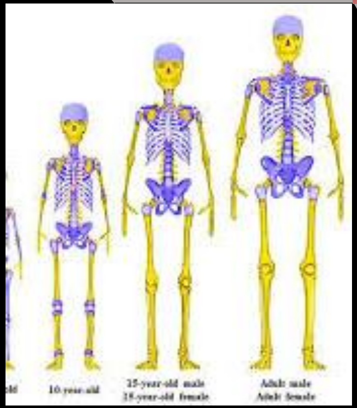
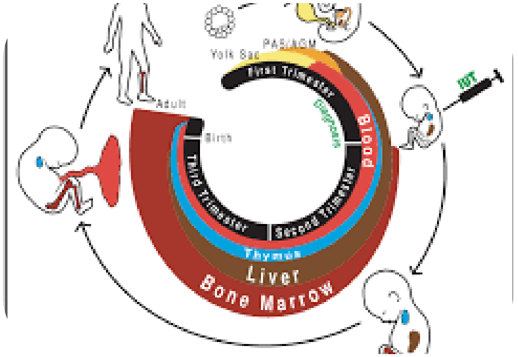


Dental & Skeletal Variations: Individual (idiosyncratic) & Population-based

Dr Arwa Kharobi

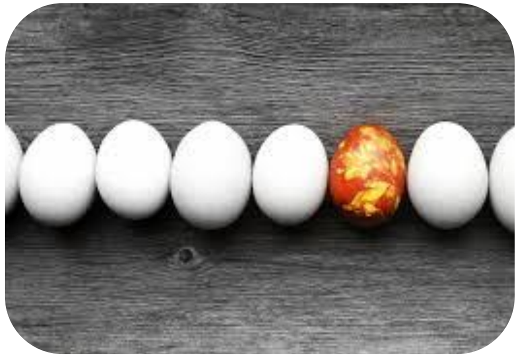
The Dynamic Nature of Bone:
Responding to Life's Stresses & Remodeling"


Mechanical & nutritional stress



I. Ontogeny

II. Sexual Dimorphism



III. Idiosyncractic Differences

IV. Geographic or Population-Based

I. Ontogeny :

growth & development of organisms (Homo sapiens)

Adult with Two Juvenile Remains, From Southern Sahara

Seven classification groups for human age groups:

1. Fetus (before birth),
2. Infant (0-3)
3. Child (3-12)
4. Adolescent (12-20)
5. Young Adult (20-35)
6. Middle Adult (35-50)
7. Old Adult (50+)

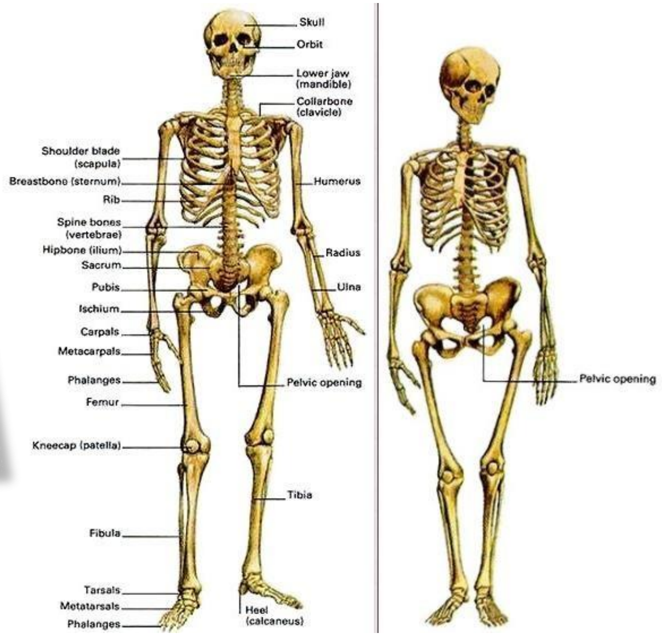
Archaeological record includes skeletons from unborn fetuses to old adults

II. Sexual Dimorphism

- Humans exhibit sexual dimorphism = differences in body size between females and males

- Differences are not as pronounced as in our primate relatives like gorillas

<u>female human skeletal remains generally have smaller bones & teeth</u> (Jurmain et al. 2010)



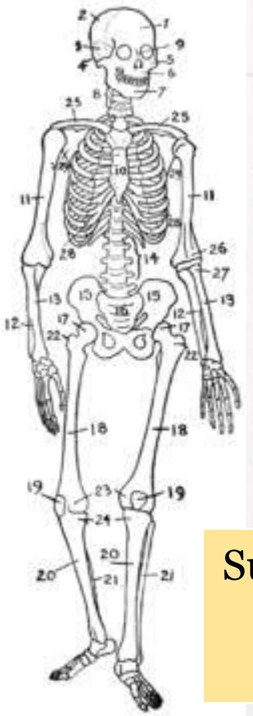
These variations are linked to the biological requirements of reproductive functions in the female skeleton

Possibilities of determination of sex from skeletal remains
White & Folkens 2005: 32

III. Idiosyncractic/individual Differences

- Idiosyncratic differences found in skeletons are simply natural variations, in the understanding that everybody is different
- Idiosyncratic differences in bone affect:

1. size
2. shape
3. topography of the bone surface

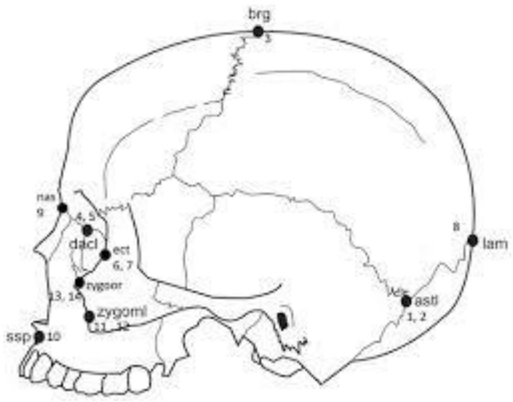


Disarticulated human bone from the site of Armana, Egypt

Such variation is very common in human skeletal remains

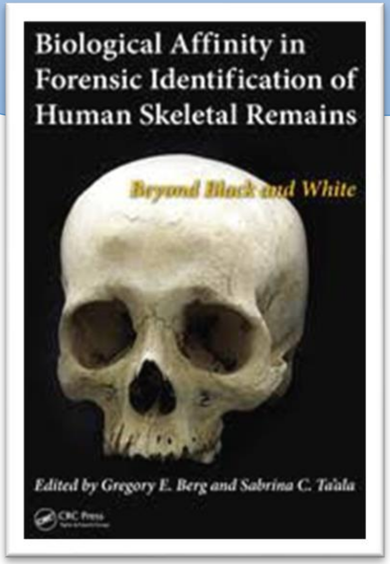
White & Folkens 2005: 32

IV. Geographic or Population-Based



different human groups can differ in many skeletal & dental characteristics

White & Folkens 2005: 32



to assess population affinities

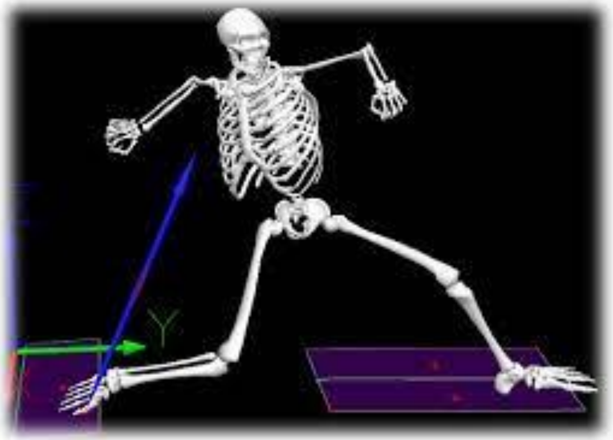
as certain environmental and genetic traits can be passed on

Biomechanic Basics

Next

must be taken into account → basics of biomechanics.

- Biomechanics is the application of engineering principles to biological materials, whilst remembering that bone can remodel and change according to pressures put upon it.



Must Remember

- ‘the density of bone tissue differs within the skeleton and within individual bones in response to the varying mechanical demands’
- response of human bone to ‘increase loading is in the distribution of bone (geometric) rather than density or any other intrinsic material property of bone’

(Larsen 1997: 197)

- Human bone is anisotropic = its mechanical properties vary according to the direction of the load

What Is Wolff's Law?

Created by the German anatomist & surgeon Julius Wolff in the 19^{th} century

- part of bone theory that explains how bones typically respond to stress
- marks the adaptive changes that bones can make internally to become stronger and stronger in order to resist strain
- applies in the inverse case: It explains the effect of decreased weight on the bone as the bone becomes less dense and weaker

To exemplify Wolff's Law

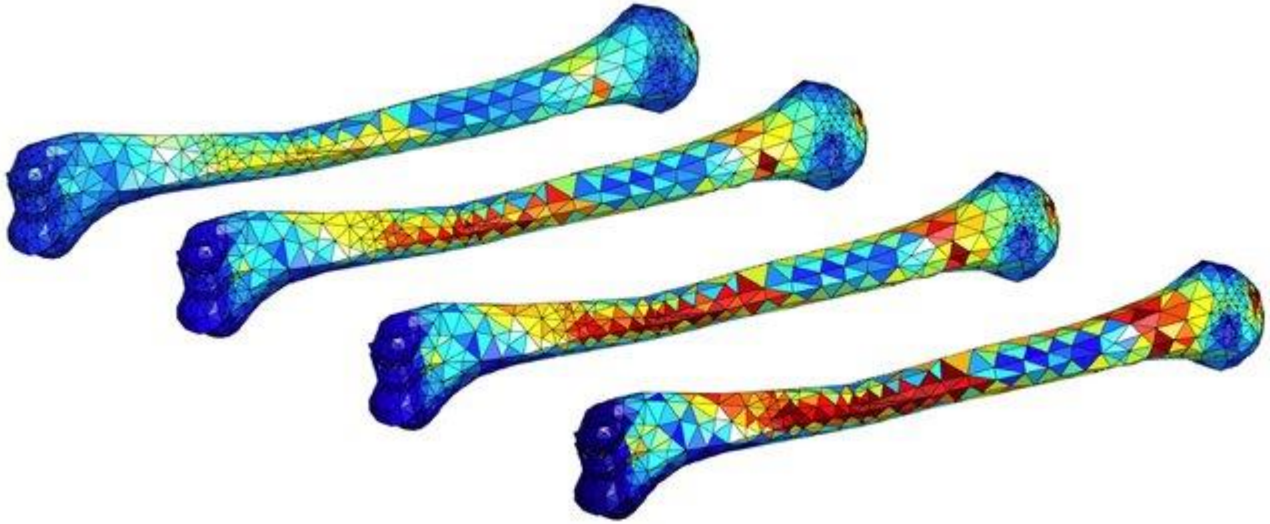
One study (Larsen 1997: 196)

Tennis player : a classic example of the remodeling capabilities of bone

→ thicker cortical bone alongside hypertrophy of the muscle attachment sites in the dominant arm

'males 35% increase in the cortical bone in the distal humerus of the **playing arm** vs the **non-playing arm**'

Krahl et al. 1994: Stimulation of Bone Growth Through Sports A Radiologic Investigation of the Upper Extremities in Professional Tennis Players



Longitudinal growth: Time sequence of density adaptation in response to critical muscle loads during phase (III) ball impact. Red colors indicate significant increase in bone mass density due to overload. Predominant axial loading by deltoid induces humeral hypertrophy with pronounced bone growth along the longitudinal axis.

Biomechanic Basics

That study was an example of bilateral asymmetry humeral loading.

