ANTHROPOLOGIE * XXVI/1 * 1988

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ECOLOGICAL ASPECTS OF SKELETAL SEXUAL DIMORPHISM IN MICROEVOLUTION OF HOMO SAPIENS

ABSTRACT — Femur and tibia of Recent Moravian, west Slavic, Neolithic and Paleolithic populations are examined to describe evolution of basic ecological morphological patterns of lower limb skeleton in human microevolution. 75 metrical traits on femur and tibia were analysed both on the level of individual groups and on the level of sexes and ecological meaning of skeletal sexual dimorphism. Basic morphological patterns of the groups are well correlated with their ecological adaptations, i.e. morphological patterns of femur and tibia are functionaly compatible with the ecological parameters of individual populations. The degree and character of sexual dimorphism differs in individual populations. The most pronounced sexual dimorphism has been found in Neolithic population. The differences on femur and tibia between males and females in Neolithic are not only in size but also in many functional characters. This degree of sexual dimorphism in Neolithic population is probably in close correlation with the origin of early agricultural strategy and it probably reflects ecological differentiation and division of labor between both sexes.

KEY WORDS: Homo sapiens — Femur — Tibia — Microevolution — Sexual Dimorphism — Ecology — Morphometrical Analysis.

Hominid sexual dimorphism, its evolution and ecological role has been more and more frequently discussed during last several years. In connection with it our understanding of a role of sexual dimorphism in Homo sapiens microevolution has shifted from simple searching for the best sexing parameters to the studying of a more general properties of human sexual dimorphism including ecological role of the sexes.

The searching for optimal sexing parameters has a crucial role for the sex determination on skeletons but they need not be of such an importance for the interpretation of the sexual dimorphism that demands the direct or undirect tracing of a number of factors including classification of the sexes. While majority of such factors can be followed directly in the recent populations in studying of skeletal prehistorical populations we are limited only on the information yielded by the analysis of skeletons and, in the better case paleontological and archeological material.

Consequently, examining the skeletal populations we should increase our attention both to the more precise and sophisticated methods of the sex determination on skeletons and also to the more complex and dynamic approaches enabeling us the investigation of the process of evolution of sexual dimorphism and its ecological role in Homo sapiens microevolution (c.f. Frayer 1984, Frayer, Wolpoff 1985, Novotný, Vančata 1985, Oxnard 1985).

Evolutionary systems approach and advanced statistical methods are such approaches that could enable us to achieve complex, dynamic and relatively objective description of morphological patterns. (cf. Novotný 1981, 1983, Novotný and Vančata 1985, Vančata 1983). Human sexual dimorphism has been

