OBJECTIVES & PROJECT BACKGROUND
We are asking all 8 bonobo-holding institutions in the United States to train as many bonobos as possible for awake finger blood pressure measurement and to submit monthly blood pressure measurements to the Great Ape Heart Project over a two-year period. We are interested in obtaining blood pressure readings from all bonobos, regardless of age, sex, or health status.

The project goals are to develop reference ranges for finger blood pressure in awake bonobos in order to define critical points for therapeutic intervention. This information could then allow for monitoring the effectiveness of high blood pressure treatments in bonobos and improve dosage recommendations for heart disease treatments in bonobos.

Significance - Cardiovascular disease affecting the heart and blood vessels is the most common cause of death in bonobos over one year of age. Heart disease appears to be more common in male bonobos, and deaths occur in males as young as 15-years of age. Cardiovascular disease appears to be more common in both the highest ranking and the lowest ranking bonobos, which may be related to the amount of stress they experience on a regular basis.

Our studies have led us to suspect that undiagnosed hypertension, or high blood pressure, is a major underlying cause of heart problems in apes. At necropsy, we see changes in many tissues that are consistent with high blood pressure. If we can detect high blood pressure in bonobos, we would be able to initiate treatment at a much earlier stage of the disease. This may prevent the development of heart failure, or at least slow the progression of changes in the heart, leading to a longer and better quality of life for affected animals.

Also, drugs used to treat heart disease are dosed to effect, which means the correct dose for any bonobo is the dose that lowers blood pressure in that animal. If we can measure blood pressure in awake bonobos, veterinarians can optimize treatment in an affected animal.

Milwaukee County Zoo Pilot Study – The Milwaukee County Zoo (MCZ) began training bonobos for awake blood pressure monitoring in 2011. MCZ has been using a PetMAP Graphic blood pressure monitoring device to collect finger blood pressures from their bonobos. Finger blood pressure measurement in bonobos has correlated well to arm and shin blood pressures taken while bonobos are under anesthesia, which shows that finger cuffs can be as accurate as the more standard cuff placement locations. Finger blood pressure measurements have been used to help identify bonobos at MCZ with elevated blood pressure readings and also been used to help monitor bonobos on treatment with ACE-inhibitors.

Based on a few pilot cases at MCZ, the PetMAP Graphic device has the potential to be a useful and reliable tool for monitoring blood pressure in bonobos. For this reason, the Great Ape Heart Project (GAHP) is expanding MCZ’s initial pilot work to all bonobo-holding institutions in the United States with funding support from the Institute of Museum and Library Services (NLG: MG-30-15-0035-15).
SUBJECTS, INSTITUTIONS AND COLLABORATORS

Subjects: As of January 2016, there are 90 bonobos at 8 institutions in the United States. For the purpose of this study, we define 9 years and older as an adult bonobo (N= 61 adult bonobos in the United States). The bonobo range in age from 0-48 years old (29 = 0-8 years; 27 = 9-19 years; 16 = 20-29 years; 10 = 30-39 years; and 8 = 40-48 years). Any bonobo that is willing to train for blood pressure readings may be included in this study, regardless of age, sex, or health status.

Institutions: The 8 bonobo-holding institutions in the United States are: Cincinnati Zoo (N=7), Columbus Zoo (N=18), Fort Worth Zoo (N=8), Jacksonville Zoo (N=11), Memphis Zoo (N=6), Milwaukee County Zoo (N=21), San Diego Zoo (N=14), and Ape Cognition and Conservation Initiative (ACCI – formerly the Great Ape Trust of Iowa – N=5).

