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Acoustical properties of amplified and unamplified stethoscopes when examining typical body sounds

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ACOUSTICAL PROPERTIES OF AMPLIFIED AND UNAMPLIFIED STETHOSCOPES WHEN EXAMINING TYPICAL BODY SOUNDS

by

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Abstract

A stethoscope is intended for three main diagnostic purposes: listening to heart sounds, listening to lung sounds, and determining the presence or absence of bowel sounds (Callahan, Waugh, Matthew, & Granger, 2007). Currently, on the market there are two types of stethoscopes for practitioners to choose: unamplified and amplified stethoscopes. Furthermore, there is little research on the sound pressure levels (SPLs) produced by stethoscopes on the market. Therefore, the current study seeks to measure the SPL produced by various popular unamplified stethoscopes and compare those findings to the SPLs produced by amplified stethoscopes. Secondly, the SPL of selected amplified stethoscopes will be compared to attempt to determine which stethoscope provides the most SPL.

Six stethoscopes (three unamplified and three amplified) coupled to KEMAR were used to measure recorded heart, lung and bowel sounds. The results showed that the type of stethoscope (unamplified vs. amplified) somewhat affected the amount of SPL produced. For example, it was found that the SPL of the Littman Cardiology III unamplified stethoscope was comparable to or exceeded that of two of the amplified stethoscopes for heart and lung sounds while the Littmann Classic II unamplified stethoscope was comparable to or exceeded the SPL for one of the amplified stethoscopes for bowel sounds. Clinical implications/applications regarding stethoscope relevance to the practitioner with and without hearing impairment were discussed.

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Chapter I

Introduction

An important decision that must be made by medical professionals is which stethoscope is going to be the best when diagnosing patients. Littman (1961) described the stethoscope to be a device containing an open chest piece, allowing for low pitched sounds to be heard; a closed chest piece with a plastic diaphragm to filter out low pitched sounds; firm tubing with a single lumen bore of short length, and a spring to hold the ear pieces. Littman also states that the stethoscope should be lightweight and easy to use. At the end of the stethoscope tubing, there is a bell, diaphragm, or bell/diaphragm combination piece, all of which allow the practitioner to hear certain body sounds (Bankaitis, 2010).

A stethoscope is intended for three main diagnostic purposes: listening to heart sounds, listening to lung sounds, and determining the presence or absence of bowel sounds (Callahan, Waugh, Matthew, & Granger, 2007). It should be noted that Callahan and colleagues (2007) reported heart sounds from 20 to 660 Hz, normal breathing from 150 to 1,000 Hz, bronchial breathing from 240 to 1,000 Hz, and crackling breathing greater than 750 Hz. Furthermore, normal bowel sounds are reported from 100-1,000 Hz and are described as gurgling noises that vary in frequency (Nursing, 2000). In order to hear these sounds, the practitioner places the binaural earpieces into his/her ears and places the chest piece (bell or diaphragm) on the patient's body. Specifically, the diaphragm is designed to pick up slightly higher pitched sounds such as breath and lung sounds whereas the bell is designed to pick up lower frequency sounds such as heart sounds. The signal is picked up by the chest piece, transmitted up the tube and delivered binaurally to the practitioner.

Currently, on the market there are two types of stethoscopes for practitioners to choose: acoustic (unamplified) and electronic (amplified) stethoscopes. The two models work in a similar manner. Specifically, both stethoscopes allow for the practitioner to hear bodily sounds to diagnosis symptoms. Both devices use a chest piece to receive the signal, which is then transmitted to the practitioner's ears via a tube. The devices differ in that the electronic (amplified) scope is a battery-operated device and amplifies bodily sounds (Bankaitis, 2010) whereas an unamplified stethoscope contains no battery and provides no amplification to the signal. Likewise, amplified stethoscopes allow for a louder frequency response but may not take into consideration the varying sensitivity of the human ear (Grenier, 1998). While the amplified stethoscope provides benefit in hearing some bodily sounds, it should be noted that these stethoscopes can also add electronic and ambient noise to the sound. These added noises can interfere with the diagnosis made by practitioners, giving false negative responses. Atcherson, Franklin and Smith-Olinde (2015) state that extra fat or muscle and background noise can impact the volume of the body sounds, even for those with normal hearing. This has lead to advancements in amplified stethoscopes.

At the current time there is little research on the sound pressure levels (SPL) produced by amplified stethoscopes on the market. Manufactures market amplified stethoscopes, making claims such as: "amplifies up to 24x compared to standard non-electronic stethoscopes" and "amplifies sound more than 100x" (Oaktree Products, 2015, pg. 106-107). This information does not convey to practitioners exactly what the scope produces nor has this information been validated in most cases, leading practitioners to believe what could be potentially false information. Atcherson et al. (2015) suggest that practitioners on the market for amplified stethoscopes should have an understanding of the decibel (dB) when reading manufacturer claims about amplification. Furthermore, they state that these products are reported in SPL rather than loudness or power. They state that when a claim of "50 times louder" than an unamplified stethoscope is made, the calculation is equivalent to an increase of approximately 33 dB SPL (Atcherson et al., 2015).

Therefore, the proposed research seeks to determine the effect of stethoscope type on SPL production when measuring typical bodily sounds (lungs, heart, and bowel). Specifically, the current study proposes to measure the SPL produced by various popular acoustic/unamplified stethoscopes and compare those findings to the SPLs produced by electronic/amplified stethoscopes. Secondly, the SPL of selected electronic/amplified stethoscopes will be compared to attempt to determine which stethoscope provides the most benefit with the least amount of interference.

Chapter II

Review of Literature

Introduction

A stethoscope is a medical instrument used to listen to the heart, lung, and bowel sounds and diagnose medical abnormalities in these systems. First, Leng, Tan, Chung, Wang, Ghista and Zhong (2015) state that in most countries the leading cause of death is heart disease with 17.5 million people dying due to cardiovascular diseases in 2012. They further state that diagnosis plays a key role in reducing the deaths that occur due to cardiovascular diseases. Though there are many advanced procedures that can give insight to the cardiovascular system such as echocardiograms, magnetic resonance imaging (MRI), and computed tomography (CT) scans, the equipment used to conduct these procedures is extremely expensive. Likewise, these machines are affordable for large hospitals in metropolitan areas but may not be practical in low and middle-income towns, cities, and countries. Therefore, the act of heart auscultation continues to be very important in the diagnosis of cardiovascular disease as identifying abnormal heart sounds allows the physician to make an early diagnosis.

Secondly, lung auscultation is an essential part of a standard physical exam. According to Bohadana, Izbicki, and Kraman (2014), there is no other clinical procedure that mimics the precision, ease, and rapidness that auscultation provides about the respiratory system. They also note that auscultation requires minimal participation from the patient, is repeatable, and is cost effective when compared to other methods of testing. Bohadana et al. (2014) also state that the increased use of electronic/amplified stethoscopes paired with recorders or smart phone applications will allow for sound tracking, which will increase the value of auscultation usefulness.

Thirdly, Biad (2009) states that abdominal assessment, which can be conducted by placing the stethoscope on the abdominal area, is typically conducted during a physical examination. The presence of bowel sounds is suspected to be indicative of a healthy gastrointestinal tract, as these normal sounds are a by-product of moving gas and fluid during digestion. This technique is taught in medical schools and is deemed necessary during a physical assessment. However, Biad (2009) suggests that there is great variation in what is considered to be normal and in the way practitioners obtain their measurements compared to other types of auscultation.

In summary, the stethoscope is the gateway to diagnosing heart, lung, and bowel normalities and abnormalities. Though simple in design, without the stethoscope there would be a greater chance of misdiagnosis of life threatening diseases. Stethoscopes, however, are managing to keep up with the ever changing world of technology and allowing the practitioner greater amplification for the *hard to hear* sounds as well as the ability to record bodily sounds for better interpretation. The following sections discuss unamplified and amplified stethoscopes as well as research associated with both.

Unamplified Stethoscopes

The ideal stethoscope is described by Littman to be one with a chest piece that is open to hear low-pitched sounds (bell-typical diameter of 3.175 cm) as well as a chest piece that is closed with a stiff diaphragm for when low-pitched sounds are not desired (diaphragm-typical diameter of 4.445 cm). It should also contain firm tubing that is practical in length (between 22 and 27 inches) and diameter (typical inner diameter= 1 cm; outer diameter=1.5 cm), a spring to hold earpieces apart, which are typically made of silicone or plastic, as well as being lightweight and easy to carry (Wallen, 2006). Wallen (2006) further described that there are three primary reasons to use a stethoscope: listening to heart sounds, listening to lung sounds, and measuring blood pressure. Furthermore, Callahan et al. (2007) described stethoscopes as being used primarily for assessing cardiac, pulmonary, and bowl sounds. A stethoscope is also used to measure Korotkoff sounds (i.e., blood pressure) with a sphygmomanometer.

Logistically, when the diaphragm or bell is placed on a patient, the body sounds vibrate the device, which in turn, creates acoustic pressure that travels up to the ears. Transmission of low frequency sounds, such as those of the heart and bowel, is better when using a bell while transmission of higher frequencies, such as those of the lungs, is best when using the diaphragm. It should be noted that heart sounds have peak power characteristics ranging from 10 to 400 Hz while lung sounds are at frequencies as high at 1,000 Hz. Wheezing measurements are thought to be at frequencies near 1,500 Hz.

Riederer and Backman (1998) state that measuring the output of a stethoscope can be problematic because it is difficult to recreate how the scope would function during auscultation. This is due to differences in placement and amount of pressure added to the bell or diaphragm each time a measurement is taken. To this end, Riederer and Backman (1998) sought to measure the frequency response of a stethoscope using an easy, accurate and repeatable measurement. A three-inch loudspeaker driver was centered in an airtight clipboard enclosure with the front rim sealed by elastic rubber and screwed to a spacer plate. The spacer plate had a hole for an air cavity that was fit with a sealed PVC plate with a hole in the middle so the chest piece of the stethoscope could be fixated to the plate. Two microphones were used, one for presenting the sound source and the other for measuring the stethoscopes response. The left earpiece was attached to an artificial ear. Fourteen different stethoscopes chosen by the researchers were measured. The results showed a repeatable, smooth frequency response with a weak resonance at 600 Hz and a decrease in the subsequent frequencies. All 14 measured stethoscopes showed a Helmholtz resonance characteristic between the chest piece cavity and the tubes when at higher frequencies (i.e., 1,500 Hz and above). Based on this, the authors stated that this limits the usable bandwidth of the stethoscope. It was also noted that the diaphragm attenuates the low frequencies (i.e., below 1,000 Hz) but preserves the resonance structure.

Comparison of unamplified stethoscopes. There are many unamplified stethoscopes on the market. While they are all designed relatively the same, the manufacturer and user claims regarding perceived sound quality are different. The following will compare and contrast signal transmission of unamplified stethoscopes. First, in a study by Ertel, Lawrence, Brown, and Stern (1966a), two objective methods were used to retrieve the transmission acoustics of the same stethoscope. The two methods were different in the way the sound source and microphone were coupled to the stethoscope. A subjective threshold correlation study was also conducted to determine if the stethoscope changed the characteristics of the ear, if the stethoscopes altered the hearing threshold levels or changed the SPLs of the stimulus as it traveled through the stethoscope, as well as to check the validity of the data that was obtained from the two objective methods.

Method A used direct coupling in that a magnetic type headphone/earphone was used as the sound source. The chest piece of the stethoscope was placed over the headphone end plate. Each earpiece of the stethoscope was placed into one opening of a 2cc coupler, which is the size of an adult human ear. A standard condenser microphone was placed in one of the 2cc couplers while the other was sealed, making it a dummy coupler. Method B used indirect coupling, where a dynamic-type headphone was used as the sound source. The headphone was attached to a non-vibrating sound stage enclosed in a 50cc cavity. There were two identical half-inch openings in the soundstage, one that connected to a monitoring microphone and the other connected to the sound stage, which was attached to the chest piece of the stethoscope. The output of the stethoscope was measured at the earpiece via a probe tube inserted into the tip of the earpiece, which was connected to a microphone, and SPLs were recorded on a graphic level recorder. Furthermore, a subjective threshold correlation was completed to determine if the presence of a stethoscope would change the characteristics of the ear, alter hearing levels, or change the SPL of the input signal.

Four subjects with normal hearing sensitivity participated in this activity. For each participant, the signal was increased until it was just audible, and the participant pushed a switch denoting this. Then, the signal was decreased until it was no longer heard at which time the participant released the switch. This procedure was conducted at each frequency and the midpoint was documented as threshold. The headphones were then removed and the stethoscope was placed between the ear and the headphone. The above procedure was conducted a second time at each test frequency. This time, SPL was measured at the ear as well as at the headphone at the stethoscope chest piece, allowing for comparison of sound pressure thresholds at the source and the ear.

The result of Method A showed a poor correlation between the observed frequency response and the audibility pattern, especially when the stimulus was at a low frequency extreme. Using Method A, a low frequency primary peak was seen at 130 Hz, and peaks of lesser amplitude were seen at 320, 500, and 700 Hz. Using Method B, a primary peak was seen at 90 Hz with secondary peaks occurring at 300 and 500 Hz. Attenuation was also seen at 800 Hz, indicating little to no amplification of the stimulus past that point. The results of the two methods differ in that the peaks of Method B occurred at lower frequencies, and there was a greater attenuation of the higher frequencies. These results were attributed to Method B being a product of the combination of stethoscope acoustics as well as the natural acoustics of the human ear. Results from the threshold correlation study showed that the threshold measured at the ear was the same regardless if a stethoscope was present or if the participant wore headphones, but the amount of sound pressure needed to reach the threshold was altered by the stethoscope. It was also found that generally stethoscope acoustics would mimic the acoustics of the human ear when worn.

