

Integrative measurement protocol for morphological and behavioral research in human and non-human primates

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Illustrations by Dana Duren

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Available for Download

The protocol is available for download at www.nyu.edu/gsas/dept/anthro/programs/csho/research.html

Should you include your data in publications, we would appreciate your reference in materials and methods to either the “Bones and Behavior Protocol, 2009’ and the web address, or to one of the groups’ abstracts also available on that site.

Comments or Suggestions?

We welcome your thoughts and contributions. Contact Josh Snodgrass (jjosh@uoregon.edu) or Susan Antón (susan.anton@nyu.edu)

INTRODUCTION

Human biologists, primatologists, and evolutionary morphologists seek to understand the evolution of human and non-human primate adaptation. Yet, despite the interdependence at an organismal level of physiology, behavior, and skeletal biology, each group of biological anthropologists tends to work in relative isolation. Although we might address similar “umbrella questions,” such as adaptation to marginal environments or ontogeny, we generally do so without integration of protocols across subareas. The exponential expansion of theory, data, and technology makes it currently impossible to specialize in all subareas. Likewise, graduate training has turned to earlier and earlier subareal specialization. This isolation, despite its many advantages, inherently weakens our ability to answer certain key research questions, and makes it more likely that proximate rather than ultimate questions will be answerable.

The potential value of linking the complementary datasets assembled by different groups of biological anthropologists could not be more profound.

- The skeletal data offer large sample sizes and the ability to consider change through evolutionary time.
- In contrast, data on extant humans and non-human primates are richer in allowing us to explore individual context, behavioral, and physiological cues and provide the ability to examine individuals through developmental time.

If the protocols for approaching the two were integrated, each dataset could inform and enrich the other. Without such integration, we are left with a limited empirical framework for understanding more universal adaptations. The limitations of the usual isolation approach become clear when trying to assemble data to address questions raised by the hominin fossil record. Such scenarios are dependent on understanding variation in living taxa relative to environmental conditions, as well as the variation in extinct taxa. The extent to which we can understand the relationship between biological, ecological, and skeletal factors in extant taxa both for individual animals and population-level differences will facilitate our answering ultimate questions about evolutionary processes. These issues can only be resolved by changing the extent to which we integrate our data collection protocols and perspectives.

To begin fostering this integration, a group of biological anthropologists with expertise in each of the target areas (The Bones and Behavior Working Group) met for two intensive workshops with the aim of developing an integrative approach to research questions concerning primate adaptation. The aim was to set the agenda for future research initiatives for this new synthesis, and to generate a measurement protocol that maximizes our ability to link behavioral, biological, and skeletal databases.

We culled a set of core measurements from across the sub-areas of biological anthropology that address issues of universal concern and that could be made maximally comparable. These are organized around “non-skeletal” measures such as body weight and overall size and “proxies for key skeletal measures” with definitions that can be approximated on both living and skeletal samples. Please note that in order to more closely approximate measures taken from bone, many of the skeletal proxy measures modify *in important ways* similar measures often taken in human biology.

Our intention is not to provide a comprehensive list of measurements for human biological or primatological research, but instead to focus on a core set of measurements that can be collected relatively quickly and that maximizes the impact for addressing broad evolutionary questions. The protocol provides a small core of these measures with the hope that researchers will add these to their lengthier and more specific research protocols.

We present standardized definitions with simple instructions for use by a non-specialist, high-resolution photos of measurements being taken (currently mostly on humans with future versions adding nonhuman primates), schematic drawings of bones relative to soft-tissue structures (again, currently in humans), and information on equipment use and availability.

CORE MEASUREMENTS

Non-Skeletal Measures

Body weight

Stature/Height

- Standing height (humans only)
- Sitting height (humans only)
- Trunk length (non-human primates only; crown-rump length)

Circumferences

- Chest
- Waist
- Hip (humans only)
- Upper arm at mid-arm (mid-arm circumference)
- Thigh

Arm Span

Skinfolds— (humans only)

- Peripheral fat measure (triceps skinfold)
- Central fat measure (subscapular skinfold)

Proxies for Skeletal Measures

Cranium (preferably include all measures)

- Head circumference (C1)
- Maximum cranial length (C2)
- Maximum cranial breadth (C3)
- Cranial height (C4)

Trunk breadth (include at least one)

- Bi-iliac breadth (T1)
- Biacromial breadth (T2)
- Clavicle length (T3)

Frame size (include at least one)

- Knee breadth (F1 – tibial and femoral)
- Elbow breadth (F2)

Appendages (at least one from forelimb and one from hind limb)

Forelimb (Arm) segments

- A1 - Arm segment I (essentially humerus length)
- A2 - Arm segment II (essentially ulna length)

Hind limb (Lower limb) segments

- A3 - Thigh segment (essentially femur length)
- A4, A5 - Leg segment (essentially tibia length or fibula length)

Digit ratio (2nd to 4th digit on hand)

DEFINITIONS FOR TAKING NON-SKELETAL MEASUREMENTS

Body weight

Equipment: scale

Measurement: *In humans*, subject should be measured in light clothing and without shoes. *In non-human primates*, subject may be measured in a sling from a hanging scale or on a floor/table scale.