Collaborators: Each institution is asked to designate one point-person who will perform the blood pressure readings and collect measurements for this project. We ask that this person, likely a veterinary technician or veterinarian, be the same person for all data collection at that institution in order to obtain the most consistent readings. The “Data Collector” role will be responsible for holding the PetMAP Graphic device, initiating the reading by manually inflating the cuff, and monitoring the reading output on the device during each reading. The Data Collector will perform at least 3 readings in one session and record each reading on the Data Submission Form along with the Nominal Session Value, which is calculated by the PetMAP Graphic. It will be necessary to have a second person act as a “Session Assistant”. Session Assistants should work with the same bonobo throughout the study. Institutions may have more than one Session Assistant for the study, but keeping Session Assistant / Bonobo pairing consistent is preferred. [For example, Keeper Stacy at the Milwaukee County Zoo is the primary trainer for Bonobo Laura. Stacy will be the “Session Assistant” for all of Laura’s blood pressure readings, but not for Bonobo Deidre because Deidre’s trainer is Ann.] Since it is common for zoos to designate specific keepers to train specific bonobos, we suggest that the Session Assistant role be a keeper that routinely works with that bonobo. The main role of the Session Assistant is to be someone who is familiar with the bonobo and can determine if and when the bonobo is calm enough to begin the blood pressure readings. The Session Assistant will interact with the bonobo’s hand(s) and guide the finger cuff into place. Throughout the reading, the Session Assistant will make sure that the bonobo remains calm and still, provide food rewards and/or verbal praise, and will monitor the session for any social or behavioral notes to include on the Submission Form.

MATERIALS

PetMAP Graphic Device - The Great Ape Heart Project has obtained one PetMAP graphic blood pressure monitoring device for each participating institution (Figure 1). The PetMAP device was developed by Ramsey Medical, Inc., and is manufactured, distributed, and serviced by CardioCommand. It is a hand-held, oscillometric blood pressure measurement device with a digital display of systolic, diastolic, mean arterial pressure, and heart rate (Figure 2). The device has unique limb and tail settings that are optimized for cats and dogs. The standard setting for the device that should be used for human and non-human primates is simply called: Optimize None. The PetMAP device displays a real-time view of the oscillometric “envelope”, i.e. a visual guide for determining if a reading is accurate. The oscillometric envelope resembles a waveform when a good reading is obtained and will detect motion-related artifacts during readings (Figure 2 – first image). The device records multiple readings within a session and will produce an additional graph of the result trends as well as a tabular list of the data. Lastly, the PetMAP device calculates a “Nominal Session
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Value” (NSV), which is a more robust calculation than a simple average of the session values. The NSV is calibrated to detect outlier readings and will provide the most representative reading value for a session. The PetMAP can monitor blood pressure between 30-260 mm Hg, heart rates between 40-240 BPM, is powered by two AAA batteries, measures 7.0cm H x 6.35cm W x 13.2cm D, and weighs 6.0oz.

Figure 1. PetMAP Graphic Blood Pressure Monitoring Device shown with a finger cuff.

Figure 2. The three main display screens for the PetMAP Graphic Blood Pressure Monitoring Device, from left to right: Measurement page showing the oscillometric envelop (waveform), Graphic Results page with all session readings graphed in red and the Nominal Session Value measurement above (NSV), and the Tabular Results page showing all session readings together.

PetMAP Finger Cuffs - Along with the PetMAP device, each institution will receive a package of 7 finger cuffs, ranging in half-centimeter sizes from 2.0cm-5.5cm. Based on pilot work performed at the Milwaukee County Zoo, we have determined that the size 3.5cm cuff is ideal for adult female bonobos, and the 4.0cm cuff is ideal for adult male bonobos, therefore, we are including one additional 3.5cm cuff (Item # 8052) and 4.0cm cuff (Item # 8056) for a total of 9 finger cuffs. Replacement cuffs can be purchased directly from CardioCommand. The finger cuff should be snuggly wrapped around the distal half of the bonobo’s finger (finger-tip end/closest to you) with the arterial line (tubing) lined up with the bottom of the finger. These sizes will be correct if the width of the cuff is approximately 40-50% of the circumference of the finger, and the index line of the cuff falls within the optimum region indicated by dotted lines on the cuff (Figure 3). If you believe that the suggested cuff size is incorrect for a bonobo, please contact the GAHP Project Manager, Marietta Danforth at gahpinfo@gmail.com or 404-234-8345, to determine which cuff should be
used instead. Once a cuff size has been selected, you should continue to use the same cuff size for all readings for that bonobo.

Training Materials - Institutions will also receive a project binder that contains the PetMAP manual, PetMAP quick reference guide, this GAHP project protocol, GAHP Blood Pressure Submission Form, and a 15-minute training video. The GAHP project manager is available by email, phone and may also provide a site-visit to each participating institution for additional training.

Figure 3. The Index line of the finger cuff should line up within the two Optimum Region lines of the cuff. This indicates a correctly sized cuff. When wrapped around the bonobo’s finger, the cuff should form a snug fit.