In a follow-up study, stethoscopes were tested using the same set-up as Method B described by Ertel, Lawrence, Brown, and Stern (1966b), with the following exception: instead of using human ears, the stethoscope terminated in artificial ears. The input was held constant through the frequency range of 20-3,000 Hz, and 28 stethoscopes were tested by placing the earpieces of each stethoscope into an ear simulator. The probe was either inserted through the wall of the artificial ear or through a hole drilled in the stethoscope earpiece. To ensure airtight seals for measurement and hold the earpieces in place, a silastic cushion was used. The chest piece was clipped to the soundstage used in Method B using petroleum jelly to prevent air leaks at the contact surface. The intensity level of the input signal was 80 dB SPL.

Six stethoscopes were used in this study. There were four basic design differences (two stethoscopes for each design) used in this study to show the transmission patterns of the stethoscope when coupled to a bell. These stethoscopes either had single or double tubing. Group I consisted of stethoscopes with double tubing and a trumpet bell, meaning the chest piece was deep and the signal was transmitted via two tubes each leaving the chest piece going directly to each ear. Group II stethoscopes used double tubing and a shallow bell, meaning the signal was still presented via two tubes leaving the chest piece going to each ear but the chest piece was much shallower. Group III consisted of single tubing trumpet bell stethoscopes, meaning the signal was transmitted from a deep chest piece through one tube leaving the chest piece and splitting to lead to each ear. Group IV were single tubing, shallow bell stethoscopes, meaning that the chest piece picking up the sound was much shallower and was delivered to the ears via one tube leaving the chest piece.

Coupling using double tubing; trumpet bell stethoscope was shown to have the greatest amount of amplification at the high frequencies (i.e., 3,000 Hz). Stethoscopes with double tubing and shallow bells were found to have no practical use for frequency responses above 500 Hz but output exceeded input in frequencies below 500 Hz. Stethoscopes with single tubing trumpet bells showed an irregularity in response patterns, where there was a period of considerable amplification followed by a period of attenuation in the mid-frequency range (i.e., 500, 1,000, and 2,500 Hz). Stethoscopes with single tubing shallow bells revealed less amplification below 500 Hz followed by insignificant amplification at the mid-frequencies (i.e., 500- 2,500 Hz) and essentially no clarity for the high frequencies (past 2,500 Hz). Based on these results, the authors concluded that single tubed stethoscopes show greater attenuation in the high frequencies, which could hinder the ability to localize cardiovascular sounds. Though stethoscopes are more advanced than they were in 1966, the designs mentioned in this article are still the basis for stethoscopes used today.

Next, Abella, Formolo, and Penny (1992) compared six popular unamplified stethoscopes including the Littmann Classic II, Littmann Cardiology II, Littman Master Classic, Hewlett-Packard Rappaport-Sprague, Tycos Harvey Triple Head, and Allen Medical Series 5 RPS Binaural. Using the Western Electroacoustic Laboratory, Inc. acoustic transfer function, the ratio of the sound pressure produced at the ear piece was compared to the sound pressure received at the chestpiece of the stethoscope at each frequency. The sound source was comprised of an electrodynamic headphone mounted in a 17 cc coupler. A white noise generator and power amplifier were used to produce white noise in the coupler at frequencies from 20-1,000 Hz. For both earpieces to be terminated in the same manner for the measurements, two artificial ears were used. Values were averaged in 12.5 Hz intervals with each value presented over the frequency range of 37 - 112 Hz. The results showed that all bell chest pieces tested amplified sound at frequencies below 100 Hz. Furthermore, the Allen Medical Series 5 RPS long tube provided the greatest amplification from 37-65 Hz; this scope also provided transmission of sound with the least attenuation in the range of 100-200 Hz. In the case of higher frequencies (125-1,000 Hz), all bells attenuated the sound to the same degree; however, the Littmann Cardiology II and Allen Series 5 showed to do so at a lesser magnitude.

When the diaphragms were tested, sound was attenuated in the low frequency range (37-87 Hz) in all scopes with the exception of the three Littmann models. Sound was amplified by as much as 10 dB with the Littmann models. Furthermore, in the Hewlett-Packard and the Tycos Harvey Triple Head stethoscopes, only sounds above 87.5 Hz were heard. In the higher frequency range (125-1,000 Hz) all diaphragms tested attenuated sounds. The most attenuation was found in the Tycos Harvey Triple Head scope. These results indicate that the bell and diaphragms for a given stethoscope may have different transmission characteristics especially at the low frequencies. Lastly, the Littmann Cardiology II, bell and diaphragm, showed to provide the most stable performance.

Moreover, Gavish and Heller (1992) acknowledged that the pre-purchase evaluation of a stethoscope is favorable; however, they explained that this is a complex acoustical phenomenon because the signal delivered to the practitioner's ear is not only based on the properties of the stethoscope but also factors such as the pressure applied to the stethoscope, the site that is being measured, and the composition of the selected body part. Furthermore, users are dependent on the output of the device as well as the sensitivity curves of hearing of each individual user. They further stated to evaluate a stethoscope a user-stethoscope-patient system should be used as a reference. To this end, their research aimed to find an easy to measure parameter that would allow for quantifying stethoscope performance.

Gavish and Heller (1992) used a bone conduction transducer from an audiometer as the sound source; it was pressed against the suprasternal notch of the chest of the subject using a rubber belt for delivery of the signal. Using a single subject and seven stethoscopes from four different and anonymous manufacturers, threshold intensity was determined. The stethoscopes were labeled 1-7 based on the cost of the instrument, with 1 being the least expensive and 7 being the most expensive. For each stethoscope tested, the threshold intensity for hearing was calculated at 48, 75, 125, 200, 320 and 510 Hz by measuring the lowest intensity that could be heard by the user. An average of three trials for each stethoscope was recorded. The stethoscopes were arranged by cost, with one being the least expensive and seven being the most expensive. It was seen that stethoscope five was the softest, with stethoscope 1 being louder and stethoscope seven the loudest. These results suggested the price of the stethoscope is not related to its ability to transmit greater intensities (i.e., greater cost is not indicative of greater performance). The results further showed that measuring threshold intensity might be one way to document performance of stethoscopes at individual frequencies.

Similarly, Callahan et al. (2007) examined the sound quality of stethoscopes and sought to classify stethoscopes into five categories using sound quality performance. To this end, Callahan et al. (2007) completed a side-by-side analysis of different brands of stethoscopes, independent of manufacturer's published test results. First, the scopes were classified into the following five categories based on the quality of the design and materials used to make the device: (1) those used for basic assessment/blood pressure, (2) those used for cardiology, (3) those that were disposable, (4) those that were used for high-end cardiology, and (5) those used for physical assessment. The authors also considered other differences in the stethoscopes including the use of the bell or a diaphragm, having double or single tubing, having hard versus soft diaphragm tubing and being a disposable or non-disposable scope. To test each device, a computer with a Sound Blaster sound card delivered the signal to each stethoscope, and a microphone picked up the sounds in the stethoscope's earpiece. Specifically, a Sonitor (i.e., device designed to transmit sounds directly from the computer sound card to the stethoscope) was connected the lineout jack of the computer's sound card and was used to amplify heart murmurs when played via the computer. The bell or diaphragm of the stethoscope was placed on the Sonitor, and a lab weight was placed on the stethoscopes' head to mimic the pressure used by a practitioner on a patient's chest. To couple the microphone to the stethoscope, a hollow rubber tube with one end in a rubber sheath acted as a coupler for the microphone and the stethoscopes earpiece.

Thirty-nine stethoscopes were assessed four times, removing the scope from the system and replacing it before each test. Please note the authors sought to determine if a stethoscope's price and category indicated a true measure of the scope's ability to transmit the audio signal from the patient to the practitioner's ear. To do this, the scope that lost the least amount of energy over the 3,000 Hz spectrum was chosen from each of the five categories. The output signal strength was divided by the input signal strength to determine loss. The authors hypothesized that those in the high-end cardiology would have the least amount of loss and that disposable scopes would have the most. The results showed the stethoscope grouping with the least amount of loss were those in the physical assessment category whereas the stethoscopes with the most amount of loss were in the basic assessment group. Based on these results, the authors concluded that manufactures labeled and priced stethoscopes unreliably. They cautioned practitioners when deciding on a scope, noting that the price and title may not be the best indicator of the scopes audio/sound performance.

Similarly, Kindig et al (1982) developed a system to analyze unamplified stethoscopes based on their output response to pure tones from 30 to 500 Hz, their response to recorded high and low pitched heart sounds, and their performance at the bedside with actual patients. Six unamplified stethoscopes were tested using a tape of pure tone frequencies from 30 to 500 Hz. At 30 Hz the recording was balanced to occlude the platform that was used to mount the stethoscope, and the frequency response for each stethoscope from 30 to 500 Hz was measured using both the bell and the diaphragm. When testing actual patients, the chestpiece had to be placed at the same place on the surface of the patient's chest; this was accomplished by using a strap device. The earpieces of each stethoscope were connected to the platform mount of the system designed by the authors, and a recording was taken at the level of the earpiece. This recording was then played back to the three listeners; each listener evaluated the performance of the stethoscope as good, fair, or poor in comparison to the other scopes.

Kindig and colleagues (1982) found in testing responses to pure tones that the bells of the stethoscopes were similar with highest responses from 75 to 125 Hz. They also found that the diaphragms of the stethoscopes had an attenuated response when compared to the bells at all frequencies but practically from 30 to 75 Hz. Furthermore, the results showed that the acoustical performances of larger, deeper bells were not superior to smaller, and shallower bells. Additionally, the results showed that diaphragms of moderately flexible composition generally performed better than those that were more flexible. Lastly, the authors found that using an identical stethoscope model with a single versus a double tube yielded no significant difference for the output response of pure tones up to 400 Hz for both the bell and the diaphragm; after 400 Hz, a significant drop off for the single tube was found. Most importantly, Kindig et al (1982) found no significant increase in intensity by any stethoscope tested for either pure tones or actual heart sounds. They further noted that the auscultatory experience of the practitioner is still far more important than the particular stethoscope they choose to use.

In summary, unamplified stethoscopes have been found to mimic the acoustic properties of the human ear. Furthermore, there are numerous variations in performance between different brands of unamplified stethoscopes, some providing better amplification than others (Callahan et al. 2007) (Gavish and Heller 1992). Likewise, research has shown that a greater price does not always dictate the most benefit, and ultimately it is at the discretion of the practitioner as to which scope works best for them and their specialty (Gavish and Heller, 1992).

Amplified Stethoscopes

An electronic (amplified) scope is a battery-operated device that allows for a louder frequency response for sounds during auscultation. Some electronic stethoscopes also allow the physician the option to record the patient's heart sounds directly to their computer for further analysis and interpretation (Leng, 2015). Furthermore, the advantages of electronic stethoscopes include increased signal level, elimination of sound loss across frequency, ability to use both the bell and diaphragm without interruption of assessment, and electronic noise filtering. Hoyte, Jensen, and Gjesdal (2005) however state that there are disadvantages to electronic stethoscopes. These include electronic and ambient artifact noise, which can lead to the increase of murmur diagnosis or the inaccurate characterization of murmurs.

Gu, Lim, and Moser (2010) investigated the relationship between abdominal auscultation and gastrological disease to validate the relationship between the two as suggested by Cannon in 1905. To this end, a stethoscope diaphragm was placed in the right lower quadrant of the abdomen to record bowl sounds of 10 healthy patients, 9 with obstruction, and 7 with ileus (i.e. a disruption in the normal movement of the gastrointestinal tract). The sounds were recorded using an E-scope II electronic stethoscope. Two 30-second audio clips were recorded from each participant, and they were assigned a number from 1 to 43. Six of the recordings were duplicated to allow for intra-observer variation. Another six recordings were taken at two different times to allow for intra-subject variation. Twenty physicians were then recruited to listen to the recordings without any other clinical information. After listening to each recording, the physicians were asked to determine if the diagnosis was normal, obstructing, or ileus. It was found that the overall median score for the physicians correctly identifying the patient's diagnosis was 70%. More specifically, 78% of the time the physician's correctly identified a normal sound; 85% of the time they correctly identified an ileus sound, and 42% of the time they correctly identified an obstruction. Overall, results revealed that auscultation of the bowel is useful in the assessment of the abdomen especially for identification of ileus. They state that while positive predictive values are high for bowel obstruction sounds, sensitivity is low and that further studies determining etiology or progression of the obstruction could aid in the correct identification of the disorder.

Kamran and colleagues (2013) state that the human ear cannot distinguish heart sound time intervals. Specifically, they explain that heart sounds can be heard effortlessly with a stethoscope; however, the human ear cannot determine the time intervals between the sounds. To this end, Kamran et al. (2013) sought to determine the practicability of using electronic stethoscopes for the assessment of heart rate variability in 50 subjects with and without cardiovascular risk factors/disease. The present study was conducted in a quiet, low light and temperature controlled room with patients lying down after a 5-minute rest period. The heart sounds were recorded with both an electronic stethoscope (i.e., Thinklabs ds32a electronic stethoscope) and Lead II electrocardiogram (ECG) for 2-3 minutes. The ECG and heart sounds were digitized for data analysis purposes. The results showed adequate heart sound recordings were acquired 100% of the time on the first attempt, suggesting that heart rate variability assessment using electronic stethoscopes is a viable quantitative measure for cardiac auscultation.

In summary stethoscopes have advantages, including increased signal level, elimination of sound loss across frequency, ability to use both the bell and diaphragm without interruption of assessment, and electronic noise filtering (Leng, 2015); as well as disadvantages, including electronic and ambient artifact noise (Hoyte et al., 2005). It was found that electronic stethoscopes were beneficial for both bowel and cardiac auscultation.

