AN ABSTRACT OF THE THESIS OF

Sayaka Uematsu for the degree of Master of Science in Comparative Health Sciences presented on December 4, 2023.

Title: Effect of Audible Static on Blood Pressure Measurement by Doppler Ultrasound Sphygmanometry in Cats

Abstract approved: ______________________________________________________

Stacie Summers

Systemic hypertension, a persistent elevation in systemic arterial blood pressure (BP), is a well-recognized disorder in cats. Failing to diagnose it accurately could lead to organ damage or unnecessary lifelong therapy. Doppler ultrasonic flow detectors are commonly used for indirect BP measurements in cats. However, whether the audible static from these devices falsely increases BP readings in cats due to causing stress or fear remains unclear. The use of headphones is recommended during BP measurement to potentially reduce stress in cats by minimizing noise and enhancing the clarity of pulse signals for better detection by operators. However, the specific benefits of this practice have not been evaluated in cats. Additionally, current guidelines recommend a series of BP readings while excluding the initial measurement for accurate BP measurement. However, ambiguity persists regarding the comparability between the initial BP reading and the subsequent average of readings. The objective of this study was to determine whether the use of headphones during Doppler ultrasonic sphygmanometry alters BP measurements in conscious cats. Secondary objectives included examining whether headphones affected the duration of BP measurements and assessing the difference between initial and subsequent BP readings in these cats. We hypothesized that when veterinary professionals wore headphones during BP measurements, it could potentially reduce the average
BP readings in conscious cats by eliminating audible static noise. It was also hypothesized that the use of headphones could reduce the time needed for BP measurements. Furthermore, without headphones, initial BP readings were expected to be higher compared to subsequent measurements due to transient situational hypertension.

To evaluate this, we conducted a randomized crossover study. Our study enrolled 32 healthy client-owned cats over a year old. Young adult cats were classified as those aged 1–6 years, while mature adult/senior cats were categorized as those aged ≥7 years. BP measurements were taken twice, 14 days apart, with and without a veterinarian wearing headphones to eliminate audible static to the cat. Physiologic parameters including heart rate (HR), respiratory rate (RR), body temperature, Fear Anxiety and Stress (FAS) score were recorded after the BP measurements. Additionally, the time taken to measure BP was documented. A linear mixed-effects model was used to compare the impact of wearing headphones on BP measurement. Pearson’s weighted correlation analysis was used to assess the relationship between BP with HR, RR and FAS score. To compare FAS scores, body temperature, HR, RR, and the initial BP reading (BP 1) and the average of subsequent readings (BP 2–6) with and without headphones, paired t-test or Wilcoxon matched paired signed rank tests were used.

There was no difference in BP measurements with or without headphones in call cats. However, the use of headphones led to lower BP readings, especially in young adult cats. 47% of cats showed an average BP measurement at least 10 mmHg higher when headphones were not used, with the majority (73%) being young adult cats. There was no difference in the time taken for BP measurement, whether headphones were used or not. However, BP measurement without headphones took approximately half a minute longer for all cats including both young adult and
mature adult/senior cat age groups. There was no difference between the initial BP reading (BP 1) and the average of subsequent readings (BP 2-6).

Our study suggests that using headphones during BP measurement with Doppler sphygmomanometry might mitigate situational hypertension, particularly in young adult cats. These findings highlight the importance of consistent use of headphones when comparing serial BP measurements in cats. Moreover, current guidelines might benefit from re-evaluation regarding the potential inclusion of the initial BP reading.
Effect of Audible Static on Blood Pressure Measurement by Doppler Ultrasound Sphygmomanometry in Cats

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Sayaka Uematsu

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APPROVED:

Major Professor, representing Comparative Health Sciences

Dean of the College of Veterinary Medicine

Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Sayaka Uematsu, Author
ACKNOWLEDGEMENTS

I would like to extend my heartfelt gratitude to my supervisor, Dr. Stacie Summers, for her invaluable guidance and support throughout the completion of this research project. Additionally, I would like to express my sincere appreciation to Dr. Jessica Quimby for her valuable insights and contributions.

A special thank you goes out to all the dedicated cat owners who generously volunteered their feline companions to be included in this study. Without their participation, this research would not have been possible.
CONTRIBUTION OF AUTHORS

Uematsu S - Trainee primary investigator, involved in study design, data acquisition, analysis of data, manuscript drafting, editing and publication.

Summers S – Supervising primary investigator for Uematsu S, involved in the study design, expenditure of grant resources, data acquisition, analysis of data, manuscript editing and publication.

Keys D – Statistician, involved in analysis of date.

