博士論文（要約）

Comparative functional-morphological study of skeleton in Japanese native fowls

（日本鶏における骨格の比較機能形態学的研究）

工藤光平

LIST OF CONTENTS

Chapter 1
General introduction

Chapter 1: General introduction

It is known that today's various breeds of domestic chickens have been created from red jungle fowl (*Gallus gallus*) (Akishinonomiya *et al*., 1996; Al-Nasser *et al*., 2007). Although there are various theories about its actual status and discussions still continue to today, the excavations from China indicated that the domestication of chickens has long history (West and Zhou, 1988; Liu *et al*., 2006; Xiang *et al*., 2014). The genetic research indicated that the first domestication started in the region currently correspond to Thai, Laos and Vietnam (Akishinonomiya *et al*., 1996). Two roots were considered as the way to Japan. First is sailing across between Malay Peninsula to Japan, and second is passing the Asian Continent from India-China Peninsula (Nozawa and Nishida, 1981; Oka *et al*., 2007).

The long history of domestication has changed their biological characters. The weight of meat type fowls can be over to 7 kg by selecting the body size (Matsuzaki, 2001; Matsuzaki *et al*., 2003; Akishinonomiya and Komiya, 2009; Nikki *et al*., 2012). Moreover, layer type fowls can produce their egg at least about 300 in one year (Luc *et al*., 1996; Sato *et al*., 2001; Ichinoe and Kuwayama, 2007). The two types of fowls have been bred to reward the needs as food. The researchers have studied the economical characteristics such as volume of meats and a number of laying eggs, and they strived to improve those characters (Shimizu and Hachinohe, 1976; Miyoshi *et al*., 1995; Shimazawa and Araki, 1999; Hocking *et al*., 2009). The intense motivation of improving the economical characteristics is indicated in the exponential growth rate (Bihan-Duval *et al*., 2008; Batkowska *et al*., 2015), improvement in the feed efficiency (Hirahara *et al*., 2012; Jin *et al*., 2014), advancement of disease resistance (Zekarias *et al*., 2002; Emam *et al*., 2014) and adjustment of rearing environment (Kristensen *et al*., 2006; Golden *et al*., 2012; Nakamura and Sugihara, 2015).

Domestic fowls obtained various feature not only as livestock but also as companion animals (Frahm and Rehkamper, 1998; Okamoto, 2001; Ichinoe and Kuwayama, 2007; Akishinonomiya and Komiya, 2009; Sheppy, 2011). In the mid-Edo Era in Japan, variegated breeds were developed to admire their color variation, voice and fight (Oana, 1951; Okamoto, 2001; Ichinoe and Kuwayama, 2007; Akishinonomiya and Komiya, 2009). Fighting fowls are highly aggressive and were bred for gambling as an

entertainment. Long-crowing fowls were selected on the basis of their ability to crow for a longer time. Ornament-type fowls acquired colorful feathers or long-tailed feathers for attracting people. Native fowls are called Jidori and their external characteristics are similar to those of the red jungle fowl.

Japanese fowls vary not only in external characteristics but also in osteological characteristics. It has been known that the morphological differences were detected by the measurement data of the skeleton, as the smallest breadth between orbits, the length of sternum, forelimb bones, tibiotarsus and tarsometatarus, and the breadth of the corpus scapulae (Hayashi *et al*., 1982; Nishida *et al*., 1985; Samejima, 1990; Samejima *et al*., 1988, 1989).

Since above osteological studies have been carried out to estimate the lineage of domestic fowls, the relationships between the morphological characteristics and the purpose of breeds and the function of osteological characteristics have remained unclear. The skeleton morphologically reflects the results of artificial selection driven not only by economical characters for agricultural productions but also by noneconomical characters for spiritual preferences such as a long voice, strong aggression and external appearances. Since Japanese fowls have been selected for fighting fowls, long-crowing fowls and ornament-type fowls, I expected that the functional morphological skeletal characteristics peculiar to the breeds in their skull could be detected in their skeleton.

Chapter 2

Functional morphological characteristics in skulls

本章“Chapter 2: Functional morphological characteristics in skulls”の内容は、学術雑誌に掲載されており、出版社との契約条件によって公表できない。本章は日本家禽学会が刊行する The Journal of Poultry Science, Vol. 55, No. 1, pp. 44-50.に掲載されている。

Chapter 3

Functional morphological characteristics in skeleton of forelimb, pectoral girdle and sternum

本章“Chapter 3: Functional morphological characteristics in skeleton of forelimb, pectoral girdle and sternum”の内容は、学術雑誌論文として出版する計画があるため公表できない。5 年以内に出版予定。

CHAPTER 4

Functional morphological characteristics in skeleton of hindlimb, pelvic girdle and pelvis

本章“CHAPTER 4: Functional morphological characteristics in skeleton of hindlimb, pelvic girdle and pelvis”の内容は、学術雑誌論文として出版する計画があるため公表できない。5 年以内に出版予定。

Chapter 5
General discussion

Chapter 5: General discussion

The contribution of this doctoral thesis to the archaeology

Through the studies of the Chapters 2 to 4, I detected the differences of the functional-morphological characteristics in skeleton among breeds. It is thought that the relationships between the functional-morphological characteristics and the differences of purpose of breeding are keys to understanding the domestication. I mentioned the archaeological controversial topic of domestication in this general introduction. The study of chicken domestication using ancient DNA indicated that the history of domesticated fowl in northern China dates back to 10000 years (Xiang *et al*., 2014). However, their investigation contains some controversial problems. The problems are indicated as, 1) the possibility of error in process of preparing the mtDNA, 2) the appropriateness of suggestion about the relationships between habitat and climate, and 3) the suspicion that the bone is not one of chicken (Peng *et al*., 2015; Peters *et al*., 2015). It is one of the interesting problems that the bone is morphologically considered as one of the dog (Peters *et al*., 2015). Xiang *et al*. (2014) remarked that the materials include the tibia, tarsometatarsus, humerus and femur, however, it is thought that their prepared bones contain ulna from their Figure 1B as seen in right top since the outline of the bone and the shape of the articular surface are similar to those of the ulna in chicken. According to the right bottom of the Figure 1B from Xiang *et al*. (2014), the bone, which was determined as the bone of domestic chicken, is not similar to the femur of chicken. Peters *et al*. (2015) pointed out that the bone is similar to one of the skeletons in dogs, however, they did not explain the morphological reason why the bone is not considered as that of chicken. It is thought that the bone actually resembles the metatarsal of dog because of the sagittal crest in distal articulation. I also think that the bone is similar to tarsometatarsus without lateral trochlea in birds. Another possible factor for suggesting the validity of the Figure in the Xiang *et al*. (2014) is that the chicken shows the skeletal disorder chondrodystrophy (Gordon *et al*., 2015). However, the suggestion that the bone in Xiang *et al*. (2014) shows suspicious characteristics, cannot be examined because of the few information of the Figure such as the small size without scale. It is thought that the archaeological controversy represents the deficiency of morphological information in domestic fowls. Although it is difficult that the

complete skeleton is excavated, I suggest that the functional-morphological studies in skeleton among domestic fowls are important to examine the differences between unearthed bone and living one. My suggestion about the relationships between functional-morphological characteristics and the purpose of breeding will contribute to reevaluate the morphological differences of excavated bones and to understand the domestication process.

The problems and solutions to understand the morphological characteristics

Although the size and shape data from this doctoral thesis indicated that the Japanese domestic fowls show the relationships between the various functional-morphological characteristics and the purposes of breeding, the morphological characteristics in vertebrae were not investigated because of difficulty in osteological measuring and preparing the whole skeleton. Since the vernier caliper cannot measure the curvature, the curvature of bone such as sternum could not be connected to quantitative data as seen in the discussion in Chapter 3. It is thought that the same problem occurs in the tail bones because of the curved shape of the caudal vertebrae. The solution for this problem is considered as the application of Elliptic Fourier analysis. The analysis can detect the morphological changes of curvature and it has been also performed in morphological studies of birds recently (Hospitaleche and Carlo, 2010; Riyahi *et al*., 2013; Felice and O'Connor, 2014). It is thought that the Elliptic Fourier analysis suits to detect the morphological characteristics in curvature of bone. I suggest that the method directly illustrates the relationships between the roundness of shape and attractiveness in the morphological characteristics of domestic animals.

It has been suggested that the orientation and movement of neck and trunk, which contains cervical and thoracic vertebrae, function as stabilizer of body and head and a generator of forward propulsion (Necker, 2007; Abourachid *et al*., 2011; Nyakatura and Andrada, 2014.; Andrada *et al*., 2015). Endo *et al*. (2012) studied the muscle mass in fighting fowls, broiler and layer fowls, and they suggested that the long neck with small muscles in Oh-Shamo can perform quick and flexible movement of pecking in game. Hence I expect that the functional-morphological characteristics of cervical and thoracic vertebrae are examined in my future work.

In this doctoral thesis, I investigated the functional-morphological characteristics in

skeleton since I thought that the size and shape of bone are related to body appearance and that the morphological characteristics indicate the differences in purposes of breeding. My investigations show that the differences of morphological characteristics of skeleton contribute to the specific behaviors, the body appearances and the purposes of breeding. Since it is suggested that the morphological characteristics in hindlimb bones and pelvis especially influence the gait, the posture and the purpose of breeding, it is thought that the study of biomechanics of gait pattern in each Japanese breed is necessary to evaluate the differences in locomotion of walking, and to understand the process of the domestication in Japanese fowls.