Amplified stethoscopes and practitioners with hearing loss. In a publication by Bankaitis (2010), amplified stethoscope options for professionals with hearing loss were discussed. She states that the art of auscultation requires clinical skill as well as assumes that the practitioner has ideal hearing capabilities and listening environments. For those medical professionals with hearing loss, the use of a traditional stethoscope yields problems in difficulty hearing necessary heart, lung, and/or bowel sounds needed for accurate diagnosis. Additional problems arise when the practitioner wears hearing instruments because although amplified stethoscopes account for the hearing loss, the simultaneous use of amplification and the stethoscope becomes a task. The goal of this article was to provide practitioners with stethoscope options that are available while using hearing instruments. It also addresses the limitations for realistic expectations such as insertion and removal of hearing instruments and comfort of stethoscope ear tips.

Likewise, Atcherson (2010) states that those professionals with normal hearing or those with primarily high frequency hearing loss are able to use unamplified stethoscopes for diagnostics due to the properties of the chest piece (both diaphragm and bell), diameter of the tubing, and the input of two ears. Furthermore, amplified stethoscopes boost amplification compared to unamplified stethoscope and thus act as a hearing aid. This helps those practitioners with normal hearing when they are in loud clinics. Practitioners with hearing loss can also benefit from the use of an amplified stethoscope due to experienced decrease in hearing sensitivity. This, however, requires the practitioners to remove hearing aids during auscultate and replace them to converse with their patient. These practitioners could also modify the stethoscope so that it is acoustically connected to the sound bore of their earmold, thus allowing them to keep uninterrupted dialogue with their patients. Likewise, amplified stethoscopes can also be connected to FM signal through direct audio input, telecoil, or bluetooth system of a hearing aid for better hearing during auscultation. While these methods work to improve hearing ability during auscultation, some practitioners consider them awkward, unsanitary, or even unmanageable.

In a technical paper by Cardionics Engineering Department (2008), it was stated that the manufacturer of the E-Scope was concerned about the information practitioners have regarding using a behind the ear (BTE) hearing aid and a stethoscope. To this end, a Phonak Savia, 311 BTE was connected to the E-Scope, model 718-7710, via a DAI cable. A signal, not described by the authors, was transmitted to the E-Scope, and the output at the Phonak Savia was measured using a sound level meter (SLM). It was found that the sound quality of the hearing aid when connected to the E-Scope was not suitable for diagnostic purposes. This was due to the limitations of the hearing aid to reproduce sounds adequately in the frequency range needed for heart sounds. To further document this effect, an informal evaluation was completed using normal hearing listeners with the Savia connected to the E-Scope while listening to heart sounds. These listeners confirmed that the sounds seemed faint and distorted. Due to these results, Cardionics does not recommend the connection of BTE hearing aids directly to the E-Scope for diagnostic auscultation. They do, however, suggest that if a practitioner has adequate low frequency hearing, the E-Scope Clinical Model or the E-Scope Belt-Clip Model could be used by either coupling the scope to the ears using ear tips or placing the headset speakers over the practitioner's ears with their hearing aids removed. They also suggest that an "open fit" BTE hearing aid could be used and the headset speakers of the E-Scope Belt-Clip Model could be placed over the hearing aid (Cardionics, 2008).

Rennert, Morris and Barre (2004) discuss how to meet the challenges practitioners with hearing loss face when using stethoscopes. The authors discussed three keys to successful usage of stethoscopes for practitioners with hearing loss. These include appropriate fine-tuning of the hearing instrument(s), choosing the best stethoscope and appropriate interface, and the practitioners' ability to learn and relearn to distinguish bodily sounds. First, Rennert et al. (2004) discuss the fine-tuning of an instrument. Specifically, due to the low frequencies of body sounds (heart and lung), they state that hearing aids with a good low frequency response tend to provide the most benefit. They further recommended a trial with different hearing aids to determine which hearing aid aided in the best in ability to hear bodily sounds in conjunction with the stethoscope. Lastly, they suggested that with hearing aid technology with multiple programs, a program specific for stethoscope use should be considered. It was also recommended that trial periods with different stethoscopes be explored to aid practitioners in making their decision regarding what hearing aid/stethoscope to purchase (Rennert et. al., 2004).

Secondly, they state that the interface chosen for the practitioner directly correlates to the type of hearing device they wear. For example, completely-in-the-canal (CIC) hearing aids are often recommended to those who use stethoscopes though it has been reported to be uncomfortable to the user (Rennert et. al., 2004). This occurs because the stethoscope terminates against the hearing aid. Another option would be to remove the aids and use an amplified stethoscope. Likewise, in-the-ear (ITE) users tend to have a difficult time in finding a compatible interface with headphones or eartips being the most compatible. Even with these interfaces, however, feedback can occur. BTE users tend to have greater degrees of hearing loss; they state that if the loss is prominent in the low frequencies, then the amplified stethoscope alone will not provide enough amplification. To aid in amplification, BTE users have the option of pairing their stethoscopes with specialty earmolds, having compatibility with telecoil/accessories, or using direct audio input (DAI) to transmit the signal to the hearing aid(s). Thirdly, for the practitioners learning or relearning how to distinguish body sounds, Rennert et al. (2004) recommended practicing with artificial sounds produced in the body (i.e., from a CD or the internet). For example, the practitioner should practice distinguishing various heart murmurs using their hearing instrument and the speaker in which the sound is being played (i.e., CD player or computer) with no stethoscope. This will allow the practitioner to troubleshoot and/or identify problems when using the instruments together.

Likewise, Jacob, Zambonato and Mondelli (2013) state that for effective use, a stethoscope should be easily handled and made compatible to the practitioners hearing instrument (i.e., hearing aid or cochlear implant) as well as portable and have good reliability in producing the sounds of the body. Their case study looked at hearing aids fitted to a stethoscope used by two healthcare students with bilateral hearing loss. The two students contacted their campus administrators with the complaint of being unable to adequately hear through their hearing aids, though it was essential for their ability to excel at the university. Due to their complaint, they were referred to an electronics technician who attached their stethoscopes to analog BTE hearing aids that had been donated to the university.

One student was a 23-year-old female student pursuing a degree in nursing. She presented with a slight sensorineural hearing loss (SNHL) in the right ear and a profound SNHL in the left ear. Due to the degree of hearing loss, a mini-BTE was used in the right ear, and a traditional BTE was used on the left ear. The other student was a 22-year-old male medical student with moderate, bilateral SNHL. Due to his symmetric loss microchannel binaural hearing aids were used. Real ear insertion gain (REIG) showed that targets were met at all test frequencies (250-4000 Hz) when compared to gain prescribed by National Acoustics Labs, Non-Linear, version 1 (NAL-NL1). The students used the devices for one semester, and returned to complete an assessment of satisfaction questionnaire related to stethoscope use with the hearing aids. The responses from these questionnaires revealed that both students achieved mastery for auscultation that was not attainable previously with just their hearing aids. They reported no limitations to the use of the stethoscope or performing diagnostic procedures. Both students reported to be highly satisfied and suggested this method be used for students and health care professionals with hearing loss.

Comparison of Unamplified and Amplified Stethoscopes

The following section discusses research conducted using both amplified and unamplified stethoscopes. Each study examines the stethoscope models in the same manner and is able to give a comparison of either objective or subjective results for the scopes. First, Grenier, Gagon, Genest, Durand and Durand (1998) conducted a study to identify the best unamplified and electronic stethoscopes as well as determine the basic characteristics of a new electronic/amplified stethoscope that they believed would be widely accepted by medical practitioners. Two medical teams were made up of nine cardiologist, 10 general practitioners, and 11 nurses. These experienced practitioners were asked to use three unamplified stethoscopes (Cardiology II, Harvey Elite, and Rappaport Sprague) and three electronic/amplified stethoscopes (Labtron, EST40, and ST3) to evaluate the auscultation patterns of the patients. A total of 1,134 auscultations were performed during 378 comparative evaluations. Each comparative evaluation was based on three subsequent auscultations of the same patient by using an evaluation grid and the three randomly selected stethoscopes; it should be noted all six stethoscopes were evaluated an equal number of times. The evaluation grid was designed to compare the clinical performance of the stethoscopes for cardiovascular evaluation while taking into consideration medical, technical, and ergonomic features of the stethoscopes on cardiovascular auscultations. The cardiologists and general practitioners evaluated all 13-evaluation criteria whereas nurses evaluated only six.

Through the 201 comparative evaluations performed by the cardiologists, 101 by general practitioners, and 76 performed by nurses, 71% of the time unamplified stethoscopes were the most preferred for use while amplified stethoscopes were preferred 29% of the time. To determine which stethoscope was most preferred, a percentage of time a given stethoscope was chosen as the best stethoscope for a specific auscultation was computed for each category of medical staff. The results showed nurses preferred the Harvey Elite, while general practitioners and cardiologists preferred the Cardiology II. The physicians and nurses were also asked for their comments on the advantages and limitations of the stethoscopes and for input on characteristics of amplified stethoscopes that would be more widely accepted. According to the comments of the physician and nurses, the specific limitations of unamplified stethoscopes are: (1) the lack of amplification of the sounds, (2) more attenuation for the higher frequency sounds, and (3) the high pressure applied on the ears by some models of stethoscope to isolate the heart sounds from ambient sounds. This main limitations of the unamplified stethoscopes were corrected by the amplified stethoscope but this is achieved at the cost of introducing other limitations such as (1) the electronic noise; (2) sensitivity to impact, manipulation, and ambient noises; (3) no standard ''bell and diaphragm'' filtering; and (4) a bad ergonomic design (Grenier et al., 1998).

Likewise, Iversen and colleagues (2005) sought to determine if there was agreement in clinicians using an amplified versus unamplified stethoscopes. Physicians were divided into the following six classifications: 1) cardiology, 2) general internal medicine, 3) registrars (i.e., doctor that is receiving specialty training), 4) senior house officers (i.e., hospital doctor during the second and third years after qualification), 5) house officers (i.e., a doctor in the first two years after qualification), and 6) medical students. The groups were to receive the 3M Littmann model 400 amplified stethoscope or the 3M Littmann Classic II unamplified stethoscope. All patient examinations were completed on the same day, with each examination lasting no more than three minutes. After each examination, the clinicians were asked to fill out a multiple-choice questionnaire which included questions pertaining to heart sounds (i.e., systolic murmur loudest at the base of the heart, systolic murmur loudest at the apex of the heart, murmur over the carotids, other systolic murmur, gallop sound, and diastolic murmur) and lung sounds (i.e., rhonchi, fine moist rales, coarse moist rales, rales form secretion, pleural friction rub, diminished breath sounds, bronchial breath sounds, and prolonged expiration). The results showed no significant difference in the kappa values of the observers using the amplified and the unamplified stethoscopes for five of six types of heart murmurs or for seven of eight types of lung sounds. When the kappa values were analyzed simultaneously, it was found that there was a borderline significant difference between agreement and clinical experience. Due to these findings, Iversen and colleagues (2005) concluded that regardless of type of stethoscope used and the amount of clinical experience, the agreement among practitioners when auscultating the heart and lungs is low.

Additionally, Dolan, Oliver, and Maurer (2001) conducted a study measuring the ear canals of participants with normal hearing while listening to live heartbeats through one unamplified stethoscope and two amplified stethoscopes. For this study, the Sprague Rappaport LAB600 (unamplified), Bosch EST40 (amplified), and the Starkey ST3 (amplified) were used. Real ear measurements were taken from six females and five males as the heartbeat of a 29-year-old male with normal cardiac function was being evaluated. These 11 participants had no experience with cardiac auscultation. An experienced nurse with normal hearing supervised as the participants were listening to the heartbeat. Real ear measures were obtained with a probe tube placed 10 mm from the end of the listeners right ear tip and connected to a Knowles microphone. The listener placed the chestpiece to the chest of the person providing the signal, and the signal at the microphone was then amplified to the listener's most comfortable listening level. Real ear measures were then obtained at this level.

It was found that the spectra for all three stethoscopes showed more acoustic energy for the heartbeat at frequencies below 500 Hz. Furthermore, the mean levels of the heartbeat were higher for the two amplified stethoscopes when compared to the unamplified stethoscope. The adjustable gain of the two amplified stethoscopes suggested that the output from the unamplified stethoscope was at levels lower than the listeners' preferred listening level (Dolan et al., 2001). This lead the authors to believe that even normal hearing persons preferred to listen to heart sounds at levels that the unamplified stethoscope could not achieve.

In terms of the frequency response curve, Dolan et al. (2001) found that at frequencies of 125 Hz and higher, the mean output of all three stethoscopes were 10 dB or more greater than the mean threshold of audibility for the listeners. At frequencies below 125 Hz, the Sprague-Rappaport (unamplified) and Starkey (amplified) stethoscopes revealed outputs to be much closer to levels of the listener's thresholds; at 50 Hz the output from these instruments were at the listeners' thresholds. They found that the Bosch EST40 (amplified) was the most effective in making critical low-frequency sounds audible; however, much of the acoustic energy of the heartbeat still fell below the threshold of audibility for frequencies below 125 Hz. Based on these findings, Dolan et al. (2001) concluded that even with amplified stethoscopes diagnostic information, low frequency information used for diagnostics may still not be available to the normal hearing listener. This would make diagnosis even more complex for practitioners with hearing loss.

Lastly, Hoyte et al. (2005) sought to determine if the use of amplified, sensor-based stethoscopes affected the cardiac auscultation skills of undergraduate medical students compared to the use of conventional, unamplified stethoscopes. Forty-eight 3rd year medical students were asked to use an amplified or unamplified stethoscope for a four-month training period. Once the training period was over, their skills of cardiac auscultation were evaluated using four patients with different cardiac murmurs. Evaluation was completed as the medical student completed a questionnaire after each listening attempt. Two experienced cardiologist, who helped determine correct answers on the questionnaire, supervised these students. The questionnaire used was composed of 13 questions that were weighted according to the relative importance as well as a correct response.

