Berkala Ilmu Kedokteran
Vol. 41, No. 4, Desember 2009: 194-201

Human sexual dimorphism: from an evolutionary perspective to practical overview

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ABSTRACT

Rusyad Adi Suriyanto - ***Human sexual dimorphism: from an evolutionary perspective to practical overview***

This paper goal is to discuss human sexual dimorphism in evolutionary perspective and practical overview. Evolution of human sexual dimorphism has wide implication in human biological study and many applications to medical field. Human sexual dimorphism has experienced changes and adaptations along its proceeding to current time and space. These changes are natural consequences. Understanding this problem as process and products of evolution, we can enter this problem into medicine and be a background. Understanding as a background, as human natural history, we will understand why human can be so now and why he/ she will change, including sexual dimorphism problem. The understanding of background is needed to avoid creation of human with narrow vision, highly specialized, excessive fanatics for self competency, easily astonished, panic and immediately tricked in real life which is complex and continuously changing. Human anatomy knowledge, as one basic medical aspect, sexually presents understanding that there are changing and developing characteristics among men (males) and women (females) over time. The medical intentions are aspects of sexual dimorphism directly applied and related closely to medicine. The paper begins with sexual dimorphism discussion, and continued by evolutionary perspective discussion, and followed up by practical discourse. This continuity is an effort to illustrate that Homo sapiens species, like us, is always dynamic and changing, like nature which is never static neither stable.

Key words: human sexual dimorphism, evolution, medical application

ABSTRAK

Rusyad Adi Suriyanto - ***Dimorfisme seksual pada manusia: Dari pandangan evolusi ke wacana praktis***

Makalah ini bertujuan untuk mendiskusikan dimorfisme seksual manusia dalam perspektif evolusioner dan wacana praktisnya. Evolusi dimorfisme seksual manusia mempunyai implikasi luas dalam studi biologi manusia dan aplikasinya dalam bidang kedokteran. Dimorfisme seksual manusia telah mengalami perubahan dan adaptasi sepanjang perjalanannya sampai waktu dan ruang sekarang. Perubahan-perubahan ini merupakan konsekuensi alamiah. Dengan memahami masalah ini sebagai proses dan produk evolusi, maka kita dapat memasukkan masalah ini dalam kedokteran dan sebagai latar belakangnya. Sebagai latar belakang, seperti halnya sejarah alam manusia, kita akan memahami mengapa manusia dapat seperti ini keadaannya sekarang dan mengapa ia akan berubah pula, termasuk di dalamnya masalah dimorfisme seksualnya. Pemahaman akan latar belakang ini diperlukan supaya kita terhindar dari mencipta manusia yang berpandangan sempit, sangat terspesialisasi, fanatik yang berlebihan akan kemampuan diri, mudah terkejut, panik dan mudah terkecoh dalam kenyataan hidup yang kompleks dan yang selalu berubah terus-menerus. Pengetahuan anatomi manusia, sebagai salah satu dasar bidang kedokteran, secara seksual menghadirkan pemahaman bahwa ada karakteristik-karakteristik yang berubah dan berkembang di antara laki-laki dan perempuan dari masa ke masa. Dalam kedokteran ini yang dimaksudkan adalah aspek-aspek dimorfisme seksual yang diterapkan langsung dalam atau berhubungan erat dengan kedokteran. Makalah ini diawali dengan pembahasan tentang dimorfisme seksual, dan dilanjutkan dengan pembahasan perspektif evolusionernya, serta ditindaklanjuti dengan wacana praktisnya. Kesinambungan ini merupakan upaya untuk menggambarkan bahwa spesies Homo sapiens seperti kita selalu dinamis dan berubah, seperti halnya alam yang tidak pernah statis dan tetap.

