

Bioarchaeology

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Rigid, the skeleton of habit alone upholds
the human frame.

Virginia Woolf

Activity Patterns

- Activity and Workload in past populations studied using pathological and non-pathological changes of articular joints and behavior related changes in non-articular surfaces of bones

"You are old," said the youth, "and your jaws are too weak for anything tougher than suet; Yet you finished the goose, with the bones and the beak- Pray, how did you manage to do it?"

"In my youth," said his father, "I took to the law, and argued each case with my wife; And the muscular strength, which it gave to my jaw, has lasted the rest of my life."

Responses of Bone to Stress

1892 Julius Wolff

"The form of the bone being given, the bone elements place or displace themselves in the direction of functional pressure and increase or decrease their mass to reflect the amount of functional pressure."

Stress in a biomechanical sense:

intermolecular resistance within an object to the action of an outside force which is applied to it

Eg- standing upright creates compression forces within the leg bones, which respond through internal resistance in terms of trabecular architecture, diaphyseal form and size, angle of the neck, etc.

Responses of Bone to Stress

Stress becomes manifest macroscopically when the force or load exceeds the bone's elastic limit and the area does not return to its original form

In well vascularized areas, remodeling will occur in response to stress
Lipping, spurring and exostoses serve to increase bone mass in the region of greatest stress to expand surface area in load bearing joints to dissipate stress?

Tension increases osteogenic activity, can cover Sharpey's fibers
Thereby muscles. Ligaments, tendons also influence bone form and size
Elevated crests, turbercles and tuberosities result from muscular pull

Classification of Occupational Markers (Kennedy 1989)

- Attrition- i.e. Dental attrition or eburnation in OA (DJD)
- Enthesopathies- hypertrophy of muscle insertion sites (Kennedy includes squatting facets, hypertrophy of crests, etc)
- Trauma- stress fractures and dental fractures
- Bone degeneration- atrophic loss of substance or volume bone (osteoporosis, joint degeneration, reorientation of trabeculae)
- Nutrition- cause of platymeria (dorso-ventral flattening of femur), platycnemia (lateral flattening of tibia), bowing
- Sex Dimorphism- robusticity, spondylolysthesis more common in males
- Cultural or ethnic differences- knees more commonly affected than hips by OA in Asian populations, Eurasians hips and knees often both affected
- Age Differences- age of onset and duration of stress important factors, elderly more likely to have OA, especially elderly women (menopause)

Classification of Occupational Markers

- Osteoarthritis and DJD changes in diarthrodial joints
 - osteophytes
 - porosity
 - eburnation
- Vertebral changes (amphiarthrodial joints)
- Facets (new articular surfaces)
- Cortical defects
- Enthesopathies

Articular Joints and their Modifications

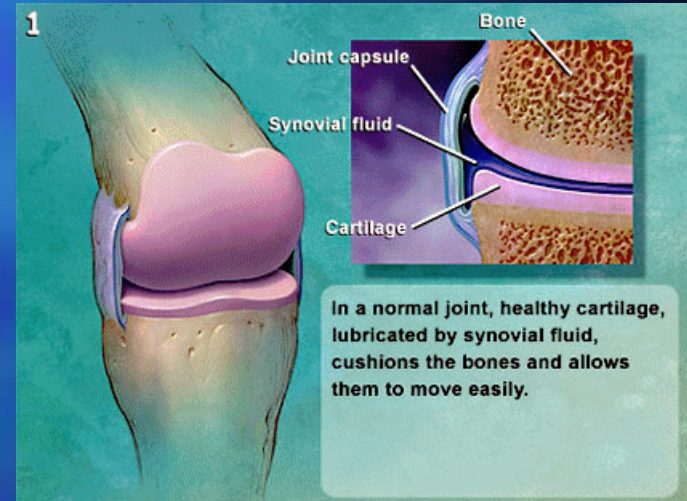
2 types of joints:

- diarthrodial (synovial)
 - stability and mobility- extensive movement depending upon the configuration of joint surfaces, ligamentous connections, and shape of capsule
 - lubricated with hyaline cartilage and movement occurs within a fibrous capsule
 - knee, elbow, phalanges
- amphi-arthrodial
 - somewhat mobile joints but mainly serve to stabilize the skeleton
 - pubic symphysis, vertebral bodies