TRAINING AND DATA COLLECTION TIMELINE

Project Timeline:
Familiarization (estimated 1-3 weeks): Upon receiving the PetMAP device and related project supplies from the GAHP, we recommend that the institution’s Data Collector thoroughly read through all the materials. The Data Collector should determine who the Session Assistants (SA) will be for each bonobo and practice taking blood pressure measurements with the SAs before attempting with an animal. The cuff should be inflated 35-40 mmHg above the anticipated blood pressure, so we recommend inflating to 220 mmHg in the beginning and adjusting the inflation as needed (typically between 200-220 mmHg). Practice on yourself – taking note of the pressure differences as you under inflate (e.g. 120 mmHg), overinflate (240 mmHg) and get just about right (200mmHg). Keep in mind how you will need to work with the bonobo and your Session Assistant to habituate this feeling. The device automatically deflates for the reading. Also notice how you can feel and hear clicking sensations in the cuff during readings. Practice moving your hand and cuffed finger to see how it affects the reading’s waveform on the PetMAP’s graph display. Once the Data Collector and Session Assistant are familiar with both the PetMAP device and the process for obtaining blood pressure readings, they can begin training bonobo subjects.
Figure 4. The Data Collector (left) and the Session Assistant (Right) work together to obtain BP readings from a bonobo. The bonobo is calmly seated with a finger presented at heart level through the enclosure’s cage mesh.

**Bonobo Training (estimated 1 week-2 months per bonobo):** Each bonobo may react differently to the PetMAP device and the entire blood pressure monitoring process. We have produced a 15-minute training video that includes training tips and demonstrates the process from start to finish. We recommend you begin training bonobos that you consider the most willing to participate in training. Ideally, you will separate the bonobo from his or her group during data collection, however in some cases the separation from group members may be stressful to a bonobo and will in turn affect the blood pressure reading. Use your best judgment for creating a safe and calm environment for blood pressure training. Consider practicing on each other in front of the bonobos to show them the process and habituate them to seeing you with the device. You may also consider showing them our training video, which shows bonobos at the Milwaukee County Zoo getting their blood pressures taken. Bonobos, like other apes, are known to learn socially from other group members and their caregivers, so use this to your advantage if you have an eager bonobo. Allow other group members to watch sessions if feasible.

**Bonobo Blood Pressure Data Collection (24 months):** The minimum data collection goal for this project is to obtain readings from at least one blood pressure monitoring session per month per bonobo for 24 months (2 years). We wanted to set an achievable goal for zoos, particularly those with larger bonobo collections, however, we welcome as many sessions as you are able to collect throughout the month.

A session is defined as a minimum of 3 *good* readings, which are taken at least 3 minutes apart. We ask that you wait 3 minutes between good readings so that the blood vessels can return to normal. If the waveform display indicates a bad reading, you can release the device trigger and start over without waiting.
3 minutes. The PetMAP device automatically calculates a “Nominal Session Value” (NSV), which should also be collected and included in submissions. A “good” reading is defined as a blood pressure measurement taken where:

- the bonobo is in a seated position at the front mesh of the enclosure (Figure 4)
- the bonobo has the third digit (middle finger) or fourth digit (ring finger) of either the left or right hand presented through the mesh and no more than two fingers are presented through the mesh to avoid squeezing the bonobo’s hand
- the correct cuff size is being used and is well wrapped around the distal end of the bonobo’s finger (fingertip end of the finger) with the tubing aligned to the bottom of the finger
- the bonobo’s finger is at heart level
- the bonobo’s hand has minimal movement, and therefore a waveform will be graphed by the PetMAP during the reading (Figure 5)

![Figure 5](image_url). The PetMAP Graphic device showing a “waveform” oscillometric envelop on the display.

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**GAHP SUBMISSION INFO**

More than one blood pressure session per month per bonobo will be accepted and is encouraged, but we ask that you do not submit multiple sessions in the same bonobo from the same day. Once a day is enough.

