) Type 1 SLM has an allowed error deviation of ±1.5 dB whereas Type 2 SLM has an allowed error deviation of ±2.3 dB. (6)

The Bylaw used by the City of Burnaby does not define the minimum SLM required; it only requires that the SLM be approved by ANSI. (3)

Smartphones

With respect to mobile operating systems, Android is the largest player in the market, with approximately 71.47% of the global mobile operating system market share, followed by iOS at 27.88%. (7) Samsung is the largest manufacturer of Android smartphones, accounting for 34.4% of the Android vendor market share as of 2022. (8)

Role of EHOs

EHOs in BC are designated under s. 78 of the BC Public Health Act, which dictates their roles and responsibilities as well as their enforcement powers. (9)

EHOs respond to complaints about excessive sound or noise levels. Since there is no additional legislation in the form of a regulation under the Public Health Act, they are designated by the municipality to enforce their bylaws. For example, the City of Burnaby's Bylaw. (3)

Smartphones Accessories for Sound Measurement

The iMM-6 is an external microphone from Dayton Audio which is compatible with Android and iOS devices and also contains calibration files. These files may be downloaded from the manufacturer's website and uploaded to the AudioTool app available for purchase ($10.99) on Google Play Store. (10)

The MicW i436 is another popular external microphone of choice as it is one of the few on the market that is certified as IEC 61672 Class 2 standardized. (11) The manufacturer dictates that it is only certified to work on iOS devices, as testing on Android devices is incomplete and currently inconclusive. (11)

SLM App Selection

Smartphone SLM apps have increased and improved over time, as smartphone technology advances.

It is apparent that out of the many hundred of apps available on the market, only a select few are repeatedly evaluated and studied in literature. This may be due to the stringent criteria required by professional equipment for regulatory measurements. Many app developers seek to release their apps into the public domain; hence they create simpler tools for ease of access.

Many of the apps selected were for iOS devices instead of Android, except for: Blair and his colleagues, and Kardous and Shaw. (12,13) A reason for this may be due to iOS devices having uniform hardware and software. The use of Android devices from various manufacturers may result in less uniformity in hardware and software components, leading to more ambiguity in measurements.

Internal vs External Microphone

The two external microphones addressed by Kardous and Shaw in 2016 were the Dayton Audio iMM-6 and MicW i436. Furthermore, Roberts et al. (2016) and Sun et al. (2019) used the same two external microphone in their studies. (14,15)

Blair and his colleagues in 2018 differed slightly in that they only used the iMM-6, and Hong and his colleagues differed completely as they used no external microphones at all. (4,12)

One probable reason for these external microphones used specifically is their practicality. The i436, as discussed earlier, has IEC Class 2 certification, which makes it appealing for researchers to use as it can provide credibility for their results. The iMM-6, despite not having certification, is a similarly specified microphone with an affordable price tag.

Methodology

Kardous and Shaw (2014/2016) and Roberts et. al. conducted their study by generating pink noise using a 20 Hz to 20k Hz frequency range. The measurements were conducted in a diffuse sound field inside a reverberant chamber at NIOSH. (13,14) Roberts et. al. had some minor differences, such as different sound groups and different time intervals. (14)

It is apparent that many of the studies chose to generate noise through speakers to measure noise or sound levels. This is probably because they desired a controlled environment.

Some of the studies, such as Sun et. al. and Blair et. al. partook in field testing. (12,15) Depending on the area, the noise may be favouring a specific direction, which could cause noise measurements to be undervalued. Since many professionals, including EHOs, take noise measurements in uncontrolled environments, it is important for field testing to occur.