TABLE 1. *Measurements included in morphometrical analysis*

1. SUBTROAP — Antero-posterior subtrochanteric diameter — M10.
2. SUBTROML — Medio-lateral subtrochanteric diameter — M9.
3. TRMAHIGH — Height of trochanter major — V3. The maximum distance between the deepest point of the transversal shape curve on the border of trochanter major and femoral shaft and the corresponding most proximal point of trochanter major.
4. TRMATRMI — Intertrochanteric diameter — VG-g.
5. HEADBRTH — Mediolateral head breadth — M19.
6. COLODIAG — Collodiaphyseal angle — M29.
7. NECKLNGH — Neck length — VG-c.
8. NECKBRAP — Antero-posterior neck breadth — M16.
9. NECKBRML — Medio-lateral neck breadth — M15.
10. TRMABRTH — Breadth of trochanter major — V11. Maximal breadth of trochanter major measured perpendicularly to the neck axis.
11. NCKLGBIO — Biomechanical neck length — MC6 (without modification).
12. TRMIHEAD — Trochanter minor to head — V13. Rectilinear distance from the most medial and the most distal point of trochanter minor to the most distant point on the proximal surface of the femoral head.
13. TRMIBRTH — Breadth of trochanter minor — V14. Maximal diameter of femoral shaft and trochanter minor measured parallely with the axis of the most dorsal point of femoral condyles.
14. TRMIHIGH — Height of trochanter minor — V15. Maximal diameter of femoral shaft and trochanter minor measured perpendicularly to the neck axis.
15. TRMINECK — Trochanter minor to neck — VV15. The minimum distance between the most lateral and most distal point of trochanter minor and superior boarder of the femoral neck.
16. SUPREPAP — Supraepiphyseal antero-posterior diameter — VV16. The sagittal diameter measured on distal epiphysis/diaphysis border.
17. SUPREPML — Supraepiphyseal medio-lateral diameter — VV17. The medio-lateral diameter measured on the distal epiphysis/diaphysis border, i.e. perpendicularly to the sagittal diameter.
18. SUPCONAP — Supracondylar antero-posterior diameter — VV18. The antero-posterior diameter measured at the deepest points of shape curves in sagittal plane above femoral condyles.
19. SUPCONML — Supracondylar mediolateral diameter — VV19. The medio-lateral diameter measured at the deepest points of the shape curves in frontal plane (section) above the femoral condyles.
20. INTEREPI — Bicondylar width — MC12.
21. DISTCOND — Distal intercondylar diameter — VV21. The distance between the most distal points of femoral condyles.
22. COLAHIGH — Height of lateral femoral condyle — VV22. The distance between the deepest point of lateral shape curve in frontal plane above the lateral condyle and the most distal point of lateral condyle.
23. COLAOBLQ — Oblique height of lateral femoral condyle — VV23. The distance between the deepest point of lateral shape curve in frontal plane above lateral condyle and the most proximal point of sulcus intercondylaris.
24. COLAMAXM — Lateral oblique diameter of the distal femoral epiphysis — VV24. The distance from the deepest point of lateral shape curve in frontal plane above lateral condyle to the most distant point on medial and distal border of the medial condyle.
25. COMEHIGH — Height of medial femoral condyle — VV25. Defined analogically as no. 22.
26. COMEOBLQ — Oblique height of medial femoral condyle — VV26. Defined analogically as no. 23.
27. COMEMAXM — Medial oblique diameter of distal femoral epiphysis — VV27. Defined analogically as no. 24.
28. INCIBRTH — Condylar notch width — MC20.
29. COLASGMX — Maximal sagittal height of lateral condyle — VV29. The distance between the deepest point of sagittal shape curve above lateral condyle and the most distant point on anterior part of joint surface.
30. COLASGMN — Minimal sagittal height of lateral condyle — VV30. The minimal distance between the deepest point of lateral shape curve in sagittal plane above lateral condyle and the closest point on facies articularis in sagittal plane.
31. COLALNGH — Length of lateral condyle — MC16.
32. COLABRTH — Breadth of lateral condyle — MC18.
33. COMESGMX — Maximal sagittal height of medial condyle — VV33. Defined analogically as no. 29.
34. COMESGMN — Minimal sagittal height of medial condyle — VV34. Defined analogically as no. 30.
35. COMELNGH — Length of medial condyle — MC 17.
36. COMEBRTH — Breadth of medial condyle — MC19.
37. ANTECOND — Anterior intercondylar diameter — VV37. The distance between the most anterior points of femoral condyles.
38. DISTEPMX — Anteroposterior diameter of the distal shaft — MC13.
39. DISTEPMN — Lower sagittal diameter of distal femoral epiphysis — VV39. Projective sagittal distance of the most anterior point of facies patellaris and the deepest anterior point of incisura intercondylaris on the distal border of epiphysis.
40. INCIDPTH — Depth of incisura intercondylaris — VV40. The perpendicular projective diameter between the connection of the most posterior points of femoral condyles and the corresponding deepest point of incisura intercondylaris.
41. DIAMDLAP — Anterio-posterior diameter of midshaft — MC15 (without modification).
42. DIAMDLML — Mediolateral diameter of midshaft — MC14.
43. FEMLNGMX — Biomechanical length of femur — M2.
44. INKLINAG — Inclination angle — M28.
45. DSTEPIAG — Bicondylar angle — HL.
46. INCIHIGH — Height of sulcus intercondylaris VV46. The perpendicular projective diameter between the connection of the most distal points of femoral condyles and the middle upper point of sulcus intercondylaris.

Tab. 1. Cont.