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INTRODUCTION

Sexuality almost exists universally in the world now because the organisms, which are sexually reproduce, have gradually insisted to organisms which asexually reproduced.[1] Sexuality plays major role in the complex evolution.[2,3] For the same function, sexuality has a high variability. The more beneficial to sexual reproduction compared to asexual reproduction is the variability that is not only triggered by any mutation, but also by recombination. The reproduction likely has a huge genetic variation, so that it is likely able to adapt to more huge environment changes. Here we can observe one more thing in the evolution of sexuality, that is, the extension of diploid period to the higher organisms. In the lower organisms, meiosis occured after fertilization, hence most of their lives are haploid; on the other hand, in the higher organisms, meiosis occures before fertilization, as a result most of their lives are diploid. It is said that most of diploid organism's lives is a body, and the rest is sex cell.

One thing that has been observed by earlier human is sexual dimorphism that is morphologic, physiologic and psychological differentiation in both sexes, which is mostly caused by reproduction function[4]. In the beginning, the job differentiation between man and woman was the reproduction function. In the hunter society, men were the main in food collection and distribution to his communities, the women in the base camp cared for the children, gathered around their neighboring, and prepared the food.[4,5] The further development was then accentuated by and represented in custom, clothes, language and other cultural aspects.

The paper aims to discuss about human's sexual dimorphism in the evolutionary perspective and practical overview. The paper begins with discussion about human sexual dimorphism, and it is continued with about the evolutionary perspective, as well as followed up by the practical overview. The continuity is an effort to describe that *Homo sapiens*, just like us, are always be dynamic, the same thing with nature that is never be static.

SEXUAL DIMORPHISM

A gene or a set of gene in the chromosome of sex Y determines sex in human. The sexual differentiation always has genetic base. There are lots of proves indicating that it is not only one or more genes which are responsible for sexual expression of living thing, while there are lots of couples of genes. The expression is controlled by genes equally interacting. The genes' expression is dependent on many factors influencing internal and external environment. The sexual determination shows various patterns. The patterns are evolution's product. It is underlined that the issue of sexual differentiation is different from fertility one, even it is assumed that they are not interrelating; however, there are signs that the higher the structural strata of living things, the more they are interrelating. The sexual issue is related to feminism and masculine valences, whereas fertility is related to capability to impregnate and be impregnated.

Sexual dimorphism studies about differentiation of expression degree that can be observed between man and woman. However, the differentiation covers characteristics, which are indirectly associated with reproduction.[6] Most of evolutionary biologists and anthropologists are indeed interested in the genesis of sexual differentiation.[7] The differentiation of *Homo sapiens's* sexual dimorphism is indicated with size, form, and behavior.[8,9] Generally, the fact is found in adult; however it has not found in baby, child and adolescent, because it is influenced by hormonal events in puberty periods.[10] The sizes of linear body and weight shows is similar shown in born male and female, and then the dimorphism turns as function of age changes; when a female reaches a level of puberty, the male has significantly grown[11]. Generally, the male's body proportion is bigger and heavier than female, including his extremity and skeleton.[8,11,12,13,14,15] Chronologically, the difference between male's and female's skull reduce as they grow older, when female's skull characteristics tends to imitate male's.[16]

Frayer &Wolpoff[8] stated two models of approaches to issue of human sexual dimorphism, i.e. proximate and ultimate. The first model describes sexual dimorphism as the answer to nutrition pressure and repair of environment in the adolescent growth. The second model describes sexual dimorphism as a genetic adaptation towards various ecological, social, economic factors or traditional work division sexually as primary

mechanism. Both models often hold key role towards unclear conclusion, because it has not been sufficiently evaluated; and on the other side, the models have not been capable to succeed describing the pattern of human sexual dimorphism. Size of body is indeed affecting its manifestation in several species; however it is not a relation that can be used universally. The marriage system and work division sexually can contribute degree of the manifestation of differences between male and female although the application is limited. The fact is meaningful that other factors are considered because sexual dimorphism can be affected by different and complex factors. Shine tried to explain the issue by describing the ecological background.[17] Jones, Holden & Mace emphasized through cultural proves and cross cultural analysis.[18,19] However, the models admit a reduction of sexual dimorphism in hominid descent.