I suggest the morphological variations of skeleton contribute to increase the adhesion of muscles as seen in the discussions in Chapters 3 and 4. I also understand that the investigation of comparing the muscle masses is important to establish the functional-morphological theory. The differences of muscle masses among breeds determine those of the muscle powers and the outline of body. In the discussion about the functional-morphological characteristics in Oh-Shamo, the results and discussion from Endo *et al*. (2012) support my suggestion. Actually a large number of studies of economical characteristics has been performed (Shimizu and Hachinohe, 1976; Miyoshi *et al.*, 1995; Luc *et al*., 1996; Shimazawa and Araki, 1999; Matsuzaki, 2001; Sato *et al*., 2001; Zekarias *et al*., 2002; Matsuzaki *et al*., 2003; Kristensen *et al*., 2006; Bihan-Duval *et al*., 2008; Hocking *et al*., 2009; Golden *et al*., 2012; Hirahara *et al*., 2012; Nikki *et al*., 2012; Emam *et al*., 2014; Jin *et al*., 2014; Batkowska *et al*., 2015; Nakamura and Sugihara, 2015), and estimations of lineage have been frequently carried out (Akishinonomiya *et al*., 1996; Moiseyeva *et al*., 2003; Komiyama *et al*., 2004; Liu *et al*., 2006; Al-Nasser *et al*., 2007; Oka et al., 2007; Kanginakudru *et al*., 2008; Bhuiyan *et al*., 2013; Lorenzo *et al*., 2015). Related to the Japanese domestic fowls, the genetics have been performed and the investigations clarified the relationships between the quantitative trait loci and the morphological and behavioural characteristics (Tsudzuki *et al*., 2007; Goto *et al*., 2011; Rikimaru *et al*., 2012; Oka and Bungo, 2014; Goto *et al*., 2015), however, the morphological studies from spiritual and cultural backgrounds are quite few (Bartels, 2003; Endo *et al*., 2012). Although the previous studies observed the morphological characteristics in skeleton, they did not mention the relationships among the osteometrical differences, the purposes of breeding and the functional roles in the

Japanese domestic fowls, since the aim of their studies is to clarify the phyletic relationships (Hayashi *et al*., 1982; Nishida *et al*., 1985; Samejima, 1990; Samejima *et al*., 1988, 1989). Since the Japanese domestic fowls show plentiful variety of the body appearances, the behavioral characters, and the purposes of breeding, I suppose that the morphological, myological, physiological, behavioral and social-psychological studies in the breeds contribute to explain the effects of the difference of body size and posture in bipedal locomotion, and the relationships among size, shape, movement and perception of people.

ACKNOWLEDGEMENTS

The author thanks Japanese Society for the study of H. I. H. Akishinonomiya Collection for encouraging us. I am grateful to Dr. Masaoki Tsudzuki and Dr. Takao Oka (Animal Breeding and Genetics Laboratory, Hiroshima University) for their providing specimens in this study. And I thank Dr. Michiko Niimi (The Nagoya University Museum, Nagoya University) for supporting to use specimens. Let me express my heartfelt appreciation to Prof. Endo (The University Museum, The University of Tokyo and Graduate School of Agriculture and Agricultural Life Sciences, The University of Tokyo) who has encouraged me in my studies.

REFERENCES

Abourachid A. 2000. Bipedal locomotion in birds: the importance of functional parameters in terrestrial adaptation in Anatidae. Canadian Journal of Zoology, 78: 1991-1998.

Abourachid A, Hackert R, Herbin M, Libourel PA, Lambert F, Gioanni H, Provini P, Blazevic P and Hugel. 2011. Bird terrestrial locomotions as revealed by 3D kinematics. Zoology, 114: 360-368.

Akishinonomiya F and Komiya T. 2009. Livestock and Poultry in Japan. pp. 140-211. Gakken, Tokyo. (in Japanese)

Akishinonomiya F, Miyake T, Takada M, Shingu R, Endo T, Gojobori T, Kondo N and Ohno S. 1996. Monophyletic origin and unique dispersal patterns of domestic fowls. Proceedings of the National Academy of Sciences of the United States of America, 93: 6792-6795.

Alley TR. 1981. Head shape and the perception of cuteness. Developmental Psychology, 17: 650-654.

Al-Nasser A, Al-Khalaifa H, Al-Saffer A, Khalil F, Al-Bahouh M, Raghb G, Al-Haddad A and Mashaly M. 2007. Overview of chicken taxonomy and domestication. Word's Poultry Science Association 63: 285-300.

Andrada E, Haase D, Sutedja Y, Nyakatura JA, Kilbourne BM, Denzler J, Fischer MS and Blickhan R. 2015. Mixed gaits in small avian terrestrial locomotion. Scientific Reports. 5: 13636.

Andrada E, Nyakatura JA, Bergmann F and Blickhan R. 2013. Adjustments of global and local hindlimb properties during terrestrial locomotion of the common quail (*Coturnix coturnix*). The Journal of Experimental Biology, 216: 3906-3916.

Angier N. 2006. The cute factor. The New York Times, January 3: 3.

Archer J and Monton S. 2011. Preferences for infant facial features in pet dogs and cats. Ethology, 117: 217-226.

Arkoff A and Weaver HB. 1966. Body image and body dissatisfaction in Japanese-Americans. The Journal of Social Psychology, 68: 323-330.

Bagley RS, Harrington ML, Tucker RL, Sande RD, Root CR and Kramer RW. 1996. Occipital dysplasia and associated cranial spinal cord abnormalities in two dogs. Veterinary Radiology and Ultrasound, 37: 359-362.

Banerjee D, Daigle CL, Dong B, Wurtz K, Newberry RC, Siegford JM and Biswas S. 2014. Detection of jumping and landing force in laying hens using wireless wearable sensors. Poultry Science, 93: 1-10.

Bartels T. 2003. Variations in the morphology, distribution, and arrangement of feathers in domestic birds. Journal of Experimental Zoology Part B Molecular and Developmental Evolution, 298: 91-108.

Batkowska J, Brodacki A, Zięba G, Horbańczuk and Łukaszewicz M. 2015. Growth performance, carcass traits and physical properties of chicken meat as affected by genotype and production system. Archives Animal Breeding, 58: 325-333.

Baumel JJ, Wilson JA and Bergren DR. 1990. The ventilatory movements of the avian pelvis and tail: Function of the muscles of the tail region of the pigeon (*Columba livia*). Journal of Experimental Biology, 151: 263-277.

Beaufrère H. 2009. A review of biomechanic and aerodynamic considerations of the avian thoracic limb. Journal of Avian Medicine and Surgery, 23: 173-185.

Beckers GJL, Suthers RA and Cate CT. 2003. Pure-tone birdsong by resonance filtering of harmonic overtones. Proceedings of the National Academy of Sciences of the United States of America, 100: 7372-7376.

Beverland MB, Farrelly F and Lim EAC. 2008. Exploring the dark side of pet ownership: Status- and control-based pet consumption. Journal of Business Research, 61: 490-496.

Bhuiyan MSA, Chen S, Faruque S, Bhuiyan AKFH and Beja-Pereira A. 2013. Genetic diversity and maternal origin of Bangladeshi chicken. Molecular Biology Reports, 40: 4123-4128.

Bihan-Duval EL, Debut M, Berri CM, Sellier N, Stanté-Lhoutellier V, Jégo Y and Beaumont C. 2008. Chicken meat quality: genetic variability and relationship with growth and muscle characteristics. BMC Genetics, 9: 53-58.

Bock WJ. 1966. An approach to the functional analysis of bill shape. The Auk, 83: 10-51.

Bock WJ. 1999. Functional and evolutionary morphology of woodpeckers. Ostrich, 70: 23-31.

Bonser RHC and RaynerJMV. 1996. Measuring leg thrust forces in the common starling. The Journal of Experimental Biology, 199: 435-439.

Brackenbury J. 1984. Physiological responses of birds to flight and running. Biological Review, 59: 559-575.

Brackenbury JH, Avery P and Gleeson M. 1981. Respiration in exercising fowl. I. Oxygen consumption, respiratory rate and respired gases. Journal of Experimental Biology, 93: 317-325.

Breitburg DL. 1987. Interspecific competition and the abundance of nest sites: Factors affecting sexual selection. Ecology, 68: 1844-1855.

Breugelmans S, Muylle S, Cornillie P, Saunders J and Simoens P. 2007. Age determination of poultry: a challenge for customs. Vlaams Diergeneeskundug Tijdschrift, 76: 423-430.

Burton RF. 2008. The scaling of eye size in adult birds: relationship to brain, head and body sizes. Vision Research, 48: 2345-2351.

Cardoso, GC. 2010. Loudness of birdsong is related to the body size, syntax and phonology of passerine species. Journal of Evolutionary Biology, 23: 212-219.

Carr JA, Ellerby DJ and Marsh RL. 2011. Function of large biarticular hip and knee extensor during walking and running in guinea fowl (*Numida meleagris*). The Journal of Experimental Biology, 214: 3405-3413.

Coulombre AJ and Crelin ES. 1958. The role of the developing eye in the morphogenesis of the avian skull. American Journal of Physical Anthropology 16: 25-37.

Coy AE, Green JD and Price ME. 2014. Why is low waist-to-chest ratio attractive in males? The mediating roles of perceived dominance, fitness, and protection ability. Body Image, 11: 282-289.

Crespo R, Stover SM, Taylor KT, Chin RP and Shivaprasad HL. 2000. Morphometric and mechanical properties of femora in young adult male turkeys with and without femoral fractures. Poultry Science, 79: 602-608.

Daley MA and Biewener AA. 2003. Muscle force-length dynamics during level versus incline locomotion: a comparison of *in vivo* performance of two guinea fowl ankle extensors. The Journal of Experimental Biology, 206, 2941–2958.

