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Review

Morphological Variation and Sexual Behavior in the Human Past
I. The Sexual Activity and Pelvic Morphology of East Asians : An Approach to Assess Sexual Activity in Fossil Records

Hiroto Naora

Research School of Biological Sciences, The Australian National University, Canberra, A.C.T., Australia

SUMMARY

The behavior, involving in a reproductive strategy was the crucial element of global population expansion in the human past. However, due to the lack of a procedure to assess sexual activity in fossil records, such an involvement is poorly understood. To establish an assessment procedure, I re-examined the hitherto observed results of hormonal analyses, sexual behavior surveys, the comparative study of reproductive organs and the pelvic structures in current different populations. It was noted that a pelvis with the long pubis was frequently seen in East Asian females, whose male partners were sexually least active. Whereas a pelvis with the short pubis was often seen in the females of the other populations in which their male partners were sexually more active. Although the dependency of pubic length on body size can not be ruled out, the possibility has been raised that the pelvic variation in females was associated with the sexual activity of their male partners. A proposal was made that male sexual activity may be indirectly assessed by the pelvic variation (in terms of pubic length) of female partners in fossil records. Using the new procedure, the sexual activity of Palaeolithic specimens, e.g. SH Pelvis 1, was inferred.

Key Words : sexual activity, pelvic morphology, East Asian

INTRODUCTION

The human behavior, including sexual activity is the crucial element of survival and reproduction. Therefore, our ancestors were likely to be individuals who behaved to lead greater survival and reproduction. Recent studies of human behavior in social sciences, including evolutionary psychology have provided us with valuable information on human reproduction strategy in evolution[1,2]. Such a strategy appears to be deeply involved in the global migration and population expansion of humans in the past. However, due to the lack of a procedure to assess the sexual activity in fossil records, such an involvement is poorly understood.

In human, sexual motivation is the internal state which determines engagement in sexual activity toward copulation (see "http://www.csun.edu/~vcpsyooh/student/sexmotiv.htm). A complex interaction among at least cognitive, neurophysiological and hormonal factors is involved in the process[3,4]. It seems possible that the constitutively elevated or diminished level of the internal state for a long period in evolution leads to

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Reprint requests to : Professor Hiroto Naora
Research School of Biological Sciences, The Australian National University, P.O. Box 475, Canberra, A.C.T. 2601, Australia.

a structural/functional change in the organs involved in sexual behavior. It has been well documented that there are biological variations among the phenotypes expressed in the people originally come from the regions of geographically related indigenous populations [5], such as Northeast/East Asia, Europe (and Middle East) and Africa. Hereafter I shall describe them as the people of populations 1, 2 and 3 respectively. However, "Asian", "European" and "African" will be also used in terms of more specific people. These variations have been observed on features not only in morphological structures, e.g. skeletons, and in physiological functions, e.g. hormonal levels [6~8], but also in sexual behavior [3,9]. Variations in pelvic morphology among different populations have been observed [6,10,11]. One aspect of the present study was to bring these findings on the same ground and to find a correlation, if any, between sexual activity and variation in relevant skeletons. To search for such a possible correlation, first I looked at the low level of global population expansion in the East Asian region. The hitherto observed results in physiological, morphological and behavioral studies on different human population were examined in a meta-analytical way. Then, I attempted to formulate a hypothesis to establish the possible procedure for the assessment of sexual activity in current skeletal variations. This paper aimed for how many hitherto observed cases the hypothesis can explain and, if possible, predict the sexual activity in the human past. It was predicted that the sexual activity of SH Pelvis 1 (>200,000 years, discovered in Sierra de Atapuerca, Spain) [12] was probably much lower than current people of population 1.

East Asian population did not significantly expand during last a half century

The global human population (head-count population number) of 10,000 years ago has been estimated to be around 5 millions under the assumed population density (around 15 persons per square miles) [13]. In the twentieth century, the world total human population has increased to more than 6 billions. Of particular interest is that in 2000, 3.74 billion people lived in the entire region of Asia, excluding the Far East of the Russian Territory (Fig. 1) [14]. The Asian population was 56.5% of the total in 1950, but was 60.2% in 2000. The global change of the Asian proportion during the past 50 years was only 7% increase. In contrast, those in Africa and "South America", (including Central America and the Caribbean Sea Islands) were 54 and 33% increase, respectively. In Asia, no major catastrophe occurred during last a half century, although some diseases, e.g. HIV, food shortage and regional wars influenced local expansion of the population to some extent. The observed slow expansion of the Asian population was mainly due to a low total-fertility-rate in Asia. The successful one-child policy in China has significantly contributed to the current decrease in the total fertility rate [15]. It has been reported that the census reports in China were unreliable [16,17]. Overall figures, however, clearly showed the low population expansion in China. Not only in China, but also in Taiwan and Japan showed the low population expansion [18~21]. It should be mentioned that these three nations were under different political, social, religious, economical and environmental situations. Yet, all of them were charac-