Stature/Height

- Standing height (humans only)

Equipment: anthropometer or portable stadiometer

Measurement: Subject should be barefoot (thin socks are ok). Subject should be standing erect with heels placed together and arms hanging relaxed at sides. Head should be in the Frankfurt Horizontal (i.e., the plane defined by the left orbitale [lower rim of the orbit] and left and right poria [top of the ear hole] should be parallel to the floor). Lower the horizontal bar of the anthropometer or stadiometer until it makes contact with the top of the head (cranium).



Stature/Height (continued)

- Sitting height (humans only)

Equipment: anthropometer

Measurement: Subject should be sitting on a table with the legs hanging down and not touching the ground (knees should be close to the edge of the table but not touching). Hands should be resting on the thighs or lap, not supporting the weight of the body. Head should be in the Frankfurt Horizontal (see Stature definition). The subject should be sitting as erect as possible with back touching the anthropometer.

The measurement should be taken with the anthropometer placed on the table.



- Trunk length (non-human primates only; crown-rump length)

Equipment: recumbent length board, anthropometer, or tape measure

Measurement: Animal should be in a supine position, with hips and shoulders flat. Elevate the lower legs to facilitate measurement against the buttocks putting the thighs at a 90 degree angle to the thorax. The measurement is taken as the maximum distance between the crown of the head and the animal's rump.

Circumferences

- Chest

Equipment: tape measure

Measurement: *In humans*, taken with the subject standing with arms hanging relaxed at sides. The measurement is taken at approximately the level of the armpit (technically it is made at the level of the 4th costosternal joint, which is typically just superior to the level of the nipple).

In non-human primates, we recommend finding maximum chest breadth at whatever level that may be – it is likely to be slightly posterior to the armpit.



Circumferences (continued)

- Waist circumference

Equipment: tape measure

Measurement: *In humans*, this measurement is taken with the subject standing relaxed with arms at the sides. The measurement should not be made over clothing if at all possible. Typically, this measurement is made immediately superior to the iliac crest, and is not necessarily the minimum circumference of the waist. *In non-human primates* we recommend that this measurement be made at the minimum girth between the rib cage and the pelvis.



- Hip circumference (humans only)

Equipment: tape measure

Measurement: This measurement is taken with the subject standing relaxed with arms at the sides and wearing at most light clothing. Measured in a horizontal plane at the level of the greater trochanter of the femur.

Circumferences (continued)

- Upper arm at mid-arm (mid-arm circumference)

Equipment: tape measure (or pediatric insertion tape)

Measurement: Measured at the midpoint of the upper arm, which is defined as the halfway point between the acromion process of the scapula and the olecranon process of the ulna (the pointy part of the elbow; nb: it may be helpful to measure the distance from the acromion process to the olecranon and mark the midpoint prior to measuring the circumference).

In humans during the measurement, the subject should be standing in a relaxed position with arms at their sides. This measurement should not be taken over clothing if at all possible. *In non-human primates* take the measure with the individual on their side and use the tape to compress the fur to minimize its contribution.