Each of the participants supplied three to four questionnaires; the end number of questionnaires scored was 78, and there were equal number of evaluation while using both the conventional unamplified and amplified stethoscopes. The results showed no mean difference in the grade and characteristics of murmurs, if present, as well as the report of non-murmurs between the stethoscopes. No differences between the study groups were found when using the conventional stethoscope versus the electronic stethoscope. The authors noted that more time and experience with the amplified stethoscope may yield better results if completed.

In summary it was found that physicians found disadvantages when using unamplified stethoscopes (lack of amplification, more attenuation for the higher frequency sounds, and high pressure applied on the ears by some models of stethoscope to isolate the heart sounds from ambient sounds) that were corrected when using amplified stethoscopes. The amplified stethoscopes however, created problems of their own (electronic noise, sensitivity to impact, manipulation, and ambient noises; no standard ''bell and diaphragm'' filtering, and a bad ergonomic design (Grenier et al., 1998). Iversen et al. (2005) determined that regardless of the experience of the practitioner, common ground is rarely found when determining which version of stethoscope (unamplified or amplified) is best to use.

Chapter III

Methods

Acoustic Analysis of Digitized Auscultation Signals

The present study used Knowles Electronic Manikin for Acoustic Research (KEMAR, Ruston, LA; see Appendix A for IRB exemption). As stated by Gunner Rasmussen's Acoustic Systems (GRAS), the manufacturer of KEMAR, KEMAR is an acoustic research instrument/manikin that allows for reproducible measurements for establishing the performance of hearing aids and other electroacoustic devices. Likewise, KEMAR is a head and torso simulator designed for acoustic research and is able to test devices that contain both loudspeakers and microphones. In addition, it is able to perform either monaural or binaural recordings of sound.

Materials and Procedures

Location: The proposed project was completed in a sound-treated booth (IAC, Model 30-9'3 x 9'7, Ruston, Louisiana) at the Louisiana Tech Speech and Hearing Clinic (Woodard Hall), with ambient noise levels appropriate for testing unoccluded ears (ANSI S3.1, 1999).

Equipment: The equipment in this research study included the following: (1) a sound-treated booth (see above); (2) KEMAR (GRAS Knowles Electronics Manikin Type, 45BA); (3) a laptop computer (Dell Latitude D630) with National Instruments Sound and Vibration Assistant software (version: 777970-03, 2007); (4) a MacBook air computer (Apple Inc., MacBook Air A1369) with internet access; (5) heart and lung sounds from www.easyauscultation.com (see below for description); (6) an iPhone 7 Plus (Apple Inc., iPhone A1661); (7) bowel sounds from the iStethoscope Expert app (see below for description); (8) a speaker pad (see below for description); (9) putty; (10) unamplified stethoscopes (described in the Unamplified Stethoscopes section below); and (7) amplified stethoscopes (described in the Electronic/Amplified Stethoscopes section below). More specifically, first, the National Instruments Sound and Vibration Assistant software is subset of the LabVIEW software, a graphical programming language designed for scientists and engineers. The software is designed to acquire sound files from the specified channel, convert the sound files to engineering units, add frequency weighting, and compute average values.

Second, the heart and lung sounds were acquired from www.easyauscultation.com, a training website designed for medical professionals. A team of physicians and course developers developed the site. To allow those medical professionals learning the art of auscultation to listen to, identify, and be examined on different auscultation techniques and procedures. This site was chosen due to the ability to listen to a variety of heart and lung sounds, both normal and abnormal, through the speakers of the computer. The app iStethoscope Expert (version 2.3) was used to acquire bowel sounds. The app was developed by Paul Chan for use by medical students, physicians, nurses, emergency medical technicians (EMTs) or anyone who wants to learn about heart, lung or abdominal sounds. Third, the speaker pad (see Figure 1) used in collecting data was manufactured by Blaufuss Medical Multimedia Laboratories (Rolling Hills Estates, CA) and is no longer manufactured. The purpose of the speaker pad was to transmit sound from the computer to the stethoscope bell/diaphragm.

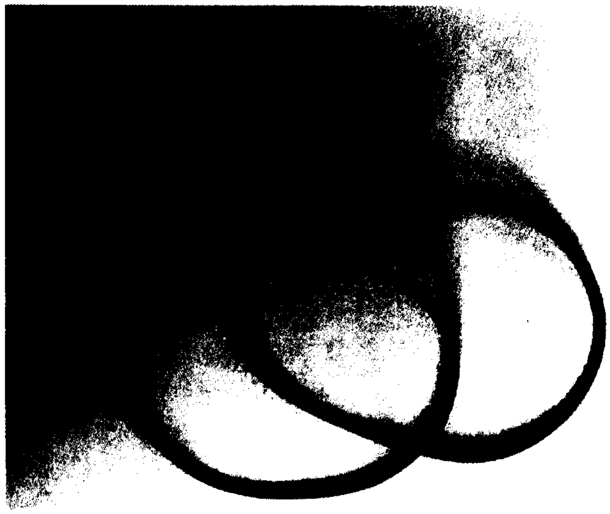


Figure 1. Speaker Pad

Unamplified/acoustic stethoscopes. The following unamplified stethoscopes were evaluated as a part of this study: Littmann Classic II SE, Omron Sprague Rappaport (ESR-112), and Littmann Cardiology III. First, the Littmann Classic II SE is a commonly used stethoscope, which contains a pressure-based sound frequency adjustment with tunable diaphragm and is an anatomically designed headset with snap-tight soft-sealing eartips. The chest piece incorporates a non-chill design for patient comfort. Tubing for this stethoscope is durable and maintains its shape and flexibility even after being placed in a pocket for long periods of time. This, along with the resistance to oils from skin and alcohol for cleaning, is essential in the life of the stethoscope. Furthermore, this stethoscope is used as a general examination stethoscope. Its chest piece allows for the monitoring of low- and high-frequency sounds by alternating pressure. Typical weight of the Littmann Classic II SE is 125 g; tube length is 28 in; diaphragm diameter is 1.75 in, and bell diameter is 1.25 in.

Second, the Omron Sprague stethoscope contains three sizes of open bells, two sizes of diaphragms, and two pair of eartips, all in a vinyl storage case. It features latex free tubing and a chrome plated chest piece. Typical weight of the Omron Sprague is

272 g with a tube length of 22 in. This stethoscope was chosen as a variation from the Littman brand of stethoscope and because it is a stereo stethoscope.

Third, the Littmann Cardiology III is a specialty stethoscope that contains a double-sided chest piece and can be used for adult and pediatric auscultation. The larger diaphragm is used for adult patients and the smaller for pediatrics, thin patients, or to maneuver around bandages. The small bell can also be transformed to a traditional bell with the non-chill sleeve provided with the scope. This allows the practitioner to not only listen to a vast variety of patients but to use one stethoscope for all sounds. This stethoscope also contains noise-reducing sound channels in the tubes of the scope. This stethoscope allows for two tubes in one design and has snap-tight soft-sealing eartips. The Littman Cardiology III also incorporates the non-chill chest piece for patient comfort. Typical weight of the Littmann Cardiology III stethoscope is 175 g; tube length comes in 22 or 27 in. The diaphragm diameter is 1.7 in, and the bell or small diaphragm diameter is 1.3 in.

Electronic/amplified stethoscopes. The following amplified stethoscopes were used: Cardionics EScpoe II, 3M Littmann Electronic Stethoscope Model 3200, and Phillips Electronic Stethoscope. First, the Cardionics E-Scope II is a digital stethoscope that includes a single adult diaphragm, which is changeable to a specialist diaphragm, specialist bell, or pediatric/infant size bell. The interchange is easy for the practitioner, achieved by the push of a button. There is also a volume control for the practitioner to increase or decrease the intensity of the sounds they are assessing. The E-Scope II also contains an automatic shut off that occurs at two minutes. This scope functions for four to five months on a standard AAA battery. It is also designed to reduce background noise when used in the heart setting. The manufacturer does, however, state that due to the broader frequency of lung sounds, more noise is heard when listening for lung sounds. This stethoscope also comes in models for both listeners with hearing impairment and those with normal hearing. The E-Scope II typically weighs 176 g and is approximately 38 in from chest piece to ear tips. The adult chest piece/diaphragm, which was used for this study, is approximately 1.75 in. For this study, the model for listeners with normal hearing was used due to the standard ear piece model being consistent with the other stethoscopes.

Secondly, the 3M Littmann Electronic Stethoscope Model 3200 is a digital stethoscope that eliminates ambient noise using proprietary ambient noise reduction. This stethoscope has the ability to store twelve 30 s samples on the stethoscope as well as a 10 s commentary about the sound that was recorded. It also contains frictional noise reduction technology to reduce handling noise. When purchasing the 3M Littmann Electronic Stethoscope Model 3200 stethoscope, the practitioner is provided with Zargis® StethAssist Heart and Lung Sound Visualization Software that allows the practitioner to visualize what they are listening to, allows play back when convenient, and allows the practitioner to keep sounds in the patient's records or share the file with colleagues. This stethoscope not only has a bell and a diaphragm setting, it also has an extended range setting that allows for listening above 500 Hz. Typical weight of the Littmann Electronic Stethoscope Model 3200 is 185 g; the tubing is 27 in long, and the diameter of the chest piece (which is used as both the bell and diaphragm) is 51 mm.

Thirdly, the Phillips Electronic Stethoscope has four volume control levels that increase by 7 dB at each level. It features an enhanced filtering circuitry reducing ambient noise. Furthermore, there are two buttons on the chest piece allowing for a change in power as well as mode selection (bell versus diaphragm). Power is provided by one 3-volt lithium battery and with normal use, can last up to one year or 15 hours of continuous use. Auto shut off is activated 3 minutes after last button is used. Typical weight for the Phillips electronic/amplified stethoscope is 145 g including the battery, and typical tubing length is 28 in.

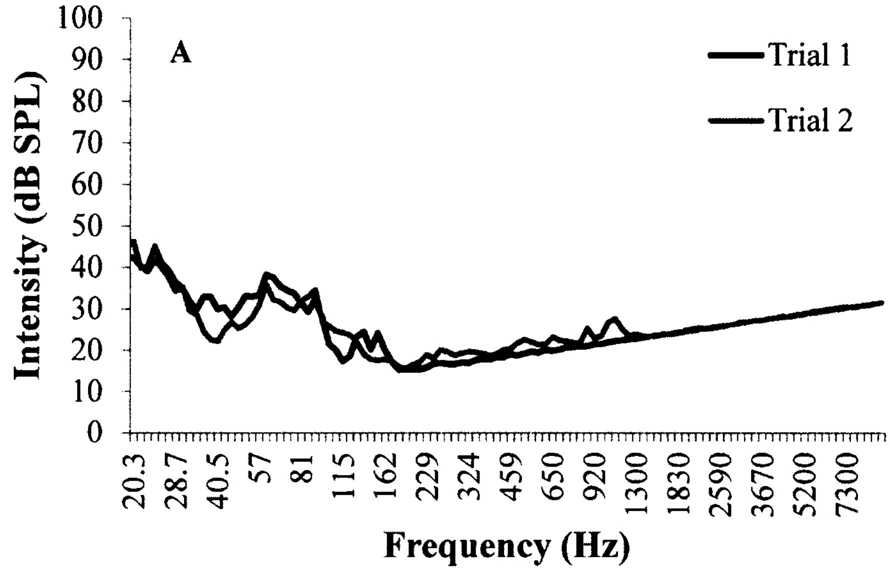
Procedures: All data was collected in a sound treated booth to eliminate background noise and obtain the true measurement of the stethoscopes. Heart and lung sounds were played through the www.easyauscultation.com website through the MacBook air computer and delivered to the speaker pad, which was connected through auxiliary jack to the laptop computer. Each chest piece of the six stethoscopes (3 unamplified and 3 amplified, see above) was mounted to the speaker pad with a small weight, weighing 100g was placed on top to ensure consistent applied pressure. Putty was also used around the stethoscope ear piece coupled to KEMAR to ensure a tight and appropriate seal. The eartips of each stethoscope were placed in KEMAR's ears, where the signal was acquired and analyzed by National Instruments Sound and Vibration Assistant (see Appendix B for step-by-step directions for measurement). Three 30-second measurements were conducted with each stethoscope and sound (i.e., heart, lung, and bowel) for a total of 54 measurements. With each measurement the ear tips for each stethoscope was removed and replaced in KEMARs ears. This was done to replicate the different insertion and removal processes among practitioners. It should be noted that the data was analyzed in 1/12 octave frequencies. In between each of the measurements, the stethoscope was removed and replaced on KEMARs ears; the weight of the chest piece was also removed and replaced. All data collected was downloaded to a laptop computer and placed into Microsoft Excel for use subsequent data analysis.