TIBIA

47. PRXEPIAP — Antero-posterior diameter of proximal tibial epiphysis — VV47. Antero-posterior diameter of the proximal tibial epiphysis measured above the transversal middle-point of eminentia intercondylaris.
48. PRXEPIML — Medio-lateral diameter of proximal tibial epiphysis — M3.
49. COMETIAP — Length of facies articularis medialis — M4a.
50. COMETIML — Breadth of facies articularis medialis — M3a.
51. COLATIAP — Length of facies articularis lateralis — M4b.
52. COLATIML — Breadth of facies articularis lateralis — M3b.
53. INTEREMI — Intertubercular diameter — VV53. Maximal transversal distance between outer borders of tuberculi of eminentia intercondylaris.
54. EMINDIST — Eminentia intercondylaris to anterior border — VV54. Sagittal diameter between the most posterior point of eminentia intercondylaris and anterior border of proximal tibial epiphysis.
55. COMEHIGH — Height of medial tibial condyle — VV55. The diameter between the deepest point of medial shape curve in frontal plane below the medial tibial condyle and facies articularis tibialis measured parallely to tibial axis.
56. COLAHIGH — Height of lateral tibial condyle — VV56. Defined analogically as no. 55.
57. SUBCONAP — Subcondylar antero-posterior diameter — VV57. Sagittal diameter of tibial shaft measured at the deepest points of tibial shape curves in frontal plane below tibial condyles.
58. SUBCONML — Subcondylar medio-lateral diameter — VV58. Transversal diameter measured on shaft perpendicularly to sagittal one.
59. TUBTIBAP — Maximal antero-posterior diameter of shaft at tuberositas tibiae — M4.
60. SUBTUBAP — Subepiphyseal antero-posterior diameter — VV60. Sagittal diameter measured on tibial shaft below tuberositas tibiae.
61. SUBTUBML — Subepiphyseal medio-lateral diameter — VV61. Transversal diameter measured on tibial shaft below tuberositas tibiae.
62. SUPREPAP — Supraepiphyseal antero-posterio tibial diameter — VV62. Transversal diameter measured on tibial shaft at the border diaphysis/distal epiphysis.
63. SUPREPML — Supraepiphyseal medio-lateral tibial diameter — VV63. Sagittal diameter measured on tibial shaft perpendicularly to the mediolateral one.
64. MALEHIGH — Height of maleolus medialis — VV64. The distance between the most distal point of maleolus medialis and the deepest point of the shape curve in frontal plane at the maleolus medialis/diaphysis border.
65. MALEBRTR — Antero-posterior breadth of maleolus medialis — VV65. The maximal sagittal diameter of maleolus medialis.
66. MALEMLBR — Medio-lateralis breadth of maleolus medialis — VV66. The maximal transversal diameter of maleolus medialis.
67. DIEPIBRT — Medio-lateral diameter of distal tibial epiphysis — VV67. Transversal diameter between the most medial point of sulcus fibularis and the most medial point of maleolus medialis.
68. ARTBRANT — Anterior oblique breadth of distal tibial epiphysis — VV68. The distance between the most medial point of incisura fibularis and anterior lateral border of maleolus medialis.
69. ARTBRPST — Posterior oblique breadth of distal tibial epiphysis — VV69. The distance between the most medial point of incisura fibularis and posterior lateral border of maleolus medialis.
70. ARTBRLAT — Lateral antero-posterior diameter of distal tibial joint surface — VV70. Maximal antero-posterior length of lateral border of the distal tibial joint surface.
71. ARTBRMED — Medial antero-posterior diameter of joint surface — VV71. Maximal antero-posterior diameter of tibial joint surface measured at the border of facies articularis maleoli.
72. ARTANTEG — Anterior medio-lateral diameter of joint surface — VV72. The maximal diameter of the anterior border of facies articularis tibiae measured from the most lateral and most anterior point to the anterior border of facies articularis tibialis and facies articularis maleoli.
73. DIATIBAP — Anterio-posterior midshaft tibial diameter — VV73. Sagittal diameter measured in the middle of tibial diaphysis.
74. DIATIBML — Medio-lateral midshaft tibial diameter — VV74. Transversal diameter measured perpendicularly to the sagittal one.
75. TIBLNGMX — Maximal tibial length — M1a.

The list of abbreviation of references to sources where the measurements are defined (with the specification of measurement by number of letter):

HL — Heiple and Lovejoy 1971
M — Martin and Saller 1957
MC — McHenry and Corruccini 1978
V — Vančata 1976
VV — Vančata 1981
VG — Van Gerven 1972

examined mostly on skulls, teeth and pelvic bones (cf. e.g. Frayer, Wolpoff 1985, Novotný 1980, 1983, 1986) but also lower limb bones seem to be very important and relevant objects for the study of sexual dimorphism in the microevolution of Homo sapiens.

This study is dealing with the sexual dimorphism on femur and tibia. They probably have not as pronounced sexual dimorphism as on the pelvis or talus (cf. Novotný, Vančata 1985) but they are related much more closely to the other characters of the organism such as body weight, body height and locomotor habits, i.e. the properties of crucial importance for the evaluation of ecological characters of a given population (cf. Jacobs 1985a, b, Vančata 1985). The main task of the study is to examine the relations among morphology, character of sexual dimorphism and major features of adaptive strategy by comparing of selected human populations representing basic adaptive strategies in Homo sapiens evolution.

MATERIAL AND METHODS

Skeletons of 124 individuals with determined sex of following three populations has been examined: Recent Moravian population representing technological adaptive strategy (63 skeletons), west Slavic midieval population representing advanced agricultural strategy (29 skeletons; Szanzkow, Ullrich 1969) and Neolithic population representing early agricultural strategy with some features of hunting gathering strategy (32 skeletons; Sondershausen, Bruchstedt, Grossörner, Seehausen III, Minsleben, Spergau, Grosskorbetha, Halle Trotha, Beberthal IV, Königsaner, Bad Salza, Bischleben, Erfurt, Eisleben-Bach1978). Casts fo femurs and tibias of 15 individuals from various Paleolithic localities (Broken Hill, Spy, Neanderthal, Skhul, Krapina, Oberkassel, La Rochelle, Combe Capelle, Aurignac) have been studied as representatives of hunting gathering strategy.

75 metrical traits were measured on the femur and tibia (see *table 1* and Vančata 1981 for the detail description). Metrical traits have been examined by both univariate and multivariate methods from BMDP programme package (Dixon 1985, BMDP3D — one-sample and two-sample t-test, BMDP7D — description of groups, BMDP7M — stepwise discriminant analysis, BMDP1R — multiple linear regression, BMDP2R — stepwise regression, BMDP1V — one-way analysis of variance and covariance).

TABLE 2. *Discriminant analysis of Homo sapiens populations* (upper line — canonical variable I., lower line — canonical variable II.)