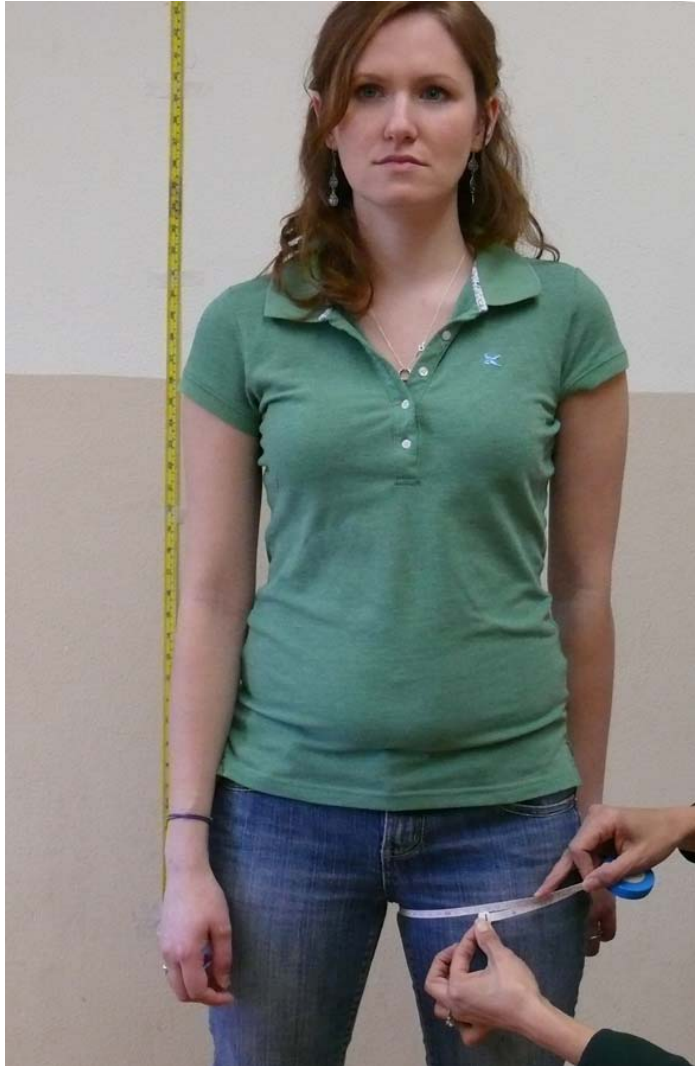
Circumferences (continued)

- Thigh circumference

Equipment: tape measure (or pediatric insertion tape)

Measurement: *In humans*, this measurement should be the maximum circumference in a horizontal plane with the subject standing; this measurement should not be taken over clothing if at all possible.

In non-human primates the measurement should be the maximum circumference of the thigh and the tape should be pulled tight to minimize the contribution of fur.



Arm Span

Equipment: tape measure (at least 2m long for humans)

Measurement: Measured between the tips of the longest fingers (typically the middle fingers) with the arms maximally outstretched laterally.

In humans, typically measured with the subject standing with feet together and with back against a wall with arms maximally outstretched laterally and parallel to the ground (measured with tape along the wall, behind the subject). *In non-human primates*, measured with the animal's torso on its back.



Skinfolds— (humans only)

Equipment: skinfold caliper

Measurement: Skinfold measurements should be taken directly on the skin, not through clothing. The skinfold should be picked up and held using one hand and the skinfold should be measured using the calipers held in the other hand. Typically, each measurement is made three times (repeating the entire sequence each time) and the average of the measurements is used.

- The triceps skinfold (peripheral fat measure) is measured at the midpoint of the upper arm, defined as the midway point between the acromion process and the olecranon process (same as definition above).



- The subscapular skinfold is measured immediately below (inferior) to the inferior angle of the scapula; this skinfold should be picked up diagonally at the natural fold line of the skin (at an approximately 45 degree angle inferolaterally).



DEFINITIONS FOR TAKING PROXIES FOR SKELETAL MEASURES

Cranium (preferably include all measures)

- C1 - Head circumference

Equipment: tape measure

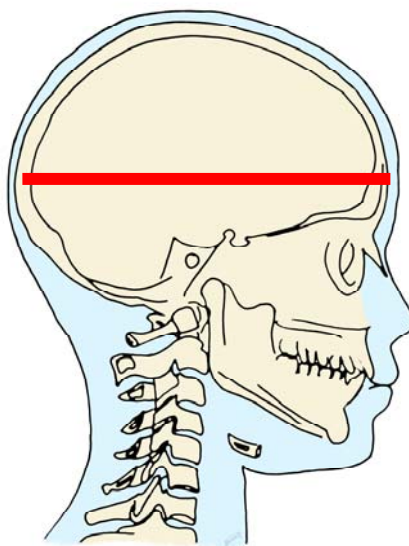
Measurement: Settle the tape around the cranium from front to back capturing the greatest circumference that includes the frontal (forehead) and the occipital (at the furthest posterior protrusion of the head) regions.