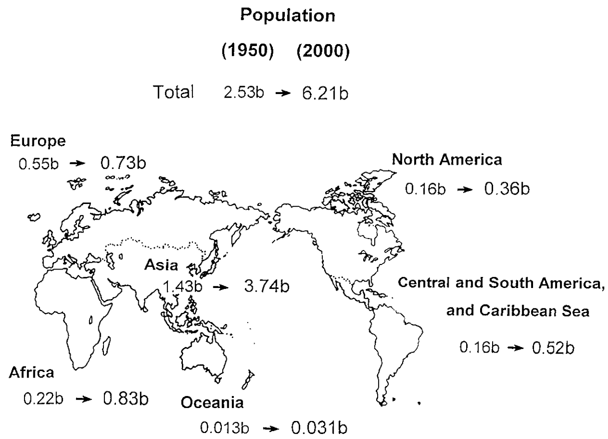

Fig. 1 World population in 1950 and 2000.
The numbers of total and regional populations showing the left and right sides with the arrows represent those in 1950 and 2000, respectively [14]. These numbers are marginally different from the United Nations Report (see ref. 15). The regions shown in the figure are defined as follows : Europe-all West and East Europe and former Soviet Union ; Asia —all South and East Asian nations and Near East ; Central and South America and Caribbean Sea —Central and South America and all nations in Caribbean Sea ; Oceania—Australia, New Zealand and all Pacific nations ; Africa—all African nations and the surrounding Islands ; North America—Canada and the United States of America. Note that this definition is used only in Fig. 1 and the second section of the text.

terized by the low population expansion. These people represented 39% of the Asian population in 2000. Sufficient information on other Asian populations was currently unavailable. In general, a population increase no doubt involves complicated matters, e.g. political, social, religious and health conditions. Notwithstanding, it primarily involves human sexual activity. Human sexual activity is a consequence of instinctive and physiological responses to internal and external stimuli, and then is finely structured through the net work of social and cultural factors [22]. Although I realize the involvement of social, cultural and other non-physiological factors in the surprisingly low figure of population expansion in East Asia, I feel that social and cultural factors would not be strong enough to account, in a simple form, for low population expansion in East Asia. Since one of the crucial determining factors in sexual activity is primarily the level of the physiological state, responsible for the activity, an alternative possibility to explain the low population expansion would be the low level of the physiological state of East Asians.

Sexual activities in different populations

The survey of male sexual activity is a complex issue, which inevitably involves female sexual motivation. Most, if not all, females copulate when they are approached by an appropriate male in an appropriate way at an appropriate time under an appropriate circumstance. In spite of such complexity, relatively reliable surveys have been successfully conducted under the defined criteria in Japan, Britain and America [9, 23~28].

The copulation frequency of sexually active (20−45 years of age) Japanese males (0.5−3 times per week) show much fewer frequencies of copulation than those of the people of population 2 and 3, living in America [24~26]. The surveys conducted under the similar criteria in America and Japan showed that the copulation frequency of Japanese males was much less at any ages than that of Europeans in America [29]. Recent global survey by the Durex (2005) (http://www.durex.com//jp) reported that the copulation frequency (0.87 times per week) of Japanese was least, followed by Singaporean, among 41 (mainly European and Asian) nations. Other Asian people, e.g. Chinese, Vietnamese etc., showed the low level of their sexual activity, irrespective of their different social, cultural, religious and environmental situations. Needless to say, Europeans showed much higher activity. More people in Asian nations, e.g. Japan, China and Vietnam, than Europeans (Italian and Dutch) expressed their view—"I do not have a high sex drive"— in the survey, confirming the sexually least active feature of population 1 people. Bancroft [3] reviewed the sexual activities in different populations, mentioning that the figures previously reported on a striking difference in sexual activities between the people of population 2 and 3 in America have been exaggerated by an inadequate comparison. In more careful analyses, however, the clear difference in their activities has repeatedly been found in separate surveys, although less marked than the earlier studies (see ref. 3). Recently, sexual activities in populations and related hormone levels have been widely studies, in particular, with regards to the preventive measure of sexually transmitted diseases and the populational difference in prostate cancer incidence. All of these studies and surveys have clearly shown that the copulation activity, in terms of copulation frequency, is population 1 < population 2 < population 3. These differences in sexual activity have been seen in not only the copulation frequency of males, but also in other variables, such as the non-marital fertilization rate, arousal and desire of pre- or early perimenopausal females [30,31]. "Non-physiological" factors, e.g. culture, education and religion, are unquestionably involved, to some extent, in sexual behaviors [3,9]. However, as opposed to the popular view that cultural and economical differences cause major variation in human sexual behaviours, a wide range of survey on sexual behavior in some populations, e.g. population 2 and 3 in America, has shown that there is little or minute, if any, effect of social, economical and religious factors on sexual permissiveness and even copulation frequency [32,33]. Population 3 youth in America has been reported to initiate sexual activity at earlier age than do population 2 youth in American and population 1 youth [34]. Browning et al.[35] reported that demographic background, family processes and developmental risk factors can explain only partially their earlier sexual onset for population 3 youth in America. Therefore, social and cultural factors have a limited, if any, effect on the activity and can not fully account for the differences widely seen among different populations.