	Recent	Slavic	Neolithic	Paleolithic
Proximal femoral epiphysis	0,67 0,62	—0,15 —0,73	—1,75 0,00	1,65 —1,62
Distal femoral epiphysis	1,90 0,02	—1,94 0,26	—1,61 0,51	—1,51 —2,38
Femur	2,47 —0,03	—2,16 1,76	—2,44 —2,03	—2,77 1,89
Knee joint	2,46 0,07	—2,30 1,28	—2,61 —0,87	—4,31 —2,09
Proximal tibial epiphysis	1,52 —0,09	—0,91 0,56	—1,84 0,10	—2,44 —1,49
Distal tibial epiphysis	2,23 —0,02	—2,52 —0,37	—1,91 0,69	—1,70 —1,91
Tibia	2,67 0,01	—2,67 1,24	—2,43 —0,89	—3,14 —1,78
Femur and tibia	4,28 0,01	—4,36 2,57	—4,31 —2,58	—6,10 0,71

TABLE 3. *Discriminant Analysis of Hominidae* (uper line — canonical variable I.. lower line — canonical variable II.)

	Recent	Slavic	Neolithic	Paleolithic	Plio-Pleistocene hominids
Proximal femoral epiphisis	0,50 0,53	0,03 —0,92	—1,78 0,20	1,58 0,74	0,82 —2,37
Distal femoral epiphysis	2,01 0,05	—2,11 —0,21	—1,68 0,94	—1,17 —1,30	—1,09 —4,09
Femur	2,43 0,01	—2,19 1,30	—2,27 —1,84	—2,96 2,20	—0,37 3,06
Knee joint	2,40 —0,05	—2,16 1,14	—2,52 —0,78	—4,09 —0,17	—3,01 —5,68
Proximal tibial epiphysis	1,62 —0,15	—0,87 0,19	—1,77 0,26	—2,07 1,94	—3,87 —4,70
Distal tibial epiphysis	2,26 0,06	—2,49 0,66	—1,92 —0,53	—1,53 1,22	—1,35 —6,31
Tibia	2,53 0,01	—2,39 1,28	—2,44 —0,88	—2,61 —0,45	—1,66 —8,15

BASIC ECOMORPHOLOGICAL PARAMETERS OF GROUPS

Comparing the general morphological patterns of Paleolithic, Neolithic, Slavic and recent Moravian population many clear-cut differences might have been determined (*Table 2*). Yet the differences cannot be determined in any case as persisting trend of gracilization in the direction from Paleolithic to Recent population. The process was very probably much more complicated and consequently character of the adaptive strategy along with its ecological parameters typical for the given population should be taken into account. For example, general morphological pattern of recent population remarkably differs from the remaining three populations that have a number of common features despite marked differences on their proximal femoral epiphysis (*Table 3*).

Relatively short, thick, rounded femoral neck with relatively big femoral head and low collodiaphyseal angle are the features typical for the Paleolithic population with no respects to the individual taxonomic status in the group. Relatively long oval femoral neck with relatively small head and very high collodiaphyseal angle characterize Neolithic population. Morphological pattern of the Slavic population seems to be intermediate between these two patterns. Slavic pattern is morphometrically the most similar to the recent population but there are also many different features, e.g. the shape of major and minor trochanter.

All non-recent populations have relatively as well as absolutely shorter femur and tibia, higher femoral and tibial condyles and higher and broader maleolus medialis. Very robust epiphyses and diaphyses are characteristic for the Paleolithic population while the Neolithic one is generally gracile with relatively small epiphyses. Slavic population is more robust, especially diaphyses. Similarly as in the Neolithic population, vertical dimensions are more pronounced and both femur and tibia are allometrically shorter in comparison with the recent Moravian population.

It follows from our results that femur and tibia of Paleolithic population were adapted for the dynamical variable bipedality. Neolithic population have structural adaptations that seems to be suitable for more statical locomotor habits. Slavic femurs and tibias are characteristic by the relatively generalized morphological patterns in various features similar to both Paleolithic and Neolithic or recent population. Femur and tibia of the Moravian population have a specific mosaic pattern suitable for time limited static and dynamic locomotor habits without a marked pattern of stress adaptation. Morphological patterns of the examined populations seem to be well correlated with their basic ecological adaptations.

SEXUAL DIMORPHISM AND ITS ECOMORPHOLOGICAL PARAMETERS IN HUMAN MICROEVOLUTION

Individual ecological adaptations influence in high degree also the character of the sexual dimorphism