- C2 - Maximum cranial length (glabella-opisthocranium)

Equipment: spreading caliper

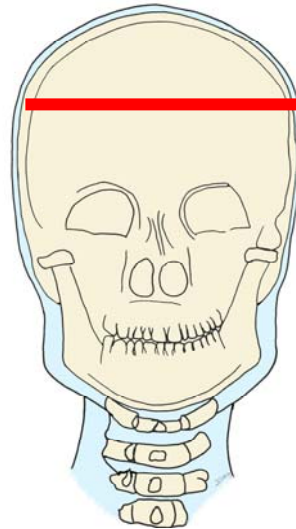
Measurement: With the head in Frankfurt Horizontal (see Stature for definition), in the mid-sagittal plane, place one end of the spreading caliper on the most anterior, midline position of the forehead (glabella). Place the other end of the caliper against the most posterior point on the cranium along the midline (opisthocranium).



- C3 - Maximum cranial breadth

Equipment: spreading caliper

Measurement: Taken perpendicular to cranial length, the greatest breadth of the cranium. *In humans*, maximum breadth usually occurs posteriorly and superiorly (on the parietal bones).



- C4 - Cranial height (porion-vertex)

Equipment: sliding caliper

Measurement: With subjects head in Frankfurt Horizontal, on one side of the head, locate the top of the ear hole (porion) and place one end of the sliding caliper there. Following a plane perpendicular to that for cranial length and more or less parallel to that for cranial breadth, place the other end of the sliding caliper at the highest point on the midline vault (vertex).

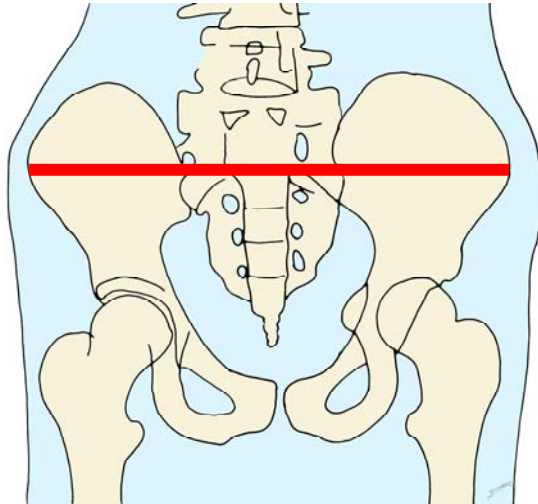


Trunk breadth (at least one)

- T1 - Bi-iliac breadth (bi-cristal breadth or pelvic breadth)

Equipment: sliding caliper (*non-human primates*) or anthropometer or a large sliding caliper (*humans*)

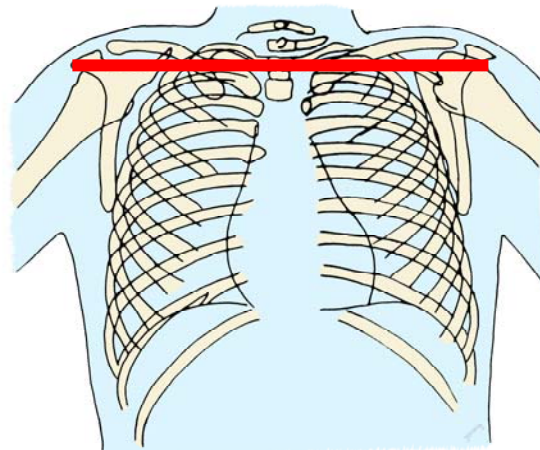
Measurement: This is the distance between bony protuberances that are the most anterior and lateral on the pelvis. *In humans*, taken with the individual standing and facing away from you. *In non-human primates* take the measure from the front at the widest bony point,



- T2 - Biacromial breadth (Shoulder and/or chest breadth)

Equipment: tape measure, large sliding caliper, or anthropometer

Measurement: With the individual standing and their back to you and shoulders relaxed and slightly forward (*humans*), or from the back (*non-human primates*), the greatest distance across the shoulders (but not including the rounded portion of the arm). This measurement should be taken between the lateral borders of the acromion processes of the scapula (note: moving the arm up (cranially) will allow you to locate the fixed point of the acromion process of the scapula).



- T3 - Clavicle length

Equipment: sliding caliper

Measurement: With arms at the sides, palpate the junction between the knobby medial protrusion of the clavicle and the sternum (*in humans*, ask the person to lift their arm while you palpate to find the junction; *in non-human primates* move the arm sideways at the shoulder to locate). The measurement should be taken from this point to the lateral end of the clavicle (the furthest bony point that is stable during arm elevation).



