Craniometry and Functional Craniology

Part I:
Anthropometry, Craniometry and Cephalometry

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Lecture outline
1. Introduction: the scope and history
2. Definition and objectives
3. Identification of anatomical landmarks
4. Measurements: metric vs non-metric; direct vs indirect
5. Measuring devices
6. Sex/gender estimation
7. Age estimation
8. Racial/ethnic estimation
9. Other methodology, comparisons, and interpretations
10. Clinical applications

Anthropometry
• Definition: measurement of human head and body
• Scope: somatometry, osteometry, craniometry, cephalometry, odontometry
• Origin: The methodology probably began because of the interest in the racial classifications (in search of the origin of the human races: monogenism vs polygenism) (Anders Retzius: Swedish; cephalic index)
• Objectives: 1) to examine the differences between species; 2) to investigate the variations within species, which include temporal changes, sexual dimorphism, geographical and ethnic differences; 3) to explore the trends and evolution as well as to interpret fossil records; 4) to apply in clinical diagnosis, treatment planning, forensics, and other commercial applications.

Anthropometric Measuring Devices
Direct method
• Sliding caliper
• Hinge (spreading) caliper
• Stadiometer/Osteometric board
• Coordinate caliper
• Head spanner/Todd’s craniostat
• Soft metric tape
• Others
Indirect method
• Digitizer
• Surface scanner
• Radiography
• Other computer assisted imaging and measuring devices (CT scan, MRI, Sonography, etc.)

Sliding Caliper
(Non-Vernier vs. Vernier)

The Mitutoyo Digital Sliding Caliper
Spreading Caliper

Stadiometer
“Stretch of the Measuring”
Johann Wolfgang von Goethe, 1779

Osteometric Board

Todd’s Craniostat
(Head Spanner)

Soft Metric Tape

Body Imaging: 3D Surface Anthropometry
The Loughborough Anthropometric Shadow Scanner
The computerized whole body image after scanning
(Surface area and volume estimations; Shape capturing and reconstruction)

3 Imaging
(morphometrics in size and shape)

The Traditional Landmarks of the Skull

**Mid-Sagittal**

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Landmark</th>
<th>Landmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthion</td>
<td>Inion</td>
<td>PNS</td>
</tr>
<tr>
<td>Alveolare</td>
<td>Lambda</td>
<td>Prosthion</td>
</tr>
<tr>
<td>Alveolus</td>
<td>Menton</td>
<td>Rhinion</td>
</tr>
<tr>
<td>Apex</td>
<td>Nasion</td>
<td>Staphyion</td>
</tr>
<tr>
<td>ANS</td>
<td>Nasospinale</td>
<td>Subnasale</td>
</tr>
<tr>
<td>Basion</td>
<td>Obelion</td>
<td>Subspinale (A)</td>
</tr>
<tr>
<td>Bregma</td>
<td>Ophryon</td>
<td>Supradentale</td>
</tr>
<tr>
<td>Glabella</td>
<td>Opisthion</td>
<td>Supramentale (B)</td>
</tr>
<tr>
<td>Gnathion</td>
<td>Opisthocranion</td>
<td>Symphyse</td>
</tr>
<tr>
<td>Incision</td>
<td>Orale</td>
<td>Vertex</td>
</tr>
<tr>
<td>Infradentale</td>
<td>Pogonion</td>
<td></td>
</tr>
</tbody>
</table>

The Traditional Landmarks of the Skull

**Bilateral**

<table>
<thead>
<tr>
<th>Landmark</th>
<th>Landmark</th>
<th>Landmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alare</td>
<td>Euryon</td>
<td>Portion</td>
</tr>
<tr>
<td>Asterion</td>
<td>Frontotemporale</td>
<td>Pterion</td>
</tr>
<tr>
<td>Coronale</td>
<td>Gonion</td>
<td>Sphenion</td>
</tr>
<tr>
<td>Crotaphion</td>
<td>Jugale</td>
<td>Stephanion</td>
</tr>
<tr>
<td>Dacryon</td>
<td>Lacrimale</td>
<td>Zygion</td>
</tr>
<tr>
<td>Ectoconchion</td>
<td>Mastoidale</td>
<td>Zygorbitale</td>
</tr>
<tr>
<td>Ectomolare</td>
<td>Masillofrontale</td>
<td></td>
</tr>
<tr>
<td>Endomolare</td>
<td>Orbitale</td>
<td></td>
</tr>
</tbody>
</table>