Alongside, it is the action of the main forces acting on human bone that help to change the bone, these include

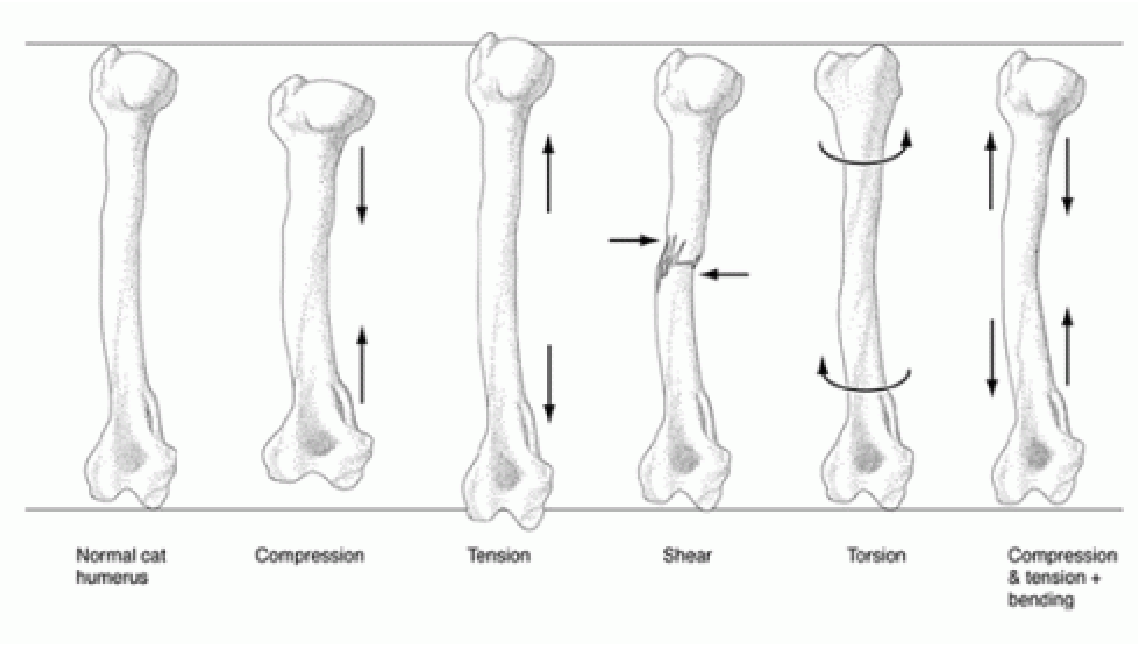
a) compression,

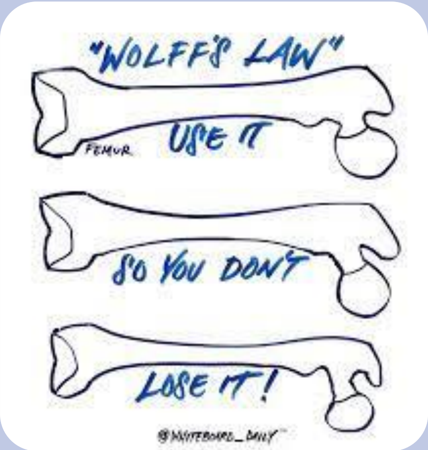
b) tension,

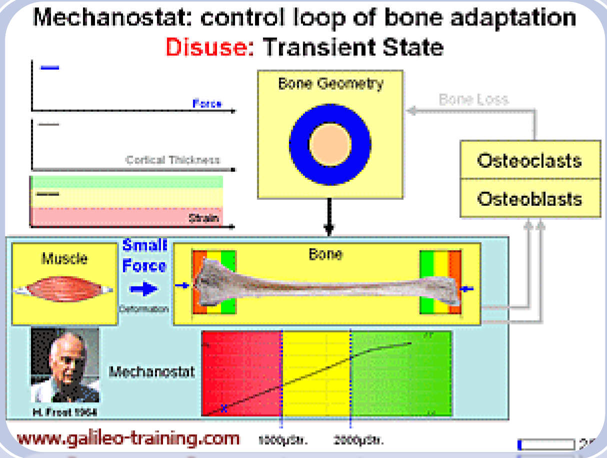
c) shear,

d) torsion

e) compression + tension+ bending.







Wolff's law states

healthy LBB load bearing bone responds to strain by

'placing or displacing themselves (at a mechanical level) in the direction of the functional pressure

& increase or decrease their mass to reflect the amount of functional pressure'-- often muscular strain and/or weight bearing pressures

(Mays 1999: 3)

Frost argues

'mechanostat', a tissue level negative feedback system, involves 'two thresholds that make a bone's strains determine its strength by

switching on and off the biologic mechanisms that increase or decrease its strength'

(Frost 2004: 3)

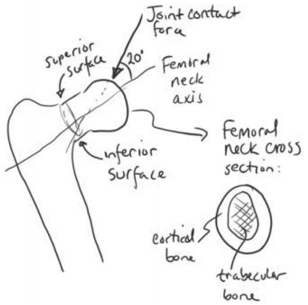
Skerry argues

1. many 'mechanostats' operating on the LBB & different elements throughout the skeleton require different strain magnitudes for maintenance

2. differences are apparent between the sexes, and genetic constitution, concomitant disease, exercise & activity patterns must be considered

Skerry (2006: 123)

Case study



- highlighted how the femoral neck width of obese people changes to accommodate the added weight.

the width of the femoral neck has increased to dissipate weight throughout the bony area by increasing surface area and strength through redistribution of bone.

This is an example of active bone remodeling adapting to changes that the person has gone through in life

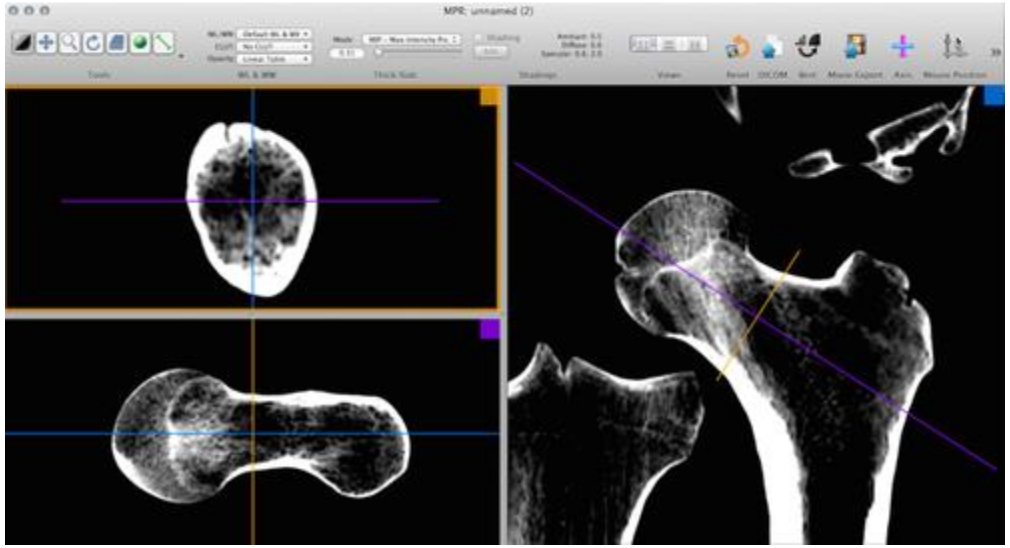
› Clin Anat. 2015 Nov;28(8):1048-57. doi: 10.1002/ca.22632. Epub 2015 Oct 5.

The effects of body mass index and age on cross-sectional properties of the femoral neck

Rachel L Wheeler [1], Aaron D Hampton [1], Natalie R Langley [1]

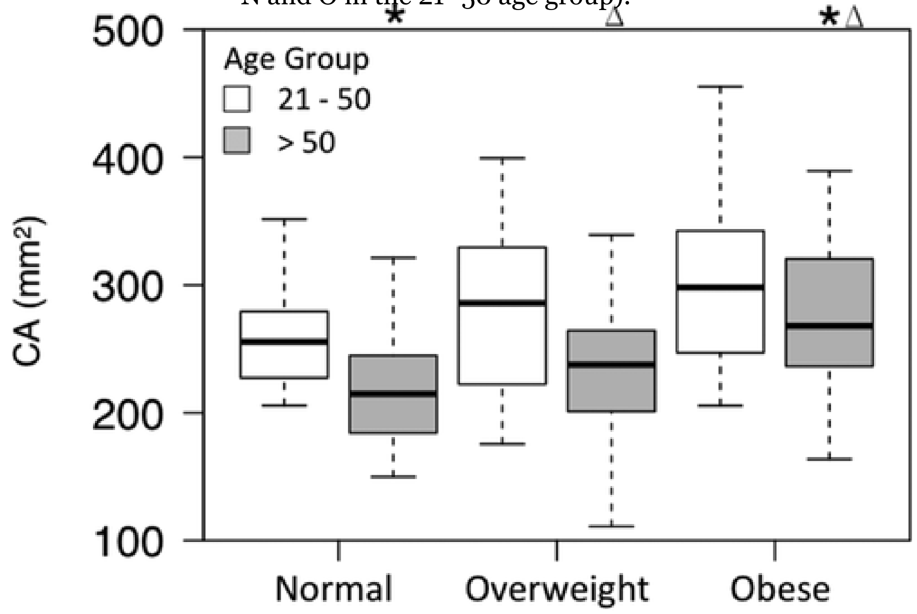
Affiliations + expand

PMID: 26385008 DOI: 10.1002/ca.22632

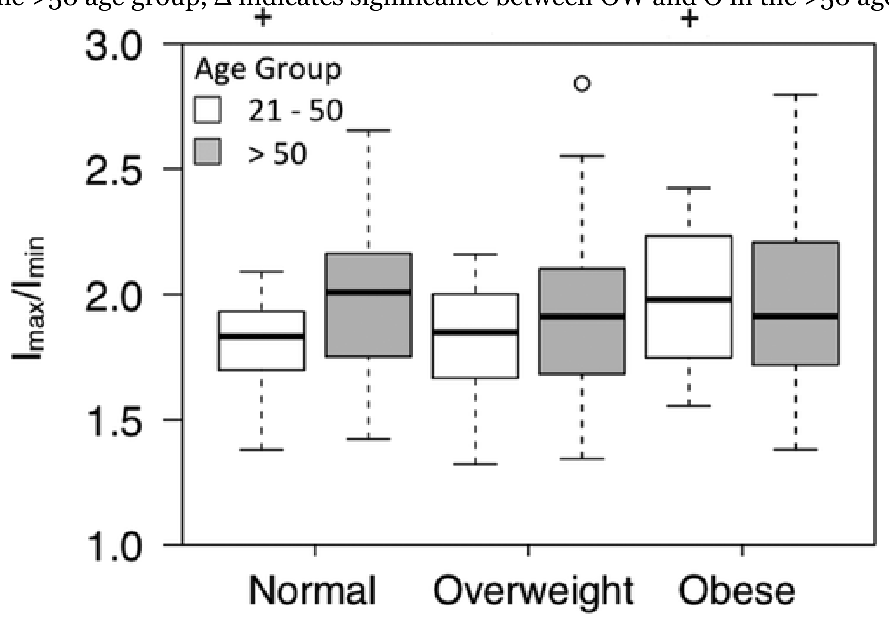


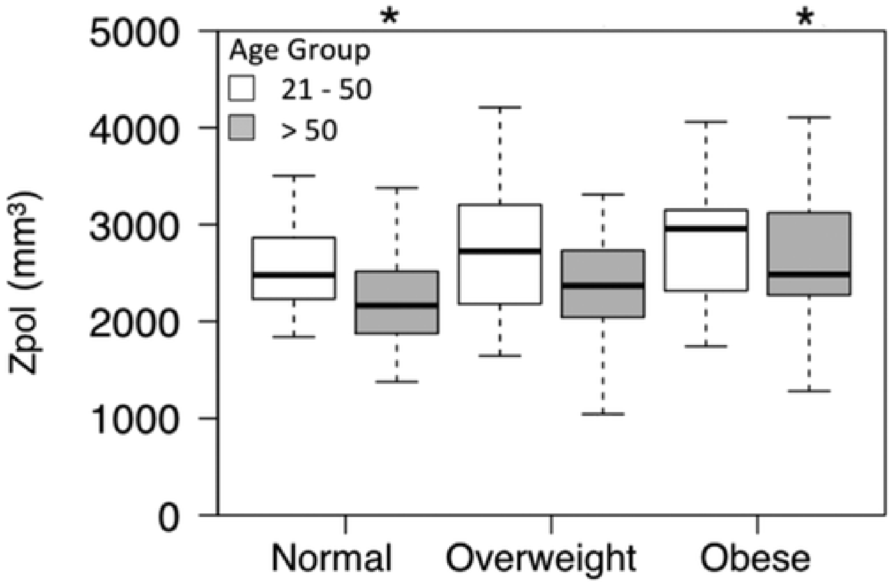
Cross-sectional slices with the axis of orientation through the left femoral neck in OsiriX.

Circularity index (I_{max}/I_{min}) for each age group and BMI group. (+ indicates significance between N and O in the 21–50 age group).

