Continued cortical bone appositional growth after metacarpal fusion:

A longitudinal comparison of adolescent and young adult hand-wrist radiographs

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Introduction

Metacarpal (MC) radiogrammetry is a method for quantifying cortical bone in the hand that has been used by researchers in various disciplines to identify bone loss associated with osteopenia and osteoporosis.[1,2] Archaeological studies require the categorization of populations into age groups, typically, young adult, mature adult, and old adult.[3] However, the young adult category remains ambiguous, with some archaeological studies including fully fused elements, regardless of age (i.e., Mays[4] includes individuals who are 17 years old as young adults). **Continued appositional growth, resulting in inconsistent cortex measures, may impact bioarchaeological sample selection and bone mass results.** **This study investigates the possibility of continued appositional bone growth of second and third metacarpals in individuals between the ages of 16 and 20.**

Materials

Figure 1. Location of Burlington, Ontario

- Hand-wrist X-Rays from the longitudinal Burlington Growth Study (1952–1971) that were available through the public access AAOF Legacy Collection[5]
  - White, suburban individuals from Burlington, Ontario, ages 3 to 21[6] (Fig. 1)
- All individuals with measurable hand-wrist X-rays at ages 16 years old and 20 years old were included.
  - X-Rays of 18 year olds were used when the 20 year image was not available
  - Female n = 26; Male n = 19

Methods

- Midpoint of the second and third MCs determined
- Total width and medullary width measurements taken at midpoint using ImageJ (NIH) v. 153
  - Endosteal borders defined following standards outlined by Ives & Brickley[1] and Meema & Meema[2]
- Cortical indices were calculated and corrected for body size[1]:

$$Cortical\ index\ (CI)\ \% = \frac{total\ width - medullary\ width}{total\ width} x\ 100$$

- Data compared statistically using SPSS v.28:
  - Sex differences using Mann Whitney *U*
  - Correlation between adolescent and young adult CIs using Spearman Rho correlation statistic
  - CI age differences (within individuals) compared with Wilcoxon Signed rank test
- Intra-observer error calculated for eight randomly selected individuals (relative technical error measurement; rTEM)