Results

The results of Kardous and Shaw's 2014 study show that an iOS device and the SPLnFFT app had the best unweighted sound level agreement. None of the Android devices and apps showed promising results, with the limited testing showing significant difference even among the same apps. (13)

Similarly, results from the follow up study in 2016 by Kardous and Shaw showed that there were no significant differences between apps when accounting for the same external microphones. (16) Additionally, Roberts and his colleagues found that both the iMM-6 and i436 performed within a 1 dBA difference from the reference. (14)

The results of the Android devices in Hong et al.'s study show that all three Android apps tested with the Huawei smartphone reported significant variation (4 to 8 dBA). (4)

The laboratory results for Blair et al.'s study show strong agreement between the SLM reference and smartphones, much like Sun and his colleagues (0.31 dBA). (12,15) The field testing showed the highest mean difference using an external microphone as 1.57 dBA, whereas Sun and his colleagues had a mean of 2.06 dBA. (12,15)

Many of the results found highlight the external microphone usage as providing significant agreement with the SLM references, compared to internal microphones. This may be partially due to the external microphones being designed for specific usage, whereas the internal microphones are designed for a variety of uses, such as phone calls and audio recording. Another reason may be that usage of external microphones provides hardware uniformity, which allows for better isolation of extraneous factors which may affect sound level measuring.

Limitations

Kardous and Shaw noted in 2016 that there were rumours of Apple moving away from dedicated headphone jacks in their iOS devices. (16) This rumour was confirmed to be true as Apple began removing the headphone jack with the release of the iPhone 7 in 2017. (17) This is relevant to our study as the external microphone of interest, Dayton Audio iMM-6, requires a 3.5 mm headphone jack in order to operate. (18)

Gaps in Knowledge

Many of the studies opted to use iOS devices for measurement instead of Android, however, the results shown from Kardous and Shaw (2016), Roberts et al. (2016), and Blair et al. (2018) show that different devices using the same external microphone and app combination provided significantly similar measurements. (12,14,16) This suggests that further testing can be conducted using an external microphone, which provides uniform hardware, regardless of the type of device an EHO may possess.

Another gap found was that only Blair and his colleagues tested a pre-defined calibration file for an app and microphone combination, such as the files available by Dayton Audio for use on the AudioTool app. (10,18) A large and expensive calibrator and a calibrator adaptor for the external microphone would not be needed.

Purpose of the Study

The purpose of this study is to compare the sound measuring capabilities of three independent setups: a Samsung Galaxy S9+ using the internal microphone only, a Samsung Galaxy S9+ using a Dayton Audio iMM-6 external microphone, and the Quest Technologies Model 2200 Sound Level Meter (Type 2 SLM).

This study will utilize the calibration files provided by the external microphone manufacturer and use the recommended app (AudioTool by Bofinit Corporation) to see if it provides statistically significant accuracy and/or precision with respect to the legislated commercial SLM.

Materials and Methods

Materials

A laptop was used for recording the data samples and producing the white noise.

NCSS 2022 and Microsoft Excel were the software used to statistically organize and record the data, respectively. (19,20) The hardware for the proposed setup included two Samsung Galaxy S9+ Smartphones, as well as the Dayton Audio iMM-6 External Microphone. (18,21) AudioTool by Bofinit Corporation was the Smartphone App used, available on the Google Play Store. (10) The Quest Technology Model 2200 Type 2 SLM was the Commercial SLM used as a control, including the Sound Level Calibrator Tool. Three tripods were used to mount the proposed setups and a measuring tape was also used. The Anker SoundCore Bluetooth speaker was used to generate the white noise. (22)

Standard Methods

The standard method used in this study was the modified version of ANSI S12.9-2005 Standard Methods. (23) As required by the ANSI S1.4-1983 standard, an appropriate reference SLM (Type 2 Model 2200) was used alongside the two experimental setups as a control. (6)

The experiment took place at the BCIT Burnaby Campus Environmental Health Lab (SW1-1230). The Anker Bluetooth speaker generated white noise through the laptop application. There were three defined sound levels: 62.5 dB, 70 dB, and 80 dB. The tripods, at distance of 144 inches away from Bluetooth speaker, mounted the Quest Technologies Model 2200 SLM and both Samsung Galaxy S9+ Smartphones (one with and one without the Dayton Audio iMM-6 external microphone). All three tripods were at an equal height of 50 inches. A measuring tape was used to verify the height of the tripods and the distance to the sound source. The ambient sound levels were measured for each sound group and recorded as 55.8 dB for the 62.5 dB sound group, 40.1 dB for the 70 dB sound group, and 36.1 dB for the 80 dB sound group.