Daley MA, Felix G and Biewener AA. 2007. Running stability is enhanced by a proximo-distal gradient in joint neuromechanical control. The Journal of Experimental Biology, 210: 383–394.

Darroch JN and Mosimann JE. 1985. Canonical and principal components of shape. Biometrika, 72: 241-252.

Davis C and Cowles M. 1991. Body image and exercise: A study of relationships and comparisons between physically active men and women. Sex Roles, 25: 33-44.

Dial KP, Goslow GE and Jenkins FA. 1991. The functional anatomy of the shoulder in the European starling (*Sturnus vulgaris*). Journal of Morphology, 207: 327-344.

Driesch A von den. 1976. A Guide to The Measurement of Animal Bones from Archaeological Sites. Peabody Museum of Harvard University, Cambridge.

Dundes A. 1994. The Cockfight. University of Wisconsin Press, Madison.

Earls KD. 2000. Kinematics and mechanics of ground take-off in the starling *Sturnis vulgaris* and the quail *Coturnix coturnix*. The Journal of Experimental Biology, 203: 725-739.

Emam M, Mehrabani-Yeganeh H, Barjesteh N, Nikbakht G, Thompson-Crispi, Charkhkar S and Mallard B. 2014. The influence of genetic background versus commercial breeding programs on chicken immunocompetence. Poultry Science, 93: 77-84.

Endo H, Mori K, Hosojima M, Mekwichai W, Ogawa H, Tsunekawa N, Yamasaki T, Hayashi Y and Akishinonomiya F. 2012. Functional-morphological characteristics in the musculoskeletal system of standing-type cocks including some game breeds. Japanese Journal of Zoo and Wildlife Medicine, 17: 131-138.

Felice RN and O'Connor PM. 2014. Ecology and caudal skeletal morphology in birds: The convergent evolution of pygostyle shape in underwater foraging taxa. Plos one, 9: e89737.

Frahm HD and Rehkämper G. 1998. Allometric comparison of the brain and brain structures in the white crested polish chicken with uncrested domestic chicken breeds. Brain, Behavior and Evolution, 52: 292-307.

Fujiyoshi M, Kondo K, Sato H and Shimada S. 1996. Analysis of perceptions and impressions of solid of revolution. Journal of Graphic Science of Japan, 30: 52-57. (in Japanese)

Gatesy SM. 1999. Guineafowl hind limb function. II: Electromyographic analysis and motor pattern evolution. Journal of Morphology, 240: 127-142.

Gatesy SM and Biewener AA. 1991. Bipedal locomotion: effects of speed, size and limb posture in birds and humans. The Zoological Society of London, 224: 127-147.

Glocker ML, Langleben DD, Ruparel K, Loughead JW, Gur RC and Sacher N. 2009. Baby schema in infant faces induces cuteness perception and motivation for caretaking in adults. Ethology, 115: 257-263.

Goetz JE, Derrick TR, Pedersen DR, Robinson DA, Conzemius MG, Baer TE and Brown TD. 2008. Hip joint contact in the emu (*Dromaius novaehollandiae*) during normal level walking. Journal of Biomechanics, 41: 770-778.

Golden JB, Arbona DV and Anderson KE. 2012. A comparative examination of rearing parameters and layer production performance for brown egg-type pullets grown for either free-range or cage production. The Journal of Applied Poultry Research, 21: 95-102.

Gordon R, Thomas R and Foster A. 2015. The health impact of selective breeding in poultry: A probable case of 'creeper' chicken (*Gallus gallus*) from 16th-century Chester, England. International Journal of Paleopathology, 9: 1-7.

Goto T, Ishikawa A, Onitsuka S, Goto N, Fujikawa Y, Umino T, Nishibori M and Tsudzuki M. 2011. Mapping quantitative trait loci for egg production traits in an F2 intercross of Oh‐Shamo and White Leghorn chickens. Animal Genetics, 42: 634-641.

Goto T, Shiraishi J, Bungo T and Tsudzuki M. 2015. Characteristics of egg-related traits in the Onagadori (Japanese extremely long tail) breed of chickens. Journal of Poultry Science, 52: 81-87.

Grammer K, Fink B, Moller AP and Thonhill R. 2003. Darwinian aesthetics: Sexual selection and the biology of beauty. Biological Reviews, 78: 385-407.

Hayashi Y, Nishida T, Fujioka T, Tsugiyama I, Mochizuki K and Tomimoto M. 1982. Measurement of the skull of jungle and domestic fowls. The Japanese Journal of Veterinary Science, 44: 1003-1006.

Henry HT, Ellerby DJ and Marsh RL. 2005. Performance of guinea fowl *Numida meleagris* during jumping requires storage and release of elastic energy. The Journal of Experimental Biology, 208: 3293-3302.

Heppner FH and Anderson JGT. 1985. Leg thrust important in flight take-off in the pigeon. Journal of Experimental Biology, 114: 285-288.

Hildebrandt KA and Fitzgerald HE. 1979. Facial feature determinants of perceived infant attractiveness. Infant Behavior and Development, 2: 329-339.

Hirahara S, Kurata N, Suzuki M and Eguchi J. 2012. Development of feeding system using by-products of food processing for laying hens. The feeding tests on laying hens using dried feed made from by-products of food processing. Bulletin of Livestock Industry Technology Station, Kanagawa Agricultural Technology Center, 1: 21-36. (in Japanese)

Hocking PM, Sandercock DA, Wilson S and Fleming RH. 2009. Quantifying genetic (co)variation and effects of genetic selection on tibial bone morphology and quality in 37 lines of broiler, layer and traditional chickens. British Poultry Science, 50: 443- 450.

Hogg DA. 1978. The articulations of the neurocranium in the postnatal skeleton of the domestic fowl (*Gallus gallus domesticus*). Journal of Anatomy, 127: 53-63.

Horvath T. 1981. Physical attractiveness: The influence of selected torso parameters. Archives of Sexual Behavior, 10: 21-24.

Hospitaleche CA and Carlo UD. 2010. The coracoids in functional and morphological studies of penguins (aves, spheniscidae) of the Eocene of Antarctica. Rivista Italiana di Paleontologia e Stratigrafia, 116: 23-34.

Hutchinson JR. 2002. The evolution of hindlimb tendons and muscles on the line to crown-group birds. Comparative Biochemistry and Physiology Part A, 133: 1051-1086.

Hutchinson JR and Gatesy SM. 2000. Adductors, abductors, and the evolution of archosaur locomotion. Paleobiology, 26: 734-751.

Ichinoe K and Kuwayama T. 2007. Kakin. Soubun, Tokyo. (in Japanese)

Iersel MBV and Mulley GP. 2004. What is a waddling gait?. Disability and Rehabilitation 26: 678-682.

Jacobson RD and Hollyday M. 1982. Electrically evoked walking and fictive locomotion in the chick. Journal of Neurophysiology, 48: 257-270.

Jin S, Chen S, Li H, Lu Y, Xu G and Yang N. 2014. Associations of polymorphism in CHRL, GHSR, and ICF1R genes with feed efficiency in chickens. Molecular Biology Reports, 41: 3973-3979.

Jollie MT. 1957. The head skeleton of the chicken and remarks on the anatomy of this region in other birds. Journal of Morphology, 100: 389-436.

Jonart LM, Hill GE and Badyaev AV. 2007. Fighting ability and motivation: Determinants of dominance and contest strategies in female of a passerine bird. Animal Behaviour, 1675-1681.

Jones MR and Witt CC. 2014. Migrate small, sound big: Functional constraints on body size promote tracheal elongation in cranes. Journal of Evolutionary Biology, 27: 1256-1264.

Jourard SM and Secord PF. 1954, Body size and body-cathexis. Journal of Consulting Psychology, 18: 184.

Jourard SM and Secord PF. 1955. Body-cathexis and the ideal female figure. The Journal of Abnormal and Social Psychology, 50: 243-246.

Kanginakudru S, Metta M, Jakati RD and Nagaraju J. 2008. Genetic evidence from Indian red jungle fowl corroborates multiple domestication of modern day chicken. BMC evolutionary biology 8: 174-187.

Kristensen HH, Perry GC, Prescott NB, Ladewig J, Ersbøll AK and Wathes CM. 2006. Leg health and performance of broiler chickens reared in different light environments. British Poultry Science, 47: 257-263.

Ksepka DT. 2007. Phylogeny, Histology and Functional Morphology of Fossil Penguins (sphenisciformes). Columbia University, Chicago.

Kuwayama T, Ogawa H, Munechika I, Kono T and Ichinoe K. 1996. Crowing characteristics of jungle fowl, Japanese native breeds and white leghorn breed of chicken. Japanese Journal of Poultry Science, 33: 89-95.

Latimer HB. 1925. The postnatal growth of the central nervous system of the chicken. The Journal of Comparative Neurology, 38: 251-297.

Lehmann V, Huis EM and Vingerhoets AJ. 2013. The human and animal baby schema effect: Correlates of individual differences. Behavioural Processes, 94: 99-108.

Little AC. 2012. Manipulation of infant-like traits affects perceived cuteness of infant, adult and cat faces. Ethology, 118: 775-782.

Liu YP, Wu GS, Yao YG, Miao YW, Luikart G, Baig M, Beja-Pereira A, Ding AL, Palanichamy MG and Zhang YP. 2006. Multiple maternal origins of chickens: Out of the Asian jungles. Molecular Phylogenetics and Evolution, 38: 12-19.

Lorenz K. 1943. Die angeborenen Formen möglicher Erfahrung. Zeitschrift für Tierpsychologie, 5: 235-409.

