The Levels of Sounds in Roland Park Country School Found with the Tacklife^{R} Decibel Meter and Three iPhone Sound Measurement Apps

By Ava Drum

Introduction

Noise is omnipresent in modern society. People encounter noise in almost every daily activity, whether it is talking to another person, listening to music, or attending a sporting event. Hearing is essential to our lives and there are many steps involved in how noise is processed between the time sound waves enter the ear canal and when they are understood by the brain. The sound waves first cause the eardrum to vibrate, thereby vibrating the malleus, incus, and stapes bones. The chain of vibrations continues when the middle ear bones create fluid ripples in the cochlea, located in the inner ear. This causes hair cells on the basilar membrane to move in a wave like formation. When the hair cells move, the stereocilia, which are on top of the hair cells, press against the tectorial membrane and cause bending of the stereocilia. When this occurs, the channels at the tips of the stereocilia open and chemicals rush to the cell. This produces an electrical signal which the auditory nerve takes to the brain ("Noise-Induced Hearing").

Studies have shown that noise levels that are greater than 85 decibels for a sustained amount of time cause harm to hair cells which cannot be regenerated, and this leads to Noise Induced Hearing Loss (abbreviated as NIHL) ("Noise-Induced Hearing"). Many people are exposed to harsh levels of noise and are not aware of the damaging effects. NIHL affects hearing which stems into our personal lives. According to the Better Hearing Institute, research suggests that untreated hearing loss can lead to "irritability, negativism and anger, fatigue, tension stress and depression, avoidance or withdrawal from social situations…". NIHL can strike at any age, young and old, mild or severe. Children without treatment suffer from "difficulty learning" and difficulty in "developing speech" which affect their quality of childhood and schooling ("Consequences of Hearing"). There is no cure for NIHL, but the best course of action is prevention.

In Roland Park Country School, many students and teachers are surrounded by noise and don't know how damaging that noise could be. With current technology that measures sound with decibel meters and apps, people now have access to tools that can help them become aware of harmful noises. Two goals are perused in this study. The first goal was to determine the decibel levels of everyday sounds within the school, and if these sounds are high enough to cause NIHL in children and teachers. The second goal was to compare the sound readings provided by the Tacklife^{R} Decibel Meter and sound meters readily available on the App Store for mobile phones to identify the most reliable app for monitoring decibel levels for preventing NIHL.

Methods

Decibel levels were collected in four locations throughout Roland Park Country School: the library in morning and afternoon; the theater before upper school morning meeting; the cafeteria during lunch; and the link (junior common area) in the afternoon. At each location, a Tacklife^{R} Decibel Meter and three iPhone apps-- the Noise Meter Free-Professional Decibel Meter by Shuqin Chen, the Decibel 10th Pro Noise Meter/Sound Pressure Level by SkyPaw Co. Ltd, and the SoundLevel Free by Smudge Apps--were used to measure the decibel levels and averaged per area per day. Measurements were collected 10 times at each of the sites from December 16th to January 13th.

Data were additionally collected in the 2 loudest locations in Roland Park Country School-- in the cafeteria during lunch and the theater before morning meeting. The Tacklife^{R} Decibel Meter was compared again with the 3 iPhone apps. Measurements were collected 10 additional times from February 8th to March 31st.

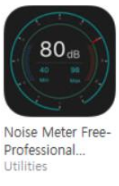
Results

Color key: Yellow: 80 ≤ x < 85 dB

Blue: 85 ≤ x < 90 dB

Red: above 90 ≤ x dB

Current Decibel Meters: Comparison of the Tacklife[R] Decibel Meter and Apps in the Four Locations in Roland Park Country School

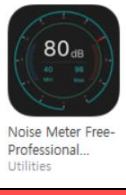
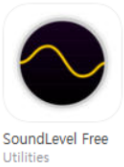
Data		Tacklife[R] Decibel Meter (dB) 	Noise Meter Free-Professional Decibel Meter, Shuqin Chen (dB) 	Decibel 10th: Pro Noise Meter/Sound Pressure Level, SkyPaw Co. Ltd (dB) 	SoundLevel Free, Smudge Apps (dB) 	Average Decibel level per Area (dB)	Average Decibel level of the day (dB)
Friday, 12/16/16 1	Library in Morning Time: 7:46	Max: 66.1 Min: 45 Avg: 55.5	61	55.6	55	56.7	72.196
	Library in Afternoon Time:	Max: NA Min:					
	Morning Meeting Time: 11:26	Max: 85.1 Min: 69.1 Avg: 77.1	84	75.2	73	77.325	
	Cafeteria Time: 10:55	Max: 83.2 Min: 76.8 Avg: 80	84	78.9	77	79.975	
	Link Time: 3:23	Max: 91.6 Min:60.1 Avg: 75.85	78	73.3	72	74.787	
2 Tuesday 1/3/16	Library in Morning Time: 7:55	Max: 81.7 Min: 57.8 Avg: 69.75	67	73	74	70.93	74.73
	Library in Afternoon Time: 3:15	Max: 72 Min: 51.6 Avg: 61.8	95	81	84	80.45	
	Morning Meeting Time: 7:58	Max: 88.4 Min: 79.9 Avg: 84.15	85	75	77.1	80.31	
	Cafeteria	Max: 84.5	82	72	77.9	77.7	