**Definition:** measurement of human dry skull

**Landmarks:**
1) true vs relative landmarks
2) mid-sagittal vs bilateral landmarks

**Measurements:**
1) qualitative (non-metric) vs quantitative (metric)
2) metric: angular, arc, linear, volumetric proportional

**Cranial and facial indices**

**Cranial and facial forms**

- **Acanthion:** the midpoint of the anterior margin of the foramen magnum.
- **Bregma:** the intersection of the coronal and sagittal sutures in the midline.
- **Glabella:** the most forward projecting point in the midline of the forehead at the level of the supra-orbital ridges and above the nasofrontal suture.
- **Opisthocranion:** the most posterior point on the skull not on the external occipital protuberance. It is the posterior end point of maximum cranial length measured from glabella. It is determined instrumentally.
- **Zygion:** the most lateral point of the zygomatic arch. It is determined instrumentally.
- **Orbitale:** the lowest point of the orbit; one of the points used in defining Frankfurt Horizontal.
- **Pogonion:** the most anterior point in the midline of the chin.
- **Porion:** the uppermost lateral point in the margin of the external auditory meatus. The right and left porion with the left orbitale define the Frankfurt Horizontal.

- **Basion:** the midpoint of the anterior margin of the foramen magnum.
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- **Zygion:** the most lateral point of the zygomatic arch. It is determined instrumentally.
Frankfort Horizontal (FH)
1) A plane passing through three points of the right and left porion and the left orbitale.
2) First proposed at the Craniometric Congress held in Munich, Germany, 1877.
3) An orientation of skull in a consistent and reproducible position.
4) Comparisons: natural head position; horizontal visual axis; and horizontal plane.

Skull: Lateral View

Skull: Frontal View

Skull: Basal View

Drawing of a Child at Birth, Age 1, Age 2
Bergmüller (1723), Countway Library, Boston

Craniometric Measurements (I)

<table>
<thead>
<tr>
<th>Cranial circumference</th>
<th>Cranial height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. cranial breadth</td>
<td>Max. cranial length</td>
</tr>
<tr>
<td>Min. frontal breadth</td>
<td>Bizygomatic breadth</td>
</tr>
<tr>
<td>Bigonial breadth</td>
<td>Total facial height</td>
</tr>
<tr>
<td>Upper facial height</td>
<td>Basion-Nasion length</td>
</tr>
<tr>
<td>Basion-Prosthion length</td>
<td>Basal height</td>
</tr>
<tr>
<td>Nasal breadth (max.)</td>
<td>Upper nasal breadth</td>
</tr>
<tr>
<td>Lower nasal breadth</td>
<td>Orbital height</td>
</tr>
<tr>
<td>Orbital breadth</td>
<td>Interorbital breadth</td>
</tr>
<tr>
<td>Biorbital breadth</td>
<td>Palate-external breadth &amp; length</td>
</tr>
<tr>
<td>Foramen magnum breadth</td>
<td>Palate-internal breadth &amp; length</td>
</tr>
</tbody>
</table>
Craniometric Measurements (II)

- Condylo-symphysial length
- Bicondylar width
- Min. ramus breadth
- Mandibular body height
- Symphyseal height
- Mastoid length
- Ascending ramus height
- Mandibular body breadth
- Mandibular body length
  
  Total facial angle
  Mid-facial angle
  Alveolar angle
  Nasion-Opisthion arc
  Transverse arc
  Sagittal cord
  Coronal cord

Skull: Frontal Measurements

Skull: Lateral Measurements

Skull: Palatal Measurements

Cranial and Facial Indices

- Cranial index
- Cranial length-height index
- Cranial breadth-height index
- Total facial index
- Upper facial index
- Nasal index
- Orbital index
- External palatal index

Orbital Index

Orbital Index = \( \frac{\text{Orbital height} \times 100}{\text{Orbital breadth}} \)

- Chamaeconchy (X<82.99): wide orbits
- Mesoconchy (83.00-89.99): average or medium
- Hypsioconchy (89.00-X): narrow or square orbits
### Nasal Index

Nasal Index = \[
\frac{\text{Nasal breadth} \times 100}{\text{Nasal height}}
\]