Lorenzo PD, Seccobelli S, Panella F, Attard P and Lasagna E. 2015. The role of mitochondrial DNA to determine the origin of domestic chicken. World's Poultry Science Journal, 71: 311-318.

Luc KM, Miyoshi S, Kuchida K and Mitsumoto T. 1996. Comparison of the clutch traits and egg production predicted by the multiphasic model among the laying strains. Japanese Poultry Science, 33: 235-241.

Mackelprang R and Goller F. 2013. Ventilation patterns of the songbird lung/air sac system during different behaviors. The Journal of Experimental Biology, 216: 3611-3619.

Matsuzaki M. 2001. Keeping and Breeding of Native Fowl for Chicken Meat in Kumamoto. Japanese Poultry Science, 38:182-189. (in Japanese)

Matsuzaki M, Yamashita H and Takano T. 2003. Restoration and make use of "Amakusadaiou". Research Bulletin of the Kumamoto Prefectural Agricultural Research Center, 12: 79-87. (in Japanese)

McCaghy CH and Neal AG. 1974.The fraternity of cockfighters: Ethical embellishments of an illegal sport. Journal of Popular Culture, 8: 557-569.

Miyoshi S, Ohta N, Kuchida K and Mitsumoto T. 1995. The relationships of the growth and egg production in egg-type chickens. Research Bulletin of Obihiro University, 19:119-126.

Mlikovský J. 2003. Brain size and foramen magnum area in crows and allies (Aves: Corvidae). Acta Societatis Zoologicae Bohemicae, 67: 203- 211.

Moiseyeva IG, Romanov MN, Nikiforov AA, Sevastyanova AA and Semyenova SK. 2003. Evolutionary relationships of red jungle fowl and chicken breeds. Genetics Selection Evolution, 35: 403-423.

Morreall J. 1991. Cuteness. British Journal of Aesthetics, 31: 39-47.

Mosimann JE. 1970. Size allometry: Size and shape variables with characterization of the lognormal and generalized gamma distributions. Journal of the American Statistical Association, 65: 930-945.

Nakamura H and Sugihara K. 2015. Effects of LED illumination on economic benefit and laying performance in practical poultry house. Bulletin of the Saitama Prefectural Agriculture and Forestry Research Center, 14: 35-38. (in Japanese)

Nash H. 1958. Assignment of gender to body regions. The Journal of Genetic Psychology, 92: 113-115.

Necker R. 2007 Head-bobbing of walking birds. Journal of comparative physiology A, 193: 1177-1183.

Nestor KE, Bacon WL, Saif YM and Renner PA. 1985. The influence of genetic increases in shank width on body weight, walking ability, and reproduction of turkeys. Poultry Science, 64: 2248-2255.

Nestor KE, Bacon WL, Moorhead PD, Saif YM, Havenstein GB and Renner PA. 1987. Comparison of bone and muscle growth in turkey lines selected for increased body weight and increased shank width. Poultry Science, 66: 1421-1428.

Niemi GJ. 1985. Patterns of morphological evolution in bird genera of new world and old world peatlands. Ecology, 66: 1215-1228.

Nikki T, Saeki Y, Ieiri S, Yoneda K, Araki T and Shibata T. 2012. Effects of rearing type on growth, meat productivity and fat accumulation in local meat-type Amakusa daio chickens. Journal of Warm Regional Society of Animal Science, Japan, 55: 157-166. (in Japanese)

Nishida T, Hayashi Y, Fujioka T, Tsugiyama I and Mochizuki K. 1985. Osteometrical studies on the phylogenetic relationships of Japanese native fowls. The Japanese Journal of Veterinary Science, 47: 25-37.

Nittono H. 2009. A behavioral science approach to “kawaii”. Bulletin of the Graduate School of Integrated Arts and Science, Hiroshima University. I, Studies in Human Science, 4: 19-35. (in Japanese)

Nozawa K and Nishida T. 1981. Domestic Animals and Man. Idemitsu-Shoten, Tokyo. (in Japanese)

Nyakatura J and Andrada E. 2014. On vision in birds: coordination of head-bobbing and gait stabilities vertical position in quail. Frontiers in Zoology, 11: 27.

Oana H. 1951. History of Japanese Domestic Fowl. Nihon-kei Kenkyusha Press, Tokyo. (in Japanese)

Oka T and Bungo T. 2014. Comparison of behavioral responses to manual restraint tests in two breeds of Japanese native chicken. International Journal of Poultry Science, 13: 545-548.

Oka T, Ino Y, Nomura K, Kawashima S, Kuwayama T, Hanada H, Amano T, Takada M, Takahata N, Hayashi Y, Akishinonomiya F. 2007. Analysis of mtDNA sequences shows Japanese native chickens have multiple origins. Animal Genetics, 38: 287-293.

Okamoto S. 2001. Zoology of Domestic Fowl. University of Tokyo Press, Tokyo. (in Japanese)

Palacios MG and Tubaro PL. 2000. Does beak size affect acoustic frequencies in woodcreepers?. The Condor, 102: 553-560.

Passi P and Gefen A. 2005. Trabecular bone contributes to strength of the proximal femur under mediolateral impact in the avian. Journal of Biomechanical Engineering, 127: 198-203.

Paxton H, Anthony NB, Corr SA and Hutchinson JR. 2010. The effects of selective breeding on the architectural properties of the pelvic limb in broiler chickens: A comparative study across modern and ancestral populations. Journal of Anatomy, 217: 153-166.

Peng M, Shi S, Yao Y and Zhang Y. 2015. Caveats about interpretation of ancient chicken mtDNAs from northern China. Proceedings of the National Academy of Sciences of the United States of America, 112: E1970-E1971.

Peters J, Lebrasseur O, Best J, Miller H, Fothergill T, Dobney K, Thomas RM, Maltby M, Sykes N, Hanotte O, O'Conner T, Collins MJ and Larson G. 2015. Questioning new answers regarding Holocene chicken domestication in China. Proceedings of the National Academy of Sciences of the United States of America, 112: E2415.

Picasso MBJ. 2012. Postnatal ontogeny of the locomotor skeleton of a cursorial bird: greater rhea. Journal of Zoology, 286: 303-311.

Reilly SM. 2000. Locomotion in the quail (*Coturnix japonica*): The kinematics of walking and increasing speed. Journal of Morphology, 243: 173-185.

Renison D, Boersma D and Martella MB. 2002. Winning and losing: causes for variability in outcome of fights in male Magellanic penguins (*Spheniscus magellanicus*). Behavioral Ecology, 13: 462-466.

Rikimaru K, Komatsu M, Suzuki K, Uemoto Y, Takeda H and Takahashi H. 2012. Association between cholecystokinin type A receptor haplotypes and growth traits in Japanese Hinai-dori crossbred chickens. Molecular Biology Reports, 39: 4479-4484.

Riyahi S, Hammer Ø, Arbabi T, Sánchez A, Roselaar CS, Alibadian M and Saetre G. 2013. Beak and skull shapes of human commensal and non-commensal house sparrows *Passer domesticus*. BMC Evolutionary Biology, 13: 200-207.

Rylander MK and Bolen EG. 1974. Analysis and comparison of gaits in whistling ducks (Dendrocygna). The Wilson Bulletin, 86: 237-245.

Samejima M. 1990. Principal component analysis of measurements in the skeleton of red jungle fowl and 12 breeds of domestic fowls: III. Ossa membri pelvini. Japanese Journal of Poultry Science, 27: 142-161. (in Japanese)

Samejima M, Ito S and Fujioka T. 1988. Principal component analysis of measurements in the skeleton of red jungle fowl and 12 breeds of domestic fowls: I. Cranium. Japanese Journal of Poultry Science, 25: 222-236. (in Japanese)

Samejima M, Ito S and Fujioka T. 1989. Principal component analysis of measurements in the skeleton of red jungle fowl and 12 breeds of domestic fowls: II. Sternum and ossa membri thoracici. Japanese Journal of Poultry Science, 26: 157-171. (in Japanese)

Sasaki K and Yamaguchi T. 1970. Onaga-dori (long-tailed fowl) and their inherited studies in Japan. World's Poultry Science Journal 26: 562-568.

Sato T, Koyama T, Nozaki T, Yamauchi Y and Hayakawa H. 2004. Investigation of parent stocks (2001). Bulletin of the Fukushima Prefectural Poultry Experiment Station, 31: 1-4. (in Japanese)

Sheppy A. 2011. The colour of domestication and the designer chicken. Optics and Laser Technology, 43: 295-301.

Shimazawa K and Araki T. 1999. Effect of rearing types on meat color and muscle fiber characteristics in local meat-type chicken. Japanese Poultry Science, 36: 371-376, (in Japanese)

Shimizu H and Hachinohe Y. 1976. Genetic response to selection for body weight at nine weeks of age in New Hampshire chickens. Japanese Poultry Science, 13: 176-185. (in Japanese)

Simons ELR. 2010. Forelimb skeletal morphology and flight mode evolution in pelecaniform birds. Zoology, 113: 39-46.

Simons ELR, Hieronymus TL and O'Connor PM. 2011. Cross sectional geometry of the forelimb skeleton and flight mode in pelecaniform birds. Journal of Morphology, 272: 958-971.

Smith NC, Wilson AM, Jespers KJ and Payne RC. 2006. Muscle architecture and functional anatomy of the pelvic limb of the ostrich (*Struthio camelus*). Journal of Anatomy, 209: 765-779.

Smith NC, Payne RC, Jespers KJ and Wilson AM. 2007. Muscle moment arms of pelvic limb muscles of the ostrich (*Struthio camelus*). Journal of Anatomy, 211: 313-324.

