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Motion to Support Research on Human Skeletal Remains

(Motion passed unanimously by the membership of the Canadian Archaeological Association at its annual business meeting, 29 April, 1982, in Hamilton, Ontario)

In 1979 the Canadian Association for Physical Anthropology published its "Statement on the Excavation, Treatment, Analysis and Disposition of Human Skeletal Remains from Archaeological Sites in Canada" (*Can. Rev. Phys. Anthrop.* 1:32-36). The statement was prepared in response to public concern over the nature and purposes of scientific study of human skeletal remains from archaeological sites. It detailed the information to be gained in three categories of research, archaeological reconstruction, medical studies, and forensic identification, and the benefits accrued for the Canadian public and for the global community at large. The report addressed the question of native peoples' concerns and called for more effective personal communication between individual researchers in archaeology and physical anthropology and native peoples. The major thrust of the statement was to identify the importance of human skeletal remains to ongoing scientific research and the imperative of retaining human skeletal collections for future research.

Two scientific organizations recently have followed the lead of the Canadian Association for Physical Anthropology in emphasizing the role of human skeletal remains in anthropological, medical, and forensic research. The American Association of Physical Anthropologists and the Physical Anthropology Section of the American Academy of Forensic Sciences have passed resolutions deploring the reburial of human skeletal remains except in situations where specific descendants can be traced and it is the explicit wish of those living descendants that the remains be reburied rather than be retained for research purposes. They have further resolved to encourage close and effective communication with appropriate ethnic groups by individual scholars who study human remains that may have biological or cultural affinity to those groups, and that **no** remains should be reburied or overlooked in archaeological sites without appropriate study by physical anthropologists with special training in skeletal biology.

It is apparent that a minority of archaeologists, for reasons best known to themselves, would ignore human burials rather than come to grips with public concern over their excavation and the scientific nature of human osteological research. Worse, there are known instances where archaeologists have gone out of their way to suppress knowledge of human burials being exposed during site excavations and have hindered or prevented scientific inquiry on human skeletal remains. In at least one instance an archaeologist publicly stated in a national news magazine that human skeletal remains have no scientific value in archaeological research.

As professional archaeologists we should explicitly recognize the significance of all materials in an archaeological site for the purpose of reconstructing past population history, and understand the significance of retaining all materials for future research as new methods and techniques of study are developed. Certain archaeological materials cannot be studied and retained to the exclusion, or at the expense of others in what is truly a holistic scientific discipline.

The motion proposed here is that the Canadian Archaeological Association resolve to wholeheartedly and without qualification support the recent stands taken by the Canadian Association for Physical Anthropology and its sister organizations with respect to human skeletal remains in archaeological research. Be it further resolved that the Canadian Archaeological Association endorses the preamble to this motion and discourages the actions of any archaeologists who would hinder or prevent scientific inquiry on human skeletal remains.

XIth International Congress of Anthropological and Ethnological Sciences

PLACE: CANADA, 1983.

PHASE I: Québec City, Québec, August 14-17, 1983.

PHASE II: Vancouver, B.C., August 20-25, 1983.

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Postural-Positional Thermoregulatory Behaviour and Ecological Factors in Primates[1]

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KEY WORDS Posture • Positional Behaviour • Thermoregulation • Primate Ecology

ABSTRACT Postures and positional behaviour of primates have been most often considered purely from a "behavioural" standpoint and remarkably little attention had been directed towards understanding the ecological significance of these patterns. This paper presents a theoretical consideration of the significance of postural and positional behaviours of arboreal primates in ecological contexts. It is shown that in many, if not most, instances, postures and positions are not dictated by social or behavioural prerequisites but are significantly influenced by physiological regulatory activities. Such physiological activity, in the case of thermoregulation, dictates changes in body posture to aid or inhibit heat loss, as does the choice of position within the environment. The final choice of a body posture and a position for any individual animal is the resultant of social, behavioural, physiological and environmental forces.

RESUME La plupart des études des postures et des comportements physiques chez les primates ont traités le sujet d'une perspective behavioriste et la signification écologique de ces comportements n'a attiré que peu d'attention. Dans ce papier l'auteur tente une esquisse d'interprétation des postures et des positions physiques des primates arboréaux par rapport avec les conditions écologiques. On montre que dans beaucoup, sinon la plupart de cas, les postures observées ne sont pas entièrement déterminées par des données d'ordre de comportement ou de socialité, mais qu'elles sont plutôt influencées par des nécessités de règlement physiologique, tel que la régulation de température. Ces processus de thermorégulation nécessitent des changements de posture ou d'attitude, afin, soit d'encourager, soit d'empêcher, les pertes calorifiques, et ils peuvent également causer des déplacements totales de l'organisme dans l'environnement. Enfin, on suggère que l'on devrait expliquer la position et la posture d'un animal comme résultat de l'action simultanée de quatre forces, c'est à dire les forces sociales, environnementales, physiologiques et de comportement.

Postures and positional behaviour are features of the behaviour patterns of all organisms, but have been primarily focused upon as "behavioural" items or have been loosely considered to be ecologically important in primates (Ripley, 1976; Morbeck, 1976; Fleagle, 1976; Mendel, 1976; Rose, 1977). However, in all of these citations the aspect of the environment or ecological circumstance to which the posture and positional behaviour are related is unstated.

From my own researches on *Alouatta palliata* in Mexico, I have come to the conclusion that both posture and position are partly the observable result of a process of behavioural thermoregulation; that is, a process of adjusting the animal's heat energy relationship to its

[1]A version of this paper was presented at the 8th annual meeting of the Canadian Association for Physical Anthropology, Ottawa, Ontario, 1980.

environment through changes in body configuration, what we recognize as posture, and in the relative exposure to sun and shade, wind and shelter, that which can be called positional behaviour. It is not that the climate or the environment **totally** directs these behaviours, but that they have a substantial and interactive effect in encouraging certain forms of posture and positioning. Thus these features of behaviour are also important factors in the overall energy budget of an organism.

While the mechanisms of behavioural thermoregulation have been mostly recognized in the study of ectotherms, animals which manage their exposure to sun and shade in order to maintain a relatively stable internal temperature, the concept and many similar mechanisms are applicable to mammals. As pointed out in several places by Malcolm Gordon (1977), behavioural, and specifically postural, changes are employed by mammals as part of their overall system of thermoregulation, and to some extent, these aspects have been cursorily examined in a few species. In the case of primates, virtually no work has been done on any significant aspect of their behavioural thermoregulation. Since the maintenance of a stable internal temperature is a very complex phenomenon produced by an interplay of internal physiological phenomena, behavioural activity patterns, morphological structural features, and environmental-ecological factors (Hill, 1976), it is useful to review some of these factors and their roles in the thermoregulation of primates before entering the main argument.

Heat is generated from the chemical energy yielded in the breakdown of sugars, lipids, and proteins during digestion and cellular maintenance; and by the energy released as a by-product during the operation of the skeletal muscle system. Indeed most mammals are fairly efficient heat engines and at environmental temperatures below normal body temperature, they are often forced to exhaust "waste" heat to their environment. Heat energy is also, to some extent, being constantly imput into an animal's body through the mechanisms of radiation, conduction and convection, but these same channels are utilized by the animal for heat loss.

Each species, in each particular thermal environment to which the members are acclimated, displays a range of ambient temperature, over which the animal is able to adjust its thermal interchange pattern without the necessity of increasing metabolic rate. This range, known as the "thermo-neutral range", is bounded by upper and lower critical temperatures which represent the points at which increases in metabolic rate are necessary to maintain stable core body temperatures. Outside of this zone an animal displays a characteristic increase in metabolic rate for each °C that the temperature rises or falls. With falling temperatures it is obvious that the metabolic generation of heat must be increased in order to maintain core temperature, although the reasons for the sharp rise in metabolism above T_{uc} are less so. When the ambient temperature is above the upper critical temperature the animal must operate against the heat gradient. Hence as specialized mechanisms such as evaporative cooling and panting are brought into operation, the metabolic rate rises rapidly to maintain their operation. This is a game of "catch-up" in which the operation of the cooling system is accomplished at the expense of a rapid rise in heat production and therefore is rather limited in its capacity. Within the thermo-neutral range, behaviour is regarded as being **the** major factor in regulating the rate of heat loss to the environment (Hill, 1976). Part of this activity set is under involuntary control which results in changes in blood flow rates in various areas of the body and in the degree of piloerection. These activities are marginally observable, at close range, where piloerection may be seen, and blood flushed skin may be visible. More grossly visible is the part of the activity set under voluntary control. These actions are the postural changes and positional movements which are discussed in the next two sections.

POSTURAL THERMOREGULATION

Each individual primate lives in an ecological environment in which heat may be input to its body through radiation — both direct and reflected solar radiation in the visible spectrum and through infrared radiation from surrounding objects — and to lesser extents through convection and conduction from air and substrates respectively. Any primate as well generates a substantial amount of metabolic heat, although the amount varies greatly according to diet, amount of food digesting, and activity. This total heat load, if in excess of that needed to

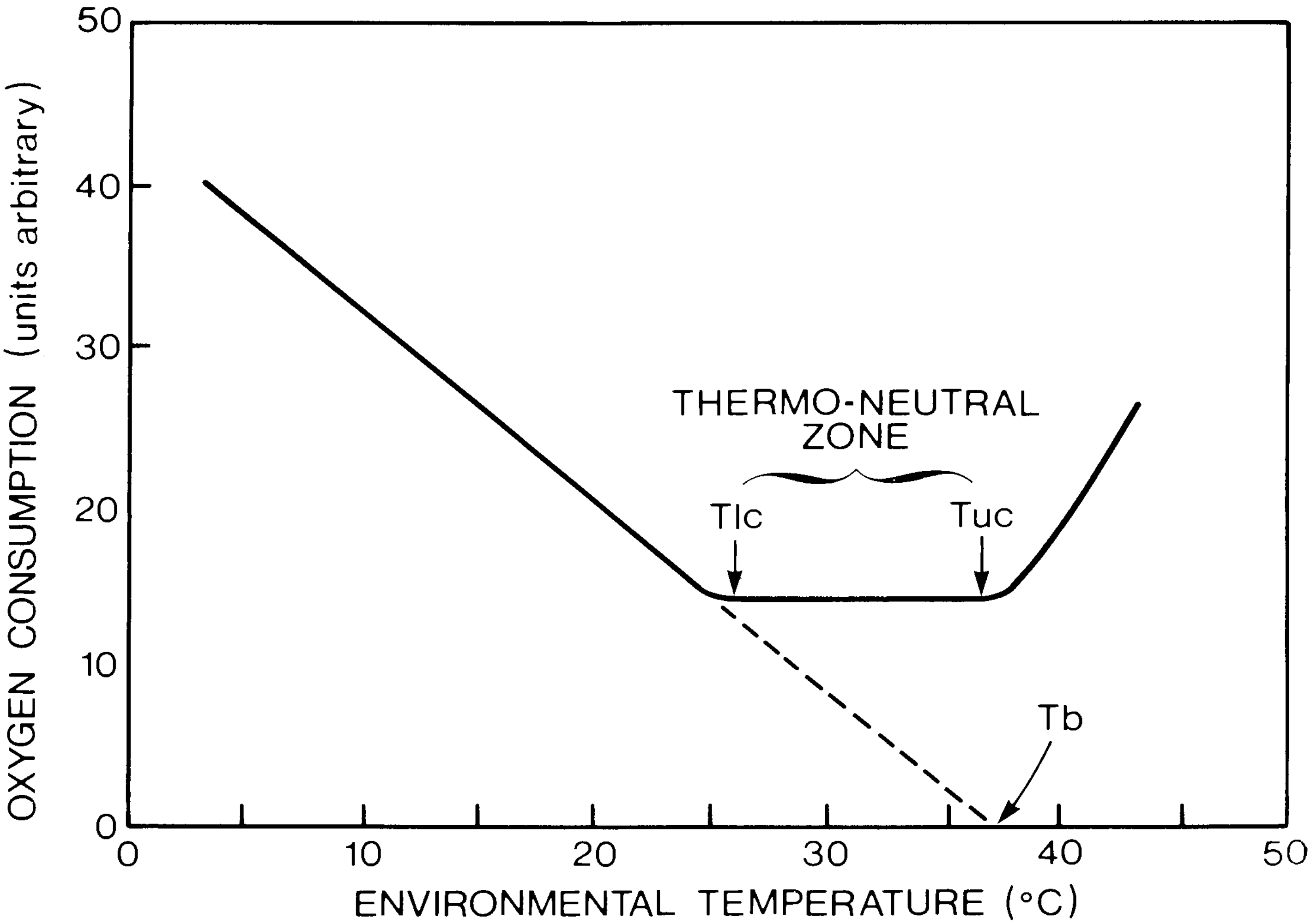

Fig. 1 Relation of oxygen consumption to environmental temperature in a hypothetical mammal, T_{lc} = lower critical temperature. T_{uc} = upper critical temperature, T_b = core body temperature. (Redrawn after Gordon, 1977).

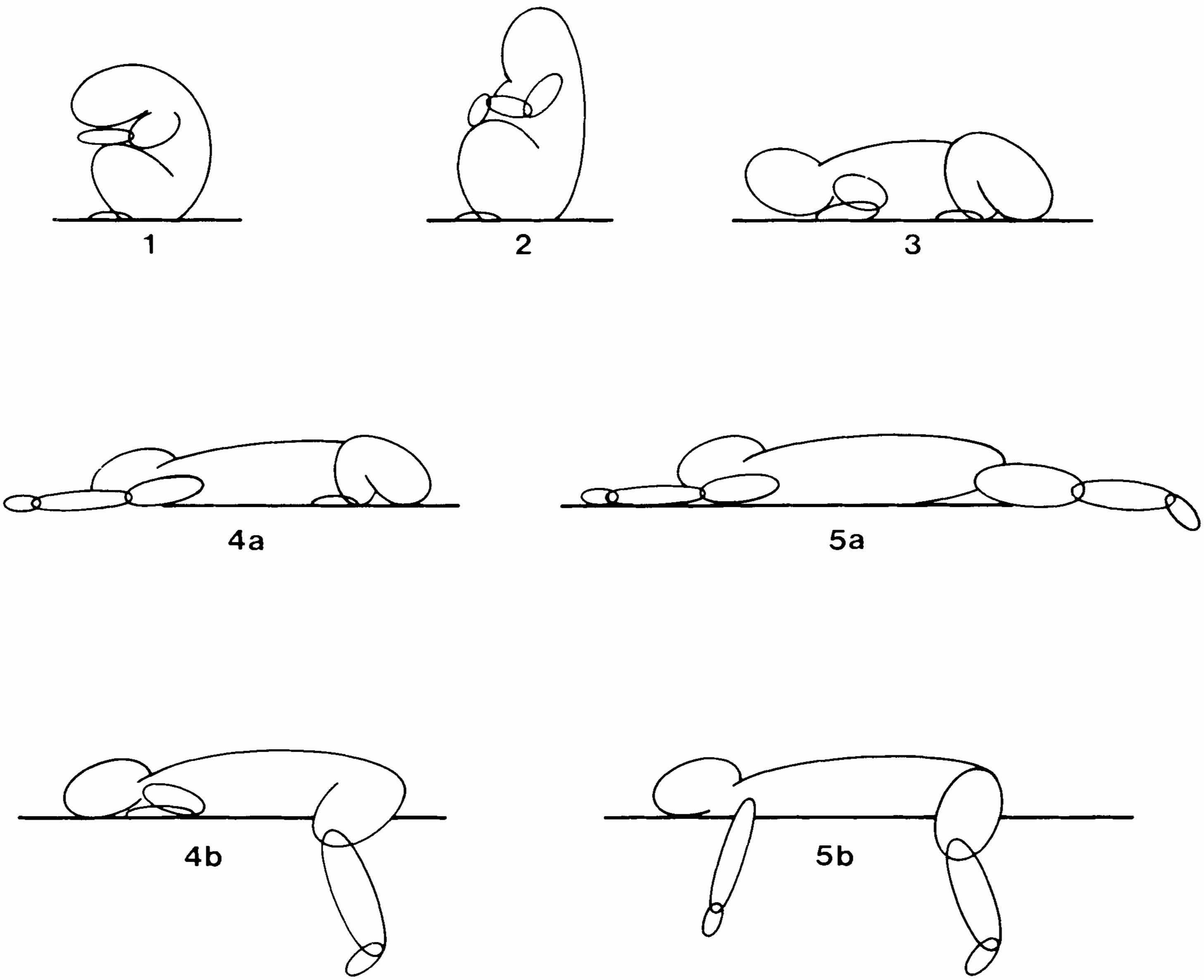

Fig. 2 Schematic approximations of resting body postures in *Alouatta palliata* representing progressive expansion of the surface to volume ratio from spherical (1) to maximum cylindrical (5a & b).

maintain body temperature, can only be excreted via the same three routes. The primate is undoubtedly able to vary the peripheral circulation patterns and through piloerection can change the insulative value of the fur, thereby enabling a degree of control over the variable called "heat flux" (measured in calories/cm^2./minute). However, the postural variations, which the primate is capable of adopting, reflect substantial changes in the exposed surface area to volume (or surface to mass) ratio.

These changes which typically range from a tightly curled "ball" to a full length sprawled "cylinder" can substantially modify radiational, convective, and conductive properties. Figure 2 represents a set of postural configurations found in howler monkeys, which represent a progressive increase in the surface area to volume ratio from posture 1 to posture 5. A degree of correlation between ambient temperature and these postures, has been found in *Alouatta palliata* (Paterson, 1980) but more precise studies are warranted.

POSITIONAL BEHAVIOUR

It is in the area of positional behaviour, related to thermoregulation, that the most frequent *en passant* comments have been made. In several studies, "sunning" is reported as a component of the species behaviour repertoire but quantitative data and correlations are not presented (Jolly, 1966; Sussman, 1974; Richard, 1974). Certainly the exposure to the sun of certain areas of the body — notably the ventral surface with its low insulative value — is an effective mechanism for picking up free heat energy, but it is not the only positional activity which can be associated with thermoregulatory functions. Totally unrecognized by primate researchers has been the relative preponderance of actions which limit the in and out flow of thermal energy. The most important of these are: the minimization of exposed surface through turning only the heavily insulated dorsal region to the sun and erection of the pelage to maximize insulation; and the movement into shade, in fact it can be suggested, with the expectation of future experimental testing, that one of the coolest areas of a forest may be the region directly below the leaf canopy in monolayer trees.

A further factor which has been totally neglected is the air flow velocity, otherwise known as wind, which has a marked influence upon convective heat flow. This factor has only been qualitatively noted in research on the Koala (*Phascolarctos cinereus*) by Degabriele and Dawson (1979; Degabriele, 1980). A primate would similarly be able to modulate its heat flux effectively by adopting positions in and out of wind flows; that is, positioning at exposed sites in the leaf canopy or behind dense vegetational structures. This could be further enhanced through the same variations in posture previously mentioned (Degabriele, 1980).

Another neglected factor in examining the positional/postural behaviour matrix is the relative influence of the substrate. Trees are essentially ectothermic, with the exception of the cooling effect derived from evaporative transpiration. Casual observations indicate that as a result trees are somewhat cooler than ambient air temperature, and this leads to the hypothesis that primates may use trees as "heat sinks" to aid their own cooling by contacting a cooler substrate with the minimally insulated ventral surface. Such contact would, via compression, reduce the insulation factor to near zero and aid the conductive transfer of heat. Such conductive heat flow is also a significant factor in the protection and maintenance of infants, since by contacting ventro-ventrally a substantial amount of heat can be transferred from mother to infant. This type of thermal relationship was observed and commented on by Baldwin and Baldwin (1973) in *Alouatta palliata*. Personal observations on *Alouatta* indicate that the periodic short movements to new resting postures of the same type may be stimulated by the equalization of temperature between plant surface and animal ventrum leading to a search for a new "cool" position. Similar activities have been observed in infant *Macaca fuscata* at Arashiyama West where ventral contact with cooler subsurface soil was deliberately sought through manual scraping under shade plants (pers. obs.).

DISCUSSION

With this matrix of information is it possible to construct models of thermal interaction patterns, which may then be quantified and equations for thermal interchange may be constructed for specific animals and environments.

Figure 3, modified from Gordon (1977), presents an example of such a model for a

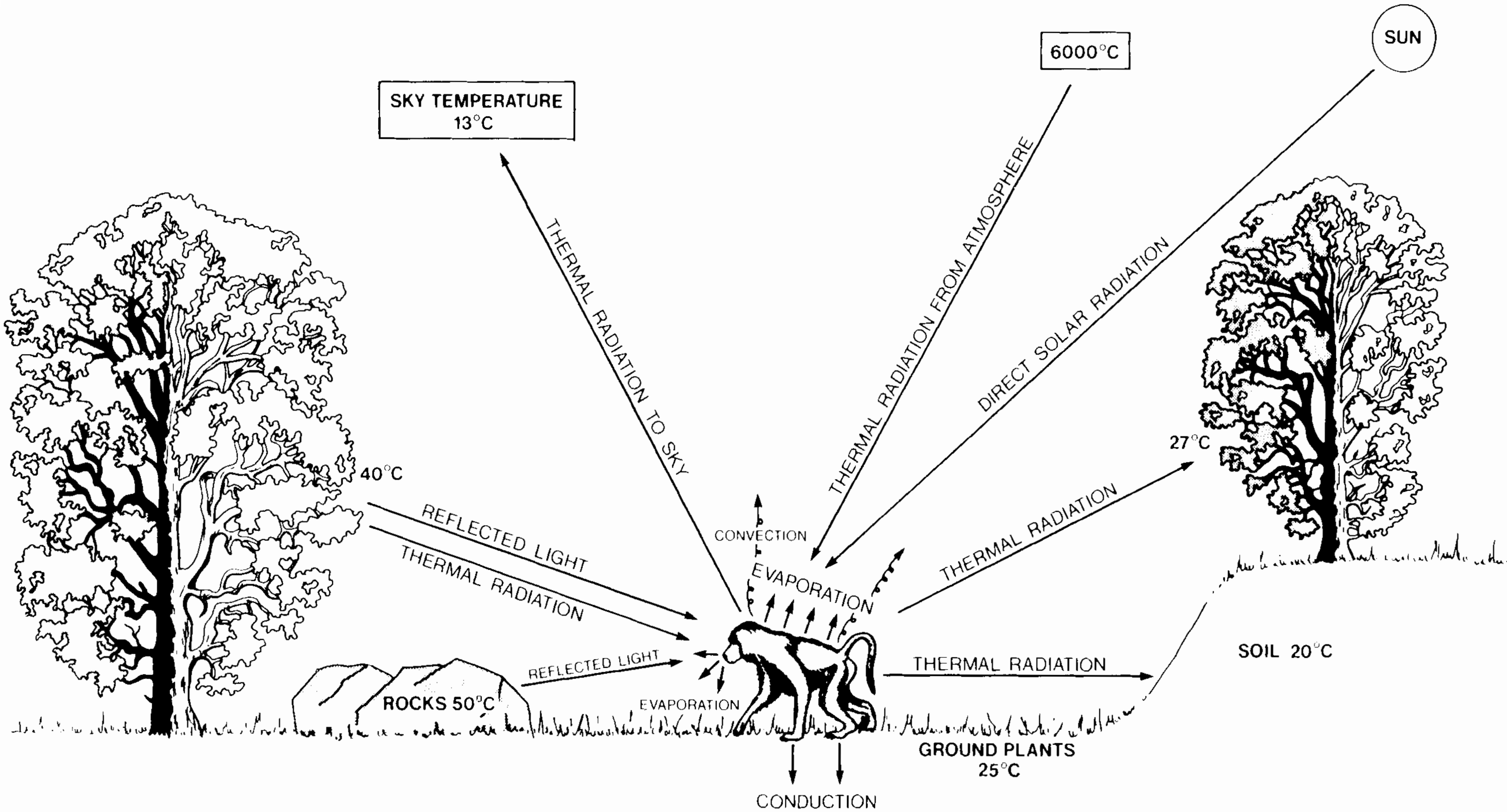

Fig. 3 An approximation model of the thermal interaction factors for a primate in an open savanna habitat. (Redrawn after Gordon, 1977).

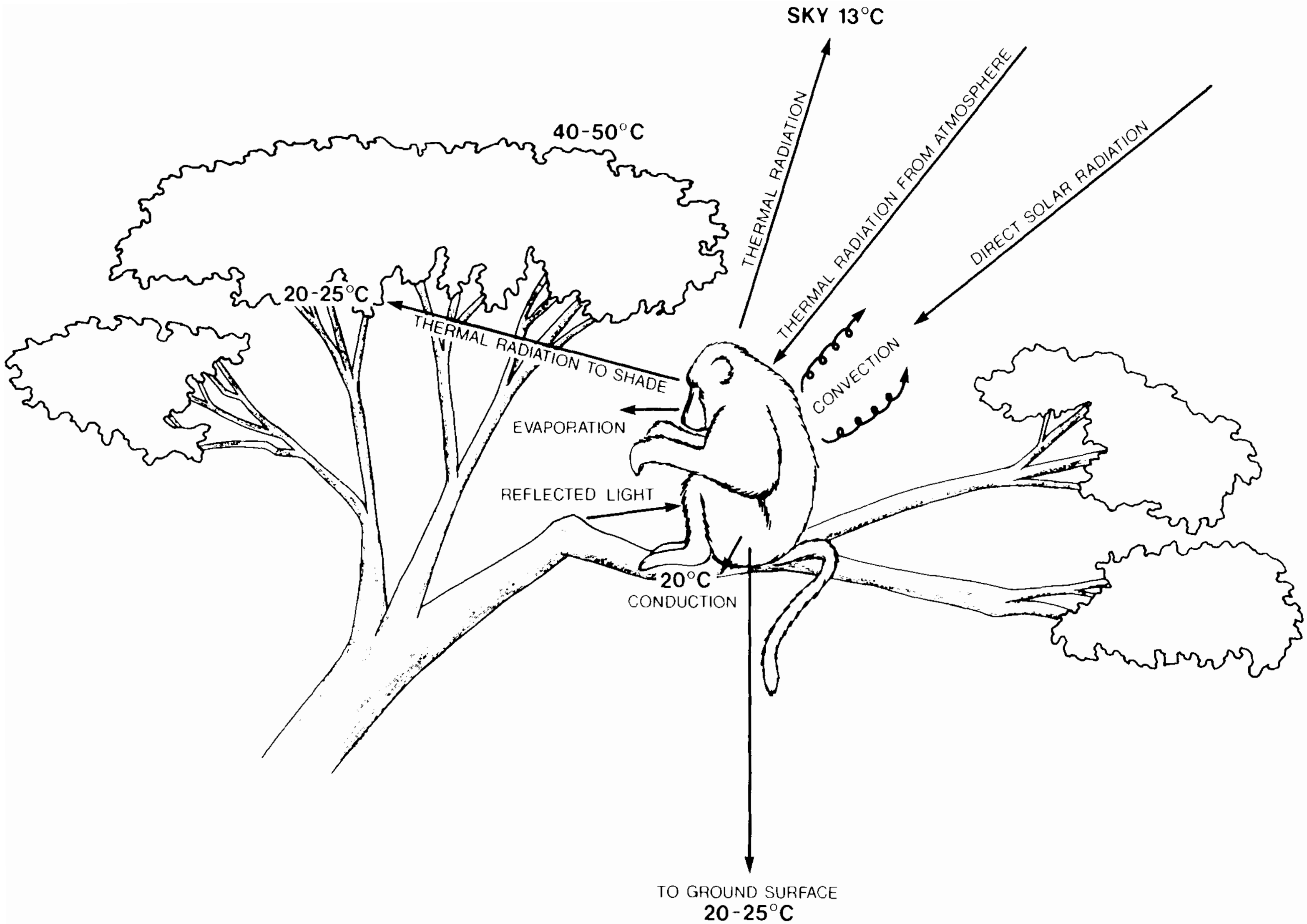

Fig. 4 An approximation model of the thermal interaction factors for a primate in an arboreal habitat.

terrestrial savanna dwelling primate. The model lists most of the thermal input and output routes which exist under such circumstances.
Figure 4 presents a model for an arboreal forest dwelling primate and it can be seen that the thermal interchange pattern may be significantly different. It might even be that for much of the year the problem for arboreal forest primates is not so much keeping cool, as it is for the terrestrial savanna forms, but instead lies in keeping warm.