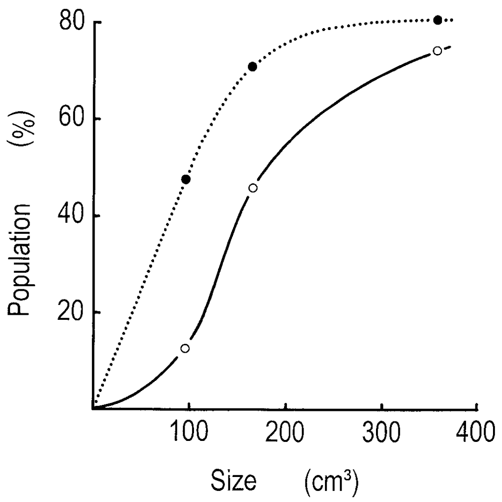

Fig. 2 Correlation between the numbers of sex partners and premarital sexual activities, and different populations. The proportions of the males in three different populations who have had more than one sex partner since the age of 18 years old (●…●) and experienced premarital copulation at the age of 11–21 years old (○—○) were referred from refs. 23, 24, 101. Proportions are expressed in % of the population. Individual population was expressed in terms of the average penis size of those who belong to a given population (97 cm^3 for population 1,165 cm^3 for population 2 and 355 cm^3 for population 3.) See the text for details.

It has been reported that the sexual activity of Japanese males declines 5–10 years earlier than that of European males [29,36]. The survey has shown that 29 % of Japanese males stopped their sexual activity, due to the loss of their own sexual interest, when they were 57.0 ± 9.8 (n : 133) years old [28]. Although the copulation frequency of Japanese males rapidly declined between 50–60 years of age, their "morning erection" activity has already decreased at the age of 30 to 40 years [29]. On the other hand, many population 2 males in America maintained their copulation activity even beyond 57 years of age [36,37]. The avoidance of copulation by female partners can not be ignored in the low copulation activity of Japanese males. The surveys reported that most of Japanese females avoid copulation with partners when they become 52.0 ± 9.3 (n : 133) years old [28].

Although people having more partners do not necessarily have more frequent copulation, the number of partners after reaching sexual maturity would represent one side of expression in sexual motivation. Surveys in America suggest that approximately 48 % of middle class East Asians, living in America, had more than one partner since they were 18 years old. On the other hand, more than 70 % of middle class non-Asians had more than one partner (Fig. 2) [24]. Similarly, premarital copulation would in part represent an active expression of sexual motivation. Population 1 males, living in America, had much less frequent premarital copulation than other populations (Fig. 2) [23].The data, obtained in the survey of the sexual life style of various populations in Britain, have also shown the patterns (population 3 > population 2 > population 1) similar to those obtained in America [3,9]. Once again, British surveys showed that religious and educational aspects can not fully account for the observed differences in sexual expression.

All of these surveys from the different angles of male sexual activity have shown that the male activity varies from population to population and in general reveals the pattern, in order of sexual activity, of population 3 > population 2 > population 1.

The level of testosterone and sex hormone binding-globulin concentrations in blood, and male sexual activity

Despite the popular view of social and cultural contribution to human sexual activity, it is becoming clear from human, non-human primate and other animal works that the sexual behavior-specific physiological state is the primary regulatory factor of sexual behavior. Testosterone has been particularly claimed for a pivotal factor in regulating male sexual activity [4,38~41]. This primacy of the physiological system makes it reasonable to postulate that physiological and morphological variations in a reproductive system follow the between-population difference in human sexual activities.

The influence of hormones for sexual behavior, in particular the concentration of circulating testosterone has been well established in animal and human males [3,4,42~44]. Testosterone is believed to be the main component to regulate the crucial enzymes for sexual activities, such as nitric oxide synthase and phosphodiesterase type 5 [41]. It is widely assumed that there is a threshold level of circulating testosterone for maintenance of normal sexual motivation in male [3]. The actual value of the level remains to be yet determined. It was previously assumed that a "short term" increase in the testosterone level above the threshold have no additional effect (see ref. 4). However, experiments on testosterone administration to eugonadal patients complaining the loss of sexual interest have shown both substantial increase in circulating testosterone levels and modest but significant increase in sexual interest [3]. Similarly, WHO Study [45] also exhibited increased "libido". It should be noted that variation in consistently elevated/decreased base levels in blood would be different from temporal (short-term) changes. The altered base levels of testosterone in blood, independent of the short-term fluctuation would play a vital role of the maintenance of their own sexual activities.

