CRANIOFACIAL ANTHROPOMETRY

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Practical Measurement of the Head and Face for Clinical, Surgical and Research Use

By

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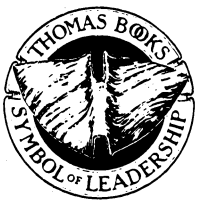

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To our children
Victoria and Ian

FOREWORD

Drs. Kolar and Salter are a husband and wife team who have produced a book that is useful to both practicing surgeons and anthropologists working with dysmorphology in the craniofacial region. This is an excellent and highly pragmatic book that is most readable for anyone interested in craniofacial anthropometry and and who does not have a previous grasp of the subject. It is fascinating both from the historical aspect and as a demonstration of how to apply a massive amount of data so that it can be utilized to help patients with significant craniofacial deformities.

There are several areas that are of practical significance to a surgeon. One is that of following the growth of an unoperated patient. Kolar and Salter point out the difficulty of getting enough data about what is "normal" growth in abnormal patients and the very limited number of abnormal cases in any one series. Only if these patients are concentrated into large centers where the opportunity for long term studies can be reached will further breakthroughs be able to occur based on scientific anthropometric analysis.

Secondly, there is the problem of trying to analyze exactly what is wrong with the face and, therefore, what must be corrected. This often is more difficult than may be apparent at first. For example, procedures for the correction of the facial features of Down Syndrome were worked out in a very simplistic and arbitrary manner in the late 1970's. Although these produced changes in facial appearance, they rarely produced complete correction but rather an amelioration of the signs of the deformity. By analyzing anthropometric data, it became obvious that one of the significant features was relative recession of the forehead. This author then corrected two patients by a forehead advancement, producing a radical correction of the deformity when combined with midface correction. This raises a philosophical question as to whether this kind of radical technique should be used on all such patients.

If the anthropologist understands the data as well as the deformity, he

or she can become involved in surgical planning. It is of no use to the surgeon if this planning is done in an abstract fashion which is unrealistic. It can only be done effectively by discussing with the surgeon what can be done practically and then using these concepts to see how movement of one part of the craniofacial skeleton may affect the proportions with another part and whether harmony will necessarily be improved or even diminished. In the past, anthropologists have tended just to give the patient's measurements and how far they were from two standard deviations. Most surgeons do not have the time, the interest, or the willingness to sit down and take this data and turn it into something of use for planning. If the anthropologist has spent time in the operating room watching how the procedures are done, and understanding the surgical difficulties, he or she realizes the need for very pragmatic advice with regard to suggestions for correction and the amount of movement that should be carried out. This has been worked out over the years by a close relationship between the surgeon and the anthropologist. What may be useful to one may be of no value to the other.

Follow up of these patients is enormously important and a very humbling experience. The surgeon first finds out that he has not achieved what he set out to achieve. This is shown in some of the pre- and post-operative clinical reports. Long-term follow up also enables him to see how a face is growing and this soon gets rid of the naive concept of many surgeons who believe that if they put the skeleton of a young child into the correct position it will grow continuously along the ideal lines.

Many people who see how much data is collected in our craniofacial anthropometric laboratory feel that the numbers are excessive and the collection of data too time consuming. However, over the years we have constantly added to the amount of data to be collected because it may not be for ten or fifteen years that one realizes one has not been collecting a certain measurement and, therefore, a proper retrospective analysis cannot be made.

Clinical anthropology, combined with modern technology such as CT and MRI scans, have now outstripped a surgeon's ability to perform the necessary movements. Kolar and Salter point out the advantages but, more practically, the disadvantages of such systems and how easy it is for modern technology, by incorrect interpretation, to lead to significantly erroneous data. Currently, very crude machines are being developed, following the principles of robotics, to enable the surgeon to know exactly where he is placing segments in space during an operation.

Follow up of these patients using anthropometric procedures is enormously important as this technology improves.

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FOREWORD

From petrolyphs, cave paintings, and ivory carvings thousands of years old, it can be inferred that humans have long been keenly interested in depicting the characteristics of human anatomy. The splendid works of Leonardo DaVinci and Michelangelo are in large part inspired by fascination with the aesthetic values of the ideal human form. Pursuit of understanding of the combination of structural and functional characteristics that make the human body such a remarkably efficient machine has long been a focus of intellectual challenge that has attracted some of our finest scientists. While the frontiers of biological science are now thought to be in the realm of molecular biology, there is still much to be learned about the processes through which the linear sequence of instructions encoded in DNA is ultimately transformed into a three-dimensional organism endowed with the capacity to interact with and modify its environment over many decades of time.