Frame size (take at least one; n.b. elbow breadth in a living human subject is a better measure of skeletal dimensions; however, since the knee is a weight-bearing joint in humans, it may be a better measure for some purposes)

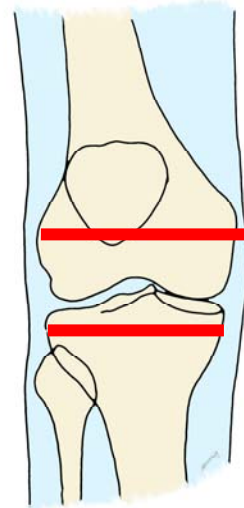
- F1 - Knee breadth (breadth of tibial plateau or femoral condyles)

Equipment: sliding caliper or spreading caliper

Measurement:

Tibia (shinbone): Measurement taken with the subject seated and the knee flexed at 90 degrees (*humans*) or just with the knee flexed (*non-human primates*). Measure from between the most lateral and most medial bony protrusions of the knee below the mid-level of the patella (that is, do not measure knee breadth at mid-patella or above, but below mid-patella to avoid measuring the femur).

Femur (Thigh bone; Shown in human picture): with the subject seated and the knee flexed at 90 degrees (*humans*) or just with the knee flexed (*non-human primates*). The measurement is taken between the most medial and lateral points of the femoral condyles, which are located at approximately the middle of the knee cap (patella) when the knee is flexed.



- F2 - Elbow breadth (breadth of distal humerus)

Equipment: sliding caliper or spreading caliper

Measurement: With the arm flexed at 90 degrees and the upper arm elevated so that the proximal segment is parallel to the ground (*humans*) or simply with the forelimb flexed at the elbow (*non-human primates*), measure between the most lateral and most medial bony protrusions of the elbow.



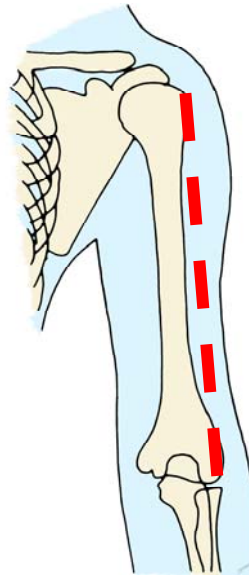
Appendages (at least one from forelimb and one from hind limb)

Forelimb (Arm) segments

- A1 - Arm segment I (humerus length; note that this modifies in important ways shoulder-elbow length typically measured in living humans (which includes 3 bones—here we focus on only one).

Equipment: tape measure or preferably long sliding caliper or anthropometer

Measurement: With the arm extended at the elbow measure from the top (round) part of the shoulder to the most lateral bony protuberance on the elbow. *In humans* taken with the individual standing and from their side. *In non-human primates* taken with the animal laying on its side.



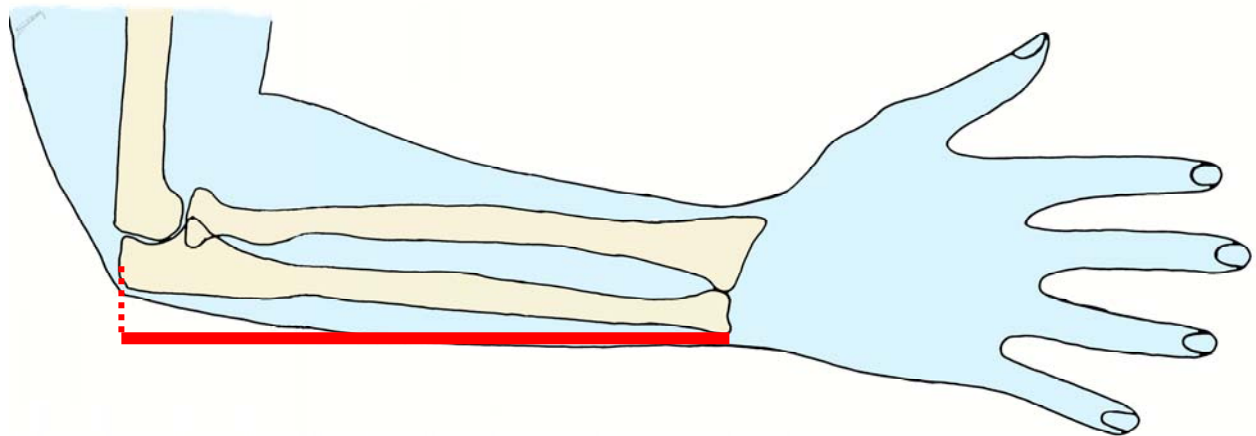
A2 - Arm segment II (ulna length; elbow-wrist length as commonly taken in living humans)

Equipment: tape measure or preferably long sliding caliper or anthropometer

Measurement: With arm flexed at the elbow, measure from the bony point on the elbow (olecranon process) to the most distal bony protrusion just above the wrist (on the side of the fifth ray – e.g. pinky side or side opposite the thumb, which is the styloid process of ulna).