In order to adhere to the Burnaby Bylaw, all sound measuring devices were set to 'A-Weighting' and 'Slow' response rate. (3) Sound measurements were recorded at an interval of 20 seconds and inputted into the Excel spreadsheet. After 50 samples were recorded, the volume was adjusted via the Bluetooth speaker buttons until the desired decibel level was reached. Overall, there was a total of 150 samples.

Calibration of Instruments

The Model 2200 SLM was calibrated using the professional calibrating tool from Quest Technologies. (24) The Smartphone (with the External Microphone) was calibrated using the calibration files provided by Dayton Audio, which were uploaded to the AudioTool app. (10,18) Additionally, the smartphone was calibrated using the AudioTool app without any calibration files. All calibrations were done before and after recording one set of 50 measurements.

Inclusion and Exclusion Criteria

The Smartphone must be Android and readily available, thus the Samsung Galaxy S9+ Smartphone was selected. The SLM app must accept pre-defined profiles or calibration files, which the AudioTool app did. Additionally, the app was adjusted to A-weighting and slow response rate, as required in the Burnaby Bylaw. (3)

The External Microphone must be readily accessible and low in cost, which the Dayton Audio iMM-6 satisfied. The final criterion was that the Commercial SLM used in the study had to be a certified Type 1 or Type 2 SLM. The Quest Technologies Model 2200 Type 2 SLM was available for use.

Results

Descriptive Statistics

The numerical data on sound measurements was represented as means and medians, which are shown in **Figures 1-3** and **Table 1** below. Additionally, the numerical data was represented as the absolute value of difference between the sample data and the reference sound level. For example, a sound measurement of 62.1 dB in the 62.5 dB sound group would equate to a -0.4 dB difference, therefore the absolute value of 0.4 dB was taken.

Table 1: Descriptive Statistics

Phone+Mic	Phone	SLM	Phone+MicVar	PhoneVar	SLMVar	
Mean: 62.76	Mean: 63.55	Mean: 62.34	Mean: 0.258	Mean: 1.05	Mean: 0.168	
Median: 62.70	Median: 63.60	Median: 62.30	Median: 0.20	Median: 1.1	Median: 0.2	
Min: 62.70	Min: 63.20	Min: 62.20	Min: 0.20	Min: 0.7	Min: 0	62.5 dB
Max: 62.90	Max: 63.90	Max: 62.60	Max: 0.40	Max: 1.4	Max: 0.3	
SD: 0.067	SD: 0.24	SD: 0.08	SD: 0.067	SD: 0.24	SD: 0.07	
Phone+Mic	Phone	SLM	Phone+MicVar	PhoneVar	SLMVar	
Mean: 70.41	Mean: 71.42	Mean: 69.89	Mean: 0.412	Mean: 1.422	Mean: 0.264	
Median: 70.4	Median: 71.4	Median: 70.1	Median: 0.4	Median: 1.4	Median: 0.1	
Min: 70	Min: 71.4	Min: 60.9	Min: 0	Min: 1.4	Min: 0	70 dB
Max: 70.6	Max: 71.7	Max: 70.2	Max: 0.6	Max: 1.7	Max: 9.1	
SD: 0.08	SD: 0.07	SD: 1.3	SD: 0.08	SD: 0.07	SD: 1.3	
Phone+Mic	Phone	SLM	Phone+MicVar	PhoneVar	SLMVar	
Mean: 80.22	Mean: 81.62	Mean: 79.95	Mean: 0.22	Mean: 1.622	Mean: 0.05	
Median: 80.2	Median: 81.7	Median: 80	Median: 0.2	Median: 1.7	Median: 0	
Min: 80.1	Min: 81.5	Min: 79.8	Min: 0.1	Min: 1.5	Min: 0	80 dB
Max: 80.4	Max: 81.8	Max: 80	Max: 0.4	Max: 1.8	Max: 0.2	
SD: 0.06	SD: 0.1	SD: 0.054	SD: 0.06	SD: 0.1	SD: 0.054	

Figure 1: Sound Level Measurement (left) and Measurement Variation (right) at 62.5 dB.