Sternglanz SH, Gray JL and Murakami M. 1977. Adult preferences for infantile facial features: An ethological approach. Animal Behaviour, 25: 108-115.

Stevens KN. 1998. Acoustic Phonetics. MIT Press, London.

Tsudzuki M, Onitsuka S, Akiyama R, Iwamizu M, Goto N, Nishibori M, Takahashi H and Ishikawa A. 2007. Identification of quantitative trait loci affecting shank length, body weight and carcass weight from the Japanese cockfighting chicken breed, Oh-Shamo (Japanese large game). Cytogenetic and Genome Research, 117: 288-295.

Watson AG, Lahunta A de and Evans HE. 1989. Dorsal notch of foramen magnum due to incomplete ossification of supraoccipital bone in dogs. Journal of Small Animal Practice, 30: 666-673.

Weiss E, Miller K, Mohan-Gibbons H and Vela C. 2012. Why did you choose this pet?: Adopters and pet selection preferences in five animal shelters in the United States. Animals, 2: 144-159.

West B and Zhou BX. Did chickens go north? New evidence for domestication. 1988. Jornal of Archaeological Science 15: 515- 533.

Xiang H, Gao J, Yu B, Zhou H, Cai D, Zhang Y, Chen X, Wang X, Hofreiter M and Zhao X. 2014. Early Holocene chicken domestication in northern China. Proceedings of the National Academy of Sciences of the United States of America, 111: 17564-17569.

Yasuda M. 2002. The Anatomical Atlas of Gallus. University of Tokyo Press, Tokyo. (in Japanese)

Zekarias B, Huurne AAHMT, Landman WJM, Rebel JMJ, Pol JMA and Gruys E. 2002. Immunological basis of differences in disease resistance in the chicken. Veterinary Research, 33: 109-125.

TABLES AND FIGURES

Table 1-1. Specimens used in the Chapter 2.

breed	sex	specimen No.	growth stage	donor	depository	breed	sex	specimen No.	growth stage	donor	depository
Onagadori	female	UMUT-14014	adult[1]	TUA	UMUT	Totenko	female	UMUT-14029	adult[1]	TUA	UMUT
Onagadori	female	UMUT-14015	adult[1]	HU	UMUT	Totenko	female	UMUT-14030	adult[1]	TUA	UMUT
Onagadori	female	UMUT-14016	adult[1]	HU	UMUT	Totenko	male	UMUT-14031	adult[1]	TUA	UMUT
Onagadori	male	UMUT-14017	adult[1]	TUA	UMUT	Totenko	male	UMUT-14032	adult[1]	TUA	UMUT
Onagadori	male	NUM-ab1-1202	adult[2]	-	NUM	Totenko	male	UMUT-14033	adult[1]	TUA	UMUT
Oh-Shamo	female	UMUT-14018	adult[1]	TUA	UMUT	Totenko	male	UMUT-14034	adult[2]	HU	UMUT
Oh-Shamo	female	UMUT-14019	adult[1]	TUA	UMUT	Chabo	female	UMUT-14035	adult[1]	TUA	UMUT
Oh-Shamo	female	UMUT-14020	adult[1]	TUA	UMUT	Chabo	female	UMUT-14036	adult[1]	TUA	UMUT
Oh-Shamo	male	UMUT-14021	adult[1]	TUA	UMUT	Chabo	female	NUM-ab1-926	adult[2]	-	NUM
Oh-Shamo	male	NUM-ab1-1230	adult[2]	-	NUM	Chabo	male	UMUT-14037	adult[1]	TUA	UMUT
Oh-Shamo	male	UMUT-14022	adult[1]	TUA	UMUT	Chabo	male	UMUT-14039	adult[1]	TUA	UMUT
Oh-Shamo	unknown	UMUT-14023	adult[1]	TUA	UMUT	Chabo	male	UMUT-14040	adult[1]	TUA	UMUT
Oh-Shamo	unknown	UMUT-14024	adult[1]	TUA	UMUT	Chabo	male	UMUT-14041	adult[1]	TUA	UMUT
Shokoku	female	NUM-ab1-1256	adult[2]	-	NUM	Chabo	male	UMUT-14042	adult[1]	TUA	UMUT
Shokoku	female	NUM-ab1-1255	adult[2]	-	NUM	Chabo	male	NUM-abl1945	adult[2]	-	NUM
Shokoku	male	NUM-ab1-973	adult[2]	-	NUM	Chabo	male	NUM-ab1-922	adult[2]	-	NUM
Shokoku	male	NUM-ab1-1307	adult[2]	-	NUM	Chabo	unknown	UMUT-14043	adult[1]	TUA	UMUT
Shokoku	male	NUM-ab1-1347	adult[2]	-	NUM	Chabo	unknown	NUM-ab1-925	adult[2]	-	NUM
Shokoku	male	UMUT-14025	adult[1]	TUA	UMUT						
Tosajidori	female	NUM-ab1-1336	adult[2]	-	NUM						
Tosajidori	female	UMUT-14026	adult[1]	HU	UMUT						
Tosajidori	male	UMUT-14027	adult[1]	TUA	UMUT						
Tosajidori	male	NUM-ab1-1281	adult[2]	-	NUM						
Tosajidori	unknown	UMUT-14028	adult[1]	TUA	UMUT						

UMUT indicates The University Museum, The University of Tokyo. NUM means Nagoya University Museum, Nagoya University. HU indicates Hiroshima University. TUA indicates Tokyo University of Agriculture. adult[1] indicates over one years old. adult[2] indicates completed ossification of skull.

Table 1-2. The measurements used in the Chapter 2.

Abbreviation of measurements	Details	Abbreviation of measurements	Details
GLs	greatest length of skull; protuberantia occipitalis externa - apex praemaxillaris[a, b, c]	BLbt	basal length of the bill tip; most frontal point of the corpus premaxillare - most frontal point of the basal incisura nassle[d]
GLi	greatest length of incisivum; apex praemaxillaris - most aboral point of the processus frontales of the incisivum in the median plane[a, b, c]	CbL	condulobasal length; aboral border of the occipital condyle - apex praemaxiilaris[a,b, c]
BLb	basal length of bill; apex praemaxillaris -most caudal points of the processus maxiallis ossis premaxillaris[d]	GBsb	greatest breadth of the sphenoidal bone; between each most wide point on the limbus sphenoidalis[c]
GLbt	greatest length of bill tip; most frontal point of the premaxillaris - the most frontal point of the nasals[d]	Bpr	breadth between the processus retriangularis; between each point of the processus retroangularis[d]
Hbt	height of bill tip; highest point above the most frontal point of the nasals - lowest point under the most frontal point of the nasals[d]	GLm	greatest length of the mandible; apex to the most aboral point of the mandible[a, b, c]
GLoc	greatest length of orbital cavity; most frontal point of the aucus zygomaticus - most aboral point of the processus frontalis[d]	Leaba	length between the aboral edge of articural bone to the apex; pars symphysialis - condylus musculris mandibularis caudalis[a, b, c]
GLmp	greatest length in the median plane; the basitemporale in the median plane - highest and median point of the braincase[a, b, c]	Lpaa	length between the processus angularis to the apex; apex to the processus angularis[c]
GBbt	greatest breadth of bill tip; most wide breadth in front of the most frontal points of the nasals[d]	Ls	length of the symphesis; between frontal apex of mandible to aboral one[a, b, c]
Lnc	length of the neurocranium; processus frontalis of the paemaxilla - protuberantia occipitalis externa[a, b, c]	Lpapr	length between the processus angularis to processus retroangularis; pcrocessus angularis - processus retroangularis[c]
GBs	greatest breadth of skull; between each point of the processus postfrontalis[a, b, c]	GLabpa	greatest length between the edge of articular bone to the processus angularis[c]
GBnc	greatest breadth of the neurocranium; between each point of the os opistoideus[c]	Lpaps	length between the processus angularis to the aboral edge of the pars symphysialis[d]
SBnc	smallest breadth of the neurocranium; between each point of the os quadratum[c]	GBco	greatest breadth of the condylus occipitalis[a]
SBo	smallest breadth between the orbits; smallest breadth of the pars nasalis of the frontale[a, b, c]	GHfm	greatest height of the foramen magnum[c]
GBb	greatest breadth of the bill; between each point of the caudal edge of the processus maxillaris ossis premaxillaris[d]	GBfm	greatest breadth of the foramen magnum[c]

[a] Driesch (1976). [b] Hayashi *et al*. (1982). [c] Samejima *et al*. (1988). [d] Yasuda (2002).

