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Growth of a Species, an Association, a Science: 80 Years of Growth and Development Research

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Abstract

Physical anthropological research was codified in the United States with the creation of the American Association of Physical Anthropology (AAPA) in 1929. That same year, a study began in yellow springs, Ohio, with a goal of identifying “what makes people different.” The approach used to answer that question was to study the growth and development of *Homo sapiens*. The resulting study, the Fels Longitudinal Study, is currently the longest continuous study of human growth and development in the world. Although the AAPA and the Fels Longitudinal Study have existed as separate entities for more than 80 years now, it is not surprising, given the relationship between anatomical and developmental research, there has been considerable overlap between the two. As the field of physical anthropology has blossomed to include subdisciplines such as forensics, genetics, primatology, as well as sophisticated statistical methodologies, the importance of growth and development research has escalated. Although current Fels Longitudinal Study research is largely directed at biomedical questions, virtually all findings are relevant to physical anthropology, providing insights into basic biological processes and life history parameters. Some key milestones from the early years of the AAPA and the Fels Longitudinal Study are highlighted here that address growth and development research in physical anthropology. These are still held as fundamental concepts that underscore the importance of this line of inquiry, not only across the subdisciplines of physical anthropology, but also among anthropological, biological, and biomedical inquiries.

Keywords

growth; development; Fels Longitudinal Study; AAPA

What makes people different? The story goes that this simple question provided the motivation in 1929 for the initiation of a study of human growth and development in the small town of Yellow Springs, Ohio (Roche, 1992). The study, originally supported by the Fels family, became known as the Fels Longitudinal Study. It could easily be imagined that this same question, what makes people different, also provided the impetus for the founding of an association, also in 1929, the American Association of Physical Anthropologists (AAPA). Although a number of longitudinal studies of growth and development began at approximately the same time, the Fels Longitudinal Study is the only one to have run continuously into the present. During that time, the AAPA has grown to become the largest association dedicated to Physical Anthropology with a membership that is truly global.

In 2011, a symposium was held to celebrate the longevity and interrelated nature of the Fels Longitudinal Study and the AAPA. The symposium was jointly sponsored by the AAPA and the Human Biology Association, and consisted of 13 presentations related to the general topic of growth and development research in physical anthropology. A number of the participants had either current or historical connections to the Fels Longitudinal Study.

The organizers of the symposium, and authors of the current paper, have spent the last decade contributing to the Fels Longitudinal Study, and have been members of the AAPA for their professional careers. The coincidental nature of the two anniversaries, and overlapping nature of the research area, suggested a need for both a celebration and the symposium topic. The primary goal was to bring together a diversity of experts from subdisciplines that 1) represent the breadth of research topics typifying modern physical anthropology and 2) discuss current work regarding the aspects of growth and development. The articles published in this special issue of the AJPA are a testament to the quality of work highlighted at the symposium.

DEVELOPMENTAL ROOTS OF THE ASSOCIATION AND THE FELS LONGITUDINAL STUDY

The American Journal of Physical Anthropology actually predates the formation of the association, and the initiation of Fels Longitudinal Study, by a decade (Hrdlička, 1918a). In the first AJPA issue, the founding editor provided an essay on the aims and scope of, what was then, modern physical anthropology (Hrdlička, 1918b). In enumerating the accomplishments of the field prior to the establishment of the journal, Hrdlička states “[Physical anthropology] has actuated and to a large extent carried out the study of the development of man from his inception onward” (Hrdlička, 1918b:12). He concludes with a call for physical anthropologists to continue detailing growth and development of modern humans from fetus through adulthood.

The inclusion of a developmental component as a core constituent of physical anthropology since the formalization of the field is unlikely to surprise many readers of the AJPA, as it is a basic aspect of training for most subdisciplines within the field. Despite the long history, however, new approaches to studying growth and development, as well as new analytical techniques, are routinely being developed and incorporated in hypotheses spanning the anthropological spectrum.

The initiation of the Fels Longitudinal Study in 1929, while it would certainly grow to have an impact on anthropological research, was not in response to Hrdlička's call for increased growth and development research. It actually belongs to a family of growth studies responding in part to the 1931 White House Conference on Child Health and Protection (Hamill, 1931; Roche, 1992). In the years following, many of the resulting studies examined the effects of the Great Depression on childhood health. Although most of these growth studies were associated with major universities in large metropolitan areas (e.g., Denver Growth Study, Harvard School of Public Health Growth Study, Berkeley Growth Study), The Fels Longitudinal Study had its roots in the Midwest in the small hamlet of Yellow Springs, Ohio. It was in Yellow Springs that the President of Antioch College, Arthur Morgan, successfully established a growth study after convincing Samuel Fels, a noted philanthropist, to provide funding.