In humans taken with the individual standing and from their side.

In non-human primates taken with the animal laying on its side.



Hind limb (Lower limb) segments

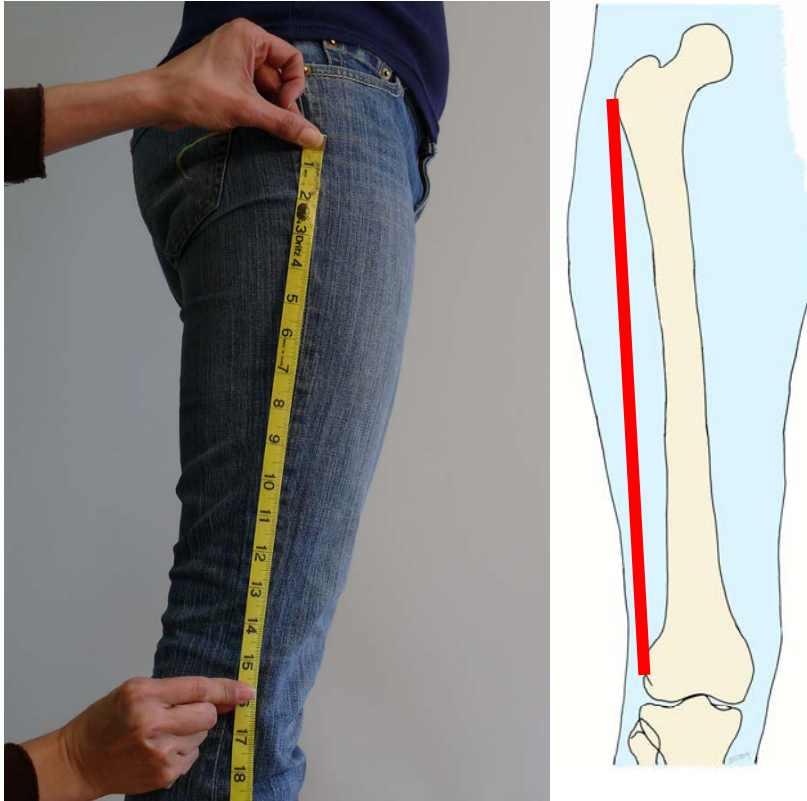
- A3 - Thigh segment (femur length; note that *this modifies in important ways* 'hip-knee length' typically taken on living humans—that measure includes three bones and the aim of this measure is to include only one)

Equipment: tape measure

Measurement: With lower limb extended at the hip and the knee, measure from the lateral-most bony point at the hip joint (e.g. greater trochanter of femur) along the lateral side of the limb to the lateralmost extension of the knee (i.e., lateral condyle of the femur), this should occur at approximately the mid point of the kneecap (patella) when the leg is extended.

In humans measure is taken while subject is standing with feet together.

In non-human primates, measure is taken while animal is on their side with the leg extended.



nb: Drawing is of an anterior view of the leg, measure should be taken from the side.

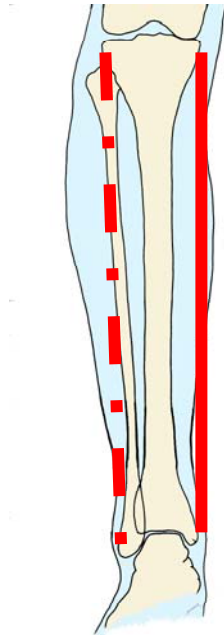
- A4, A5 - Leg segment (essentially tibia length or fibula length; tibial length, A5, preferred)

Equipment: tape measure or anthropometer

Measurement:

A4 (fibula length) Taken on the lateral (outer) side of the leg, with lower limb extended at the hip and the knee. Measure from the lateral point used to take “tibial knee breadth” along the lateral side of the leg to the inferior-most point on the lateral bulge at the ankle. *In humans* it is typically taken with the subject standing. *In Non-human primates* it is taken with the subject on the side but with hip and knee extended.

A5 (tibia length) Taken on the medial (inner) side of the leg, with lower limb extended at the hip and the knee, measure from the medial point used to take “tibial knee breadth” along the medial side of the leg to the inferiormost point on the medial bulge at the ankle. *In humans* it is typically done with the subject sitting with slightly flexed knee, and with the leg crossed over the opposite leg; measured from the medial border of the proximal tibia to the distal tip of the medial malleolus). *In non-human primates* it is taken with the subject on the side and with knee flexed.