EVOLUTION OF SEXUAL DIMORPHISM

Sexual dimorphism is easier to observe in the living human population compared to paleoanthropological-archaeological population, that is generally is inhibited by the inexistent soft tissue. Several characteristics of skeleton actually show a unique to each of sexes, but the rests can indicate clearly, i.e. pelvis and skull. The overview has been studied in details and straightly in the system of skeleton and teeth, because it is important for determination of sexes from the remains of paleoanthropological-archaeological skeleton and teeth.[20,21,22]

The earlier populations show more really degree of sexual dimorphism. The strong evidences show a reduction in hominid descent, as well as related to their skeletons, skulls and teeth dimensions.[8,23,24,25,26,27] Sexual dimorphism in the body size of hominid had changed in three million years, from full 100%, as it is seen in the baboon and gorilla goes to 20% until 40% in the groups of modern human.

Some researchers belief that the reduction of degree of sexual dimorphism is more determined by human evolution, i.e. by the growing brain volume and reduced posterior teeth size, besides cultural factors combined with sources of biologic selection worked in previous fossils of human ancestor.[8,9,10,20,21,22,25,26,27,28] Hominid Pliocene-Pleistocene shows bigger degree of sexual dimorphism for skull dimensions, skeleton dimensions and teeth than groups of their descents.[8,24]

The groups of European Upper Paleolithic has clearer degree of sexual dimorphism than their descents of Mesolithic and Neolithic.[29] They show average degree for the size of neurocranium from Upper Paleolithic by 4.6%; while Mesolithic 4.2% and Neolithic 2.9%. For their size of viscerocranium are respectively 8.1%, 5.9% and 5.2%, and their size of mandible are respectively 6.7%, 6.0% and 5.4%. The reduction is caused by gracilization male between Upper Paleolithic and Mesolithic populations associated with changes in technologic pattern associated with hunting and types of hunted animals. The same thing happened between Mesolithic to Neolithic populations, and from Neolithic to modern European populations that showed closer link with changes happened among the females. The reduction of degree of sexual dimorphism in the dimension of hominid teeth size of hominid is affected by adaptation in period of Middle Pleistocene. The development of techniques in processing food in Upper Pleistocene played important role in the event where from the techniques and types of big animals to smaller animals, and the increased the plants consumption.[23]

Evolution in sexual dimorphism showed that difference in particular characteristics of hominid morphology between male and female reduced to now including the epigenetic characteristics. The result of research about sexual dimorphism in the epigenetic characteristics of human skull showed a little consistency[30]; even though Hauser & De Stefano[31] proved that several characteristics were more realistic in the group of males, where it is associated with early manifestation whose genetic background, i.e. the earlier emerge and then experienced progressive growth until adult age, and then constantly cared. The research of the issue is also done on Mongoloid's and Australomelanesoid's skull populations from the Age of Mesolithic-Neolithic in Bali Island and Flores Island and around.[32,33,34,35] The study of morphologic

characteristics of intra population of *Homo sapiens* should show sex, because genetically male and female are different, although the difference is tiny.[30,36,37]

Based on the ethnographic studies, even though the degree of dimorphism is smaller, however, it can be observed exactly. Frayer certainly assumed that traditional societies in almost around the world also showed that clearer male's morphologic characteristics compared to females', because the subsistence activities in the remote area is mainly worked by males.[28]

The females are more resistant to environment changes, which is more harm than males'.[4] The changes are also associated with limited food. The rare of natural resources, especially related with nutrition sources also showed a big role. Continuous starvation in years will cause biologic adaptation. Population will reduce the biomass, i.e. body weight of the entire population; so the number of the inhabitants or body weight will reduce, or both of them, so the important calorie will be reduced too. The fat will be reduced and inner organ will be smaller. The ectomorph is more than endomorph in the population. The body will reduce the activities, so that less calorie will be needed. In other words, the population will live in the level of lower energy.