Quimby J – Co-investigator, involved in manuscript editing and publication.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chapter 1 – Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Chapter 2 – Literature Review</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Chapter 3 – Materials and Methods</td>
<td>7</td>
</tr>
<tr>
<td>3.1.</td>
<td>Animals</td>
<td>7</td>
</tr>
<tr>
<td>3.2.</td>
<td>Study design</td>
<td>7</td>
</tr>
<tr>
<td>3.3.</td>
<td>Statistical analysis</td>
<td>9</td>
</tr>
<tr>
<td>4.</td>
<td>Chapter 4 – Results</td>
<td>11</td>
</tr>
<tr>
<td>4.1.</td>
<td>Demographic characteristics</td>
<td>11</td>
</tr>
<tr>
<td>4.2.</td>
<td>Prevalence of hypertension and headphone-related BP variation</td>
<td>11</td>
</tr>
<tr>
<td>4.3.</td>
<td>Comparison of BP measurements and associated parameters with and without headphones</td>
<td>12</td>
</tr>
<tr>
<td>4.4.</td>
<td>Impact of headphone use on BP measurement stratified by age groups</td>
<td>12</td>
</tr>
<tr>
<td>4.5.</td>
<td>Effect of headphone use on time required for BP measurement in cats of different age groups</td>
<td>13</td>
</tr>
<tr>
<td>4.6.</td>
<td>Comparative analysis of initial and subsequent BP measurement with and without headphones</td>
<td>15</td>
</tr>
<tr>
<td>5.</td>
<td>Chapter 5 – Discussion</td>
<td>16</td>
</tr>
<tr>
<td>6.</td>
<td>Chapter 6 – Conclusion</td>
<td>20</td>
</tr>
<tr>
<td>7.</td>
<td>Bibliography</td>
<td>21</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1 – Study design</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2 – Dot plot of the average blood pressure measurement</td>
<td>14</td>
</tr>
</tbody>
</table>
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1 – Blood pressure measurements with and without headphones</td>
<td>14</td>
</tr>
<tr>
<td>Table 2 – The average time required to collect blood pressure measurements</td>
<td>15</td>
</tr>
<tr>
<td>Table 3 – The initial blood pressure and the subsequent average blood pressure measurements</td>
<td>15</td>
</tr>
</tbody>
</table>
DEDICATION

I would like to dedicate my thesis to my incredibly supportive husband, Bill, and my beloved grandmother, Tomo. To my parents, Kaz and Mari, who have believed in me and offered constant encouragement throughout my academic journey. I am forever grateful for your love and support.
Chapter 1 – Introduction

Systemic hypertension is a persistent pathological increase in systemic arterial blood pressure (BP), characterized by sustained elevations in the systolic BP. This condition is well-recognized in cats and becomes more common with advancing age and the presence of disease.\(^1,2\) Pathological hypertension can be a result of underlying disease like chronic kidney disease and/or hyperthyroidism,\(^1,3\) as well as medications or toxins known to induce hypertension, which is referred to as secondary hypertension.\(^3-5\) It can also occur without an identifiable cause, termed idiopathic hypertension.\(^6\) The diagnosis and treatment of secondary and idiopathic hypertension should only occur after ruling out transient BP increases caused by factors such as excitement, fear, stress, anxiety, or pain, which are known as situational hypertension.\(^6,7\) Failing to distinguish situational hypertension from pathological hypertension can lead to unnecessary lifelong treatment and potentially result in iatrogenic systemic hypotension.\(^6,7\) Conversely, failing to confirm the presence of pathological hypertension can result in target organ damage.\(^7\) Therefore, accurately diagnosing systemic hypertension is essential for reducing the risk of further medical complications.

BP can be directly measured via an intra-arterial catheter or indirectly through non-invasive devices involving a compressive cuff positioned on a limb or the base of the tail. While invasive BP measurement is considered the most accurate, it is not widely used due to its impracticality in regular clinical settings.\(^8,9\) Consequently, veterinarians commonly rely on indirect BP measurement, such as Doppler ultrasonic and oscillometric machines.\(^10,11\) The Doppler technique is preferred over the traditional oscillometric method due to its ability to provide accurate reading when used correctly.\(^7\) Doppler devices have been extensively used in feline medicine,\(^2,12\) with a study demonstrating their good correlation and accuracy when compared to direct BP assessment.\(^13\)
When employing the indirect Doppler method, an issue that can potentially distress and frighten the feline patient is the audible static noise that arises during the placement of the Doppler flow probe. This noise, when present during BP measurement, has the potential to startle the cat and create challenges in distinguishing pathological hypertension from situational hypertension. While there has been a recommendation for veterinary professionals to use headphones to mitigate this noise during BP measurement, this practice is not consistently implemented. An abstract reported that the utilization of headphones had no impact on BP measurements in cats. Nevertheless, the research did not consider the factor of age, and there was limited information provided regarding the practices used to standardize BP measurements.