Metacarpal Radiogrammetry

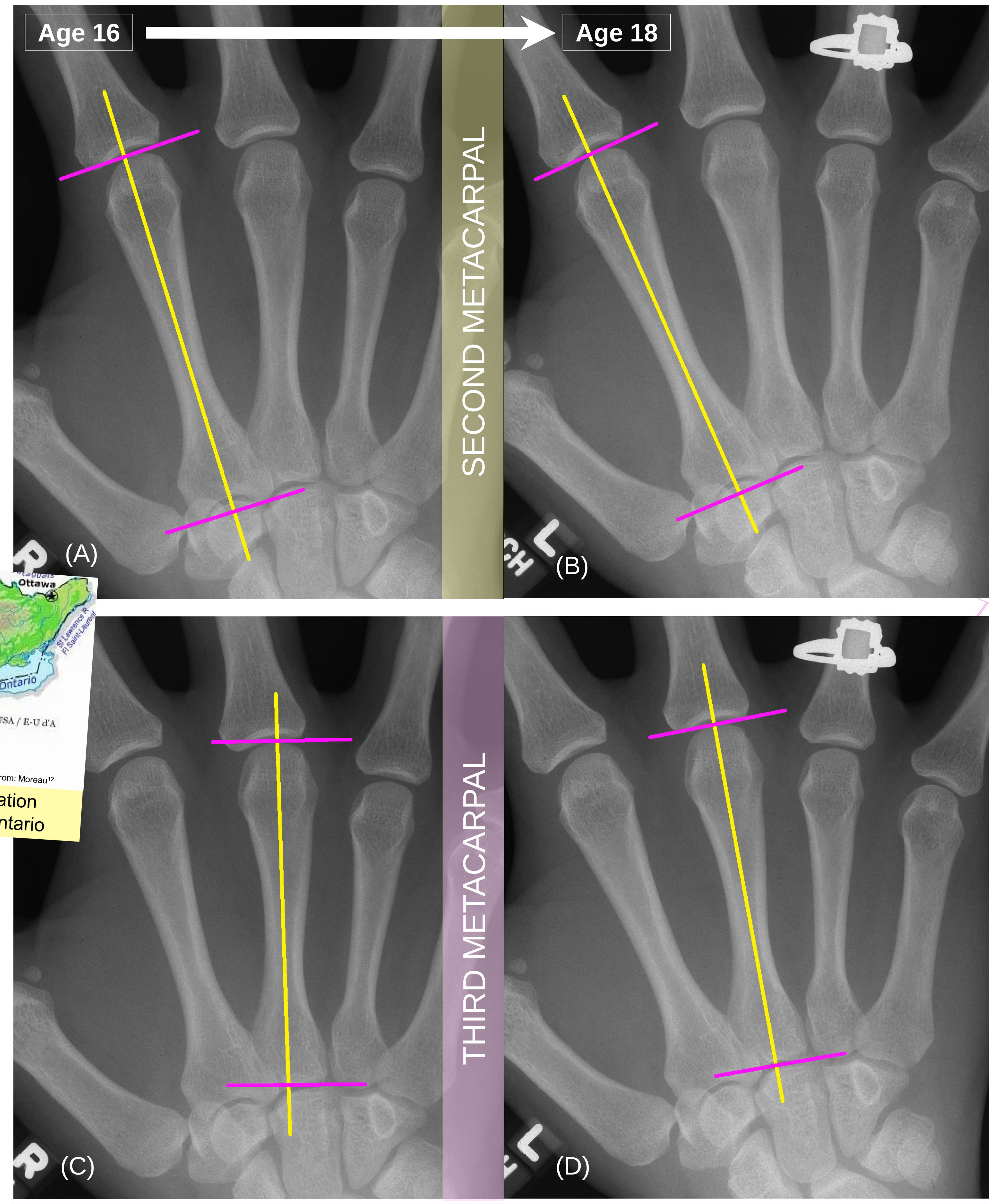

Figure 2. Determination of proximal and distal metacarpal ends; yellow lines represent line best fit to bone's longitudinal contour, pink lines show placement for proximal and distal ends (after Harris et al.[6] and Schneider & Gilmour[7]. (A) 2nd MC measurement placement, adolescent X-Ray; (B) 2nd MC measurement placement, young adult X-Ray for same individual; (C) 3rd MC measurement placement, adolescent X-Ray; (D) 3rd MC measurement placement, young adult X-Ray for same individual.[7, 8]

Results

Table 1. Change in and correlation between cortical indices (CI) from adolescents (16 years) to young adults (20 years). Sex combined (n=45)*.

Metacarpal (MC)	Mean CI Increase (%)	Wilcoxon Signed rank test (Z)	Spearman Rho correlations (r)	Intra-observer error rTEM (%)
MC 2	2.51	Z=-2.929, p=0.003	r=0.894, p<0.001	1.83
MC 3	4.71	Z=-3.189, p=0.001	r=0.812, p<0.001	2.78

*Mann Whitney *U* test indicates no significant difference between female and male CIs (MC2: *U*=167.000, *p*=0.066; MC3: *U*=174.000, *p*=0.093).

Conclusions

- Strong correlation between ages indicates that the adolescent CI is strong predictor of young adult CI (see Fig 3)
- However, a significant difference between adolescent and young adult CIs suggest that appositional bone growth continues between 16 and 20 years old (Table 1. & Figure 4.)
- **To best represent age-related changes in cortical bone we propose:**

Caution when combining individuals younger than 18-20 years old with 'adults' for cortical bone quantification studies, regardless of their state of fusion.

Inclusion of a distinct adolescent age category in order to better capture variation and discuss factors influencing bone growth (e.g. nutrition, subsistence, activity, genetics, disease, etc.)[9,10]

Future studies should compare CIs between unfused and fused metacarpals across populations to better understand cortical bone apposition rates (Gilmour et al[11] ROI method may be one possible approach to assessing unfused MCs)