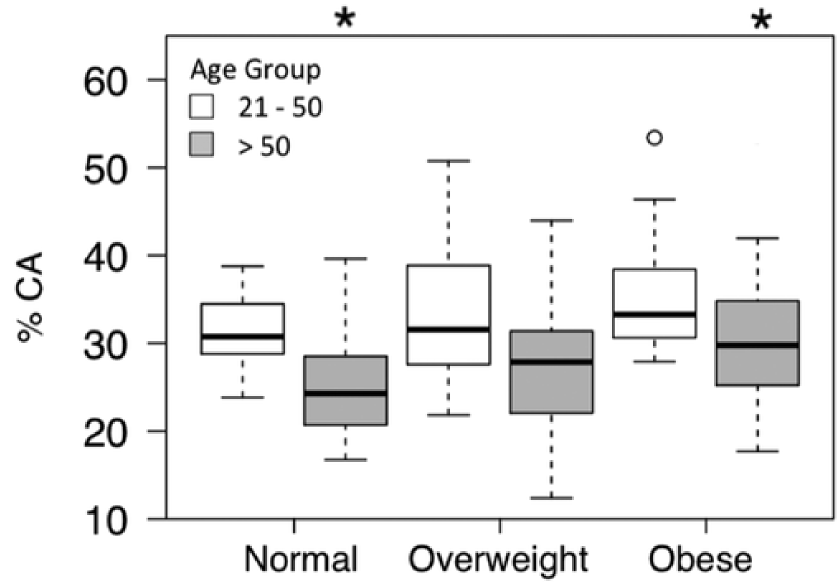


Cortical area (CA) for each age group and BMI group. (* indicates significance between N and O in the >50 age group, Δ indicates significance between OW and O in the >50 age group).





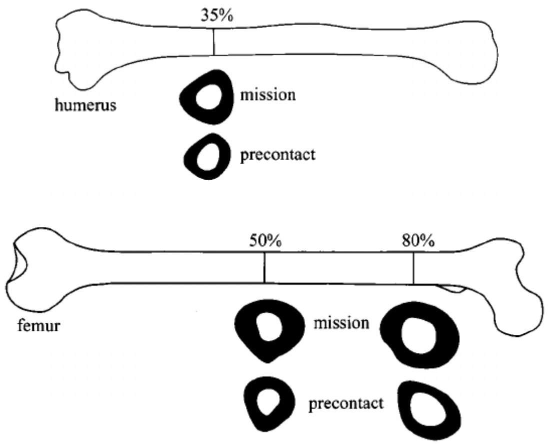
Percent cortical area (%CA) for each age group and BMI group. (* indicates significance between N and O in the >50 age group).



Section modulus (Zpol) for each age group and BMI group. (* indicates significance between N and O in the >50 age group).

An archaeological examples

Study case I. Bridge 1991, analysis on femora & humeri cross-sectional geometry Pickwick Basin of northwestern Alabama showing differences:



earlier Archaic Period hunter-gatherers

later Mississippian Period agriculturalists

long bone strength increased ++ with the adoption of agriculture:
+ in the legs of males
+ in the arms in females

more physically demanding lifestyle with the adoption of agriculture

An archaeological examples

Study case I. Bridge 1991

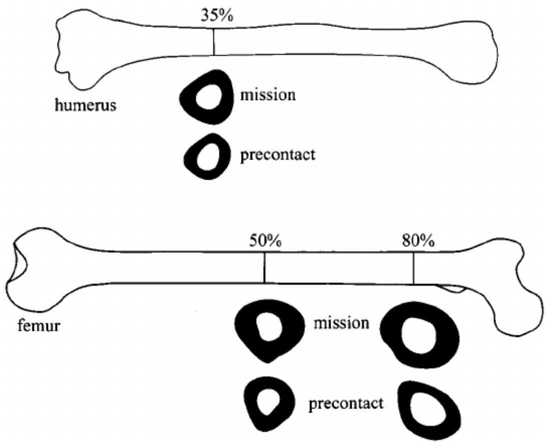
changes are from a greater range of activity undertaken by females than males

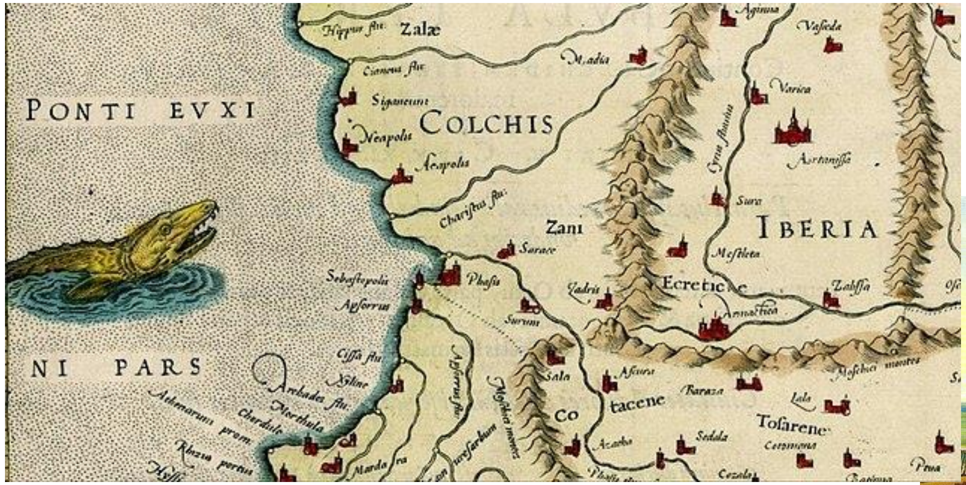
+signs of osteoarthritis
shift to food production (maize production) →
greater impact physically on women?

from Larsen 1997: Bioarchaeology: Interpreting Behavior from the Human Skeleton. New York: Cambridge University Press.

On the other hand

Study case II. Ruff, et al. 1 984, on prehistoric people of the Georgian coast showed the opposite:





A decrease ---- in long bone cortical area & presumably less mechanical stress due to the adoption of agriculture

Contradictory Studies

No consistent set of changes in long bone morphology caused by the transition from a hunter-gather to agricultural.

Rather, differences in:

1. technology used,
2. divisions of labor,
3. kinds of resource exploitation,

MUST be taken into account

Understand variation in the shape of the life course itself as an object of study

Are there common patterns for how lives unfold within a society?

Are there events or experiences that channel life courses?

approach to the **life course** adopted for ancient & modern lives

A key element: developing new methodologies for characterizing & comparing how lives develop through time

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Beyond Individual Lives: Using Comparative Osteobiography to Trace Social Patterns in Classical Italy

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ABSTRACT Osteobiographical studies have usually focused upon investigating an individual's life experience. However, we can also understand variation in the shape of the life course itself as an object of study: Are there common patterns for how lives unfold within a society? Are there events or experiences that channel life courses? This approach to the life course can be adopted for ancient as well as for modern lives. A key element here is developing new methodologies for characterizing and comparing how lives develop through time, for instance, by ordering biological data in sequence, looking for time-structured patterns in them both by eye and through multivariate statistics. This article presents an initial exploration of this problem, using skeletal and archaeological data on 47 adults from the fifth to third centuries B.C. at Pontecagnano, an urban site in Campania, Italy. The results show both the importance of gender in the life course and the effects of different kinds of physical stress, probably due to specialization in labor. The result is not discrete categories of people but fuzzy envelopes of life possibilities.

Keywords: biography; gender; work; Italy; Etruscan; specialization; life course

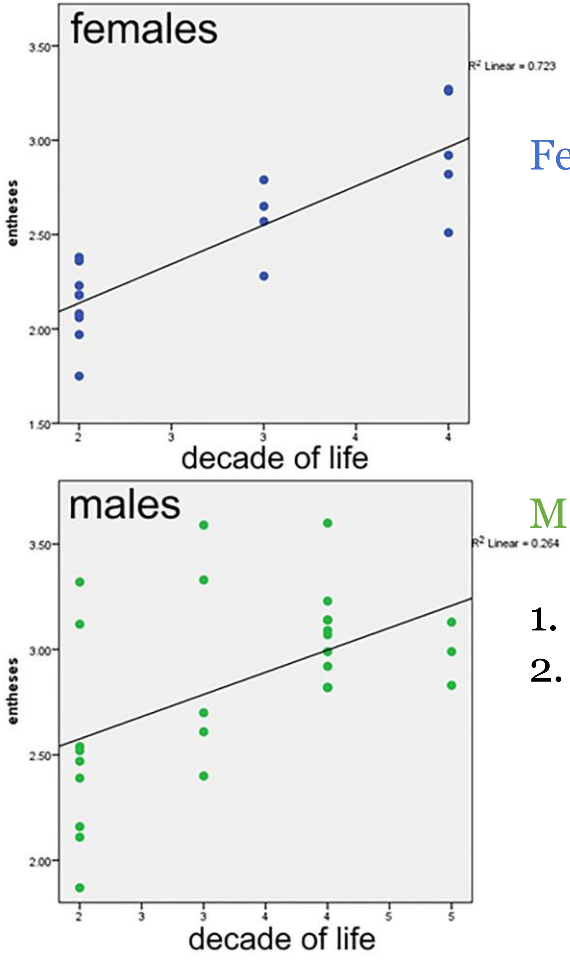
multivariate statistics approach

Results

skeletal & archaeological data on 47 adults

5^{th} – 3^{rd} centuries

Urban Italian Site

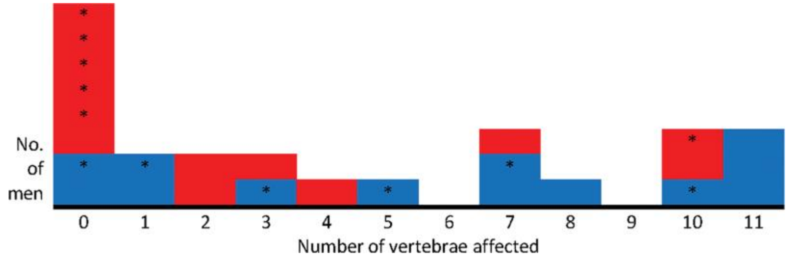


Relationship between average entheseal scores and age at death

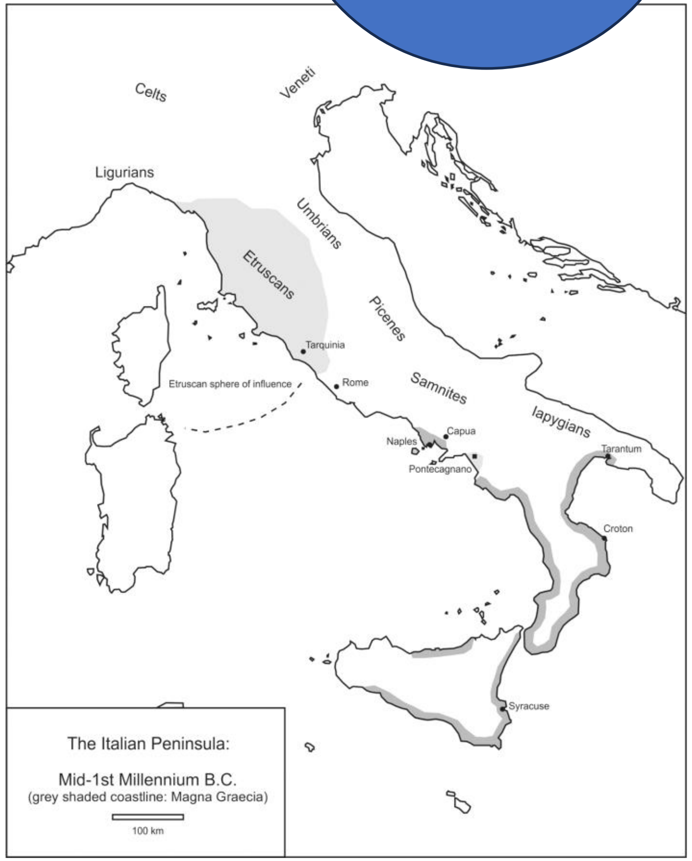
Females: No signs of activity markers
No adaptations to marked physical stress