The regulation of growth and the shaping of the structures it produces and modifies is a process that can be studied at many levels, from the molecular to the organismic. For instance, molecular-level research has shown that highly-conserved sequences of DNA determine the earliest stages of embryogenesis in both vertebrates and invertebrates. Comparative anatomy and physiology have shown that many details of early growth and development are strikingly similar among vertebrates, giving strong indication that prolonged, sustained selection has placed rigid constraints on the degree to which deviations from normal developmental pathways can be tolerated. The wide disparity between the estimated frequency of conception and that of live births in our own species suggests that selection is still a powerful force restricting the range of human morphological variation in virtually every respect.

While it is incorrect to assert that "ontogeny recapitulates phylogeny", it is nevertheless true that many attributes of ontogeny have been preserved in a wide range of phyla, with the underlying interaction between cell division, induction, and differentiation governing the dynamics of

morphogenesis. In view of the numerous opportunities for perturbations of this process encountered during ontogeny, the high success ratio attained in the lengthy and prolonged period of human gestation, infancy, and childhood is impressive. When certain perturbations occur, but the developing individual survives, we have the opportunity to examine the limits of human variation. Thus, while the ideal expression of human anatomy may have inspired some of the world's great art, departures from the ideal have challenged biological scientists motivated by the desire to better understand them and through that understanding to gain insights into the factors governing normal growth and development.

With understanding of the processes that produce normal anatomical structures has come increased capacity to intervene when abnormalities occur. Harnessing the dynamic processes of growth and development to correct defects that profoundly effect the quality of life is one of the most impressive practical achievements of biomedical science. The methods and theories Drs. Kolar and Salter address illustrate the degree to which biological anthropologists and physicians have been able to collaborate in the solution of complex problems with profound humanitarian implications.

While most physical anthropologists were at one time physicians by training, their interest in the particulars of human variation was more avocational than professional. Interest in the description of anatomical characteristics representative of specific human groups was often the focus of their studies. Consequently, much early anthropometry was purely descriptive, and great emphasis was placed on craniometric differences between human populations. Given the prevailing attitudes of the late eighteenth and nineteenth centuries such comparisons lent themselves to racist and ethnically-biased interpretations. Such interpretations never represented the main stream of academic physical anthropology in the United States. Nevertheless, we still encounter criticisms of the field predicated on the assumption that anthropometry, and, by extension, all of physical anthropology, was for the most part preoccupied with comparisons of racial and ethnic differences often reflected in craniometric values.

Of course, physical anthropology has undergone considerable change since the emergence of the "new physical anthropology" in the early 1960's. While anthropometry remains an important tool, new methodologies reflecting a broadening scope of research interests continue to find their way into the biological anthropologist's toolkit. The result has

been the opening up of new areas of activity in which team work with scientists of other disciplines is often essential. The common interests shared by biological anthropologists, physicians, and other biomedical scientists have led to productive relationships within which the expertise of each can be utilized to exploit advances in technology that provide exciting new dimensions for the measurement of human variation. Drs. Kolar and Salter have provided us with a very useful, practical, and up-to-date source for the professional whose interests lie in the area of human craniometry. Their contribution reflects the extent to which biological anthropology has adapted to the contemporary environment of collaborative research in a biomedical setting. The descriptions of methods and the accompanying photographs will prove invaluable to anyone embarking on research in the fascinating and always-timely topic of variation in human growth and development.

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PREFACE

In 1920, Ales Hrdlička published his monograph, *Anthropometry,* which has become the standard English-language text on the subject in North America. He revised and republished this as *Practical Anthropometry* in 1939. The text was further revised by T.D. Stewart and a third edition published in 1947. Hrdlička included a battery of 14 measurements of the head and face used at the Division of Physical Anthropology, the Smithsonian Institution, with an admonition to limit the examination to "... only those measurements and observations that will be indispensable or of the greatest promise ..." (1939:49). Subsequent investigators (Comas, 1960; Vallois, 1965; Olivier, 1969; Weiner and Lourie, 1969) followed Hrdlička's lead with little variation, adding a very small number of measurements (1–4) derived from earlier authors (Broca, 1879; Martin, 1914).

The application of anthropometry to the study of craniofacial anomalies led to an increase in the number of measurements used to distinguish normal and abnormal morphology, first at Charles University, Prague, Czechoslovakia (Hajniš, 1974), and later at the Hospital for Sick Children, Toronto, Canada (Farkas, 1981) and at the Craniofacial Center, Medical City Dallas Hospital. These new methods of measurement have been handed down primarily by oral tradition from one investigator to the next. Very few of them have been described in any detail in print. In most cases, the published descriptions consist of the identification of landmarks, name(s) of the measurement, and the instrument used. There is little information on the specific techniques of taking the measurements.