What this paper has endeavoured to show is that when an animal adjusts its posture and/or position it does so for a number of reasons which may be based in physiological relationships and not solely in social or behavioural ones. This is not to say that social or behavioural prerequisites may not be involved, in many cases they may be the entire causative force, but in many others they may be only partially or un-involved. Seemingly inexplicable postural and locational movements of primates, which previously were incomprehensile or perhaps erroneously attributed to other causes may now be explained through this model. It can be said that the entire web of social, physiological, environmental, and ecological forces determine, from moment to moment, the posture and position of an individual primate.

This paper also implies that in the preparation of an overall energy budget for any primate, it is necessary to consider the thermal energy gains and losses which are promoted through the avenues of posture and position. Positional thermoregulatory patterns may also indicate significant differences in the energy budgets of primates from season to season as climatic conditions, ecological conditions and food qualities fluctuate. At the present time, these improvements in energy budget calculation are unrealized but may most easily be related to species of folivorous primates who tend to low activity — high resting regimens. It is to be hoped that when appropriate data become available frugivorous and omnivorous species may also be included.

A final point to make is that Bergmann's and Allen's rules, which have only been based upon morphological characteristics and proportions can be seen to extend into the behavioural dimension. Whether it will prove more efficient to rephrase these rules or to construct behavioural analogs is an open question awaiting the results of further research. The entire research field of primate bioenergetics is currently wide open to investigation and it is hoped that a rapid development of environmental physiology studies will take place.

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Osteoarthritis and Its Incidence and Relationships to Concave and Convex Surfaces

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KEY WORDS Osteoarthritis • G Statistic • Late Woodland

ABSTRACT The tendency for osteoarthritis to represent itself (incidence and severity) differently on concave articular surfaces VS convex ones is observed in a Late Woodland skeletal population. Statistical analyses are performed using the G statistic. The variables included in the analyses are weight bearing and non-weight bearing joints, articular surface shape and severity of osteoarthritis.

An etiologic characteristic of the disease is its rapid progression among concave surfaces relative to convex ones. It is also noted that the incidence of the disease is higher among non-weight bearing surfaces at higher severity levels. This is contrary to present day medical observations.

RESUME La tendance pour l'arthrite ostéite de se developper (en incidence et gravité) différemment sur des surfaces articulaires concaves par rapport aux surfaces convexes, a été observée chez la population squelettique du Late Woodland. Les analyses statistiques ont été faites en utilisant la statistique G. Les variables incluses dans l'analyse sont les articulations portantes et les articulations non-portantes, les formes des surfaces articutaires et la gravité de l'arthrite ostéite.

Une caractéristique étiologique de cette maladie, est sa rapide progression chez les surfaces concaves relativement aux surfaces convexes. Il est aussi observé que l'incidence de la maladie est davantage élevée chez les articulations non-portantes, à un degré de gravité plus élevé. Ceci va à l'encontre des observations medicales faites jusqu'à présent.

INTRODUCTION

The tendency for osteoarthritis to represent itself more (incidence and severity) on the concave portion of synovial joints as opposed to their respective convex articular surfaces was first observed by Anderson (1968). His investigations of the skeletal material excavated from the Serpent Mounds site in Ontario, Canada were in sharp contrast to the clinical literature which defines the disease in relation to the whole joint. Anderson recorded percentages of the incidence of osteoarthritis for the concave and convex portions of the joints in the upper and lower extremities which appeared to show that concave surfaces were carrying the brunt of the disease. All severity levels of osteoarthritis were included, however, and so it was not possible to evaluated the effect of severity of the disease against other variables.

The following report is an attempt to treat the relationship between osteoarthritis and articular surface shape statistically. The variables included in the analysis are articular surface shape, severity of osteoarthritis and weight bearing and non-weight bearing categories.

MATERIAL AND METHODS

The following analysis is performed on skeletal material excavated from the Robinson Site, on the east shore of Lake Nokomis, Oneida County, Wisconsin (Melbye, 1969). The skeletal remains represent a Northern Woodlands Indian population of the Late Woodland period (1000 - 1400 A.D.). A minimum number of 81 individuals are represented from 32 burials.

The same includes 550 articular surfaces of the appendicular skeleton which are summarized in Table 1. This sample represents infracranial joint surfaces which show a relatively well defined concave or convex surface shape. Joints of the upper limb are treated as non-weight bearing (NWB). Joints of the lower limb are treated as weight bearing (WB).

TABLE 1

	UPPER EXTREMITY	n	LOWER EXTREMITY	n
CONCAVE	glenoid fossa	45	acetabulum	39
	trochlear notch	41	med. condyle of tibia	34
	radial head	30	lat. condyle of tibia	24
	distal radius	30	calcanial facet of talus	25
			distal tibia	40
CONVEX	humeral head	27	femoral head	43
	trochlea of humerus	25	med. condyle of femur	37
	capitulum of humerus	40	lat. condyle of femur	45
		238	trochlea of talus	25
				312

Scoring of the surfaces was accomplished in an ordinal manner from 0 to 4 (scoring definitions from Melbye, pers. comm.). Severity scale 0 (SS0) represents the unaffected joint surface. Severity scale 1 (SS1) exhibits the first sign of osteoarthritis as it is observed in skeletal material: slight, discontinuous lipping around the articular margin. At this stage no articular surface change is evident. Severity scale 2 (SS2) exhibits continuous lipping around the articular margin and, as in SS1, no surface changes. Severity scale 3 (SS3) displays bony spurs from the margin and/or surface changes. Severity scale 4 (SS4) involves the entire gamut of osteoarthritic change in its most severe form: spurs, irregular bone growth and visible cystic and sclerotic areas on the articular surface.

Statistical analyses are performed using the Log-likelihood Ratio, or, G statistic which may be written as

$$G = 2[\sum_i \sum_j f_{ij} \ln f_{ij} - \sum_i R_i \ln R_i - \sum_j C_j \ln C_j + n \ln n]$$

where fij = individual values in the ith row and the jth column, Ri = row totals, Cj = column totals, n = the sample number under investigation and ln refers to the natural logarithm (Sokal and Rohlf, 1969).

The G statistic tests for heterogeneity is evaluated with the same degrees of freedom and statistical tables as a chi square test. It is much more sophisticated that chi square, however, in that more than 2 variables can be introduced and dealt with simultaneously. This statistic can therefore assess joint independence and interaction between several variables and can also be used when subdividing combinations of variables for discriminating treatments. Table 2 presents the data for the G analyses.

The reasons for including the SS0 category are threefold; (1) it is expected that of a given set of articular surfaces, the SS0 class is ultimately the supplier set to which all osteoarthritic surfaces take their toll; (2) analyses of the population should reflect all the material when useful; and (3) it is interesting to note what effects the SS0 class has on the results.

TABLE 2

N/WB	SHAPE	SEVERITY 0	1	2	3	4	Total
non-weight bearing (NWB)	Concave	34	40	58	11	3	146
	Convex	42	30	11	8	1	92
	Subtotal	76	70	69	19	4	238
weight bearing (WB)	Concave	60	58	40	4	0	162
	Convex	71	46	31	2	0	150
	Subtotal	131	104	71	6	0	312
SHAPE SUMMARY	Concave	94	98	98	15	3	308
	%	(31)	(32)	(32)	(5)	(1)	
	Convex	113	78	42	10	1	242
	%	(47)	(31)	(17)	(4)	(4)	
	Total	207	174	140	25	4	550

RESULTS

Table 3 presents a summary of the G analyses performed. Test 5 is significant at the .005 level which illustrates a lack of independence between the various factors. It does not follow, however, that this lack of independence is shared among the three possible pairs of variables. It becomes necessary to partition this G so that the principle relationships can be adequately explained.

TABLE 3

	HYPOTHESIS TESTED	df	G
1	Shape x Severity Independence	4	21.78**
2	N/WB x Shape Independence	1	4.90*
3	N/WB x Severity Independence	4	24.16**
4	Interaction	4	8.52 ns
5	N/WB x Shape x Severity	13	59.28**

*$p \leqslant 0.05$
**$p < 0.005$

Test 1, testing for the independence of severity and shape, is significant at the .005 level. This relationship is a very interesting one because of the complexity of the arthritic pattern. An examination of the Shape Summary in Table 2 will show that while the percentage of cases in the SS0-convex category is higher than that of the concave one this discrepancy diminishes by SS1. Clearly by SS2, however, the concave surfaces have acquired a greater proportion (14% more) of the disease.

Test 2 tests for the independence of the non-weight bearing and weight bearing categories (N/WB) and shape. A relationship is indicated but it is not possible to make an evaluation of the N/WB categories except to include severity as a third variable. If percentages are evaluated, however, NWB surfaces show the same arthritic pattern as discussed for Test 1. Weight bearing surfaces on the other hand, show but a 10% difference in favor of SS0-convex surfaces, and then only slight increases among the concave surfaces in the remaining categories.

Testing for the independence of N/WB and severity is another practical consideration. The significant result of Test 3, however, has to a greater extent been dealt with and is mirrored in the result of Test 2.

Inasmuch as Test 5 illustrates a lack of independence between the variables, Test 4 indicates that the three variables do not jointly interact with each other.

DISCUSSION

The main interests here are the relationships between articular surface shape and the incidence and severity of the disease in weight bearing and non-weight bearing surfaces. An examination of these relationships should provide valuable information regarding the etiology of the disease in Historic populations. With respect to the advance of the disease from the SS0 and SS1 levels to the SS2 level in concave surfaces, certain biomechanical factors are explanatory.

Sokoloff (1969) says that "the traditional anatomic teaching has stated that the thickness of the cartilage is related directly to the pressure in the joint, and to the incongruence of the bony cortices. In general, the cartilage of the concave, or female, members is thicker at the periphery, and of the convex, or male, ones at the center" (p. 76). Thicker cartilage will be slightly more "indentable" than thinner cartilage. It is particularly reasonable, then, that this is a protective configuration adapted to the flared articular rims common to concave surfaces. The rims have less subchondral bone to absorb mechanical stress and so are prone to trauma and degenerative effects.

Sclerotic changes in the central areas of the articular surfaces are concomitant with subchondral resorption along the outer periphery due to restricted movement. This dramatically limits the ability of the articular rim to absorb stress: much more on concave surfaces than convex ones. Subsequent pressure and the continuing degenerative effects to the joint have dramatic reparative effects. The result is hyperplasia and hypertrophy of cartilage at the articular margin and ultimate endochondral ossification.

Ultimately, due to the proliferation of cartilage and bone in the peripheral areas, increased stress is placed on them in weight bearing and joint movement. A mechanical feedback for greater repair and consequent increase in the stress and chronic trauma elicits a vicious cycle: an etiological characteristic of the disease.

> The loss of cartilage centrally and the building up of cartilage and bone peripherally produce incongruity of the joint surface which, in turn, alters both the distribution and the magnitude of the biomechanical stresses on the joint. Some areas are subjected to much more stress than normal while others are subjected to less than normal. Thus, the pathological process is self-perpetuating and a vicious cycle is established (Salter, 1970: 196-197).

The most interesting point to make concerning N/WB concave and convex surfaces concerns the severity scale distributions characteristic of non-weight bearing surfaces as opposed to weight bearing ones. Figure 1 illustrates the percentages of the incidence of the disease for SS0 - SS4 (first bar graph tiers) and for SS1 - SS4 (second bar graph tiers) in both weight bearing categories. The similarity between concave and convex surfaces at different severity scales within the weight bearing category is striking. Although first tier values for SS1 and SS2 are slightly higher in the concave surfaces, when the percentages are derived for the affected surfaces only, the second tier patterns are nearly the same. The patterns for concave and convex surfaces in the non-weight bearing category, however, are quite different.

The NWB concave pattern in Figure 1 is quite distinctive. Both first and second tier values increase from SS0 and peak at SS2 with 52% of the affected NWB concave surfaces. This contrasts with the peak of 39% in the WB concave surfaces. Incidence of the disease falls sharply at SS3 and SS4 levels.

The NWB convex tier patterns show similarities to the WB patterns at SS0 and SS1 but differ at SS2. Non-weight bearing convex surfaces carry far less of the disease at SS2 than their WB counterparts (even though NWB surfaces as a whole carry a greater proportion). Conversely, SS3 incidence is much higher than among WB surfaces but is close to that of NWB concave surfaces.

All the evidence considered, certain aspects of the etiology of the disease in this skeletal population can be seen. In the NWB category it is likely that osteoarthritic changes occur **first** on concave surfaces in respect to their associated convex surfaces. Evidently, progression of the disease proceeds to SS2 more rapidly than in NWB convex surfaces as shown by the high percentage of SS2 NWB concave incidence. Severity scale 0 and SS1 are accordingly reduced below the NWB convex values.

Among convex surfaces in the NWB category, the progression of the disease proceeds more slowly. The greatest percentages of affected

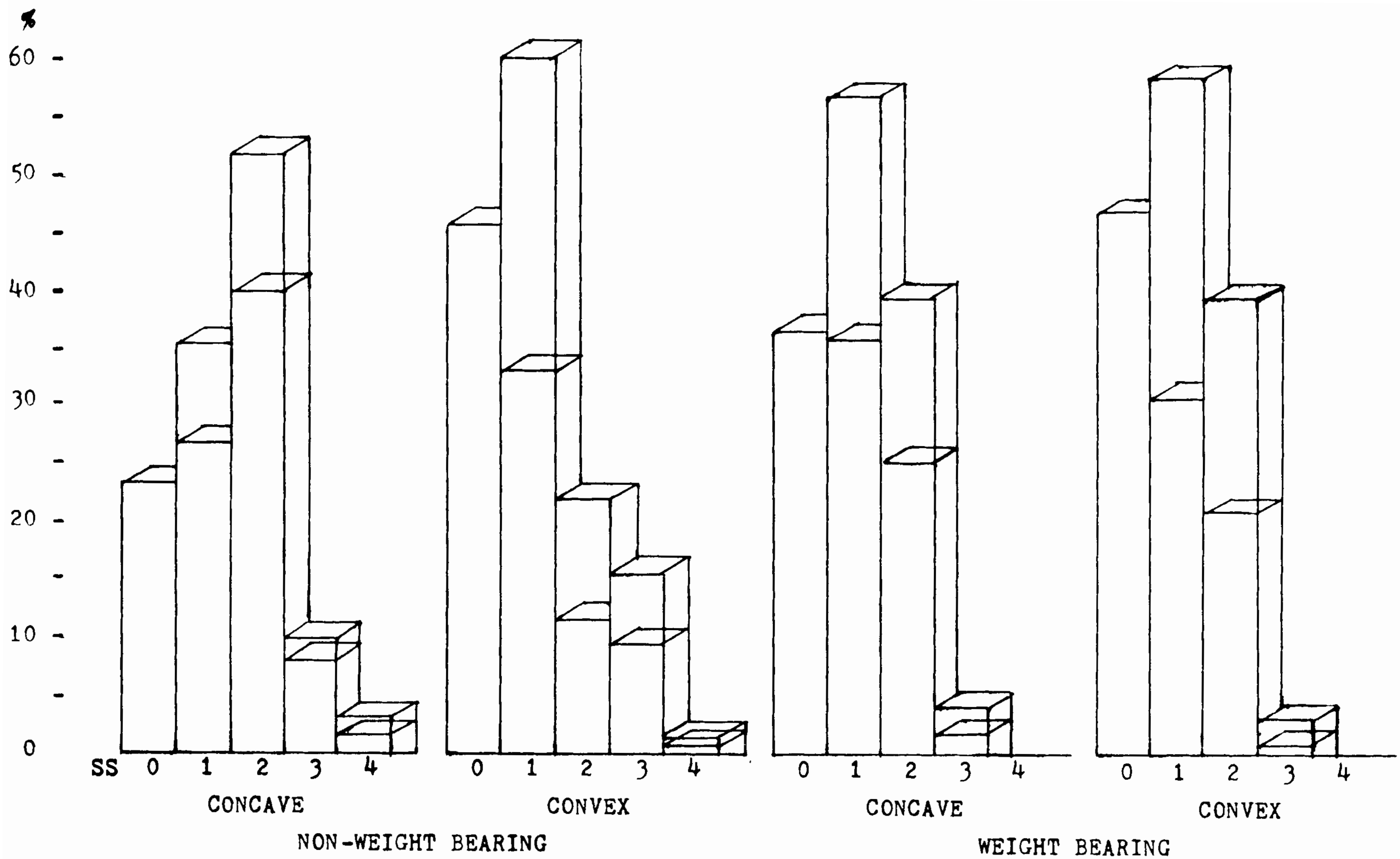

Fig. 1 Percentages of the incidence of osteoarthritis for concave and convex surfaces at different severity levels utilizing SS0 - SS4 (first tier level) and SS1 - SS4 (second tier level) data.

articular surfaces are at the SS0 and SS1 levels. Thus, in respect to their NWB surfaces, most individuals are dying when their convex surfaces are at the SS0 and SS1 levels and their concave surfaces have already reached SS2. A small percentage of individuals of either relatively great age or high susceptibility to the disease reach SS3 and SS4 as well.

The bar graphs for concave and convex WB surfaces are nearly the same indicating similar etiologies. Some minor differences do exist, however, at the first tier level (SS0 - SS4 data). Among concave surfaces, progression of the disease is proceeding more quickly through SS1 into SS2 as opposed to convex surfaces. This is similar to the NWB pattern. The disease cuts off sharply at SS3 with very few affected surfaces and none for the SS4 level.

An explanation of this pattern may relate to the general movement pattern characteristic of most diarthrodial joints. Most concave surfaces are relatively stationary compared to the convex portion operating within it. Under most normal joint movement the convex surface moves in such a way as to allow greater involvement of the articular cartilage in **actual** articulation. This would tend to distribute stress over a wide area per unit time. The concave surface, on the other hand, maintains nearly the same articular contact. Therefore, more stress per unit area is being imposed. The suggestion from this is that greater stress speeds up the deterioration of the concave surfaces already affected by age changes characteristic of the disease.

The incidence and severity of the disease is higher on non-weight bearing surfaces at levels SS2 - SS4 which is in contradistinction to present day medical observations. For **this** skeletal population it might be suggested that this is the result of a particularly aggressive life-style in which the upper limbs were used extensively. The manufacturing of tools, the use of the arms in hunting and gathering food and other such culturally specific explanations can be invoked. Pickering (1979) has addressed this problem in a very elegant way by statistically examining the differential severity of the disease among the sexes in a Late Woodland Illinoian skeletal population. The developmental pattern of the disease among certain joints in the upper limb between the sexes is considered to be possibly due to different subsistence activities. (See also Martin, et al., 1979, who emphasize a population approach when studying the impact of osteoarthritis among different cultural traditions).

CONCLUSION

The observation that the incidence and severity of osteoarthritis represents itself more on concave surfaces is an oversimplification. In very general terms the convex portions of the joint surfaces studied here exceeded those of the concave portions in incidence for the SS0 and SS1 levels. Concave surfaces tended to be represented more at the SS2 - SS4 levels. This fact suggests that concave surfaces are affected by degenerative changes in the articular cartilage first which then leads to further pathology of the joint surfaces. Concave surfaces appear to progress more swiftly to SS2 and higher severity levels due to their morphology, particularly around the articular margin.

Continued research into the phenomena outlined here should include the age, sex, and siding of the bones (e.g., Pickering, 1979), none of which were available for this study. Cross-populational studies of this type could also be useful. An understanding of the disease as well as a better understanding of early populations is possible given the references to demographic and cultural information.

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The Magnitude and Consequences of Measurement Error in Human Craniometry[1]

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KEY WORDS Measurement Error • Craniometry • Penrose Distance • Iroquois

ABSTRACT An intra- and inter-observer measurement error study on a sample of human crania revealed information on the patterning and consequences of systematic and random imprecision in craniometry. While further studies are needed to establish a universal list of error-prone measurements, the results of this study suggest that certain measurements are **generally** difficult to replicate. Material sources of this difficulty are discussed, as well as the effect of differential technical experience on the magnitude of error. The univariate and bivariate analyses identified one palatal measurement, two orbital measurements, two cranial vault curvature fractions, a measure of lower facial flatness and an upper facial height measurement as the overall "worst" measurements, in the inter-observer analysis. The consequences of measurement error were explored by applying different subsets of traits (according to measurement error considerations) to Penrose distance computations. These results are quite sobering, and indicate that one must give careful consideration to the distortion potential of measurement imprecision when interpreting biometric distance results. Specific recommendations are itemized.

RESUME Un étude d'erreur de mesure inter- et intra-observateur sur un échantillon de crânes humains a révélé des informations sur les régularités et conséquences des imprécisions systématique et fait au hasard en craniométrie. Tandis que d'autres études sont nécessaires pour établir une liste universelle de mesures prédisposées d'erreur, les résultats de cette étude suggèrent que certaines mesures sont **en générale** difficile à reproduire. Les sources matériels de cette difficulté sont discutées, en même que l'effet d'expérience technique différentiel sur la grandeur d'erreur. Les analyses univariés et bivariés ont identifié une mesure palatale, deux mesures orbitaires, deux fractions de courboture de crâne, une mesure d'aplotissement facial inférieur et une mesure de longueur supérieure faciale comme les "pires" mesures dans l'analyse inter-observateur. Les conséquences d'erreur de mesure ont été explorées en appliquant des sous-ensembles différents (en accord avec les considérations d'erreur de mesure) à les distances Penrose. Ces résultats sont très alarmants et servent comme leçon pour qu'ils considèrent soigneusement le potentiel de distortion d'imprécision en mesure quand ils interprètent des résultats de distance biométrique. Des recommandations spécifiques sur ce dernier sont détaillées.

INTRODUCTION

There are multiple sources of potential error in human osteological studies (Zegura, 1971; Howells, 1973). First, there is the serious problem of potential sampling error. To reduce its magnitude, the osteologist must give careful consideration to whether a particular skeletal series is a reasonably meaningful unit to employ in a population biology inquiry. If the skeletal series is too heterogeneous in time and/or space provenance, population analysis may be inappropriate (Cadien, Harris, Jones and Mandarino,

[1]A version of this paper was presented at the 6th annual meeting of the Canadian Association for Physical Anthropology, Niagara-on-the-Lake, Ontario, 1978.

1976; cf. Lane, 1977). Errors in estimating the age and sex composition of the series are also distorting, especially when applying these data to paleodemographic analyses. Another source of error concerns the preservation of specimens. This is a nagging problem in this era of widespread multivariate statistical analysis, for these procedures normally require complete data sets on each specimen. As this situation is rarely encountered, the necessity of estimating missing values (by direct or mathematical means) injects an unknown quantity of error into our studies. Other sources of error include the mistakes one invariably makes in the recording and transcription of data. These errors, stemming from the misreading of instruments, recording mistakes and keypunching blunders are relatively common (Zegura, 1971; Howells, 1973) yet are actually the least troublesome, if the data base is conscientiously verified, screened and edited. Computer programmes that assist in the detection of these kinds of errors are now widely available (e.g. Churchill and Truett, 1957; Dixon, Brown, Engleman, Frane and Jennrich, 1979: 112-116, 146-154, 185-198, 855, 861).

Another potential source of error is the application of inappropriate statistics in data analysis. A kindred problem is computer error resulting from statistical programmes which have not been entirely debugged (Corruccini, 1978). The last important source of error is measurement error, sometimes referred to as "measurement imprecision", "personal error", "personal equation", or "observer error". The assessment of its magnitude, and the determination of its consequences in classifying the biometric relationships of skeletal groups, are the concerns of this paper.

The present study is based on a multiple-investigator and multiple-run study of 25 virtually intact Ontario Iroquoian crania. The study has little to say about measuring accuracy, i.e. the determination of the closeness of measured values to true values. The values that osteologists derive from the metrical assessments of continuous traits are but estimates of true values. It is difficult to know what constitute true values for traits quantified with calipers and other instruments. It **is** feasible to be consistent, i.e. to be able to reproduce values, within acceptable limits, when repeated measurements are done on identical specimens (Bowles, 1976). The desirability of measurement precision is self-evident, for if what we do in quantitative anthropological studies qualifies as observational science, then it is necessary that we be able to reproduce our basic data. Without such reproducibility, higher level analytic results and consequent interpretations must surely suffer in proportion to the magnitude of error.

I have chosen to investigate measurement error in craniometry in a number of ways. First, it is assessed at both the intra- and inter-observer levels. Also, it is determined whether the imprecision is of a systematic or random nature. Systematic errors, in this study, are those which occur when there is a consistent bias in the direction in which values of identical measurements differ, when taken on different occasions. In cases such as this, the calculated mean values will be affected more than calculated measures of dispersion. In contrast, when measurement error is of a randomly fluctuating nature, sample means are much less affected. Indeed, high levels of random imprecision can be consistent with obtaining identical mean values for separate runs.

After assessing the magnitude of random and systematic error through univariate and bivariate statistical procedures, the consequences of introducing measurement error into Penrose distance computations are examined. Based on the results of these analyses, several recommendations are offered.

PREVIOUS STUDIES

There have been relatively few systematic measurement error studies in the general field of anthropometry, considering the long tradition of mensuration in physical anthropology. Previous studies on the precision of anthropometric measures on living adults include those by Lincoln (1930), Davenport, Steggerda and Drager (1935), Steggerda (1942), Gavan (1950), Gaito and Gifford (1958), Spielman, DaRocha, Weitkamp, Ward, Neel and Chagnon (1972), and Jamison and Zegura (1974). Of these, the latter two are the most critical as the authors partitioned the sources of external variation (intra- and/or inter-anthropometrist) and evaluated it relative to the natural (so-called "error") variation among the subjects. Additionally, Jamison and Zegura (1974) discriminated random from systematic error.

Kindred measurement error studies include those by Meredith (1936), Marshall (1937), Kemper and Pieters (1974), and Martorell, Habicht, Yarbrough, Guzman and Klein (1975) on the anthropometry of children. Bjork (1947) and Solow (1966) have assessed measurement imprecision in cephalometric (mostly taken from radiographs) studies. Other useful studies include Tanner and Weiner's (1949) reliability testing of photogrammetric anthropometry, Steegman's (1970) error testing of facial contourometer readings and Townsend's (1976) study and literature review of precision and dental mensuration.

Within the more comparable realm of human osteology published measurement error studies approach rarity. While perhaps most investigations in the field have (and continue to) run casual checks on the reproducibility of their data, few have bothered to publish their findings except, at best, in passing. Stewart (1939, 1941, 1942) has been an exception to this practice, although these studies were restricted to univariate comparisons of the arithmetic differences in sample mean values from one observer/observation run to another. Recently, more critical studies have been published by Page (1976), Haugen (1977) and Molto (1979). The latter is a very thorough analysis of intra-observer error in scoring discontinuous characters of the human cranium. The Page and Haugen studies concern reproducibility of continuous cranial traits.