Males: signs of labor

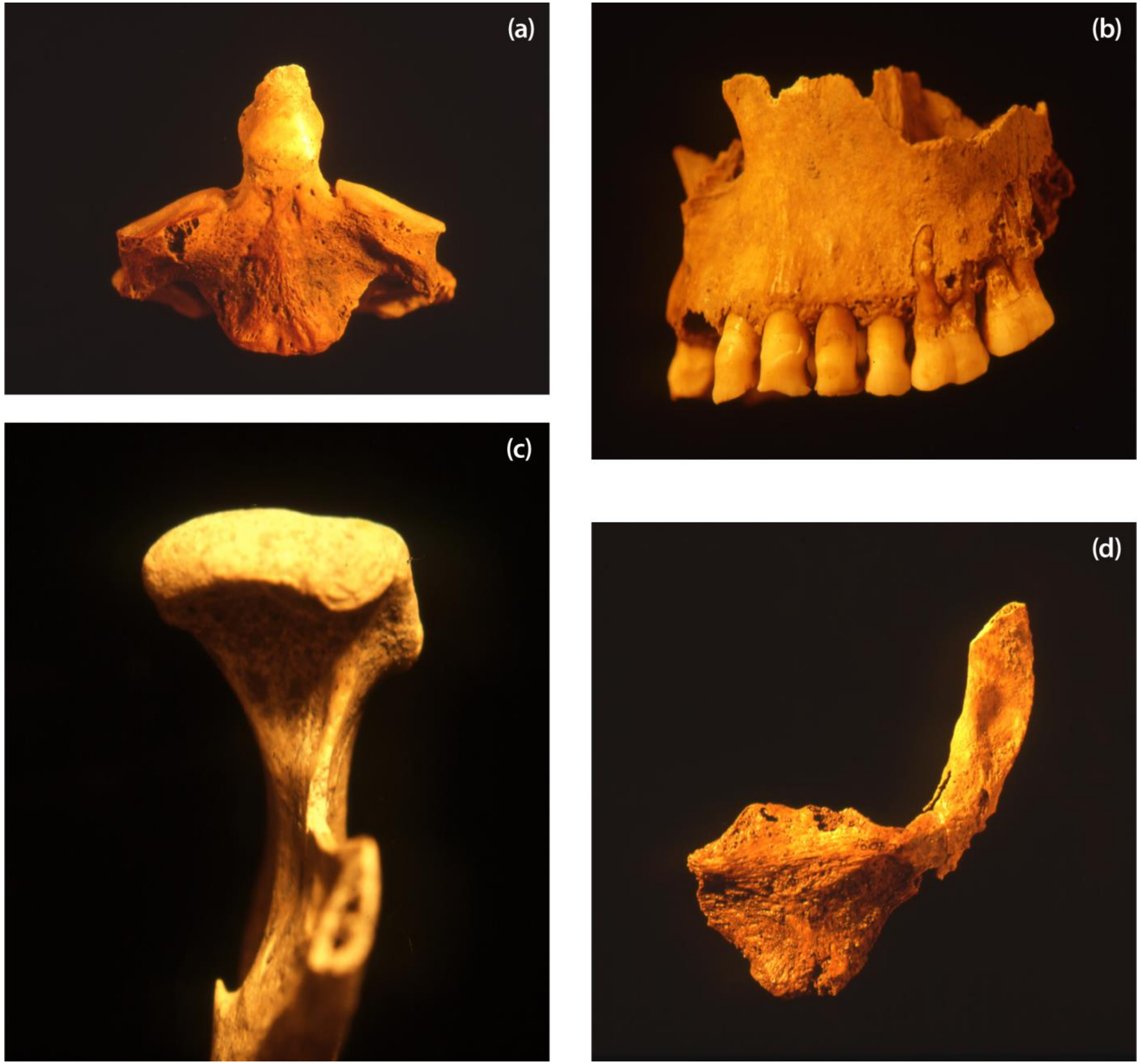
1. no or few Schmorl's nodes * more likely not to be "specialists"
2. with many Schmorl's nodes * more likely to be "specialists"



The number of vertebrae affected by Schmorl's nodes in males; red shows individuals flagged as possibly performing specialized labor, blue shows individuals not flagged as such

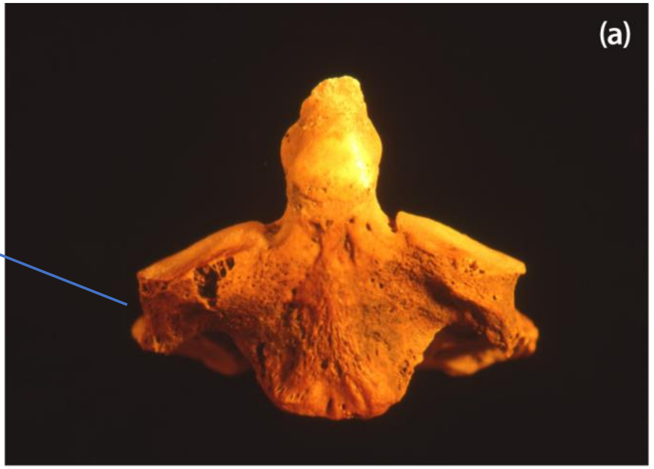


Examples of skeletal features considered potentially related to **specialized activity**

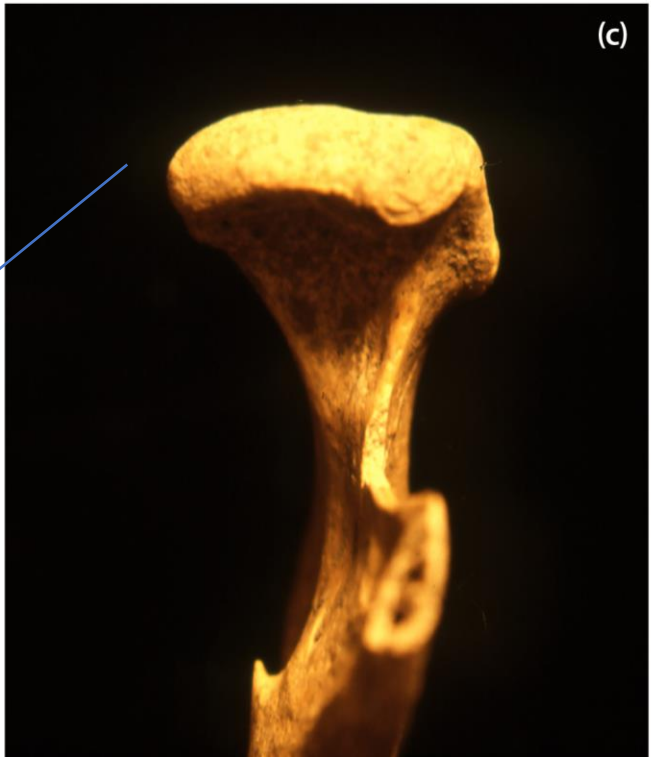


Examples of skeletal features considered potentially related to **specialized activity**

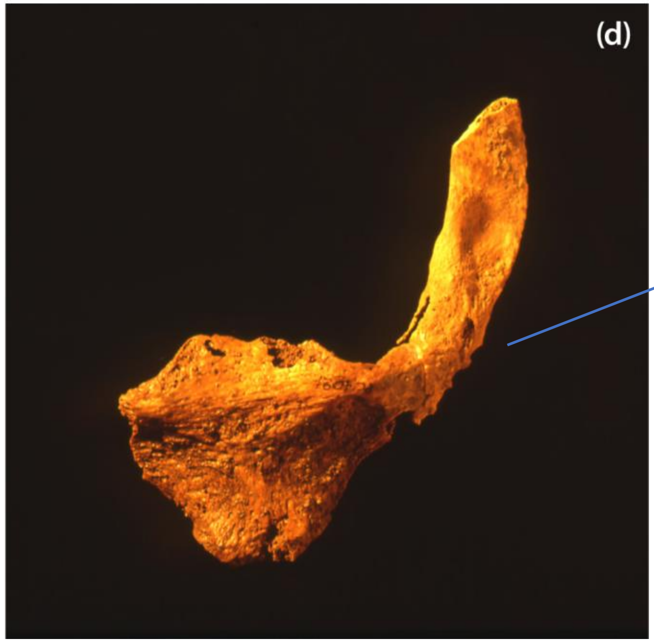
eburnation, dens C1



interdental grooving between multiple upper teeth



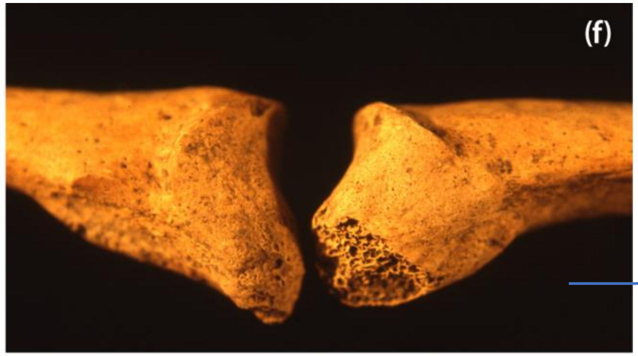
spur at insertion of lateral pterygoid muscle, mandible



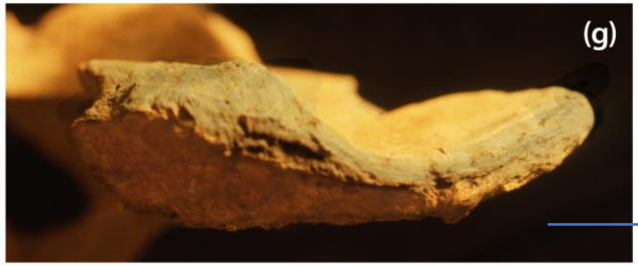
ankylosis of manubrium and left first rib

Examples of skeletal features considered potentially related to **specialized activity**

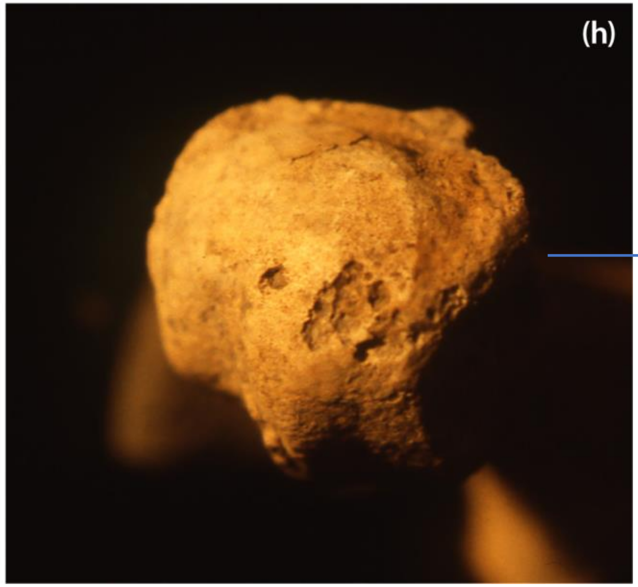
osteophyte limiting motion at coronoid process of left ulna



bilateral extension of proximal articular surface onto anterior surface of clavicles



broadened iliac crest with markedly rugose insertion of erector spinae



eburnation, head of first metatarsal

Congenital “humerus varus” condition

right & left humeri

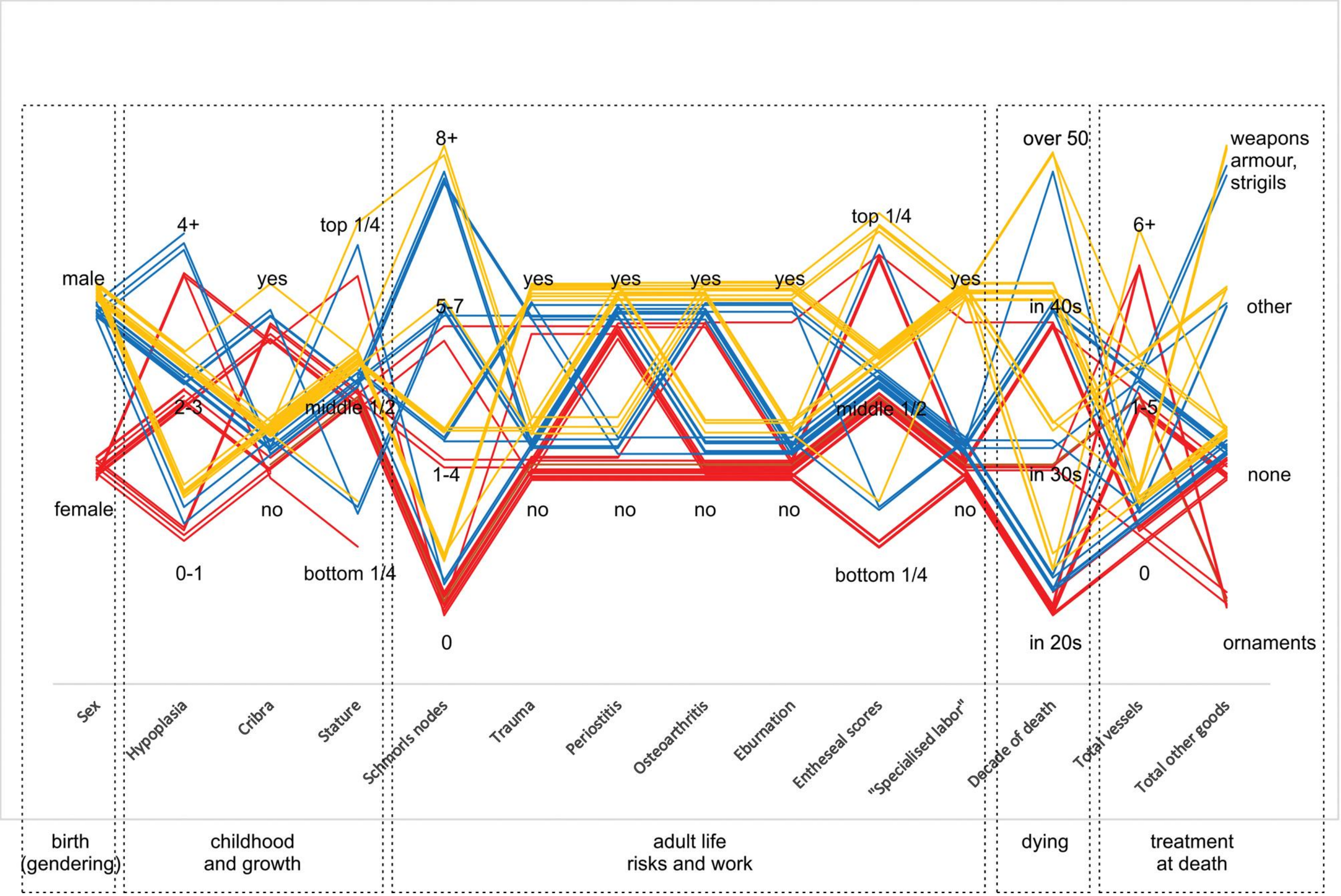
proximal epiphysis, left humerus

Comparative life paths for Pontecagnano individuals.