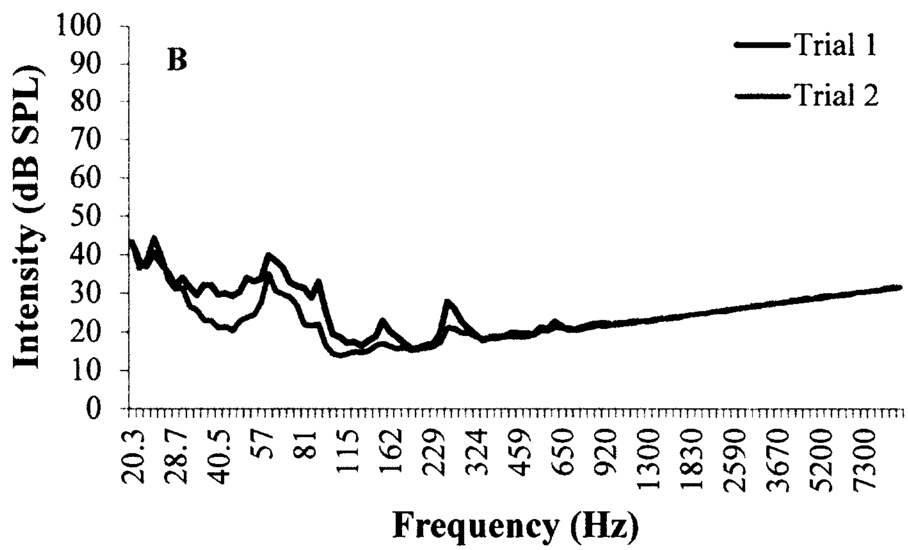
Chapter IV

Results

SPL Production of Stethoscopes

One purpose of the present study was to determine the effect of stethoscope type on SPL production when measuring typical body sounds (i.e., lungs, heart, and bowel) using KEMAR and a recording software developed by National Instruments (Note: The purpose of this software was to record the SPL from KEMARs ears in 1/12 octave bands for 30 seconds across the frequency range of 20-10,000 Hz). Three trial runs were obtained using each stethoscope for heart, lung, and bowel sounds; therefore, a total of nine trials were obtained for each stethoscope (i.e., three using heart sounds, three using bowels sounds, and three using lung sounds). These sounds were downloaded into a Microsoft excel document for subsequent data analysis. When looking at the three trials for each body sound and stethoscope, it was found that two of the three trials were typically identical while the third either showed more or less SPL. Therefore, the one of the three trials was disregarded, and the remaining two trials that were the most similar were retained for subsequent data analysis. This was because these were determined to be the most representative of the typical stethoscope function. Figures 2-7 show SPL as a function of frequency for each stethoscope for heart, lung, and bowel sounds. It should be noted that bowel sounds could not be measured using the Cardionics E-Scope II amplified stethoscope due to in ability to switch settings.


A
Trial 1
Trial 2
Intensity (dB SPL)
100
90
80
70
60
50
40
30
20
10
0
20.3
28.7
40.5
57
81
115
162
229
324
459
650
920
1300
1830
2590
3670
5200
7300
Frequency (Hz)


B
Trial 1
Trial 2
Intensity (dB SPL)
100
90
80
70
60
50
40
30
20
10
0
20.3
28.7
40.5
57
81
115
162
229
324
459
650
920
1300
1830
2590
3670
5200
7300
Frequency (Hz)

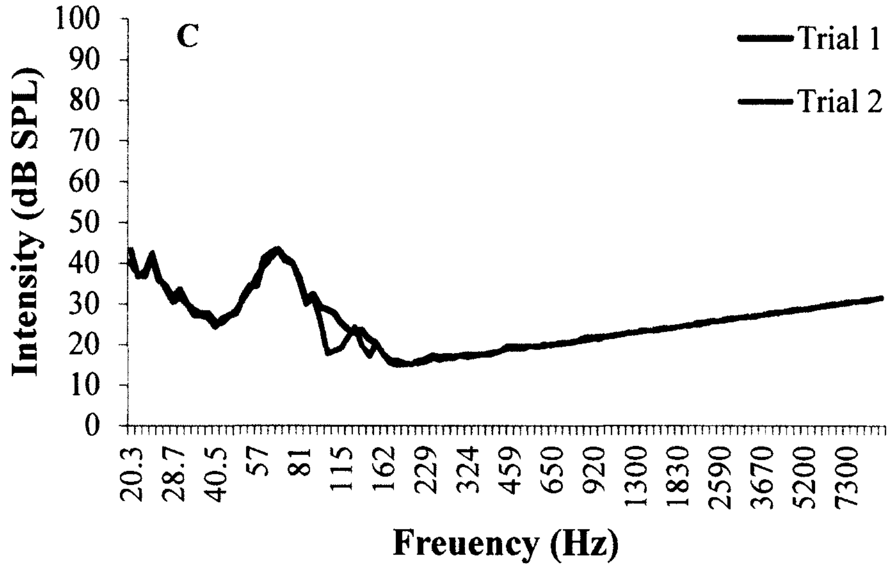
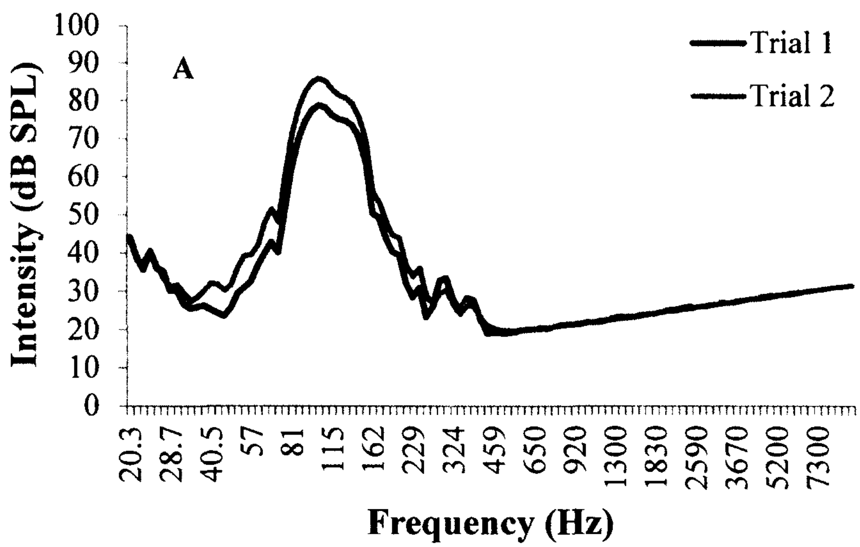
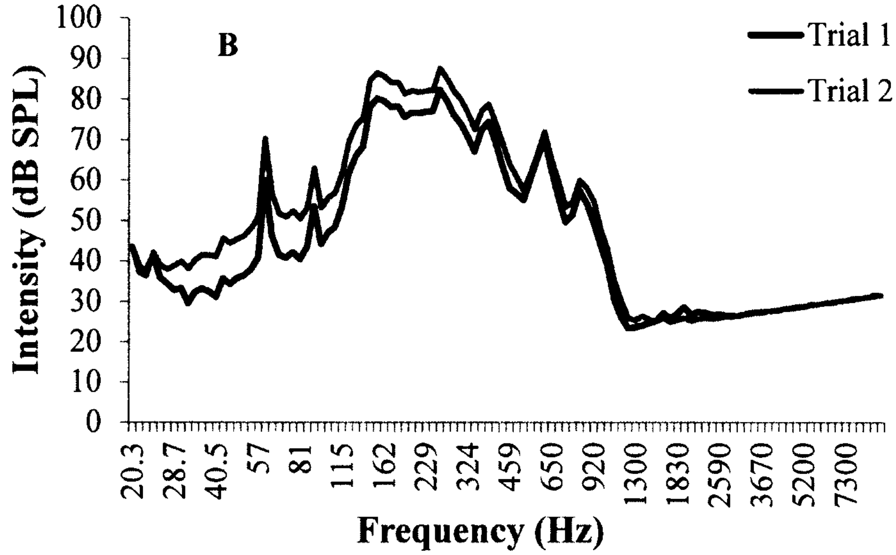


Figure 2. SPL as a function of frequency using the Omron Sprague Rappaport (ESR-112) unamplified stethoscope for (A) heart, (B) lung, and (C) bowel sounds.





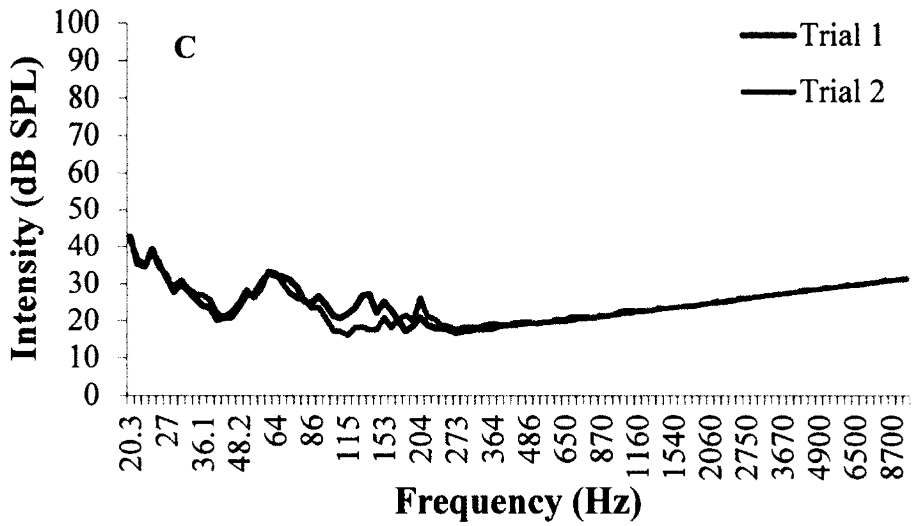
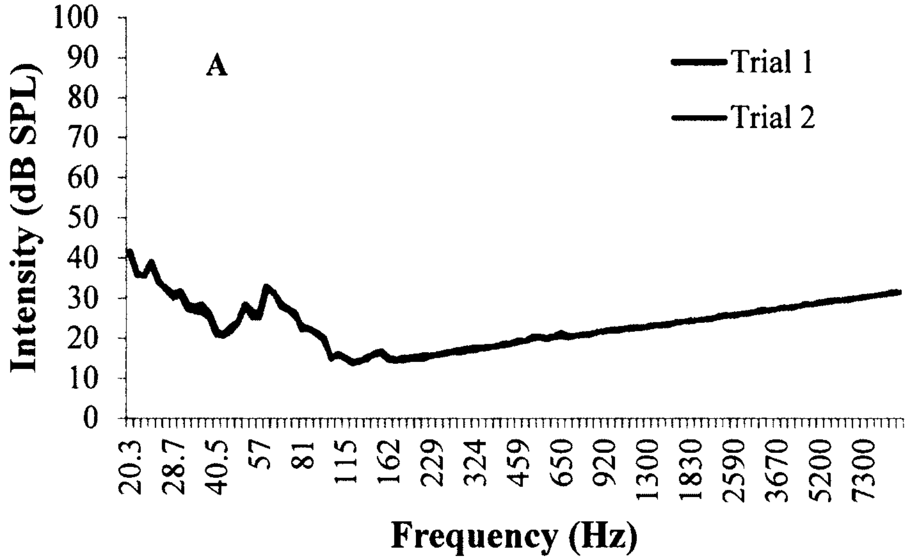
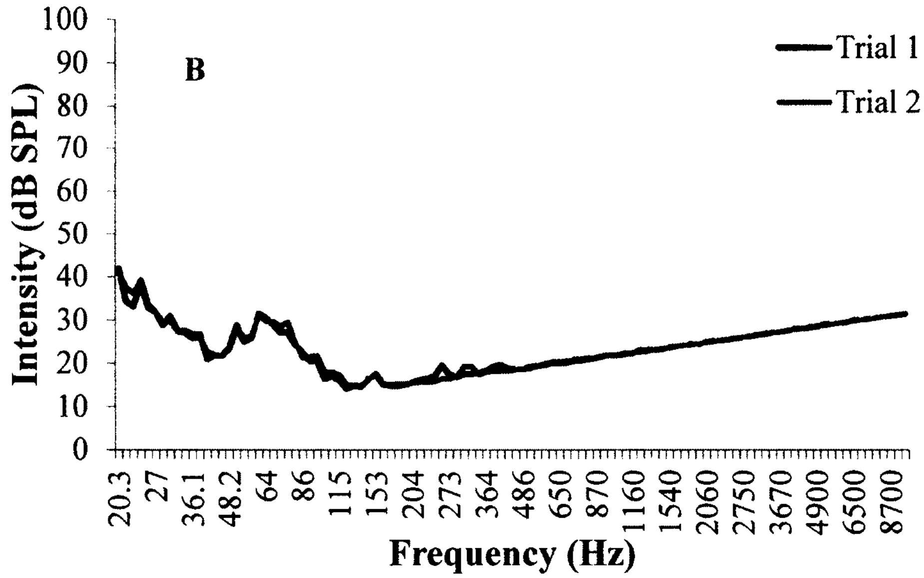


Figure 3. SPL as a function of frequency using the Littmann Cardiology III unamplified stethoscope for (A) heart, (B) lung, and (C) bowel sounds.