Given the enthusiasm which human osteologists have for addressing problems of biological distance among skeletal groups, this casual concern for measurement error is unfortunate. Spielman et al. (1972), Jamison and Zegura (1974) and Molto (1979) have all found that measurement error can be of sufficient magnitude to distort inter-group biological distances appreciably. The authors of the former two studies have emphasized that when a comparative study employs data from several different workers, the metrical differences among the study samples should be evaluated **relative to** the determined measurement error. Neel, Schull, Yanamoto, Uchida, Yanese and Fujiki (1970) have stressed that the proper analysis of small differences among groups (as in micro-evolutionary studies of intra-regional populations) requires an awareness of the precision error particular to the measurements done on the study populations. Yet in spite of this chorus of warnings, few researchers in our field appear concerned with the (admittedly tedious) problem of measurement error control.

While Page (1976) has studied method error in a mostly non-traditional, three-dimensional coordinate approach to craniometry, only Haugen (1977), to my knowledge, has reported on a study at all comparable to the present one. The present paper differs from Haugen's in the following respects: (1) Haugen investigated primarily the measurements of the facial skeleton, while the entire cranium is considered in this paper. (2) Haugen used a single omnibus measure of imprecision, the "method error coefficient", while the current paper employs two complementary statistics (after Jamison and Zegura, 1974) that allow discrimination between random and systematic error. (3) Haugen's use of "corrective third time" measurements, in cases where there was in excess of one mm. difference between duplicated measurements, obviated his need to assess the significance of differences among measurement runs. The present study does the latter and ranks the craniometric variables according to the measures of their reproducibility. (4) Haugen's study was restricted to the intra-observer level. (5) Haugen was not concerned with the problem of the consequences of measurement imprecision on biometric distance determinations.

MATERIALS AND METHODS

Materials

The crania used in this investigation were sampled from the Kleinburg Ossuary site (A1Gv-1), which is located one mile east of the village of Kleinburg, Ontario. Trade goods suggest a date of A.D. 1585-1615 (F.J. Melbye, personal communication) for the site. The people interred there are assigned to the Late Ontario Iroquois Tradition and represent a proto-historic, south-central Ontario Iroquois population, (J.E. Molto, personal communication) which could be either Huron or Neutral. Twenty-five of the most complete crania of both sexes (11 estimated males and 14 estimated females) were measured independently by the author ("GMH"), a professional colleague (F.J. Melbye: "FJM"), and an advanced undergraduate student (Toni Grossi: "TG").

Measurements and Specific Techniques

The measurements taken comprise most of the University of Toronto, Physical Anthropology Laboratory's recommended craniometric battery (see Appendix A). Two investigators (GMH and TG) triplicated all measurements on the crania. Observation run numbers one through three are indicated by subscripts, e.g. GMH_1, GMH_2, GMH_3. The generation of two sets of triplicated values allowed for separate assessment of intra-observer measurement precision. At the beginning of the study, GMH was a moderately-experienced craniometrist, while TG was a virtual neophyte. The third, FJM, is an experienced professional; he contributed one set of measurements of the study crania. His contribution permitted exploration of the effect of experience on inter-observer error. The data from FJM were produced in 1973, while GMH and TG measured the crania during the summer of 1978. It should be noted that (with three exceptions[2]) while all craniometrists adhered to the same measurement definitions, and used identical instruments, there was no personalized tutoring of specific measuring procedures. This is, FJM did not tutor GMH nor TG, and GMH did not tutor TG prior to the data-generation phase of the study.

Five different instruments were used to produce the craniometric data: (1) a GPM 300 mm spreading caliper (#106), with rounded ends; (2) a GPM 200 mm sliding caliper, Martin type (#104); (3) a Mitutoyo 150 mm sliding caliper with inside blades; (4) a GPM 222 mm standard coordinate caliper (#115); and (5) a Lufkin 2 meter steel tape (#146ME). The accuracy of the calipers was checked periodically with the GPM caliper checking gauge (#219).

In most cases, no estimation of values was necessary as the 25 crania studied were selected on the basis of their completeness. In cases where either landmark ambiguity or postmortem damage necessitated an estimation, the single/double/triple question mark system of Howells (1973: 34-35) was followed. All values (including estimates) were employed in the statistical analyses. If this alarms the reader, it should be emphasized that out of 950 measurements taken during each observer run, fewer than 6% of the values were estimated, and most of these were the single question mark variety, indicating mere vagueness in landmark location, as opposed to more problematic estimation due to serious bone damage.

All 38 craniometric determinations are direct measurements; none are computed values or indices. Appendix A presents a listing of the measurements and their short names (used in the text).

Univariate and Bivariate Statistical Methods

The data were analyzed for measurement imprecision by using simple, randomized one-way analysis of variance (ANOVA) and Pearson product-moment correlation coefficients. Basic summary statistics were generated to describe the central tendencies, dispersions and normality of the distributions for each measurement run. These summary statistics were: mean, standard deviation, variance, coefficient of variation, standard error of the mean, kurtosis and skewness. Raw data and a full listing of the summary statistics are not included in this report, but can be provided by the author, on request. Appendix B presents mean and standard deviation data for five observation runs.

To insure that parametric statistical test assumptions were not violated, several precautions were taken. Normality of value distributions was assessed by scrutinizing the coefficients of skewness and kurtosis. While sample size (N = 25) may cause some to question the choice of these coefficients to measure non-normality, a revisionist article by Shapiro, Wilk and Chen (1968) reported that moderate non-normality can be detected, by various procedures, in sample sizes as small as 20. Further, these authors found that skewness and kurtosis, considered jointly, are second only to the W statistic in sensitivity to distribution asymmetry. In the two cases where it was judged necessary[3] to correct for non-

[2]FJM did not take OBH, OBB and PAB with inside calliper blades as did GMH and TG. Also, FJM used endobasion, and GMH and TG basion, for the BPL and BNL measurements (see Howells, 1973:166).

[3]Only two variates, FMB and ZMS, had more than two of their seven measurement runs showing significant non-normality at the 5% level. Only in these two cases were raw values transformed for the computation of F values. While arbitrary, it was felt that this procedure teased apart non-normality as a function of measurement imprecision vs. being a natural property of a distribution. Indeed, it was found that, of the 265 distributions, 41 were significantly non-normal, and 59% (24) of these non-normal distributions were contributed by the more error-prone neophyte (TG), who contributed only 3/7 (43%) of the data base.

normality, the raw values were transformed into common logarithms, since these distributions were skewed right (Sokal and Rohlf, 1969), and the ANOVA F values were recomputed. In neither case were interpretations affected by the transformations, i.e. significance values for the F ratios were essentially unchanged.

In cases where inter-run variances were obviously disparate, Bartlett's test for homogeneity of variances was employed (Sokal and Rohlf, 1969). In 11 cases where variance heterogeneity at or below the 5% probability level was encountered, the "approximate test of equality of means" (Sokal and Rohlf, 1969) was run in addition to ANOVA to determine the effect of heteroscedasticity on ANOVA F values. In no case was it found that the unequal variance was of sufficient magnitude to distort the p values of the F-ratios.

Rationale for Using ANOVA and Pearson's r for Evaluating Imprecision

ANOVA was chosen to evaluate the magnitude of directional, or systematic error, as it assesses the ratio of the variance among the different groups (observation runs) to the so-called error variance within the groups. While ANOVA literally means "analysis of variance", it should be kept in mind that the one-way model is essentially a "means test". ANOVA treats data in such a way that the inter-group differences in the central tendencies of the value distributions affect the ANOVA results (F values) much more than the (inherent) variation within each group. Thus, if a high F value is computed for two groups, this invariably indicates that there is a marked difference in mean values between the two groups. This kind of difference is the outcome of **systematic** measurement imprecision, e.g. one observer consistently producing larger values for a given trait, on identical crania.

Pearson's r, in contrast, was used to examine "the relationships among the measurement values themselves" (Jamison and Zegura, 1974:200). This statistic provides information on the magnitude of **random** measurement error **when** the r's are examined **with** the ANOVA F-ratios.

> . . . A high positive correlation between the results of two investigators who measured the same group of subjects could mean either that they obtained essentially the same results or that the values covaried in a systematic fashion (Jamison and Zegura, 1974:200).

In the latter case, **both** the r and F values would be high. If the r was high and the F low, one would know that essentially the same results were obtained in the observation runs. A low r and low F would indicate that the measurement values varied substantially, yet randomly in such a manner that there was a "cancelling out" effect. When an F value is high and the corresponding r is low, the imprecision is of a random nature, but the magnitude of the differences in one direction greatly exceeds those in the other direction, allowing for large differences in mean values between groups.

The total picture of measurement error could not be grasped through the use of only one of these statistics. Studies that employ statistics which measure the magnitude but not the directionality (or vice-versa) of between-observer differences, are deficient in their information content. While I do not disagree with Spielman et al. (1972) and Molto (1979) that random error has less serious consequences than systematic error in human taxonomic studies, it is my conviction that efforts to control for random error can be worthwhile. Such efforts may only be indicated when one is using multivariate procedures which are based on variance-covariance (or correlation) matrices. While empirical testing of this contention awaits, it seems intuitively reasonable that substantial random error could distort such dispersion matrices to the point of adversely affecting multivariate test results, e.g. Mahalanobis D^2.

Distance Analyses

Penrose (1954) distance statistics were generated to examine the effects of measurement imprecision on higher-order, among-group phenetics (both when the "groups" are identical sets of crania and when the Kleinburg crania are compared to other cranial series). It has been repeatedly demonstrated (e.g. Penrose, 1954; Hiernaux, 1964; Jantz, 1972) that the Penrose mean square distance (C^2_H) and its modification, the generalized distance analog (C^2_R or D^2_p), correlate highly with the statistically more elegant generalized distance (D^2) of Mahalanobis (1936). In should be noted, however, that such high correlations are dependent upon inter-trait correlations being approximately equal and of the same direction (all positive or all negative) (Knuszmann in Van Vark, 1970). As the Penrose statistic makes fewer assumptions about trait distributions and inter-trait covariation, it may sometimes be preferable, in anthropological applications, to D^2. Rightmire (1969), Van Vark (1970) and Albrecht (1980), among others, present contrary opinions on this matter.

The Penrose distances were computed according to Rahman (1962).[4] The advantage of using the Rahman extension is that the magnitude of the between-group distances can be assessed through tests of significance. By weighting the size, shape, and generalized distance analog (D^2_p: i.e., the Penrose approximation of the Mahalanobis D^2) coefficients times $\frac{n_1 n_2}{n_1 + n_2}$, values are obtained that are approximately distributed as χ^2. The chi-square values of the Size and Shape components of D^2_p are distributed with 1 and p-1 degrees of freedom, respectively, where p is the number of variables used.[5]

Criticisms have been raised (Rohlf and Sokal, 1965; Lestrel, 1976; Constandse-Westermann, 1972) concerning the morphological meaning of the Penrose Size and Shape distances. Some writers seem to assume strict morphological equivalence of the two coefficients (Hughes, 1969; Watson, Freedman, Lockett and MacIntosh, 1977). This is valid enough in the first case, for the Size distance depends on the sum of the d values (differences between transformed means for each pair of populations, retaining positive and negative signs). Shape distances, on the other hand, measure the **variances** of the d values (Bass, Evans and Jantz, 1971). That is, they are measures of the extent to which the d values vary among themselves, within the context of each paired group comparison. Shape distances may not always be interpretable in morphological terms. Commonly however, Shape coefficients **can** be cautiously interpreted in morphological terms, for in effect, Shape distances assess the degree to which there is a between group difference in the respective within-group patternings of mean inter-trait proportionality (Heathcote, 1980).

The Penrose Shape distance is increasingly regarded (Okada and Yamaguchi, 1975, 1976; Watson et al., 1977; Yamaguchi, 1977; Szathmary, 1979) as a preferred distance to use in human taxonomic studies. This conviction is influenced by Corruccini's (1973) demonstration that inter-group Penrose Shape distances are in better agreement with known phylogenetic relationships than are size-related (including generalized) distance coefficients. While Corruccini's study concerned diverse hominoid genera and species, a recent study by Bräuer (1979) guardedly suggests a taxonomic superiority of the Penrose Shape distance in intra- and inter-regional studies of modern human populations.

Computations

Univariate statistical parameters were mostly computed on programmable calculators, using verified programmes written by Patterson (1979a, 1979b). The Pearson r coefficients were computed at the Erindale College Computing Centre using an interactive APL package. Penrose distances were computed on a programmable calculator, using two complementary programmes (Patterson, 1979, n.d.a.). Supporting statistics, namely Bartlett's test and the approximate test for the equality of means with unequal variance were also performed on programmable calculators (Patterson, 1978b, 1978a). Transformations of raw metrical values into common logarithms were done using a keyboard function of the Texas Instruments TI-59 calculator. In cases where distributions appeared non-normal, preliminary data screening was done with calculator programmes that ordered the data (Patterson, n.d.b.) for subsequent generation of histograms (Swinnen, 1977). Spot verifications of the analytic results were done through hand calculation, often following the step-by-step procedures of Bruning and Kintz (1977).

RESULTS AND DISCUSSIONS

I. MAGNITUDE OF MEASUREMENT ERROR

F-tests

It is immediately apparent, in Table 1, that there is little consistency of ANOVA results at the different levels of comparison. In the left-most column of Table 1 are the F values for the intra-GMH analysis. The values are ranked from

[4]I followed Penrose (1954) in using an average r value of +0.23 in computing D^2_p.

[5]Cole (1975:92) is in error on this point, as she states that the Size coefficients are distributed as chi-squares with p degrees of freedom; cf. 1 d.f. (Rahman, 1962:98).

TABLE 1

Variables ranked by their F-ratios.[1]

	Intra-observer Analyses				Inter-observer Analyses					
Variable	GMH_1 vs. GMH_2 vs. GMH_3 F	Rank	TG_1 vs. TG_2 vs. TG_3 F	Rank	GMH_3 vs. FJM F	Rank	GMH_3 vs. TG_3 F	Rank	GMH_3 vs. TG_3 vs. FJM F	Rank
FRC	0.002	1	0.23	21	0.003	3	0.22	14	0.16	6½
PAS	0.003	2½	0.03	7½	0.04	6	0.01	5	0.02	1
OCC	0.003	2½	0.13	18	0.06	11	0.15	11	0.20	11½
OCS	0.005	4	0.61	32	2.05	32	0.28	16	2.10	28
FRF	0.007	5	0.12	17	0.08	14	4.55*	32	3.59*	30
ASB	0.01	6½	0.04	10	0.001	2	0.24	15	0.16	6½
BBH	0.01	6½	0.001	1	0.05	8½	0.36	18	0.18	8½
GOL	0.02	9	0.05	11½	0.37	23½	0.29	17	0.22	13
NAS	0.02	9	0.19	20	0.12	16	0.21	13	0.33	14
XCB	0.02	9	1.67	36	0.01	4	21.59*	36	14.59*	34
WFB	0.03	13	0.08	15½	0.13	17	0.001	2	0.08	4
BPL	0.03	13	0.01	4½	1.61	31	0.003	3	1.11	23
OCF	0.03	13	1.41	35	0.36	22	3.59*	30	1.90	25
JUB	0.03	13	0.002	2	0.26	20	5.10*	33	2.43	29
EKB	0.03	13	0.03	7½	0.72	27	8.05*	34½	5.59*	31
PAK	0.04	16½	0.003	3	0.05	8½	0.15	11	0.19	10
NLH	0.04	16½	0.36	26	0.000	1	1.35	27	0.97	20
FRK	0.05	18½	0.03	7½	1.17	29	0.47	20	0.59	17
AVB	0.05	18½	0.59	31	0.02	5	83.17*	38	55.51*	37
PAC	0.07	21	0.31	22	0.20	18	0.77	23	0.37	15
OCK	0.07	21	0.06	13	1.53	30	0.71	22	0.91	19
OBH	0.07	21	0.58	30	2.23	33	2.96*	29	1.71	24
FRS	0.08	23½	0.01	4½	0.05	8½	0.07	9	0.12	5
BNL	0.08	23½	0.47	28	0.24	19	0.37	19	0.18	8½
NLB	0.12	25	0.03	7½	0.10	15	0.000	1	0.07	3
ZMB	0.14	26½	0.50	29	0.37	23½	0.02	6½	0.20	11½
WNB	0.14	26½	0.05	11½	0.05	8½	0.02	6½	0.03	2
ZMS	0.18	28	0.15	19	10.84*	35	0.88	24	10.06*	33
BSL	0.21	29	0.07	14			8.05*	34½		
PAL	0.23	30	0.35	25	51.24*	37	0.15	11	29.98*	36
ZYB	0.28	31	0.33	24	0.07	12½	28.04*	37	17.98*	35
OBB	0.32	32	3.39*	37	13.91*	36	2.84*	28	6.83*	32
AVL	0.35	33½	0.32	23	0.27	21	0.91	25	1.09	22
NPH	0.35	33½	5.67*	38	3.26*	34	0.05	8	2.01	26
FMB	0.42	35	0.42	27	1.12	28	0.49	21	0.61	18
STB	0.65	36	0.75	34	0.38	25	4.18*	31	2.08	27
PAF	0.90	37	0.69	33	0.58	26	0.007	4	0.38	16
PAB	1.31	38	0.08	15½	0.07	12½	1.19	26	1.01	21
Mean	0.17		0.52		2.53		4.78		4.47	
Median	0.05		0.15		0.22		0.37		0.76	

[1]see footnote 6, in text; significant imprecision is denoted by asterisks.

CRITICAL VALUES OF F, for Ho: F = 0

Significance Level	3-group comparisons df = 2,72	2-group comparisons df = 1,48
$F_{.001}$	7.61	8.01
$F_{.01}$	4.92	7.20
$F_{.05}$	3.12	4.04
$F_{.10}$	2.37	2.82
$F_{.20}$	1.64	1.69

"best" (lowest F values) to "worst" (highest F value). Since the trait with the worst F value, PAB, fails to fall outside even the 20% significance level acceptance region (see Sokal and Rohlf, 1969:158) systematic imprecision can be considered very low among GMH's measurement runs. In contrast, the neophyte observer (TG) was systematically imprecise in repeated measurements of two of the 38 variables, at or below the 10% significance level.[6]

At the inter-observer level, significant systematic measurement imprecision between the two experienced craniometrists (GMH and FJM) is detected in four of 37 ANOVA tests, while 11 of 38 variables are found to be insufficiently reproducible between GMH and TG. This differential, related to technical experience, is also expressed in the mean and median F values (Table 1). GMH vs. TG mean and median F values are nearly twice the magnitude of the GMH vs. FJM comparison.

A simpler way of considering systematic imprecision is to examine maximum inter-run differences in mean values. In the three GMH runs, 89% of the variables had maximum inter-run differences of one millimeter or less. Only XYB, PAB, STB and PAF fell outside this boundary. TG reproduced 74% of his measurements to within one millimeter's mean difference. The figure falls to 65% and 27% in comparisons between the three GMH runs plus FJM's, and the total set of seven measurement runs (including all three craniometrists), respectively. It is most alarming to note that there are five variables (PAL, ZMS, PAF, OCK and OBB) that have maximum mean differences of two millimeters or more in comparing the three runs of GMH with the other experienced observer, FJM.

F-tests and r analysis: a joint consideration

As discussed above, a more critical univariate approach to assessing measurement error is to consider jointly the results of ANOVA and Pearson's product-moment correlation tests.[7] Table 2a presents a listing of the 38 variables, ranked in 3 ways. First, they are ranked according to the author's (after Gavan, 1950) pre-analysis impression of their ease of reproducibility, by categories. These categories (Table 2b) are defined on the basis of inherent, material factors, such as landmark ambiguity and degree of mechanical difficulty in taking each measurement. Next, their coefficients are presented and ranked. Beside the r rankings are the corresponding F-ratio rankings, for comparison. Spearman's rank order correlation tests were considered, but their results yielded no information beyond the obvious.

Table 2a reveals that there is not a strong relationship between the r and F assessments of measurement imprecision. This has been previously observed by Jamison and Zegura (1974). This is of course an expected finding, as the two analyses may often address two different kinds of imprecision. Consider the PAF variable in the GMH_3 vs. TG_3 analyses (Table 2a). The F value is 0.007 (Table 1), the 4th best, in rank. The r coefficient for this comparison is +0.52, the 5th worst, in rank. In this case, imprecision was rather extreme in a randomly fluctuating manner, yet balanced between positive and negative inter-run value differences, such that the differences cancelled each other out allowing the group means to be proximal (and F-ratios low).

An interesting observation about the r results (Table 2a) is that, once again, technical experience is seen to have a marked effect on the degree of measurement error. To illustrate, the mean correlation coefficient for GMH's intra-observer tests is +0.93. The r coefficient for GMH vs. FJM is nearly as high, at +0.90, while that for GMH vs. TG is a much lower +0.77. Comparing these results to those reported in Jamison and

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[6] I have arbitrarily, but with good reason, settled on the 10% significance level as the threshold for determining acceptable reproducibility in the ANOVA (but not the Pearson r) tests. While this may seem to be an overly stringent critical (p) value, I may well be erring in the opposite direction. Consider that when one is normally carrying out a test of significance of differences between/among groups, one is deciding whether two (or more) groups of specimens are sufficiently homogeneous as to be considered samples from a single (statistical-biological) population. In this study, our specimens are **known** to be from a single study population. Indeed our **specimens** are known to be identical. That being the case, it is surely judicious to use a more conservative significance level than the conventional 5% one (see Labovitz, 1968).

[7] The 5% significance level was selected as the threshold for determining acceptable r values. Selecting a less conservative threshold for r than F is based on two considerations: (1) as discussed above, systematic imprecision is far more distorting than random imprecision in biological distance studies. (2) It has been pointed out to me (C.J. Utermohle, personal communication) that r's are very sensitive to extreme outlying values (I have empirically confirmed this). Therefore, one can regard the r test as **inherently** more conservative than ANOVA (in the context of error analysis) and thus find reasonable justification for opting for a less conservative critical value.

TABLE 2A

Variables ranked a priori, by r and F.

		Intra-observer Analysis			Inter-observer Analyses					
	Variables by Category[1]	GMH$_2$ vs. GMH$_3$ r		F	GMH$_3$ vs. FJM r		F	GHM$_3$ vs. TG$_3$ r		F
		Coef.	Rank	Rank	Coef.	Rank	Rank	Coef.	Rank	Rank
A	BBH	.997	1½	6½	.99	3½	8½	.99	1½	18
	BNL	.98	12	23½	.97	10	19	.78	23	19
	ASB	.89	31	6½	.99	3½	2	.95	5½	15
	JUB	.97	18½	13	.84	27½	20	.78	23	33
	FRC	.99	5½	1	.99	3½	3	.87	20½	14
	FRK	.99	5½	18½	.99	3½	29	.98	3	20
	GOL	.99	5½	9	.99	3½	23½	.99	1½	17
B	XCB	.99	5½	9	.99	3½	4	.65*	32	36
	WFB	.97	18½	13	.97	10	17	.97	4	2
	ZYB	.98	12	31	.97	10	12½	.75	26½	37
	OBH	.92	27	21	.93	17½	33	.87	20½	29
	NLB	.97	18½	25	.93	17½	15	.92	10½	1
	WNB	.91	28	26½	.96	14½	8½	.92	10½	6½
C	BSL	.94	24½	29				.89	17½	34½
AVL	AVL	.93	26	33½	.92	19½	21	.78	23	25
	PAL	.68*	38	30	.82	31½	37	.54*	33	11
D	BPL	.98	12	13	.97	10	31	.89	17½	3
	NPH	.98	12	33½	.92	19½	34	.95	5½	8
	NLH	.98	12	16½	.87	26	1	.37*	36	27
	PAC	.96	22½	21	.90	23½	18	.91	13½	23
	PAK	.99	5½	16½	.91	21½	8½	.90	15½	11
	OCC	.997	1½	2½	.96	14½	11	.93	8	11
	OCK	.99	5½	21	.91	21½	30	.77	25	22
E	OBB	.86	32	32	.46*	37	36	.50*	35	28
	STB	.97	18½	36	.98	7	25	.69	30	31
	EKB	.96	22½	13	.81	33	27	.92	10½	34½
	FMB	.81	35	35	.84	27½	28	.88	19	21
	ZMB	.90	29½	26½	.82	31½	23½	.70	29	6½
	AVB	.98	12	18½	.96	14½	5	.67*	31	38
	PAB	.85	33	38	.83	29½	12½	.72	28	26
F	NAS	.90	29½	9	.90	23½	16	.92	10½	13
	ZMS	.97	18½	28	.89	25	35	.90	15½	24
G	FRS	.97	18½	23½	.96	14½	8½	.94	7	9
	PAS	.98	12	2½	.97	10	6	.91	13½	5
	OCS	.94	24½	4	.78	34	32	.75	26½	16
H	FRF	.73	36½	5	.77	35	14	.10*	37	32
	PAF	.73	36½	37	.75	36	26	.52*	34	4
	OCF	.82	34	13	.83	29½	22	-.31*	38	30
	Mean	.93			.90			.77		
	Median	.97			.92			.88		

[1]See Table 2B.

CRITICAL VALUES OF r (see footnote 7, in text), for Ho: r = 1; significant imprecision is denoted by asterisks; df = 23 for all 2-group comparisons:

$r_{.001} = .24$ $\quad$ $r_{.10} = .77$

$r_{.01} = .48$ $\quad$ $r_{.20} = .96$

$r_{.05} = .68$

TABLE 2B

A priori classification of craniometric variables, according to their seeming ease of reproducibility. In descending fashion, Categories A — H represent (estimated) increasing tendency for measurement imprecision.

Category	Variables	Remarks
A	BBH, BNL, ASB, JUB, FRC, FRK, GOL	Measurements taken either (a) from one anatomical landmark to another, or (b) where one landmark is "found" by a caliper arm and the other caliper arm is fixed at an anatomical landmark. Landmarks are normally unequivocal and there is no mechanical difficulty in taking the measurement.
B	XCB, WFB, ZYB, OBH, NLB, WNB	Both landmarks are found with the calipers. There is no mechanical difficulty in taking the measurement.
C	BSL, AVL, PAL	Same as A (a), but there is some mechanical difficulty in taking the measurement.
D	BPL, NPH, NLH, PAC, PAK, OCC, OCK	Same as A (a), but one anatomical landmark tends to be ambiguous in its location.
E	OBB, STB, EKB, FMB, ZMB, AVB, PAB	Same as A (a), but both anatomical landmarks tend to be ill-defined, due to morphological non-equivalence from one cranium to another (due to inherent variation and/or bone remodelling in response to aging and/or infection, e.g. periodontal disease).
F	NAS, ZMS	Subtenses[1] referenced to an anatomical landmark.
G	FRS, PAS, OCS	Subtenses[1] found with the central arm of a coordinate caliper.
H	FRF, PAF, OCF	Fractions[1] determined by G measurements.

[1]Subtenses, it is generally agreed, are mechanically the most difficult measurements that osteologists commonly take on crania. Especially troublesome is the task of determining the point at which the chord is subtended, i.e., the fraction.

Zegura's (1974) inter-observer study on anthropometry of the living, this study compares favourably. By pooling Jamison and Zegura's male and female data, a +0.79 (cf. the GMH vs. FJM r of +0.90) mean r value is obtained. Since Jamison and Zegura are both experienced observers, this most likely means that craniometrics are inherently less prone to random imprecision than are anthropometrics of the living. Intuitively this is expected, given the greater ambiguity in finding skeletal landmarks, when one has to palpate them through soft tissues.