Women's lives

Men with signs of possible specialized labor

Men without signs of specialized labor



Skeletal & Dental Variations

1. **Stature**
2. Stress Markers
3. Activity Markers
4. Degenerative Joint Disease DJD

1. Stature

one of the three basic characteristics, besides sex and age of every osteological analysis:

most common

i. K. Pearson 1899
ii. M. Trotter & G. C. Gleser 1977; 1958

based on the length of the corpse, and linear regression equations were formulated using bones from the autopsies of previously measured cadavers

iii. M. H. Raxter et al. 2008
iv. C. B. Ruff et al. 2012

developed from skeletal materials using stature derived from arduous anatomical reconstruction

recent date & broad material base

2. Estimation of stature

i. K. Pearson 1899

Based on a small sample (50 women & 50 men) from Lyon

Most reliable results for extensive series of individuals, from the Middle Ages

Giannecchini & Moggi-Cecchi (2008) for Italy & J. Kozak (1996) for Poland : useless

ii. Trotter & Gleser 1977; 1958

The most frequently used worldwide, whereas a linear regression stature estimation using long bones

Based mainly on samples of military victims of the Second World War and the Korean War (male only)

Then supplemented with contemporary civilian subjects from the Terry Anatomical Collection

Series divided into 4 different ancestral groups for men & 2 for women

2. Estimation of stature

iii. Raxter et al. 2008

Based on a series with 3% of the individuals, male only, Luxor of the Roman period

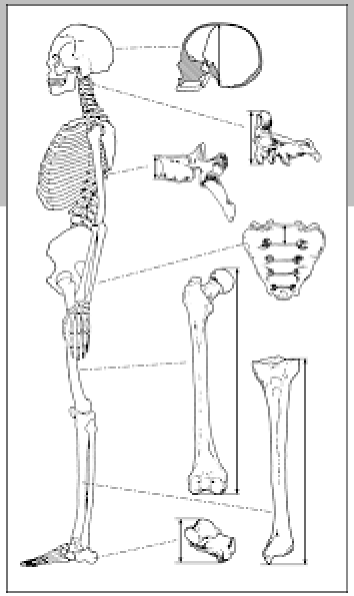
The remaining skeletons originate largely from the Old Kingdom Giza, constituting 89% of all the women and men in the sample

Suitable for Egyptian populations

iv. Ruff et al. 2012

Based on the most comprehensive series, both chronologically and geographically, of all the methods tested

501 skeletons dating from Mesolithic to modern times from all over Europe



Which to choose?

A formalized approach to choosing the best methods for reconstructing stature in the case of poorly preserved skeletal series

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Abstract
Stature, as the universal measure of the well-being of a population, is one of the three basic characteristics, besides sex and age, of every osteological analysis. Reconstructing living stature using the length of long bones and linear regression is the method of choice, especially in the case of poorly preserved human skeletal material obtained from archaeological excavations. Although the choice of the best formulae is usually based on intuition, the need for a more formal approach is paramount. However, the solutions adopted to date require a significant number of well-preserved skeletons, which is rarely possible in bioarchaeological research.
For skeletal series consisting of very incomplete skeletons, it has been shown that a simple comparison of the mean differences in stature estimation using femur, humerus, and radius bone pairs may be instrumental for selecting the most appropriate of the available stature reconstruction methods. The results were confronted with the consistency of the same methods but also using bones that could not have been used previously; that is the tibia, fibula and ulna. All the methods tested were then compared with those selected as being the most consistent to see if the results they produce are significantly different.

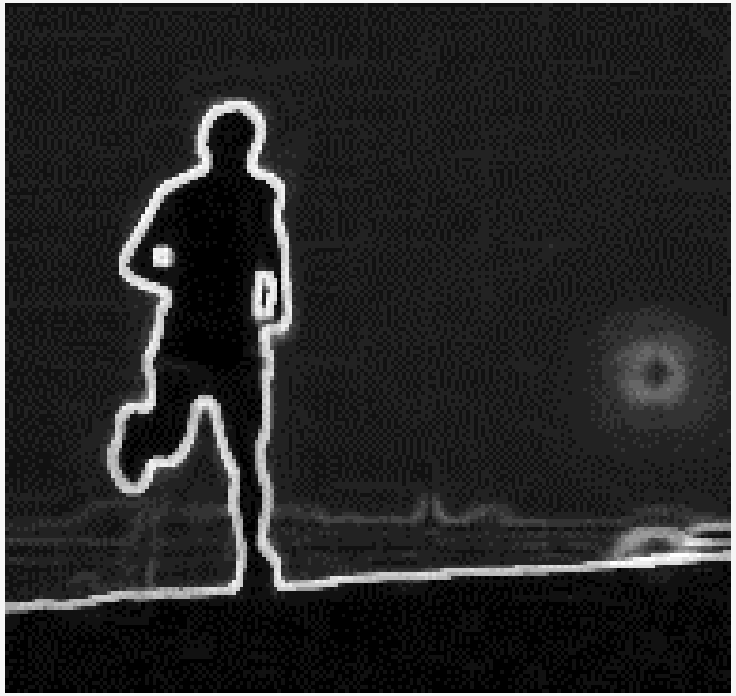
KEYWORDS
bioarchaeology, regression formulae, skeletal material, stature reconstruction

Mahler 2021. A formalized approach to choosing the best methodsfor reconstructing stature in the case of poorlypreserved skeletal series. rchaeometry. 2021;1–16. DOI: 10.1111/arcm.12700.

Comparing reconstructed statures of archaeological groups is crucial for population studies, offering insights into past well-being and population changes.

Eco-sensitivity of stature depends on sex, allowing for the study of diachronic changes from the perspective of sexual dimorphism.

When estimating stature from long bones, researchers should select the best method and account for possible uncertainties by assessing the morphological similarity between the studied population and the population used to develop the method.

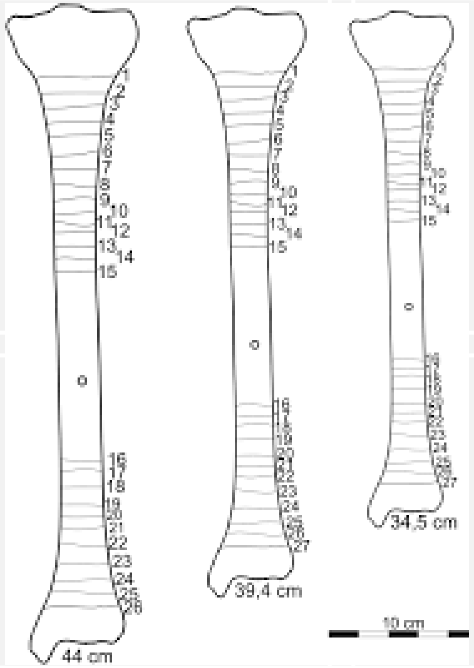


Skeletal & Dental Variations

1. Stature
2. **Stress Markers**
3. Activity Markers
4. Degenerative Joint Disease DJD

2. Indicators of stress

- Harris lines
- Enamel Hypoplasia
- Enamel Microdefects
- Porotic Hyperostosis
- Cribra Orbitalia
- Infectious diseases



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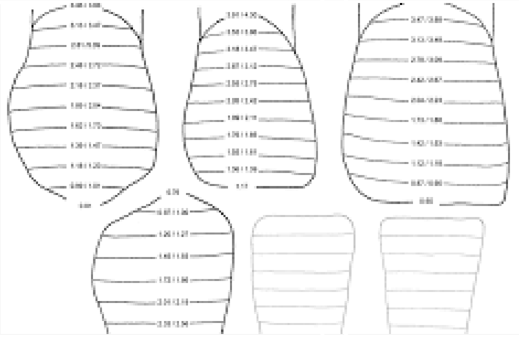
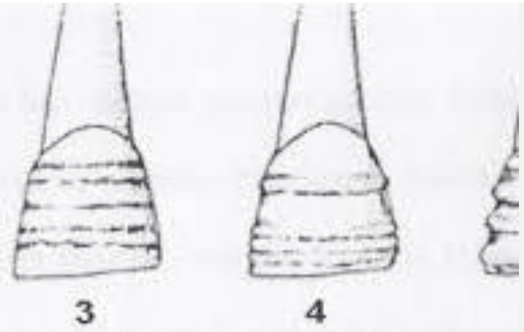


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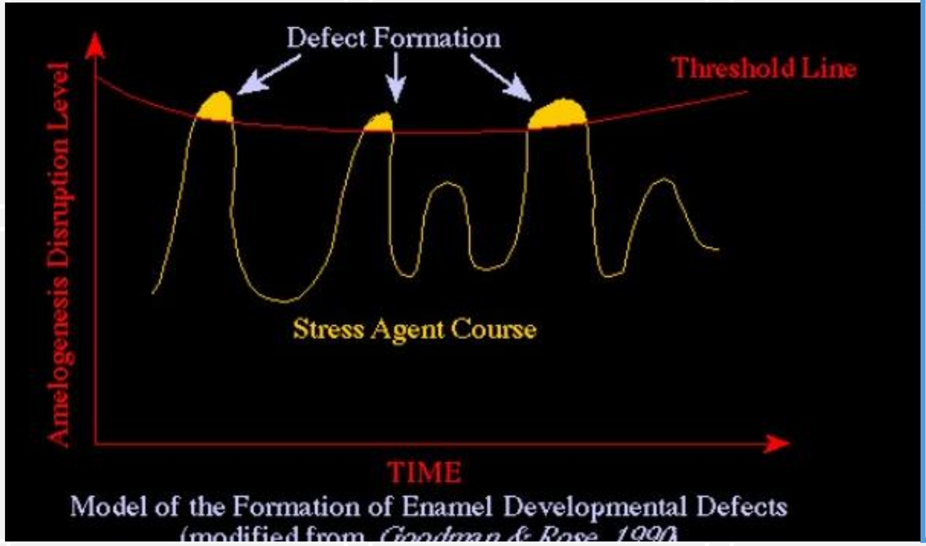

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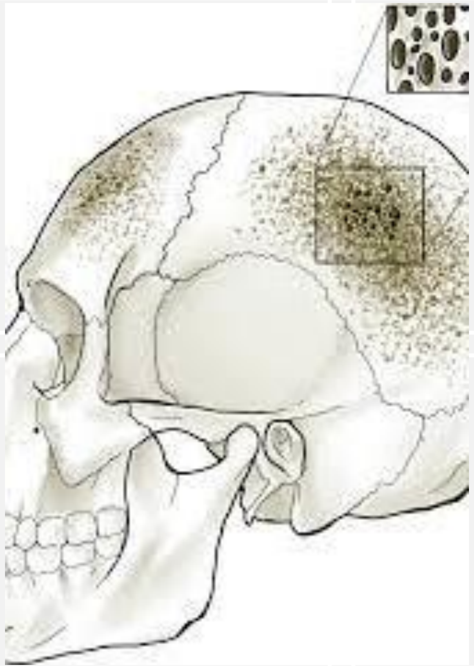