Acknowledgments & References

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1. Ives, R., & Brickley, M. (2004). A procedural guide to metacarpal radiogrammetry in archaeology. *International Journal of Osteoarchaeology*, *14*(1), 7–17.
2. Meema, H. E., & Meema, S. (1987). Postmenopausal osteoporosis: Simple screening method for diagnosis before structural failure. *Radiology*, *164*(2), 405–410.
3. Glencross, B., & Agarwal, S. C. (2011). An investigation of cortical bone loss and fracture patterns in the Neolithic community of Catalhöyük, Turkey using metacarpal radiogrammetry. *Journal of Archaeological Science*, 38(3), 513-521.
4. Mays, S. (2000). Age-dependent cortical bone loss in women from 18th and early 19th century London. *American Journal of Physical Anthropology*, *112*(3), 349–361.
5. *The University of Toronto Burlington Growth Study*. AAOF legacy collection home page. (2022). Retrieved October 1, 2021, from https://www.aaoflegacycollection.org/aaof_collection.html?id=UTBurlington
6. Burlington Growth Centre. (2017). *Introduction and Historical Background of the Burlington Growth Centre Collection*. Burlington Growth Centre (Unpublished Document).
7. Harris, E. F., Aksharanugraha, K., & Behrents, R. G. (1992). Metacarpophalangeal length changes in humans during adulthood: A longitudinal study. *American Journal of Physical Anthropology*, *87*(3), 263–275.
8. Schneider, M., & Gilmour, R. J. (n.d.). *Exploring radiogrammetry beyond the second metacarpal: Using the third, fourth, and fifth metacarpals to quantify cortical bone.* [Manuscript submitted for publication].
9. Heaney, R. P. (2009). Bone Mass, nutrition, and other lifestyle factors. *Nutrition Reviews*, *54*(4).
10. Magan, A., Nyati, L. H., Micklesfield, L. K., Norris, S. A., & Pettifor, J. M. (2017). Metacarpal growth during adolescence in a longitudinal South African cohort. *Journal of Bone and Mineral Research*, *32*(9), 1926–1934.
11. Gilmour, R. J., Brickley, M. B., Hoogland, M., Jurriaans, E., Mays, S., & Prowse, T. L. (2021). Quantifying cortical bone in fragmentary archeological second metacarpals. *American Journal of Physical Anthropology*, *174*(4), 812–821.
12. Moreau, N. (2012). *Burlington*. The Canadian Encyclopedia. Retrieved October 5, 2022, from https://www.thecanadianencyclopedia.ca/en/article/burlington