The Fels Research Institute, as it was initially called, was funded by the Fels Fund of Philadelphia. The original Director was the physician Lester Sontag who continued to work with the study until his retirement in 1970 (Roche, 1992). In 1973, the Ohio General Assembly established the School of Medicine at Wright State University (WSU) and in 1977 the Fels Fund of Philadelphia donated the Fels Institute to the new medical school. Since joining WSU, the Fels Longitudinal Study (currently part of the research efforts at the Lifespan Health Research Center, WSU) has largely been directed at answering questions of biomedical relevance with primary funding from the National Institutes of Health. At any given time, multiple studies concurrently examine the aspects of growth, development, and human biology through the Fels Longitudinal Study.

As a longitudinal study of growth and development, it is not surprising that the Fels Longitudinal Study has played a role in physical anthropological research. The earliest AJPA article describing work from the Fels Longitudinal Study was published in 1943 and was titled *Degree of Kinship and Pattern of Ossification: A Longitudinal X-ray Study of the Appearance Pattern of Ossification Centers in Children of Different Kinship Groups* (Reynolds, 1943). A long-term relationship between physical anthropology and the Fels Longitudinal Study was established when Stanley Garn, a few years after graduating from Harvard University, came to the Fels Research Institute. Garn became the chairman of the Physical Growth Department of the Institute in 1952 (Garn, 1981).

One of the most prolific writers in physical anthropology, Stanley Garn wrote numerous articles on body composition, nutritional assessment, anthropometric methods, and skeletal and dental development while working with the Fels Longitudinal Study (Garn and Young, 1956; Garn and Rohmann, 1959; Garn and Haskell, 1959a,b; Garn and Rohmann, 1960a,b; Garn et al., 1961; Garn, 1962). His firsthand account of the history of growth and development research in physical anthropology (Garn, 1981) documents many aspects of the history of longitudinal growth studies in the United States, and the relationship between physical anthropology and biomedical research.

An important contribution to the understanding of cranial and dental growth also resulted from research conducted on the Fels Longitudinal study. Notable aspects of this study were conducted by Garn (Garn et al., 1960a,b; Garn et al., 1963; Garn et al., 1965), but a number

of seminal articles on cranial growth also resulted from the work of the renowned orthodontist, Arthur B. Lewis who analyzed the substantial collection of cranial radiographs in the Fels Longitudinal Study. Anyone who has ever discussed basicranial anatomy in the last four decades has likely, in some manner, referenced the work of Lewis (e.g., Lewis and Roche, 1972, 1974, 1977).

Following in the tradition of growth and development research, the 2011 AAPA/HBA symposium resulted in eight articles (plus this introductory paper) included in this special issue of the AJPA. Together, these articles cover a wide range of topics and these are discussed below. Articles are grouped based on the general themes, although, in practice, each article may fit multiple categories.

BODY MASS

As noted above, the 1930s saw an increased interest in examining the effects of nutrition and environment (and the Great Depression) on children's health. One of the easiest metrics for assessment of basic health is the combination of weight and stature (or recumbent length in infants) as body mass index (BMI or ponderal index in pediatrics). In practice, a BMI measure indicating a child is too lean for their current length (stature) is a potential indication of malnutrition or other growth disturbance. The simple relationship between stature and weight remains an important tool for the assessment of healthy growth, and several of the articles in this issue use this relationship to address the aspects of growth (e.g., May et al., this volume, Johnson et al., this volume). In an ethnically diverse sample of infants enrolled in the Women, Infants, and Children (WIC) program, May et al.'s study demonstrates the value of these simple measures in assessments of early childhood health. May et al. (this volume) analyze the relationships between feeding patterns and weight gain and change in weight status (weight-for-length z-score) in the first 12 weeks of life. They also examine infants in the extreme tails of the birthweight distribution and those that experience rapid weight gain over the first 3 months.

The BMI is frequently correlated with an increased risk for certain diseases such as metabolic syndrome. In the first of two contributions to this special issue, Johnson and colleagues discuss the negative association between age at menarche and BMI in girls participating in the Fels Longitudinal Study. Secular trends in precocious sexual development and elevated BMI during adolescence have been noted in many studies, including studies from nearly every industrialized nation. In their article, Johnson et al. (this volume) explore the possibility of a shared genetic etiology of the two phenomena. The effects of specific genetic risk scores on BMI found during adolescence points to a new perspective on these basic phenotypes that are generally modeled without reference to their shared genetic underpinnings.

It has become an interesting twist that, now, the focus of discussions of childhood body mass in the United States has moved from concerns of leanness and malnutrition, typical in the early days of the Fels Longitudinal Study, to those of overweight and obesity. In what may be one of the more surprising contributions to these discussions, Tardif and colleagues (this volume) describe a nonhuman primate model for pediatric obesity. The surprising

aspect of this study is not the inherent value of a nonhuman primate model, but the choice of the diminutive marmoset as that model. Of the many interesting aspects of that study is the potential identification that a subset of the marmoset population under study may be considered “super-obese.” Attainment of obese status early in development for marmoset does make them an interesting model for the current wave of childhood obesity seen in the US children.