The copulation ability is controlled separately from sexual motivation, a prerequisite to the male sexual activity [44,46]. The neural center, which regulates male sexual motivation, is present in the dorsomedial hypothalamis area [47,48]. Gonadal hormones, e.g. testosterone, have been shown to primarily influence sexual motivation through this center [48]. The hormone-receptor interaction followed by a series of intracellular signal transductions is crucial for the regulation of male sexual motivation. Female sexual motivation involves more complex processes [44] and thus will be separately described in detail elsewhere.

Most testosterone present in circulating blood is bound with sex hormone binding-globulin (SHBG) and transported to target organs. SHBG itself appears to be involved in the regulation of sexual activities as well [49]. The levels of circulating total and "bioavailable" (mainly unbound) testosterone (see ref. 50), and SHBG of the people of various populations have been analysed [8,51~55]. In some reports, clear differences in total testosterone concentrations have been observed between population 2 and 3 in America [8]. In other studies, no obvious differences have been made [51,55,56]. Since the level of total testosterone has been reported to vary by various factors [8,50,51,55,57], the observed discrepancies among different studies are in part due to the analyses under the non-comparable conditions and/or to an inappropriate adjustment. It has been shown in primates that the percentage of SHBG-bound testosterone correlates inversely with various measures of their sexual behavior [38]. Hence the ratio of total testosterone and SHBG would roughly represent a simple and relative index of bioavailable testosterone, responsible for sexual activity. Such a ratio has been reported to be higher in population 3 males in America than population 2 males [56], suggesting the elevated level of bioavailable testosterone in former males. Unlike the conflicting results of total testosterone levels, more consistent reports have been seen on the between-population level of bioavailable testosterone.

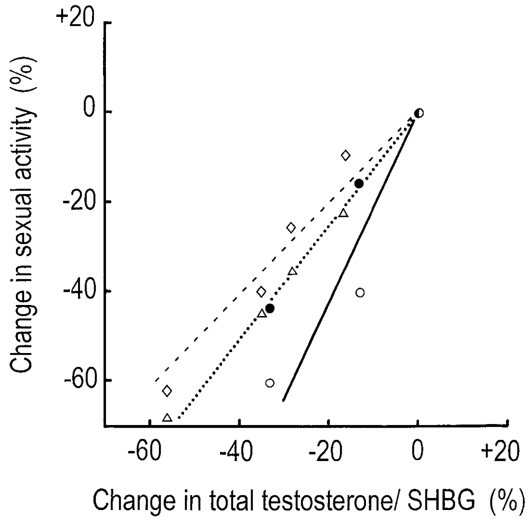

Fig. 3 Correlation between changes in sexual activity, and the ratio of total testosterone and SHBG.
Changes in sexual activities (◇ : erectile function and △ : orgasmic function) with aging and the ratio of total testosterone and SHBG in blood were expressed in terms of the percentage of the levels decreased from those of the <40 years old male group [59]. The proportions of the male who have more than one partner since the age of 18 years old (●), and who have had premarital copulation (○) shown in Fig. 2, were expressed in the same way as the above, except for changes from those of population 3 males. Total testosterone and SHBG levels of population 1, 2 and 3 were taken from refs. 8, 51, 52, 54−56, 102. Note that the progressive decline in sexual activity is the function of the decrease in the ratio of total testosterone and SHBG observed in the aging process and also among different populations.

A clear decline in various sexual activities has been observed during the aging process with falling total testosterone level and the concomitant increase of SHBG [50,58~60]. The decline in sexual activity would be in part due to a decrease in the tactile sensitivity [61, 62] and in the number of active testosterone receptors in penis [63]. However, the decreased level of bioavailable

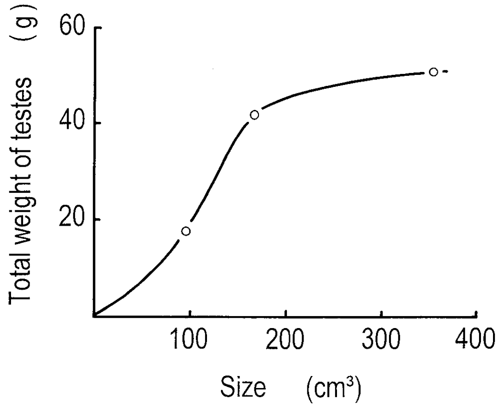

Fig. 4 Correlation between the size of total testes and the erect penis.
The values of average total testis weight and the median size (expressing in cm^3) of the erect penis of the people in different populations, mentioned in Fig. 2, were taken from refs. 66, 68, 70). Note a positive correlation of both organs in size.

testosterone appeared to be more crucial in the aging process (Fig. 3). The figure shows that a progressive decline in sexual activity, e.g. erectile and orgasmic functions, during the aging process is clearly associated with steady decline in the ratio of total testosterone and SHBG in a linear manner. It should be noted that between-population variations in sexual activities are really dependent upon the bioavailable testosterone level as well. Thus, the between-population variation of the physiological state for male sexual activity and corresponding sexual behaviors would be equivalent to that seen in other processes, such as aging. Taken altogether, it appears likely that between-population variation in sexual activity, that is population 1 < population 2 < population 3, is supported on the sound basis of physiology.