TABLE 4. *Differences between sexes for individual measurements*

	Recent		Slavic		Neolithic	
	T-test	F-test	T-test	F-test	T-test	F-test
1. SUBTROAP	HS	+	HS	+	HS	+
2. SUBTROML	HS	+	HS	S	HS	+
3. TRMAHIGH	HS	HS	HS	+	HS	+
4. TRMATRMI	HS	HS	HS	+	HS	+
5. HEADBRTH	HS	+	HS	+	HS	+
6. COLODIAG	+	+	+	+	+	+
7. NECKLNGH	HS	+	HS	HS	+	+
8. NECKBRAP	HS	+	HS	+	HS	+
9. NECKBRML	HS	S	HS	+	HS	+
10. TRMABRTH	HS	HS	HS	+	HS	+
11. NCKLGBIO	HS	+	HS	+	HS	+
12. TRMIHEAD	HS	HS	HS	+	HS	+
13. TRMIBRTH	HS	+	HS	+	HS	+
14. TRMIHIGH	+	+	HS	+	HS	S
15. TRMINECK	HS	HS	+	+	HS	+
16. SUPREPAP	HS	+	S	+	+	S
17. SUPREPML	HS	+	+	+	HS	+
18. SUPCONAP	HS	+	S	+	HS	+
19. SUPCONML	HS	+	+	+	HS	+
20. INTEREPI	HS	+	S	+	HS	+
21. DISTCOND	HS	+	HS	+	HS	+
22. COLAHIGH	HS	HS	HS	+	HS	+
23. COLAOBLQ	HS	+	HS	+	HS	+
24. COLAMAXM	HS	+	HS	+	HS	+
25. COMEHIGH	HS	+	HS	S	HS	HS
26. COMEOBLQ	HS	+	HS	+	HS	+
27. COMEMAXM	HS	+	HS	+	HS	+
28. INCIBRTH	HS	+	+	+	+	+
29. COLASGMX	HS	+	HS	+	HS	+
30. COLASGMN	HS	+	HS	+	HS	+
31. COLALNGH	HS	+	+	+	HS	+
32. COLABRTH	HS	+	HS	+	HS	+
33. COMESGMX	HS	+	HS	+	HS	+
34. COMESGMN	HS	S	HS	+	HS	+
35. COMELNGH	HS	+	+	+	HS	+
36. COMEBRTH	S	+	HS	+	HS	+
37. ANTECOND	HS	+	HS	+	HS	+
38. DISTEPMX	HS	+	HS	+	HS	+
39. DISTEPMN	+	+	+	+	HS	S
40. INCIDPTH	S	+	HS	+	HS	S
41. DIAMDLAP	HS	+	HS	+	HS	+
42. DIAMDLML	+	HS	+	+	HS	+
43. FEMLNGMX	HS	+	HS	S	HS	+
44. INKLINAG	+	S	HS	+	+	+
45. DSTEPIAG	+	+	+	+	HS	+
46. INCIHIGH	+	+	+	+	+	+
47. PRXEPIAP	HS	S	+	+	HS	+
48. PRXEPIML	HS	+	HS	+	HS	+
49. COMETIAP	HS	+	S	+	HS	+
50. COMETIML	HS	+	S	+	HS	+
51. COLATIAP	HS	+	HS	+	HS	+
52. COLATIML	HS	+	+	+	HS	+
53. INTEREMI	HS	+	+	+	+	+
54. EMINDIST	HS	+	HS	+	HS	+
55. COMEHIGH	HS	HS	+	+	HS	+
56. COLAHIGH	HS	+	+	+	HS	+
57. SUBCONAP	HS	S	HS	+	HS	+
58. SUBCONML	HS	S	S	+	HS	+
59. TUBTIBAP	HS	+	HS	+	HS	+
60. SUBTUBAP	HS	+	+	S	HS	+

Tab. 4 Cont.

	Recent		Slavic		Neolithic	
	T-test	F-test	T-test	F-test	T-test	F-test
61. SUBTUBML	HS	+	+	+	HS	+
62. SUPREPAP	HS	+	HS	+	HS	+
63. SUPREPML	HS	+	HS	+	HS	+
64. MALEHIGH	HS	+	+	+	+	+
65. MALEBRTR	HS	HS	HS	+	HS	+
66. MALEMLBR	HS	+	+	+	HS	+
67. DIEPIBRT	HS	+	HS	+	HS	+
68. ARTBRANT	HS	+	HS	+	HS	+
69. ARTBRPST	HS	+	HS	+	HS	+
70. ARTBRLAT	HS	+	HS	+	HS	+
71. ARTBRMED	HS	+	+	+	HS	+
72. ARTANTEG	HS	+	HS	+	HS	+
73. DIATIBAP	HS	+	+	+	HS	+
74. DIATIBML	HS	+	HS	+	HS	+
75. TIBLNGMX	HS	+	+	+	HS	S

HS — highly significant (P > 0,005)
S — significant (P > 0,05)
\+ — nonsignificant

