The impact of global climatic variations upon middle ear ossicles dimensions

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Abstract

Hypothesis: The morphology of middle ear ossicles varies between people living in different climatic regions.

Background: The differences between climatic conditions in different world regions have a morphological and physiological influence on human development. The present study is aimed to investigate morphological variations of middle-ear ossicles collected from different geographic locations on the globe. **Methods**: Middle ear ossicles (total samples 631) were collected from 6 different geographic regions: Australia, Chile, France, India, Israel and Kenya. Latitude and longitude, and climatic parameters (mean temperature, humidity and daylight duration of the warmer and colder months, and altitude above sea level) were collected for each region. The associations between middle ear ossicles' dimensions and climate were evaluated using Pearson's correlations. **Results:** Significant differences between samples of middle ear ossicles' characteristics were found. Correlations between the 'above sea level' altitude and longitudinal sizes of the malleus, incus and stapes were negative. Correlations between warm temperature and longitudinal sizes of the malleus, incus and stapes were positive. **Conclusions**: Differences in characteristics of middle ear ossicles encountered between territorial samples could be the result of climatic variations

Key words: middle ear ossicles, climate.

Влияние глобальных климатических изменений на размеры косточек среднего уха

Гипотеза: морфология косточек среднего уха отличается у людей, живущих в различных климатических районах. Справочная информация: различия климатических условий в различных регионах мира имеют морфологические и физиологические воздействие на развитие человека. Данное исследование направлено на исследование морфологических изменений косточек среднего уха, собранных в различных географических точках земного шара. Методы: косточки среднего уха (всего 631 образец) были собраны в 6 различных географических регионах: Австралия, Чили, Франция, Индия, Израиль и Кения. Широта и долгота, климатические параметры (средняя температура, влажность и продолжительность светового дня теплых и холодных месяцев, высота над уровнем моря) были определены для каждого региона. Связь между размерами косточек среднего уха и климатом были оценены с использованием корреляции Пирсона. Результат: были найдены значительные различия в характеристиках образцов косточек среднего уха. Корреляция между «над уровнем моря» и продольными размерами молоточка, наковальни и стремечка были обратнопропорциональными. Корреляция между теплой температурой и продольными размерами слуховых косточек были прямопропорциональными. **Выводы:** Различия в характеристиках косточек среднего уха различных территориальных образцов могут быть результатом климатических изменений.

Ключевые слова: косточки среднего уха, климат.

Introduction

The influence of climatic conditions in different regions of the world upon physiological and morphological characteristics of the human body has been largely investigated [1-8]. The skeletal morphogenesis including bone-aging parameters varied significantly among people living in different world climatic areas [1, 9-16].

The present report will focus on structural features of the middle ear ossicles in six human populations living in different geographic regions. The inter-population differences will be described in relation to several aspects of climatic parameters including monthly temperatures, precipitation, altitude, daylight duration, and humidity.

Material and methods

The structural features of 631 middle ear ossicles collected from France, India, Israel, Kenya, Chile and Australia were analyzed (tab. 1). Normal undamaged right and left ossicles of adult individuals of both sexes were studied. The osteometric analyses of bone samples were prepared on POWER LOOK UMAX-30-bit system with a UTA-II Scanner. All morphometric measurements were performed by the "UTHSCSA" Image Tool (version 3) for Windows (http://ddsdx.uthscsa.edu/dig/itdesc.html). The standard osteometric measurements [17] obtained for the middle ear ossicles are detailed in table 2. Data on geographical coordinates and on climatic factors that were collected for each population is presented in table 3. Climatological data included the mean monthly temperature in January and July, mean annual precipitation, mean monthly precipitation in January and July, and altitude. The day-light duration (in hours) in January and July were obtained from the Monthly Climatic Data for World-1980-1990 [18]. Appropriate corrective amendments were made for the inversed seasonal changes of climate that accounts for different hemispheres of the globe. In particular, the influences of temperature, humidity, and day-light length (duration) in cold and warm months of the year, January and July for Northern hemisphere and July and January for the Southern hemisphere, were analyzed. In addition to analysis of the absolute meteorological parameters, we estimated inter-seasonal differences between parameters of warm and cold months of the year for temperature, humidity, and day lengths.

All results were expressed by means ± SD. The analyses included descriptive statistics, correlation analysis (Pearson and Spearmen). *A posteriori* multiple comparisons of means were applied by the Tukey Kramer honest significant difference test (Breakdown & one-way ANOVA). The P values indicated the *post hoc* significance levels for the respective pairs of means considering $p < 0.05$ as significant. The aforementioned calculations were performed using the SPSS statistical package (1990) and STATISTICA 6 package StatSoft. Inc (2002).