	Time: 11:32	Min: 73.3 Avg: 78.9					
	Link Time: 3:12	Max: 83.1 Min: 67.8 Avg: 75.45	66	58	57.7	64.28	
3 Wednesday 1/4/17	Library in Morning Time:	Max: NA Min: Avg:					71.85
	Library in Afternoon Time: 2:37	Max: 75.1 Min: 45.4 Avg.: 60.25	59	52	53	56.0625	
	Morning Meeting Time: 10:44	Max: 93 Min:78 Avg: 85.5	94	81	82.4	85.725	
	Cafeteria Time: 11:53	Max: 82.1 Min:65.3 Avg: 73.7	81	75	72	75.425	
	Link Time: 2:31	Max: 82.7 Min: 59.6 Avg: 71.15	74	67	68.6	70.1875	
4 Thursday 1/5/17	Library in Morning Time: 7:55	Max: 79.6 Min: 59.1 Avg: 69.35	74	66	64.7	68.5125	71.198
	Library in Afternoon Time: 2:19	Max: 73.4 Min: 48 Avg: 60.7	62	59	66.2	61.975	
	Morning Meeting Time: 10:46	Max: 85.8 Min: 74.3 Avg: 80.05	89	79	80.2	82.0625	
	Cafeteria Time: 11:25	Max: 83.6 Min:66.2 Avg: 74.9	80	71	73.7	74.9	
	Link Time: 2:15	Max: 79.4 Min: 53.4 Avg: 66.4	72	67	68.8	68.55	
5 Friday 1/6/17	Library in Morning Time: 7:56	Max: 68.2 Min: 44.4 Avg: 56.3	63	55	53.6	56.975	66.281
	Library in Afternoon Time: 3:20	Max: 68.7 Min: 45.5 Avg: 57.1	64	61	60.6	60.75	
	Morning Meeting Time:	NA					
	Cafeteria Time: 11:36	Max: 87.5 Min: 66.5 Avg: 77	83	75	76.2	77.8	
	Link Time: 3:17	Max: 77.8 Min: 61	75	68	66	69.6	

		Avg: 69.4					
6 Monday 1/9/17	Library in Morning Time: 7:55	Max: 67.8 Min: 46.2 Avg: 57	61	56	58	58	69.94
	Library in Afternoon Time: 3:20	Max: 63 Min: 43.5 Avg: 53.25	63	52	54	55.5625	
	Morning Meeting Time: 10:44	Max: 85.2 Min: 73.9 Avg: 79.55	90	76	78	80.8875	
	Cafeteria Time: 11:44	Max: 85.7 Min: 72.3 Avg: 79	85	77	77.5	79.625	
	Link Time: 3:15	Max: 83.7 Min: 57.3 Avg: 70.5	79	77	76	75.625	
7 Tuesday 1/10/17	Library in Morning Time:	NA					72.068
	Library in Afternoon Time: 3:28	Max: 60.8 Min: 42.9 Avg: 51.7	59	53	55.1	54.7	
	Morning Meeting Time: 10:43	Max: 87.9 Min: 76.7 Avg: 82.3	91	82	82.5	84.45	
	Cafeteria Time: 11:31	Max: 85.7 Min: 69.9 Avg: 77.8	85	74	76.6	78.85	
	Link Time: 3:26	Max: 84.8 Min: 55.8 Avg: 70.3	71	71	68.8	70.275	
8 Wednesday 1/11/17	Library in Morning Time: 7:53	Max: 68.1 Min: 47 Avg: 57.55	71	63	64.3	67.1875	71.306
	Library in Afternoon Time: 3:05	Max: 77.4 Min: 56.2 Avg: 67.1	71	70	70.2	69.575	
	Morning Meeting Time: 10:43	Max: NA Min: Avg:					
	Cafeteria Time: 11:24	Max: 91.5 Min: 72.7 Avg: 82.1	88	79	82.1	82.8	
	Link Time: 3:02	Max: 77 Min: 52.3 Avg: 64.65	70	61	67	65.6625	
9 Thursday 1/12/17	Library in Morning Time: 7:45	Max: 77.3 Min: 47 Avg: 62.15	77	60	63.5	65.6625	70.5425