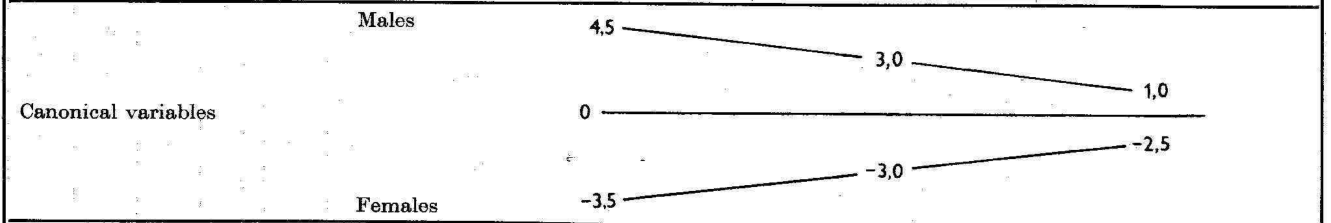
in a given populatin. In this sense the femur and tibia are very suitable objects because they reflect by their pattern in particular functional regions as well as in overall functional complex a number of factors starting with reproduction through the body mass and body height up to the locomotor habits. The degree of sexual dimorphism (see *table 4* for the differences in individual traits) is in no case identical with the degree of sexual differences in body mass or body height and the differences in individual parameters are not usually isometrical. This has also been proved by the recent analysis of data with the decreased size effect by logarithmic transformation (Vančata — unpublished results).

The most pronounced differences in the patterns of sexual dimorphism have been found in Neolithic population that is the most gracile among examined populations (*Fig. 1*). Despite that our sample of Paleolithic Homo sapiens is not directly suitable for examining of sexual dimorphism the recent study by Frayer and Wolpoff (1985) support our conclusions that Neolithic Homo sapiens has more pronounced sexual dimorphism than other human populations including Paleolithic man.

High degree of sexual dimorphism confirmed by all relevant multivariate and univariate analyses, is based almost exclusively on significant allometrical differences among individual characters in both sexes (see *Table 5*, *Fig. 1*), which is supported also by the fact that the length of their femur and tibia is relatively and absolutely smallest and sexual differences in these two features are relatively low.

Recent population has relatively and absolutely longest femur and tibia. Relatively high differences exists between sexes in their length but the degree of sexual dimorphism is the lowest among examined populations. Many differences between males and females in recent population are isometrical, i.e. only in size (see *table 6*). Slavic population seems to have somewhat lower degree of sexual differences (see *table 4, 7*) in comparison with the Recent population if individual parameters are examined but the differences are higher if the patterns of individual functional regions are studied (*Tables 8, 9, 10*). The analysis of patterns seems to be more conclusive and conse-

MORPHOMETRICAL DIFFERENCES	Neolithic population	Slavic population	Recent population



MORPHOLOGICAL DIFFERENCES	Neolithic population	Slavic population	Recent population
Length of femur and tibia Male/Female differences	short significant	middle significant	long very significant
Character of diaphyses Male/Female differences	gracile different	middle middle differences	robust low differences
Size of femoral and tibial epiphyses Male/Female differences	small very different	relatively robust different	robust lower differences
Character of sexual differences The degree of Male/Female differences	allometric, linear very marked	allometric/isometric, non-linear marked	isometric/allometric, linear marked

FIGURE 1. *Differences between sexes in the examined human populations.*

TABLE 5. *Analysis of variance and covariance in selected traits in males and females of Neolithic population*

Variable Dependant	Covariate independance t-test		Equality of adj. means F-test		Zero slopes F-test		Equality of slopes F-test		Adjusted Group Means t-test	
	Independant									
	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia
1. SUBTROAP	S	+	+	S	S	+	+	+	+	S
2. SUBTROML	+	S	S	S	+	S	+	+	S	S
7. NECKLNGH	S	S	+	+	S	S	+	S	+	+
8. NECKBRAP	S	S	S	S	S	S	+	S	S	S
9. NECKBRML	S	S	S	S	S	S	+	+	S	S
11. NCKLGBIO	S	S	S	S	S	S	+	S	S	S
12. TRMIHEAD	S	+	S	S	S	+	+	+	S	S
20. INTEREPI	S	S	S	S	S	S	+	S	S	S
22. COLAHIGH	S	S	S	S	S	S	+	+	S	S
25. COMEHIGH	S	S	+	+	S	S	+	S	+	+
31. COLALNGH	S	S	S	S	S	S	+	S	S	S
35. COMELNGH	S	S	S	S	S	S	+	+	S	S
41. DIAMDLAP	S	S	S	S	S	S	+	+	S	S
42. DIAMDLML	S	S	+	+	S	S	+	+	+	+
43. FEMLNGMX	—	S	—	+	—	S	—	S	—	+
47. PRXEPIAP	S	+	S	S	S	+	+	+	S	S
48. PRXEPIML	S	S	S	S	S	S	+	S	S	S
55. COMEHIGH	S	S	+	S	S	S	+	+	+	S
56. COLAHIGH	S	S	+	+	S	S	+	+	+	+
67. DIEPIBRT	S	+	S	S	S	+	+	+	S	S
71. ARTBRMED	S	+	S	S	S	+	+	S	S	S
73. DIATIBAP	+	+	S	S	+	+	+	+	S	S
74. DIATIBML	S	S	+	+	S	S	+	S	+	+
75. TIBLNGMX	S	—	+	—	S	—	S	—	+	—

S — *highly significant* (P > 0,005)
S — *significant* (P > 0,05)
\+ — *nonsignificant*

TABLE 6. *Analysis of variance and covariance in selected traits in males and females of Recent population*