The size of a testis and penis in erection

Male testosterone is mainly produced by Leydig cells in testes and is secreted into a circulating system[50,64], although the human adrenal is a source of circulating androgen precursors[65]. The total weight of testes is within the ranges of 16.8 – 17.9 g in Japanese[66] and 16.6 – 19.0 g in Chinese[67] (see also ref. 68), and is significantly smaller than those of a European (42.0 g)[69] and an African (50.2 g)[70]. Even after adjustment of the testis size for body weight is made, Japanese and Chinese testes are still much smaller than those of Europeans.

In mammals, intense sperm competition is associated with relatively large testes[71~73]. This is also likely in humans[74]. Sperm competition has put the male under strong pressure to be able to place his sperms in the most effective location within a vagina for fertilization[73,75] and also to transfer the message to the female partner through their sexual excitement and orgasm for prompt preparation of the best conditions for fertilization. Thus the testis and the penis appear to have co-evolved. In fact, a good correlation can be seen between the sizes of these organs (Fig. 4). Ootaguro[76] observed that the penis co-grows with the testis during the postnatal and adolescent growth periods. In Fig. 4, the following values of the median sizes of the erect penis are used : the people of population 1 (97 cm^3 in volume, 10.2 – 14.0 cm in length), population 2 (165 cm^3 in volume, 14.0 – 15.2 cm in length) and population 3 (355 cm^3 in volume, length 15.9 – 20.3 cm in length)[74]. The volume was calculated under the assumption of a cylindrical form. Similar values have been reported on a few more East Asian populations by Yoshioka and Muto[77]. The size of the penis does not necessarily correlate with the body size[74,76]. Although the inter-individual variation in penis size within a given population is seen to some extent, between-population differences in size are statistically significant.

Such a between-population variation in penis size would be an evolutionary consequence of the human reproductive strategy acquired under the long period of evolution. Thus the median penis size could be representative of a unique nature, in terms of reproductive strategy, of individual population.

The reproductive tract of females and its co-evolution with the penis size of their partners

It has been urged that selection on males for a longer penis would be countered by selection on females for a longer reproductive tract[73,74]. In fact, the longer penis of chimpanzee might have co-evolved with the female's swelling. Vaginal length increases by 50 % in same females at the height of swelling. Males with short penises would suffer a reproductive disadvantage[38]. The size of human vagina varies slightly during her life span, depending upon the past history of parturition and copulation. On the average of 103 cases, the posterior wall of a Japanese vagina is 8.2 cm long[78]. The vagina of an European is more than 40 % longer in the posterior wall than that of Japanese[70]. The observed size difference is not due to the difference in their body sizes, since an obvious difference is still seen when the comparison is made with the similar body sizes in both populations (see ref. 70). Since the erect penises of population 2 people are approximately 20 % longer than those of Japanese, this observation indicates that the erect penis and the vagina of the people in each population have coordinately changed their sizes in evolution possibly for its full compatibility.

The vagina itself is not a large organ located in the pelvic cavity. A magnetic resonance imaging study on the copulation of European (presumably) couples revealed that female sexual arousal before copulation enhanced the movements of the anterior wall of the vagina and the wall was elongated by 1 cm[79]. During copulation, the vagina was further elongated by the intromitted penis. In complete intromission, the penis filled up the anterior or posterior fornix. Schultz et al.[79] have described their convincing impression of the enormous sizes, relative to the size of her pelvic cavity, of the intromitted penis and the expanded vagina. Thus, it is clear that the large pelvic space is required for the long penis and thus the enlargement of the erect penis would become a strong evolutionary pressure on females. The inclination of the female pelvis might also be involved in this issue. The angles are 53 − 55° in the people of population 1, 55 − 60° in population 2 and around 60° in population 3[80]. In fact, an increment of 5° to 10° in the inclination of the female pelvis leads to a distinct alteration of the hip posture and to the expansion of the pelvic space.