There is a consistent pattern in Table 2a, in that the r rankings are in much greater agreement with pre-analysis rankings, than are the F rankings. This indicates that predictable **material** sources of error contribute more to random than to systematic measurement imprecision. Put another way, there may be a tendency for traits high in systematic imprecision to be more a product of personal idiosyncracy (or inconsistency) in specific technique, than to landmark ambiguity or mechanical difficulty.

To further aid in summarizing the univariate and bivariate results, Table 3 lists the traits found to be the least reproducible. These are traits with F coefficients falling outside the 10% and r values outside the 5% significance level acceptance regions. One intra- and two inter-observer analyses are considered. Some noteworthy observations can be made from this table:

1. Sixteen of the 38 traits in the craniometric battery appear in this listing of worst traits. Fourteen appear only once, and **all but two of these are accounted for by the inter-observer tests involving the neophyte.** One trait (OBB) appears twice, and another (PAL) appears in all three sets of tests.
2. Of the four traits found to be unacceptably error-prone in the analyses of the two experienced observers, three (PAL, OBB and

NPH) are characterized by landmark ambiguity. The remaining variable, ZMS, plus PAL (again), are measurements which are mechanically difficult to take.

3. All three fraction measurements in the battery appear in Table 3 as expected.
4. Of the 10 linear landmark-to-landmark measurements where either both landmarks tend to be ambiguous (Category E traits; see Table 2b), or the measurements are mechanically difficult to take (Category C), six are listed in Table 3. This total includes two of the four palatal/alveolar measurements (PAL and AVB). Imprecision here is influenced by bone remodelling in response to premortem tooth loss and periodontal disease.
5. Somewhat surprisingly, only one of the five subtenses (ZMS) in the battery (Categories F & G) proved to be substantially difficult to reproduce.
6. Of the six linear measurements where both landmarks are found with the calipers (Category B), only two (XCB and ZYB) were shown to be unacceptably imprecise.

What Table 3 does not resolve is whether the variables judged to be measurement error prone in one set of inter-observer analyses are to be considered generally noisy, or merely a function of idiosyncratic shortcomings particular to the two observers under comparison. A way of addressing this problem is to scrutinize the exact probabilities of the r and F coefficients in each paired-observer comparison. For example, of the 12 traits which appeared only in the GMH vs. TG "least reproducible" list, one can inquire into the number which were inside the 5% and 10% (for F and r, respectively) acceptance regions but outside **more conservative** 10% and 20% acceptance regions in the GMH vs. FJM tests. Of those 12 traits, only three were thus found to be unacceptably imprecise using the more conservative criteria: OBH, PAF and FRF. This means that TG, the neophyte, was idiosyncratic in his imprecise measuring of the following nine variates: STB, JUB, BSL, EKB, ZYB, OCF, XCB, AVB, and NLH. This is not to suggest that these measurements might not be difficult for other craniometrists to reproduce. It would be

TABLE 3

Preliminary listing of the least reproducible craniometric traits, according to three sets of analyses[1]

	Unacceptably low r value only	Unacceptably high F value only	Both r and F values unacceptable
GMH intra-observer tests	PAL[2]	—	—
GMH_3 vs. FJM	—	NPH[3] ZMS[5] PAL[2]	OBB[4]
GMH_3 vs. TG_3	PAL[2] PAF NLH	OBH STB JUB BSL EKB ZYB	OBB[4] OCF FRF XCB AVB

[1]The traits are listed in a ranked order. From top to bottom the ranking indicates progressively serious imprecision.

[2]Staphylion is often difficult to locate, due to palatine bone damage. The other landmark, orale, is also often ambiguous, due to alveolar remodeling.

[3]Discrepancy probably due to one investigator compensating more for alveolar bone loss at prosthion.

[4]The medial landmark, dacryon, is often difficult to locate due to lacrimal bone damage. As well, the lateral landmark (ectoconchion) is rather ambiguous when the lateral margin of the orbit is indistinct.

[5]Imprecision here, must relate to the difficulty of locating subspinale, while at the same time keeping the lateral caliper blades on (sometimes rather subjective) pencil-marked landmarks.

interesting to see if other neophytes might not have similar difficulties with these particular measurements. Interestingly, the two traits (ZMS and NPH) which "failed" F tests in only the GMH vs. FJM comparisons, "passed" GMH vs. TG ANOVA and r correlation analyses, using the more conservative critical values.

On the basis of the above supplementary examination, a generalized list of least reproducible craniometric traits can be identified. This list "controls" for the neophyte factor, and thus can be viewed (with caution) as a list of traits that **may** generally be prone to measurement imprecision. It is hoped that this list will prove useful as a guide to researchers faced with the need to employ craniometric data gathered by other researchers. This **omnibus worst traits list** consists of the following seven traits, ranked in order of decreasing seriousness:

PALATAL LENGTH (PAL)
ORBITAL BREADTH (OBB)
ORBITAL HEIGHT (OBH)
FRONTAL FRACTION (FRF)
PARIETAL FRACTION (PAF)
ZYGOMAXILLARE SUBTENSE (ZMS)
NASION-PROSTHION HEIGHT (NPH)

I am less certain about the general error proneness of the last two traits, as replication of values between the author and the neophyte proved satisfactory. A caveat here is that specific technique inconsistency (footnote 2) likely inflated the determined imprecision of OBB and OBH.

II. CONSEQUENCES OF MEASUREMENT ERROR

Intra-Observer Imprecision and Distance Measures' Distortion

To illustrate the extreme sensitivity of computed Penrose distance computations to measurement error noise, the intra-observer level will be considered initially. At this level, recall that systematic imprecision (assessed by F's) was found to the minimal in intra-GMH tests, but relatively high in the intra-TG analyses. Table 4 illustrates the greater distance distortions that result from systematic (vs. random) measurement error.

Footnotes 1 and 2 to Table 4 explain the procedure for selecting batteries of worst traits for the Penrose computations. The striking point made by the Table is that TG's tendency for rather high levels of systematic imprecision

TABLE 4

Penrose distances between identical sets of crania, using the least reproducible traits determined by intra-observer ANOVA and correlation analyses

Paired Runs on Identical Crania	DISTANCES GENERATED BY BATTERIES COMPRISED OF: 6 worst traits, in terms of F-ratio[1]			6 worst traits, in terms of Pearson r's[2]		
	D^2_p =	Size +	Shape	D^2_p =	Size +	Shape
GMH_1 vs. GMH_2	0.41	0.12	0.29	0.29	0.06	0.23
GHM_1 vs. GMH_3	0.44	0.08	0.36	0.25	0.06	0.20
GMH_2 vs. GMH_3	0.07	0.003	0.07	0.08	0.000	0.08
TG_1 vs. TG_2	2.09	0.09	2.00**			
TG_1 vs. TG_3	1.48	0.05	1.42*			
TG_2 vs. TG_3	0.30	0.004	0.30			

[1]The six traits with the highest F-ratios for GMH_1 vs. GMH_2 vs. GMH_3 are: AVL, NPH, FMB, STB, PAF and PAB. The six traits with the highest F-ratios for TG_1 vs. TG_2 vs. TG_3 are: PAF, STB, OCF, XCB, OBB and NPH.

[2]The six traits with the lowest r's for the GMH_2 vs. GMH_3 runs (TG's intra-observer r's were not calculated) are: OBB, PAB, PAL, FRF, PAF and OCF.

*$p < .005$
**$p < .001$

(except for his 2nd vs. 3rd runs) resulted in highly significant Shape distances being generated. Even though the batteries of traits are heavily biased, these results are alarming when one reflects on the fact that "groups" found to be significantly different biometrically are indeed **identical** sets of crania, measured by a single (albeit neophyte) observer. Supervisors of osteological laboratories which make heavy use of inexperienced hands in generating descriptive data should take heed.

Another interesting point revealed in Table 4 is that practice does (almost) make perfect. Note the difference between the distances generated in measurement runs two and three vs. the two other comparisons. The pattern holds for both observers, but is especially dramatic in the case of TG. Distances referenced to his first measurement run, when he was a neophyte in the strictest sense, are the only outrageously inflated ones.

Inter-observer Imprecision and Distance Measures' Distortion

Although the above results are interesting, it is more important to explore distance distortion at the inter-observer level. This is so because (1) error at this level is generally of greater magnitude, and is (2) likely to be more systematic in nature, which (3) creates a potentially serious problem for the investigator desiring to use another worker's data in a comparative phenetic study.

To assess the consequences of inter-observer measurement error, six batteries of craniometric traits were utilized to generate six sets of Penrose distances. These "false" distances are strictly a product of the collective measurement imprecision of GMH, TG and FJM, for — keep in mind — the distances are referenced to identical Iroquoian specimens. The trait composition and strategy behind the six batteries are described in Footnote 1 of Table 5.

Table 5 is very revealing. First, note the marked differential between the distances generated by high F traits (Battery 1) vs. the Battery 2 distances, computed from low r traits. In the latter case, half of the Size and Shape distances were statistically significant, while all of the distances generated by the high F trait battery were significant at less than the p = .005 level (Ho:distance is zero). Naturally, distances derived from the two "best traits" batteries (3 and 4) are miniscule. These distances serve as a baseline for considering the other batteries' distances.

At first glance it is very alarming that Batteries 5 and 6 yielded inter-observer distances that, in over half the paired comparisons, departed from zero in a statistically significant manner. Battery 5 is a random draw of six variates, while Battery 6 is comprised of the six craniometric traits that appear to be most commonly reported in the osteological literature. Closer examination shows that Battery 6 includes two, and Battery 5, one trait from the highest F battery (#1). In both cases, the "bad" variates, XCB and ZYB, were the result of idiosyncratic imprecision on the part of the neophyte observer, TG.

A last observation on Table 5 is that the mean GMH vs. TG distances are nearly twofold those of the GMH vs. FJM comparisons. This reinforces the above findings and suggests that it is safe to generalize that technical experience in craniometry is an important factor to consider when one contemplates using another observer's data.

It now remains to place the above "false" distances into a context where their magnitudes can be assessed relative to actual inter-populational phenetic relationships. For this purpose, Howells (1973) was utilized for comparative data on Arikara males and females and Zulu males.[8] The former data allow inter-group distance assessment with another Native American series, while the Zulu male data provide an opportunity to compare intra-series (Kleinburg) and intra-Amerindian distances with those referenced to a more morphologically and historically distant group.

Two sets of distances were computed (Table 6A). One was generated from six traits found to have the highest F values in ANOVA's run on GMH_3, TG_3, and FJM data. The purpose of this was to maximize artifically all intra-Kleinburg "false" distances to see if they could equal or exceed those based on, say, a Kleinburg-Zulu comparison. The second set of distances was computed from the six variates found to have the greatest precision in the above-mentioned ANOVA runs.

[8]Zulu females were not included due to programme limitations on the number of groups which could be used in the Penrose computions.

TABLE 5

Penrose distances between observers, using six different batteries of craniometric traits

Distance	Pair Compared	BATTERIES[1] #1	#2	#3	#4	#5	#6	Mean
D^2_p								
	GMH_3 vs. TG_3	10.05	0.93	0.04	0.14	2.65	3.91	(2.95)
	GMH_3 vs. FJM	4.97	4.31	0.03	0.17	0.32	0.50	(1.72)
	TG_3 vs. FJM	9.20	5.84	0.09	0.09	2.62	3.40	(3.54)
	Mean	(8.07)	(3.69)	(0.05)	(0.13)	(1.86)	(2.60)	((2.74))
Size[2,4]	GMH_3 vs. TG_3	2.13	**0.26**	**0.00**	**0.01**	**0.17**	0.73	(0.55)
	GMH_3 vs. FJM	1.10	0.85	**0.00**	**0.00**	**0.05**	**0.02**	(0.34)
	TG_3 vs. FJM	6.28	**0.17**	**0.00**	**0.01**	0.39	1.00	(1.31)
	Mean	(3.17)	(0.43)	**(0.00)**	**(0.00)**	**(0.20)**	(0.58)	((0.73))
Shape[3,4]	GMH_3 vs. TG_3	7.93	**0.66**	**0.04**	**0.13**	2.49	3.18	(2.41)
	GMH_3 vs. FJM	3.88	3.46	**0.03**	**0.17**	**0.27**	**0.48**	(1.38)
	TG_3 vs. FJM	2.92	5.68	**0.08**	**0.08**	2.23	2.40	(2.23)
	Mean	(4.91)	(3.27)	**(0.05)**	**(0.13)**	(1.66)	(2.02)	((2.01))

[1]#1: Worst variables re F-ratios (GMH_3 vs. TG_3 vs. FJM): OBB, ZMS, XCB, ZYB, PAL, AVB

#2: Worst variables re Pearson's r's (means of GMH_3 vs. TG_3 and GMH_3 vs. FJM): PAL, PAF, NLH, OBB, FRF, OCF

#3: Best variables re F-ratios (GMH_3 vs. TG_3 vs. FJM): PAS, WNB, NLB, WFB, FRS, ASB

#4: Best variables re Pearson's r's (mean of GMH_3 vs. TG_3 and GMH_3 vs. FJM): FRS, WFB, ASB, GOL, FRK, BBH

#5: Six randomly selected variates: PAS, XCB, EKB, FRK, OCK, FRS

#6: Six of the most commonly-reported craniometric variables: GOL, XCB, ZYB, NPH, BBH, BPL

[2]Since the sample size for each pair is 25, the critical values can be calculated (see Rahman 1962:99) as:

$\chi^2.05$ [1] 0.31
$\chi^2.01$ [1] 0.53
$\chi^2.005$ [1] 0.63

[3]Likewise, the critical values for Shape distances are:

$\chi^2.05$ [5] 0.89
$\chi^2.01$ [5] 1.21
$\chi^2.005$ [5] 1.34

[4]Bold type denotes inter-pair (or mean) distances which are **not** significantly different from zero (for Size and Shape components only).

TABLE 6A

Intra-group (Kleinburg) and inter-group Penrose distances

					Level of Significance[1]	
DISTANCES BASED ON TRAITS WITH HIGHEST F-RATIO[2,4] Pair	D^2_p =	Size	+	Shape	Size df = 1	Shape df = 5
GMH$_3$ vs. TG	6.99	0.59		6.40	.01	<< .001
GMH$_3$ vs. FJM	2.56	0.31		2.24	.05	.001
GMH$_3$ vs. Arik. Males	5.15	1.60		3.55	<< .001	<< .001
GMH$_3$ vs. Arik Females	2.16	0.53		1.64	.01	.001
GMH$_3$ vs. Zulu Males	3.76	0.26		3.50	.05	<< .001
TG$_3$ vs. FJM	6.53	1.77		4.77	<< .001	<< .001
TG$_3$ vs. Arik. Males	18.11	4.13		13.97	<< .001	<< .001
TG$_3$ vs. Arik. Females	7.91	**0.002**		7.90	.90	<< .001
TG$_3$ vs. Zulu Males	6.19	**0.07**		6.13	.50	<< .001
FJM vs. Arik. Males	9.75	0.50		9.25	.01	<< .001
FJM vs. Arik. Females	6.68	1.66		5.03	<< .001	<< .001
FJM vs. Zulu Males	6.28	1.14		5.14	<< .001	<< .001
Arik. Males vs. Arik. F	5.68	3.96		1.72	<< .001	.001
Arik. Males vs. Zulu M	6.32	3.15		3.17	<< .001	<< .001
Arik. Females vs. Zulu M	1.20	**0.05**		1.15	.50	.001
DISTANCES BASED ON TRAITS WITH LOWEST F-RATIOS[3,4] Pair						
GMH$_3$ vs. TG$_3$	0.048	**0.003**		**0.005**	.90	.995
GMH$_3$ vs. FJM	0.033	**0.0001**		**0.033**	.975	.995
GMH$_3$ vs. Arik. Males	2.31	**0.04**		2.27	.50	<< .001
GMH$_3$ vs. Arik. Females	1.21	0.55		**0.66**	.01	.50
GMH$_3$ vs. Zulu Males	3.27	0.51		2.76	.005	<< .001
TG$_3$ vs. FJM	0.10	**0.004**		**0.096**	.90	.975
TG$_3$ vs. Arik. Males	2.64	**0.02**		2.61	.90	<< .001
TG$_3$ vs. Arik. Females	0.98	0.48		**0.51**	.025	.50
TG$_3$ vs. Zulu Males	2.86	0.59		2.27	.001	<< .001
FJM vs. Arik. Males	2.13	**0.04**		2.08	.50	<< .001
FJM vs. Arik. Females	1.32	0.57		**0.75**	.01	.10
FJM vs. Zulu Males	3.27	0.49		2.77	.005	<< .001
Arik. Males vs. Arik. F	2.75	0.30		2.45	.05	<< .001
Arik. Males vs. Zulu M	8.04	0.83		7.21	.001	<< .001
Arik. Females vs. Zulu M	5.46	2.13		3.34	<< .001	<< .001

[1]Bold face Size and Shape distances are not significantly different from zero.

[2]The traits used to compute these distances are: OBB, ZMS, XCB, ZYB, JUB and FRF.

[3]The traits used to compute these distances are: PAS, WNB, NLB, FRC, FRS and ASB.

[4]These trait lists differ slightly from batteries 1 and 3 (Table 5) because of variable substitutions necessitated by nonequivalence of the Howells (1973) and University of Toronto's craniometric batteries.

TABLE 6B

Summarization of results from Table 6A.

	MEAN DISTANCES[1] GENERATED BY BATTERIES COMPRISED OF:					
	Highest F-ratio Traits			Lowest F-ratio Traits		
Pooled Comparisons	D^2_p =	Size +	Shape	D^2_p =	Size +	Shape
All intra-Kleinburg comparisons, based on measurements of identical crania	5.36 (2.56)	0.89 (0.31)	4.47 (2.24)	0.06 (0.03)	0.002 (0.0001)	0.04 (0.03)
All Kleinburg vs. Arikara Male comparisons	11.00 (7.45)	2.08 (1.05)	8.92 (6.40)	2.36 (2.22)	0.03 (0.04)	2.55 (2.18)
All Kleinburg vs. Arikara Female comparisons	5.58 (4.42)	0.73 (1.09)	4.86 (3.34)	1.17 (1.27)	0.53 (0.56)	0.64 (0.71)
All Kleinburg vs. Zulu Male comparisons	5.41 (5.02)	0.49 (0.70)	4.92 (4.32)	3.13 (3.27)	0.53 (0.50)	2.60 (2.77)
All (N = 15) paired comparisons	6.35	1.31	5.04	2.42	0.43	1.99

[1]The coefficients in parentheses result when TG is removed from the analyses.

To facilitate interpretation of the data in Table 6A, a summarization is presented in Table 6B. By examining these two tables, a number of observations can be made. First, the mean ("false") distance among the three Kleinburg runs nearly equals the distances generated in Kleinburg-Arikara females and Kleinburg-Zulu male comparisons, when the highest F-ratio trait battery is used. In contrast, the intra-Kleinburg distances are necessarily extremely low when generated by the lowest F-ratio traits. Most intriguing about this latter set of distances is that the Kleinburg-other group distances are more accurate. That is, the computed phenetics are in concordance with known phylogenetics.

A curious finding is the differentially high magnitude of Kleinburg-Arikara male distances, especially in the case of the high F traits battery. If this result were due to 56% of the Kleinburg sample being female, then one would expect the Size component of D^2_p to be disproportionately large. This is not the case (cf. Arikara male-Arikara female results).

Too much should not be made of such statistical anomalies, however. Given the small sampling of group mean phenotypes (and genomes) that six-trait batteries represent, taxonomic irregularities are not unexpected.

One last set of observations concerns the parenthetical values in Table 6B. Since TG contributed disproportionately to the magnitude of the F values of measurements in the "worst traits" battery, it was decided to see what effect his data's removal would have on the results. Predictably, all intra-Kleinburg distances were reduced. Yet, alarmingly, there remained significant size ($p = .05$) and shape ($p < .001$) intra-Kleinburg distances (in the case of the high F battery) when only the two experienced observers' data were used. The Arikara male anomaly remained, as well, in the highest F-ratio distance matrix. In the revised set of distances based on the lowest F-ratio traits, phenetic agreement with known phylogenetics is the most concordant of any of the four sets of computed distances. Again, too much should not be made of this, given the limited scale of this study.

CONCLUSIONS AND RECOMMENDATIONS

Some conventional measurements of the orbit (OBB, OBH), palate (PAL), cranial vault curvature fractions (FRF, PAF), lower facial protrusion (ZMS), and upper facial height (NPH) have been shown to be the most generally prone to measurement imprecision. All of these troublesome measurements, excepting orbital height, are referable to such material factors as landmark ambiguity, mechanical difficulty in taking the measurement, or estimation error due to bone remodeling. Orbital height's error proneness on the other hand, is not similarly understandable, and may have been heavily influenced by FJM's differing technique (footnote 2).

A consideration of the consequences of measurement error in craniometry has proven most sobering. Due to the biasing effects of the inclusion of a neophyte's data, the Penrose distance results were alarmingly, if artificially, inflated. Yet even when this bias was removed, "significant" (false) distances were generated on identical crania when a worst (F-ratio) traits battery was used. The inescapable conclusion to be drawn is that when comparative phenetic studies do not include complementary inquiries into measurement precision, their results may not be meaningfully interpreted. Every effort should be made to insure that measures of overall biological similarity are just that, and not artifacts of measurement error.

These results prompt the following recommendations:

1. In descriptive osteological reports, one's method error should be routinely reported. This can be done by calculating F's and r's between intra-observer runs, or by other techniques (e.g. Haugen, 1977).
2. In comparative studies where another author's data are used, an inter-observer error study should be done as an indication guide of which variates may be more confidently employed than others.
3. While the above is ideal, it is unrealistic to suppose that it can be widely realised. As a compromise measure, it is recommended that the 7 measurements in the **omnibus worst traits list** be used with caution, if not avoided. The reader should, however, appreciate that the wisdom of generally excluding them from comparative craniometric studies depends upon the extent to which the present craniometrists (especially GMH and FJM) are representative of others. The general referability of the 7 worst traits to landmark ambiguity and mechanical difficulty leads me to suspect that these measurements are universally error prone.
4. In comparative studies where one observer is to generate all the data, a preliminary study of intra-observer error can assist in trait selection. Such a process is often more practicable than repeating all measurements during data generation, and then doing corrective third-time measurements. Traits thus excluded will vary from investigator to investigator.
5. Additionall systematic inter-observer studies should be conducted. Only in this light, will study-specific vs. universal error proneness of specific traits be elucidated.

APPENDIX A

Listing of Measurements[1]

Measurement	Short Name	Definition and Specific Technique
Glabello-Occipital Length	GOL	See note 4
Basion-Nasion Length	BNL	See note 4
Minimum Frontal Breadth	WFB	See note 5
Maximum Cranial Breadth	XCB	See note 4
Basion-Bregma Height	BBH	See note 4
Basion-Subnasal Point Length	BSL	after note 6; taken with the occiput down, left side facing observer; basion (not endobasion) used
Basion-Prosthion Length	BPL	See note 4
Orbital Height	OBH	See note 4
Orbital Breadth	OBB	See note 4
Nasal Breadth	NLB	See note 4
Alveolar Breadth	AVB	Same as "MAB" in note 4
Alveolar Length	AVL	Same as "Maxillo-Alveolar Length" in note 2; taken with cranial base up, face to observer
Palatal Breadth	PAB	Individualistic: The greatest breadth across the internal alveolar borders, wherever found, perpendicular to the median plane; cranium positioned as in AVL; taken with inside blades
Palatal Length	PAL	See note 2; cranium positioned as in AVL
Nasion-Prosthion Height	NPH	See note 4
Nasal Height	NLH	See note 4
Bizygomatic Breadth	ZYB	See note 4
Bistephanic Breadth	STB	See note 4
Bijugal Breadth	JUB	See note 4
Ectoconchion Breadth	EKB	See note 4
Minimum Nasal Breadth	WNB	See note 4
Biasterionic Breadth	ASB	See note 4
Fronto-Malar Breadth	FMB	See note 4
Nasio-Frontal Subtense	NAS	See note 4
Zygomaxillare Breadth	ZMB	See note 4
Zygomaxillare Subtense	ZMS	Same as "SSS" in note 4
Nasion-Bregma Chord	FRC	See note 4
Nasion-Bregma Subtense	FRS	See note 4
Nasion-Subtense Fraction	FRF	See note 4
Bregma-Lambda Chord	PAC	See note 4
Bregma-Lambda Subtense	PAS	See note 4
Bregma-Subtense Fraction	PAF	See note 4
Lambda-Opisthion Chord	OCC	See note 4
Lambda-Opisthion Subtense	OCS	See note 4
Lambda-Subtense Fraction	OCF	See note 4
Occipital Arc	OCK	See note 3; taken with the frontal bone down, face to the right
Frontal Arc	FRK	See note 3; taken base down, face to the left
Parietal Arc	PAK	See note 3; taken as in FRK

[1]Listed in the order in which they were taken (by GMH and TG only). GOL-BSL taken with spreading calipers, BPL-ASB with sliding calipers, FMB-OCF with coordinate calipers and OCK-PAK with steel tape

[2]Bass (1971:70-71)

[3]Brothwell (1972:81)

[4]Howells (1973:166-183)

[5]Olivier (1969:151)

[6]Stewart (1947:139)

APPENDIX B

Means and standard deviations (in parentheses) for five observation runs on the Kleinburg crania (N = 25)

VARIATE	OBSERVATION RUN				
	GMH_1	GMH_2	GMH_3	TG_3	FJM
GOL	182.68 (5.60)	182.84 (5.59)	183.04 (5.34)	182.20 (5.60)	182.04 (5.40)
BNL	102.24 (4.01)	101.80 (4.01)	101.96 (4.09)	102.64 (5.60)	102.68 (4.31)
WFB	91.96 (3.45)	91.80 (3.38)	91.72 (3.06)	91.40 (3.19)	91.68 (3.29)
XCB	136.52 (5.38)	136.80 (5.38)	136.76 (5.26)	128.92 (6.59)	136.60 (5.66)
BBH	134.36 (6.92)	134.36 (6.89)	134.36 (7.06)	133.44 (7.10)	134.20 (7.22)
BSL	90.08 (4.45)	90.40 (4.97)	90.92 (4.52)	87.64 (3.59)	(measurement not taken)
BPL	99.88 (5.17)	100.20 (5.00)	100.00 (5.02)	99.92 (5.24)	101.84 (5.21)
OBH	34.20 (1.89)	34.04 (1.74)	34.20 (1.73)	35.04 (1.72)	34.96 (1.86)
OBB	39.00 (1.44)	38.96 (1.24)	39.24 (1.30)	39.96 (1.70)	40.96 (1.90)
NLB	26.40 (1.66)	26.52 (1.76)	26.64 (1.80)	26.64 (1.60)	26.80 (1.73)
AVB	64.40 (4.64)	64.56 (4.10)	64.80 (4.12)	54.72 (3.68)	64.96 (3.99)
AVL	55.12 (2.51)	55.56 (2.65)	55.68 (2.32)	55.00 (2.71)	56.04 (2.54)
PAB	39.64 (2.55)	40.68 (2.63)	40.64 (2.55)	39.84 (2.64)	40.84 (2.70)
PAL	45.68 (3.53)	46.04 (2.44)	45.52 (2.22)	45.24 (2.86)	50.04 (2.24)
NPH	70.36 (4.29)	69.64 (4.23)	69.44 (3.66)	69.68 (3.73)	71.44 (4.15)
NLH	52.36 (2.78)	52.36 (2.87)	52.56 (2.84)	53.64 (3.68)	52.56 (2.89)
ZYB	133.20 (5.75)	133.96 (5.29)	134.22 (5.22)	125.80 (6.12)	133.92 (5.63)
STB	107.00 (7.21)	108.40 (5.66)	108.88 (5.09)	105.92 (5.14)	107.96 (5.50)
JUB	115.08 (4.65)	115.16 (4.48)	115.40 (4.56)	112.52 (4.46)	114.68 (5.34)
EKB	98.16 (2.84)	98.08 (2.83)	98.28 (2.61)	96.28 (2.37)	99.08 (3.94)
WNB	9.20 (1.78)	8.96 (1.88)	8.96 (1.86)	9.04 (1.86)	9.08 (1.93)
ASB	107.48 (4.67)	107.68 (4.55)	107.60 (4.50)	106.92 (5.51)	107.56 (4.30)
FMB	96.92 (2.91)	97.68 (3.75)	97.00 (2.97)	97.56 (2.68)	97.88 (2.91)

VARIATE	OBSERVATION RUN				
	GMH_1	GMH_2	GMH_3	TG_3	FJM
NAS	16.80 (2.29)	16.80 (2.38)	16.68 (2.51)	17.00 (2.48)	16.44 (2.38)
ZMB	99.60 (4.79)	99.16 (5.13)	98.84 (5.14)	98.64 (5.25)	97.96 (5.04)
ZMS	27.20 (3.44)	26.76 (2.98)	27.24 (3.04)	26.44 (2.99)	30.16 (3.22)
FRC	110.68 (4.82)	110.60 (4.81)	110.64 (4.83)	110.00 (4.80)	110.72 (4.94)
FRS	24.48 (2.66)	24.76 (2.63)	24.52 (2.62)	24.68 (2.64)	24.32 (2.66)
FRF	49.04 (4.54)	49.16 (3.47)	49.16 (4.53)	52.58 (6.89)	49.48 (3.33)
PAC	110.28 (6.39)	110.92 (6.55)	110.40 (6.28)	108.88 (5.95)	109.60 (6.44)
PAS	22.96 (3.67)	23.00 (3.40)	23.04 (3.48)	22.96 (3.36)	22.84 (3.36)
PAF	51.00 (7.02)	53.40 (7.77)	52.30 (6.06)	53.04 (7.28)	54.48 (5.78)
OCC	96.52 (5.79)	96.44 (5.80)	96.40 (6.20)	95.76 (5.48)	96.80 (5.82)
OCS	29.04 (2.84)	29.00 (2.96)	29.08 (2.93)	28.64 (2.91)	30.24 (2.80)
OCF	45.40 (7.50)	45.32 (7.60)	45.80 (7.44)	49.48 (6.24)	47.00 (6.66)
OCK	116.48 (7.74)	116.12 (8.60)	115.60 (8.51)	117.36 (6.10)	118.40 (7.46)
FRK	123.56 (6.29)	123.32 (6.41)	123.00 (6.17)	124.24 (6.59)	124.96 (6.64)
PAK	112.48 (8.51)	123.04 (8.47)	122.48 (8.65)	123.40 (8.15)	121.96 (8.24)

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Evidence for Cyclic Regulation of Dietary Calories

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KEY WORDS Dietary Regulation • Caloric Intake • Cycle • F Ratio

ABSTRACT Dietary records were maintained by different samples of 29 and 26 subjects for seven consecutive days in mid-May, 1977 and 1979 respectively. Dietary calories were about 550 per day less in 1979 than in 1977. Analysis of the interaction of age and sex reveals a statistically significant 6-day cycle for young females and old males, but a different shift angle.