Variable Dependant	Covariate independance t-test		Equality of adj. means F-test		Zero slopes F-test		Equality of slopes F-test		Adjusted Group Means t-test	
	Independant									
	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia
1. SUBTROAP	S	S	+	S	S	S	S	+	+	S
2. SUBTROML	S	S	+	+	S	S	S	S	+	+
7. NECKLNGH	S	S	+	+	S	S	+	+	+	+
8. NECKBRAP	S	S	+	S	S	S	S	S	+	S
9. NECKBRML	S	S	S	S	S	S	S	S	S	S
11. NCKLGBIO	S	S	+	S	S	S	+	+	+	S
12. TRMIHEAD	S	+	S	S	S	+	+	+	S	S
20. INTEREPI	S	S	+	S	S	S	+	+	+	S
22. COLAHIGH	S	S	S	S	S	S	S	+	S	S
25. COMEHIGH	S	S	+	+	S	S	S	S	+	+
31. COLALNGH	S	S	+	S	S	S	+	+	+	S
35. COMELNGH	S	S	+	+	S	S	S	+	+	+
41. DIAMDLAP	S	S	+	S	S	S	+	+	+	S
42. DIAMDLML	S	S	+	+	S	S	S	S	+	+
43. FEMLNGMX	—	S	—	S	—	S	—	+	—	S
47. PRXEPIAP	S	S	+	+	S	S	+	+	+	+
48. PRXEPIML	S	S	+	+	S	S	+	+	+	+
55. COMEHIGH	S	S	+	+	S	S	+	+	+	+
56. COLAHIGH	S	S	+	+	S	S	+	+	+	+
67. DIEPIBRT	HS	S	+	S	S	S	+	+	+	S
71. ARTBRMED	S	HS	+	+	S	S	+	+	+	+
73. DIATIBAP	S	S	+	+	S	S	+	+	+	+
74. DIATIBML	S	S	+	+	S	S	+	+	+	+
75. TIBLNGMX	S	—	+	—	S	—	+	—	+	—

HS — *highly significant (P > 0,005)*
S — *significant (P > 0,05)*
\+ — *nonsignificant*

TABLE 7. *Analysis of variance and covariance in selected traits in males and females of Slavic population*

Varible Dependant	Covariate independance t-test		Equality of adj. means F-test		Zero slopes F-test		Equality of slopes F-test		Adjusted Group Means t-test	
	Independant									
	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia	Femur	Tibia
1. SUBTROAP	+	+	S	S	+	+	+	+	HS	S
2. SUBTROML	+	+	S	S	+	+	S	+	S	S
7. NECKLNGH	+	+	S	S	+	+	+	+	S	S
8. NECKBRAP	+	+	S	S	+	+	+	+	S	S
9. NECKBRML	S	+	HS	S	S	+	+	+	S	S
11. NCKLGBIO	+	+	S	S	+	+	HS	+	S	S
12. TRMIHEAD	+	+	S	S	+	+	+	+	S	S
20. INTEREPI	+	+	S	S	+	+	+	+	S	S
22. COLAHIGH	+	+	S	S	+	+	+	+	S	S
25. COMEHIGH	S	S	S	S	S	S	+	+	S	S
31. COLALNGH	+	+	+	+	+	+	+	+	+	+
35. COMELNGH	S	S	+	+	S	S	S	+	+	+
41. DIAMDLAP	S	S	S	S	S	S	S	+	S	S
42. DIAMDLML	+	+	+	+	+	+	+	+	+	+
43. FEMLNGMX	—	S	—	+	—	S	—	S	—	+
47. PRXEPIAP	+	+	+	+	+	+	+	+	+	+
48. PRXEPIML	+	+	S	S	+	+	+	+	S	S
55. COMEHIGH	S	S	+	+	S	S	+	+	+	+
56. COLAHIGH	+	+	+	+	+	+	+	+	+	+
67. DIEPIBRT	S	S	S	S	S	S	+	+	S	S
71. ARTBRMED	+	S	+	+	+	S	+	+	+	+
73. DIATIBAP	+	+	+	+	+	+	+	+	+	+
74. DIATIBML	+	+	S	S	+	+	+	+	S	S
75. TIBLNGMX	S	—	+	—	S	—	+	—	+	—

HS — *highly significant (P > 0,005)*
S — *significant (P > 0,05)*
+ — *nonsignificant*

TABLE 8. *Discriminant Analysis of sexual differences in Homo Sapiens populations (Canonical variables)*

	Recent		Slavic		Neolithic	
	♂	♀	♂	♀	♂	♀
Proximal femoral epiphysis	0,82	—2,58	1,41	—1,32	2,21	—1,51
Distal femoral epiphysis	0,90	—3,01	2,29	—2,29	2,93	—2,25
Femur	1,50	—5,02	11,60	—11,60	13,43	—10,27
Proximal tibial epiphysis	0,52	—1,64	1,21	—1,13	2,75	—1,99
Distal tibial epiphysis	0,44	—1,39	1,21	—1,13	2,50	—1,81
Tibia	0,59	—1,85	1,73	—1,62	2,81	—2,03