In reduce of the body bio-mass, it will be affected by sexual dimorphism.[4] Males are more sensitive toward environmental changes so the jump of pre-pubertal growth is also affected too; so there is a longer excellence in period of females in the period of peri-puberty. The period that only in 1-2 years can last for 3-7 years. The excellence can include height, weight or other sizes. The line of female's growth will cross over the male's growth in ages of 9-12 years old, and cross again between 11-16 years old. In the condition of poorness and lack of food, the cross over happens again after 14 years old so the period of female's excellence is more than four years. The final result of the difference is a slight sexual dimorphism, i.e. the difference of height between male and female. The female is 3-12% shorter than males. The difference is smaller in Africa than Europe.[38] The difference is only 3.1-7.0% in the San ethnic community in Africa. The nutrition promotion in the ethnic caused the bigger difference. In the other words, in fact, that males are easier to cross over the growth curve, likely caused by males only has X chromosome.

Modern humans, however, show comparatively little dimorphism and we are a relatively monogamous species. This suggests that males in monogamous species do not have to compete as drastically for mates as those in polygamous species. Therefore, since it requires much more energy to support a larger body than a smaller one, males may have simply evolved through time to a more energy economical state once the reason for the large body size had been eliminated. Our polygamous roots are not that far removed in an evolutionary sense from current humans and they are bound to have some effect on our social structure. Possibly, this little bit of sexual dimorphism we have left has contributed to many of our ideas about gender roles. Although our societal values and roles have changed much in modernity, we still carry along a some of our ancestral ideas about men and women today. For instance, women are still barred from combat in the armed forces, and women still receive less pay for the same degree of work.

Another important physiological difference between men and women in modernity is the storage of body fat. Women are much more efficient at storing subcutaneous body fat, thereby resulting in an increased ability to function and develop during times of malnutrition. The reason for this difference is quite obvious. Women's bodies undergo considerable more physiological stress due to the rigors of pregnancy and they must be able to maintain their own bodies as well as successfully gestate offspring and continue to nurse them afterwards. Men, on the other hand, do not have this problem and so do not need to be more economical in their subcutaneous fat storage. As we are able to study this factor in modern humans, it seems likely that at least some of our ancestors also had this characteristics.

If trends in human evolution continue as they have been, men and women will decrease in sexual dimorphism until nothing but obvious secondary sexual characteristics like wider hips and breasts in females and primary sexual characteristics remain. Although, it is interesting to note that while females are evolving to be taller now, reaching six feet tall and higher, men are evolving in a parallel fashion to

maintain that ten percent larger size. Given that height and size seems to be traits that are selected for in our current populations, it is possible that we will maintain our little bit of sexual dimorphism while a society evolves with less separation between the sexes.

PRACTICAL OVERVIEW

To start over the discussion in this part, recalling how important the practical study of interdisciplinary, the discussion will be briefly presented a published work of dissertation. Slavec[13] successfully determined genealogic of Celje Dynasty based on 18 skulls (10 adult males, 6 adult females and 2 children) from the empire's members who past away in 1350–1450 and stored in Celje Minorite's Church. The success of the work is supported by strategies of his research, adopting various disciplines, i.e. physical anthropology, anatomy, stomatology, radiology, palaeopathology, genetics, history and particularly medical forensic, in order to determine and ascertain the ages, sexes, morphologic, pathologic, and epigenetic characteristics, in which the information of identification is not much available; it is also his ability to explore, collect and learn sociologic, cultural and historic information in that period. The research presents a new understanding among social and natural disciplines and gives answers of interdisciplinary. The research also inspires us not to be taboo and then we can sympathetically accept contribution of knowledge and scientific method from other discipline subject. However, a particular discipline's subject can not deny other discipline's subject; moreover the present researches tend to be more multidisciplinary and comprehensive. Thus, cooperation and respect between disciplines' subjects are significant; and it can build and fertilize seeds of solidarity value, it is not narrow fanatics, open and democratic, which had been internalized in the family and primary school.