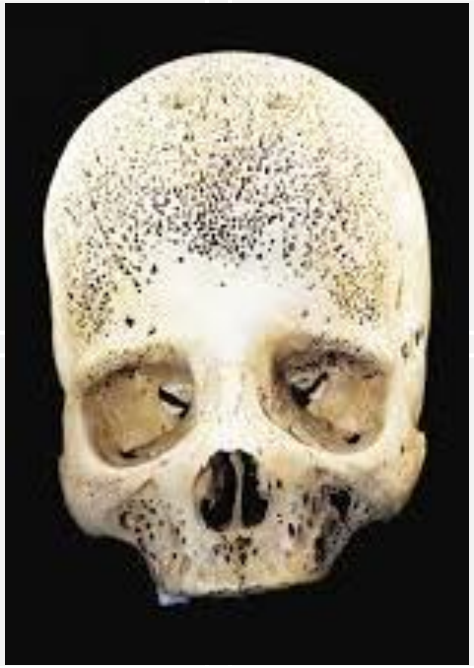

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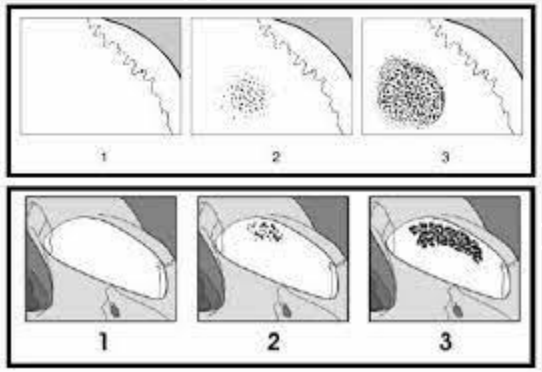
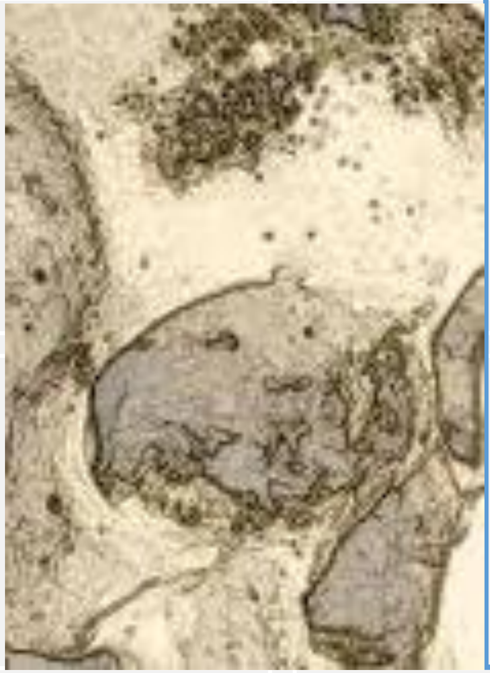
- Cribra Orbitalia
- Infectious diseases



2. Indicators of stress

- Harris lines
- Enamel Hypoplasia
- Enamel Microdefects
- Porotic Hyperostosis
- Cribra Orbitalia
- Infectious diseases



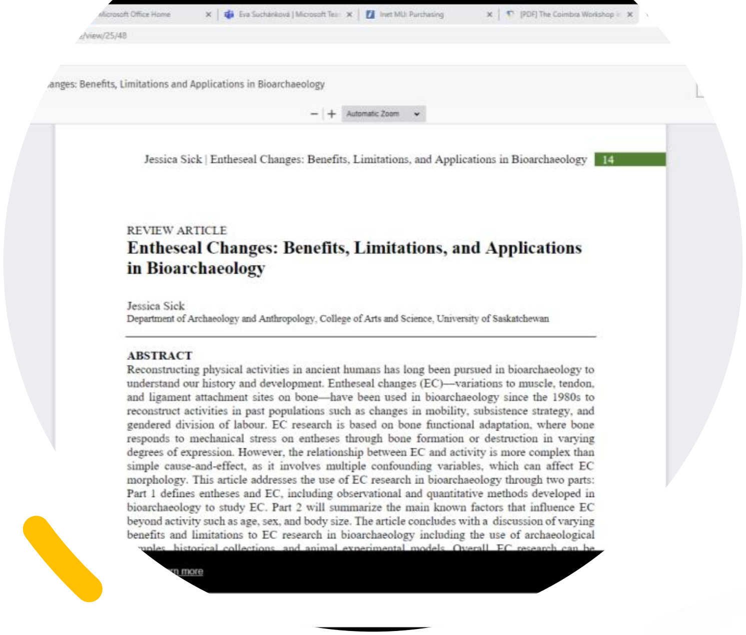
Skeletal & Dental Variations

1. Stature
2. Stress Markers
3. **Activity Markers**
4. Degenerative Joint Disease DJD

3. Activity Markers

Three are widely used & most popular indicators in bioarchaeology:

1. cross-sectional bone geometry (CSBG)
2. osteo-arthritis (OA)
3. entheseal changes (EC)



3.2. Osteo-arthritis (OA)

a chronic & degenerative condition of synovial joints characterized by a combination of inflammatory bone responses to hyaline cartilage breakdown

Skeletally, present as:

- marginal hypertrophic changes (osteophytes)
- pitting
- porosity
- erosion on joint surfaces

3.2. Osteo-arthritis (OA)

++ Ubiquitous in modern & ancient populations

--- Multifactorial (many risk factors)

- ✓ physical activity
- ✓ age
- ✓ sex
- ✓ genetics
- ✓ skeletal trauma experienced during life

3.2. Osteo-arthritis (OA)

Used to describe general levels of physical activity in ancient populations

Attention! Muse be accompanied by:

- ✓ archaeological evidence
- ✓ strong statistical methods
- ✓ population-level comparisons

3.3. Entheseal changes (EC)

The morphological alterations to entheses(muscle, tendon, & ligament attachment sites on bone) that occur as an adaptative response to biomechanical stress

Analysis of bony changes at sites of insertion of muscle and ligaments

Developpment of several methodological approaches for the analysis of human skeletal remains from (different contexts & chronologies) all aimed at inferring behavior

Crubézy, 1988;
Hawkey and Merbs, 1995;
Al Oumaoui et al., 2004;
Mariotti el al., 2004;
Galtés et al., 2006;
Villotte, 2006

Researchers have questioned the validity of this approach and its correlation with past human lifestyles
Jurmain, 1999; Weiss, 2003

(EC) also known as:

musculo-skeletal stress markers MSM
(Hawkey and Merbs 1995),

markers of occupational stress MOS
(Kennedy 1983; İşcan and Kennedy 1989),

evidence for occupation EO
(Kelley and Angel 1987),

activity-induced pathology
(Merbs 1983),

activity-induced stress markers
(Hawkey and Street 1992)

clinical literature: enthesophytes, enthesopathies, & enthesiopathies
(Benjamin et al 2002, 2006; Jurmain et al. 2012).

The recent shift of terminology to ‘EC’ was intended *to avoid the assumption that occupation, activity, or pathological changes are the sole contributors to EC*, which are now known to have a multifactorial etiology

(Villotte et al. 2010)

Coding Enthesopathies?

Villotte et al. 2010. Enthesopathies as Occupational Stress Markers: Evidence From the Upper Limb. AJPA. 142. 224-34.

a visual method of studying fibrocartilaginous enthesopathies of the upper limb

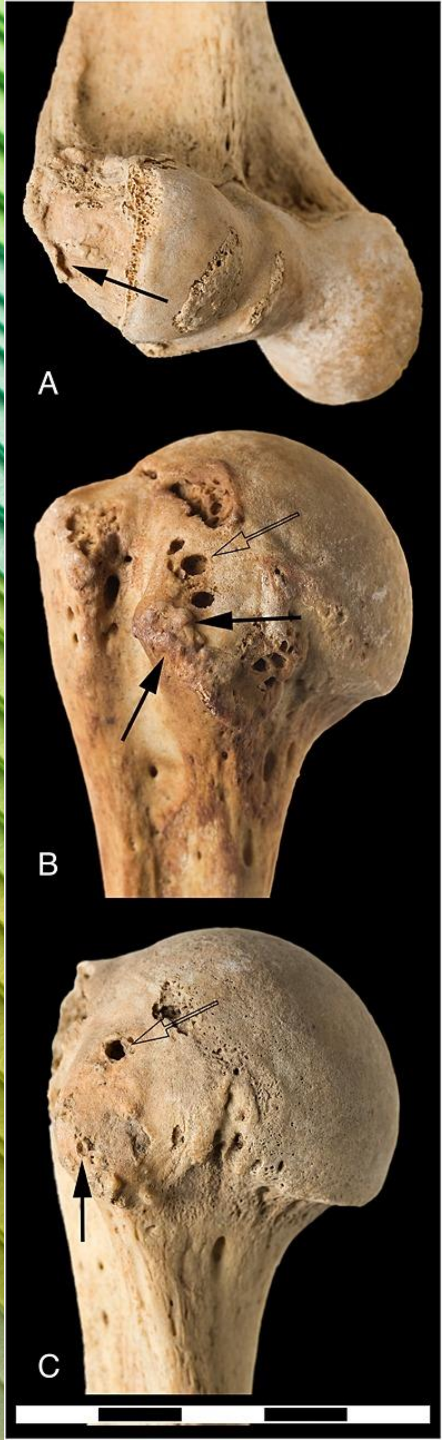
applied to 367 males died between (18th-20th centuries), from 4 European identified skeletal collections:

1. the Christ Church Spitalfields Collection,

2. the identified skeletal collection of the anthropological museum of the University of Coimbra,

3. the Sassari and Bologna collections of the museum of Anthropology,

4. University of Bologna.



Yes, but…

established a strong link between enthesopathies and physical activity

men with occupations involving heavy manual tasks have significantly (P-value < 0.001) more lesions of the upper limbs than nonmanual and light manual workers

probability increases with age & is higher for the right side compared with the left

enthesopathies can be used to reconstruct past lifestyles of populations if bioanthropologists:

1. pay attention to the choice of entheses in their studies

2. use appropriate methods.

ELSEVIER

Journal of Human Evolution
Volume 1, Issue 2, March 1972, Pages 225-226, IN7-IN8, 227-232

Trauma and degenerative diseases in ancient Egypt and Nubia ☆

J.B. Bourke

International Journal of Osteoarchaeology

RESEARCH ARTICLE | Full Access

Degenerative joint disease in the Chalcolithic population of El Mirador cave (Sierra de Atapuerca, Spain): The vertebral column

Marta Yustos, Marina Lozano, Juan I. Morales, Javier Iglesias-Bexiga, Josep M. Vergès

First published: 03 November 2020 | https://doi.org/10.1002/oa.2936

› Am J Phys Anthropol. 1997 Aug;103(4):481-95.
doi: 10.1002/(SICI)1096-8644(199708)103:4<481::AID-AJPA6>3.0.CO;2-Q.

Comparative degenerative joint disease of the vertebral column in the medieval monastic cemetery of the Gilbertine priory of St. Andrew, Fishergate, York, England

C J Knüsel [1], S Göggel, D Lucy

Affiliations + expand

PMID: 9292166 DOI: 10.1002/(SICI)1096-8644(199708)103:4<481::AID-AJPA6>3.0.CO;2-Q

Skeletal & Dental Variations

1. Stature
2. Stress Markers
3. Activity Markers
4. **Degenerative Joint Disease DJD**

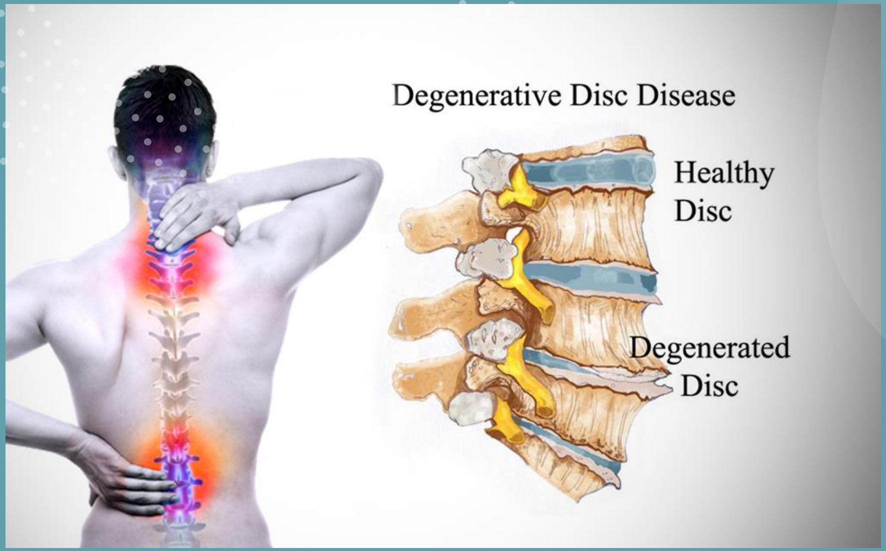
What is Degenerative Joint Disease?

a type of a medical condition that causes a tissue or organ to weaken over time

many associated with aging, or gets worse during the aging process

Causes

- a wide variety of factors
- some are a direct result of normal wear & tear of the body
- others are extended by poor health or an unhealthy lifestyle



Diagnosis

three main groups:

1. Cardiovascular (hypertension, coronary disease, & myocardial infarction)

2. Neoplastic (tumours & cancer)

3. Nervous system (Parkinson’s & Alzheimer’s)

Degenerative Disease (DD)

Skeletons across the ages display degenerative bone changes associated with age and wear:

- **ankylosing spondylitis** is when the spine is inflamed, leaving characteristic bone markers on the vertebrae.