Since the GAHP Blood Pressure Submission form is available electronically, it can be filled out and emailed immediately to gahpinfo@gmail.com after a session is performed. Alternatively, you can wait to submit all bonobo sessions at the end of each month. Please use the following subject line for your emails:

“Bonobo BP Project – Name of Your Zoo”

e.g. Bonobo BP Project – Milwaukee County Zoo
DATA COLLECTION INSTRUCTIONS:

How to use the PetMAP blood pressure measurement device:

1) Read the entire manual.
2) Initially practice taking BP measurements on yourself, then other colleagues, before trying on an animal.
3) Press the POWER BUTTON once to turn the device on. If you press and hold the same button for 4 seconds, it will turn the device off. When the device is ON, pressing the button will act as a page changer for the readout. [See the PetMAP “Quick Reference Card” for a diagram of the unit]
4) Press and release the MULTI-FUNCTION BUTTON until it says NONE. It is important that readings on bonobo fingers are taken with the NO OPTIMIZATION selected. Do not use the optimizations for Cat or Dog, or for Forearm, Hind foot or Tail. If you press and hold this same button it will change the screen brightness.
5) This device is battery operated. The display will turn off when unit is motionless for 12 sec. The entire unit will automatically turn off in not re-pressurized within 10 minutes.
6) The red LED LO-BAT signal will light up when about 1 hour of battery power remains. To change batteries, loosen the battery change screw on the top of the device, remove the battery cover and replace BOTH batteries. Do NOT use NICAD or Heavy Duty batteries. One battery will have positive up, other will have negative side up – follow printed +UP and –UP on device.
7) Remove batteries from device if it will not be used for an extended length of time.
8) Do not expose PetMAP device to water.
9) Always turn unit on BEFORE attaching cuff, to insure no input pressure. Always close trigger AFTER attaching cuff.

To obtain optimal readings:

1) Animal should not be agitated; should not be moving or trembling; should not be cold
2) Use cuff of right size and ensure a snug fit. Use 3.5 for adult female bonobos and 4.0 for adult males. This size will be correct if the width of the cuff is approximately 40-50% of the circumference of the finger, and the index line of the cuff falls within the optimum region indicated by dotted lines on the cuff. (see GAHP Training Video for a demonstration)
3) Use the same finger and the same cuff size for ALL readings on the same animal. Use the third digit (middle finger) of either the right or left hand. If a particular animal has old fractures or scars on those fingers due to previous trauma, use the fourth digit (ring finger) of either the left or right hand. Once a finger is selected for a bonobo, use that finger for all future readings.
4) Get at least 3 good readings and report each of them including the “Nominal Session Value“ which is mathematically generated by the PetMAP device.

To take the finger BP using the PetMAP device:

1) Have bonobo sit at the front mesh of the enclosure and slide the finger of choice out of the mesh at heart level.
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2) No more than 2 fingers out of the mesh because squeezing them through could impede blood flow

3) IMPORTANT: fingers must be at heart level to standardize the readings and avoid the effects of hydrostatic pressure/gravity

4) IMPORTANT: Use the correct finger cuff size and selected finger for that bonobo. Remember to use the 3.5 cuff for adult females and 4.0 cuff for adult males.

5) Turn PetMAP device ON

6) Set the device to OPTIMIZE NONE (press and release Multi-function button to find correct setting)

7) With trigger down (open), attach the correct size cuff to device. Always turn on device BEFORE attaching cuff. Always attach cuff before closing trigger.

8) Wrap cuff snugly around the distal half of the finger to be sampled

9) Close trigger, moving it into up (locked) position. Gently squeeze bulb to inflate cuff 35-40 mmHg higher than anticipated blood pressure. Start by inflating to 220mmHg and then adjust accordingly from there

10) Leave trigger in up (locked) position and cuff will automatically deflate.

   (NOTE – if any signs of panic or pain are noted, just pull down on the trigger button to immediately deflate the cuff).

11) Evaluate progress of the readings on the display. When reading is bad, terminate the reading by opening the deflate trigger. See page 15 if the PetMAP manual for examples of bad readings that should be terminated.

12) Ideally allow 3 min. between readings to allow the artery to relax to “normal” state. Try to get a minimum of 3 readings per session

13) To see a listing of the session values, press Power/Page button twice. Record your readings and Nominal Session Values on the GAHP Blood Pressure Submission Form data sheet.

CLEANING THE DEVICE
Clean with damp cloth. Do NOT immerse in water or other liquid. Do NOT use alcohol. Do NOT use steam or heat to sterilize.

CLEANING THE CUFFS
Remove the cuff from the device and close the tube with a plug. Place the hook and fasteners in the closed position. Wipe with mild detergent and water (1:9 solution), then rinse and dry. OR wipe with 70% isopropyl alcohol.