Articular Joint Pathology

Degenerative Joint Disease or Osteoarthritis (and Osteoarthrosis)

articular cartilage can be damaged gradually because of wear and tear. OA often begins with injury or ligament weakness. The progressive deterioration of cartilaginous tissues is often accompanied by pain, stiffness and limitation of movement. Since articular cartilage is avascular, aneural and alymphatic, those damages are often irreversible. Osteoarthritis, the most prevalent form of arthritis, was estimated to affect more than 20 million Americans in 1998 (Lawrence *et al.*, 1998).



Articular Joint Pathology

Osteoarthritis and Osteoarthrosis

- same pathogenesis, etiology, and symptoms
- definition: the result of a physiological imbalance between mechanical stress in the joint tissue and the ability of the joint to withstand that stress

Also called Degenerative Joint Disease:

Osteophytosis, porosity and eburnation

Osteoarthritis (implies inflammatory response)

Osteoarthrosis (these changes in vertebral bodies)



Osteoarthritis and Osteoarthrosis

Worldwide variation in OA according to age

- urban, industrial societies after age 30
- older adolescents and young adults in some prehistoric and Medieval agricultural populations

Climate

- Warmer climates produce less severe symptoms

Body Weight

- obese individuals have greater frequency and severity in weight bearing joints

Sex

- males have higher prevalence rates in young adulthood (not dependant on subsistence strategy or socio-political complexity)
- females have greater incidence, more severe, and more generalized in Middle Age due to hormonal factors of Menopause

Metabolism, nutrition, bone density, infection, trauma, heredity

Osteoarthritis and Osteoarthrosis

Population specific patterns

■ Early Hominids

- AL 288-1 OA in thoracic vertebrae- lipping disk collapse, elongation of centra
- La Chapelle- TMJ disease, osteophytosis of occipital condyles, cervical vertebrae, thoracic vertebrae, acetabulum, bilateral eburnation of humeral heads
- Shanidar- extensive OA in 5 adult individuals, mostly vertebral; one individual with knee, foot and ankle OA secondary to trauma

■ Hunting and Gathering groups

- OA in lumbar region, shoulders, elbows for males

■ Agricultural groups

- OA in cervical, thoracic, lumbar regions, elbow, and knees
- Often more sex dimorphic (except Dickson Mounds)

Osteoarthritis and Osteoarthrosis

Angel (1966)

Atlatl elbow in California

Extension and abduction of arm limited to elbow rather than shoulder
(spear throwing)

Ortner (1963)

OA in distal humerus for Peruvians and Inuit

Differential usage of upper arm in food acquisition

- Inuit OA 18% versus 5% in Inuit population
- Inuit had bilateral asymmetry
- Spear throwing in Peruvians and atlatl in Inuit R arm
- Inuit relying more heavily upon hunting and thus provide strong signature

Osteoarthritis and Osteoarthrosis

Sadlermiut Inuit from NW Territories (Merbs 1983)

- Males

- Bilateral OA of acromioclavicular joint
- hypertrophy of deltoid tuberosity
- kayaking?
- Atlatl elbow

- Females

- TMJ disease 2x more than males from occupational use of teeth as tools?

- Both sexes

- vertebral OA from tobogganing and sledding?

Osteoarthritis and Osteoarthrosis

Pat Bridges (1990)

Upper Limb OA in Archaic and Mississippian groups from Alabama

Distinguished atlatl from bow and arrow

- atlatl affects R arm at elbow
- bow and arrow affects shoulder and elbow in both arms

Females showed higher prevalence of R elbow OA

Some groups show symmetrical pattern

- Arizona agriculturalists using both arms to grind corn
- affected mainly females

Osteoarthritis and Osteoarthrosis

Pat Bridges (1992)

Meta-analysis of 25 Native American populations (published studies)

- reviewed evidence for OA in shoulder, elbow, hip, knee
- Difficult to compare studies because of lack of consistency in methods
- No clear relationship to subsistence mode
 - agriculturalists lower in wrists and hands but not all foragers high
 - elbow and knee are most frequently affected and have most asymmetrical involvement
 - hands, ankles and feet are seldom affected in any populations
 - sex dimorphism is mixed