As research, including clinical applications, in this area has developed, it has become apparent that these techniques need to be standardized to ensure the reliability of results by individual investigators, and replicability between investigators. This book is intended to provide that standardization by presenting detailed instructions on measurement techniques, based on years of experience with normal subjects and patients with a

wide variety of congenital deformities of the head and face, gathered at the largest craniofacial treatment center in North America.

The book is divided into three parts. The first part (Chapters One through Three) includes preliminary information needed by the investigator to set up a research and/or clinical anthropometry program. Chapter One presents a brief history of the development of anthropometry, particularly craniofacial measurements, before discussing the logistics of setting up a well-equipped anthropometry laboratory and effective craniofacial research program. Chapter Two presents detailed descriptions, with illustrations, of the instruments needed to perform the techniques in this book. Sources for obtaining these instruments, some of which are standard and others of which are custom-made, are listed at the end of the chapter. Chapter Three describes the craniofacial landmarks used throughout the book. These are listed alphabetically by abbreviation for each craniofacial region. Each landmark is presented in a standard format. The standard name and abbreviation are given first. Any synonyms found in the historical literature are presented next. The landmark location is described, followed by any remarks about difficulties of location, substitutions, or historical notes.

The second part of the book (Chapters Four through Ten) presents the measurements used clinically in the Anthropology Laboratory of the Craniofacial Center, Medical City Dallas Hospital. Chapters Four through Nine present our standard measurements, organized by craniofacial region, beginning with the head. Each chapter begins with a discussion of the measurement battery for that region, before presenting the measurements themselves. These are arranged by instrument, in the sequence taken in our laboratory, a sequence we have found to be most efficient and reliable.

The format for presenting the measurements is similar to that used in Chapter Three for the landmarks. The measurement name is given, with any synonyms found in the historical literature; the landmarks and their abbreviations listed; the instrument used; the method of measurement described in detail; and any remarks on variations and historical development noted. Each measurement is accompanied by figures illustrating the measurement techniques.

Chapter Ten presents a number of non-standardized measurements clinically useful for describing certain craniofacial deformities, especially asymmetries. This chapter also discusses the problems of doing anthropometry in less than ideal situations, whether in the laboratory or

in the field, with pointers on how to adjust these techniques to such circumstances to maintain reliability.

The final part of the book deals with the analysis of the anthropometric data. Chapter Eleven discusses the collection and analysis of data from clinically normal subjects, which provide the database for our clinical applications. Chapter Twelve presents the results of studies of quantitative dysmorphology in several congenital craniofacial anomalies, with comparisons to the standard clinical literature. Chapter Thirteen describes methods for applying anthropometric techniques to planning detailed reconstructive craniofacial surgery, including step-by-step examples of the calculations required for specific surgical procedures. We conclude in Chapter Fourteen with a look at some of the three-dimensional imaging systems that are being developed for the study of craniofacial morphology and their potential.

ACKNOWLEDGMENTS

This book is the product of years of work with the support and cooperation of many people. We are particularly grateful for the herculean efforts of the Media Production Department of Medical City Dallas Hospital—Mike Lorfing, Terry Cockerham, Sue Green, and Max Sturdivant—in preparing the photographs which are such an essential part of this atlas and for the tables throughout. Several medical illustrators provided the figures for this text. We especially would like to thank Dave Brown of Synapse Media Productions for the illustrations in Chapters Three (Landmarks) and Thirteen (Surgical Planning) and for the wire-frame model on the cover. Lou Sadler prepared the artist's rendering of the patient with Crouzon syndrome in Chapter Twelve, while Bill Winn drew the illustration for Down syndrome in the same chapter. Lois Lehman, R.R.T., was especially helpful in preparing the CT and MRI images in Chapter Fourteen. We greatly appreciate the work of our research librarians, Debbie Stovall and Miriam Muallen, in tracking down the numerous historical references that contribute to the background discussions of the measurements presented here. Lon Rogers, Medical Engineering Department, The Hospital for Sick Children, Toronto, was very helpful in redesigning the specialized instruments shown in Chapter Two. Many of our colleagues, in Toronto, Dallas, and elsewhere, have contributed comments which have helped revise and refine the assessment system presented here. We especially want to thank Dr. Ian R. Munro, of the Craniofacial Center, Medical City Dallas Hospital, who has encouraged us over the years to develop the clinical program that has led to this book. We also want to acknowledge Dr. Leslie G. Farkas, The Hospital for Sick Children, Toronto, who introduced Kolar to craniofacial research and who taught him a number of the techniques discussed in this book. Finally, we would like to thank Medical City Dallas Hospital for its support through the long process that resulted in this text.