100
90
80
70
60
50
40
30
20
10
0
A
Trial 1
Trial 2
Intensity (dB SPL)
20.3
28.7
40.5
57
81
115
162
229
324
459
650
920
1300
1830
2590
3670
5200
7300
Frequency (Hz)


100
90
80
70
60
50
40
30
20
10
0
B
Trial 1
Trial 2
Intensity (dB SPL)
20.3
27
36.1
48.2
64
86
115
153
204
273
364
486
650
870
1160
1540
2060
2750
3670
4900
6500
8700
Frequency (Hz)

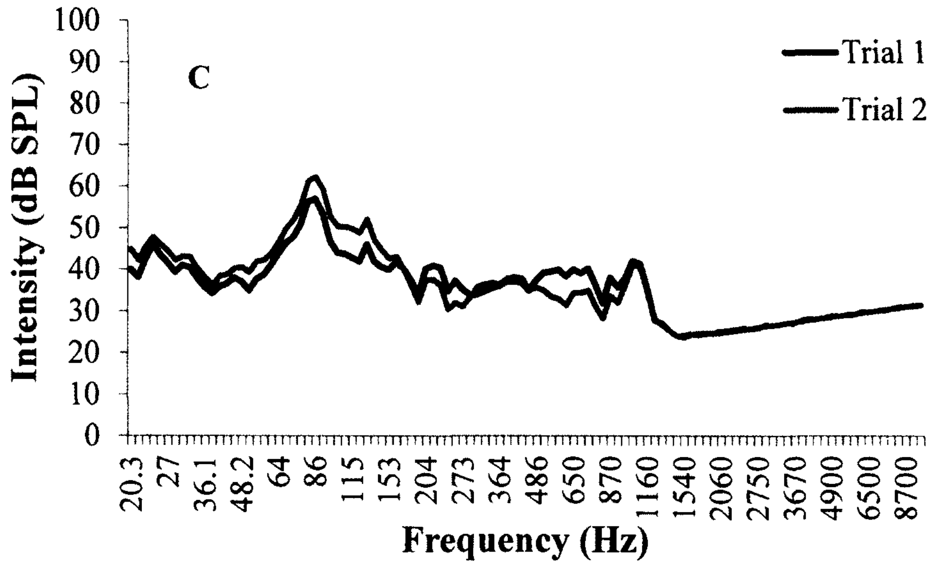
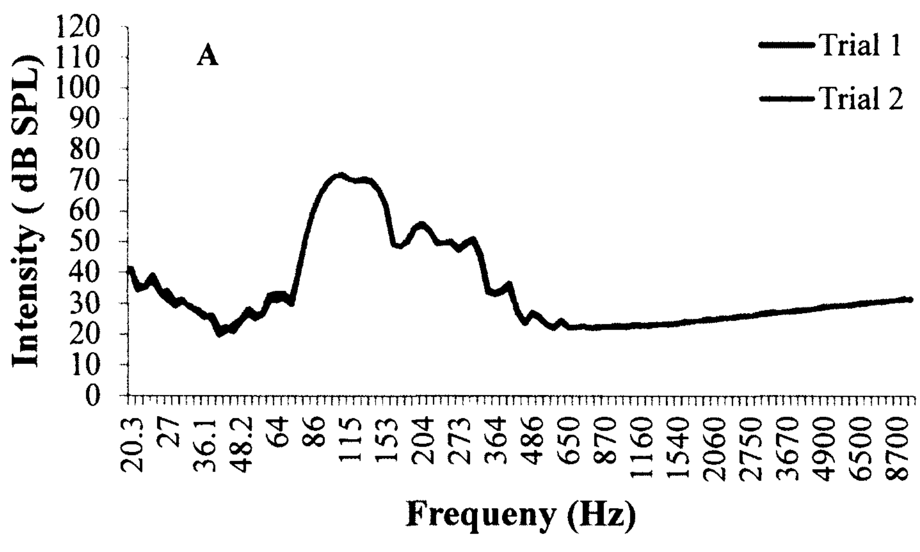
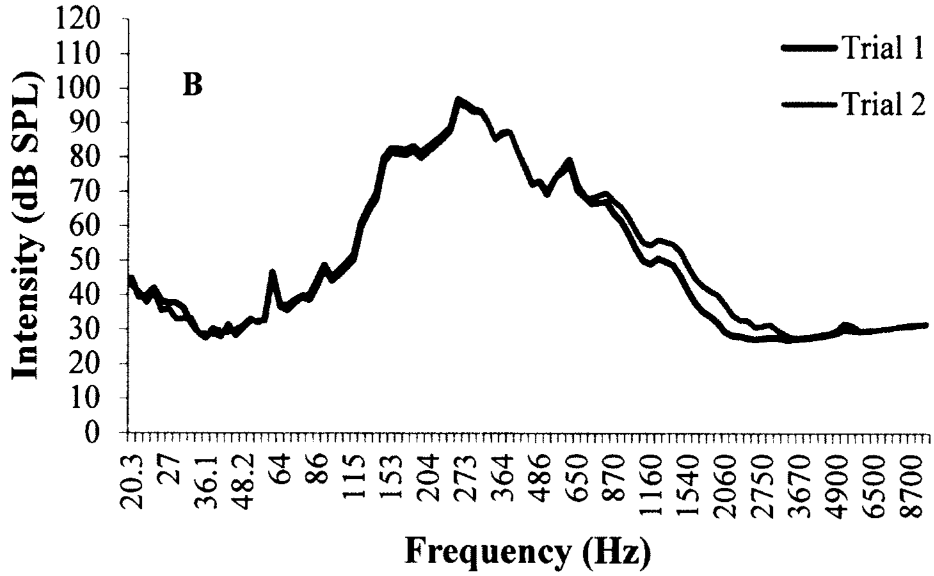


Figure 4. SPL as a function of frequency using the Littmann Classic II SE unamplified stethoscope for (A) heart, (B) lung, and (C) bowel sounds.





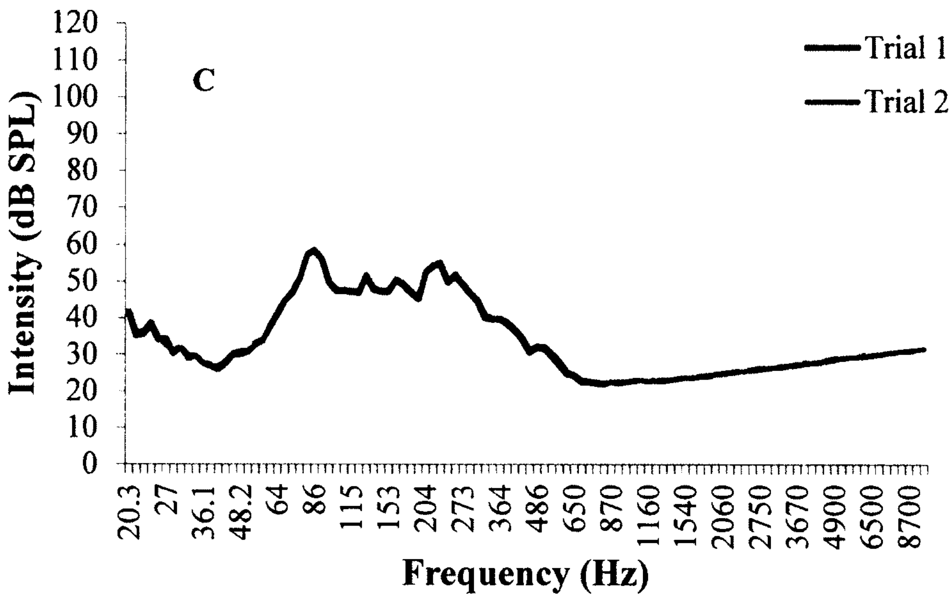
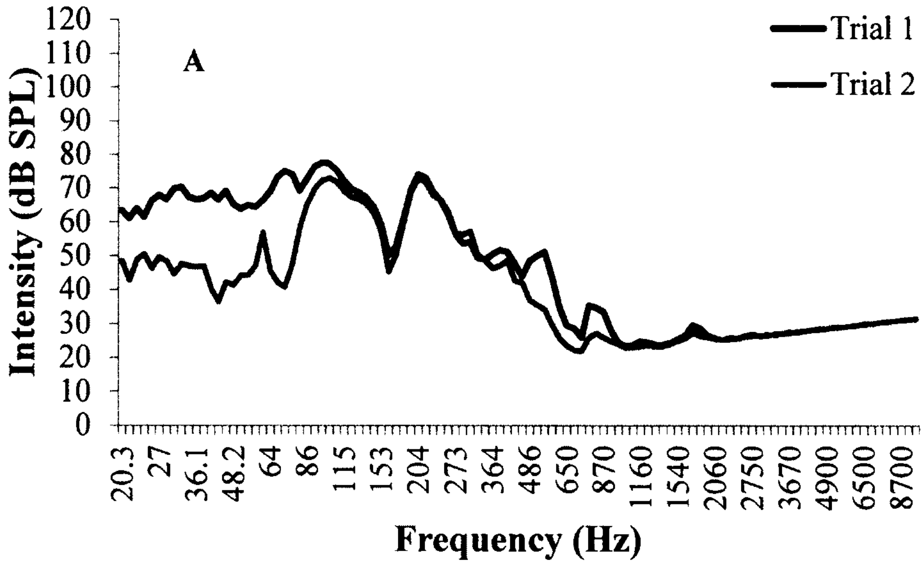
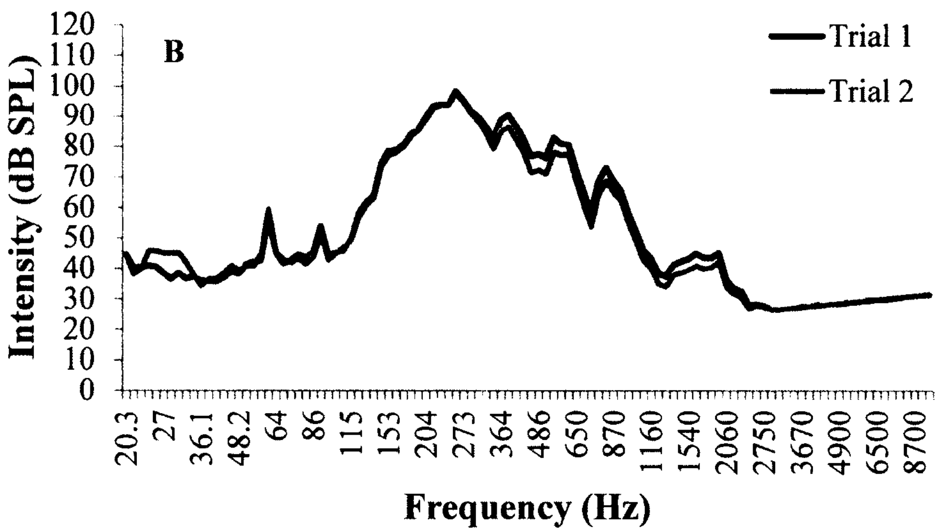


Figure 5. SPL as a function of frequency using the Phillips amplified stethoscope for (A) heart, (B) lung, and (C) bowel sounds.


A
Trial 1
Trial 2
Intensity (dB SPL)
120
110
100
90
80
70
60
50
40
30
20
10
0
20.3
27
36.1
48.2
64
86
115
153
204
273
364
486
650
870
1160
1540
2060
2750
3670
4900
6500
8700
Frequency (Hz)


B
Trial 1
Trial 2
Intensity (dB SPL)
120
110
100
90
80
70
60
50
40
30
20
10
0
20.3
27
36.1
48.2
64
86
115
153
204
273
364
486
650
870
1160
1540
2060
2750
3670
4900
6500
8700
Frequency (Hz)

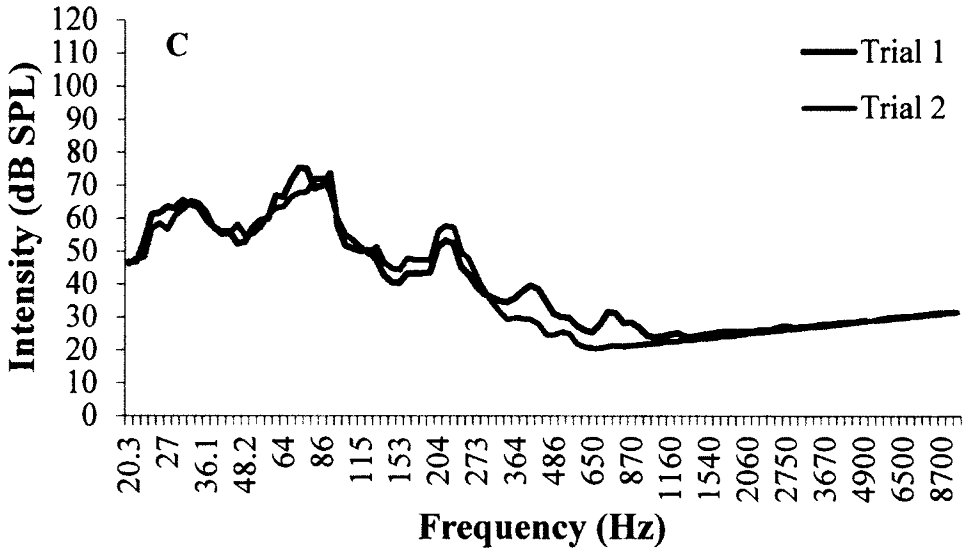
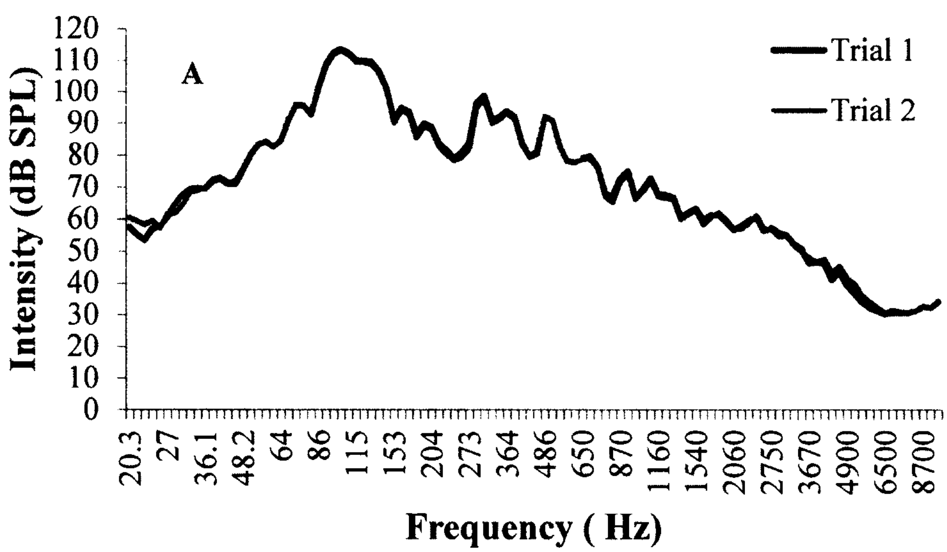


Figure 6. SPL as a function of frequency using the 3M Littmann Electronic Stethoscope Model 3200 amplified stethoscope for (A) heart, (B) lung, and (C) bowel sounds.