RESUME On a enregistré de façon continue le régime alimentaire d'échantillons différents de 29 et de 26 sujets durant sept jours consécutifs à la mi-mai 1977 et 1979 respectivement. Les calories alimentaires se sont révélées d'environ 550 moindre par jour en 1979 qu'en 1977. L'analyse de l'interaction de l'âge et du sexe révèle un cycle statistiquement significatif de six jours chez les femmes jeunes et les mâles plus âgés mais avec un angle de changement différent.

INTRODUCTION

Single 24-hour dietary recalls or records are not representative of habitual diet (Balogh, Kahn and Medalie; '71) and, so, are not suitable as a means of assessing the nutrient intake of individuals. Seasonal, weekly, and day effects are known to be present in dietary behavior (Stapleton and Abernathy; '79). We have observed dietary intake over seven consecutive days for the purpose of elaborating the weekly pattern in terms of inter-day variability. Observations were made in mid-May of 1977 and 1979 on different samples of 29 and 26 volunteer subjects respectively. There were 36 females and 19 males. The age range was 18 to 65. No dietary restrictions were present and all subjects were in apparent good health. None was involved in a heavy labor occupation, most being office staff, nurses, housewives, businessmen, graduate students or retired.

Subjects were instructed to eat their "normal" diets. The importance of adhering to normal eating habits was stressed. A report of the individual results was returned to each subject which is thought to have added incentive. Records were collected and checked for completeness. The dietary information given by the subjects was detailed and indicated a high degree of cooperation. Subjects stated that recording their food intake had little or no effect on their eating habits.

Each subject maintained a complete record of all food consumed during a 24-hour period for each of the seven consecutive days of the surveys. Each survey started on Tuesday morning. Food intake was recorded on a meal basis i.e. breakfast, lunch, dinner and snacks. The weight or serving size of each foodstuff was estimated by the subjects. Subjects were instructed not to weigh servings, as this could not be done routinely. Vitamin-mineral supplements were not included in the dietary records. The nutrients in each food were calculated from the United States Department of Agriculture food composition tables

(USDA; '63) and from Church and Church ('75) using a computer program.

RESULTS

Here we restrict attention to caloric intake. The inter-nutrient correlation profile is very similar to that observed by Pennington ('76), and so we expect that the results will apply, in a qualitative way, to protein, fat, total saturated fatty acid, oleic acid and cholesterol.

TABLE 1

Average calories (kcal) per day by age, sex and survey year
(Standard deviation in parentheses)

	Less than 30 years		Greater than 30 years	
	Female n = 18	Male n = 11	Female n = 18	Male n = 11
1977	2348.8	3320.0	2088.2	2539.7
	(689.0)	(957.9)	(868.3)	(1037.0)
1979	1888.0	2211.3	1892.6	2222.1
	(635.8)	(813.3)	(647.2)	(673.8)

In Table 1 is mean daily consumption of calories by age, sex and survey year. Significant F ratios are present for the main effects of sex ($F(1,47) = 8.59$, $p = 0.005$) and survey year ($F(1,47) = 8.65$, $p = 0.005$). This last result leads to the estimate that mean daily calories decreased from about 2514 to about 1965 between 1977 and 1979. The age main effect was not significant.

We also observed a significant interday effect which interacts with sex and age ($F(6,282) = 2.52$, $p = 0.03$). The interpretation of this interaction is the primary objective of this report.

Functions of the family

$$y = C + A \sin (2\pi/k)d + B \cos (2\pi/k)d$$

where d = 1, 2,...,7, day in sequence, were fitted and parameters estimated for k = 3,4,...,13, period. Subjects were categorized for age less than 30 years or greater than or equal to 30 years. A six-day period is most effective for young females (YF, $F(2,106) = 9.66$, $p = 0.0001$) and old males (OM, $F(2,64) = 4.54$, $p = 0.015$). Among young males a six-day period while not explaining a significant portion of variability ($F(2,46) = 1.72$, $p = 0.20$), is still the best choice. For old females the best choice is a three-day period, though it is not at all satisfactory ($F(2,106) = 0.47$, $p = 0.6$). In the sequel we further restrict attention to the categories YF and OM.

The estimated parameters (and their standard errors) for YF are A = -278(63.6), B = 61(67.7). Similarly for OM, A = -245.7(112.9), B = 277.4(120.2). Within both these groups there is evidence of heterogeneity in the parameters. It is notable, however, that the age-sex interaction in mean daily calories is apparently due to parameter differences between groups.

Phase shift angle is given by $\Theta = \tan^{-1} B/A$. Converting Θ to days indicates that the YF begin at day -0.24(0.22)(6), which corresponds approximately to about 0200 hours on Tuesday; for OM the period begins at -0.94(0.39)(6), which corresponds approximately to 0900 hours on Monday. In Table 2 are the predicted daily deviations from the weekly means for each of these groups. The t statistic for the differences between YF and OM starting time is 6.8 with 27 degrees of freedom which is highly significant. These results underscore the inadequacy of estimating mean caloric intake from a single day's dietary. But more importantly they indicate the present of cyclic nutrient regulation for energy balance which, due to high internutrient correlations, has implications for the normal daily variability in other nutrients. The period of the cycle may vary with age and sex. It is not known whether the cycles are of environmental (cultural) or physiological origin or some combination of both.

TABLE 2

Predicted daily deviations of caloric intake from weekly means

Day	Young Female(YM) kcal	Old Male(OM) kcal	
1	61.00	277.42	Tuesday
2	-210.25	-74.07	Wednesday
3	-271.26	-351.49	Thursday
4	-61.00	-277.42	Friday
5	210.25	74.07	Saturday
6	271.26	351.49	Sunday
7	61.00	277.42	Monday

[4]The standard error of Θ is estimated by

$$SE_{\Theta} = \sqrt{\left(\frac{B^2}{A^2 + B^2}\right)\left(\frac{S^2_A}{A^2} - \frac{2\,COV(AB)}{AB} + \frac{S^2_B}{B^2}\right)}$$

DISCUSSION

We recognize the improbability that a 6-day cycle is true, say, through a month. Very likely, weekends result in a re-start of weekday behavior. The duration of the cycle is probably the least important result we obtained, though its statistical significance is beyond doubt. The observation of a regular cyclic pattern in dietary behavior is, however, of fundamental importance. Is this an artifact of Western culture? Is it indicative of some physiological regulatory mechanism? The central fact of indisputable significance is that the daily pattern of deviation around the individual weekly mean is cyclic! The existence of regularity within a seven day period immediately suggests the possibility of longer term cycles as well. Certainly the amount of residual variability, after removing that which can be accounted for by a sinusoidal function, is large. Obviously one needs longer data series in order to estimate parameters for multiple co-existent cycles. We suggest that the Fourier decomposition of long term dietary behavior will result in a relatively simple and intuitively meaningful set of descriptive cycle periods. Possible origins of the regularity are worth attention.

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Breastfeeding and Postpartum Ovulation: A Research Design and Some Preliminary Results[1]

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KEY WORDS Breastfeeding • Lactation • Postpartum Ovulation

ABSTRACT Prolonged lactation is known to have an adverse effect on fertility. The research design of a longitudinal study that intends to correlate individual breastfeeding patterns with the return of postpartum ovulation is presented. Breastfeeding mothers are interviewed, and asked to record all nursing episodes and monitor their ovulation using the sympto-thermal method of birth control or natural family planning. This method involves the recording of three events: (1) the daily waking basal body temperature, (2) changes in cervical mucus consistency, and (3) changes in the position of the cervix.

Some examples of the raw data, their use in determining ovulation, and some very preliminary results are provided. No formal analyses have been undertaken as yet. It seems, however, that the first postpartum menstrual cycles are ovulatory. Changes in routine, such as alterations in nightfeeding, rather than the initiation of supplementary foods, may trigger the reinstatement of the cycle.

RESUME Nous savons qu'une lactation prolongée a des effets négatifs pour la fertilité. Nous présentons, ici, la stratégie de notre projet de recherche à long terme qui vise la correlation de schèmes individuels d'allaitement avec la reprise d'ovulation. L'approche consiste à obtenir, de mères qui allaitent leurs enfants, des renseignements tant aux périodes d'allaitement. De plus, elles surveillent l'ovulation utilisant la méthode sympto-thermale de contraception naturelle. Celle-ci consiste à noter (1) la température basale au levé, (2) tout changement de consistence du mucus cervical et (3) tout changement de la position du cervix.

Quoique des analyses poussées n'aillent pas encore été effectuées, nous présentons néanmoins des résultats préliminaires ainsi que quelques examples de données brutes et de leur utilisation dans la détermination de l'ovulation. Ceux-ci suggèrent que l'ovulation a lieu à la première menstruation après une naissance. Des changements d'horaire d'allaitement plutôt que l'introduction de nourriture supplémentaire puissent précipiter le début du cycle menstruel.

INTRODUCTION

Factors affecting fertility are complex and interactive: a circle of cultural, biological and ecological influences. Throughout most of human existence, contraceptives have not been used regularly. This is still largely the case today. In populations that do not substantially control their fertility, rates of fertility can be translated into the effects of the birth interval (Preston, 1979). Investigators have emphasized the profound effects of lactation on this interval (Preston, 1979; Corsini, 1977). Studies with non-primate animal species (Grosvenor *et al.*, 1967; Kann and Martinet, 1975; Restall and Starr, 1977), non-human primates (Dang, 1979) as well as humans (Jain *et al.*, 1977; Mosley, 1978; Konner and Worthman, 1980; Wenlock, 1979; Ayangade, 1978) have repeatedly demonstrated the adverse effect that lactation has on the ability

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to conceive. The extent to which this occurs, however, depends, in part, upon the frequency, duration, and perhaps intensity of nursing episodes (Knodel, 1977; Tyson and Perez, 1978).

This research examines how lactation, as a physiological process, and breastfeeding, as a social/cultural phenomenon, interact to influence the birth interval and, hence, how they possibly affect fertility. The distinction between these two exists because it is lactation, through the suckling stimulus and hormonal action, that potentially lengthens the interval. The method or manner of breastfeeding, as it controls the frequency, duration, and intensity of episodes, however, appears to determine the extent to which conceptive potential is altered (Corsini, 1977).

The argument put forth states that, given culturally dependent breastfeeding patterns, the return of fertility will vary accordingly. The variety of lifestyles that human societies have experienced has influenced breastfeeding practices considerably. This may have played some role in population regulation and growth throughout human evolution (Lee, 1979; Howell, 1976; Kolata, 1974).

The idea is by no means new (Gioiosa, 1955). The recent flourish of research in anthropological demography and nutritional anthropology, concurrent with a return to breastfeeding in certain segments of our society, has revitalized interest in this topic. Precision of research and standardization of variables have been noticeably lacking in current studies, making comparison among them difficult. In a recent critical review of this problem area, one author states that "the major research on lactation and postpartum anovulation is yet to be done" (Masnick, 1979:109).

Studies have been conducted whereby breastfeeding patterns are correlated with the return of menstruation, (e.g., Kippley, 1974). Since the first postpartum menstrual cycles may be anovulatory, consequently infertile, menstruation alone is not an accurate indication of potential fertility. The longitudinal study presented here, however, is attempting to correlate individual breastfeeding patterns with the return of postpartum ovulation. The best evidence for longer birth intervals through lactation comes from the rural areas of Third World countries. In contrast, an urban, North American study, where lifestyles differ considerably, and where most women are well-nourished, offers an ideal opportunity for comparison and examination of this process.

The exact hormonal regulation of ovarian function in relation to the postpartum period remains obscure (Tyson *et al.*, 1972; Short, 1976). In fact, it may not be suppression of ovulation at all that is responsible for lactational infertility. Coutinho (1971) suggests that, due to the hormone oxytocin, excessive fallopian tubal motility may inhibit ovum implantation or conception. In all probability, however, the return of the ovulatory cycle is the most accurate and profitable variable to measure.

METHODS

The sympto-thermal method, a birth control or natural family planning method, is employed to determine ovulation (Aguilar, 1980; Kippley and Kippley, 1979; Roetzer and Keefe, 1977; Roetzer, 1977). Three physiological occurrences are monitored: (1) the waking temperature, (2) cervical mucus, and (3) cervix auto-palpation. A distinct change in quantity and consistency of cervical mucus production, and in the position and texture of the cervical opening followed by a rise in the basal body temperature result from the cyclic hormonal changes that indicate ovulation. These events are quite easily recognizable by daily self-examination.

This method is not encouraged as an alternative to other forms of birth control, but rather presented as a way in which to determine potential ovulation for the purposes of this study. The overall user-effectiveness rate using post-menstrual and pre-menstrual days is extremely high. There were only seven "surprise pregnancies" in 12,323 cycles of 380 women (Roetzer, 1977). The user-effectiveness rate for pre-menstrual days only, that is those days between the observation of ovulation symptoms and the onset of menstruation, is 100%.

There is no absolute proof that a cycle, monitored using the above method, is ovulatory. To say that ovulation has occurred is a diagnosis, and only secure if the egg is seen leaving the ovary (which necessitates elaborate laboratory techniques) or if conception occurs (Roetzer and Keefe, 1977). The above physiological phenomena are symptoms or signs of potential ovulation. It is generally concluded that ovulation has not occurred if none of the signs are present. Roetzer (1977) has found in more than 9,000 cycles that "monophasic" cycles, those which show no signs of ovulation, particularly a rise in temperature, are very uncommon (1.5% of all cycles) among fertile women. Thus, in using this method, overenumeration of ovulation is never a problem; in fact, the reverse, under-enumeration, is more likely to occur.

Approximately 30% of the total number of women who will be involved have been incorporated, to varying degrees, into the research design. Potential volunteers are obtained through the La Leche League in Toronto and the surrounding area. Actually, after the initial contacts, the bulk of the women's names have accumulated by word of mouth.

The precision of information requested requires a high level of accurate communication between the researcher and the participants. The women, thus far, have been middle to upper-middle class, well educated, and generally between the ages of 25 and 35. As a group, they are homogenous, too, in the values and attitudes they maintain regarding breastfeeding practices. It has been hypothesized that the **relative** effects of nursing on postpartum sterility (a physiological process) are constant across societies, although the **absolute** effects vary from society to society, depending on the manner of breastfeeding (Ginsberg, 1973). Ethnic diversity would manifest itself in individual patterns of feeding rather than in any physiological differences.

At the outset, a phone call is made to arrange a date and time for the 'home interview'. Theoretically, a maximum of ten interviews are possible per week (that is, two per day). The amount of time needed for each interview varies from ½ to 3 hours with a mean of about one hour.

The interview has two parts: (1) a questionnaire or survey that is conducted in a discussion format in the home, and (2) a thorough explanation of what participation entails. The intent or purpose of the study is stated, and assurance of maintenance of anomymity throughout the duration of participation is given. Flexibility and individuality of each woman's participation is stressed. It is important to mention the fact that **any** information, collected under terms suitable to each woman's interest, time, and willingness, is valuable.

The breastfeeding survey requests information pertaining to the woman's background. Items such as birthdate, birthplace, parent's birthplace, education, annual income, marital status, and occupation are included. Specific questions about reproductive and breastfeeding history are asked next. Although the data collection focuses on the child currently breastfeeding, information is obtained for all other children as well; their breastfeeding experiences and patterns, implementation of supplementary foods (solids and liquids), bottlefeeding, and weaning are some examples. The remaining questions pertain to the mother and tend to be of a more personal nature. They cover such topics as height, weight, birth control history, abortions, stillbirths, miscarriages, menstrual cycle regularity or irregularity, sexual activity, feelings about and reasons for breastfeeding, and resumption of postpartum menstruation (or ovulation, if known).

After the survey is complete, the data collection format is explained in detail. Each woman is given a six page handout that simply and concisely reiterates the methods and procedures of the research. It is not perused during the interview, but serves mainly as a reference. Next comes the explanation of the sympto-thermal method, which must be undertaken with great care as it is the most technical element in the study. Many women are at least vaguely familiar with this method, and several of them actively use it for birth control. Supplementary handouts written by two different experts (Kippley and Kippley, 1979; Roetzer and Keefe, 1977) in this area are provided for further understanding. A basal body temperature thermometer, which differs from a regular thermometer in structure and expense, is provided. No commitment is requested at the time of the interview. Everyone is given a week to read through the material provided and decide whether and how much to participate.

Finally, the data collection sheets are presented along with a completed sample (see Figs. 1 and 2). Each sheet is equivalent to seven days. Space is provided across the top for the sympto-thermal method information; the daily temperature recordings, cervical mucus consistency, and cervical positioning. The remainder of the sheet is for the recording of feedings. In hourly designations beginning at midnight, time blocks run vertically down the left-hand side of the page. Ideally, everything the child consumes

Code: 004	July 9	July 10	July 11	July 12	July 13	July 14	July 15
temp	36.5	36.4	36.7	36.5	36.5	36.3	--
external							
internal							
cervix							
12 midnight		15 min E	10 min H		20 min M		
1:00 am	10 min H			10 min H			
2:00 am							
3:00 am	15 min M			20 min H		15 min E	
4:00 am			20 min E				
5:00 am	10 min				20 min H		
6:00 am						15 min H	
7:00 am		15 min H			10 min M		
8:00 am	10 min M	10 min E	10 min H			10 min E	
9:00 am	(nursed)		10 min E	20 min	10 min M	20 min	
10:00 am	10 min M	15 min M	(nursed)	10 min	(nursed)		
11:00 am			20 min E		5 min H	15 min H	
12 noon	10 min E tblsp. fruit	15 min		10 min M	10 min	10 min	
1:00 pm				30 min E			
2:00 pm	15 min H	10 min M	15 min H		20 min E		
3:00 pm				5 min H		15 min H	
4:00 pm	5 min M cookie & water			10 min			
5:00 pm		1 tbsp. fruit 10 min H	15 min H	10 min E			
6:00 pm	10 min E	10 min H				1/3 C fruit 10 min E	
7:00 pm			20 min				
8:00 pm	10 min M					5 min M	
9:00 pm	(nursed)	30 min	30 min E			5 min M	
10:00 pm	10 min E	10 min E				10 min E	
11:00 pm							

Fig. 1 Weekly breastfeeding patterns of a menstruating, ovulatory woman with a 6½ month old child.

Code: 022	Sept. 5	Sept. 6	Sept. 7	Sept. 8	Sept. 9	Sept. 10	Sept. 11
temp	36.4	36.2	36.3	36.2	36.2	--	36.3
external	dry throughout ------						
internal	of no particular consistency throughout ------						
cervix	Firm, Low and Closed throughout ------						
12 midnight							
1:00 am							
2:00 am							
3:00 am							
4:00 am							
5:00 am							
6:00 am	20 min H	20 min H	20 min H	15 min H	20 min M	25 min H	25 min H
7:00 am							
8:00 am						20 min M	
9:00 am			20 min M	20 min H	20 min M		
10:00 am	20 min M	20 min M					20 min M
11:00 am							
12 noon						3 oz. formula	
1:00 pm	20 min H 5 tsp cer	20 min H 4 tsp cer		7 oz form 6 tsp cer	20 min H 3 tsp cer	expressed 4 oz milk	
2:00 pm			20 min H 6 tsp cer				20 min H 6 tsp cer & banana
3:00 pm							
4:00 pm							
5:00 pm			20 min M	20 min M	25 min M 3 tsp cer	25 min H	15 min H
6:00 pm	20 min M 4 tsp appl sauce	20 min H 5 tsp applesauce	6 tsp applesauce & yoghurt	6 tsp applesauce & yoghurt	6 tsp applesauce & yoghurt	8 tsp cer & banana	
7:00 pm							
8:00 pm							15 min H 5 tsp cer
9:00 pm			25 min H		20 min H		
10:00 pm	15 min H	20 min H		15 min H		20 min H	
11:00 pm							

Fig. 2 Weekly breastfeeding patterns of a non-menstruating, anovulatory woman with a 5 month old child.

should be recorded. Clearly, this requires a lot of work for the mother. The completion of a whole day is better for analysis than bits and pieces distributed randomly throughout the week. If the recording of daily feeding patterns is too time consuming, it is suggested that a woman choose one or two days a week specifically for this activity, then forget about it for the other five or six days. Many women have noted that, once the data collection becomes established in their routines, it is no longer such a burden.

Each month the completed sheets are sent to the researcher by mail in a stamped, self-addressed envelope. This insures proper collection of data and allows for commencement of analysis before the end of the study. The volunteer is not visited again, but follow-up phone calls are made on a regular basis. They occur more frequently in the beginning, and, depending on the length of participation, once per month after that. Volunteers are encouraged to call the researcher if questions arise and to report noteworthy events, such as the resumption of menstruation. Each phone call is designed specifically for each woman. The questions asked are dependent upon such things as length of participation, particular phase of breastfeeding, or age of the child. In addition, standard questions about changes in routine, unusual stress or separation of mother and child are asked. Responses to data received prior to the call may be given.

RESULTS

So far, the data return has been slow, but quite good. No formal analysis has been carried out yet, but some examples of the raw data, how it is used to determine ovulation, and some preliminary, rather speculative, results are provided.

The woman in Figure 1 is breastfeeding very frequently, but for short durations. Her child was 6½ months old at the time of this recording and receiving very few supplementary foods as yet. This type of pattern is usually associated with anovulatory, amenorrheic women, however this woman began to menstruate when her son was not quite 6 months old. It is not known if her first cycle was ovulatory, but the second cycle showed ovulatory signs, according to her waking temperature.

The woman in Figure 2 breastfeeds less frequently but for longer duration. Her child, almost 5 months old, sleeps from 10:30 p.m. until 6:00 a.m. (7½ hours each night), and has begun receiving supplementary foods. This woman is still amenorrheic and probably anovulatory.

Figure 3 is a charting of the sympto-thermal method observations from the same woman who provided the data in Figure 2. None of the signs — the waking temperature, mucus consistency or cervical positioning — indicate potential ovulation. The temperature peak on the 34th day (Sept. 3) is due to illness.

The fourth figure is from a woman who began to menstruate when her son was 5 months old, but had received **no** supplementary feeding yet. The child however, was very large and slept long hours without waking each night when he was approximately 6 to 8 weeks old. In addition, this woman has a history of extreme cyclic regularity. This is not her first cycle, but even though her son is still not receiving supplementary foods, she shows all three ovulation signs — a distinct temperature rise (beginning on Sept. 5), changes in mucus consistency, and cervical positioning.

DISCUSSION

Although the sample size is not yet large enough for statistical testing, and more examples are needed to understand the idiosyncracies of individual cycles, the trend is for the first postpartum cycles to be ovulatory, or rather to show the signs of potential ovulation. In addition, there seem to be some key factors that may trigger postpartum cycling. It has been suggested elsewhere that initiation of supplementary feeding, and consequently less suckling, may start the cycle (Kolata, 1974; Kippley, 1974; Lee, 1979). Since the introduction of supplementary foods is such a gradual process with most of the mothers in this study, it has not proved to be a predominant factor as yet. Other changes in routine, such as illness, hospitalization of mother or infant, actual weaning and sleeping through the night seem to be more important thus far.