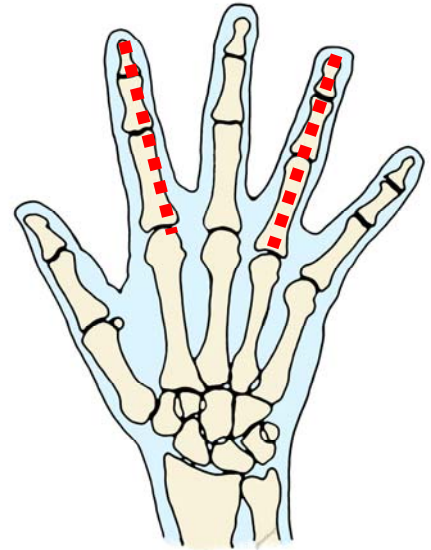
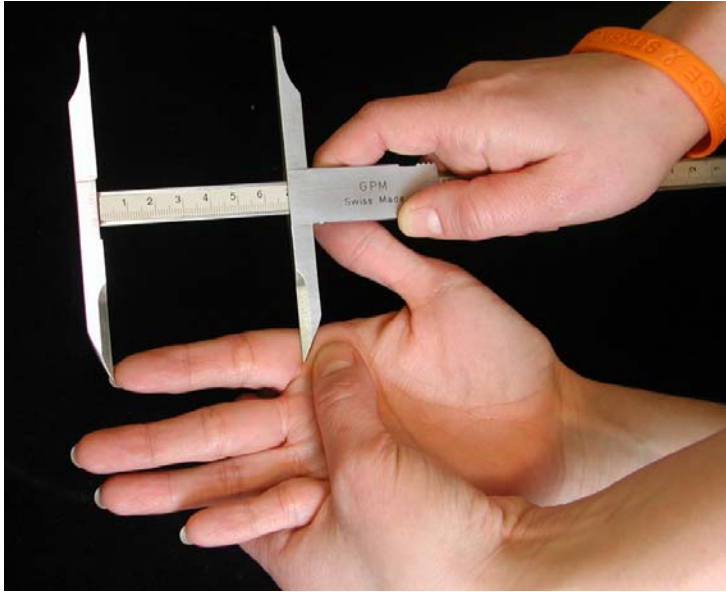


Digit ratio (2nd to 4th digit; represents the combined length of three phalanges);

- Possibly on both right and left hands to look at asymmetry

Equipment: sliding caliper

Measurement: With the fingers extended and on the palm surface, measure on the 2nd (index) and 4th (ring) rays from the base of the crease where the finger joins the palm to the tip of the finger (do not include the nail).



MEASUREMENT EQUIPMENT

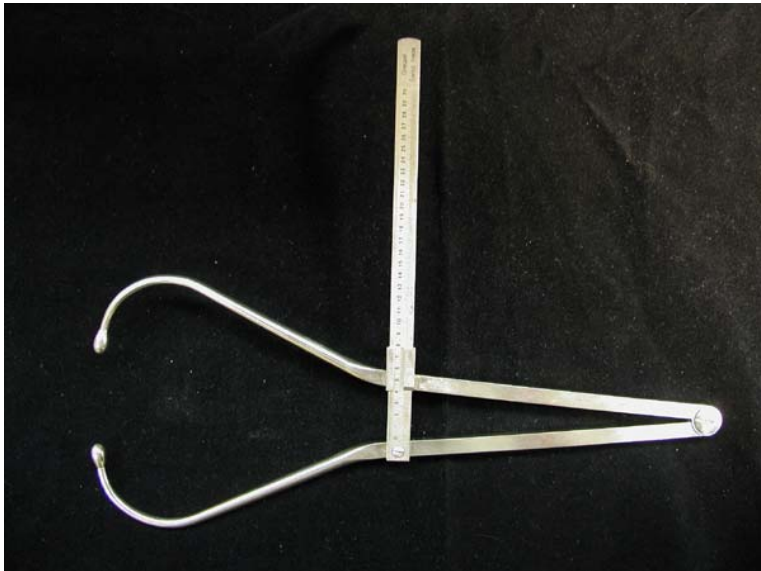
Anthropometer



Sliding Calipers (also available in digital models)



Spreading Calipers



Osteometric Board



Measuring Tape

A standard flexible measuring tape.

For some of the measurements described in this protocol (e.g., upper arm circumference at mid-arm or head circumference), a **pediatric insertion** tape can be used instead. This is often a good option for nonhuman primates.