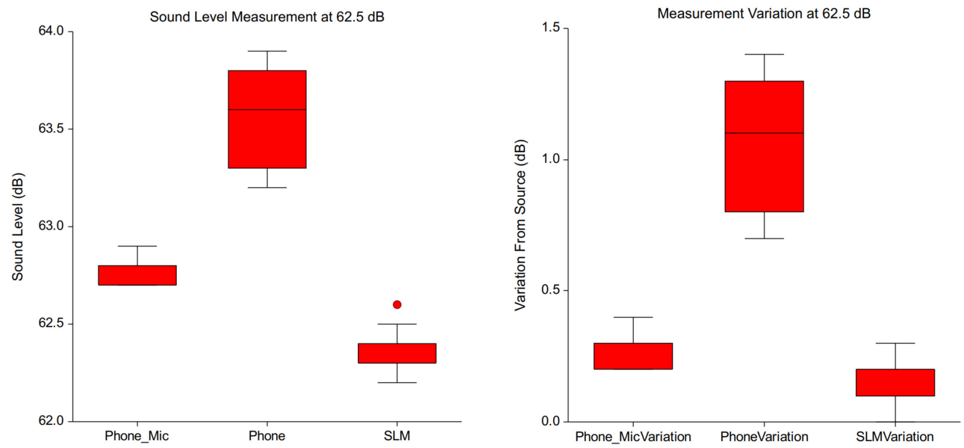


Figure 2: Sound Level Measurement (left) and Measurement Variation (right) at 70 dB.

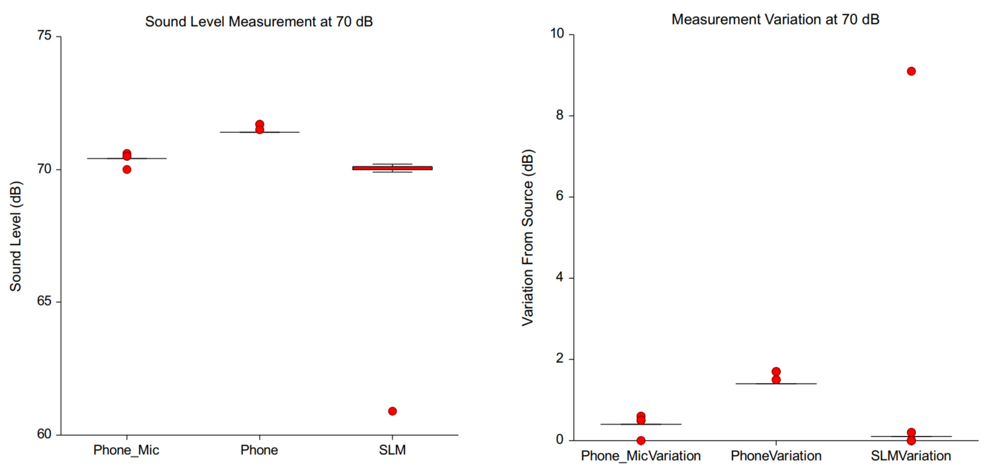
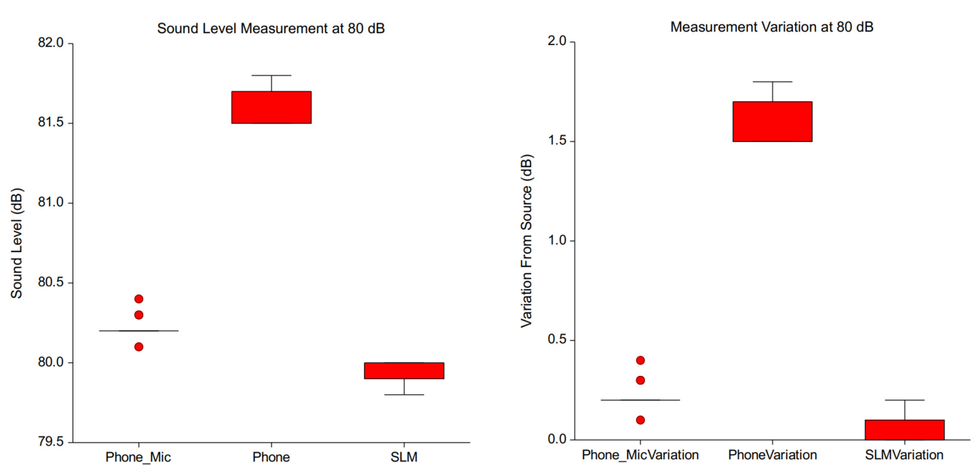


Figure 3: Sound Level Measurement (left) and Measurement Variation (right) at 80 dB.