Table 1-3. Mean values and standard deviations for skull measurements in various breeds.

breed	measurements	GLs	GLi	BLb	GLbt	Hbt	GLoc	GLmp	GBbt	Lnc	GBs	GBnc	SBnc	SBo	GBb	
comparing pair with significant difference		AEFGHIJLMO	AEFGHIJLMO	AEFGHILMO	ACEFGHILMO	AFGHI	AFGHI	AEFGHILMO	AFGHI	ACEFGHILMO	ACEFGHIJLMO	ACEFGHIJLMO	AFGHILO	AFGHI	AFGHI	
Onagadori	mean value	67.19	34.45	24.01	13.10	5.75	21.11	20.83	8.51	37.07	29.14	25.64	22.60	13.89	12.92	
	standard deviation	4.81	2.53	2.43	1.20	0.79	1.01	0.95	0.63	3.41	2.25	1.75	1.22	2.20	1.91	
Oh-Shamo	mean value	85.86	45.37	30.86	16.53	8.46	24.49	25.40	11.77	46.31	37.83	32.48	28.37	19.80	19.43	
	standard deviation	6.39	4.50	2.61	1.25	0.92	1.88	1.37	2.10	2.82	1.84	2.02	1.42	1.43	1.49	
Shokoku	mean value	67.27	35.96	23.87	12.54	5.56	18.91	20.31	8.70	36.14	29.20	25.89	22.98	13.70	13.73	
	standard deviation	5.10	3.31	2.40	1.54	0.89	2.60	1.46	1.33	2.67	2.44	1.52	1.58	2.01	2.46	
Tosajidori	mean value	58.26	28.78	20.38	10.67	4.87	18.32	18.76	7.45	32.32	25.39	22.66	20.88	12.22	12.25	
	standard deviation	2.77	0.99	1.16	0.69	0.77	0.45	0.47	0.32	1.19	1.51	1.15	0.75	1.46	0.82	
Totenko	mean value	67.73	34.98	25.07	13.29	5.77	20.91	21.16	9.03	37.10	30.13	25.65	22.73	14.58	13.86	
	standard deviation	5.66	3.45	2.08	1.14	1.04	1.21	1.32	0.71	2.89	2.13	2.11	1.87	1.42	2.09	
Chabo	mean value	57.67	28.82	20.26	10.40	5.08	19.06	18.54	7.96	32.11	25.58	22.46	20.69	12.53	12.70	
	standard deviation	3.99	2.06	1.31	0.79	0.56	0.83	0.76	0.59	1.30	1.15	1.00	0.76	2.05	1.17	

breed	measurements	BLbt	CbL	GBsb	Bpr	GLm	Leaba	Lpaa	Ls	Lpapr	GLabpa	Lpaps	GBco	GHfm	GBfm	GM
comparing pair with significant difference		AEFGHILMO	ACEFGHILMO	ACEFGHIJLMO	ACEFGHIJLMO	AEFGHILO	ACEFGHIJLMO	ACEFGHIJLMO	ACEFGHIJLMO	ACEFGHIMO	ACEFGHIMO	ACEFGHIJLMO	AFGHI	EGIJL	ACEFGHILO	ACEFGHIJLMO
Onagadori	mean value	11.98	61.84	19.87	43.40	29.38	54.06	49.31	49.11	9.29	11.12	9.66	3.22	6.25	7.36	34.42
	standard deviation	0.83	4.60	1.19	6.60	5.18	3.82	3.59	3.36	1.13	1.43	0.81	0.48	0.57	0.60	2.17
Oh-Shamo	mean value	14.85	78.29	25.03	52.60	39.33	70.00	63.06	62.74	10.49	15.24	13.69	4.54	6.46	8.31	43.52
	standard deviation	0.97	5.84	1.50	4.40	3.30	5.70	5.40	4.97	0.78	1.32	0.97	0.31	0.63	0.53	2.36
Shokoku	mean value	11.18	60.73	20.28	40.33	28.80	53.25	48.43	48.11	8.27	10.57	9.48	3.42	6.48	6.89	34.17
	standard deviation	1.63	4.72	1.01	2.98	2.68	4.20	3.89	3.48	0.50	1.20	1.01	0.37	0.71	0.56	2.62
Tosajidori	mean value	10.03	52.72	17.18	33.52	24.95	45.27	40.94	40.57	7.46	8.97	7.96	2.93	5.28	6.24	30.26
	standard deviation	0.65	3.28	0.79	1.20	0.97	1.49	1.52	1.68	0.50	0.46	0.60	0.34	0.26	0.33	0.99
Totenko	mean value	12.20	62.08	20.39	41.58	29.52	55.13	50.03	49.63	8.48	10.72	9.81	3.34	5.71	7.05	35.08
	standard deviation	0.89	5.34	2.01	4.16	2.35	4.13	3.90	4.55	0.73	0.54	0.85	0.28	0.85	0.54	2.45
Chabo	mean value	9.60	51.60	16.85	33.08	24.58	44.99	40.50	40.07	7.22	9.31	8.18	3.01	5.28	6.00	30.14
	standard deviation	0.93	2.94	0.92	1.35	1.63	1.78	1.58	1.66	0.50	0.45	0.46	0.32	0.44	0.38	1.35

Each alphabet indicates comparing pair with significant difference as follows; [A] Onagadori - Oh-Shamo, [B]Onagadori - Shokoku, [C] Onagadori - Tosajidori, [D]Onagadori - Totenko, [E]Onagadori - Chabo, [F]Oh-Shamo - Shokoku, [G] Oh-Shamo - Tosajidori, [H] Oh-Shamo - Totenko, [I] Oh-Shamo - Chabo, [J] Shokoku - Tosajidori, [K] Shokoku - Totenko, [L] Shokoku - Chabo, [M] Tosajidori - Totenko, [N]Tosajidori - Chabo and [O] Totenko - Chabo.

Table 1-4. Mean values and standard deviations for skull measurement ratios in various breeds.

breed	measurements	GLs	GLi	BLb	GLbt	Hbt	GLoc	GLmp	GBbt	Lnc	GBs	GBnc	SBnc	SBo	GBb
comparing pair with significant difference		-	gijl	-	eio	fghi	abijl	agijl	-	-	-	-	cegimo	-	a
Onagadori	mean value	1.95	1.00	0.70	0.38	0.17	0.61	0.61	0.25	1.08	0.85	0.75	0.66	0.40	0.37
	standard deviation	0.03	0.02	0.04	0.03	0.01	0.02	0.01	0.01	0.05	0.02	0.02	0.02	0.05	0.03
Oh-Shamo	mean value	1.97	1.04	0.71	0.38	0.19	0.56	0.58	0.27	1.06	0.87	0.75	0.65	0.46	0.45
	standard deviation	0.06	0.06	0.03	0.01	0.02	0.01	0.01	0.05	0.02	0.02	0.01	0.01	0.03	0.03
Shokoku	mean value	1.97	1.05	0.70	0.37	0.16	0.55	0.59	0.25	1.06	0.85	0.76	0.67	0.40	0.40
	standard deviation	0.02	0.04	0.04	0.03	0.02	0.04	0.01	0.02	0.02	0.01	0.02	0.01	0.04	0.05
Tosajidori	mean value	1.92	0.95	0.67	0.35	0.16	0.61	0.62	0.25	1.07	0.84	0.75	0.69	0.40	0.40
	standard deviation	0.05	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.01	0.04	0.02
Totenko	mean value	1.93	1.00	0.71	0.38	0.16	0.60	0.60	0.26	1.06	0.86	0.73	0.65	0.42	0.39
	standard deviation	0.04	0.06	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.05
Chabo	mean value	1.91	0.96	0.67	0.35	0.17	0.63	0.62	0.26	1.07	0.85	0.75	0.69	0.42	0.42
	standard deviation	0.06	0.05	0.04	0.02	0.01	0.04	0.01	0.02	0.03	0.02	0.01	0.02	0.06	0.03

breed	measurements	BLbt	CbL	GBsb	Bpr	GLm	Leaba	Lpaa	Ls	Lpapr	GLabpa	Lpaps	GBco	GHfm	GBfm
comparing pair with significant difference		-	ei	l	cei	i	egilo	cegilo	cegilo	ae	afghi	afghi	-	afi	a
Onagadori	mean value	0.35	1.80	0.58	1.26	0.85	1.57	1.43	1.43	0.27	0.32	0.28	0.09	0.18	0.21
	standard deviation	0.02	0.03	0.01	0.18	0.12	0.04	0.03	0.03	0.03	0.02	0.01	0.01	0.02	0.02
Oh-Shamo	mean value	0.34	1.80	0.58	1.21	0.90	1.61	1.45	1.44	0.24	0.35	0.31	0.10	0.15	0.19
	standard deviation	0.01	0.06	0.02	0.04	0.04	0.06	0.06	0.05	0.01	0.02	0.01	0.00	0.02	0.01
Shokoku	mean value	0.33	1.78	0.59	1.18	0.84	1.56	1.42	1.41	0.24	0.31	0.28	0.10	0.19	0.20
	standard deviation	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.00	0.02	0.01
Tosajidori	mean value	0.33	1.74	0.57	1.11	0.82	1.50	1.35	1.34	0.25	0.30	0.26	0.10	0.17	0.21
	standard deviation	0.01	0.07	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Totenko	mean value	0.35	1.77	0.58	1.18	0.84	1.57	1.43	1.41	0.24	0.31	0.28	0.10	0.16	0.20
	standard deviation	0.02	0.04	0.02	0.06	0.03	0.04	0.03	0.06	0.01	0.02	0.01	0.01	0.03	0.01
Chabo	mean value	0.32	1.71	0.56	1.10	0.82	1.49	1.34	1.33	0.24	0.31	0.27	0.10	0.18	0.20
	standard deviation	0.03	0.05	0.02	0.04	0.04	0.05	0.05	0.05	0.02	0.01	0.01	0.01	0.01	0.01

Each alphabet indicates comparing pair with significant difference as follows; [a] Onagadori - Oh-Shamo, [b] Onagadori - Shokoku, [c] Onagadori - Tosajidori, [d] Onagadori - Totenko, [e] Onagadori - Chabo, [f] Oh-Shamo - Shokoku, [g] Oh-Shamo - Tosajidori, [h] Oh-Shamo - Totenko, [i] Oh-Shamo - Chabo, [j] Shokoku - Tosajidori, [k] Shokoku - Totenko, [l] Shokoku - Chabo, [m] Tosajidori - Totenko, [n] Tosajidori - Chabo and [o] Totenko - Chabo. – signified that every pair shows no significant difference.