Medical anthropology likely is in the form of anthropology in medicine,[4] i.e. aspects of biologic or cultural anthropologies, which applied directly in medical. Medicine as a group of other disciplines and technologies, in its function, understands and manages disturbance in health. Usage of biologic anthropology in this subject is much more of examples, but it is more difficult to be recognized, because part of it was indeed born in medical, so that it can not be assumed as part of anthropology, for examples weight and height measurement, thickness of skin fold, pelvimetry and others, and techniques for anthropometry (anthroposcopy), dermatoglyphics, identification and others. Anthropology gives its attention to human variability and it teaches more population to find range of normal variation. In the anthropology, each of individuals is unique, *einmalig*, without precedence and non-recurrence; but as groups of each race, sex or class of age they have similarity, even all of species have similarity. Human is the focus of anthropology and medicine. The first is the study on human variation, both as biologic and cultural creatures, the cause and process; whereas the medicine is a study and technology on management of human disturbance on health, as live system that consisting bio-physics-chemical sub-systems and forming bio-socio-cultural supra-systems.

The human study covers biologic variation vertically and/or horizontally and causes that emerged.[1] Vertical variation covers human phylogeny, i.e. human evolution from prehistoric age until now and the present and future microevolution, and human ontogeny, especially development and growth in postnatal to senility, with special attention to pre-pubertal and circum-pubertal and also the process of aging. Horizontal variation covers racial and geographic variation, interaction between genetics and environment (can be abiotic, biotic and cultural), and human adaptability. Non-racial morphologic variation is included in biotypology, in which it is learnt posture, body composition and androgyny, i.e. sexual dimorphism in morphology.

By understanding sexual dimorphism as process and product of evolution, thus we can put the issue into medicine and as its background. As background, just like history of human nature, we ca understand why it is the human's condition and why it will changes, including issue of sexual dimorphism. The fact had been described widely in early previous part, i.e. in discussion on human sexual dimorphism. The understanding of the background is necessary so we can be avoided from creating *Fachidiotie*

(only knowing and limited to self subject of discipline),[39] human with narrow point of view, extremely specialized, over fanatic to self capability, easy to cause surprised, panic and easy to deceive in complex real life that continuously changing. Knowledge of human anatomy, as a base of medical subject, sexually presents understanding that there is a characteristic that easy to change and develop among male and female from time to time. In the medicine, the objective is the aspect of human sexual dimorphism that applied directly in or highly associated to medicine.

The pattern of pathology is not a matter of chance but reflects the adaptation of populations; and behavioral differences that are gender-based can affect the pathological profile of a population.[40] Differential access to resource based on gender is a critical factor in producing pathology. On of the difficulties that we have in measuring biological outcomes is how to differentiate results of physiological sex differences from the social aspects of gender. Stini discussed this issue in his analysis of the impact of nutritional deficiencies on sexual dimorphism in human stature. Females should be able to resist nutritional deficiencies because of the buffering impact of the hormonal system.[9] If all things are equal and that males and females are equally subjected to nutritional stress, there should be a greater reduction in the stature of males than females. However, if females are subjected to greater nutritional stress because of differential access to food, then they may suffer a greater percentage reduction in stature than the males.[41] Ortner raises a similar issue with respect to the greater immune reactivity in women than in men.[42] He presented an empirical evidence to test the hypothesis and offers an evolutionary explanation for the differences. Gender-related differences in immunity may be related to differential selection because of the women's role in child bearing and nurturing. This would represent a period of increased vulnerability to infection. There is evidence that hormonal differences in males and females affect immunological competence. In the examination of life tables constructed for prehistoric and ancient populations, women showed a pattern of increased mortality during child-bearing years. Women showed a decrease in mortality in the later years and experienced greater longevity. It is interesting to note that these differences were apparent in most life tables constructed for populations until the beginning of the twentieth century, when they begin to show decreased differences. Recent changes in the lifestyle of women have further reduced these differences.