In regard to **Table 1**, the Smartphone group without the external microphone had sound levels means significantly higher than the other two sound level means. The means for the Smartphone with External Microphone groups were very close to the SLM group. Not factoring in the outlier in the 70 dB sound level group, the Type 2 SLM had lower means for variation from the reference sound level, with the mean in the 80 dB group as low as 0.05 dB.

Inferential Statistics

Both sets of numerical data (measurements and variations) were analyzed using One-Way Analysis of Variance (ANOVA) in NCSS. A test of Normality concluded the data was non-parametric. Therefore, the non-parametric equivalent, Kruskal-Wallis One-Way ANOVA on Ranks, was used for statistical analysis. (19) **Tables 2** and **3** below summarize the tested hypotheses, the results, and the interpretations of the results.

Table 2: Sound Measurements Hypotheses and Results

H_0 and H_A	Test(s) Used	p-value	Interpretation
H_0: The medians of all three sound measurement groups at 62.5 dB are equal. **H_A:** The medians of all three sound measurement groups at 62.5 dB are **not** equal.	Kruskal-Wallis One-Way ANOVA on Ranks Tukey-Kramer Multiple Comparison Test	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in sound level measurement among three sound measurement groups. The Tukey-Kramer post-hoc test concludes that all three groups are significantly different from each other.
H_0: The medians of all three sound measurement groups at 70 dB are equal. **H_A:** The medians of all three sound measurement groups at 70 dB are **not** equal.	Kruskal-Wallis One-Way ANOVA on Ranks Tukey-Kramer Multiple Comparison Test	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in sound level measurement among three sound measurement groups. The Tukey-Kramer post-hoc test concludes that all three groups are significantly different from each other.
H_0: The medians of all three sound measurement groups at 80 dB are equal.	Kruskal-Wallis One-Way ANOVA on Ranks	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in sound level measurement among three sound measurement groups. The Tukey-Kramer post-hoc test concludes that

H_A: The medians of all three sound measurement groups at 80 dB are **not** equal.	Tukey-Kramer Multiple Comparison Test		all three groups are significantly different from each other.

Table 3: Sound Measurement Deviation Hypotheses and Results

H_0 and H_A	**Test(s) Used**	**p-value**	**Interpretation**
H_0: The medians of absolute variation from the actual sound level at 62.5 dB for all groups are the same. **H_A:** The medians of absolute variation from the actual sound level at 62.5 dB for all groups are not the same.	Kruskal-Wallis One-Way ANOVA on Ranks Tukey-Kramer Multiple Comparison Test	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in the absolute values of the sound deviations among the groups. The Tukey-Kramer post-hoc test concludes that all three groups are significantly different from each other.
H_0: The medians of absolute variation from the actual sound level at 70 dB for all groups are the same. **H_A:** The medians of absolute variation from the actual sound level at 70 dB for all groups are not the same.	Kruskal-Wallis One-Way ANOVA on Ranks Tukey-Kramer Multiple Comparison Test	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in the absolute values of the sound deviations among the groups. The Tukey-Kramer post-hoc test concludes that the Smartphone (Internal Microphone) group's deviation is significantly different from the other two groups.
H_0: The medians of absolute variation from the actual sound level at 80 dB for all groups are the same. **H_A:** The medians of absolute variation from the actual sound level at 80 dB for all groups are not the same.	Kruskal-Wallis One-Way ANOVA on Ranks Tukey-Kramer Multiple Comparison Test	0.00000	Reject the null hypothesis and conclude that there is statistically significant difference in the absolute values of the sound deviations among the groups. The Tukey-Kramer post-hoc test concludes that all three groups are significantly different from each other.

Discussion

Overall, the results show that all three sound measurement setups were significantly different from each other across all three sound level groups. The results for variance from the reference level show that all three sound measurements setups were significantly different from each other across the 62.5 dB and 80 dB sound level groups. The 70 dB group showed that the proposed setup (Smartphone + External Microphone) was similar to the Type 2 Commercial SLM setup.