Nightfeeding, especially, has been of interest. For example, if a child sleeps through the night for four to six weeks of age, then reestablishes nightfeeding, the lapse of just two weeks may be enough to reinstate cycling. Further, women who have a history of extreme cyclic regularity, exclusive of the birth control pill, seem to resume cycling before irregular cyclers. Though this aspect is not emphasized, the mean value for the

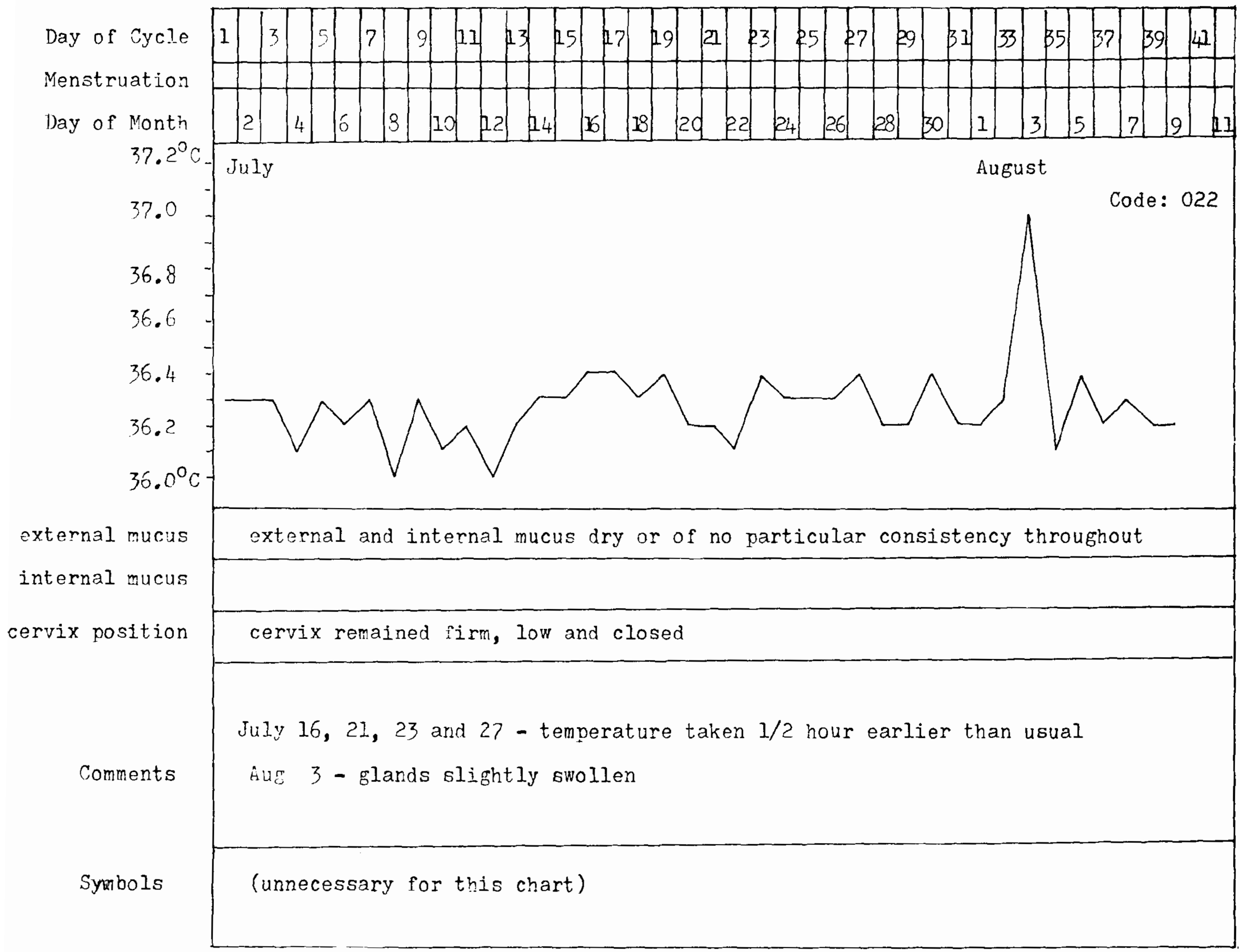

Fig. 3 Sympto-thermal chart, of the woman in Fig. 2, showing no signs of ovulation.

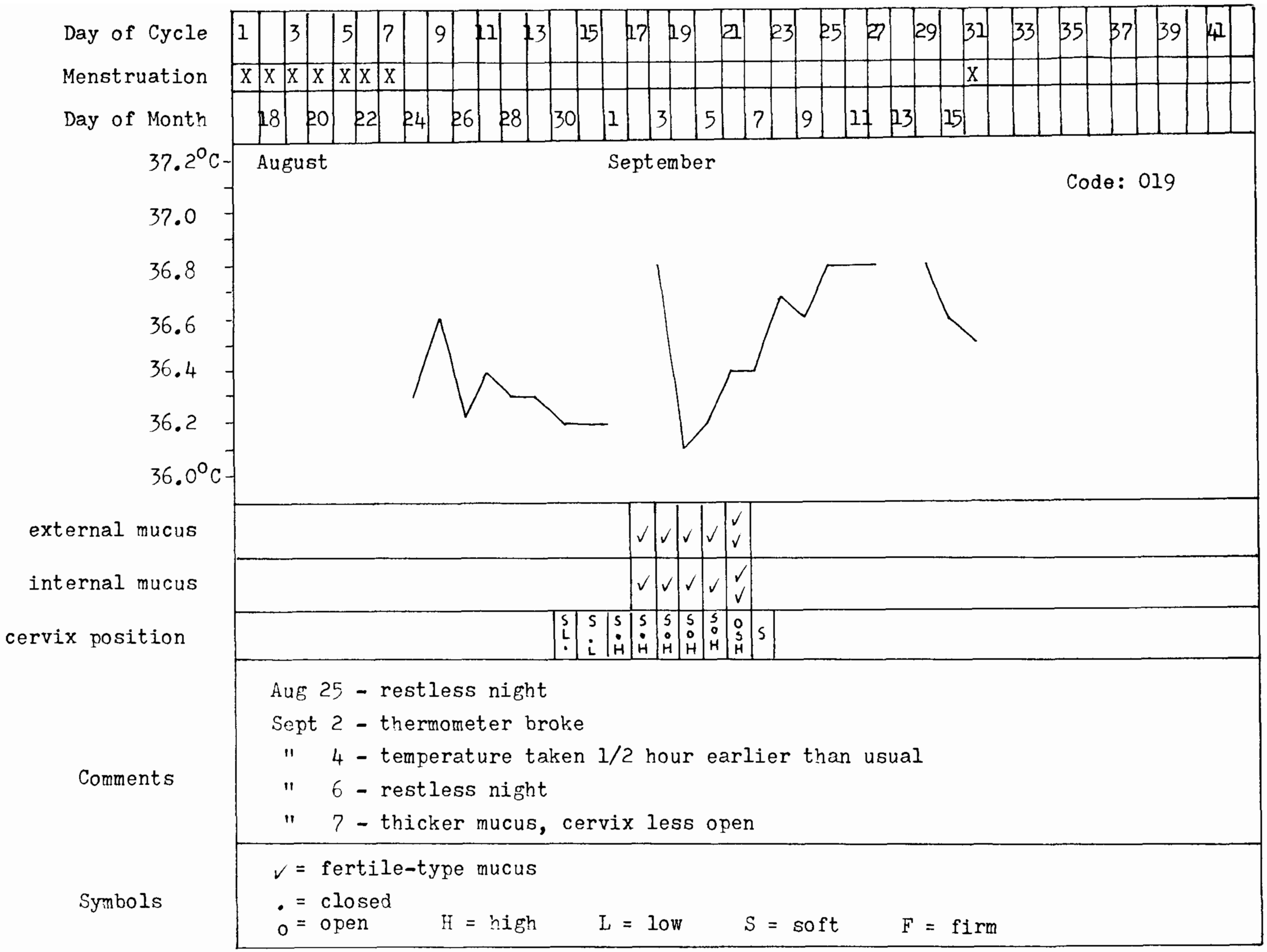

Fig. 4 Sympto-thermal chart demonstrating all three signs of ovulation.

resumption of menstruation (N=42) is ten months, with a range of 2½ months to 2½ years. This is encouraging since these values are congruent with other reports of studies conducted with North American, urban women (Kippley, 1974).

Discussion of lactation and reproduction without mentioning nutrition is akin to sailing a rudderless ship. Lactation has high nutritional demands, even higher than pregnancy. Within a population, the groups having the highest risks for nutritional stress are infants and pregnant or lactating women. The effect of nutrition on fertility is nonetheless very poorly understood (Caliendo, 1979).

A controversial theory, the 'critical fatness hypothesis', states that "a minimum of stored, easily mobilized energy is necessary for ovulation and menstrual cycles in females" (Frisch and McArthur, 1974:949). Further, the hypothesis indicates that lactating women may fall below the critical level (measured height for weight) with resulting infertility. Thus, it may afford another explanation for birth spacing.

Several have criticized this hypothesis (Johnston *et al.*, 1971, Trussell, 1978, 1980; Huffman *et al.*, 1978). Some critical level may be necessary for the initiation of menarche, and possibly larger fat reserves may extend the childbearing span in the other direction as well, by delaying menopause. There is, however, no unequivocal evidence that critical levels are necessary for resumption of ovulation postpartum, unless the population is experiencing **severe** malnutrition, as in the case of famine. In some special cases, though, as among the !Kung San, this may prove to be an appropriate hypothesis (Howell, 1979).

Specifically, Frisch and McArthur (1974) set a minimum level of about 20% of body weight in fat as necessary for the "restoration and maintenance of menstrual cycles" (p. 949). Recently, Trussell (1980) has demonstrated the errors in the statistical procedures used by Frisch and McArthur (1974) to determine relative body fatness. The regression equation (Mellits and Cheeck, 1970) that estimates fatness has been shown to yield imprecise values; "so imprecise as to render her (Frisch's) evidence invalid" (Trussell, 1980:719).

Prior to the availability of this information, the mean fat percentage of the thirty one breast-feeding mothers interviewed was found to be 30.6% (standard deviation = 4.47; range = 22.9 to 40.0%)[2]. The weight value used in the equation was the average, non-pregnant weight reported by each woman. Obviously, data on weight changes during the postpartum period are needed. The taking of skinfold measurements has been incorporated into this research design and will be requested of future participants.

Although more precise estimates of fatness will become known, this hypothesis still may not explain why the women are amenorrheic and/or anovulatory. It is probable that most North American women today remain above a minimum fat level below which reproductive abilities might be hindered. Of course, dramatic weight losses and declines below a level of 20% weight in fat will merit attention and investigation.

Human reproduction appears to be extraordinarily resistant to adverse nutritional conditions, especially in contemporary, urban societies. Chronic malnutrition does not seem to have a large effect on population fertility (Mosley, 1978; Huffman *et al.*, 1978). "It is possible for nutritional status to exert a **statistically significant** but **demographically unimportant** influence on fecundity; this distinction is important and often overlooked" (Trussell, 1980:719). This does not imply that nutrition is an irrelevant factor. However, a reduction in nutritional status is not essential for the maintenance of long birth intervals. "The large variability observed in postpartum amenorrhea can perhaps be best explained by the frequency, duration and intensity of nursing, independent of nutritional status of the mother" (Mosley, 1978:313).

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[2]Calculations made from Mellits and Cheek (1970) following Howell (1979: 200) where total body water (T.B.W.) = -10.313 + 0.252 (weight in kg.) + 0.154 (height in cm.); index of fatness = T.B.W. ÷ weight in kg.; fat percentage = 1.00 - 1.39 (index of fatness).

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Size and Morphology of the Permanent Dentition of the Waorani Indians of Ecuador

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KEY WORDS Tooth Size • Dental Morphology • South American Indians • Dentition

ABSTRACT Dental stone models of 91 Waorani Indians from eastern Ecuador were analyzed to determine their dental morphology and tooth size. Incisor crown shape and cingulum form, Carabelli's trait, cusp number on molars and premolars, protostylid and sixth and seventh cusp expressions and prevalence indicated that these previously unstudied people accorded well with the reported results for Mongoloid populations and in many of their traits were similar to other South American Indians. Buccolingual and mesiodistal diameters for the teeth displayed a large amount of sexual dimorphism. There is little evidence of admixture as determined by the morphology of the dentition.

RESUME On a analysé des moulages dentaires de 91 indiens Waorani de l'Ecuateur oriental afin de déterminer leur morphologie dentaire et les dimensions de la dent. La forme de la couronne de l'incisive et du cingulum, le trait de Carabelli, le nombre de cuspides molaires et prémolaires, le caractère et la prédominance du protostylide ainsi que de la sixième et septième cuspide indiquent que cette population qui n'avait jusqu'ici jamais été étudiée s'accorde bien avec les résultats connus pour des populations mongoloides et par plusieurs de leur traits sont semblables à d'autres groupes indiens sud-américains. Le diamètre buccolingual et mésiodistal de la dent montre un dimorphisme sexuel prononcé. On remarque peu d'évidence de métissage sur la base de la morphologie de leur dentition.

South American Indian groups have received relatively little attention from physical anthropologists, and dental morphology studies of them are poorly represented in the literature. The following report provides the initial odontologic description of a South American population, the Waorani Indians, as part of an ongoing human biological description of these people and an analysis of their biological and social relationships with other Central and South American populations (Larrick et al., 1979; Kaplan et al., 1980).

The Waorani Indians, a tribe of approximately 600 individuals, inhabit an area south of the Rio Napo in Eastern Ecuador, a region of virtually unexplored Amazon headwaters. They can generally be described as hunters and agriculturalists, subsisting on game animals, fish and domesticated plants. Because of this diet, it is necessary for groups of individuals to change their habitat several times a year in their search for harvestable vegetation (Kaplan et al., 1980). Little is known of the past migrations of this tribe or their descendants. It is assumed that they have had very little contact with the outside world and, therefore, have preserved the ancestral cultures of their distinct inbreeding population.

The Waorani were first contacted in the late 1950's by missionaries. Soon after that, the Ecuadorian Government established the Waorani Protectorate, an area about 1/13 of their original homeland, which attracted about 90% of the people and initiated the development of villages. The area is now visited occasionally by missionaries and nurses (Kaplan et al., 1980).

MATERIALS AND METHODS

In 1976, a seven-member medical and dental team visited the Waorani villages for the purpose of studying the medical and dental aspects of this South American Indian tribe. An earlier report outlined the oral health of these people (Larrick et al., 1979).

A total of 91 standard full-mouth alginate impressions were obtained from individuals who presented themselves to the research team for medical or dental care. Subjects were selected on the basis of co-operation, a relatively complete dentition, and time constraints. Eight had deciduous dentitions and, therefore, are excluded from the present study. The resulting dental stone casts were utilized for the observations and measurements.

Eight morphological traits as well as mesiodistal and buccolingual diameters of all permanent teeth were examined. Expressions of shovel-shaping were observed for both maxillary and mandibular central and lateral incisors, while cingulum form was noted in the maxillary incisors. Both maxillary and mandibular first and second premolars were surveyed for the number of cusps present. The presence and expressions of the Carabelli's trait and hypocone of the maxillary molars were examined as well as the expressions of the sixth cusp, seventh cusp and protostylid on the mandibular molars.

The method of recording the observations and measurements of these traits were as follows:

Shovel-shaping — The shovel-shaping characteristic has been described by Hrdlicka (1920) as a pronounced central fossa on the lingual surface produced by the prominent mesial and distal marginal ridges surrounding it. Coding of the shovel-shaping characteristic was based on visual inspection of the casts and comparing the teeth to Dahlberg's widely used "standard" plaques (Dahlberg, n.d.). The various degrees of shovelling were coded as absent, trace, semi-shovel, shovel-shaped and marked.

The maxillary centrals and laterals were also classified according to the presence of a) only mesial or distal ridging on the labial surface (three-quarter shovel-shaping) and b) both mesial and distal ridging on the labial surface (double shovel-shaping). Peg- or conical-shaped and barrel-shaped incisors were also noted.

Cingulum Form — The form of the cingulum in the maxillary incisors was coded according to Barnes' (1969) groupings as follows: a smooth cingulum, fingerlike projection extending incisally from the cingulum, a cusp with a definite groove between the cingulum and rest of the tooth and a notch as a result of the marginal ridges forming an incomplete rim around the cingulum.

Carabelli's Trait — This feature on the lingual surface of the mesiolingual cusp of maxillary molars was evaluated based on the criteria described by Dahlberg's plaques as follows: a smooth surface, pit, groove, small, medium or large cusps.

Hypocone — The size of the maxillary molar's distolingual cusp was assessed according to the four classes shown by Dahlberg's plaques: 4, four well-developed cusps; 4-, noticeably smaller size of hypocone; 3+, the trigon with hypone present only as a very small cusp; 3, trigon cusps with hypocone completely missing.

Number of Cusps — All mandibular premolars and molars were scored for the number of cusps present; a cusp being defined as an elevation in which a definite groove separates it from the others.

Sixth Cusp (Tuberculum sextum) — All mandibular molars were examined and coded for the presence and expression of C6, located on the distoocclusal surface of the mandibular molar extending towards the lingual. Coding of this trait follows Turner's plaques (Turner, n.d.) as such: absence of C6, slight protuberance, small cusp separated from others with a groove that runs cervically on the distal of the molar, medium cusp with groove, large cusp with groove.

Seventh Cusp (tuberculum intermedium) — All mandibular molars were surveyed for the presence and expression of C7, located between the mesiolingual and distolingual cusps. Coding for this cusp followed Turner's plaques as follows: absence of C7, slight protuberance, small cusp separated by definite grooves which extended onto the lingual surface, medium cusp with described grooves, large cusp with described grooves.

Protostylid — The protostylid found on the buccal surface of the mesiobuccal cusp of mandibular molars was examined and its presence and expressions was recorded according to classes demonstrated on Dahlberg's plaques: absence, pit, a distal deviation of the mesiobuccal groove, a small cusp with a definite groove, a large cusp.

Mesiodistal and Buccolingual Diameters — The methods of measuring each of the teeth closely follow those of Selmer-Olsen (1949), who defines the mesiodistal measurement as the distance between points of contact with normally-positioned teeth. A certain degree of subjective judgement was necessary to determine the points of contact in cases of malpositioned teeth, but a model of a dentition with ideal alignment was used as a guide. Buccolingual diameters were taken as the greatest measurement of the teeth perpendicular to the mesiodistal diameter. Any teeth with excessive occlusal wear beyond the height of contour were excluded. A Peacock dial caliper was used, and readings were recorded to the nearest one-hundredth of a millimeter. Measurements were repeated regularly to check on the accuracy of the measurement technique. Those teeth with moderate to heavy interproximal wear were excluded.

For all traits studied, each tooth was examined and scored separately and counts were given for teeth, not individuals, and right and left values were kept separate. In all cases where Dahlberg's plaques and Turner's plate were used, each cast was individually compared to the standard to ensure consistency and accuracy.

Unfortunately, because of attrition, deciduous dentition present, unclear impressions or absent teeth due to trauma, agenesis, extractions or caries, many teeth could not be scored. Mandibular molar patterns were not evaluated due to heavy molar attrition.

Means, standard errors, standard deviations, minimum and maximum values were calculated for the tooth size data and frequency distributions were determined for the morphological observations.

RESULTS

Sexual dimorphism was investigated with Chi^2 tests for morphological traits and t-tests were used for the odontometrics. With one exception, no significant differences were revealed between males and females in the frequency of occurrence of degree of expression of the morphological characteristics studied. The incidence and expression of the sixth cusp on mandibular right first molars was more prevalent in males. Numerous mesiodistal and buccolingual measurements showed sexual dimorphism with the male values being consistently larger.

Shovel-shaped Incisors

Table 1 shows the distribution of the shovelling characteristic on maxillary and mandibular central and lateral incisors. Of the frequencies in the maxillary incisors, semi-shovelling is the highest (50%), followed by shovel-shaping (36%). Absence of the shovelling characteristic in the maxillary dentition was uncommon (3% of the central incisors and 1.4% of the lateral incisors), whereas in the mandibular dentition, almost half of the central incisors and more than one-quarter of the lateral incisors showed no indication of shovel-shaping. Most of the mandibular incisors exhibited trace shovelling with very little range of expression.

The shovelling characteristic was best developed in the maxillary incisors with a higher incidence of occurrence and wider range of expression than in the mandibular incisors. Neither maxillary nor mandibular incisors demonstrated any occurrences of marked shovel-shaped, peg-shaped or barrel-shaped incisors.

Labial Marginal Ridge Development

A greater frequency of labial marginal ridging was found in the central incisors (Table 2) than in the laterals. They also demonstrated a high proportion of three-quarter and double shovel-shaped characteristics. All maxillary incisors exhibiting the three-quarter shovel-shaped characteristic had the mesial labial marginal ridge developed. Double shovelling was, generally, more common than three-quarter shovelling in the teeth studied.

Cingulum Form

Table 3 summarizes the data on the cingulum form characteristic. Most of the maxillary central incisors had a smooth cingulum (approximately 67%), while the alternative feature found was fingerlike projections incisally over the lingual surface from the cingulum. With the lateral incisors, the expressions of cingulum form ranged from a smooth cingulum and fingerlike projec-

TABLE 1

Shovel-Shaping of Incisors

	N	Absent	Trace	Semi-Shovel	Shovel-Shaped
Maxillary					
Central Incisor — Right	67	2 (3.0%)	7 (10.4%)	36 (53.7%)	22 (32.8%)
— Left	65	2 (3.1%)	7 (10.8%)	36 (55.4%)	20 (30.8%)
Lateral Incisor — Right	69	1 (1.4%)	8 (11.6%)	31 (44.9%)	29 (42.0%)
— Left	70	1 (1.4%)	10 (14.3%)	32 (45.7%)	27 (38.6%)
Mandibular					
Central Incisor — Right	75	36 (48.0%)	38 (50.7%)	1 (1.3%)	—
— Left	75	35 (46.7%)	39 (52.0%)	1 (1.3%)	—
Lateral Incisor — Right	76	20 (26.3%)	56 (73.7%)	—	—
— Left	77	21 (27.3%)	56 (72.7%)	—	—

TABLE 2

Labial Marginal Ridge Development of Maxillary Incisors

	N	Absent	Three-quarter Shovel	Double Shovel
Central Incisor — Right	67	26 (38.8%)	15 (22.4%)	26 (38.8%)
— Left	65	25 (38.5%)	14 (21.5%)	26 (40.0%)
Lateral Incisor — Right	69	35 (50.7%)	14 (20.3%)	20 (29.0%)
— Left	70	36 (51.5%)	12 (17.1%)	22 (31.4%)

TABLE 3

Cingulum Form of Maxillary Incisors

	N	Smooth	Fingerlike Projections	Cusp	Notched
Central Incisors — Right	68	46 (67.6%)	22 (32.4%)	—	—
— Left	64	42 (65.6%)	22 (34.4%)	—	—
Lateral Incisors — Right	63	31 (49.2%)	11 (17.5%)	6 (9.5%)	15 (23.8%)
— Left	59	26 (44.1%)	14 (23.7%)	6 (10.2%)	13 (22.0%)

TABLE 4

Expressions of Carabelli's Trait

	N	Smooth	Pit	Grooves	Small Cusp
First Molar — Right	48	27 (56.3%)	8 (16.7%)	11 (22.9%)	2 (4.2%)
— Left	43	28 (65.1%)	5 (11.6%)	8 (18.6%)	2 (4.7%)
Second Molar — Right	37	36 (97.3%)	1 (2.7%)	—	—
— Left	37	35 (94.6%)	2 (5.4%)	—	—
Third Molar — Right	9	9 (100.0%)	—	—	—
— Left	6	6 (100.0%)	—	—	—

tions to cusped and notched cingula, each showing relatively high frequencies of occurrence.

Carabelli's Trait

Table 4 shows the frequency distribution of Carabelli's trait in each of the permanent maxillary molars. It should be noted that the occurrence of many alterations of the lingual surface of the mesiolingual cusp ranging from a pit or groove to a definite, well-formed cusp, was recorded as an expression of this trait. Examination of the maxillary first permanent molars with intact mesiolingual surfaces, revealed a moderately high frequency of teeth totally lacking any expression of Carabelli's cusp, while the intermediate forms of this trait characterized by pits, grooves and small cusps, were present in low frequencies. There was an increase in the percentage of teeth with smooth surfaces as one proceeds distally with 96% of second molars and all of the third molars showing no expression of the trait.

Hypocone

The occlusal surface patterns of the maxillary molars suggest a distinct trend toward the reduction and loss of the hypocone in this Indian population (Table 5). The first permanent molars were predominantly four-cusped with either four well-developed cusps (4) or with a slightly reduced hypocone (4-). The hypocone was present, to some degree, (even as a very small cusplet on the distal border) in all maxillary first molars, but was well-developed on only about 63% of the teeth. The maxillary second and third molars showed a decreasing frequency of occurrence and relative size of the hypocone with more than half of the second and all of the third molars having either three main cusps (3) or a very slight expression of an additional cusplet (3+).

Tables 6 and 7 show the frequency distribution of the cusp numbers of mandibular premolars and molars. Mandibular first and second premolars, predominantly, were one- and two-cusped, respectively, with additional cusps being relatively frequent in both groups. Almost all of the permanent mandibular first molars (95%) were found to have five cusps. In contrast to this and in accordance with the concept of increasing morphological variability as one goes posteriorly within the molar group, the second molars showed a higher incidence of four cusps, a tendency towards the loss of the hypoconolid. There were not enough third molars in the sample from which any firm conclusions could be drawn.

Sixth Cusp (Tuberculum Sextum)

A rather striking feature in this study is the high incidence of the sixth cusp and its range of expression (Table 8). The first and second molar groups displayed similar expressions of this trait, with about 55% of all first and second mandibular molars presenting a cusp of variable size. This supernumerary cusp was present in addition to both the original five-cusped molars and those teeth in which the cusp number had been reduced to four. Again, the sample size of third molars was too small for analysis.

Seventh Cusp (Tuberculum Intermedium)

Table 9 shows the very low frequency of expression of the seventh cusp. Less than 15% of the first and second molars showed any characteristic of the trait, being only of a slight cusp. One unexpected cusp was observed on a mandibular left first molar.

Protostylid

The varying range of expression of the protostylid is seen in Table 10. Of the permanent mandibular teeth examined, about 22% of the first molars showed some degree of expression, with comparable results for the mandibular second molars. Very few definite cusps were observed.

Odontometrics

Odontometrics are presented in Tables 11 and 12 for the mesiodistal and buccolingual diameters of all maxillary and mandibular teeth studied. In comparing the maxillary measurements with their counterparts in the mandible, it was found that maxillary incisors, canines and first premolars were larger mesiodistally than the mandibular teeth, whereas the second premolars and molar region teeth of the mandibular dentition were larger in this dimension. With the buccolingual diameters, all maxillary teeth were larger than those of their related tooth in the mandible.

TABLE 5

Maxillary Molar Patterns

		N	4	4-	3+	3
First Molar	— Right	39	24 (61.5%)	14 (35.9%)	1 (2.6%)	—
	— Left	40	26 (65.0%)	13 (32.5%)	1 (2.5%)	—
Second Molar	— Right	31	3 (9.7%)	11 (35.5%)	11 (35.5%)	6 (19.4%)
	— Left	37	3 (8.1%)	14 (37.8%)	12 (32.4%)	8 (21.6%)
Third Molar	— Right	4	—	—	3 (75.0%)	1 (25.0%)
	— Left	8	—	—	6 (75.0%)	2 (25.0%)

TABLE 6

Mandibular Premolar Cusp Number

		N	One Cusp	Two Cusps	Three Cusps
First Premolar	— Right	66	51 (77.3%)	15 (22.7%)	—
	— Left	68	47 (69.1%)	21 (30.9%)	—
Second Premolar	— Right	54	—	44 (81.5%)	10 (18.5%)
	— Left	60	—	48 (80.0%)	12 (20.0%)

TABLE 7

Mandibular Molar Cusp Number

		N	Four Cusps	Five Cusps
Permanent First Molar	— Right	31	2 (6.5%)	29 (93.5%)
	— Left	34	1 (2.9%)	33 (97.1%)
Permanent Second Molar	— Right	18	12 (66.7%)	6 (33.3%)
	— Left	14	14 (100.0%)	—
Permanent Third Molar	— Right	4	2 (50.0%)	2 (50.0%)
	— Left	1	—	1 (100.0%)

TABLE 8

Expressions of Sixth Cusp

		N	Absent	Slight Cusp	Small Cusp	Medium Cusp	Large Cusp
Permanent First Molar	— Right	15	7 (46.7%)	2 (13.3%)	2 (13.3%)	4 (26.7%)	—
	— Left	19	12 (63.2%)	3 (15.8%)	1 (5.3%)	3 (15.8%)	—
Permanent Second Molar	— Right	12	5 (41.7%)	2 (16.7%)	1 (8.3%)	3 (25.0%)	1 (8.3%)
	— Left	10	7 (70.0%)	1 (10.0%)	—	—	1 (10.0%)
Permanent Third Molar	— Right	1	1 (100.0%)	—	—	—	—
	— Left	1	—	—	1 (100.0%)	—	—

The mesiodistal and buccolingual diameters were analyzed statistically for sexual differences within each group. When the t-scores were computed for sexual dimorphism, a large number of highly sigificant differences were found, the greatest number being in the buccolingual measurements.