Recent survey studies have identified challenges related to Doppler sphygmomanometry. Veterinarians noted that they perceived Doppler as slower to set up and distressing compared to traditional oscillometric machine. Additionally, many faced difficulties in detecting pulse signals with the Doppler, citing equipment-related obstacles. One survey indicated that only a limited number of veterinarians utilized headphones to alleviate noise during measurements, while another survey did not address the use of headphones. To our knowledge, there has been no specific study assessing the setup time differences between BP measurements taken with and without headphones in cats.

The American College of Veterinary Internal Medicine (ACVIM) and the American Association of Feline Practitioners (AAFP) developed and recently updated guidelines for the appropriate collection of indirect BP measurements in conscious cats. These guidelines involve steps such as acquainting the patient with the environment, equipment, and staff, ensuring correct patient and cuff positioning, using appropriately sized cuffs, and having a trained individual
conduct multiple measurements. The guidelines also recommend taking multiple BP measurements (a minimum of six) to enhance accuracy and disregarding the initial reading and averaging the subsequent measurements. While a prior study examined the impact of headphones on the variation between initial and subsequent BP readings in dogs, no similar evaluation has been conducted in cats.

Therefore, it is beneficial to conduct a more comprehensive examination of the potential advantages of utilizing headphones during Doppler BP measurements in cats, using a standardized study design that aligns with current guidelines and to consider age as a factor. The objective of this study was to determine whether the use of headphones during Doppler ultrasonic sphygmomanometry alters BP measurements in conscious young adult (1-6 years) and mature adults/senior (>7 years) cats. Secondary objectives included examining whether headphones affected the duration of BP measurements and assessing the difference between initial and subsequent BP readings in these cats. We hypothesized that when veterinary professionals wore headphones during BP measurements, it could potentially reduce the average BP readings in conscious cats by eliminating audible static noise, particularly those displaying signs of fear, anxiety, or stress. This would contrast with measurements taken without headphones. It was also hypothesized that the use of headphones could reduce the time needed for BP measurements. Cats could be more cooperative in a quieter environment, potentially resulting in shorter measurement times. Additionally, wearing headphones could enable operators to better discern pulse signals, leading to clearer and more precise readings. Furthermore, without headphones, initial BP readings were expected to be higher compared to subsequent measurements due to transient situational hypertension as observed in dogs.
Chapter 2 – Literature Review

Blood pressure (BP) can be measured through two approaches: directly using intra-arterial catheterization or indirectly with non-invasive devices that incorporate compressive cuffs placed on a limb or the tail base. Invasive blood pressure (IBP)/direct blood pressure (DBP) measurement is considered the most accurate method, but it is not commonly used due to its impracticality in everyday clinical settings. It necessitates specialized skills, advanced medical equipment, and can cause discomfort for the patient. Thus, IBP measurements, acquired through non-invasive methods like Doppler ultrasonic sphygmomanometry or oscillometry, are more commonly used in veterinary medicine for conscious pets. Studies have aimed to establish accurate reference intervals for systolic blood pressure (SBP) in healthy conscious cats, using methods such as intra-arterial, Doppler, and oscillometric equipment. While precise reference intervals for each equipment remain elusive, various studies suggest that traditional oscillometry measurements in conscious cats are less accurate compared to Doppler measurements. This discrepancy is particularly evident in underestimating SBP, especially at higher values. Conversely, both Doppler and DBP measurement methods exhibit good accuracy, especially when conducted by a well-trained observer in a specific location, such as the median artery in the forelimb, and when five consecutive BP readings are averaged.

Ensuring the accuracy of non-invasive blood pressure (NIBP) measurements is an essential requirement before their use. However, interpreting SBP in cats can be complex due to situational hypertension, triggered by stress or excitement, commonly experienced during veterinary clinic visits. The precise prevalence of situational hypertension remains elusive, although a recent study indicated that at least 5.4% of conscious cats aged over 10 years, classified as mature adult/senior, experienced it. Although routine BP measurement is generally
recommended for older cats due to the anticipation of situational hypertension being more common in younger cats, the prevalence of this condition among young adult cats remains unknown.  

The American College of Veterinary Internal Medicine (ACVIM) and the American Association of Feline Practitioners (AAFP) developed and recently updated guidelines for appropriately collecting indirect BP measurements in cats.  

These include acclimatizing the patient to the room, equipment, and personnel; proper patient positioning and crystal placement; using an appropriately sized cuff, and having an experienced individual collect repeated measurements. It is also advised to gather at least six consecutive readings, excluding the initial one, and then calculate the average of the subsequent five readings. To ensure the collection of accurate BP readings and the reduction of situational hypertension, it is essential to employ these techniques.