(a)

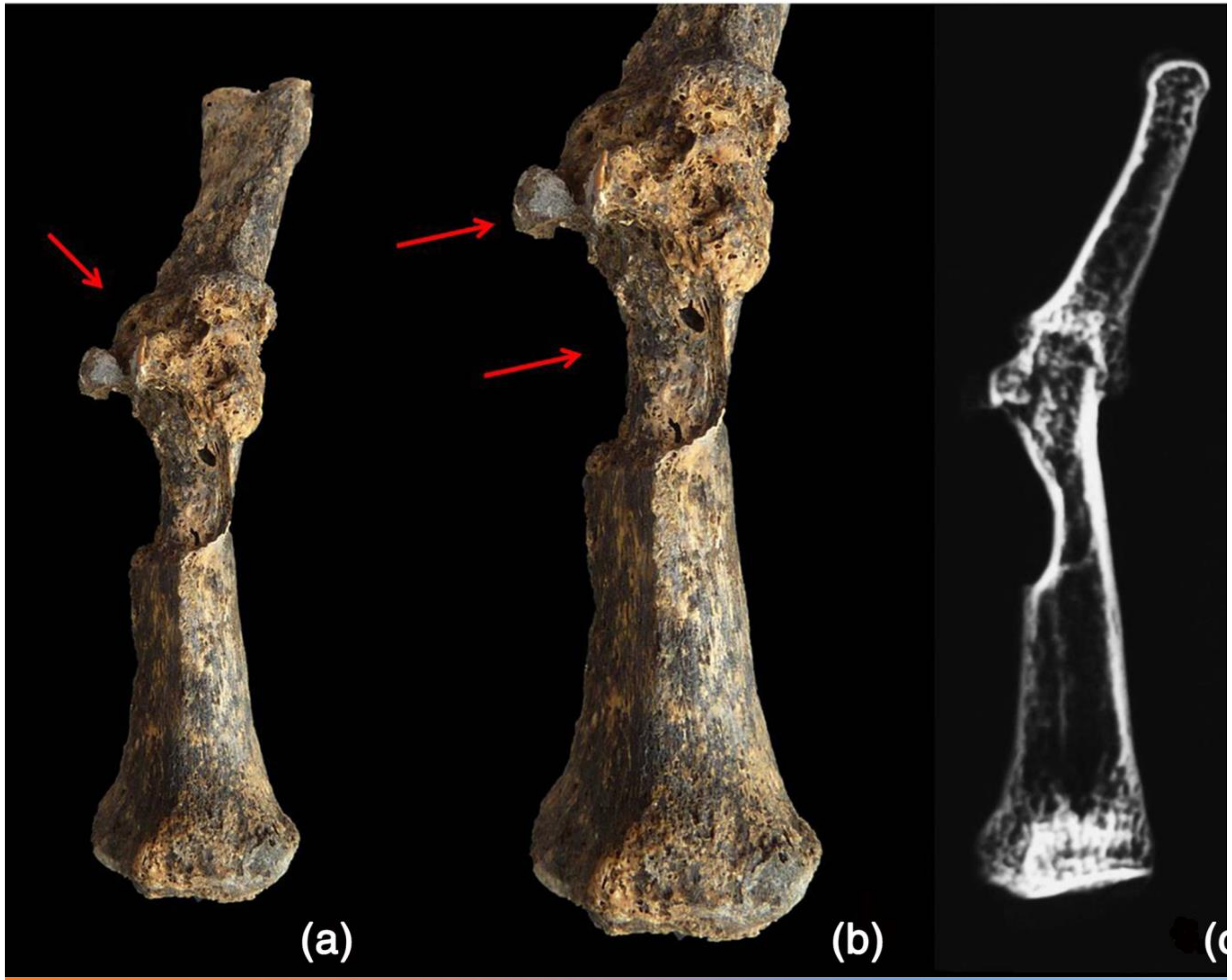
(b)

Degenerative Disease (DD)

Skeletons across the ages display degenerative bone changes associated with age and wear:

- **gout** is caused by increased uric acid in the blood, which can crystallize and be deposited in joints, in extreme cases causing erosion of the joint surfaces.

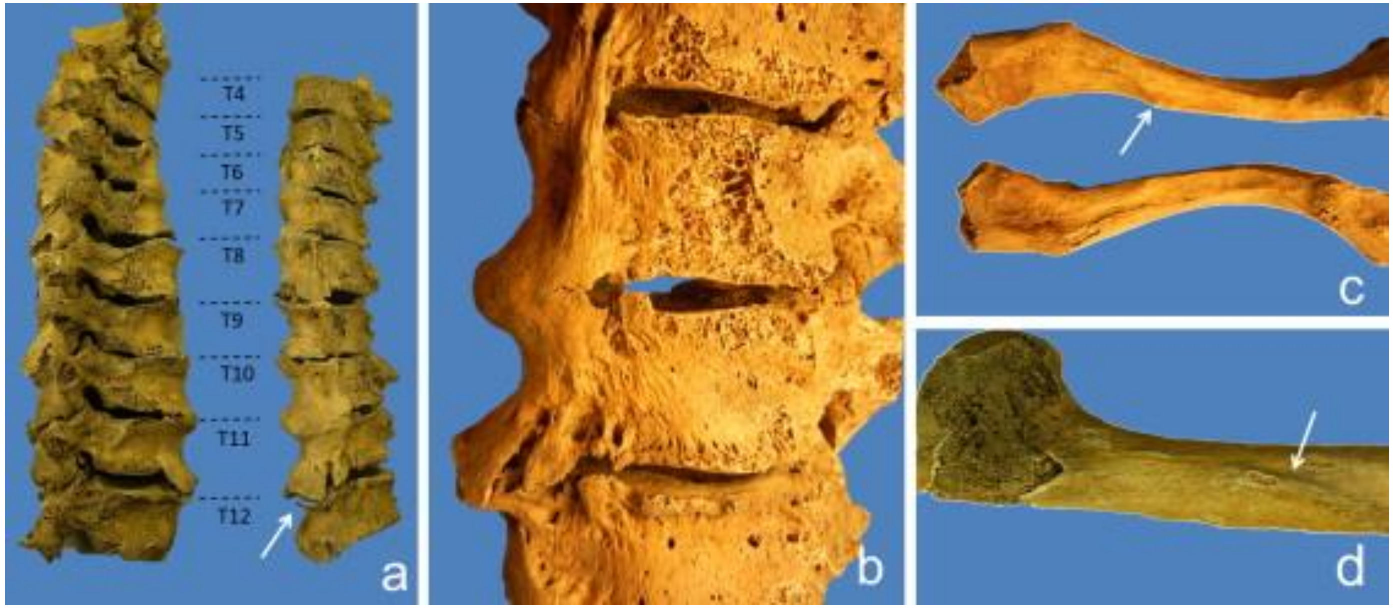
It is commonly associated with a diet high in red meat, associated with a high social status.



Degenerative Disease (DD)

Skeletons across the ages display degenerative bone changes associated with age and wear:

- **diffuse idiopathic skeletal hyperostosis** is when the ligaments of the spine become bone and fuse together. It particularly affects older males and can be associated with type II diabetes.



Spine showing signs of fusing as a result of diffuse idiopathic skeletal hyperostosis

Case study: Cancer

- one of the world's leading causes of death today
- almost absent in the archaeological record

Why?

Assuming that the disease is mainly a product of modern living and increased longevity

PLOS ONE

PLoS One

PLoS One. 2014; 9(3): e90924.
Published online 2014 Mar 17. doi: 10.1371/journal.pone.0090924
PMCID: PMC3956457
PMID: 24637948

On the Antiquity of Cancer: Evidence for Metastatic Carcinoma in a Young Man from Ancient Nubia (*c.* 1200BC)

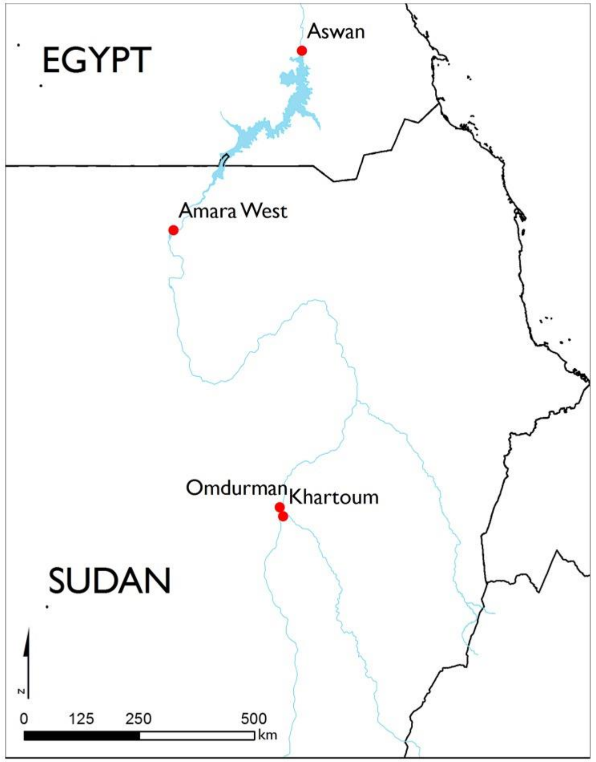
Michaela Binder,[1,*] Charlotte Roberts,[1] Neal Spencer,[2] Daniel Antoine,[2] and Caroline Cartwright[3]

Michael D. Petraglia, Editor

Case study: Cancer

- a male, young-adult individual

- displaying multiple, mainly osteolytic, lesions on the vertebrae, ribs, sternum, clavicles, scapulae, pelvis, humeral & femoral heads

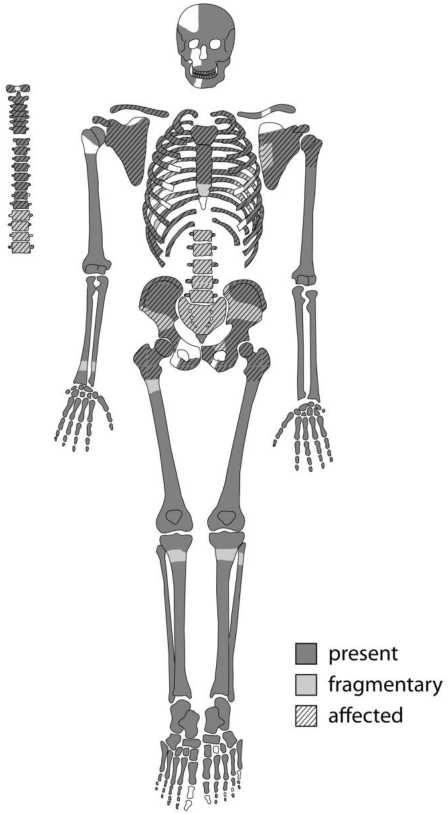


Amara West in northern Sudan (*c.* 1200BC)

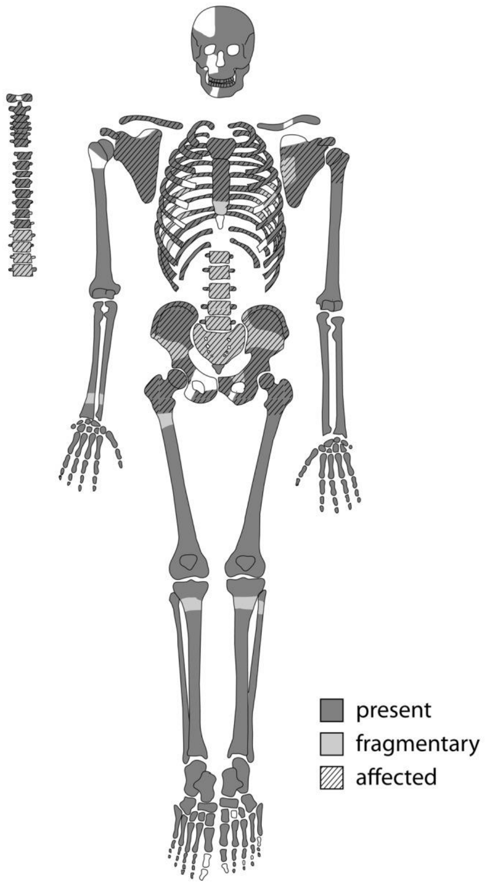
Skeleton Sk244-8 in its original burial position & the amulet