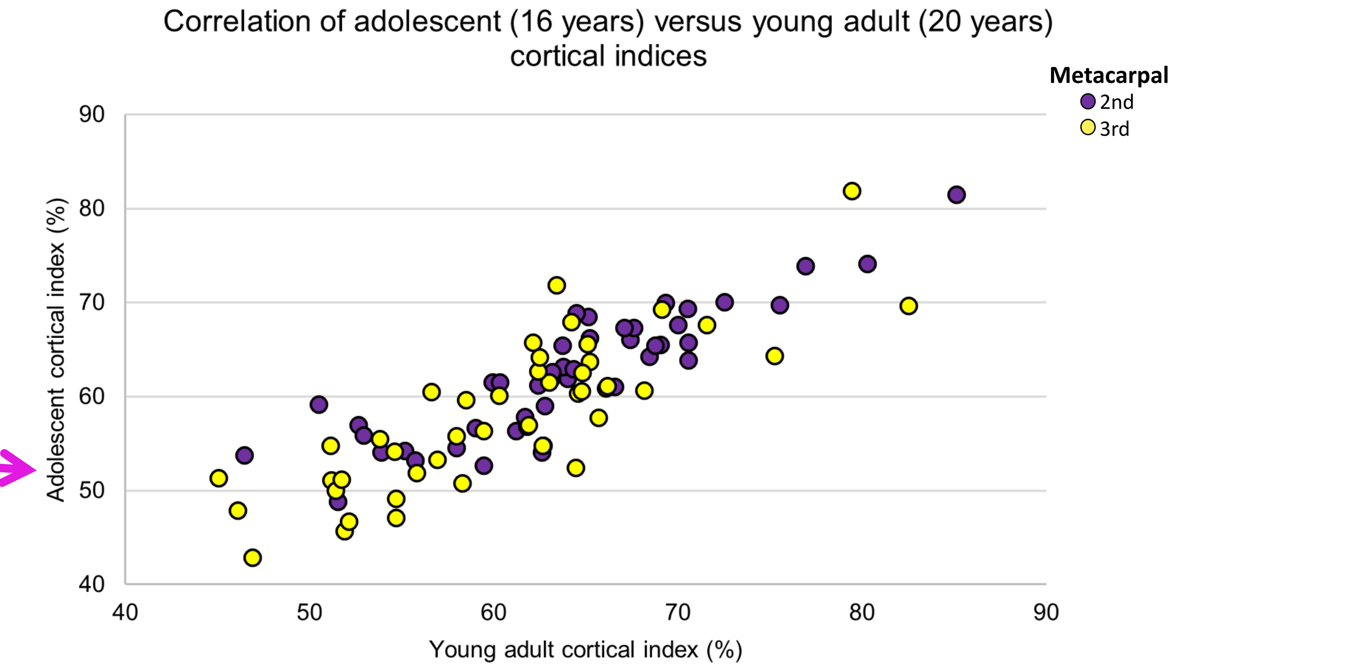

Figure 3. Relationship between adolescent and young adult second and third MC CIs.

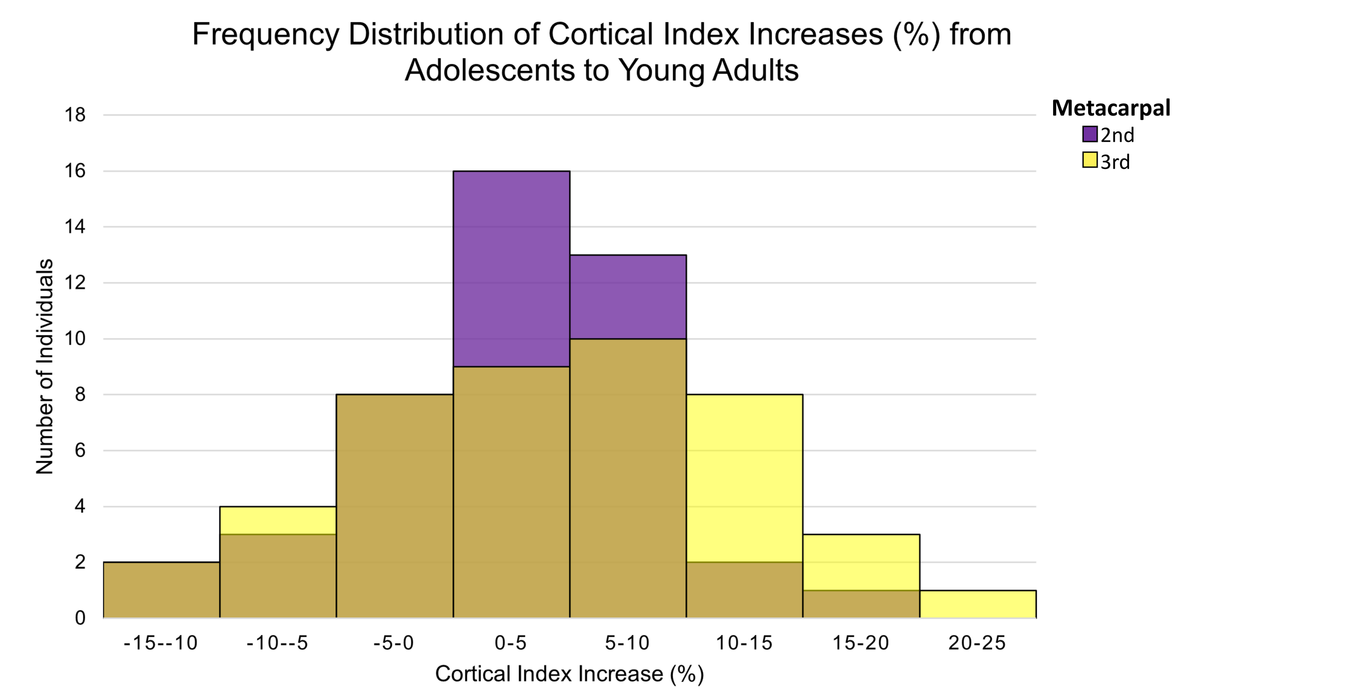

Figure 4. Percent CI change between adolescent and young adult individuals.