Recent survey studies conducted among veterinarians have highlighted a number of challenges associated with the use of Doppler. The majority of veterinarians surveyed expressed consensus that this method tends to induce more patient distress and involves a lengthier setup and measurement time when compared to oscillometric BP devices. Furthermore, veterinarians commonly reported equipment-related barriers, with 71.6% citing difficulties in hearing the pulse signal for Doppler users. When utilizing the indirect Doppler technique, one factor that might induce stress and anxiety in the patient is the audible static noise produced while positioning the Doppler flow probe. This noise during BP measurement could potentially startle the cat and complicate the differentiation between pathological hypertension from situational hypertension. There is an option to wear headphones to eliminate the noise during BP measurement. The use of headphones by the veterinary professional has been recommended, although not routinely used.
A previous study that assessed the effect of headphone use on indirect Doppler flow systolic BP measurements in dogs recommended the utilization of headphones.\textsuperscript{19} In this study, the initial BP measurement exhibited an increase when conducted without the use of headphones; however, this discrepancy did not persist for the mean BP measurements taken between the 2nd and 6th readings.\textsuperscript{19} This study highlights the importance of employing headphones during BP measurements, as it effectively mitigates the higher BP 1 readings and enhances the overall accuracy of the results. This study compared the time needed to obtain BP readings with and without headphones in dogs, revealing no apparent difference.\textsuperscript{19} To the best of our knowledge, there has not been any study conducted to ascertain the time needed for obtaining readings with and without headphones in conscious cats.

An abstract presented at a conference investigated the impact of headphones in conscious cats and concluded that their use did not lead to any changes in BP measurements taken using the indirect Doppler technique.\textsuperscript{15} However, the participants had a diverse range of health conditions, including those with normal kidney function, as well as mild and stable chronic kidney disease (CKD) at International Renal Interest Society (IRIS) Stage II or III, in addition to cats diagnosed with hypertension or hyperthyroidism. Although the cats included in the study were reportedly stable and well managed with medications, the actual impact of headphones on BP measurements in cats remains uncertain due to the possible interference of underlying disease processes in the recorded readings.

A knowledge gap exists in evaluating the audible static noise in BP measurements obtained via Doppler ultrasonic sphygmomanometry in conscious cats, as well as in exploring the potential influence of this static noise on the ease of setting up the Doppler machine.
Chapter 3 – Materials and Methods

3.1 Animals

Privately owned cats were enrolled at the Oregon State University, College of Veterinary Medicine Veterinary Teaching Hospital between November 2021 and March 2022. Prior to enrollment, the owners provided informed consent and details about their cats’ health status, medication history within the past 3 months, and known medical conditions. To be eligible for participation, cats had to be at least 1 year old. Cats with a history of chronic illness or aggressive behavior requiring sedation during veterinary visits, as well as those receiving medications other than flea and tick preventatives or joint supplements, were excluded from the study. Young adult cats were classified as those aged 1–6 years, while mature adult/senior cats were categorized as those aged ≥7 years.36

3.2 Methods

A prospective crossover study design was used to assess the impact of noise elimination during blood pressure (BP) measurements using Doppler ultrasonic sphygmomanometry (Figure 1). Approval for the study was granted by the Institutional Animal Care and Use Committee (IACUC-2021-0218) at Oregon State University. The treatment order for cats in each age group (young adult cats and mature adult/senior cats) was randomized. The randomization process was conducted using an online research randomizer (randomizer.org).

The BP measurement was conducted twice, with a 14-day interval, following the guidelines specified in the AAFP Hypertension Educational Toolkit.7 A Doppler flow detector (Parks Medical Electronics) was utilized to measure BP, either with or without the veterinary
professional wearing headphones, based on the randomization order for each cat. All
measurements were carried out by a single veterinarian with assistance from the same handler.
Cats were directly taken to a private examination room from the parking lot, bypassing the
waiting room. A feline pheromone analog diffuser (Feliway Classic Calming Diffuser; Ceva
Animal Health) was used in the examination room. In the examination room, the carrier was
positioned on the floor, allowing a 10-minute acclimation period for the cat to adjust to the
environment before the BP measurement. The cat was permitted to exit the carrier before being
placed on an exam table with a non-skid surface. Alternatively, if the top of a hard-sided kennel
could be removed, BP measurements were conducted with the cat remaining in the carrier on the
exam table.