Table 2-1. Specimens used in the Chapter 3.

breed	sex	specimen No.	growth stage	donor	depository	breed	sex	specimen No.	growth stage	donor	depository
Chabo	female	UMUT-15166	adult[1]	HU	UMUT	Shokoku	female	UMUT-15161	adult[1]	HU	UMUT
Chabo	female	UMUT-15167	adult[1]	HU	UMUT	Shokoku	male	UMUT-15162	adult[2]	TUA	UMUT
Chabo	male	UMUT-15168	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-1212	adult[2]	-	NUM
Chabo	female	UMUT-14035	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-221	adult[2]	-	NUM
Chabo	male	UMUT-14042	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-222	adult[2]	-	NUM
Chabo	female	UMUT-14035	adult[2]	TUA	UMUT	Shokoku	female	NUM-ab1-223	adult[2]	-	NUM
Chabo	male	UMUT-14041	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-226	adult[2]	-	NUM
Chabo	male	UMUT-14039	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-227	adult[2]	-	NUM
Chabo	-	UMUT-11018	adult[2]	IHA	UMUT	Shokoku	male	NUM-ab1-236	adult[2]	-	NUM
Oh-shamo	male	UMUT-15171	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-237	adult[2]	-	NUM
Oh-shamo	male	UMUT-15172	adult[2]	HU	UMUT	Shokoku	female	NUM-ab1-238	adult[2]	-	NUM
Oh-shamo	male	UMUT-15150	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-57	adult[2]	-	NUM
Oh-shamo	male	UMUT-15151	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-1347	adult[2]	-	NUM
Oh-shamo	-	UMUT-15152	adult[2]	HU	UMUT	Shokoku	male	NUM-ab1-224	adult[2]	-	NUM
Oh-shamo	male	UMUT-15153	adult[1]	HU	UMUT	Tosa-Jidori	female	UMUT-15163	adult[1]	HU	UMUT
Oh-shamo	female	UMUT-14018	adult[2]	TUA	UMUT	Tosajidori	-	UMUT-15164	adult[2]	HU	UMUT
Oh-shamo	female	UMUT-14019	adult[2]	TUA	UMUT	Tosajidori	male	UMUT-14027	adult[2]	TUA	UMUT
Oh-shamo	-	UMUT-15154	adult[2]	TUA	UMUT	Tosajidori	female	NUM-ab1-1336	adult[2]	-	NUM
Oh-shamo	male	UMUT-14021	adult[2]	TUA	UMUT	Tosajidori	female	NUM-ab1-1349	adult[2]	-	NUM
Onagadori	male	UMUT-15155	adult[1]	HU	UMUT	Totenko	male	UMUT-15165	adult[2]	TUA	UMUT
Onagadori	male	UMUT-15156	adult[1]	HU	UMUT	Totenko	male	UMUT-14031	adult[2]	TUA	UMUT
Onagadori	male	UMUT-15157	adult[1]	HU	UMUT	Totenko	female	UMUT-14030	adult[2]	TUA	UMUT
Onagadori	male	UMUT-15158	adult[1]	HU	UMUT	Totenko	male	UMUT-14034	adult[2]	HU	UMUT
Onagadori	female	UMUT-15159	adult[1]	HU	UMUT	Totenko	male	UMUT-14033	adult[2]	TUA	UMUT
Onagadori	female	UMUT-15160	adult[1]	HU	UMUT	Totenko	female	UMUT-14029	adult[2]	TUA	UMUT
Onagadori	female	UMUT-14015	adult[1]	HU	UMUT						

UMUT indicates The University Museum, The University of Tokyo. NUM indicates Nagoya University Museum, Nagoya University. HU indicates Hiroshima University. TUA indicates Tokyo University of Agriculture. IHA indicates Imperial Household Agency. adult[1] indicates over one years old. adult[2] indicates completed ossification of sternum.

Table 2-2. The measurements used in the Chapter 3.

Abbreviation of measurements	Details	Abbreviation of measurements	Details
Lpr	Length between the edge of the processus costalis to the median point of the rostrum sterni[c]	Bpu	Breadth of the proximal end from the facies articularis medialis or ventralis to the facies articularis lateralis or dorsalis[a,b]
SBf	Smallest breadthe between the facets for the costosternal articulations, measured at the narrowest part[a]	Didu	diagonal of the distal end of the ulna [a,b]
GLst	Greatest length of the sternum; from the processus carinatus sterni to the cranial edge of the processus costalis[c]	SBu	Smallest breadth of the ulna[a,b]
Lms	Length from the manubrium sterni; from the cranial point of the manubrium sterni (or the median point of the line joining the cranial points of the manubrium sterni) to the caudal border (or point) of the metasternum in the median plane[a,b]	Dip	Diagonal of the proximal end from the caudal border of the olecranon to the cranial border of the facies articularis lateralis or dorsalis[a,b]
Lc	Length of the crista sterni; from the apex cristae sterni to the caudal border (or point) of the metasternum in the median plane[a,b]	Bph	Breadth of the proximal end from the tuberculum laterale or dorsale to the tuberculum mediale or ventrale, without the crista lateralis[a,b]
Hs	Heighth of the sternum; from the apex sterni to the facies articularis costalis[b,c]	GLh	Greatest length of the humerus[a,b]
Lap	Length between the apex sterni to the edge of the processus costalis[c]	SBh	Smallest breadth of the humerus[a,b]
Lar	Length between the apex sterni to the ventral edge of the rostrum sterni[c]	Bdh	Breadth of the distal end of the humerus[a,b]
GLco	Greatest length of the coracoid; measured generally to the distal point of the basal articular surface, exceptionally to the distal point of the processus lateralis[a,b]	GLr	Greatest length of the radius[a,b]
GBc	Greatest basal breadth of the coracoid[a,b]	Bpr	Breadth of the proximal end of the radius[c]
Bfc	Breadth of the facies articularis basalis of the coracoid (= basal articular surface) [a,b]	SBr	Smallest breadth of the radius[a,b]
SBc	Smallest breadth of the coracoid[b]	Bdr	Breadth of the distal end of the radius[a,b]
Lmc	Medial length of the coracoid[a,b]	Ba	Breadth of the acromion[c]
GLsc	Greatest length of the scapula[a,b]	Hcau	Heighth of the os carpi alulae ulnare[c]
GBs	Greatest breadth of the scapula[b]	Wcau	Width of the os carpi alulae ulnare[c]
SBs	Smallest breadth of the scapula[b]	Hcar	Heighth of the os carpi alulae radiale[c]
Dic	Cranial diagonal of the scapula[a,b]	Wcar	Width of the os carpi alulae radiale[c]
GLcl	Greatest length of the clavicula[c]	Didc	Diagonal of the distal end of the carpometacarpus[a,b]
Lsa	Length between the synostosis interclavicularis to the apophysis bifurculae claviculae[c]	Bpc	Breadth of the proximal extremity of the carpometacarpus[a,b]
Bc	Breadth between the facies articularis clavicularis[c]	Lm	Length of the metacarpus II, from articular surface to articular surface without the processus distalis[a,b]
Lcc	Length of the corpus claviculae; from the median point of the synostosis interclavicularis to the edge of the facies articularis acrocoracoidae[c]	GLcm	Greatest length of the carpometacarpus[a,b]
GLu	Greatest length of the ulna[a,b]		

[a] Driesch (1976). [b] Samejima *et al*. (1989). [c] Yasuda (2002).

Table 2-3-1. Mean values and standard deviations for skeleton measurements of forelimb, pectoral girdle and sternum in various breeds.

breed	measurements	GLst	Lms	Lc	Hs	Lap	Lar	GLco	Lpr	SBf	GBc	Bfc	SBc	Lmc	GLsc	GBs
comparing pair with significant difference		ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIK	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIM	ABCEFGHIMO	ABCEFGHIKMO	ABCEFGHIKMO	ACEFGHIJM
Chabo	mean	80.74	80.41	66.78	26.90	36.77	24.25	38.13	12.96	21.83	10.91	8.66	3.51	35.48	50.10	5.63
	standard deviation	4.15	3.99	6.49	2.04	2.18	1.86	2.83	1.08	1.88	0.77	0.56	0.36	2.68	1.91	0.53
Ohshamo	mean	155.26	158.46	136.70	54.90	74.44	49.04	79.69	27.72	46.48	23.15	18.32	6.67	74.76	99.07	11.97
	standard deviation	14.44	14.23	14.07	4.92	6.64	5.13	7.40	4.40	5.98	2.85	2.40	0.89	6.54	9.97	1.38
Onagadori	mean	118.99	119.15	96.44	40.73	58.84	41.04	59.25	19.82	30.76	15.03	11.31	4.51	56.86	76.46	6.56
	standard deviation	7.81	7.82	7.16	3.54	4.29	4.16	3.63	1.08	1.23	1.37	1.04	0.42	3.53	3.96	0.61
Shokoku	mean	118.95	117.81	98.66	44.00	61.64	42.58	60.03	20.44	31.13	15.23	12.42	4.80	57.40	77.51	8.00
	standard deviation	8.99	9.54	9.36	3.98	5.96	5.02	4.83	2.08	2.55	1.56	1.49	0.63	4.46	5.13	0.92
Tosajidori	mean	85.42	85.27	71.96	29.72	40.98	29.15	42.52	14.07	24.00	11.06	8.95	3.65	40.30	55.69	5.58
	standard deviation	4.46	5.14	5.89	1.41	0.97	1.40	1.29	0.91	2.44	0.71	0.71	0.58	1.07	1.30	0.59
Totenko	mean	114.60	113.90	93.44	41.22	58.38	42.33	58.56	17.73	30.49	14.57	11.41	4.85	55.68	76.03	7.11
	standard deviation	13.29	14.12	11.16	4.31	6.29	4.77	6.61	1.89	3.81	1.75	1.49	0.54	6.74	8.19	0.66

