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Discernment of mortality risk associated with childbirth in archaeologically derived forager skeletons

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ABSTRACT

An obstetric dilemma may have been a persistent characteristic of human evolution, in which the bipedal female's pelvis is barely large enough to accommodate the birth of a large-brained neonate. Evidence in the archaeological record for mortality risk associated with childbirth is rare, especially among highly mobile, immediate return hunter-gatherer populations. This research explores the idea that if excess mortality is associated with first pregnancy, females will outnumber males among young adult skeletons. The sample is of 246 skeletons (119 males, 127 females) representing Later Stone Age (LSA) foragers of the South African Cape. Young adults are distinguished through incomplete maturation of the medial clavicle, iliac crest and vertebral bodies. With 26 women and 14 men in the young category, a higher mortality risk for women is suggested, particularly in the Southern Cape region. Body size does not distinguish mortality groups; there is evidence of a dietary protein difference between young and older women from the Southern Cape. Possible increased mortality associated with first parturition may have been linked to morphological or energetic challenges, or a combination of both. Exploration of the sex ratio among young adult skeletons provides a tool for exploring the antiquity of an important evolutionary factor.

1. Background to the question

Childbirth has been characterized as "a major source of mortality before about 500 years ago and therefore a major agent of natural selection" (Trevathan, 2010:98). The basis of the risk is normally characterized as the potential mismatch between pelvic dimensions and neonate size. A confluence of recent scholarship proposes alternate interpretations of those features of human birth long known as the obstetric (or obstetrical) dilemma (OD). Evidence from archaeologically derived skeletons is not often addressed in the exploration of this topic.

Based on early studies of pelvic morphology and parturition among primates (Schultz, 1949, 1969), the OD has encapsulated the distinctly human balancing point between fetal/neonate growth and the birthing challenges imposed by maternal pelvic morphology. The core premise is that the altricial condition of the neonate is necessitated by selective pressures that have constrained maternal pelvic capacity. The human female pelvis must provide an adequate obstetric canal while maintaining characteristics needed for efficient bipedalism. Relative to other primates, the human female has an obstetric canal that provides less space for the neonate's head and shoulders (Trevathan and Rosenberg, 2000), and solicitation of assistance for the birth event is a common cultural practice. Grabowski demonstrates that when compared to apes, the pelvic canal in humans is less integrated with other pelvic traits, resulting in greater variation in the canal upon which selection can act. It has been argued that humans have a greater ability to respond to selection acting on the pelvis, and obstetric traits have greater independence in their capacity to evolve (Grabowski, 2012). Recent work has demonstrated that pelvic measures reflecting obstetric capacity are more variable across populations than would be predicted from ecogeographic principles, and that the population differences are consistent with the protection of birth canal dimensions (Kurki, 2011a,b, 2013).

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Modern epidemiological values for mortality risk associated with childbirth cannot be directly applied to past millennia, but childbirth remains a mortality risk factor throughout the world. Current values from the USA attribute 1.7–3.6% of young female deaths to pregnancy, childbirth and the puerperium (Heron, 2012), while careful study of Bangladeshi women generated a value of 37% (Koenig et al., 1988). Compared to subsequent births, first-time childbirth is a risky undertaking, prone to complication by cephalopelvic disproportion, fetal presentation, and potentially by other complications (Rush, 2000). Stature is not strongly correlated with pelvic canal size (Tague, 2000), but short stature is associated with an increased risk of problem childbirth in modern medical contexts (Rozenholc et al., 2007; Stulp et al., 2011). Wells et al. (2012) have argued that plasticity in maternal skeletal growth, in response to poor health and nutrition during development, can result in reduced pelvic size, while neonatal size tends to track intergenerational signals of environment and neonatal brain growth (head size) and is protected in conditions of undernutrition.

Decades of scholarship have identified the OD as a factor in skeletal design and perhaps in the relative success of past lineages since the onset of the distinctly human adaptations of bipedalism and encephalization (Wells et al., 2012), yet this perspective has not been without challenges. Analytically dynamic approaches to efficiency in locomotion have generated challenges to the assumption that the female pelvis is suboptimal for normal patterns of locomotion (Wall-Scheffler, 2012), leading to questions about the nature of possible selective constraints. A focus on metabolic loads during human pregnancy has led to the suggestion that it is the energetics of gestation and growth (EGG) that constrains the length of gestation, rather than the size of the neonate relative to the obstetric canal (Dunsworth et al., 2012; Ellison, 2008; Wells et al., 2012).