Table 1

Number of middle ear ossicles of different global regions

	France	India	Israel	Kenya	Chile	Australia	Total
Malleus	31	48	96	47	27	18	267
Incus	31	35	89	47	25	21	248
Stapes	17	35	21	31	8	4	116

Table 2

Standard osteometric measurements of ear ossicles

Malleus	
Total length	Maximal distance between top of the head and distal edge of the manubrium
Length of manubrium	Maximal distance between superior edge of the lateral process and the distal end of manubrium
Width of head	Maximal width of the projected outline of the head, lying on its anterior aspect; measurement taken perpendicular to the long axis of the neck
Length of head and neck	(calculated) difference between total length of the manubrium and total length of the malleus
Angle between long axis of the manubrium neck	measured in its posterior outline, the bone lying on its posterior aspect
Index	Length of manubrium x 100/ total length
Incus	
Total length	Maximal distance between superior edge of the body and the distal end of the long process; measured along the longitudinal axis of the long process
Total width	Maximal distance between the tip of the short process and the most protruding (inferior) border of the articular malleolar facet; bone lying on its medial aspect
Angle	Between the inferior edge of the short process and the posterior edge of the long process; outlined in projection; bone lying on the medial aspect
Index	Total width x 100/total length of Incus
Stapes	
Total length	Maximal distance between the vestibular aspect of the footplate and top of the head
Length of footplate	Maximum length of the long axis
Index	Length of foot plate x 100/length of foot plate

Table 3

Climatic characteristics of six global regions

Parameters \ Region		France	India	Israel	Kenya	Chile	Australia
Latitude (°)		44.5N	22.5N	32N	1.18S	33.2S	35.2S
Longitude (°)		0.34W	88.2E	35E	36.45E	70.4W	149.0E
Altitude(above sea level)		152	9	33	1661	567	6
Daylight Duration (hours)	**January**	9.8	11.75	11.0	12.5	15	14.7
	July	15.8	14.1	15.2	12.5	11	10.5
Precipitation (mm)	**January**	76	10	10.3	64	0.4	59
	July	53	325	23.3	17.5	86.6	41
Rainfall (annual) (mm)		852	1601	100	1024	367	618
Temperature (°C)	**January**	5.5	20	12	18	20.5	21.7
	July	21.1	29	28	19	8.5	15.5

N = north, S = south, E = east, W = west.

Results

Direct osteometric measurements of the malleus, incus, and stapes of the six regional groups are presented in table 4.

Significant differences of the middle ear ossicles morphometric characteristics between the samples of each geographical region were found and presented in table 5.

The correlation between the ossicular morphometric parameters and the meteorological parameters of climatic conditions on each geographical region are detailed in table 6 (Data detailed for values of significance, only). The most prominent results included: a. negative correlation between various measures of all three ossicles and regional altitude; b. negative correlations of measures of the incus and malleus and hot month precipitation and annual rainfall; c. positive correlations between parameters of all ossicles and high temperature and temperature differences of warm and cold months of the year.

Table 4

Measurements of ear ossicles of different geographical samples

Traits		France	India	Israel	Kenya	Chile	Australia
Malleus							
Total Length (mm)	Means	7.95	7.76	8.04	7.38	7.63	7.33
	SD	0.31	0.40	0.41	0.35	0.47	0.44
Head width (mm)	Means	2.23	2.21	2.38	2.25	2.31	2.34
	SD	0.11	0.21	0.23	0.16	0.16	0.21
Manubrium length (mm)	Means	4.49	4.45	4.81	4.18	4.31	4.24
	SD	0.37	0.37	0.42	0.36	0.30	0.37
Length (Total-manubrium) (mm)	Means	3.46	3.31	3.23	3.20	3.32	3.09
	SD	0.27	0.35	0.42	0.34	0.35	0.29
Malleus index	Means	56.50	57.40	59.90	56.7	56.6	57.70
	SD	3.46	3.93	4.52	4.08	2.97	3.24
Malleus angle (°)	Means	144.59	138.28	141.71	154.46	142.53	150.32
	SD	4.48	8.29	7.81	42.42	3.36	6.68

Incus								
Total Length (mm)	Means	6.48	6.42	6.79	6.10	6.53	6.36
	SD	0.32	0.32	0.30	0.45	0.45	0.37
Width (mm)	Means	5.02	4.85	5.18	4.72	4.92	4.76
	SD	0.29	0.26	0.32	0.38	0.35	0.32
Incus index	Means	76.83	75.62	77.83	77.41	75.52	77.58
	SD	5.08	3.50	6.27	5.19	3.39	7.68
Incus angle (°)	Means	87.28	87.88	91.22	88.23	87.89	88.43
	SD	4.04	6.88	5.71	6.47	5.73	4.19
Stapes							
Total height (mm)	Means	3.35	3.43	3.41	3.11	3.38	3.26
	SD	0.28	0.18	0.17	0.26	0.20	0.17
Width (foot plate) (mm)	Means	2.75	2.81	2.82	2.75	2.91	2.88
	SD	0.20	0.17	0.13	0.18	0.07	0.10
Stapes index	Means	82.65	82.00	83.51	88.68	86.36	81.94
	SD	3.96	5.26	7.52	5.58	5.23	4.49