Osteoporosis and osteopenia illustrate the interplay between sex and gender in an analysis of a problem.[43] Studies conducted on prehistoric populations, primarily from Sudanese Nubia (North Africa), document the patterning of bone loss and maintenance. Prehistoric populations living from 10, 000 to 1, 000 years ago experienced two distinct types of bone loss. Many women between their twentieth and thirtieth year lose a significant amount of bone (osteopenia) that appeared to be related to the demands of pregnancy, lactation, and a diet that was poor in calcium. The production of milk during lactation extracts calcium from the bone, and in the presence of under-nutrition, this calcium may not be replaced as women grow older. While these women do not show the clinical problems of bone fractures, it indicates that diet is an important component of bone health in younger women. The examination of children shows that their bone development and maintenance are also affected. While they show a relatively slight decrease in long bone growth and a significant deficit in cortical wall development, the indications of increased bone resorption and a lack of mineralization are part of the process. The dietary aspect of the problem focuses attention towards gender as a relevant factor in access to resources.

Armelagos argues that people who lived in prehistoric period began to lose bone following their thirtieth year age.[40] In this pattern of loss, the prehistoric populations are similar to living populations. In both living and extinct populations, males and females experience a decrease in bone mass, but the process is quite different between the sexes. Females, because they have less bone than males as they approach middle age, are especially at risk. After menopause, the rates of loss may increase because of a decrease in the production of estrogen. In this instance, hormonal differences related to sex are the focus of attention. There is, however, a major difference in the amount of bone

that modern and prehistoric women loose. By 50 years of age, ancient Nubians had lost about 15% of their bone mass. However, they did not suffer from the debilitating fractures that plague modern women. In Nubia, only 4% of the women reached 50 years of age and most died soon after. Today, women over the age of 50 appear to be at greater risk for bone loss as menopause results in a decrease in estrogen. As more women are living longer they are therefore losing more bone. In the USA, 75% of the population reaches their sixtieth year, 29% their eightieth year, and 6% reach their ninetieth year. It may seem a paradox, but the improvement in living conditions that increases longevity in modern nations has created one of women's most significant health problems.

Diagnosis in determining sex in the present forensic identification in fact does not use merely a foundation and method that used by paleo-anthropologist or archaeologist, for example in identifying genus of *Australopithecus* or *Pithecanthropus*. Here, it must be several adjustments. It is the same thing if we are willing to anticipate the issue in the future, so tools and method should be updated, because as described above, that human in the journey to the present days shows reduced degree of dimorphism. The sexual differentiation based on material of bones will also deal with higher accuracy, precision and resolution.[12,44,45,46,47]

The application examples of the issue will not be over discussed, because it will to wide in limited space here. The key is to offer an argumentation that *Homo sapiens*, just like us, will always experience changes and deal with efforts to adapt through time, including effort to diagnosis, cure and take ourselves.

CONCLUSION

Health and treatment is part of culture, whereas human is a species who multicultural, as efforts to overcome the environment in various space and time. The human environment, culture and effort will affect their biology. Briefly, the changes and adaptations are the central theme in the history of human nature.

Sexual dimorphism has experienced changes and adaptations in its journey of present space and time. The changes are the natural consequence. The treatment and medical education adjust the equipment, method and theory. The examination and application also obtain continuous special attention.