The veterinarian recorded a subjective score for Fear, Anxiety, and Stress (FAS) after BP
measurement, ranging from 0 for relaxation to 5 for severe signs of flight or aggression (FAS
score 0 = relaxed, 1 = subtle signs, 2–3 = moderate signs, 4=severe signs [flight/freeze/fret],
5=severe signs [flight/aggression]). The cat’s right front leg was used for BP measurement and
selected the cuff size to be 30–40% of the limb circumference. To prepare for the Doppler probe
placement, a small, cat-friendly clipper was used to shave the fur over the metacarpal artery, then
applied ultrasonic gel on the probe and placed it over the artery to detect the pulse. Six readings
were taken with the Doppler box positioned a foot away from the cat, ensuring consistent sound
levels for each measurement. The cuff was inflated near the heart level with minimal restraint,
employing a towel sprayed with a feline pheromone analog (Feliway Classic Calming Spray;
Ceva Animal Health) for gentle handling. Before recording, the cuff was inflated and deflated
twice to acclimate the cat. It was slowly inflated to 20–40 mmHg above the point where blood
flow sounds ceased. The average systolic BP was calculated from five readings, excluding the
first one. The same procedure was repeated in 14 days by the same veterinary professionals, maintaining consistency in cuff size, position, restraint techniques, and body position for BP measurement as per the AAFP Blood Pressure Form. Following the BP measurement, a physical examination was conducted, encompassing axillary body temperature, respiratory rate, heart rate, body and muscle condition scoring, and body weight evaluation. Subsequently, a non-dilated indirect fundoscopy was performed.

3.3 Statistical analysis

A predetermined sample size calculation conducted beforehand (https://statulator.com/SampleSize/ss2PM.html) indicated that including 14 cats would yield an 80% statistical power and maintain a significance level of 0.05 to detect a mean difference of 10 mmHg between pairs, assuming a standard deviation of 12 mmHg. Previously published blood pressure data in cats obtained through Doppler ultrasonic sphygmomanometry were used to estimate variability. Additional power analysis revealed that including 8 cats would result in an 80% statistical power, maintaining a significance level of 0.05 to detect a mean difference of half a minute between pairs.

Statistical analyses were conducted using SAS 9.4 and Prism version 9.5.1 (GraphPadSoftware). A linear mixed-effects model was developed to assess and evaluate the impact of wearing headphones on BP. Initially, the model incorporated fixed factors such as headphones, age group, an interaction between age group and headphones, sex, and period (first vs. second hospital visit), alongside sequence effects (i.e. AB vs. BA). Each cat had a random intercept. The Satterthwaite degrees of freedom method and REML estimation were employed. Evaluation of histograms and Q-Q plots of conditional model residuals confirmed adherence to the assumption
of normality. No significant effects were found for period (P=0.9), sequence (P = 0.4), or sex (P = 0.8); hence, these factors were excluded from the final model. Differences in marginal means were reported along with a 95% confidence interval (CI). Pearson’s weighted correlation analysis was used to examine the relationships between BP and heart rate, respiratory rate, and FAS scores. Additionally, the relationship between BP 1 and the average of BP 2-6 measurements for all cats, adult cats and senior cats were also examined by Pearson’s weighted correlation analysis. Based on data normality, either a paired Student’s t-test or Wilcoxon matched-pairs signed rank test was used to compare FAS score, body temperature, heart rate, respiratory rate, the duration needed to obtain BP measurements, and the difference between BP 1 and BP 2-6 average readings with and without headphones. A significance level of P < 0.05 was considered for all analyses.

**Figure 1.** Randomized crossover study design to compare the effects of eliminating audible static during Doppler sphygmomanometry.
Chapter 4 – Results

4.1 Demographic characteristics

Thirty-two cats were enrolled in the study with a median age of five years (ranging from 1 to 14 years), a median weight of 5.8 kg (ranging from 2.3 to 8 kg), and a sex distribution of 9 spayed females and 23 neutered males. The breeds included domestic shorthair (23 cats), British Shorthair (3 cats), domestic longhair (2 cats), and single representatives from Himalayan, Ragdoll, Siamese, and Tonkinese breeds. Among these cats, 18 were classified as young adults (median age: 3 years; range: 1-6 years) while 14 were considered mature adults/seniors (median age: 8 years; range: 7-14 years). Half of the cats (16) had their measurements initially taken with headphones, while the other 16 had measurements taken without headphones first. For 17 cats, the time taken for blood pressure (BP) measurements was recorded during both visits. All cats underwent a normal fundic examination.

4.2 Prevalence of hypertension and headphone-related BP variation

As per the guidelines provided by AAFP and ACVIM on hypertension, persistent hypertension (>160 mmHg) was observed in only one cat throughout the 14-day study duration. Among the remaining cats, eight out of 31 (26%) exhibited situational hypertension. Among these eight cats, four (2 adults and 2 seniors) showed elevated average BP readings (>160 mmHg) solely during the visit with headphones, while the other four (1 adult and 3 seniors) displayed elevated BP measurements exclusively during visits without headphones. Many cats had an average BP measurement that was at least 10 mmHg higher (≥10 mmHg: 15/32, 47%; ≥15 mmHg: 8/32, 25%; ≥20 mmHg: 5/32, 16%) when headphones were not worn compared with when headphones were used. When cats were grouped by age, 61% (11/18), 28% (5/18) and
22% (4/18) of young adult cats and 29% (4/14), 21% (3/14) and 7% (1/14) of mature adult and senior cats had 10 mmHg, 15 mmHg and 20 mmHg higher measurement, respectively, when headphones were not worn.