SKELETAL AND DENTAL DEVELOPMENT

It is well understood that, for many people, physical anthropology is synonymous with the examination of skeletal collections. The earliest volumes of the AJPA and the first meetings of the association were dominated by the work on modern skeletal collections or on fossil remains. This interest and use, of course, has never waned and has grown as the diversity in the fossil record has expanded, and the technological abilities to provide everdetailed insight into the anatomy have improved.

The contributions by Ruff et al. (this volume) and Šešelj (this volume), both use modern skeletal data to make inferences about past populations. Modern approaches such as those undertaken in these articles seek to extract the maximal amount of information from skeletal remains. This includes making inferences, not only on longitudinal growth in extinct groups or taxa, but also on general influences on bone growth as well as aspects of life history parameters.

The third article dealing with the skeleton (Duren et al., this volume) examines lifetime changes in basic skeletal phenotypes and the concomitant changing genetic landscape that influences these traits. Working with the Fels Longitudinal Study, we have been able to explore the changing influence of genetics and environment on skeletal traits not only during childhood but also throughout the entire life span. This is the first presentation of such data and we hope that it will become a resource for future inquiries in physical anthropology, whether they are based on the issues of modern bone remodeling or susceptibility to environmental perturbations in the child skeleton, or applications to the human fossil record and life history reconstructions.

STATISTICAL METHODOLOGY

The remaining articles in this issue resulting from the symposium deal with complex statistical modeling of growth and developmental parameters. Johnson’s second contribution to this volume describes modeling of infant growth curves (Johnson et al., this volume). This contribution clearly illustrates the value of longitudinal data, specifically the ability to assess individual variability in growth.

For those interested in growth, the concept of catch-up-growth is a familiar one in cases of small-for-date infants. In that case, individuals frequently enjoy a period of accelerated growth until they attain a more normal size. Nahhas et al. (this volume), describe a similar condition, this time concerning skeletal maturation instead of body size. Using a semiparametric regression, they are able to predict the probability of an imminent maturational spurt. This is done by creating conditional reference values. In other words, a

current skeletal maturity assessment for an individual is used to predict the skeletal maturity of that individual at a point in the future.

DISCUSSION

The articles compiled into this special issue can brush only the surface of current growth and development research that has become a standard aspect of biological anthropology inquiry. As the participants in the symposium and this volume represent a small sample of those researchers actively engaged in growth and development research, so does the Fels Longitudinal Study represent but a sample of studies devoted to the topic. Many of the growth studies founded in the 1930s such as the Bolton-Brush Study, or the Denver Growth Study, have not seen participants for some time. There are, of course, current studies focused on new recruitment and continuing research in longitudinal growth and development, such as the Birth to Twenty Study in South Africa (e.g., Sheppard et al., 2009; Hawley et al., 2012).

Sadly, as preparations were being made for the symposium, we learned about the passing of one of the true pioneers of growth and development research, James M. Tanner (1920-2010). In his presentation on the contribution of the Fels Longitudinal Study to European Auxology (Cameron, 2011), Noel Cameron discussed the work of Tanner and described a trip Tanner made in 1948 to visit the Fels Longitudinal Study and other growth studies in the United States. As the organizers of the symposium, we felt it fitting to dedicate the symposium to James Tanner in recognition of his singular contribution but also as a representative of the many researchers who have paved the way for growth and development research.

Additionally, it is important to recognize the significant contribution of the participants of the Fels Longitudinal Study who have made research a part of their life and, indeed, their family history to remain a part of this remarkable study. Their contribution cannot be understated. As we have chosen James Tanner to represent the researchers involved in growth and development research, we can hold the Fels Longitudinal Study participants as representatives of the numerous participants worldwide who have, who are, and who will contribute to biological anthropology research. The contribution of these individuals should never be taken for granted and we would like to dedicate this special issue to those individuals past, present, and future.

Acknowledgments

The Symposium

The 2011 AAPA/HBA symposium included 12 formal presentations followed by a lively and entertaining synthesis of those articles by the discussant, John Himes. Although not all speakers were available to provide articles for this issue, the overall theme of the symposium is captured by those that are included in the pages. It was an intentional gesture on the part of the organizers to include speakers and topics that approach the boundaries of anthropological inquiry and may be more accurately described as biomedical in nature. This was done both to acknowledge the past and current contribution of the Fels Longitudinal Study to the biomedical literature and to acknowledge the ongoing role biological anthropology has played, and is playing, in biomedical research.

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