REFERENCES

1. Jacob T. Anthropologi untuk fakultas kedokteran. In: Indriati E. Editor. Buku bacaan antropologi biologis. Jakarta: Direktorat Jenderal Pendidikan Tinggi Departemen Pendidikan Nasional, 1999/2000: 3–27.
2. Dawkins R. Sungai dari firdaus: suatu pandangan darwinian tentang kehidupan. Palar DTW, Simbolon PT. Translaters. River out of eden: a darwinian view of life. Jakarta: Kepustakaan Populer Gramedia, 2005.
3. Diamond J. Mengapa seks itu asyik? Astuti JERD, Primanda A. Translaters. Why is sex fun?: the evolution of human sexuality. Jakarta: Kepustakaan Populer Gramedia, 2007.
4. Jacob T. Manusia makhluk gelisah: melalui lensa bioantropologi. Surakarta: Muhammadiyah University Press, 2006.
5. Leakey R. Asal-usul manusia. Primanda A. Translater. The Origin of humankind. Jakarta: Kepustakaan Populer Gramedia, 2003.
6. Wolpoff MH, Caspari R. Race and human evolution: a fatal attraction. Boulder: Westview Press, 1998.
7. German RZ, Stewart SN. Sexual dimorphism and ontogeny in primates. In: Minugh-Purvis N, McNamara KJ. Editors. Human evolution throught developmental change. Baltimore: The John Hopkins University Press, 2002: 7-27.
8. Frayer DW, Wolpoff MH. Sexual dimorphism. Annual Review of Anthropology 1985; 14: 429-73.
9. Stini WA. Growth rates and sexual dimorphism in evolutionary perspective. In: Gilbert RI Jr, Milke JH. Editors. The analysis of prehistoric diets. Orlando: Academic Press, 1985: 191-226.
10. Beach FA. Human sexuality and evolution. In: Washburn SL, Mc Cown ER. Editors. Human evolution: biosocial perspective. Menlo Park: Cummings, 1978: 123-53.
11. Watts ES. Evolution of human growth curve. In: Falkner F, Tanner JM. Editors. Human growth. 2nd ed. New York: Plenum Press, 1986: 153-66.
12. Mitani JC, Gross-Louis J, Richards AF. Sexual dimorphism, the operational sex ratio and the intensity of male competition in polygamous primates. The American Naturalist 1996; 147 (6): 966-80.
13. Slavec ZZ. New method of identifying family Related Skulls: Forensic Medicine, Anthropology, Epigenetics. Wien: Springer-Verlag, 2004.
14. Fessler DMT, Haley DA, Linney AD. Size and shape differences between male and female foot bones: is the