4.3 Comparison of BP measurements and associated parameters with and without headphones

The average BP measurements obtained with or without headphones in cats, and specifically young adult cats and mature adult/senior cats are summarized in Table 1 and represented in Figure 2. The average BP measurement did not significantly differ when using headphones compared with when not using headphones for all cats (P = 0.07; mean difference −7 mmHg; 95% CI −14 to 0.6) (Table 1). There was no difference in FAS score (with and without headphones: median 1, range 0–4, respectively; P = 0.4), body temperature (P= 0.4), heart rate (P = 0.5) or respiratory rate (P = 0.8) with and without headphones. There were no associations between the average BP measurement and the FAS score (r = 0.26, P = 0.2), heart rate (r= 0.33, P = 0.07) and respiratory rate (r = −0.26, P = 0.4).

4.4 Impact of headphone use on BP measurement stratified by age groups

When cats were categorized by age, the average BP measurement was lower (mean difference −11 mmHg; 95% CI −1.7 to −21.1) in adult cats when using headphones compared with when not using headphones (P = 0.02). For mature adult/senior cats, the use of headphones by the veterinary professional did not affect the average BP measurement (P = 0.7; Table 1). When evaluating all BP measurements (both with and without headphones), the average BP measurement was lower in adult cats compared with senior cats (mean difference −13 mmHg; 95% CI −3 to −23; P = 0.01).
4.5 Effect of headphone use on time required for BP measurement in cats of different age groups

The average time required for BP measurements in conscious cats, with and without headphones are summarized in Table 2. The time required to collect BP measurements increased by 23%, 18%, and 30% for all cats, young adult cats, and mature adult/senior cats, respectively, when headphones were not utilized. However, there were no differences observed in the time required for BP measurements all cats (mean difference, -0.5, 95% CI -0.3, -0.5; P = 0.16), young adult cats (mean difference -0.4, 95% CI -0.5, -0.8; P = 0.36) and mature adult/senior cats (mean difference, -0.6, 95% CI -0.4, -0.6; P = 0.07) when comparing measurements with and without headphones.

4.6 Comparative analysis of initial and subsequent BP measurement with and without headphones

The initial (BP 1) and the subsequent average of measurements (BP 2-6) obtained with and without headphones in cats are summarized in Table 3. There was a strong positive correlation between BP 1 and the average of BP 2-6 measurement when using headphones (r = 0.87, P < 0.001) and when not using headphones (r = 0.83, P < 0.001). When headphones were used, the initial BP measurement (BP1) was higher compared to the average of BP 2-6 readings (mean difference 4 mmHg; 95% CI 7, 6.5; P = 0.01). When BP1 and BP 2-6 were compared within age groups, a similar finding was appreciated for the young adult cats (mean difference, 5 mmHg; 95% CI 7.2, 7.7; P = 0.04) when headphones were used. Conversely, without headphones, the BP 1 was not different from BP2-6 in young adult cats (Table 3). For senior/mature adult cats, there were no differences observed between BP 1 and BP 2-6 measurements. This was consistent both with (mean difference, 3 mmHg, 95% CI 12.2, 12.4; P =
0.59) and without the use of headphones (mean difference, -2 mmHg, 95% CI -9.6, -11; P = 0.89).

**Table 1.** Blood pressure (BP) measurements obtained by Doppler sphygmomanometry when either using or not using headphones in all cats, young adult cats (aged 1-6 years) and mature adult and senior cats (aged ≥7 years)

<table>
<thead>
<tr>
<th></th>
<th>Headphones (mmHg)</th>
<th>Without Headphones (mmHg)</th>
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<tbody>
<tr>
<td>All Cats (n=32)</td>
<td>133 ± 18</td>
<td>141 ± 18</td>
</tr>
<tr>
<td>Young Adults (n=18)*</td>
<td>125 ± 15</td>
<td>137 ± 17</td>
</tr>
<tr>
<td>Mature Adult/Seniors (n=14)</td>
<td>143 ± 17</td>
<td>145 ± 19</td>
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</table>

Data are mean ± SD

*Group with a statistically significant difference in BP measurement when using headphones compared with when not using headphones (P < 0.05)

![Figure 2. Dot plot of the average blood pressure (BP) measurement (mmHg) in cats obtained by Doppler sphygmomanometry using headphones (closed circle) and not using headphones (open circle) in all cats (n = 32), and in young adult cats (n = 18) and mature adult and senior cats (n = 14). Lines connecting the dots signify paired samples from an individual cat.](image-url)
Table 2. The average time required to collect blood pressure (BP) by Doppler sphygmomanometry when either using or not using headphones in all cats, young adult cats (aged 1-6 years) and mature adult and senior cats (aged ≥7 years)