The variation of the Smartphone + External Microphone setup from the reference sound level ranged from [0.22 ± 0.06 dB @ 80 dB] to [0.412 ± 0.08 dB @ 70 dB], which was well within the acceptable accuracy range of ± 1.5 dB for the Quest Technologies Model 2200 SLM. (6) The Smartphone group, additionally, was within the Model 2200's acceptable accuracy range at [1.05 ± 0.24 dB] for the 62.5 dB sound level and [1.422 ± 0.07 dB] for the 70 dB sound level. Despite this, the Smartphone + External Microphone group presented a higher likelihood for success when used as an SLM.

The results of the iMM-6 external microphone are consistent with Kardous and Shaw's study in 2016, [0.023±0.530 dB], as well as Roberts et. al.'s study, [0.55 ± 0.09 dB], in 2016. (14,16) Additionally, the findings also agree with Blair et. al.'s study in 2018 as the laboratory readings (in addition to the field testing) were within the allowable accuracy range [± 2.6 dB] for a Type 2 SLM.

The results cannot be compared to Sun et. al.'s study in 2019 as the iOS operating system was used instead. Additionally, the results cannot be compared to Hong et. al.'s study in 2017 as only one smartphone device, the Samsung Galaxy S9+, was used.

The results are valid due to the fact that standard methods from ANSI were followed for sound measurements and the use of a calibrated Type 2 SLM. This means that the alpha and beta errors are eliminated, hence the results are not significant due to random chance. The results, however, can only be extrapolated to future studies that focus on Android smartphones with the AudioTool app and the Dayton Audio iMM-6 external microphone.

Limitations

The primary limitation was the inadequate amount of time and budget provided for this study. Due to this, only one specific smartphone (Samsung Galaxy S9+), one specific SLM app (AudioTool), and one specific external microphone (iMM-6) were tested.

If time, budget, and other resources were more appropriate for the study, then testing multiple combinations of external microphones, smartphones, and SLM apps would be recommended. The results would be presented as more beneficial.

Another limitation of the study was the uncontrolled environment. The fluctuating ambient sound levels were dependent on the level of human activity outside of the lab, which likely affected the results. Another limitation was the SLM app itself (AudioTool), since it was not designed to be ANSI certified like the NIOSH SLM app.

Knowledge Translation

Due to the limitations and limited scope of the results, this study can only serve as a follow up to the growing research in smartphone SLM usage. The results of the study can be provided to Regional Health Authorities in BC, which would allow more research to be conducted by them. The main benefit is the mitigation or reduction in addressing noise complaints. Building Managers in Strata complexes, for example, may respond to an internal noise complaint by conducting a preliminary assessment. It may also be used in small to medium sized workplaces to assist in investigations regarding noise in the workforce. This may save a lot of resources in the form of time and costs for EHOs to travel and address a complaint.

Additionally, an EHO may conduct a preliminary investigation using smartphone and external microphone technology. If the noise is within legislative limits, it eliminates the need for further investigation.

Future Research

- Due to phone manufacturers opting to remove 3.5 mm headphone jacks, adaptors using the charging port are available. A future study can analyze whether these adaptors cause unnecessary interference when using an external microphone.
- A future study where smartphone technology with external microphones is used to measure noise levels in uncontrolled environments, such as a construction zone or noise within an apartment building.

Conclusions

The results of the study show that all three sound measurement setups were significantly different from each other, except for the 70 dB variation group. The least variation from the reference sound level was found in the Smartphone + External Microphone group (Samsung Galaxy S9+ and Dayton Audio iMM-6 External Microphone) at the 80 dB sound level [0.22 ± 0.06 dB]. This study shows that the sound measurement results from the Samsung Galaxy S9+, using the Dayton Audio iMM-6 External Microphone, are comparable to a Type 2 SLM. External microphones may be used to conduct preliminary investigations by EHOs or Strata building managers. Further research, however, is required to solidify the accuracy and precision of external microphones.

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Competing Interests

The authors declare that they have no competing interests.

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