- Leptorrhiny (X-47.99): narrow nasal aperture
- Mesorrhiny (48.00-52.99): average or medium
- Platyrrhiny (53.00-X): broad or wide nasal aperture

### Cranial Index

Cranial Index (Dry Skull) = \[
\frac{\text{Max. cranial breadth} \times 100}{\text{Max. cranial length}}
\]

- Dolichocrany (X-74.99): narrow or long calvarium
- Mesocrany (75.00-79.99): average or medium calvarium
- Brachycrany (80.00-84.99): broad or round calvarium
- Hyperbrachycrany (85.00-X): very broad headed calvarium

### Cephalic Index

Cranial Index = \[
\frac{\text{Max. cephalic breadth} \times 100}{\text{Max. cephalic length}}
\]

- Dolichocephaly (X-74.99): narrow or long headed
- Mescephaly (75.00-79.99): average or medium
- Brachycephaly (80.00-84.99): broad or round headed
- Hyperbrachycephaly (85.00-X): very broad headed

### Facial Index

Facial Index = \[
\frac{\text{Total facial height} \times 100}{\text{Bizygomatic breadth}}
\]

- Hypereuryprosopy (X-79.99): very broad face
- Euryprosopy (80.00-84.99): broad face
- Mesoprosopy (85.00-89.99): average or medium
- Leptoprosopy (90.00-94.99): slender or narrow face
- Hyperleptoprosopy (95.00-X): very slender or narrow face

### Sex/Gender Differences in the Skull

<table>
<thead>
<tr>
<th>Trait</th>
<th>Male</th>
<th>Female</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>General size</td>
<td>Large</td>
<td>Small</td>
<td>Externally and internally lighter, more prominent</td>
</tr>
<tr>
<td>Supraorbital rim</td>
<td>Broad</td>
<td>Narrow</td>
<td>Forehead broader, more lateral arching of hair</td>
</tr>
<tr>
<td>Maxilla</td>
<td>Broad</td>
<td>Narrow</td>
<td>Larger, more protruding, greater angle of curvature</td>
</tr>
<tr>
<td>Occipital bone</td>
<td>Muscle-horned</td>
<td>Smooth</td>
<td>Smaller, broader, more rounded</td>
</tr>
<tr>
<td>Forehead</td>
<td>Small</td>
<td>Large</td>
<td>Larger, broader, more rounded</td>
</tr>
<tr>
<td>Nasal cavity</td>
<td>Small</td>
<td>Large</td>
<td>Larger, more rounded</td>
</tr>
<tr>
<td>Cheek bone</td>
<td>Square, heavy, relatively small with smooth inner table and inner surface</td>
<td>Round, heavy, with prominent inner surface</td>
<td>Has a noticeable area that may or may not contribute to the aesthetic appearance of the face</td>
</tr>
</tbody>
</table>

Source: Drs. Bryan Scott & Sonia Abraham
Sexing the Skull
(Multiple Regression Analysis)

Caucasian samples

1.236 (Glabella.Opisthocranion) – 1.0 (Euryon.Euryon)  
+3.291 (Zygion.Zygion) + 1.528 (Porion.Mastoidale)  
= [563.93] (mm)

Score > 563.97: Male  
Score < 563.97: Female  
85.5% confidence of accuracy

Source: modified from Giles (1970)

Temporal Changes
(Infant vs Adult)

proportion comparison  size comparison

Racial/Ethnic Differences

<table>
<thead>
<tr>
<th>Race</th>
<th>Differences btw Species: Lateral view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australopithecus afarensis</td>
<td>A. australopithecus sapiens</td>
</tr>
<tr>
<td>Female chimpanzee</td>
<td>Female gorilla</td>
</tr>
<tr>
<td>Homo erectus</td>
<td>Homo sapiens sapiens</td>
</tr>
</tbody>
</table>

Differences btw Species: Cranial view

Australopithecus afarensis  Homo sapiens sapiens  Homo erectus  Early Homo
Comparison of Skulls: Occipital View

Modern human Homo erectus, Archaic Homo sapiens, & Neanderthal

The Face

Cephalometry

Radiographic Cephalometry

Imaging

Growth norms
Growth comparisons
Growth estimation
Growth prediction (?)

Clinical applications in orthodontics, dento facial orthopedics, craniofacial surgery

Radiographic Cephalogram (PA view)

Cephalometric Radiograph and Tracing (lateral view)

Cephalometric Landmarks
References


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