The males had a mean maxillary mesiodistal crown diameter statistically significantly larger than the females for the right and left canines, and right first premolars. Mandibular mesiodistal crown diameters were larger for the males than the females with a 99% significance level for the right and left canines, left second premolars and right second molar and with a 95% significance level for the left lateral incisor, right first premolar and left first and second molar.

More sexual dimorphism was apparent with respect to the buccolingual diameters in which males consistently had larger measurements in such maxillary teeth as right and left central incisors and canines (with 99% significance level) and right and left first premolars and second molars and right second premolars (with 95% significance level). With the mandibular teeth, almost all teeth showed higher mean buccolingual diameters for molars (with 99% significance level), except for the right and left second premolars and third molars, and right first molars.

DISCUSSION

Comparison of our results with other studies of Indian groups is necessarily reduced because of differing criteria and standards used in scoring the traits, the failure of many studies to report some of the various expressions of a particular trait, and small sample sizes. Similarities of morphological dental traits and odontometric measurements between different populations appear to indicate biological relationship. This is based on the assumption that these features are genetically determined (Moorrees, 1957, 1961) and that groups sharing more inherited traits are biologically more closely related than groups with fewer shared traits (Simpson, 1961). Since little is known about the mode of inheritance of dental traits, environmental factors are suspected to influence the results, and the morphological features tend to have wide variances (Mayhall, 1976), few firm conclusions can be made based on comparisons of phenotypic characters alone. Further studies, including analysis of pedigrees, are needed. For these reasons, only postulations of the relationship between groups can be made.

The presence and high frequency of the shovel-shaped characteristic found in the incisors of this group of Waorani Indians resembles that of other Mongoloid populations (Hrdlicka, 1920). When grouping semi-shovel and shovel-shaped characteristics together, the Waorani Indians demonstrated occurrences of over 85% in the maxillary central and lateral incisors examined. With the Queckchi Indians of Guatemala, expression of the shovel-shaped characteristics to any degree (trace, semi or marked) was much less prevalent (only 40-50% of the maxillary incisors observed) (Escobar et al., 1977). In contrast to this, all maxillary and mandibular incisors of the Peruvian Indians (Goaz and Miller, 1966) and all maxillary incisors of the Yanomama Indians (Brewer-Carias, et al., 1976) of Southern Venezuela and Northern Brazil and the Pewenche Indians of Chile (Rothhammer et al., 1968), displayed some form of shovel-shaping, thus yielding results similar to those of the present study. The differences that exist between these groups are primarily in the prevalence of the various expressions. The Waorani Indians mainly had semi-shoveled incisors whereas the Yanomama's were mostly shovel-shaped or marked. Some degree of genetic affiliation seems to be indicated between these Indian groups and other Mongoloid populations, based on the common high incidence of incisor shovelling.

Variants of incisor morphology such as peg- and barrel-shaped teeth are usually associated with Mongoloid populations (Dahlberg, 1949), though none were found in the Waorani Indians examined. Comparatively, very low frequencies of the characteristic peg- and shovel-shaping were found in studies of Pewenche Indians of Chile (0.04%) (Rothhammer et al., 1968), again suggesting the possibility of population similarities.

The distribution of the double and three-quarter shovel-shape characteristic for the maxillary central incisors of the Waorani Indians seems to resemble the relatively high frequency of marginal ridging on the labial surface of incisors of the Peruvian Indians (Goaz and Miller, 1966) and is in line with findings of other Mongoloid populations (Dahlberg, 1947; Snyder, 1963).

Double shovelling was underrepresented in the maxillary lateral incisors of the Waorani Indians as compared to observation of the Peruvian Indians (Goaz and Miller, 1966.) In cases of three-quarter shovelling in the Waorani Indians, the labial ridge was predominantly in the mesial surface, which is consistent with previous studies by Snyder et al. (1969) and Goaz and Miller (1966).

None of the other studies of South American Indian dental morphology has included an analysis or description of cingulum form for the incisors. It should be noted here, however, that we found the majority of incisors to have smooth cingula. The wider range of expression demonstrated in the lateral incisor as compared to the centrals is in accordance with the field concept described by Dahlberg (1945).

A low frequency of Carabelli's cusp has generally been regarded as a diagnostic racial trait for Mongoloid populations (Dahlberg, 1949; Pederson, 1949). Carabelli's trait in its various expressions of pit, groove and definite cusp, on the first molar, demonstrated a relatively low incidence in the Waorani Indians when compared to other Indian groups of Central and South American, such as the Peruvians (Goaz, 1966), Tarahumara (Snyder et al., 1969), Yanomama (Brewer-Carias et al., 1976) and Queckchi (Escobar et al., 1977). The frequency of this trait in the Waorani Indians is lower than average for those described by Dahlberg (1963) for other American Indian groups. This may suggest a higher degree of isolation and a greater resistance to admixture of the Waorani Indians with outsiders than has occurred with some of the other Indian tribes. The homogeneity in the expression of this trait suggests the hypothesis that the Waorani Indians may be the descendants of the same people who occupied the area before them.

The expression of the hypocone was quite consistent among most of the Central and South American Indian tribes of previous studies; Tarahumara (Snyder et al., 1969), New Mexican (Nelson, 1938), Yanomama (Brewer-Carias et al., 1976) and Peruvian (Goaz and Miller, 1966) as well as this present study. The cusp formula of the Indian maxillary molar has deviated from the original 4-4-4 formula suggested for ancient man (Nelson, 1938) towards a reduced formula 4-3-3. This trend was quite apparent in the Waorani Indians and the reduced forms were more prevalent than in the other comparable populations. This morphological trend toward a reduction in the number of cusps is considered to be a simplification of basic characters in evolution (Moorrees, 1961). A tendency to exhibit fewer cusps, an advanced characteristic observed in the mandibular posterior teeth of the Waorani Indians, is consistent with findings of other Indian tribes of Central and South America (Goaz, 1966; Escobar et al., 1977). This is in accordance, again, with the field concept of increasing morphological variability and loss of "control" of the expression of a trait as one goes posteriorly within a tooth group, in this case, the molars.

One unexpected finding in this study is the high incidence of expression of the sixth cusp on mandibular molars of Waorani Indians. It is significantly more prevalent than in Peruvian Indians (Goaz, 1966), but consistent with the Yanomama Indians (Brewer-Carias et al., 1976). Although the literature is limited concerning this trait, relatively high incidences were found previously in American Indian and other Mongoloid groups with a greater expression in the third molars as compared with the first and second (Hellman, 1928). The present study shows no indication of this trend. The comparatively higher prevalence of this cusp in Waorani Indians may, to some extent, be accounted for by the definition of a cusp and the standards used, but even when allowance is made for variation in scoring procedures, the incidence is still relatively high. The retention of this additional cusp thus increases the cusp number of the mandibular molars and tends to indicate a more conservative occlusal surface which might suggest that the environment the Waorani Indians inhabit was relatively undisturbed and that their isolated existence with presumed inbreeding has led to the retention of this presumably primitive characteristic.

Although no previous studies of Central or South American Indians included an analysis of the seventh cusp, comparison with other Mongoloid groups indicates mixed findings. The low incidence of expression of C7 in the Waorani Indians is supported by one study of Mongoloids (Turner, 1967) and contradicted by others (Hellman, 1928; Suzuki and Sakai, 1956; Mayhall, 1980).

The frequency distribution of the protostylid trait lies somewhere between a higher prevalence

TABLE 9

Expressions of Seventh Cusp

		N	Absent	Slight Cusp	Small Cusp	Medium Cusp	Large Cusp
Permanent First Molar	— Right	31	25 (80.6%)	6 (19.4%)	—	—	—
	— Left	33	29 (87.9%)	3 (9.1%)	—	—	1 (3.0%)
Permanent Second Molar	— Right	22	21 (95.5%)	1 (4.5%)	—	—	—
	— Left	19	17 (89.5%)	2 (10.5%)	—	—	—
Permanent Third Molar	— Right	3	3 (100.0%)	—	—	—	—
	— Left	4	4 (100.0%)	—	—	—	—

TABLE 10

Expressions of the Protostylid

		N	Absent	Pit	Groove	Small Cusp
Permanent First Molar	— Right	32	23 (71.9%)	3 (9.4%)	4 (12.5%)	2 (6.3%)
	— Left	33	28 (84.8%)	2 (6.1%)	3 (9.1%)	—
Permanent Second Molar	— Right	24	21 (87.5%)	1 (4.2%)	2 (8.3%)	—
	— Left	21	14 (66.7%)	3 (14.3%)	4 (19.0%)	—
Permanent Third Molar	— Right	2	2 (100.0%)	—	—	—
	— Left	3	3 (100.0%)	—	—	—

of Tarahumara (Snyder et al., 1969) and lower prevalence of Queckchi Indians (Escobar, 1977). All comparable studies of Central and South American Indian dentition have demonstrated a low incidence of this characteristic. Protostylid, being an ancestral trait found in some fossil forms, appears very rarely in modern dentitions studied to date and, therefore, may have some significance in evolutionary trends. Dahlberg has stated that the protostylid is manifested fully in modern man only when particular gene combinations occur that allow expression of this ancestral trait (Dahlberg, 1950).

The mesiodistal and buccolingual diameters of the maxillary dentition of the Waorani Indians were generally larger than the comparable Peruvian Indians (Goaz and Miller, 1966). The greatest difference was 1.18 mm between the buccolingual diameter of the maxillary first premolars of these two Indian populations. Similarly with the mandibular dentition, the Waorani teeth were generally larger mesiodistally and buccolingually, but to a lesser degree than in the maxillary dentition.

A relatively small difference between the average mesiodistal crown diameter of the maxillary central and lateral incisors was found in the Waorani Indians studied (1.14 mm), a characteristic of Mongoloid populations (Moorrees, 1957).

The sexual difference observed for many of the maxillary and mandibular mesiodistal and buccolingual diameters is consistent with findings reported in Mongoloid and other populations (Moorrees, 1957; Mayhall, 1980).

The Waorani Indians were found to have many of the characteristics previously recognized as typically Mongoloid, such as high incidence of shovel-shaping and labial marginal ridging in incisors, low incidence of Carabelli's trait, sexual dimorphism in the mesiodistal and buccolingual measurements and a small difference in mesiodistal diameter between maxillary central and lateral incisors (Moorrees, 1961). In comparison to other Central and South American Indian groups, the Waorani Indians were found to be similar in some morphological traits to the Pewence Indians of Chile, the Peruvian Indians, New Mexican Indians, Tarahumara tribe of North Western Mexico and the Yanamama of Southern Venezuela and Northern Brazil.

The similarities found between the Waorani Indians of Ecuador and other Central and South American Indian groups seem to indicate some

TABLE II

Mesiodistal Diameters of the Maxillary and Mandibular Teeth

TOOTH		MALES			FEMALES					
Maxillary		Number of Teeth	Mean	Standard Deviation	Number of Teeth	Mean	Standard Deviation	T-scores Males-Females	d.f.	Significance
Central Incisor	— right	29	9.08	0.387	22	8.88	0.452	1.70	49	
	— left	26	8.95	0.438	26	8.76	0.429	1.63	50	
Lateral Incisor	— right	29	7.95	0.621	27	7.74	0.542	1.37	54	
	— left	29	7.80	0.648	24	7.64	0.559	0.92	51	
Canine	— right	28	8.66	0.475	22	8.15	0.366	4.20	48	**
	— left	28	8.74	0.339	21	8.20	0.348	5.44	47	**
First Premolar	— right	17	7.99	0.364	19	7.59	0.353	3.32	34	**
	— left	12	8.03	0.450	12	7.81	0.325	1.40	22	
Second Premolar	— right	19	7.45	0.487	17	7.24	0.495	1.27	34	
	— left	13	7.71	0.562	8	7.38	0.567	1.29	19	
First Molar	— right	12	11.28	0.537	11	11.07	0.479	0.99	21	
	— left	9	11.13	0.431	13	10.83	0.567	1.33	20	
Second Molar	— right	8	10.89	0.516	10	10.46	0.897	1.20	16	
	— left	12	10.51	0.630	10	10.39	0.600	0.47	20	
Third Molar	— right	2	9.86	0.290	1	9.13	0.000	2.04	1	
	— left	0	—	—	0	—	—	—	—	
Mandibular										
Central Incisor	— right	26	6.92	0.542	29	6.38	0.320	4.43	40	**
	— left	29	6.93	0.519	26	6.38	0.374	4.46	53	**
Lateral Incisor	— right	28	7.15	0.495	31	6.80	0.320	3.20	45	**
	— left	28	7.23	0.526	22	6.79	0.309	3.71	45	**
Canine	— right	27	8.99	0.552	25	8.12	0.452	6.23	50	**
	— left	28	9.01	0.614	18	8.12	0.444	5.35	44	**
First Premolar	— right	30	8.98	0.610	23	8.41	0.346	4.33	47	**
	— left	34	9.10	0.512	26	8.67	0.475	3.30	58	**
Second Premolar	— right	26	9.36	0.634	18	9.13	0.469	1.34	42	
	— left	29	9.52	0.564	23	9.32	0.580	1.26	50	
First Molar	— right	15	11.57	0.438	10	11.25	0.417	1.87	23	
	— left	11	11.56	0.482	14	11.13	0.389	2.49	23	*
Second Molar	— right	8	11.70	0.530	8	10.64	0.324	4.82	14	**
	— left	8	11.35	0.589	8	10.61	0.381	2.96	14	**
Third Molar	— right	2	11.73	0.064	2	11.19	0.410	1.82	2	
	— left	2	11.28	0.170	1	11.59	0.000	-1.49	1	

*Significant at 95 percent level of confidence
**Significant at 99 percent level of confidence

TABLE 12

Buccolingual Diameters of the Maxillary and Mandibular Teeth

TOOTH		MALES			FEMALES					
Maxillary		Number of Teeth	Mean	Standard Deviation	Number of Teeth	Mean	Standard Deviation	T-scores Males-Females	d.f.	Significance
Central Incisor	— right	33	8.44	0.513	29	8.03	0.381	3.57	60	**
	— left	32	8.45	0.511	27	8.06	0.358	3.48	55	**
Lateral Incisor	— right	29	7.35	0.536	26	7.15	0.467	1.51	53	
	— left	25	7.40	0.532	21	7.20	0.341	1.54	41	
Canine	— right	25	9.67	0.751	22	9.18	0.373	2.93	36	**
	— left	28	9.80	0.612	22	9.13	0.564	3.99	48	**
First Premolar	— right	21	11.18	0.632	25	10.76	0.346	2.74	30	*
	— left	22	11.17	0.619	17	10.73	0.493	2.38	37	*
Second Premolar	— right	24	10.88	0.543	22	10.52	0.428	2.47	44	*
	— left	18	10.91	0.818	17	10.48	0.563	1.82	33	
First Molar	— right	12	12.28	0.909	16	11.97	0.546	1.12	26	
	— left	11	12.40	0.839	19	11.93	0.598	1.77	28	
Second Molar	— right	11	12.64	0.733	10	12.00	0.489	2.32	19	*
	— left	12	12.67	0.836	10	11.77	0.754	2.60	20	*
Third Molar	— right	1	12.52	0.000	1	11.52	0.000	0.00	0	
	— left	1	12.17	—	0	—	—	—	—	
Mandibular										
Central Incisor	— right	22	5.45	0.377	23	5.53	0.350	-0.73	43	
	— left	24	5.44	0.410	24	5.53	0.304	-0.90	46	
Lateral Incisor	— right	26	6.34	0.389	24	6.20	0.334	1.36	48	
	— left	26	6.51	0.372	31	6.25	0.394	2.51	55	*
Canine	— right	32	7.45	0.446	27	6.94	0.407	4.48	57	**
	— left	33	7.58	0.493	26	6.90	0.378	5.75	57	**
First Premolar	— right	31	7.74	0.431	25	7.46	0.420	2.47	54	*
	— left	35	7.72	0.490	28	7.56	0.486	1.30	61	
Second Premolar	— right	27	7.98	0.690	19	7.81	0.479	0.94	44	
	— left	32	8.12	0.582	24	7.86	0.514	1.75	54	**
First Molar	— right	12	11.99	0.498	9	11.36	0.427	3.02	19	
	— left	13	12.13	0.454	14	11.67	0.426	2.73	25	*
Second Molar	— right	10	12.20	0.559	8	10.79	0.591	5.20	16	**
	— left	6	11.71	0.929	11	10.78	0.662	2.38	15	*
Third Molar	— right	4	11.40	0.540	1	10.23	0.000	1.94	3	
	— left	2	11.69	0.049	1	11.24	0.000	7.34	1	

*Significant at 95 percent level of confidence
**Significant at 99 percent level of confidence

genetic or biological relationship between them. It has been suggested by Moorrees (1961) that there may be a basic pattern of dental traits of Mongoloids which is subject to modification and variability of expression amongst the differing populations. Therefore, the dentition of individuals could be used for differentiating between populations within the Mongoloid race (Moorrees, 1961).

The morphological traits of the Waorani Indians studied seem to be consistent with those of the typical Mongoloid population more so than in comparison with the individual Indian groups. The Waorani were not consistently similar to any of the Central or South American Indian groups previously studied, including those populations living in regions surrounding the Waorani territory and in close proximity to them, thus suggesting that the Waorani Indians may be an isolated group with little or no admixture with outside groups and that they are possibly the descendents of the prehistoric population that occupied the area before them.

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A Critique of Indicial Methods of Determining the Sex of the Innominate

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KEY WORDS Skeletal Sexing • Indicial Sex Determination

ABSTRACT A number of researchers have suggested that indicial sexing of the hip bone is a useful method for skeletal remains which are fragmented or which do not exhibit obvious visual sex differences. A set of three indices are examined here by analyzing the adult hip bones from the Kleinburg and Ossossané Ossuaries. Indicial sex determinations are compared to morphological sex assessments to identify the level of agreement. If correspondence between methods is accepted as being analogous to accuracy then the results are not encouraging. The indicial methods fall far short of the claims made for them and their use is not recommended for late prehistoric and early historic Iroquoian skeletal populations.

RESUME Un nombre de chercheurs one suggéré l'examen de l'os de la hanche comme méthode utile pour déterminer le sexe de squelettes fragmentaires ou ne montrant pas de différences sexuelles visibles évidentes. On examinera ici un ensemble de trois indices à partir d'os de la hanche adulte venant des ossuaires de Kleinburg et d'Ossossané. Les indices servant à déterminer le sexe sont comparés aux évaluations morphologiques du sexe afin d'identifier leur niveau de conformité. Si l'on considère que la concordance entre les méthodes est synonyme d'exactitude, les résultats ne sont alors pas très encourageants. Les méthodes basées sur des indices ne répondent pas à ce qu'on en attend et leur emploi n'est pas recommandé pour l'étude des squelettes iroquois de la fin de l'époque préhistorique et du début de l'époque historique.

A fundamental concern to osteologists involves the accurate determination of the sex of skeletons. These determinations, however, may sometimes be of dubious reliability as a result of ambiguous morphological features or fragmented skeletal material. To help obviate these problems, some researchers have proposed the use of indices which are designed to reduce ambiguity and bias as well as be applicable in instances where complete skeletons are unavailable for analysis (cf. Olivier and Demoulin, 1978). Most such indices use measurements of the innominate since this bone displays, in the component anatomical parts, the greatest absolute and relative differences between males and females.

This paper examines three of these indices: those based on measurements of the ischium and pubis (Schultz, 1930), the sciatic notch and acetabulum (Kelley, 1979a) and the pubis and acetabulum (Breathnach, 1965). These three indices have been selected because, on an *a priori* basis, they appear to have considerable potential for generating accurate sex determinations. In addition, tests have indicated high rates of accuracy for the ischium-pubic index (Washburn, 1948, 1949; Hanna and Washburn, 1953) as well as for the sciatic notch-acetabulum index (Kelley, 1979a).

TABLE 1

Summary Statistics for Component Measurements

Sample	Measurement (mm)			
Kleinburg	Pubis Length	Ischium Length	Sciatic Notch Width	Acetabulum Height
X	99.27	91.62	50.05	52.51
s	6.60	5.71	6.24	2.69
N	42	114	113	42
S_k	-.79	-.20	-.70	-.55
K_s	+1.23	-.16	-.14	+.04
Ossossané				
9	95.54	93.38	48.86	53.89
s	8.54	5.96	5.73	2.89
N	24	47	49	84
S_k	+.54	-.81	-.07	-.11
K_s	-.83	+.07	-.17	-.37

MATERIALS AND METHODS

The indices are evaluated by examination of the adult hip bones from the Kleinburg and Ossossané Ossuaries. These are both Huron ossuaries in Ontario with the Kleinburg remains dated to *circa* A.D. 1600 (F.J. Melbye, personal communication) while the Ossossané skeletal material represents a Feast of the Dead ceremony held in A.D. 1636 (Kidd, 1953). Pfeiffer (1974) notes the presence of at least 561 individuals in the Kleinburg Ossuary while Katzenberg and White (1979) propose 681 as the minimum number of individuals for the Ossossané Ossuary. There are at least 270 and 559 adults in the Kleinburg and Ossossané Ossuaries, respectively.

Only four measurements are needed to calculate the indices. These include pubis and ischium lengths, as described by Schultz (1930) and Washburn (1948)[3], and sciatic notch width and acetabulum height in the manner described by Kelley (1979a).

Measurements were taken to the nearest .5 mm with a GPM 200 mm sliding caliper. Accuracy was tested by a re-evaluation of a sample of 50 measurements with one week intervening between observation dates. This indicated a measurement error of just under 3%.

Morphological sex assessments were made concurrently but independent of the metric determinations. Five quasi-discrete features were used to assign sex. These include the ventral arc, subpubic concavity and medial aspect of the *os pubis* (Phenice, 1969) parturition scars on the dorsal *os pubis* (Suchey et al., 1979; Kelley, 1979b) and in the pre-auricular groove (Houghton, 1974; Kelley, 1979b).

RESULTS

Basic statistics of the measurements are given in Table 1. The distributions of each measurement, in each ossuary, were tested with the object of determining how closely they approximate the normal distribution. To this end, coefficients of skewness and kurtosis (Simpson, et al., 1960) are given in Table 1. For all measurements it can be seen that the distributions fall within acceptable limits for skewness and height.

Table 2 presents the summary statistics for the indices as well as the results derived from Student's t-tests (Simpson et al., 1960) applied to the Kleinburg-Ossossané indicial means and the means of previously published skeletal series.

[3]In the original publications, there is a difference in the manner of determining pubis length between the ischium-pubic and pubic-acetabulum indices. Schultz (1930) and Washburn (1948) use a point near the centre of the acetabulum as one of the landmarks to identify length. On the other hand, Breathnach (1965) uses a point on the anterior margin of the acetabulum in the same plane as the point on the pubic symphysis. For purposes of standardization, we have modified Breathnach's technique to conform with the more commonly used method of Schultz.

TABLE 2

Summary statistics of the indices and comparisons of the Kleinburg and Ossossané means with published data.

	Ischium-Pubic Index	Sciatic Notch-Acetabulum Index	Pubic-Acetabulum Index
Kleinburg			
X	110.21	97.78	189.29
s	8.56	12.87	12.84
N	42	35	42
Ossossané			
X	103.69	91.08	179.01
s	8.03	11.88	16.16
N	24	44	23

t-test scores

	Ischium-Pubic Index		Sciatic Notch-Acetabulum Index	
	Eskimo*		Amerindian**	
	Male	Female	Male	Female
Kleinburg	27.95	10.85	11.52	.84†
Ossossané	19.23	4.34	8.60	3.07

*Comparative data from Hanna and Washburn (1953)
**Comparative data from Kelley (1979a)
†.4<P<.5 (P<.01 for all other t-scores)

The t-test results indicate that there are highly significant differences between the indicial means of the published test series and the Kleinburg-Ossossané populations for all but one of the combinations. Therefore, in order to evaluate the indicial sex determinations, *vis à vis* the morphological sex determinations, it is necessary to adjust the published male-female cutoff points. Failure to do so would give markedly biased results. In this regard, Saunders (1974) has observed that the published cutoff values for the ischium-pubic index do not give useful results for the Kleinburg hip bones.

New cutoff values are derived by calculating the mean for an index and using the range of plus or minus one index unit around the mean as an area of overlap. Values above this, for all three indices, constitute the range for females while the male range lies below this region of overlap. The cutoff values derived for the Kleinburg and Ossossané hip bones are given in Table 3.

The sex determinations given by the indices were then compared with the determinations based on the morphological criteria. The rate of agreement between methods is presented in Table 3. Here it can be seen that the agreement of the two approaches is considerably higher for the Ossossané hip bones than those from the Kleinburg collection. The ischium-pubic index provides the highest level of correspondence for the Kleinburg hip bones, and is followed by the sciatic notch-acetabulum and pubic-acetabulum indices. By contrast, the levels of agreement for the three indices, when applied to the Ossossané hip bones, are approximately equal with the pubic-acetabulum index having only a slight edge over the other two.

DISCUSSION

Following Hanna and Washburn (1953) the level of agreement between methods is taken to be analogous to the degree of accuracy of the sex determinations. When this is done it is clear that

TABLE 3

Cutoff values and rates of agreement between indicial and visual inspection sex determination methods.

Cutoff Values	Ischium-Pubic Index	Sciatic Notch-Acetabulum Index	Pubic-Acetabulum Index
Kleinburg			
Male	109	97	188
Female	111	99	190
Indet.	109.1-110.1	97.1-98.9	188.1-189.9
Ossossané			
Male	102	90	178
Female	104	92	180
Indet.	102.1-103.9	90.1-91.9	178.1-179.9
Concordance of methods			
Kleinburg			
Agree	30	22	24
Disagree	8	10	16
Indet.	4	3	2
% Agree	79	69	60
Ossossané			
Agree	18	33	17
Disagree	4	9	5
Indet.	2	2	1
% Agree	82	79	77
Total			
Agree	48	55	41
Disagree	12	19	21
% Agree	80	74	66

the indicial methods fall short of the claims made for them. Part of this can be ascribed to some inevitable inaccuracies of the morphological sex determinations as well as measurement error. However, these factors cannot entirely account for the disparity between the present results and the initial predictions of accuracy.

Part of the problem may arise from the fact that the amount of sexual dimorphism can vary markedly between different biological populations (Hamilton, 1975). In this regard, it is interesting to note that, despite the biological affinities of these two skeletal populations, the indices give better results for the Ossossané remains than for the Kleinburg remains. Therefore, it is possible that among these two populations there are different degrees of dimorphism.

In spite of the foregoing, the major problem very likely lies in the nature of the measurements (Stewart, 1954). Each pooled sex series of measurements are distributed as normal curves. Beyond this, the distribution of all cases of the indices also approximate normal curves. Since a bimodal distribution is not generated, although it is required for clearly assigning sex, it is not surprising that the results fall short of a level of accuracy required to give confidence in these methods.

CONCLUSIONS

The results of indicial sexing of the hip bones from the Kleinburg and Ossossané Ossuaries have a relatively low level of correspondence with the results given by morphological sex determinations. Therefore, it is concluded that, at least for late prehistoric and early historic Iroquoian populations, the three indices examined here should be used only when no other methods are available and then only with caution.