Table 5

Differences of significance of morphometric characteristics between samples of each geographical region

	France	India	Israel	Kenya	Chile	Australia
	1	2	3	4	5	6
Malleus						
Total length	4, 5, 6	3, 4, 5, 6	2, 4, 5	1, 2, 3	1, 2, 3, 6	12,5
Head width	2, 4, 5,6	1,3,4	2	1,2		1
Manubrium length	2, 4, 5,6	1,3,4,5,6	2,4	1,2,3	1,2	1,2
Length (total manubrium)	2, 4, 5	1,3,6	2,5	1	1,3,6	2,5
Malleus index	2	3,4,5,6	2	2	2	2
Malleus angle	4	4,5	4,5	1,2,3,6	3,4	4
Incus						
Total Length	2,3	3,4	2,6	1,2,5,6	4	3,4
Width	4	3,4,5	2,4	1,2,3,5,6	2,4	4
Incus index		4		2		
Incus angle	2	3,4,5,6	2	2,5,	2,4	2
Stapes						
Total height	4	4	4	1,2,3,6		4
Width (foot plate)	6					1
Stapes index	4	4	4	1,2,3		

Table 6

Matrix of the correlation coefficients* between measured ear ossicles parameters and climatic characteristics **

Ossicle parameters / Climatic parameters	Total Length-Incus	Width Incus	Total Length-Malleus	Length-Manubrium (Malleus)	Total height Stapes
Altitude	-0.45	-0.32	-0.44	-0.41	-0.51
Hot month temperature	0.40	0.30	0.45	0.45	0.45

Dif temperature	0.54	0.49	0.54	0.53	0.36
Rainfall (annual)	-0.38	-0.35	-0.26	-0.36	
Cold month prec (mm)	0.43			0.36	
Hot month prec (mm)	-0.24	-0.23	-0.31		0.23
Cold month duration day					-0.32
Hot month duration day	0.30	0.22			0.38
Dif day duration	0.28				0.36

Dif = difference, prec = precipitation, *all coefficients are significant ($p < 0.05$), Correlation < 0.22 not presented, ** Full matrix not presented.

Discussion

The present study, buttressed by univariate analysis, shows that our osteometric data correlates significantly with altitude above see level. Yet there is also a significant correlation with the mean warm temperature and inter-seasonal temperature differences. It is well known that temperature and humidity are basic climatic factors which directly influence the level of thermoregulation and, indirectly, the activity of circulating system, including the main parameters of metabolism and metabolic processes [19-23]. Residents of contrasting climatic-geographical regions differed significantly between some physiological parameters, such as water-salt exchange, circulating and endocrine functions, aging of bones [7, 21, 24, 25]. In particular, Belkin et al [7] found that climatic factors such as temperature, humidity, and inter-seasonal temperature differences may predispose the early onset of skeletal changes.

From a bio-climatological point of view, seasonal climatic contrasts were correlated with specific adverse effects on health [20, 26, 27].

Human middle ear ossicular morphology and size are fully developed by the 32 week of pregnancy [28, 29]. Several reports [30, 31] described a relationship between chronic hypoxia at high altitudes and fetal growth, reduced birth weight, and increased infant mortality. Krampl et al. [32] using ultrasound fetal biometry, have shown that all fetal measurements including biparietal and occipitofrontal diameters, head and abdominal circumferences, femur length, and fetal weight, followed a lower trajectory in high altitude places than at sea level. Therefore, it is reasonable to assume that climatic parameters influence the intra-uterine morphogenesis of the ossicles, especially related to the hypoxia that characterizes high altitude conditions.

In most species, individuals reared at lower temperatures have increased adult body sizes (33-34). Smith et al (35) found that none of the environmental variables included in their study (altitude, latitude, rainfall, and temperature) showed a significant correlation with temporal bone shape, however, a significant positive correlation was found between size and temperature and size and latitude. This does not apply to the intrauterine development of middle ear ossicles.

In conclusion, it is reasonable to assume, that the results of the present study confirm the hypothesis that a straight relationship exists between the complete fetal development of the ear ossicles, the altitude over the sea level, the temperature and the climatic inter-seasonal distinctions.

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