<table>
<thead>
<tr>
<th></th>
<th>Time with headphones (min)</th>
<th>Time without headphones</th>
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<tr>
<td>All cats (n=17)</td>
<td>2.1 ± 0.57</td>
<td>2.6 ± 0.95</td>
</tr>
<tr>
<td>Young adult (n=9)</td>
<td>2.2 ± 0.70</td>
<td>2.6 ± 0.36</td>
</tr>
<tr>
<td>Mature adult/senior (n=8)</td>
<td>2.0 ± 0.41</td>
<td>2.6 ± 0.77</td>
</tr>
</tbody>
</table>

Data are mean ± SD

Table 3. The initial blood pressure (BP 1) and subsequent average (BP 2-6) measurements obtained by Doppler sphygmomanometry when either using or not using headphones in all cats, young adult cats (aged 1-6 years) and mature adult and senior cats (aged ≥7 years)

<table>
<thead>
<tr>
<th></th>
<th>BP 1 (mmHg)</th>
<th>Mean of BP 2-6 (mmHg)</th>
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<tr>
<td>All Cats (n=32)</td>
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<tr>
<td>With headphones*</td>
<td>138 ± 19</td>
<td>137 ± 18</td>
</tr>
<tr>
<td>Without headphones</td>
<td>137 ± 19</td>
<td>133 ± 18</td>
</tr>
<tr>
<td></td>
<td>139 ± 20</td>
<td>141 ± 18</td>
</tr>
<tr>
<td>Young Adults (n=18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With headphones*</td>
<td>132 ± 16</td>
<td>131 ± 17</td>
</tr>
<tr>
<td>Without headphones</td>
<td>130 ± 15</td>
<td>125 ± 15</td>
</tr>
<tr>
<td></td>
<td>134 ± 18</td>
<td>137 ± 17</td>
</tr>
<tr>
<td>Mature Adult/Seniors (n=14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With headphones</td>
<td>145 ± 21</td>
<td>144 ± 18</td>
</tr>
<tr>
<td>Without headphones</td>
<td>147 ± 21</td>
<td>144 ± 21</td>
</tr>
<tr>
<td></td>
<td>1443 ± 17</td>
<td>145 ± 19</td>
</tr>
</tbody>
</table>

Data are mean ± SD

*Group with a statistically significant difference in BP measurement when using headphones compared with when not using headphones (P < 0.05)
Chapter 5 – Discussion

This study evaluated the effect of audible static on average BP measurements in conscious cats during Doppler ultrasonic sphygmomanometry. It compared measurements obtained with and without the veterinary professional wearing headphones. Overall, when considering all cats together, there was not a significant difference in average BP measurements between measurements taken with and without headphones. However, a trend indicating lower BP measurements was observed when headphones were used. This effect appeared to vary depending on the age groups of the cats. Specifically, we observed a significantly lower average BP measurement in young adult cats when the veterinary professional wore headphones, unlike mature adult/senior cats where no significant difference was detected.

Young cats seem to exhibit greater susceptibility to anxiety, particularly in stressful settings like veterinary clinics, which could potentially affect BP readings. Within our study cohort, approximately 26% of all cats experienced situational hypertension, with 10% accounted for by young adult cats. In young adult cats, when measuring BP without headphones, 61% showed minimum increase of 10 mmHg, with 28% demonstrating an increase of at least 15 mmHg, and 22% displaying an elevation of at least 20 mmHg compared to measurements taken with headphones. These findings imply that young adult cats are more predisposed to transient BP fluctuations, potentially due to being startled by external stimuli, including the audible static produced by Doppler sphygmomanometry. The guidelines recommend initiating annual BP measurement in healthy cats once they reach three years of age. Our study further indicates that young cats are more prone to situational hypertension, increasing the likelihood of false positive readings. Therefore, clinical considerations for measuring BP in young cats should be carefully evaluated.
Our findings indicated a higher average BP in mature adult/senior cats compared to young adult cats, aligning with previous studies.\(^{24,41}\) While studies in human medicine propose that age-related arterial stiffening contributes to systemic hypertension,\(^{42-44}\) no such phenomenon has been reported in cats. Further investigations are needed to explore this possibility in feline physiology. Another aspect to consider is the potential impact of age-related changes in auditory perception among cats. While progressive age related hearing loss has been demonstrated in dogs,\(^{45}\) the occurrence of similar auditory changes in cats lacks documentation in clinical studies to date. This unexplored aspect could be of relevance, especially considering the observed differences in the response to audible statics between young adult and mature adult/senior cats in our study. Further investigations focused on the auditory capabilities of aging cats might provide insights into how such sensory changes could influence their responses to environmental stimuli and consequently affect their physiological reactions during veterinary procedures. Unlike findings in other studies involving dogs\(^{24}\) and cats,\(^{2,9}\) our research did not find a correlation between sex and systolic BP.