ACKNOWLEDGEMENTS

We wish to express our thanks to Dr. F.J. Melbye, Department of Anthropology, University of Toronto, for permission to analyze materials curated by him. Gratitude is also due to Gary M. Heathcote, M. Anne Katzenberg and Eduarda L. Sousa, Department of Anthropology, Erindale College, University of Toronto, for their comments on the design of the study and the manuscript.

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ABSTRACTS OF PAPERS PRESENTED AT THE EIGHTH ANNUAL MEETING OF THE CANADIAN ASSOCIATION FOR PHYSICAL ANTHROPOLOGY/ L'ASSOCIATION POUR L'ANTHROPOLOGIE PHYSIQUE AU CANADA OTTAWA, ONTARIO, NOVEMBER 6-9, 1980

SKELETAL INDICATIONS OF HEALTH, LIFESTYLE, AND DIVISION OF LABOR IN PREHISTORIC HUMAN POPULATIONS FROM SOUTH COASTAL BRITISH COLUMBIA

OWEN BEATTIE
University of Alberta

An analysis of 115 prehistoric human skeletons from the Gulf of Georgia region of British Columbia revealed a series of skeletal abnormalities suggestive of a very physically demanding lifestyle. Degenerative joint disease (DJD) is discussed, and changes in lifestyle and the division of labor are demonstrated over the 4,000 year time period spanned by the human remains. The pattern and location of DJD is used to justify these interpretations, particularly the differences observed between males of the earlier and more recent time periods. A very early case (ca. 1000 B.C.) of rheumatoid arthritis is also presented.

RELATIONSHIP BETWEEN SOCIOCULTURAL VARIABLES AND DIFFERENTIAL PHYSIOPATHOLOGICAL AGING

DIANE BERTHELETTE
University of Montreal

Aging is a complex phenomenon involving interacting morphological and physiological alterations. Many of these modifications develop slowly. They are associated with the diminution of physiological performances and an increase of various diseases. Many studies indicate that the nature and the speed of these processes vary considerably between individuals.

Francis Forest at the University of Montreal has developed an index which estimates differential physiopathological aging. Using physiological, morphological and diagnostic data from the Sorel-Tracy sample, this index has been computed for almost 3,000 individuals. In this way we can evaluate the impact of environmental factors on the variation of such an index.

The results suggest that of the many variables used to assess the multifaceted effect of the environment on the aging process, some were found to be more important such as:

cigarette smoking, alcohol consumption, use of medication, physical activity, some socio-economic conditions, heredity, stress at work, etc.. We wish to describe in this paper, the relationship between those environmental variables and the variation of differential physiopathological aging.

REPRODUCTIVE PERFORMANCE OF THE ANGLICAN PARISH OF FOGO: THE BIOCULTURAL IMPLICATIONS

MARIAN BINKLEY
University of British Columbia

Marital histories and reproductive performance of 1,002 couples married within the Anglican Parish of Fogo, Newfoundland, from 1850 to 1949 were investigated. An examination of the components of reproductive performance revealed that over the study period only 30% of all children born within the population actually took part in the breeding structure of the parish. Emigration of young adults, due to lack of opportunities in the fishery, was identified as the major factor promoting this situation. In view of the results obtained by Crow's Index of Total Selection, the biocultural implications of the fertility differentials seen among the Anglicans of Fogo will be discussed. The economic restraints of the fishing economy are viewed as the major cultural factor influencing the potential for microevolution within the population.

THE MATING PREFERENCES IN MACACA SYLVANUS OF GIBRALTAR

FRANCES BURTON and LAETITIA GODWIN
University of Toronto

The purpose of this study is to ascertain if there are stable mating preferences in the monkeys of Gibraltar, if consort pairs formed in one year perpetuate, and if females, although permitting copulation by other males during early estrus, mate preferentially with one particular male at the height of assumed fertility.

The hierarchical structure of one group has been truncated recently by the loss of the fully mature breeding males. Prior to this historical event, a degree of selection for a particular male was observed in both groups. Moreover, this selection appeared to be repetitive, the older females typically mating with the older males, even when they had passed their prime.

Known degrees of genetic relatedness were used to evaluate their function as an inhibitory mechanism against close familial matings. Since the establishment of the macaque colony on Gibraltar, there have been few incidences of birth anomalies, despite the fact that it is a small and genetically isolated community.

However, this study demonstrates the increase of genetic homogeneity in one of the two local groups, and an increase in birth anomaly is foreseen. No mechanism either enhancing or inhibiting mate selection along genetic lines was found.

AN EARLY HUMAN SKELETON FROM GORE CREEK, BRITISH COLUMBIA

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British Columbia Ministry of Environment
JAMES C. HAGGARTY
British Columbia Provincial Museum
MORLEY ELDRIDGE
University of Victoria

Early human skeletal remains in Canada are rare and leave much to be desired in terms of their state of preservation and completeness, in the certainty of their temporal contexts, and in their potential for bioarchaeological inference. We report the well-represented postcranial skeleton, with hyoid bone, of a young adult male, discovered in southcentral British Columbia in 1975. In situ parts were recorded below a volcanic ash lens that has been identified with the Mount Mazama eruption of 6,600 BP, and the right humerus yielded a collagen date of 8,250 ± 115 C-14 years. The collagen date, enhanced by isotopic fractionation analysis, together with a well-defined geochronological context, makes the Gore Creek find the oldest, well-dated, most complete individual currently available for the Pacific Northwest. Preliminary morphological and metric considerations suggest that the individual was of a tall-linear body build, a form usually associated with an inland hunting adaptation. This finding might be used to support C.E. Borden's (1979) construct of a Protowestern cultural tradition populating the North Pacific region from the south during the Late Paleo-Indian Period.

Literature Cited: Borden, C.E. 1979 Peopling and early cultures of the Pacific Northwest. Science, 203:963-971.

PRINCIPAL-COMPONENTS ANALYSIS: ITS USE FOR MULTIPLE INFORMATION REDUCTION IN A STUDY OF TWO REPETITIVE SIMPLE MOTOR TASKS

YVON DESJARDINS
University of Montreal

Sometimes in a study of phenomena which take the form of a multiple repetitive task, it is rather difficult to synthesize the whole phenomena in a single dimension. But there is one method in particular which can help to overcome that difficulty, principal-components analysis. We applied that method to two simple repetitive tests in hopes to draw one or two dimensions from the results of the tests. We found a dimension of general ability and a dimension of bilateral asymmetry on manual performance for the two tests.

A CRITIQUE OF CURRENT SOCIOBIOLOGICAL STUDIES OF MACACA RADIATA

GEORGE ELLIS
University of Montreal

(Abstract not submitted)

NOTES ON SOME TECHNIQUES OF BUTCHERING HUMANS IN THE HIGHLANDS OF VITI LEVU, FIJI

C. E. EYMAN
University of Calgary

(Abstract not submitted)

SELECTED FEATURES OF THE DEMOGRAPHY OF JAPANESE MONKEYS

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HAROLD GOUZOULES
University of Wisconsin
SARAH GOUZOULES
University of Chicago

The demographic data from the Arashiyama West group of Japanese macaques, 1972-1979, are used to explore several problematic areas in the study of primate life-histories. These include sex ratios at birth; different male and female mortality and migration patterns; effects of provisioning on population growth; and the relation of age, rank and kinship to reproductive success in females.

One of the unique features of the Arashiyama West group is that prior to their arrival at LaMoca, Texas, in 1972, they were studied by primatologists in Japan for 18 years. Koyama et al. (1975) have published and communicated to us their findings on the population dynamics of these monkeys from 1954-1972. Thus we are able to make some comparisons between past and present demographic patterns. There have been some changes in the natality, mortality and migration patterns, which will be delineated in the presentation. However, after an initial period of adjustment, many demographic trends returned to patterns similar to those observed in Japan.

TESTING A THEORETICAL MODEL ABOUT STRESS AND HEALTH AT WORK

FRANCIS FOREST and URSULA FOREST-STREIT
University of Montreal

Some teams working on the problem of stress and health in different professional situations adopt a rather empirical approach, while other teams give much more importance to theoretical aspects of the topic. Having several data banks from different origins at our disposal, the members of our team decided to investigate several theoretical models concerning the relations between stress and health at work, and to test, with the help of these data banks, one of the most complete of these models. We first met the difficulty of finding the proper indicators in our bank for the different concepts implied in the model. This step is now overcome, and we expect results very soon.

PHYSIOPATHOLOGICAL AGING AMONG A FRENCH CANADIAN FEMALE SAMPLE

GLORIA FRAPPIER
University of Montreal

This report provides descriptive results of the health status of a sample of 200 French Canadian women residents of Sorel-Tracy in Quebec. For different age and occupational groups, we evaluated many physiological variables characteristic of cardiovascular, respiratory, visual, auditory, genito-urinary, locomotive and endocrine systems as well as morphological and neuropsychiatric variables by considering anthropometric measurements, physiological test results, and symptomatic indices. From the results of these variables, we estimated a physiopathological aging index by means of univariate and multivariate biometric methods. This index, evaluated in terms of number of years, permits us to examine how the variation of physiopathological aging works in relation to the chronological age of individuals or groups.

We cannot deny the fact that age and health levels are highly negatively correlated whichever physiological variable we consider, and our variation study for age groups well represents this reality. For occupational groups, we expect that on the average, women working as high level office employees or professionals present a much higher general health level than homemakers or women working as non-specialized manual workers; the former might manifest a physiopathological age lower than their chronological age, as compared to the average.

SOCIAL DOMINANCE IN A GROUP OF CAPTIVE MANDRILLS (MANDRILLUS SPHINX): AN ANALYSIS OF BEHAVIOR INDICES

NASHA HOLT
McMaster University

Social dominance has been defined and measured in various ways in studies of non-human primate social organization. In this project, dominance is defined operationally as an inter-correlated cluster of behaviors, one of which is the ability to aggress on an individual without that individual responding with aggression. Behavioral observations are conducted on a captive group of mandrills (*Mandrillus sphinx*) in order to determine whether dominance relationships are present and to examine the validity of traditional measures of dominance. A cluster of inter-correlated behaviors is identified which indicates dominance and ranks the animals into a linear hierarchy. The primary significance of the dominance hierarchy lies in conferring predictability to certain limited types of behavioral interactions, including agonistic encounters, non-agonistic approach-retreat patterns, and non-agonistic presenting. Delineation of such clear-cut dominance hierarchies is rare in non-captive situations, and possible reasons for this difference are discussed. An improved methodological approach to the study of dominance is proposed as a basis for comparative analysis utilizing the dominance concept.

BEOTHUCK SKELETAL MATERIAL: A DESCRIPTION

SONJA M. JERKIC
Memorial University of Newfoundland

People have been aware of the existence of the Beothuck Indians since Europeans first touched the shores of Newfoundland. However, since the last known Beothuck died in 1829, our only source of description of these people lie in historic reports and in what can be deduced from available skeletal material.

There are only 11 known Beothuck skeletons available for study. As described in this paper, they provide indications as to the actual size and morphology of this group whose members were reported to be giants. The limited metric and morphological evidence points toward the possibility that they might have displayed some minor results of random genetic drift due to their island isolation.

BREASTFEEDING AND POSTPARTUM OVULATION: A RESEARCH DESIGN

MELISSA KNAUER
University of Toronto

Lactation is known to have an adverse affect on the ability to conceive. The extent to which this occurs, however, depends on the frequency, duration and intensity of nursing bouts, as well as the nutritional status of the mother and infant. The variety of lifestyles that human societies have experienced has influenced breastfeeding practices considerably. This possibly has played some role in population regulation and growth throughout human evolution.

Studies have been conducted whereby breastfeeding habits are correlated with the return of menstruation. Since the first postpartum cycles may be anovulatory, menstruation is not an accurate indication of potential fertility. In this longitudinal study, breastfeeding women are contacted, interviewed and asked to volunteer their time as suits their individual willingness to participate. By employing the symptothermal method of birth control for ovulation detection, breastfeeding patterns will be correlated with the resumption of postpartum ovulation in contemporary, urban women.

VALIDATION DE L'INDICE DE VIEILLESSEMENT DIFFERENTIEL

NORMAND LAPLANTE
Université de Montréal

Les facteurs susceptibles d'affecter la variation des niveaux de santé sont multiples. On peut supposer que le vieillissement différentiel contribue à cette variation. Aussi, l'indice de vieillessement différentiel sera utilisé comme variable indépendante dans une analyse de variance multiple. Ceci permettra d'estimer la contribution relative du vieillessement différentiel par rapport aux autres critères considérés (habitudes de vie, indices d'envi ronnement au travail, antécédents, etc...). Les indices de vieillessement considérés comme critères différeront selon les systèmes physiologiques analysés. Par exemple, pour estimer la contribution du vieillessement différentiel à la variation des données audiométri ques il est important de constituer un indice de vieillessement ne tenant pas compte des variables de l'audition.

COMPARISON ENTRE DES CRANES IROQUOIENS DU QUEBEC ET DE L'ONTARIO

ROBERT LAROCQUE
Université de Montréal

(Complete paper published in Vol. 2, No. 1)

'BONE LOSS' AS AN INDICATOR OF NUTRITIONAL INADEQUACY IN A SKELETAL POPULATION FROM SUDANESE NUBIA (350 A.D.)

DEBRA L. MARTIN and ALAN H. GOODMAN
University of Massachusetts

Skeletal methods for the determination of the nutritional status of archaeological populations have been overlooked because pathologies related to specific deficiencies are rare. However, the skeletal system provides general indicators of stress that can aid in the analysis of nutritional adequacy. In this paper we report on the premature loss of bone, rates of mineralization, and porosity and density of long bone cortices in femora from 86 adults (44 males and 42 females) from an X-Group cemetery from Sudanese Nubia. Taken together, these measures provide an index of skeletal health and maintenance. Analysis of the relationship between these measures indicates that the rate of bone loss and mineralization are related to age and sex. Females exhibit both bone loss and slower mineralization during peak reproductive years (20-35), while males and older females do not show these trends. It is hypothesized that stress related to childbearing becomes critical in terms of mortality and morbidity when combined with an underlying nutritional inadequacy.

DYNAMIQUE BIO-CULTURELLE D'UN ISOLAT: ST-BARTHELEMY, ANTILLES FRANCAISES:

FRANCINE-M. MAYER
Université de Montréal

l'étude de la dynamique bio-culturelle de l'isolat de St-Barthélémy comprend une analyse approfondie de l'histoire socio-démographique de la population de l'île, une enquête d'ethno-médecine et une analyse des changements sociaux récemment survenus dans l'île. Cette recherche est faite parallèlement à une enquête médicale menée par le groupe de recherches en épidémiologie génétique de l'INSERM[1] dans le but d'évaluer la pathologie héréditaire de la population. La combinaison des approches socio-démographique, ethnologique et biologique permettra de dégager les processus sociaux qui modulent la micro-évolution biologique de la population et de contribuer à l'explication et éventuellement à la prévention des phénomènes pathologiques qui s'y déroulent et qui cont liés à son isolement et à sa structure.

(1) INSERM: Institut national de la santé et de la recherche médicale, Paris.

THE DENTAL MORPHOLOGY OF THE WAORANI INDIANS OF ECUADOR: COMPARISONS WITH SOUTH AMERICAN SAMPLES

JOHN T. MAYHALL and S.A. KARP
University of Toronto

The dental stone models of 91 Waorani Indians from the Napo river valley of eastern Ecuador were studied to provide an initial description of the dental morphology of their permanent teeth. These Indians were first contacted in the late 1950s and have continued as hunters and agriculturists with only occasional visits by missionaries and nurses. Eight morphological traits as well as the mesiodistal and buccolingual diameters of the permanent teeth were examined, and these were compared with previously described Indians from Chile, Peru, Guatemala, Mexico, and Brazil as well as Mongoloids in general.

Most trait frequencies were approximately the same as those for the other Indian groups with the exception of Carabelli's trait which was consistently lower in the Waorani. Tooth size was generally larger than in the comparison populations. The results indicated that the Waorani displayed the normal Mongoloid dental characteristics but appeared to be more homogeneous in their trait expressions, possibly suggesting a very low admixture rate and a high degree of isolation.

A BLACKDUCK INFANT BURIAL FROM SOUTHEASTERN MANITOBA

CHRISTOPHER MEIKLEJOHN and ANTHONY T. BUCHNER
University of Winnipeg

We report a fragmentary child's burial excavated in 1975 from the Bjorklund site in southeastern Manitoba. The burial is associated with cord-marked ceramics of the Blackduck Phase and has an estimated date of AD 1200 - 1400. The burial is believed to be secondary and is associated with potsherds, lithic materials, and bone, some of it altered. This form of burial is so far unique for the Manitoba Blackduck Phase. Its implications are discussed.

GRAVESTONE DATA FROM AN ONTARIO CEMETERY: APPLICATIONS TO PALEODEMOGRAPHY

F. JEROME MELBYE and ANNE KATZENBERG
University of Toronto

Gravestone data have been used to study stylistic changes by archaeologists and, more recently, to study demographic change by physical anthropologists. Several studies have confirmed the validity of using gravestone data to reflect demographic reality by comparing the data to census records.

The authors have collected data from a moderately large church cemetery from southern Ontario which includes individuals who died between 1791 and 1979. The data are compared with church records and Ontario census records to determine how well the cemetery was represented by gravestone information and how closely it resembles the living population. Problems encountered in gathering the data are reviewed and analogies are drawn to paleodemographic studies based on prehistoric cemeteries.

WITHIN-GROUP RELATIONSHIPS INFERRED THROUGH SKELETAL DATA

J. E. MOLTO
University of Toronto

Generally, morphogenetic skeletal data are used to determine relationships between excavated population samples. This paper represents a departure from this trend, in that it considers the possibility of such data being used to infer relationships among skeletons interred in a given burial area. More specifically, it outlines a model, based on discontinuous cranial traits, that is used to infer familial relationships. Case studies from southern Ontario's Woodland period are used to demonstrate the potential importance of this approach to interpreting prehistory.

HISTORICAL DEMOGRAPHY OF WESTERN CANADIAN NATIVE POPULATIONS: GRANDE CACHE, ALBERTA, 1800-1975

TRUDY NICKS
Provincial Museum of Alberta

Although geographically isolated and non-literate for most of its history, the native population at Grande Cache in west-central Alberta can be documented for almost two centuries from records left by fur traders, explorers, missionaries, and various government officials. Combining these records with information obtained through field work, it has been possible to trace the population from its founding at the beginning of the nineteenth century to its contemporary representatives. The population arose through unions between local Indian women and immigrant Iroquois and European males

FERTILITY DIFFERENTIALS AMONG MACACA SYLVANUS OF GIBRALTAR

WAYNE RHODES
University of Toronto

Records on Macaca sylvanus of Gibraltar of births, deaths, importations, culling, maternity, and paternity have been kept by the British Army since 1935. This rich resource of information lends itself particularly to a longitudinal, familial study of demographic parameters. This kind of nominal approach to demographic analysis allows a more processual, dynamic method of investigation that opens the way to understanding how demographic processes, such as fertility differentials, may affect evolutionary changes. Reproductive success as defined by Jacquard (1971), Gomila (1975), and Sawchuk (1978) will be examined for all lineages existing between 1948 and 1978. This information will also be presented as a pack analysis similar to the analysis carried out by Roberts (1968) on the inhabitants of Tristan de Cunha. The resulting contributions of offspring to the gene pool by particular lineages will be presented. Potential genetic contributions will be proposed using the less accurate, but useful, data on paternity, by including male contributions as well. The implications of disproportionate contributions by certain lineages will be discussed with respect to potential evolutionary change.

ENAMEL HYPOPLASIA IN GORILLA AND CHIMPANZEE

MARK SKINNER
Simon Fraser University

Enamel hypoplasia has been well studied in recent and prehistoric populations as an interpretive guide to the incidence and timing of environmental stress during childhood. Recently similar observations of a preliminary nature have been made on South African australopithecines. Interpretation of these results has been hampered by a lack of comparative data from recent non-human primates.

This study reports the results of research on enamel hypoplasia in two sympatric species, 119 lowland gorillas and 110 chimpanzees wild shot in the late 1920s and early 1930s in the Cameroons of West Africa. Observations were made on sex and species differences of the incidence of enamel hypoplasia from the permanent lower left mandibular dentition.

Preliminary results indicate (a) considerable tooth differences with the canine being most affected, (b) that gorillas are significantly more affected than chimpanzees, and (c) that both sexes in each species are equally affected.

The significance of these results is discussed in terms of the timing of environmental stress considering possible nutritional, infective or social mechanisms for their etiology.

MIGRATION AND ILLNESS: CANCER EPIDEMIOLOGY OF CHINESE CANADIANS

JOSEPH K. SO
Trent University

Cancer mortality data of Canadians of Chinese ethnic origin in Ontario were examined for the years 1968 to 1977. Compared with the general Ontario population, the Chinese figures are significantly higher for cancers of the nasopharynx, liver, and esophagus, but lower for cancers of the breast, uterus, prostate, pancreas, skin and brain, among others. Compared with data on Chinese in Hong Kong, several sites show an increase in mortality, especially for large intestine and rectum, showing a migrant effect. A number of possible explanations, both environmental and genetic, are discussed.

who had come west with the fur trade. Subsequent generations involved intermarriage between descendants of founding families, or through recruitment of members from other bands of fur-trapping specialists. In the late 1960's the arrival of urban and industrial development in the Grande Cache region initiated a change from a hunting and trapping lifestyle to one based on wage labour. The mobility associated with hunting and trapping, which brought members of the population into contact with native peoples over a wide area of northern Alberta, has been curtailed by the changes in lifestyle. As a result, former patterns of alliance are being replaced by immigration of Europeans from the new town.

The present study demonstrates the potential for longitudinal studies of native populations in the post-European contact period in western Canada. The insights such studies can provide concerning historical population structures will be of value for the interpretation of biological data for recent native populations.

THERMOREGULATORY BEHAVIOUR AND ECOLOGICAL FACTORS IN PRIMATES

JAMES D. PATERSON
University of Calgary

(Complete paper published in this number)

AN ANALYSIS OF MORPHOLOGICAL VARIATION IN ARCHAEOLEMUR SPP.

ANDREW J. PETTO and LAURIE R. GODFREY
University of Massachusetts

Two species of Archaeolemur have been identified from two highly fossiliferous regions in the north-central and southwest coastal areas of Madagascar. Earlier studies of the functional morphology of a variety of subfossil species from Madagascar revealed a poor fit with current diagnostic criteria for animals from a group of sites in the central coastal and south central inland regions of the island. The relationship among the three regions is best described by a directional and graded size factor running from the smallest in the southwest coastal to the largest in the north-central inland sites. Nine statistical tests of six possible alternative hypotheses to explain the variation fail to reject only two: (1) that the variation is clinal, or (2) that animals at intermediate sites are hybrids with roughly equivalent contributions from both parent populations. Trend surface mapping shows the direction and strength of the size variation, and indicates environmental variables which may be good indicators of biogeographical factors related to the development and maintenance of size variation.

THE IMPACT OF ADULT AGE DETERMINATION TECHNIQUES ON PALEODEMOGRAPHY

SUSAN PFEIFFER and P. LYNN
University of Guelph

Using skeletal material from the Kleinburg Ossuary (AlGv-1), estimates of adult age at death were derived from examination of femoral cortical remodelling. The resulting adult age distribution is compared with the ages derived from pubic symphysis examination by Saunders (1974). There are statistically significant differences in the 30-35 year and 40-55 year age categories. Cortical remodelling appears to yield consistently higher ages. This pattern is similar to that obtained by Ubelaker (1974). The impact of such differences in adult age distributions is discussed. It is concluded that such uncertainty about "true" age seriously limits the accuracy that can be claimed for paleodemographic research. Further, there is evidence accumulating for a systematic over-ageing error in cortical remodelling estimates (as compared to pubic symphysis age estimates.) A number of causes for such a pattern are discussed, as is the need for further research.

A CRITIQUE OF BIVARIATE METRIC SEX DETERMINATION TECHNIQUES

NORMAN C. SULLIVAN
University of Toronto
RICHARD HALL
McMaster University

(Complete paper published in this number)

GLUCOSE INTOLERANCE IN THE DOGRIB: ASSOCIATED CHARACTERISTICS

E.J.E. SZATHMARY
McMaster University

(Abstract not submitted)

A REASSESSMENT OF GRAY SITE DEMOGRAPHY AND CHRONOLOGY

WILLIAM D. WADE
University of Manitoba

Previous accounts of the population of the Gray burial site in southeastern Saskatchewan have provided independent analyses of its demographic composition and the temporal span of its existence based on radiocarbon dates. This paper presents a minor revision of the age and sex estimates of the population, a reassessment of its biological heterogeneity in the light of new data, and a reexamination of its radiocarbon-based chronology with the addition of new fluorine dates. In conclusion, a tentative resolution is offered of the seeming discrepancy between the size of the cemetery population and its extended distribution through time.

THULE SKELETAL REMAINS FROM KNUD PENINSULA, ELLESMERE ISLAND, N.W.T.: EXPLORING NEGATIVE EVIDENCE

J. EDSON WAY
Beloit College

(Abstract not submitted)

A REVIEW OF RECENT DEVELOPMENTS REGARDING EURASIAN NEOGENE HOMINOIDS

LAUREN R. WILLIAMS
Lakehead University

(Abstract not submitted)

IDIOSYNCRACY AS INNOVATION IN THE DEVELOPMENT OF TRADITION

MARGOT WILSON
University of Toronto

(Abstract not submitted)

ERRATUM

OOPS!!

Somehow these three abstracts from the 1981 meetings slipped through our hands. My thanks to Dr Mary Jackes for bringing them to my attention, and my apologies to her for the oversight.

J.D. Paterson

NONMETRIC TRAITS: BILATERAL INCIDENCES AND POPULATION INCIDENCES (Poster)

Dr Mary Jackes
University of Alberta

There is some evidence that the indicence of bilaterality in nonmetric traits increases as the overall trait incidence (by side or skull) increases. The pattern does not seem to hold for all traits, however, and data from more populations is required to test this reversal of the expected trend.

PERTHES DISEASE: COMMON IN SOUTHERN ONTARIO INDIANS? (Poster)

Dr Mary Jackes
University of Alberta

Abnormal femora from six individuals in a Neutral cemetery are described and the suggested diagnosis is Legge-Calvé-Perthês disease. The familial nature of the disease seems confirmed and it is suggested that it is a disease common among southern Ontario Indians.

NON-METRIC TRAIT INCIDENCES AFTER MATURITY

Dr Mary Jackes
Univeristy of Alberta

It is sometimes implied in the literature that the incidences of non-metric traits do not stabilize upon maturity. The claims of several authors are examined and new information is given which shows that there is as yet no solid evidence for changes after adult status is reached.

WINNERS OF THE OSCHINSKY-McKERN AWARD

In 1975, an award was instituted to honour the memory of Lawrence Oschinsky, and the name of the late Thomas McKern was added the following year. The award is given each year in recognition of the best student paper presented at the annual meeting of the Canadian Association for Physical Anthropology/l'Association pour l'Anthropologie Physique au Canada. The following individuals have received this prize:

1975	Winnipeg	Shelley Saunders University of Toronto
1976	Toronto	Susan Hornshaw University of Toronto
1977	Banff	Rosemary Vyvyan University of Manitoba
1978	Niagara-on-the-Lake	William Fitzgerald McMaster University
1979	Ste.-Adèle	Diane Berthelette, Robert Larocque Université de Montréal
1980	Ottawa	Nasha Holt McMaster University
1981	Banff	Brian Chisholm Simon Fraser University

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