female foot predisposed to hallux abducto valgus deformity?. Journal of the American Podiatric Medical Association 2004; 94 (5): 434-52.
15. Byers SN. Introduction to forensic anthropology. 3rd ed. Boston: Pearson Education, Inc., 2008.
16. Breathnach AS. Frazer's anatomy of human skeleton. 6th ed. London: J & A Churchill Ltd., 1965.
17. Shine R. Ecological causes for the evolution of sexual dimorphism: a review of the evidence. The Quarterly Review of Biology 1989; 64(4): 419-61.
18. Jones DM. Sexual selection, physical attractiveness and facial neoteny: cross-cultural evidence and implications. Current Anthropology 1995; 36: 723-48.
19. Holden C, Mace R. Sexual dimorphism in stature and women's work: a phylogenetic cross-cultural analysis. American Journal of Physical Anthropology 1999; 110: 27-45.
20. Bass WM. Human osteology: A laboratory and field manual. 3rd ed. Columbia: Missouri Archaeological Society Inc., 1989.
21. Carpenter JC. A comparative study of metric and non-metric traits in a series of modern crania. American Journal of Physical Anthropology 1976; 45: 337-44.
22. Ferembach D, Schwidetzky I, Stloukal M. Recommendations for age and sex diagnoses of skeleton. Journal of Human Evolution 1980; 3: 517-49.
23. Brace CL, Ryan AS. Sexual dimorphism and human tooth size differences. Journalof Human Evolution 1980; 9: 417-35.
24. Wolpoff MH. Paleoanthropology. New York: Alfred A Knoft, 1980.
25. McHenry HM. Body size and proportions in early hominids. American Journal of Physical Anthropology 1992; 87: 407-31.
26. McHenry MM. Behavioral ecological implications of early hominid body size. Journal of Human Evolution 1994; 27: 77-87.
27. Jablonski NG, Chaplin G, McNamara KJ. Natural selection and the evolution of hominid pattern of growth and development. In: Minugh-Purvis N, McNamara KJ. Editors. Human evolution through developmental change. Baltimore: The Johns Hopkins University Press, 2002: 189-206.
28. Armelagos GJ, Van Gerven DP. Sexual dimorphism and human evolution: an overview. Journal of Human Evolution 1980; 9: 437-46.
29. Frayer DW. Sexual dimorphism and cultural evolution in the Late Pleistocene and Holocene of Europe. Journal of Human Evolution 1980; 9: 399-415.
30. Cosseddu GG, Floris G, Vona G. Sex and side differences in the minor non-metrical cranial variants. Journal of Human Evolution 1979; 8 (7): 685-92.
31. Hauser G, De Stefano GF. Epigenetic variants of the human skull. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung, 1989.
32. Suriyanto RA. Dimorfisme seksual dalam karakteristik epigenetic upper viscerocranium dari sampel tengkorak manusia Gilimanuk (Bali). Berkala Arkeologi 2006; XXVI (2): 85-113.
33. Suriyanto RA. Perbedaan Karakteristik-karakteristik epigenetis upper viscerocranium dari sampel tengkorak manusia Liang Bua, Lewoleba, Melolo, dan Ntodo Leseh (Nusa Tenggara Timur) dan Gilimanuk (Bali). Berkala Arkeologi 2007; XXVII (1): 53-83.
34. Suriyanto RA, Koesbardiati T. Karakteristik-karakteristik epigenetic dan metris upper viscerocranium manusia prasejarah Liang Bua, Lewoleba Melolo dan Ntodoh Leseh di Nusa Tenggara Timur. Jurnal Anatomi Indonesia 2006; 1 (2): 60-70.
35. Suriyanto RA, Jacob T, Aswin S, Indriati E. Kajian perbandingan karakteristik epigenetis populasi tengkorak manusia Paleometalik Gilimanuk (Bali) dan Liang Bua, Lewoleba, Melolo dan Ntodo Lesch (Nusa Tenggara Timur). Humanika 2006; 19 (1): 43-64.
36. Dobzhansky T. Mankind evolving: the evolution of the human species. New Haven: Yale University Press, 1962.
37. Damon A. Human biology and ecology. New York: WW Norton & Co., 1977.
38. Tobias PV. Brain-size, grey matter and race: fact or fiction? American Journal of Physical R, Sailer K. Lehrbuch der anthropologie. Bd. 2-4, 3. Stuttgart: Gustav Fischer Verlag, 1966.
40. Armelagos GJ. Introduction: sex, gender and health status in prehistoric and contemporary populations. In: Grauer AL, Stuart-Macadam P. Editors. Sex and gender in paleopathological perspective. Cambridge: Cambridge University Press, 1998: 1-10.
41. Storey R. The mothers and daughters of a patrilineal civilization: the health of females among the Late Classic Maya of Copan, Honduras. In: Grauer AL, Stuart-Macadam P. Editors. Sex and gender in paleopathological perspective. Cambridge: Cambridge University Press, 1998: 133-48.
42. Ortner DJ 1998. Male-female immune reactivity and its implications for interpreting evidence in human skeletal paleopathology. In: Grauer AL, Stuart-Macadam P. Editors. Sex and gender in paleopathological perspective. Cambridge: Cambridge University Press, 1998: 79-92.
43. Weaver DS 1998. Osteoporosis in the bioarchaeology of women. In: Grauer AL, Stuart-Macadam P. Editors. Sex and gender in paleopathological perspective. Cambridge: Cambridge University Press, 1998: 27-44.
44. White TD. Human osteology. London: Academic Press Inc., 1991.
45. Armelagos GJ, Carlson DS, Van Gerven DP. The theoretical foundation of development of skeletal biology. In: Spencer F. Editor. A history of physical anthropology. Orlando: Academic Press, 1982: 305-28.
46. Burns KR. Forensic anthropology training manual. Upper Saddle River: Prentice Hall, 1999.
47. Indriati E. Antropologi forensik: identifikasi rangka manusia, aplikasi antropologi biologis dalam konteks hukum. Yogyakarta: Gadjah Mada University Press, 2004.