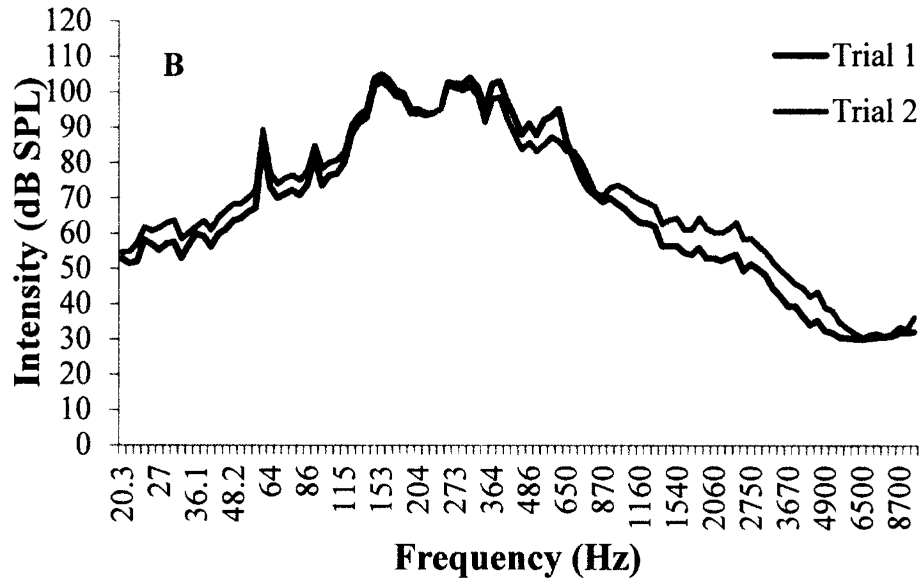


Figure 7. SPL as a function of frequency using Cardionics E-Scope II amplified stethoscope for (A) heart and (B) lung sounds.

The results showed that the primary frequencies affected for normal heart sounds were between 50 and 400 Hz; lung sounds were between 50 and 600 Hz, and bowel sounds were between 50 and 300 Hz. It was found that even when taking the ear tips out of KEMAR's ears between runs, that each trial showed nearly the same amount of SPL at the same frequencies for each sound. For the Sprague unamplified stethoscope, essentially the same amount of SPL was produced for all three bodily sounds (30 to 40 dB SPL; see Figure 1). For the Littmann Cardiology III unamplified stethoscope, approximately 80 to 90 dB SPL was produced when listening for normal heart and lung sounds as compared to bowel sounds, which showed about 25 to 30 dB SPL (see Figure 2). For the Littmann Classic II SE unamplified stethoscope, the most SPL was visualized when listening to bowel sounds (approximately 50 to 60 dB SPL) while the SPL for the heart and lung sounds was comparable (approximately 20 to 30 dB SPL; see Figure 3).

Results for the amplified stethoscopes generally showed higher SPL values when compared to SPL values for the unamplified stethoscopes. For the Philips amplified stethoscope, approximately 60 to 70 dB SPL was produced when listening to normal heart sounds whereas normal lung sounds revealed an SPL between at approximately 70 to 90 dB SPL. When listening to normal bowel sounds with the Phillips amplified stethoscope, an SPL between 40 and 55 dB SPL was produced (see Figure 4). For the Littmann Model 3200 amplified stethoscope, the SPL produced when listening to heart sounds was between 50 and 75 dB; normal lung sounds showed approximately 50 to 95 dB SPL. When listening to normal bowel sounds, SPL produced was between 55 and 70 dB SPL. Lastly, the E-Scope II produced the most SPL for normal heart and lung sounds between 80 and 110 dB SPL. The acquired E-Scope II did not provided a mode to listen to bowel sounds.

Comparison of Stethoscopes

Furthermore, the two trials (from 20-10,000 Hz) were averaged for each stethoscope and body sound to determine a mean curve for each stethoscope and body sound. Figures 8-10 show average SPL values as a function of frequency for each stethoscope for heart, lung, and bowel sounds. As mentioned before, previous research indicates that typical heart sounds range from 20 to 660 Hz (Callahan, 2007); normal breathing ranges from 150 to 1,000 Hz (Callahan, 2007), and normal bowel sounds are reported from 100-1,000 Hz (Nursing, 2000). This study revealed, the most SPL produced for normal bowel sounds was between 50 and 300 Hz; for normal heart sounds the range was between 50 and 250 Hz, and normal lung sounds ranged from 50 and 500 Hz. Therefore, for Figures 8-10, the following frequencies were chosen to compare unamplified and amplified stethoscopes: heart (20 to 700); lung (20 to 1,000), and bowel (25 to 1,000) sounds Due to the low frequency nature of the normal body sounds, it was not imperative that frequencies above 1,000 Hz be included.

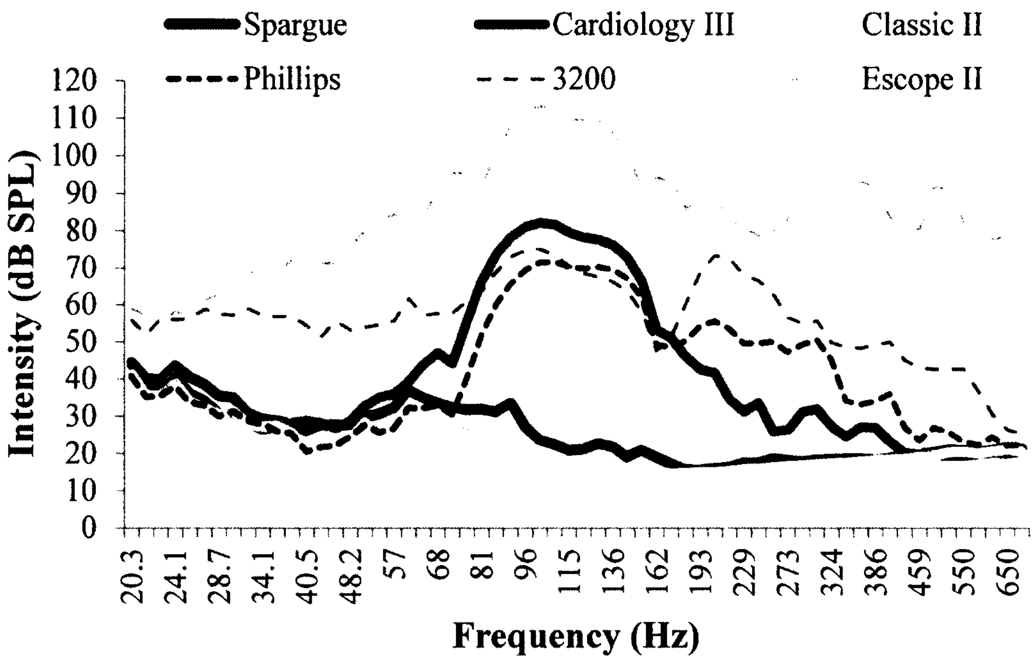


Figure 8. SPL as a function of frequency for heart sounds for six stethoscopes (three unamplified and three amplified).

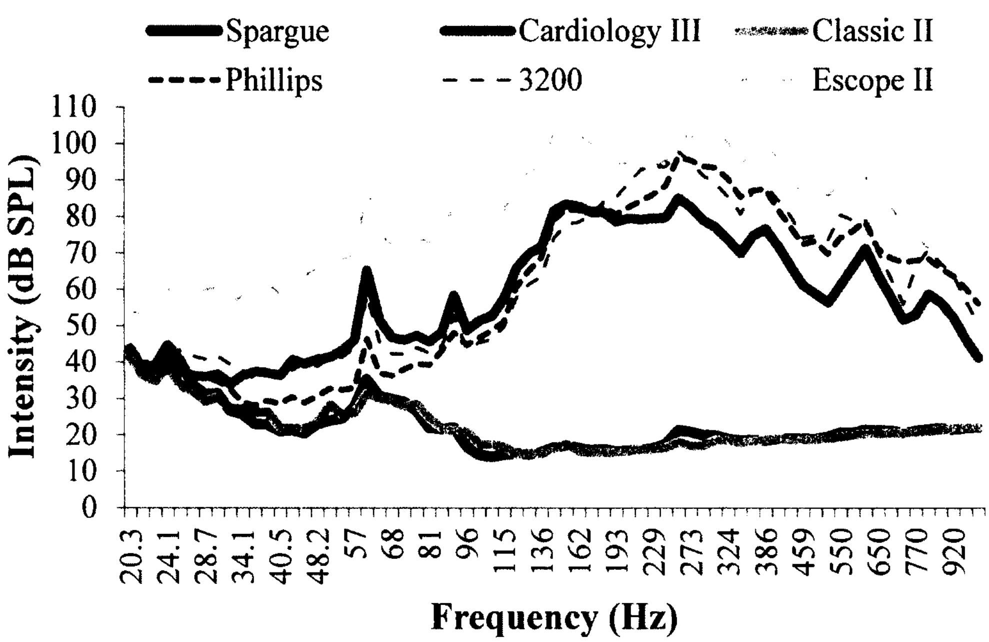


Figure 9. SPL as a function of frequency for lung sounds for six stethoscopes (three unamplified and three amplified).

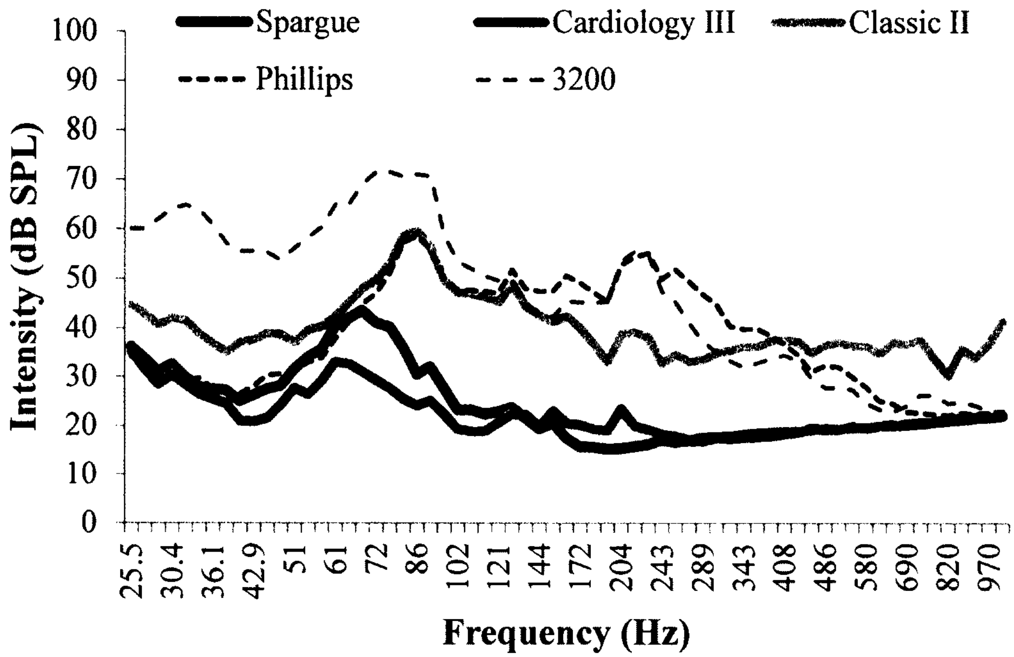


Figure 10. SPL as a function of frequency for bowel sounds for five stethoscopes (three unamplified and three amplified). Note: E-Scope II was not used due to inability to use a bell for bowel sounds.

For heart sounds, descriptive statistics showed the unamplified stethoscope that provided the most SPL was the Littmann Cardiology III with a peak SPL of 82 dB SPL. In comparison, the Littmann Classic SE and the Sprague were comparable in SPL with the peak values at 31 and 33 dB SPL, respectively. Moreover, amplified stethoscopes showed that the E-Scope II provided the most SPL with a peak at 113 dB SPL. The Littmann Model 3200 provided the next highest SPL for amplified stethoscopes with the peak SPL seen at 75 dB while the Phillips amplified stethoscope provided the least amount of SPL with a peak SPL of 73 dB. It should be noted that the Littmann Cardiology III unamplified stethoscope provided slightly more SPL for heart sounds than the Littmann 3200 and Phillips amplified stethoscopes. These results suggest that the

Littman Cardiology III is the best unamplified stethoscope for practitioners to use, even surpassing the SPL produced by some amplified stethoscopes. Furthermore, in terms of amplified stethoscopes, the recommended stethoscope would be the E-Scope II, at least when listening to *normal* heart sounds.

For lung sounds, the unamplified stethoscope that provided the most SPL was the Littmann Cardiology III with a peak SPL of 85 dB while the Littmann Classic II SE and the Sprague unamplified stethoscopes produced similar SPL with the largest peaks at 31 and 32 dB SPL, respectively. In regards to the amplified stethoscopes for lung sounds, the E-Scope II again produced the most SPL with a peak of 104 dB SPL. The Littmann 3200 and Phillips stethoscopes provided similar SPL with a peak value of 96 and 97 dB SPL, respectively. For those practitioners listening for lung sounds looking for an unamplified stethoscope, the Littmann Cardiology III would be the best choice. This stethoscope's SPL is only slightly surpassed by the SPL of several of the amplified stethoscopes tested. These results further suggest that for practitioners with and without hearing impairment looking for an amplified stethoscope for lung auscultation, consideration should be given to the E-Scope II.

For bowel sounds, the unamplified stethoscope that provided the most SPL was the Littmann Classic II SE with a peak SPL of 59 dB. The Littmann Cardiology provided the next highest SPL with the peak observed at 43 dB SPL, and the Sprague produced the least amount of SPL with a peak of 29 dB SPL. When comparing amplified stethoscopes for bowel sounds, there were only two stethoscopes measured due to the E-Scopes inability to convert to a bell. The amplified stethoscope that provided the most SPL was the Littmann 3200 with a peak SPL of 71 dB while the Phillips amplified stethoscope produced an SPL of 57 dB. It should be noted that the Littmann Classic II SE provided more SPL for bowel sounds than the Phillips amplified stethoscope. Based on these results, the best unamplified stethoscope for diagnosis of *normal* bowel sounds would be the Littmann Classic II SE. Furthermore, for practitioners with and without hearing loss wanting to assess bowel sounds with an amplified stethoscope, the Littmann Model 3200 would be recommended.