Osteoarthritis and Osteoarthrosis

Subsistence Economy

Stressors from “digging, hoeing, and back-breaking stooping” (Cockburn et al 1979) hypothesized to cause more OA in agricultural populations

Actually no clear or consistent relationship

Jurmain (1977, 1978, 1980)

OA in the appendicular skeleton for a range of populations

- Agriculturalists activity limited to growing season and so OA less prevalent?
- Inuit peoples subject to manual labor year round and so prevalence is higher?
- Not the type of labor but the duration of stressors versus recovery time

Cohen and Armelegos (1984) 8 of the articles discussed OA prevalence

- reports not standardized in terms of aging methods or OA reporting so difficult to compare and conclude any specific pattern

Osteoarthritis and Osteoarthrosis

Why is OA such a popular condition in studies of activity in bioarchaeology?

- It is the most common pathology after dental disease in most collections
- Relatively easy to diagnose through gross examination
- Rich clinical literature
- Debilitating condition with socio-cultural implications
- Provides a window into human activities (?)

Sources of Error

- Considered irreversible and progressive
- Non-specific diagnostic criteria
- Non-specific etiology
- Over-emphasis on bone

However, Merbs study on spondylolysis an example of how osteologists can help advance understanding of a condition through careful study

Osteoarthritis and Osteoarthrosis

Diagnostic criteria developed by clinicians in modern populations
Poor understanding of how soft tissue damage relates to bone surface
Soft tissue changes and bony modifications different diagnostic criteria
Clinicians cannot see bone surface, osteologists cannot see bursa



Osteoarthritis and Osteoarthrosis

Primary influence from mechanical stress and physical activity?

Studies of modern or documented occupational groups:

- lifting in miners caused changes in hips, knees, vertebrae
- similar modifications in workers using pneumatic tools
- cotton workers and weavers- hands
- farmers- knees and hips, back

However, can you work backwards?

If miners have distinctive changes do those distinctive changes mean someone was a miner? Identification of an occupation tricky

Doesn't always work- weavers at Spitalfields did not have any higher incidence of OA in the hands than the general population

Relationships are NOT consistent nor diagnostic

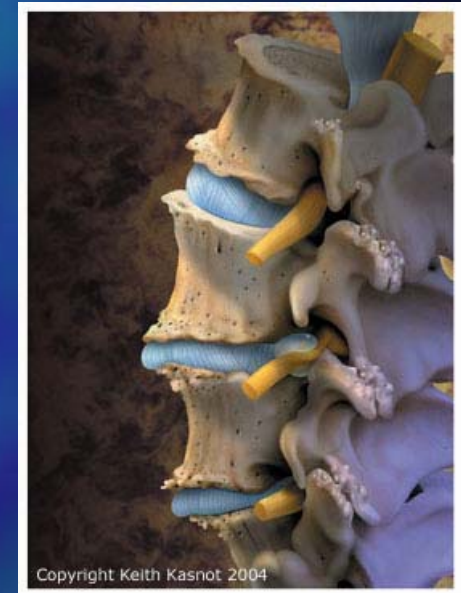
Vertebral DJD

Osteophytes

- Ankylosis- fusion of vertebral osteophytes (reduction in mobility)
- OA in spine often concomitant with compression fractures

Pitting or rarefaction of bone surface indicates cartilage has failed

Polishing, eburnation, and grooving indicates failure of articular cartilage but continued use of the joint



Stress Fracture

Spondylolysis

separation of the vertebral neural arch (type of fracture)

unique to bipedal hominids

most common in middle adulthood, heals in later life

L5 most common site and is a bilateral defect

excessive mechanical loads over a long duration (high frequency in manual laborers and football players)

Structural characteristics influencing development of spondylolysis

long 'pre-arcuate' spine

inclined superior sacral surface

lumbar lordosis or scoliosis

superior sacral articular facets with minimal curvature and depth

size of articular facets

spina bifida

Stress Fractures and Related Changes

Spondylolisthesis

after spondylolytic fracture, vertebral body below slips anteriorly
muscles, ligaments and intervertebral disks often prevent slippage
can only be approached archaeologically if there are other changes
such as lipping that match up on both surfaces

