A Quantitative Method for Assessing MSM Rugosity

Charlotte Henderson
Department of Archaeology, Durham University, Durham, UK
Presentation Outline

Introduction:
- **Anatomy**
- **Multifactorial aetiology**

Materials:
- Male skeletons

Methods:
- New recording method

Results:
- Differences in size and shape

Discussion:
- **Over-simplification**

Conclusions:
- Future research

http://www.rogerscup.com/english/default.asp#
Introduction: Definitions

Enthesis:
- Attachment of soft tissue to bone includes:
  - Ligament
  - Tendon
  - Muscle

Enthesopathy:
- Here defined to mean: “any deviation from normal anatomy at an enthesis”
- Enthesophyte not used: indicates bone formation – lytic lesions also occur
Introduction: Anatomy 1

Locations of entheses:
➢ Diaphyses
➢ Close proximity to joints

So different mechanical environments

Smooth and well delimited

Poorly delimited and “rough”
Introduction: Anatomy 2

**Fibrous**
- Diaphysis
- “Large”, poorly delimited, roughened
- Soft tissue, (periosteum), bone

**Fibrocartilaginous**
- Near joints
- “Small”, well delimited, smooth
- Soft tissue, unmineralised fibrocartilage, mineralised fibrocartilage, bone

Both images adapted from Benjamin et al. 1986
Introduction: Anatomy 3

Fibrocartilaginous entheses
- Not uniform
- Different depths of cartilage
- Some regions lacking cartilage

This is probably an adaptation to localised stress conditions

Simplified model of surface stress when surface is pulled in direction of arrow
Introduction: Multifactorial Aetiology

Disease

- Examples of diseases associated with enthesopathies
  - Ankylosing spondylitis
  - DISH
  - Acromegaly
  - Fluorosis
  - Leprosy

Ageing process

Figures of a skeleton from Whitefriars, Norwich courtesy of Anwen Caffell
Introduction: Aims

Can entheses be characterised quantitatively?

- Can differences in size be found between normal entheses and those with enthesopathies?
- Can differences in shape be found between normal entheses and those with enthesopathies?
- How much normal variation exists?
Materials

Skeletal sample used:
- Fishergate House, York.
- Late medieval (14th-15th century)
- Probably low socio-economic status
- Adult, male skeletons only
- N=43
- Age not recorded
Methods: 1

Visual recording of the skeleton:
- Fractures
- DJD
- Presence of signs indicating potential enthesopathy forming disease:
  - presence of unilateral or bilateral sacroiliac ankylosis along with spinal ligament ossification on 2 or more vertebrae

Spinal ossification as found in potential “bone formers”
Methods: 2

Measurement:

- Long bone measurements (Buikstra and Ubelaker 1994)
- 2 measurements of the entheses: x and y (in mm)
- Clinical comparisons exist for the supraspinatus and biceps brachii insertions
Methods: 3

Surface roughness:

- Profile gauge
- x and y dimensions used for measurement
- Barrier used to avoid damage to surface: double checked against actual surface
- Line drawn onto paper
- Line scanned
- Line rotated and flipped to standardised left and right sides
- File saved as greyscale bitmap.
Methods: 4

Roughness parameters used to quantify surface shape (Gadelmawla et al 2002):

- **Vertical variation (amplitude)**
  - E.g. $R_q$ – standard deviation
  
  $$ R_q = \sqrt{\frac{1}{n} \sum_{i=1}^{n} y_i^2} $$

- **Horizontal variation (spacing)**
  - E.g. peak number
  
  $$ g = \frac{1}{L} \sum_{i=1}^{n} g_i $$

- **Hybrid**
  - E.g. mean slope – derivative
  
  $$ \Delta_x = \frac{1}{n-1} \sum_{i=1}^{n-1} \delta_{xi} $$

Example of output from Matlab routine written to smooth line and calculate roughness parameters
Methods: Hypotheses

- There is normal variation in size and shape of entheses.
- The size of entheses does not vary between entheses without and with enthesopathies.
- The shape of entheses does vary between entheses without and with enthesopathies.
- This shape variation can be quantified using roughness parameters.
Results: Size 1

Measurement:

- Measurements compare well with the clinical data on enthesis measurements

<table>
<thead>
<tr>
<th>Axis</th>
<th>Study</th>
<th>Mean (mm)</th>
<th>Range (mm)</th>
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<tr>
<td>X</td>
<td>Henderson</td>
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<td>6.76-22.49</td>
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<td></td>
<td>Mazzocca et al. 2007</td>
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<td></td>
<td>Forthman et al. 2008</td>
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<td>3.6-12.7</td>
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<tr>
<td>Y</td>
<td>Henderson</td>
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<td>15.82-32.21</td>
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<td></td>
<td>Mazzocca et al. 2007</td>
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<td>16-30</td>
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<td>Forthman et al. 2008</td>
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<td>13.8-27.3</td>
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Biceps brachii measurements:
comparison with clinical data
Results: Size 2

There is normal variation in size of the enthesis

- Minimal compared to abnormal variation
- “Bone formers” have larger entheses

<table>
<thead>
<tr>
<th></th>
<th>No enthesopathy</th>
<th>Enthesopathy</th>
<th>“Bone former”</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>9.62</td>
<td>11.01</td>
<td>15.54</td>
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<tr>
<td>Standard deviation</td>
<td>1.34</td>
<td>4.04</td>
<td>4.16</td>
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</tbody>
</table>
Results: Shape 1

Normal shape variation

- Shape of some entheses more variable than others

Normal common extensor origin variation

<table>
<thead>
<tr>
<th></th>
<th>Rq</th>
<th>Peak num</th>
<th>Mean slope</th>
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<tbody>
<tr>
<td>Min</td>
<td>0.307</td>
<td>0.05</td>
<td>-0.025</td>
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<td>Max</td>
<td>1.105</td>
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<tr>
<td>Mean</td>
<td>0.6499</td>
<td>0.0641</td>
<td>-0.012</td>
</tr>
<tr>
<td>Median</td>
<td>0.619</td>
<td>0.063</td>
<td>-0.014</td>
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<tr>
<td>St. dev</td>
<td>0.212</td>
<td>0.008</td>
<td>0.009</td>
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</tbody>
</table>

Normal biceps brachii insertion variation
Results: Shape 2

Shape varies between entheses with and without enthesopathies

![Biceps brachii x](image)

<table>
<thead>
<tr>
<th></th>
<th>F90L</th>
<th>F90R</th>
<th>F67R</th>
<th>F67L</th>
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<tbody>
<tr>
<td>Rq</td>
<td>0.758</td>
<td>1.076</td>
<td>0.722</td>
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<td>Peak num</td>
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<tr>
<td>Mean slope</td>
<td>0.026</td>
<td>0.022</td>
<td>0.033</td>
<td>0.022</td>
</tr>
</tbody>
</table>

F90L and F67R are normal. F90R and F67L have enthesopathies.
Results: Shape 3

This shape variation is quantifiable

F77 and F204 are both “bone-formers” with enthesopathies
Discussion: Hypotheses

- There is normal variation in size and shape of entheses
  - YES
- The size of entheses does not vary between entheses without and with enthesopathies
  - NO
- The shape of entheses does vary between entheses without and with enthesopathies
  - YES

General size and shape variation of the humerus
Discussion: Implications 1

Stress distribution

➢ Size and shape effect stress distribution

Size:

➢ Size is linked to the size of the individual
➢ Linear trend, but anomalies
➢ Are these individuals more likely to develop enthesopathies?

No enthesopathy

Enthesopathy
Discussion: Implications 2

Stress distribution
- Size and shape effect stress distribution

Normal surface shape
- Variability is enthesis dependent

Enthesopathies
- Spurs and lytic lesions change the surface area:
  - This effects stress distribution
  - This change is measurable
Discussion: Over-simplification

MSM studies:

- Frequently use same recording methods for different types of entheses
  - Anatomy different
  - Normal variation needs to be fully understood

So:

- All these factors must be taken into account when recording MSM
- Ranking which muscles have been used most – probably inappropriate

Enthesopathies:

- Clinical data is unclear about the relationship between enthesopathies and stress
- Disease and the ageing process are also contributing factors
Conclusions

This research demonstrated:

- Variation can be quantified by studying the size and shape of entheses
- Normal variation must be taken into account when recording entheses

Future research:

- Test this method on skeletons of known sex, age and occupation

Tombstone of a Danish Whaler
References