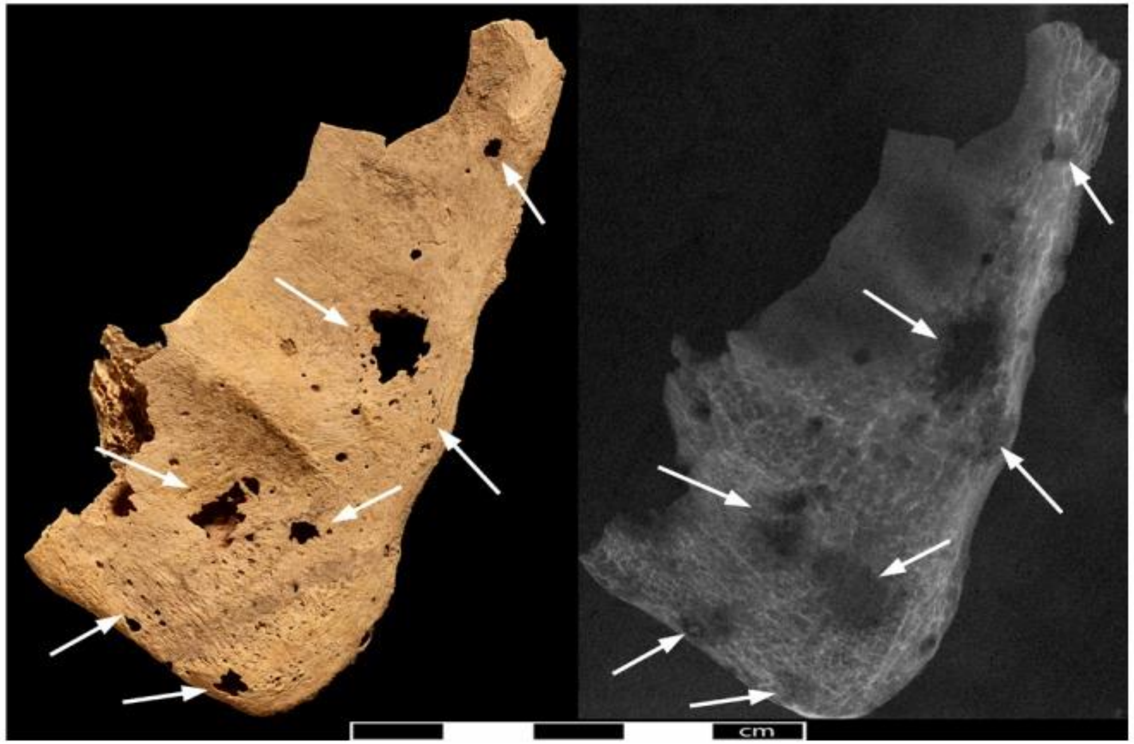
Case study: Cancer

The left clavicle- Binder et al. 2014



Case study: Cancer

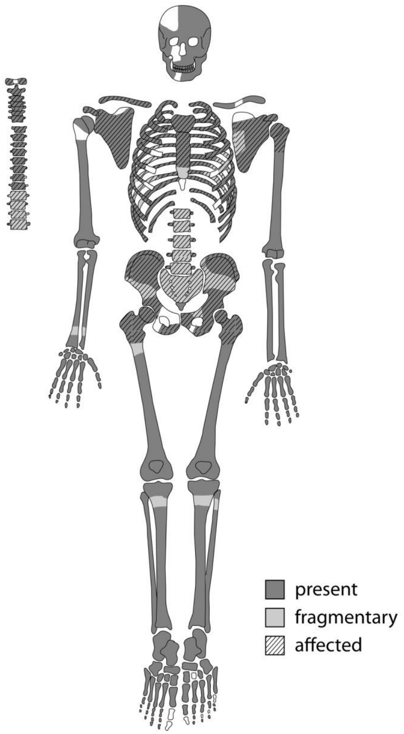


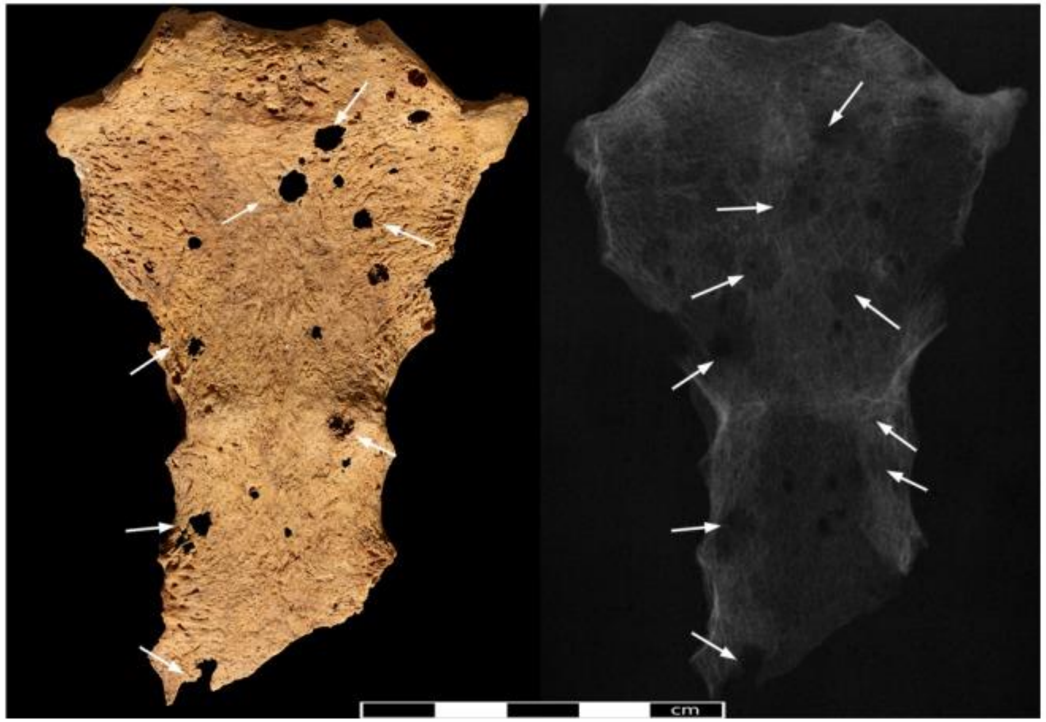


Pathological lesions in the right scapula.Binder et al. 2014

Case study: Cancer

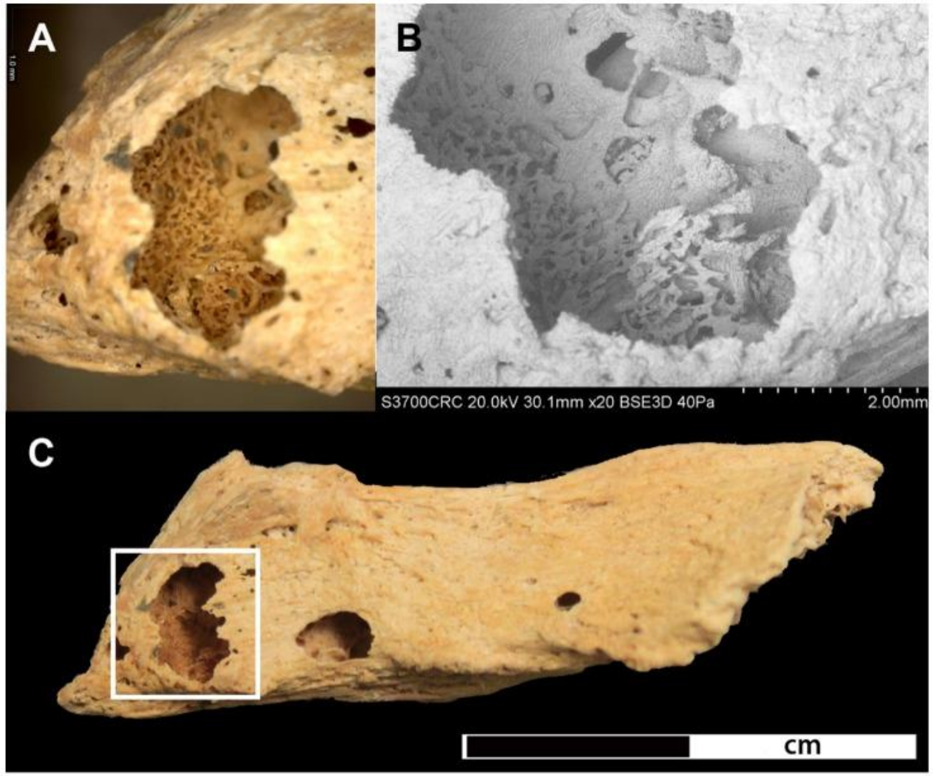
Anterior surface of the sternum

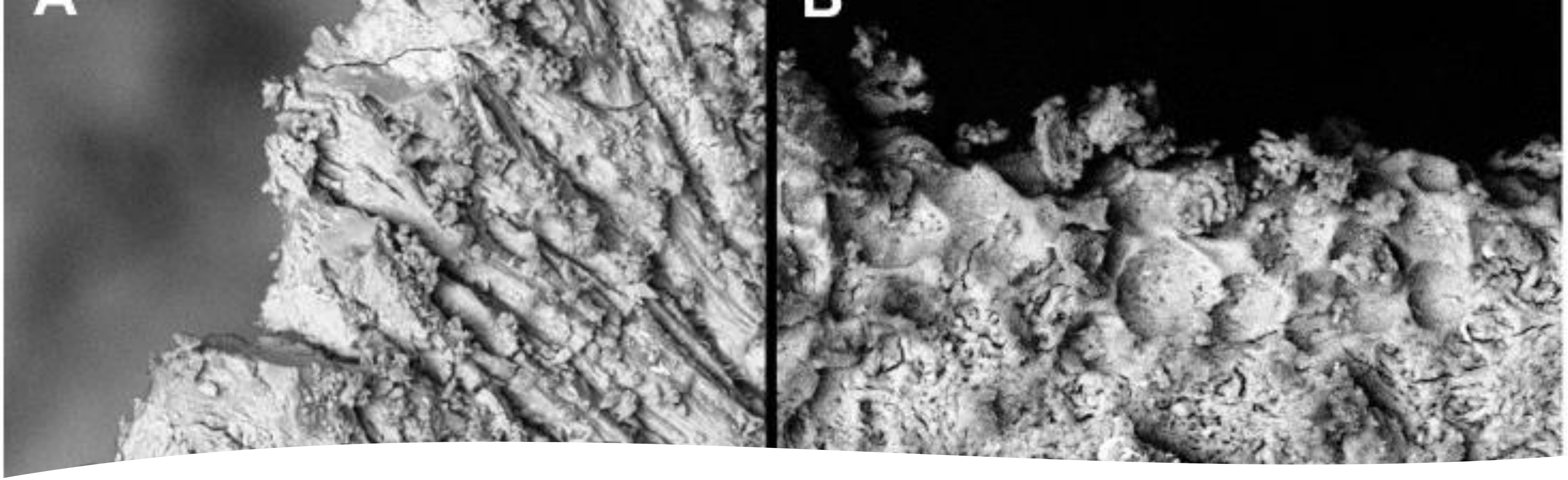




Case study: Cancer

- Lytic lesions in the first rib
- the spinous process of the 5th thoracic vertebra





Methods of the analysis:

Radiographic

Microscopic

Scanning electron microscopic (SEM) imaging

A consideration of differential diagnoses

- modern analytical techniques applied to differential diagnoses
- a well-documented archaeological and historical context

Case study: Cancer

Diagnosis

- metastatic carcinoma secondary to an unknown soft tissue cancer
- the earliest complete example in the world of a human who suffered metastatic cancer to date
- providing new insights into the history & antiquity of the disease as well as its underlying causes & progression

Key Take-Home Message:
Stress Markers

- The term "stress" in the context of archaeological human remains is often vague and misused.
- Should looked at it from the perspectives of dental and skeletal anthropology & paleopathology.
- The term "stress" should only be used in archaeology if precisely defined, such as "mechanical stress."
- This precision is crucial to avoid ambiguity in the study of skeletal remains.

Key Take-Home Message:
Activity markers

Both in forensic & archaeological contexts

Importance of determining the occupational and/or social status of individuals

Skeletal markers can be observed & quantified to reveal clues about physical activities:

- occupation
- gendered divisions of labour
- subsistence strategies
- mobility

- Attention: Relationship (activity during life & skeletal markers) are consequences of a multitude of external & internal factors that complicate our interpretations