Pseudoarthrosis

fracture of the spinous process in lower cervical or upper thoracic
hyperextension or hyperflexion of the neck
scapular retraction toward spine while raising rib cage
shoveling heavy soil

Vertebral DJD

Spondylolysis



Compression Fracture



Schmorl's Nodes



Vertebral DJD

Vertebral DJD most commonly studied

1910 spondylitis in Ancient Nubians (Elliot-Smith and Wood-Jones)

1990 Kilgore

emphasized age, weight-bearing and trauma over activity

1994 Bridges

NW Alabama VOP and OA

highest incidence in lumbar region (common pattern)

high incidence in cervical region could indicate activity

most significant factor in population comparison is methodology

1994 Lovell

Distinguished lipping, porosity and eburnation in a detailed manner

Fragmentary sample meant limited control over age and sex

Vertebral DJD

Trends in VOP

- Right side dominance (osteogenic stimulation caused by Aorta?)
- Kyphosis and Lordosis
 - common between C4 and C6
 - lower thoracic more affected than upper (T7-T9)
 - L1 to L5 show most lesions of entire vertebral column
 - C7 to T3 least affected
- Mobility
 - thoracic less affected due to greater freedom of movement
 - lumbar most affected due to more restricted mobility
 - cervical intermediate
- Mechanical loading
 - more common in cervical and thoracic if burdens are carried on the head (Harappans)

Vertebral DJD

Trends in Vertebral Apophyseal OA

- C2- C5 most affected
- C7/T1 common site
- T9/T10
- L5/S1 very commonly affected
- Much less common in general than VOP

Vertebral DJD

Inference about activity

Merbs (1983) emphasized pattern was typical for humans as a species
“activities difficult to identify precisely”

Cervical VOP often explained as related to carrying objects on the head
(Lovell 1994, Bridges 1994)

Often attributed solely to aging or “some activity related stress”

Non-Pathological Articular Surface Changes

Facets

Habitual postures

squatting

kneeling

Difficult to sort out activity levels from habitual postures

Facets on MT-phalanges more convincing than those on femur, tibia, talus
found as far back as Neandertals

Cortical defects

linear depressions at muscle insertion sites caused by chronic mechanical stress

humerus, radius, femur, tibia, MC, MT, phalanges

irregular floor, smooth margins

rare- high frequency in War of 1812 soldiers (along with Schmorl's nodes)

Non-Pathological Changes at Attachment Sites

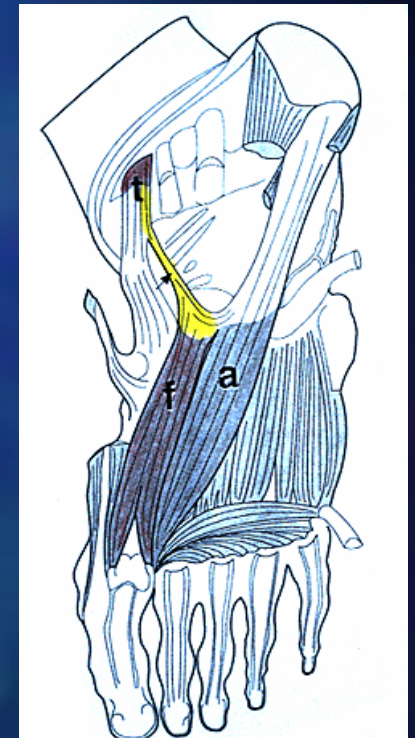
Enthesopathies

hypertrophied tendon, ligament and muscle attachment sites

irregularities, rough patches or osteophytic growth

Example- exostoses on radial tuberosity where biceps brachii inserts (primary flexor of the elbow) due to carrying heavy loads?

Excessive walking and running can lead to enthesopathies at posterior calcaneus (achilles tendon) and plantar surface of calcaneus (adductor hallucis)



Practicum

Look now at overheads produced from Kennedy (1989) on 140 markers of occupational stress

Locate markers on human skeletal material