Since the normal conjugate of a Japanese female pelvis is 13.1 ± 0.72 cm long (n : 115)[81], the Japanese female seems to have the pelvic space large enough for the adequate accommodation of the vagina that is expanded, even if towards her sacrum, by a small (around 12 cm long) erect penis. However, females would encounter a new situation if their partners have much longer organs. Levin[82] has argued that if a number of the changes induced by sexual arousal in a female are inadequately expressed during copulation, sexual and reproductive dysfunctions could arise. Since female sexual arousal is often induced during copulation, the enlargement of the penis would be one of the delicate key factors in evolution. Thus, it seems likely that selection on males for a larger and longer penis would eventually lead to selection on females for a larger pelvic space to accommodate the expanded vagina. In general, a female pelvis would function in the following at least four ways : the pelvis is 1) to adapt for weight-bearing, 2) to respond to obstetric needs, 3) to adapt for bipedal locomotion and posture and 4) to provide an adequate support and the appropriate allocation of various internal organs in the cavity for their functional demands. The present concern deals with the fourth function of the pelvis. There is no doubt that a female pelvis should contribute to respond to mother's obstetric needs. In reality, however, that the considerable evolutionary advantages of other functions, such as bipedalism, encephalisation and proper accommodation of internal organs in the cavity might have prevented the full structural demands of parturition in female pelvic morphology. Ragir[83~86] has mentioned that reorganization of the skeletal birth canal might have been accompanied by a variety of adaptive responses, but not solely by demands in the process of birth. It seems clear that changes in pelvic structures were extremely limited under these restrictions.

The pelvic structure of females and its co-evolution with the penises of their male partners

According to the shape of the pelvic brim, pelvises have been originally classified into four basic categories : gynaecoid, platypelloid, anthropoid and android pelvises[87,88]. This classification has been reported to involve the problems arising from a wide range of structural variation[89]. However, as the present study is based on the meta-analysis of the hitherto observed data, the author's original classification was mentioned. The combined types of pelvises, e.g. a gynaecoid-type pelvis with an android tendency, are observed as well[89~91]. In general, the feature of the posterior segment determines the types of the pelvis and that of the anterior segment determines the tendency (see ref. 91).

During the period of 1954 − 1956, pelvic measurements of the Japanese females, who were delivered of infants in the Tokyo U.S. Army Hospital, were carried out. It was found that the bony pelvises of most of them consistently showed the "true" gynaecoid type [92]. Recently Kasai [80] reported that 70% (minimum 60–maximum 80%) of Japanese female pelvises were of the gynaecoid type and that the anthropoid and platypelloid types were only 16% and 9%, respectively. The android pelvis was rare (5%) in the Japanese female population. More than 60% of Chinese female pelvises were the "shallow" types, i.e. gynaecoid and platypelloid. The anthropoid type was 20% [93]. In contrast, 41% of population 3 females showed the anthropoid type, whereas the anthropoid type of population 2 females was only 24% [94]. The typical gynaecoid pelvis, dominant in Japanese females, has unique anatomical features : the posterior sagittal diameter of the inlet is only slightly shorter than the anterior sagittal. The sides of the posterior segment are well rounded and wide. The inlet is either slightly oval or round. The pelvis has a shallow cavity with a broad sacrum. The platypelloid pelvis is virtually a flattened gynaecoid type with a shallow cavity. The anthropoid pelvis is characterized by the transverse diameter of the inlet smallest among the basic pelvic types. Comparative studies of pelvic morphology of the population 2 and 3 people in America and South Africa have demonstrated the clear morphological variations specifically associated with them [6,10,11]. It has been observed that the transverse diameter is of high value (with 88% accuracy) in identifying these populations [6]. Walrath [89] has mentioned that between-population variation in metric and non-metric features has been well documented. Such a variation has also been noted in obstetrics [80,91,94]. This in fact reflects variations in the shape of birth canal, which supports the view of no single "normal" process of birth mechanism[89]. Trevathan [95] reported the presentation of the neonate in population 1 is different from those in population 2. Such variation in presentation is in good accordance with the observation that the gynaecoid pelvis is widely seen in most of Japanese and Chinese females, while the pelvises of population 2 females are the mixture of all types. Ambiguity in pelvis typology, due to a range of variation [89] does not necessarily jeopardise the general feature of pelvis typology, since these types can be rather accurately identified when correct techniques in radiography and direct measurements are used by experienced physicians [90] (also Kasai, personal communication). This is further supported by the observation with cadaveric specimens that there are no significant differences in both radiographic and direct measurements of the transverse diameter of the pelvic rim, which is one of the crucial measures in pelvis typology [96]. Whatever the accuracy of pelvis topology was, it seems obvious that the pelvises of population 3 females were in general characterized by a longer anteroposterior diameter than the transverse and a deep cavity. On the other hand, Asian female pelvis showed the relatively short posterior sagital diameter of the inlet and a shallow cavity. Population 2 females in America showed the intermediate features between population 3 and 1. Thus, it can be seen that "architectual" changes in female pelvis topology from population 1 through 3 exactly took place in parallel to the progressive penis enlargement of their male partners. It has been shown that the pelvic structure is sensitive to external influence during the postnatal growth, in particular in early childhood [6,90]. Therefore, it seems likely that the basic structure of the pelvis is genetically determined, corresponding to the evolutionary history of each population, but modified to some extent according to the external situation.