The exploration of alternate interpretations draws attention to aspects of human development and population demography that are anomalous within the OD scenario. Menarche occurs after the peak of height velocity during the adolescent growth spurt, and full sexual maturation occurs a year or two after menarche (Sinclair and Dangerfield, 1998). Human pelvic dimensions do not reach full adult size until several years after maximum stature is reached (LaVelle Moerman, 1982; Tague, 1994) so that fertility, in many populations, can precede peak obstetric capacity. This seems inconsistent with selection for obstetric capacity. In addition, there is little evidence for the patterns of differential mortality that the OD would predict. Wells and colleagues (2012) note that neonatal mortality has been variable across populations and millennia, which is unexpected under conditions of directional selection. Their approach of comparing apparent perinatal mortality between hunter-gatherers (foragers) and early agriculturists demonstrates higher mortality in the latter group, consistent with more obstetric complications among agriculturists. However, palaeodemographic approaches rely on relatively scant information, especially from past populations of immediate return hunter-gatherers. Those samples that provide information about mortality among foragers prior to the advent of farming come from cemeteries (Bocquet-Appel and Bar-Yosef, 2008; Bocquet-Appel and Naji, 2006; Wells et al., 2012). These collective burial grounds and related cultural features reflect social organizations that are more complex than those of the highly mobile immediate return foraging bands known from most of human evolution. Methodological variations in how adult age at death is quantified have stalled attempts to identify mortality patterns among adults. The research reported here seeks to address these shortcomings.

The skeletons of Holocene foragers from across a broad swathe of southern-most Africa can be examined for evidence of differential mortality. This population shows a long temporal span of distinctively small adult body size, as seen in some fragmentary remains from over 100,000 years ago (Pfeiffer, 2012). Skeletal remains are scarce for most of the ensuing millennia, but have been recovered from multiple sites representing the most recent 10,000 years. Pelvic morphology in this population has distinctive features that appear to have protected the obstetric canal, despite small body size. The lower planes of the pelvic canal are elongated in the antero-posterior and posterior aspects, although the inlet of the canal is small and overall the canal is narrow compared with other populations, including other small-bodied populations (Kurki, 2013). Natural selection for obstetric capacity has been postulated (Kurki, 2007; Kurki et al., 2010, 2008, 2012). We hypothesize that among these foragers there should be higher mortality among very young adult women as compared to very young adult men if there is heightened mortality risk at around the time of a woman's first pregnancy. The final stages of skeletal maturation can be used to differentiate relatively narrow age categories from late adolescence to full maturity. If childbirth is a source of mortality among very young adult women, the ratio of female to male skeletons in this age group will be skewed. If an imbalance in mortality is present, morphological and isotopic variables available for these skeletons may provide information about the sources of personal risk. Given the association of stature with birth difficulties, femoral lengths and head diameters are used as proxies for stature and mass.

1.1. Holocene foragers of southern Africa

The Later Stone Age (LSA) of southern Africa, from ca. 40,000 BP to European contact, has been well characterized (Barham and Mitchell, 2008; Deacon and Deacon, 1999; Mitchell, 2002). Archaeological evidence and genetic studies (Scheinfeldt et al., 2010; Schuster et al., 2010; Tishkoff et al., 2009) indicate that contemporary Khoe-San speakers are descendants of an ancestral population that probably extended north to at least the Kalahari and the Zambezi regions and south to the shores of the South Atlantic and Indian Oceans. The oldest mitochondrial DNA (mtDNA) haplogroups can be traced back to about 100,000 years ago. Patterns of mtDNA control region variation in seven living Khoe-San groups track well onto known archaeological periods of population growth and expansion (Schlebusch et al., 2013). There is a correlation between physical and genetic distance that is consistent with an archaeologically based reconstruction of geographically stable hunter-gatherers, and an absence of large-scale migration or population replacement (Deacon and Deacon, 1999; Mitchell, 2002). The homogeneity of cranial geometric morphometrics (Stynder, 2006; Stynder et al., 2007a,b) dental morphometry (Black, 2014; Black et al., 2009), and diverse osteological measures (Ginter, 2011) further reinforce the conclusion that the population was relatively isolated for many millennia.

Both the ancestral and descendant populations can be characterized as immediate return hunter-gatherers (as per Woodburn, 1982). High levels of terrestrial mobility within locally known spaces are characteristic of these groups (Stock and Pfeiffer, 2001), as they exploited a wide range of marine and terrestrial foodstuffs. Evidence for food storage is scant, as is evidence of items that might connote differential personal status or role specialization. Features of their Holocene material culture include hunting with bows and arrows, the use of composite poisoned bone arrowheads, relatively short and light spears, digging sticks weighted with bored stones, and the presence of standardized ostrich eggshell beads that were prepared using grooved stones (d'Errico et al., 2012). The strong similarities between the Holocene tool kit and the ethnographically documented tool kit of Khoe-San foragers, combined with the physical similarities and geographic continuity of the populations, have led researchers to assume that cultural practices such as those regarding marriage and childbirth were also similar between