TABLE 9. *Discriminant Analysis of sexual differences in Homo Sapiens populations (classification functions)*

	Recent		Slavic		Neolithic	
	Variables	% correct classif.	Variables	% correct classif.	Variables	% correct classif.
Proximal femoral epiphysis	5, 12, 9, 6	93,5	5, 7	93,1	10, 12, 6, 5	100,0
Distal femoral epiphysis	22, 21, 40, 16, 33, 45, 24	96,7	32, 28, 18, 37, 27, 36	100,0	20, 39, 45, 17, 19	100,0
Femur	43, 44, 22, 26, 45, 42, 9, 39, 14, 18, 25, 12, 40, 33, 34, 27	100,0	32, 28, 18, 2, 37, 13, 11, 27, 36, 19, 39, 14, 10, 22, 1, 6, 44	100,0	20, 39, 24, 8, 3, 9, 26, 22, 13, 34, 36, 38, 29, 2, 33, 37	100,0
Proximal tibial epiphysis	51, 55	87,1	59, 58, 51	89,7	47, 60, 54, 49, 53	96,7
Distal tibial epiphysis	70, 67	83,9	70, 72, 69	86,2	68, 66, 70, 64	100,0
Tibia	75, 70	93,5	70, 72, 73, 58, 65, 56	93,1	47, 60, 64, 66, 70	100,0

TABLE 10. *Discriminant Analysis of Homo Sapiens populations (all sexes)*

	Recent		Slavic		Neolith	
	♂	♀	♂	♀	♂	♀
Proximal femoral epiphysis	1,67 0,47	—1,41 —0,13	0,96 —1,60	—1,33 —1,08	0,18 0,30	—2,81 0,76
Distal femoral epiphysis	2,19 0,06	0,06 2,71	—1,04 —2,49	—2,05 —0,41	—0,63 —1,80	—3,07 1,36
Proximal tibial epiphysis	1,66 0,14	—0,13 1,94	0,37 —1,04	—1,40 —0,46	—0,68 —1,85	—2,86 0,54
Distal tibial epiphysis	2,50 0,25	1,40 —1,39	—2,07 1,71	—2,84 0,07	—1,66 1,00	—2,53 —1,61
Tibia	3,01 —0,23	1,41 1,98	—1,73 —2,02	—2,90 —0,42	—2,33 —1,15	—3,59 1,71

quently Slavic population should have higher degree of sexual dimorphism than recent man.

The main causes of these inconsistencies are either "threedimensional" character of sexual dimorphism in femur and tibia of the examined Slavic population and, above all, the fact that many of the measured traits are non-lineary dependent on size parameters represented in our study by the length of femur and tibia (*Table 7*). While the features characterizing size and general overall structure in individual functional regions are the most important for the differentiation between sexes in Neolithic population, the differentiation between Slavic and Recent population is based mainly on the differences in joints and those parts that are closely connected with them.

It should be stressed that qualitative differences exist between the patterns of sexual dimorphism of Moravian and west Slavic population and, consequently, they are not directly comparable (*Tables 6, 7, 10*).

CONCLUSIONS

Any generalization of our results *in toto* would be premature but some important conclusions can be made also in this early stage of the analysis as it is shown on the following example.

The origin of marked sexual differences in Neolithic population seems to be in close connection with the origin of a new human adaptive strategy, origin of early agriculture and it most probably reflects new and remarkable ecological differentiation and division of labor between both sexes.

Our conclusions are strongly supported by the recent study of Paleolithic, Mesolithic and Neolithic populations by Frayer and Wolpoff (1985) that shows coastal Neolithic populations to have lower sexual dimorphism in comparison with middle European ones.

This example demontrates that the detail investigations of ecological aspects of sexual dimorphism in Homo sapiens microevolution can give us new important information making possible deeper understanding of evolution of human reproduction as well as origin and development of the different role of both sexes in the evolution of post- Paleolithic human society.

ACKNOWLEDGEMENTS

I thank prof. dr. L. Malinovský, DrSc. and Dr. V. Novotný, CSc. (Department of Anatomy LF UJEP, Brno; LEB ČSAV, Praha), prof. dr. H. Bach and dr. A. Bach (Institute für Humangenetik und Anthropologie, Universität Jena, Jena) and dr. H. Ullrich (Zentralinstitut für alte Geschichte und Archaeologie AdW DDR, Berlin) for their permission to study Homo sapiens skeletons, Dr. J. Jelínek, DrSc. Anthropos Institut, Brno), Dr. A. Bach (Institut für Humangenetik und Anthropologie, Universität Jena, Jena) and dr. Thomas Weber (Landesmuseum Halle, Halle/Saale) for their permission to study casts of skeletons of Paleolithic Homo sapiens. Dr. V. Novotný, CSc., Dr. J. Brůžek, CSc., and Dr. D. Zemková provided number of valuable discussions. Special thanks should be expressed to dr. T. Havránek, CSc. for his assistence in statistical processing of data and to dr. V. Novotný, CSc. and Dr. M. A. Vančatová for their help during the finishing of the final version of manuscript.

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