The available pelvic capacity is actually defined by the delicate arrangement of soft tissues, e.g. ligaments and muscles. The vagina in general forms angle of around 30° with the plane of the pelvic outlet [77]. If the angle slightly changes by secondary attachment of soft tissues, it would make a difference in the space available for the enlarged vagina during copulation. It appears that the exact location of the vaginal orifice is also defined by soft tissues [77]. Nevertheless, it appears clear that the skeletal frame primarily defined the pelvic capacity.

The assessment of sexual activity in pelvic morphology

Linea terminalis length is defined as curved length from the apex of auricular surface to the dorsomedial aspects of superior pubis [97]. It has been shown that linea terminalis length is highly correlated with some measures, including the size of posterior segment, of the inlet [97]. Since pubic length is a component of linea terminalis length and the posterior segment of the inlet directly determines the pelvic shape, average female pubic length in each population was compared with the size of the erect penises of their partners (Fig. 5). Fig. 5 shows that average pubic length differs from one population to others and is inversely correlated with the size of the erect penis of the partner. The differences of pubic length among different populations were statistically (t-test) significant. It was of interest to mention that each female population has the unique size of pubis : longest in population 1, medium in population 2 and shortest in population 3. Clear differences in pubic length have also been reported between population 2 and 3 females in South Africa[10]. Indigenous people in South African are characterized by short pubic length. The measurement procedures in pelvic morphology have differed slightly among researchers. Pubic (acetabulosymphyseal) length from the edge of the acetabulum—hereafter called pubic (acetabulosymphyseal) length—was mainly reported in fossil specimens[98]. Rosenberg[98] has described that pubic (acetabulosymphyseal) length is related with the body size (expressed in femoral head diameter squared). She has mentioned the involvement of two factors, i.e. absolute and relative weight, in this relationship and the requirement of a complex model for the explanation of the relationship. She emphasised that the morphology of the extremely long pubis in Neanderthals remained unexplained, as their pubic lengths were well above what one would predict based on their body size[98]. Since y-intercept for the female regression line of the relation shown in Rosenberg's figure (Fig. 5 of ref. 98) was 47.0 mm and modern human pubis varies from around 55 mm to 82 mm in length, only one-third (on average) equivalent portion of the pubis was "size-dependent". Current Japanese females are obviously smaller in body size (in terms of height and body weight) than European and African American (population 2 and 3) females (Fig. 6). The relative pubic length (average pubic length/average height) of Japanese females is more than 17 % longer than those of other populations, thus showing the independence of pubic length on body size. Fig. 6 shows that female pubic length is clearly associated with the reciprocal of the penis size and the sexual activity of her male partner, but not with her body size. I would not totally rule

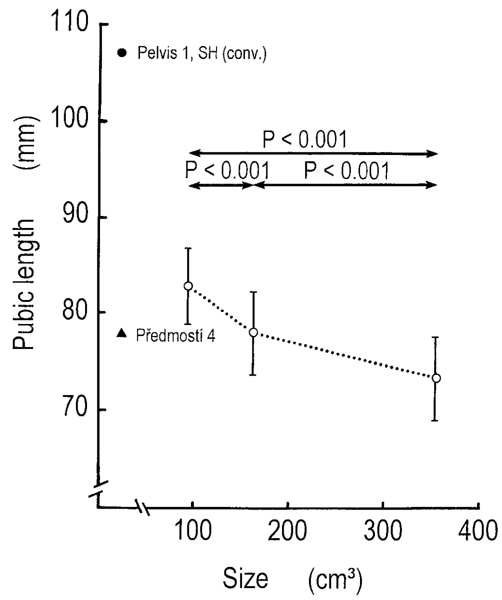

Fig. 5 Correlation between the pubic length of a female and the erect penis size of her partner.
The length (means ± S.D.) of female pubis in three populations was plotted against the penis size (in volume, see Fig. 2). Difference in pubic length were statistically (t-test) significant. Since raw data in individual measurements were unavailable in the present study, no further statistical analysis was made. Note that the pubic length of the female representing a given population is inversely correlated with the size of the erect penis of the partner in the population. The figure also shows the values of Palaeolithic specimens, SH Pelvis 1 (female estimated from the male value, ●) and Předosmotí 4, ▲.

out the possible dependency of pubic length on body size, but I feel strongly that the length of female pubis depends upon the shape of her pelvic cavity, which appears to be in part related to the penis size of her partner. Since the size of human penis is in general not necessarily related to their body size[74,76], the body size factor is not included in Fig. 5. The pubic length of Eskimo was similar to that of Japanese pubis[99]. Taken altogether with the data already described, it seems clear that the male partner of population 1 female with the longest pubic length is sexually least active, while the partner of population 3 female with shortest pubis is sexually most active. The sexual activity and the pubis length of population 2 male and female are just intermediate. Therefore, it would be fair to say that a reciprocal of female pubic length would indirectly represent the sexual activity of her male partner in a given population. It should be noted here