	Library in Afternoon Time: 2:54	Max: 64.8 Min: 50.3 Avg: 57.55	60	59	59	58.8875	
	Morning Meeting Time: 10:47	Max: 90 Min:70.7 Avg: 80.35	83	78	78.5	79.9625	
	Cafeteria Time: 11:42	Max: 91.2 Min: 67.9 Avg: 79.55	81	76	78.8	78.8375	
	Link Time: 2:50	Max: 79.9 Min:60 Avg: 69.95	73	65	69.5	69.3625	
10 Friday 1/13/1	Library in Morning Time: 7:46	Max: 63.2 Min:50.7 Avg: 56.95	61	60	56.4	58.5875	68.468
	Library in Afternoon Time: 3:24	Max: 76.7 Min:48.9 Avg: 62.8	68	61	61.8	63.4	
	Morning Meeting Time:	Max: NA Min: Avg:					
	Cafeteria Time: 11:33	Max: 87.4 Min: 69.8 Avg: 78.6	81	77	76	78.15	
	Link Time: 3:19	Max: 90.3 Min: 55.2 Avg: 72.75	77	72	73.2	73.7375	
Average Readings		68.039	75.38	68.568	69.556	70.387	

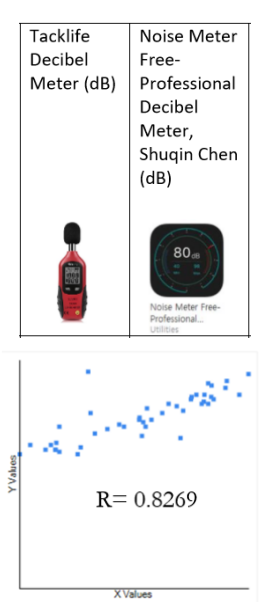
Current Decibel Meters: Comparison of the Tacklife[R] Decibel Meter and Apps in the Two Loudest Locations in Roland Park Country School

Data		Tacklife[R] Decibel Meter (dB) 	Noise Meter Free-Professional Decibel Meter, Shuqin Chen (dB) 	Decibel 10th: Pro Noise Meter/Sound Pressure Level, SkyPaw Co. Ltd (dB) 	SoundLevel Free, Smudge Apps (dB) 	Average Decibel level per Area (dB)	Average Decibel level of the day (dB)
1 2/8/17	Morning Meeting Time: 10: 42	Max: 91.6 Min: 74.5 Avg: 83.05	92	81	83	84.7625	81.4625
	Cafeteria Time: 11: 30	Max: 89.4 Min: 64.7 Avg: 77.05	80	74	81.6	78.1625	
2 2/14/17	Morning Meeting Time: 10:46	Max: 90.1 Min: 72.1 Avg: 81.1	95	82	84.7	85.7	84.3687
	Cafeteria Time: 11:44	Max: 92.7 Min: 73.2 Avg: 82.95	89	78	82.2	83.0375	
3 2/24/17	Morning Meeting Time: 10:43	Max: 92.4 Min: 78.8 Avg: 85.6	91	84	85.2	86.45	83.35
	Cafeteria Time: 11:31	Max: 90.6 Min: 73.2 Avg: 81.9	84	77	78.1	80.25	
4 2/28/17	Morning Meeting Time: 10:45	Max: 90.9 Min: 77.4 Avg: 84.15	93	82	87	86.5375	81.8937
	Cafeteria Time: 11:26	Max: 83.3 Min: 63.7 Avg: 73.5	85	72	78.5	77.25	
5 3/1/17	Morning Meeting Time: 10:45	Max: 89.9 Min: 75.3 Avg: 82.6	89	78	78.4	82	81.8937
	Cafeteria Time: 11:25	Max: 91.5 Min: 72.4 Avg: 81.95	85	80	80.2	81.7875	