In summary, when looking at unamplified stethoscopes and listening to normal heart and lung sounds, the unamplified stethoscope that should be considered is the Littmann Cardiology III. For normal bowel sounds, the stethoscope that should be considered is the Littmann Classic II SE. When looking at amplified stethoscopes and normal heart and lung sounds, the stethoscope that should be considered is the E-Scope II The amplified stethoscope that should be considered when listening to normal bowel sounds is the Littmann Model 3200. Overall, when considering an unamplified stethoscope for general auscultation, a practitioner should consider the Littmann Cardiology III unless they are a specialist which requires particular attention to bowel sounds. This stethoscope, in some cases, provided more SPL than some of the amplified stethoscopes tested in this study. For those considering an amplified stethoscope for general auscultation, the E-Scope II should be considered.

Chapter V

Discussion

The purposes of the current study were as follows: 1) to determine the effect of stethoscope type (unamplified versus amplified) on SPL production and 2) to compare amplified stethoscope performance when listening to normal body sounds. A total of six stethoscopes (three unamplified and three amplified) were used in the study. Each stethoscope was used to measure the SPL produced in KEMARs ears for normal heart, lung, and bowel sounds. The average of two trials was used for data analysis. Furthermore, individual data analysis along with previous research showed that the frequencies of interest for normal heart sounds were from 20 to 700 Hz; for normal lung sounds were between 20 and 1,000, and for normal bowel sounds were from 25 to 1,000 Hz. These frequencies were plotted to show the overall/peak SPL of each stethoscope (see Figures 8-10).

As stated previously, the first purpose of the present study was to determine the effect of stethoscope type (unamplified versus amplified) on SPL production. The results revealed that the amount of SPL produced was somewhat affected by type of stethoscope. For example, the SPL of the Littmann Cardiology III unamplified stethoscope exceeded that of the Littmann Model 3200 and Philips amplified stethoscopes when listening to heart sounds. However, two of the unamplified stethoscopes (Littman Classic II and Sprague) produced SPLs much less than all the other stethoscopes. The E-Scope II (amplified), as expected based on the nature of amplified stethoscopes, produced more SPL than all other scopes when listening to heart sounds.

For normal lung sounds, the Littmann Cardiology III was also very close in SPL production to the Littmann 3200 and Phillips amplified stethoscopes, exceeding their SPL at certain frequencies. It, however, did not exceed SPL produced by the E-Scope II. Furthermore, like for normal heart sounds, there were two unamplified stethoscopes (Littman Classic II SE and Sprague) that produced SPLs much less than all stethoscopes.

For normal bowel sounds, the Littmann Classic II unamplified stethoscope produced similar SPLs when compared to the Phillips amplified stethoscope. However, the Littmann Classic II did not produce SPLs near that of the Littmann Model 3200 amplified stethoscope. Furthermore, like for normal heart and lung sounds, it was found that two unamplified stethoscopes (Sprague and Littmann Cardiology III) produced SPLs much less than all others.

Results for the unamplified stethoscopes were expected based on previous research. First, it was expected that the unamplified stethoscopes would provide less SPL than the amplified stethoscopes due to the electronic nature of amplified stethoscopes. It was also expected that the Littmann Cardiology III stethoscope would produce more SPL that the other unamplified stethoscopes as this stethoscope is preferred among practitioners. For example, Grenier et al. (1998) found after evaluating amplified and unamplified stethoscopes that practitioners preferred the Littmann Cardiology III mostly due to the introduction of ambient noise by amplified stethoscopes, their lack of sensitivity to impact, manipulation, and the inability to have standard bell and diaphragm filtering. Likewise, Abella et al. (1992) found that the Littmann Cardiology II stethoscope provided the most stable performance in attenuating outside noise. Furthermore, results for the amplified stethoscopes were expected based on previous results that showed the E-Scope II provided the most SPL for heart and lung sounds but was limited when it came to bowel sounds. The Littmann Model 3200 provided the most SPL for bowel sounds. In agreement, Gu et al. (2010) found that when using the E-Scope II, practitioners were able to identify normal body sounds 78% of the time.

In relation to the comparison of unamplified versus amplified stethoscopes, the results were somewhat expected. Unamplified stethoscopes should not provide additional amplification to the sounds being assessed. Due to this, we did not expect the SPL of any unamplified stethoscope to exceed that of an amplified stethoscope. Therefore, we did not expect the SPL of Littman Cardiology III (unamplified) stethoscope to surpass that of two of the amplified stethoscopes. On the other hand, there has been previous research that showed unamplified stethoscopes preform the same as amplified stethoscopes. For example, Iversen and colleagues (2005) found that when comparing the Littmann Model 400 (amplified) and the Littmann Classic II (unamplified) stethoscopes, there was no difference in the practitioner's ability to diagnose sounds. Likewise, Hoyte et al. (2005) found that there were no mean differences when listening to and diagnosing sounds using amplified and unamplified stethoscopes. Additionally, Dolan et al. (2001) found that practitioners with normal hearing preferred to listen to amplified stethoscopes because they preferred to listen at levels that the unamplified stethoscope could not achieve.

Stethoscopes and Practitioners with Normal Hearing

For the practitioner with normal hearing, it is assumed that an unamplified stethoscope provides adequate SPL for diagnostic purposes, as these are the types of stethoscopes typically chosen by practitioners with normal hearing. Based on the current study, the best unamplified stethoscope to use when listening to and diagnosing normal heart and lung sounds is the Littmann Cardiology III; for heart sounds, this stethoscopes appears to provide the most SPL between 50 and 250 Hz. For lung sounds, this stethoscope appears to provide the most benefit between 50 and 500 Hz. Furthermore, when listening to and diagnosing bowel sounds the unamplified stethoscope providing the most SPL is the Littman Classic II SE; the most SPL is seen 50 and 300 Hz. In short, for practitioners with normal hearing looking to use a traditional unamplified stethoscope, the results for this study suggests that the best stethoscope for general assessment would be the Littmann Cardiology III. However, for a practitioner who primarily assesses bowel function (e.g., gastroenterologist), the Littmann Classic II SE would be the best stethoscope to utilize. Moreover, even those with normal hearing may benefit from the amplification provided by the amplified stethoscope when in a noisy clinic.

Stethoscopes and Practitioners with Hearing Loss

In agreement with Atcherson (2010), this research revealed that those practitioners with primarily high frequency hearing loss could still practice with a traditional unamplified stethoscope. However, they may find difficulty when the clinic environment is noisy. For those practitioners with low frequency hearing loss, however, an amplified stethoscope would be most beneficial. When comparing the results of the amplified stethoscopes, the E-Scope II produced the most SPL for normal heart and lung sounds. For normal heart sounds, this stethoscope appears to provide the most SPL between 50 and 250 Hz and produced an approximate SPL of 31 dB more the next loudest amplified stethoscope, the Littmann Model 3200 stethoscope. For normal lung sounds, the E-Scope II appears to provide the most SPL between 50 and 500 Hz and produced a SPL of 20 dB more than the next loudest stethoscope, the Littmann Model 3200. For normal bowel sounds, maybe due to the limitation of the provided E-Scope II not having a bell, the Littmann Model 3200 produced the most SPL between 50 and 300 Hz, and was approximately 6 dB louder than the Phillips amplified stethoscope.

In a typical diagnostic hearing assessment for listeners with suspected hearing loss, octave frequencies between 250 and 8,000 Hz are tested. Therefore, due to the standard measure of hearing thresholds, it is often difficult to determine if the practitioners hearing is normal at frequencies to hear some bodily sounds. For example, in the current study the unamplified stethoscope (Littmann Cardiology III) and amplified stethoscope (E-Scope II) producing the most SPL for heart and lung sounds showed the most SPL between 50 and 250 Hz (heart) and 50 and 500 Hz (lung). Likewise, the unamplified stethoscope (Littmann Classic II SE) and amplified stethoscope (Littmann 3200) producing the most SPL for bowel sounds showed the most SPL between 50 and 300 Hz. Due to standard audiometric testing not being completed below 250 Hz, audiologist cannot speak to hearing sensitivity for practitioners at many of the important frequencies for measuring normal heart, lung, and bowel sounds. One way to somewhat overcome this challenge would be to measure hearing sensitivity at 125 Hz on patients that reported regular stethoscope use. It should be noted, however, that Atcherson et al. (2015) points out that most body sounds are broad band in nature, thus allowing more area of the cochlea to be stimulated and possibility audible to the listener. This information begs the question could all practitioners benefit from an amplified stethoscope to ensure adequate diagnosis of low level, low frequency body sounds?

For patients with hearing loss, the used of a stethoscope can become challenging. Fit can become a hassle when trying to use both a hearing instrument as well as the ear tips of the stethoscope. The dual pieces in the ear can cause excess pressure in the canal that over time can cause pain in the canal. Also, if not coupled properly, accuracy of the sounds heard could be compromised. The key for accurate auscultation for those wearing hearing aids and using a stethoscope, whether amplified or unamplified, is appropriate fit (Bankaitis, 2010). Moreover, hearing aids typically amplify frequencies sounds and are verified from 250 to 8000 Hz with high frequency roll off occurring around 4000 Hz. This does not encompass the low frequencies of interest when measuring normal heart, lung, and bowel sounds. Thus, similar to being unable to ensure those with normal hearing are accurately interpreting these sounds, there is no way to know if those with low frequency hearing loss are receiving enough benefit from hearing aids to appropriately hear these sounds.

Another option could be for the patient to remove their hearing instrument during assessment and use an amplified stethoscope. Insertion of the hearing instrument would then be required to continue the appointment with the patient once assessment was completed. This avoids the potential inaccuracy caused by inappropriate coupling and the pressure put on the ear canals; however, this introduces the inconvenience of removal and reinsertion of hearing instruments, potential introduction of bacteria to the practitioners hearing instruments, and potential for misplacement of the instruments (Bankaitis, 2010).

Conclusions and Future Research

In summary, the current research found that for practitioners with normal hearing or high frequency hearing loss, an unamplified stethoscope would suffice for appropriate diagnostics of typical body sounds. Specifically, those practitioners assessing heart and lung sounds regularly should consider the Littmann Cardiology III and those primarily assessing bowel sounds should consider the Littmann Classic II SE. In regards to amplified stethoscopes, practitioners with normal hearing as well as all degrees of hearing loss can benefit from the amplification provided, especially when in a busy or noisy clinic environment. Specifically, those practitioners primarily assessing heart and lung sounds should consider the E-Scope II and those primarily assessing bowel sounds should consider the Littmann Model 3200.

Future research should be conducted using abnormal bodily sounds to determine the frequencies of interest and SPL produced by stethoscopes for these sounds. Future research could also determine how the stethoscopes preform on a human ear rather than using KEMAR. This information would determine if the SPL produced using KEMAR was similar to that of the human ear. Research could also be conducted using practitioners with hearing loss who wear hearing instruments to determine how sounds would be produced with the use of hearing instruments. This research could provide practitioners with hearing loss insight on which stethoscope couples and produces the most SPL with their instrument style. Additionally, research could be completed with different stethoscopes, both unamplified and amplified, and compared to the results found in this study to determine if another stethoscope on the market provided more SPL than those tested in the current study.

Appendix A

IRB Exemption Letter

LOUISIANA TECH
UNIVERSITY

OFFICE OF UNIVERSITY RESEARCH

EXEMPTION MEMORANDUM

TO:	**Ms. Jeni Abrams and Dr. Melinda Bryan**
FROM:	**Dr. Stan Napper, Vice President Research and Development** **san@latech.edu**
SUBJECT:	**HUMAN USE COMMITTEE REVIEW**
DATE:	**May 13, 2016**
TITLE:	**Acoustical Properties of Amplified and Unamplified Stethoscopes When Examining Typical Body Sound**
Human Use Study	**HUC 1436 Exempt**

Thank you for submitting your Human Use Proposal to Louisiana Tech's Institutional Review Board. It has been determined that your study meets the requirements for exemption as it does not involve human subjects, but an acoustic research instrument/manikin to test hearing aids and other electroacoustic devices.

If you have any questions, please contact Dr. May Livingston at 257-5066 or 257-2292.

Appendix B

Instruction for Running National Instruments Software

Sound and Vibration Assistant
Settings for Measurements
Using KEMAR

1) Insert stethoscope ear tips to KEMAR's ears and chestpiece to speaker pad.
2) Open sound and vibration assistant.
3) Add step
   a) Acquire signal
      i. DAQmx acquire
      ii. Analong input
      iii. Sound pressure
   b) Under configuration; channel settings
      i. Choose Dev1/aio
   c) Sound pressure setup; settings
      i. Max level (dB)= 100
      ii. Scaled units= custom
      iii. Sensitivity= 10.5
      iv. Iex source= internal
      v. Iex value (A)= 2m
      vi. Sensitivity units= mv/Pa
      vii. Terminal Configuration= Pseudodifferential
      viii. dB reference= 20u
      ix. Custom scaling= linear
   d) Timing Settings
      i. Acquisition mode= continuous samples
      ii. Samples to read= 25000
      iii. Rate= 25k
4) Add Step
   a) Analysis
      i. Frequency domain measurements
      ii. Octave analysis
      iii. Input= sound pressure
      iv. Configuration
      v. Bandwidth= 1/12 octave
      vi. Weighting= linear
      vii. Frequency range= low frequency: 20 high frequency= 10000
      viii. Averaging= linear
      ix. Recording options= choose sound pressure
5) Push play for sound (heart, lung, bowel)
6) Click run to collect data
7) Click stop after 30 seconds
8) Add step
   a) Load/save signals
   b) Save to ASCII/LVM
9) Copy and paste X/Y values to .txt file
10) Delete Save to ASCII/LVM step

11) Repeat Steps 1, 6, 7 and 8 for lung and bowel sounds
12) Export data to Excel

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