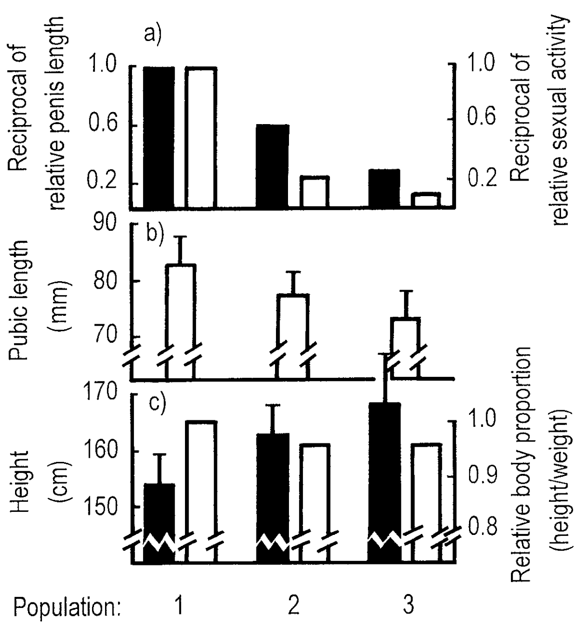

Fig. 6 Between-population comparison of female pubic length with their body size and the penis size of their partners.
a) The reciprocal values of median penis size (filled bars) and male sexual activity (the percentage of males in a given population who have had more than one sex partner since 18 years old, see in Fig. 2) (unfilled bars) of population 2 (European American) and population 3 (African American) were normalised for those of population 1 (Japanese) . b) The length of the pubis was measure from the joint of pubis and ischium in the acetabulum to the dorsomedial aspects of the superior pubis of females in three populations. These values (means ± S.D.) were taken from refs. 81,103. c) The body size (height and weight) collected in 1960th was shown [104]. This was to minimize the recent obesity problem. The figure shows the tallest height (17−18 years old females, filled bars) during their growth. The body proportion (height/weight, unfilled bars) of population 2 and 3 females were normalised for that of population 1 females. Note that female pubic length in each population neither show any direct correlation with their height nor body proportion, but is correlated with the reciprocal values of the penis length and sexual activity of their partners.

that this correlation is only biologically meaningful if we consider it as the feature acquired in evolution in a given population. Thus, between-population differences in sexual activity appear to follow coordinately from the progressive changes of following key factors : the bioavailable testosterone level in blood, the sizes of testis and penis, the size of the female reproductive organ, the shape of the pelvic cavity and the pubic length. All of these factors can no doubt support the inverse correlation between female pubic length and the sexual activity of male partners, but the detailed mechanism, by which these factors precisely contribute to each other, remains to be resolved. Consequently, the above correlation should be considered as a working hypothesis at present.

A comparison of pubic length was made between Palaeolithic, for example SH Pelvis 1 (discovered in Sierra de Atapuerca, Spain)[12] and Předmostí 4 (near Prerov, Czech Republic) (see ref. 98), and current samples. Since SH Pelvis 1 was an adult male, the pubic length of his partner was estimated under the assumption that the dimorphism of Neanderthals was the same as that of current humans. The estimated pubic length was much longer than the mean of the current East Asian pubis. Even considering his large body size, however, the estimated pubic length of his female partner was still quite long, compared with the average of current human population. The proposed hypothesis can deduce that his sexual activity was obviously lower than current East Asians. This will be discussed in the article to be reported elsewhere in more detail.

Other measures, e.g. pelvic aperture (anteriorposterior diameter/transverse diameter x 100) and subpubic angle, are also important determinants of the pelvic structure [100], which are potentially useful for assessment of the structural changes of pelvises. However, more information is required.

CONCLUSION

Surveys on sexual activity have repeatedly reported that Japanese, probably the people of population 1 in general, are sexually least active when compared with the people of other populations. This proposition has been supported by the lowest level of the "bioavailable" testosterone, responsible for sexual behaviour, in population 1 males. Comparative studies on major populations have shown that the size of male reproductive organs is correlated with their sexual activity. The differences in sexual activity among populations can not be fully explained solely by social and cultural factors. It was observed that the male partner of the population 1 female, who has the longest pubis among various populations, is sexually least active, while the partner of population 3 female with the shortest pubis is sexually most active. The sexual activity and the pubic length of population 2 male and female are just intermediate. Since pubic length is a component of linear terminalis and the posterior segment of the inlet determines the pelvic type, it was hypothesized that a reciprocal of female pubic length indirectly represent the sexual activity of her male partner in a given population.

The female pubic length estimated from the male value of SH Pelvis 1 specimen, discovered in Sierra de Atapuerca, Spain, was longer than the mean of the current East Asian's pubis.

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