6 3/06/17	Morning Meeting Time: 10:46	Max: 90.5 Min: 80.7 Avg: 85.6	94	81	83.5	86.05	84.35
	Cafeteria Time: 11:36	Max: 92.1 Min: 71.9 Avg: 82	86	79	83.6	82.65	
7 3/23/17	Morning Meeting Time: 10:46	Max: 92.9 Min: 71.3 Avg: 82.1	89	77	80.2	82.075	80.4125
	Cafeteria Time: 11:31	Max: 86.3 Min: 67.7 Avg: 77	87	75	76	78.75	
8 3/27/17	Morning Meeting Time: 10:41	Max: 87.8 Min: 70.9 Avg: 79.35	88	80	82	82.3375	82.475
	Cafeteria Time: 11:28	Max: 90.3 Min: 76.2 Avg: 83.25	88	80	79.2	82.6125	
9 3/30/7	Morning Meeting Time: 10:45	Max: 89.2 Min: 75.3 Avg: 82.25	84	75	82.5	80.9375	81.8125
	Cafeteria Time: 11:27	Max: 92.1 Min: 74.8 Avg: 83.45	85	79	83.3	82.6875	
10 3/31/17	Morning Meeting Time: 10:44	Max: 90.1 Min: 72.2 Avg: 81.15	90	76	79.1	81.5625	84.7
	Cafeteria Time: 11:30	Max: 94.1 Min: 78.6 Avg: 86.35	93	84	88	87.8375	
Average Readings		81.8175	88.35	78.7	77.635	82.6718	

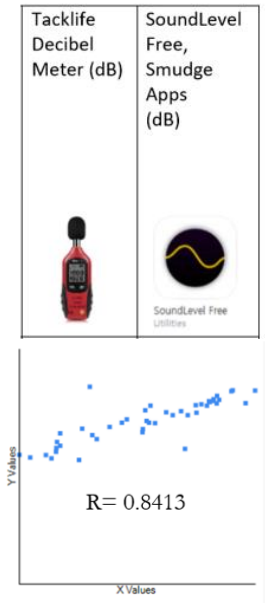
Graphs #1, #2, and #3 below show on the y-axis the decibel measurements determined by Tacklife[R] Decibel Meter across all 5 locations. On the x-axes are shown the decibel measurements found with the Noise Meter Free-Professional Decibel Meter by Shuqin Chen (Graph #1), the Decibel 10th Pro Noise Meter/Sound Pressure Level by SkyPaw Co. Ltd (Graph #2), and the SoundLevel Free by Smudge Apps (Graph #3). 44 data points are graphed.

Graph #1



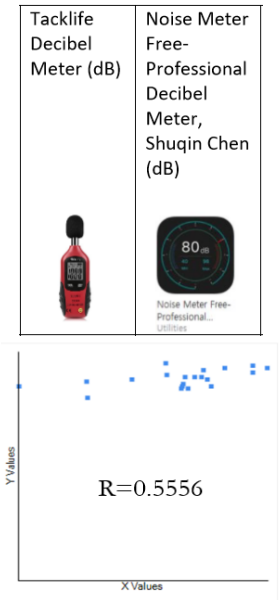
Graph #2

Graph #3

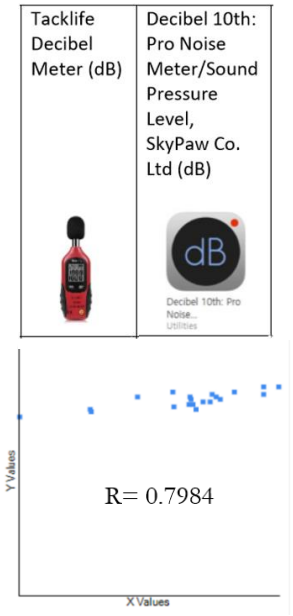


Graphs #4, #5, and #6 below show on the y-axis the decibel measurements determined by the Tacklife[R] Decibel Meter across the 2 loudest locations. On the x-axes are shown the decibel measurements found with the Noise Meter Free-Professional Decibel Meter by Shuqin Chen (Graph #4), the Decibel 10th Pro Noise Meter/Sound Pressure Level by SkyPaw Co. Ltd (Graph #5), and the SoundLevel Free by Smudge Apps (Graph #6) on the x-axis. 20 data points are graphed.