CONTENTS

CRANIOFACIAL ANTHROPOMETRY

Chapter One

INTRODUCTION

HISTORICAL BACKGROUND

Defining the form of the human body is an ancient concern. As far back as the third millenium, B.C., Egyptian artists had developed elaborate systems of proportions they used in bas-relief tomb carvings of the pharoahs and nobles. These systems defined the body in terms of some anatomical unit, such as a hand, finger, cubit (the distance from the elbow to the tip of the thumb), etc. Body proportions were expressed in multiples of the unit used (Boyd, 1980).

In Classical Greece and Rome, artists used numerous **canons**, rules of simple proportions, to describe the "ideal" form of the human figure. Like the Egyptian systems, these canons defined the body in terms of multiples of specific body parts or some other arbitrary standard. For example, the Greek Sculptor, Polycleitus, in the fifth century, B.C., in his figure, the Lancebearer, divided the body vertically into 15 equal parts. The head and face constituted two of these parts (Figure I-1) (Boyd, 1980; Richer, 1890). On the other hand, a century later the sculptor Lysippus defined the head and face as an eighth part of the total vertical height (Figure I-2) (Pliny, 1857). This proportion was adopted by the Roman writer Vitruvius in the first century B.C. He also divided the face into three equal parts—forehead, nose, and lower face (Vitruvius, 1931). This aesthetic standard is still used in modern orthodontics (Dagys, 1987).

Unlike the Egyptian proportions with their elaborate rules, partial units, and grid systems, the Greco-Roman canons emphasized simplicity. They were grounded in a numerological system based on the decad (10) and its subunits, the **tetraktys** ($1 + 2 + 3 + 4 = 10$) (Boyd, 1980). Even the so-called Golden Section or Golden Proportion (1 : 1.618) was a relatively simple calculation [1: $(1 + \sqrt{5}) / 2$] derived from the Fibonacci series (Ricketts, 1981, 1982a,b).

The use of canons was revived during the Renaissance by artists such

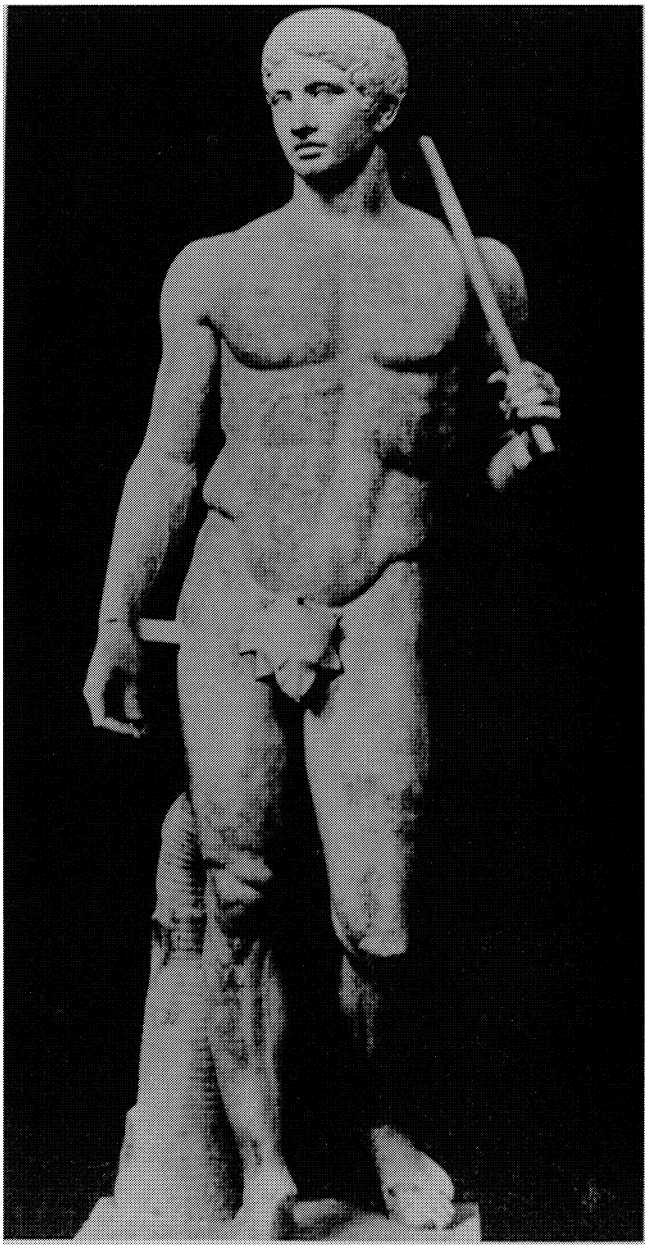

Figure I-1. The Lancebearer by Polycleitus (Greek, 5th century, B.C.). The figure is divided vertically into fifteen equal parts, of which the head and face represent two parts (13.3%), the mean ratio for modern North American Caucasians (Farkas and Munro, 1987).