For one of the measurements described in the protocol (i.e., arm span), it is necessary to have a long (2 meter) measuring tape.

Skinfold Calipers

Note: There are multiple types of skinfold calipers on the market. We recommend either Lange calipers (see below) or Harpenden skin fold calipers. It is critical that these be correctly calibrated.



PURCHASING MEASUREMENT EQUIPMENT

<p>Baty International http://www.baty.co.uk</p> <p><u>Contact:</u> Victoria Road Burgess Hill West Sussex, RH15 9LR Phone: +44 (0) 1444 235621 Fax: +44 (0) 1444 246985 e-mail: sales@baty.co.uk Distributor of Harpenden skinfold calipers</p>	<p>Biotech & Scientific Industries http://www.biotechagra.com.com http://www.indiamart.com/biotech</p> <p><u>Contact:</u> 193-a, Civil Lines Opp Sanjay Place Bagh Farzana AGRA-282002 (UP), INDIA Phone: 2854103, 2254649 Fax: 05672-2522696 e-mail: btiagra@hotmail.com or biotechagra@biotechagra.com</p>
<p>The Human Solution http://www.thehumansolution.com/</p> <p><u>Contact:</u> The Human Solution 9442 Capital of Texas Hwy N Plaza One, Suite 500-131 Austin, TX 78759 Phone: 800-531-3746 or 512-697-9330 Fax: 512-828-8000</p>	<p>Creative Health Products http://www.chponline.com/</p> <p><u>Contact:</u> 5148 Saddle Ridge Road Plymouth, MI 48170 Phone: 800-742-4478 or 734-996-5900 Fax: 734-996-4650 e-mail: websales@chponline.com</p> <p>Distributor of Lange skinfold calipers and several anthropometric instruments</p>
<p>WARD'S Natural Science http://wardsci.com/</p> <p><u>Contact:</u> 5100 West Henrietta Road P.O. Box 92912 Rochester, NY 14692-9012 Phone (toll free): 800-962-2660; Phone (local): 585-359-2502 Fax (toll free): 800-635-8439; Fax: 585-334-6174 e-mail: customer_service@wardsci.com</p> <p><u>Contact (International):</u> Phone: 1.585.321.9411; Fax: 1.585.321.9105 e-mail: international@wardsci.com</p>	<p>Carolina Biological Supplies http://www.carolina.com/</p> <p><u>Contact (USA):</u> 2700 York Road Burlington, NC 27215-2298 Phone: 800-344-5551</p> <p><u>Contact (International):</u> International Sales Department Carolina Biological Supply Company PO Box 6010 Burlington, NC 27216-6010 Phone: 226-584-0381 ; Fax: 336-583-7686 e-mail: internationalsales@carolina.com</p> <p>Distributor of osteometric boards</p>
<p>Paleo-Tech Concepts http://paleo-tech.com/</p> <p><u>Contact:</u> PO Box 2337 Crystal Lake, IL 60039-2337 Phone: 815-444-9537 Phone (UK): (020) 3004 8061 Fax: 815-444-9537 e-mail: sales@paleo-tech.com</p> <p>Maker of anthropometric instruments and distributor of Mitutoyo digital calipers</p>	

A SAMPLING OF ANTHROPOMETRIC/OSTEOMETRIC RESOURCES

The following is a list of publications that contain additional information on anthropometrics of humans and non-human primates. These references may be used to supplement the core measurements provided by this measurement protocol.

Living Human

CDC (Centers for Disease Control). 1988. National Health and Nutrition Examination Survey III: Body Measurements (Anthropometry). Rockville: Westat.

(<http://www.cdc.gov/nchs/data/nhanes/nhanes3/cdrom/NCHS/MANUALS/ANTHRO.PDF>)

CDC (Centers for Disease Control). 2007. National Health and Nutrition Examination Survey (NHANES): Anthropometry Procedures Manual. (http://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf)

Hrdlicka A. 1952. Practical Anthropometry. Philadelphia: Wistar Institute of Anatomy and Biology.

Lohman TG, Roche AF, Martorell R. 1988. Anthropomorphic Standardization Reference Manual. Champaign: Human Kinetics Books.

Wood Jones F. 1929. Measurements and Landmarks in Physical Anthropology. Honolulu: Bishop Museum.

Human Skeletal

Bass WM. 1995. Human Osteology: A Laboratory and Field Manual (4th edition). Columbia: Missouri Archaeological Society.

Buikstra JE, Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains. Fayetteville: Arkansas Archaeological Survey.

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