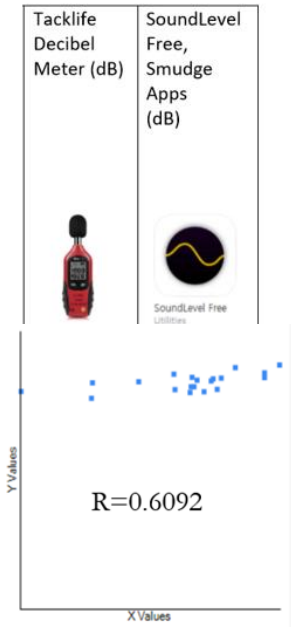
Graph #4



Graph #5



Graph #6



Discussion

The data collected from 5 different locations around Roland Park Country School suggest that there are times when sound levels in these common areas are relatively high. In particular, the highest decibel reading was found in the theater before morning meeting and in the cafeteria during lunch. The first set of data, which included decibel readings from the library in the morning and the afternoon, morning meeting, cafeteria, and the link, show that the 2 loudest locations in the school are the cafeteria and theater at morning meeting. A second set of data were collected, which included decibel readings from the 2 loudest locations, the theater before morning meeting and the cafeteria, further establishing that these were the 2 loudest locations in the school. The decibel readings collected in both sets of data prove that the app, Decibel 10th: Pro Noise Meter/Sound Pressure Level, is the most accurate decibel meter app when compared to the purpose-built Tacklife^{R} Decibel Meter. 2 different methods of statistical analysis were completed to compare the Tacklife^{R} Decibel Meter to each app.

2 variable t-testing was completed to find the least statistical significance. The p-values that compared the Tacklife^{R} Decibel Meter and each app were found. For the larger set of data, which included 5 locations and 44 readings for each meter, the p-values were found for the Tacklife^{R} Decibel Meter compared to the Noise Meter Free-Professional Decibel Meter, Shuqin Chen ($p=1.16 \times 10^{-6}$), Decibel 10th: Pro Noise Meter/Sound Pressure Level, SkyPaw Co. Ltd (p=0.0037), and SoundLevel Free, Smudge Apps (0.9979). This reveals that the measurements from SouldLevel Free, Smudge Apps, had the least statistical significance compared to the Tacklife^{R} Decibel Meter, showing that this app is most similar to the Tacklife. For the smaller set of data, which included 5 locations and 20 readings for each meter, the p-values found for the Tacklife^{R} Decibel Meter compared to the Noise Meter Free-Professional Decibel Meter, Shuqin Chen (p=0.0113), Decibel 10th: Pro Noise Meter/Sound Pressure Level, SkyPaw Co. Ltd (p=0.5174), and SoundLevel Free, Smudge Apps (0.8804). The readings for the SoundLevel Free app were again least statistically different compared to the other 2 apps. Both sets of data show that the SouldLevel Free app was most consistent with the Tacklife.

A non-parametric data analysis was conducted to find the r values that compared each meter to the Tacklife^{R} Decibel Meter. Non-parametric data sets are used for categorical data, where outliers do not significantly effect r value outcome. This is important when analyzing the data because multiple outliers are present, where decibel readings can change as noise changes in a location. For the data with 5 locations, the r values, as seen in graphs 1, 2, and 3, are very similar. All were relatively close to 1, meaning there was a strong correlation between the Tacklife^{R} Decibel Meter and each of the three apps. This can be explained because each of the apps were being used on the same phone, which utilize the same hardware. Additionally, since 44 data sets were collected and analyzed non-parametrically, there was higher correlation causing the r values to have only a maximum .03 difference. However, the r values for the data from the 2 loudest locations, as seen in graphs 4, 5, and 6, vary significantly more. The data were focused on 2 locations where most of the decibel readings were above 80 dB. There was more variation between sound levels that were closer together because there were fewer outliers, compared to sound level readings further apart where there were more outliers, particularly those data collected from the five different locations. The r values for data from 5 locations still correlate to data from the 2 loudest locations. Both conclude that the Decibel 10th Pro Noise Meter/Sound Pressure Level has the greatest correlation with the Tacklife^{R} Decibel Meter, with r values of 0.8518 (5 locations) and 0.7984 (2 locations).

Conclusion

Noise levels in the theater before morning meeting and in the cafeteria during lunch at Roland Park Country School at times exceed sound levels established as those which could result in hearing loss. For future analysis, this study recommends the use of the Decibel 10th Pro Noise Meter/Sound Pressure Level or the SoundLevel Free, Smudge Apps, as they are both more convenient to use than the purpose-built Tacklife^{R} Decibel Meter with near comparable results. Each of these apps are free and can be conveniently used with an iPhone. To further distinguish between the 2 apps and determine which is most consistent with the Tacklife^{R} Decibel Meter, additional studies are required.

Works Cited

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www.betterhearing.org/hearingpedia/consequences-hearing-loss

"Noise-Induced Hearing Loss." *National Institute on Deafness and Other Communication Disorders (NIDCD)*, U.S. Department of Health and Human Services,

www.nidcd.nih.gov/health/noise-induced-hearing-loss