Previous research has indicated that stress and anxiety-related behaviors in dogs and cats are linked to elevated BP.\(^{32,46}\) Moreover, stress has been shown to cause a temporary rise in BP in animal models.\(^{47}\) In humans, acute stress escalates BP by enhancing cardiac output and heart rate, without impacting total peripheral resistance. Additionally, acute stress in humans has been associated with increased levels of various hormones, including catecholamines, cortisol, vasopressin, endorphins, and aldosterone, providing a potential explanation for the increase in BP.\(^{48,49}\) Contrary to these findings, this study did not identify a significant correlation between BP and the FAS score. The FAS score remained consistent regardless of whether measurements were conducted with or without the use of headphones. The FAS score utilized in this study is a
subjective assessment system based on body positions to evaluate fear, anxiety, and stress, omitting vocalization as a behavioral indicator. This scoring system lacks validation and is likely to restrict the detection of subtle changes in demeanor due to its limited range. Considering the context, using a compliance score and video recordings to assess the effect of audible static noise on BP measurement might have been a more suitable measure than relying solely on the FAS score.

When examining the time needed for BP collection with and without headphones, our study identified no time difference in BP measurement, regardless of headphone use. This outcome aligns with earlier research in dogs, which similarly showed no time distinction in BP reading with or without headphones. However, when headphones were not used, the time required for BP measurements increased by 23%, 18%, and 30% across all cat groups, young adult cats, and mature adult/senior cats, respectively. On average, the duration required to collect BP extended by approximately half a minute when headphones were not utilized. The lack of statistical significance could be due to our relatively small sample size, indicating the necessity for additional evaluations to apply these findings to a larger population. Further investigation is required to effectively extrapolate these results to broader contexts.

It is recommended to collect multiple BP measurements to improve accuracy. This typically involves obtaining at least six readings, discarding the initial one, and averaging the following five. Prior research in dogs indicated that the initial BP reading taken without headphones displayed no significant difference from subsequent readings or their average. However, our study revealed contrasting findings: the initial BP readings with headphones were higher compared to subsequent readings for both all cats and young cats. While a difference of 4 mmHg among all cats and 5 mmHg in young cat was found, this variation is unlikely to have
clinical relevance. It is plausible that all cats experienced transient situational hypertension, but wearing headphones might have allowed cats more time to adjust and acclimatize to the environment, resulting in slightly higher BP in the initial reading compared to subsequent ones. This effect was more noticeable in young cats, possibly owing to their increased susceptibility to experiencing anxiety.\textsuperscript{40} Moreover, while guidelines suggest discarding initial readings,\textsuperscript{7} our findings did not indicate a significant difference between BP1 and the average of BP 2-6. This proposes a re-evaluation of the practice of disregarding initial readings. Further examination in a larger population is needed to validate these findings and reconsider existing recommendations.

There are several limitations in this study. Firstly, the health status of the cats was reliant on owner-reported data, raising the possibility of overlooking systemic diseases such as chronic kidney or occult heart disease. Secondly, the treatment (headphones) was not blinded in this crossover study, introducing the potential for bias, despite efforts to minimize it. Thirdly, our choice to exclusively use the right radial artery for BP measurements may not be representative of situations where the coccygeal artery is employed.\textsuperscript{51} Lastly, the 14-day interval between BP measurements was determined based on the ACVIM consensus statement, which recommends a repeat evaluation within 14 days of recording a BP exceeding 180 mmHg in a patient without signs of target organ damage. As such, our findings may not accurately reflect repeat evaluations conducted within shorter (<14 days) or longer (>14 days) periods.
While the use of headphones during Doppler blood pressure (BP) measurement did not yield a statistically significant difference in the overall average BP, our study revealed an age-dependent influence of headphones. Notably, in young adult cats, BP measurements obtained with headphones were lower than those taken without headphones. This reduction suggests a potential efficacy in managing situational hypertension, particularly in young adult cats.

Our study did not detect a statistical difference in the time needed for BP collection with or without headphones. Despite this lack of statistical significance, there was an observed trend, with BP collection taking about half a minute longer when headphones were not utilized. This emphasizes the need for additional assessment to extend these findings to a larger cat population, considering our study's limited sample size.

Moreover, our study challenges the convention of discarding the first BP reading, as we found no difference between the initial reading and the average of the subsequent five readings. These findings emphasize the importance of consistent headphone use to minimize audio static noise during serial BP measurements with Doppler ultrasound sphygmomanometry in cats.
Bibliography