breed	measurements	SBs	Dic	GLcl	Ba	Lsa	Bc	Lcc	GLu	Bpu	Didu	SBu	Dip	Bph	GLh	SBh
comparing pair with significant difference		ACEFGHIMO	ABCEFGHIKMO	ABCEFGHIKMO	ACEFGHI	ABCEFGHIKMO	ABCEFGHI	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO
Chabo	mean	3.82	9.13	42.19	8.60	8.69	18.04	33.47	47.14	6.73	7.43	3.53	9.84	14.35	50.72	5.46
	standard deviation	0.26	0.63	2.52	0.64	1.22	2.31	1.67	3.33	0.39	0.48	0.22	0.73	3.60	3.30	0.37
Ohshamo	mean	7.92	18.17	86.28	15.22	22.35	45.31	65.86	102.14	12.56	13.87	6.26	19.50	29.41	102.39	9.79
	standard deviation	1.00	1.88	6.66	2.18	3.09	7.27	5.08	10.20	1.45	1.78	0.71	2.01	3.59	9.93	1.10
Onagadori	mean	4.60	12.30	67.62	8.83	17.77	27.72	50.39	75.82	9.04	9.45	4.44	12.94	20.76	76.74	6.87
	standard deviation	0.29	0.89	3.70	1.50	1.53	7.47	2.88	3.04	0.73	0.70	0.35	1.23	1.60	3.52	0.51
Shokoku	mean	5.09	12.76	68.31	10.86	17.69	27.00	51.83	76.29	9.51	9.55	4.49	12.43	20.84	78.82	6.82
	standard deviation	0.53	1.24	5.76	1.69	1.85	4.44	4.61	6.33	0.86	1.03	0.53	1.39	1.88	6.30	0.77
Tosajidori	mean	3.66	9.51	48.10	9.32	10.39	20.34	38.14	52.52	6.95	7.17	3.58	9.91	15.36	54.96	5.41
	standard deviation	0.37	0.49	1.67	0.65	0.63	3.35	0.64	2.71	0.33	0.37	0.30	0.82	0.70	2.39	0.29
Totenko	mean	5.20	12.44	66.86	11.50	16.19	27.45	51.69	74.50	9.18	10.21	4.73	13.08	20.75	76.19	7.13
	standard deviation	0.55	1.21	7.41	2.22	1.15	3.23	6.30	9.73	0.90	1.19	0.63	1.46	2.02	8.57	0.59

Each alphabet indicates comparing pair with significant difference; See the caption of Table 2-3-2.

Table 2-3-2. Mean values and standard deviations for skeleton measurements of forelimb, pectoral girdle and sternum in various breeds.

breed	measurements	Bdh	GLr	Bpr	SBr	Bdr	Bpc	Hcau	Wcau	Hcar	Wcar	Lm	GLcm	Didc	GM
comparing pair with significant difference		ABCEF GHIKM	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIM	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O	ABCEF GHIKM O
Chabo	mean	12.37	42.07	4.19	2.56	5.42	10.11	5.62	6.51	4.31	6.30	24.45	26.74	5.90	36.12
	standard deviation	0.86	2.85	0.30	0.22	0.44	0.64	0.44	0.41	0.25	0.39	1.63	1.65	0.39	2.11
Ohshamo	mean	23.46	91.31	8.17	4.83	10.23	17.62	10.29	12.06	8.47	11.56	51.89	56.16	10.62	73.85
	standard deviation	2.57	9.36	1.06	0.61	1.38	1.63	0.91	1.27	1.02	1.35	5.37	5.61	1.35	6.55
Onagadori	mean	15.74	68.65	5.35	3.21	7.06	12.49	7.55	8.76	5.75	8.14	39.93	42.63	7.72	53.02
	standard deviation	1.41	2.61	0.68	0.29	0.78	1.17	0.70	0.78	0.65	0.86	1.75	2.03	0.40	3.15
Shokoku	mean	15.93	69.23	5.72	3.41	6.79	12.73	7.27	8.47	5.86	8.09	39.52	42.26	7.24	54.42
	standard deviation	1.55	5.75	0.77	0.27	0.78	1.08	0.76	0.89	0.58	0.72	3.32	3.45	0.71	4.32
Tosajidori	mean	11.87	47.23	3.97	2.76	5.39	10.41	5.57	6.46	4.52	6.35	28.01	30.17	5.68	39.31
	standard deviation	0.71	2.25	0.27	0.29	0.51	0.69	0.30	0.50	0.41	0.46	1.23	1.32	0.31	2.60
Totenko	mean	15.71	67.43	5.50	3.27	7.08	12.69	7.33	8.73	5.76	8.14	38.18	41.24	8.03	52.29
	standard deviation	1.33	8.85	0.56	0.23	0.69	1.01	0.69	0.91	0.67	0.80	5.02	5.26	0.71	5.96

Each alphabet indicates comparing pair with significant difference as follows; [A] Oh-Shamo - Chabo, [B] Onagadori - Chabo, [C] Shokoku - Chabo, [D] Tosajidori - Chabo, [E] Totenko - Chabo, [F] Onagadori - Oh-Shamo, [G] Shokoku - Oh-Shamo, [H] Tosajidori - Oh-Shamo, [I] Totenko - Oh-Shamo, [J] Shokoku - Onagadori, [K] Tosajidori - Onagadori, [L] Totenko - Onagadori, [M] Tosajidori - Shokoku, [N] Totenko - Shokoku and [O] Totenko - Tosajidrori.

Table 2-4-1. Mean values and standard deviations for skeleton measurement ratios of forelimb, pectoral girdle and sternum in various breeds.

breed	measurements	GLst	Lms	Lc	Hs	Lap	Lar	GLco	Lpr	SBf	GBc	Bfc	SBc	Lmc	GLsc	GBs
comparing pair with significant difference		afg	afj	-	cgm	bcefgim	bcefgi	be	-	fgi	cfghi	befgi	-	bce	fgi	bfgij
Chabo	mean	2.24	2.23	1.85	0.74	1.02	0.67	1.06	0.36	0.60	0.30	0.24	0.10	0.98	1.39	0.16
	standard deviation	0.08	0.07	0.11	0.03	0.04	0.05	0.04	0.03	0.03	0.01	0.01	0.01	0.04	0.06	0.01
Ohshamo	mean	2.10	2.15	1.85	0.74	1.01	0.67	1.08	0.38	0.63	0.31	0.25	0.09	1.01	1.34	0.16
	standard deviation	0.06	0.05	0.08	0.04	0.05	0.06	0.04	0.05	0.04	0.02	0.02	0.01	0.04	0.05	0.02
Onagadori	mean	2.24	2.25	1.82	0.77	1.11	0.77	1.12	0.37	0.58	0.28	0.21	0.08	1.07	1.44	0.12
	standard deviation	0.04	0.04	0.05	0.03	0.04	0.06	0.03	0.01	0.02	0.01	0.01	0.01	0.03	0.07	0.01
Shokoku	mean	2.19	2.16	1.81	0.81	1.13	0.78	1.10	0.38	0.57	0.28	0.23	0.09	1.06	1.43	0.15
	standard deviation	0.04	0.04	0.04	0.02	0.06	0.06	0.05	0.02	0.02	0.02	0.01	0.01	0.04	0.05	0.01
Tosajidori	mean	2.18	2.17	1.83	0.76	1.05	0.74	1.08	0.36	0.61	0.28	0.23	0.09	1.03	1.42	0.14
	standard deviation	0.08	0.05	0.06	0.03	0.07	0.06	0.04	0.02	0.02	0.02	0.01	0.01	0.04	0.06	0.01
Totenko	mean	2.19	2.18	1.79	0.79	1.12	0.81	1.12	0.34	0.58	0.28	0.22	0.09	1.06	1.46	0.14
	standard deviation	0.07	0.06	0.08	0.02	0.04	0.01	0.05	0.02	0.02	0.01	0.01	0.01	0.05	0.05	0.01
breed	measurements	SBs	Dic	GLcl	Ba	Lsa	Bc	Lcc	GLu	Bpu	Didu	SBu	Dip	Bph	GLh	SBh
comparing pair with significant difference		bcfg	bcfg	bcefgi	bcfkl	abcekmo	g	i	bce	ab	abcdgln	abc	bcg	-	-	abcemn
Chabo	mean	0.11	0.25	1.17	0.24	0.24	0.50	0.93	1.31	0.19	0.21	0.10	0.27	0.40	1.40	0.15
	standard deviation	0.01	0.01	0.03	0.02	0.03	0.08	0.04	0.05	0.01	0.01	0.00	0.02	0.10	0.05	0.01
Ohshamo	mean	0.11	0.25	1.17	0.21	0.30	0.62	0.89	1.38	0.17	0.19	0.08	0.26	0.40	1.39	0.13
	standard deviation	0.01	0.01	0.07	0.02	0.03	0.10	0.06	0.07	0.01	0.01	0.01	0.01	0.02	0.05	0.01
Onagadori	mean	0.09	0.23	1.28	0.17	0.34	0.52	0.95	1.43	0.17	0.18	0.08	0.24	0.39	1.45	0.13
	standard deviation	0.00	0.01	0.06	0.03	0.03	0.14	0.05	0.06	0.01	0.01	0.00	0.01	0.01	0.04	0.01
Shokoku	mean	0.09	0.23	1.26	0.20	0.33	0.50	0.95	1.40	0.17	0.18	0.08	0.23	0.38	1.45	0.13
	standard deviation	0.01	0.01	0.07	0.03	0.03	0.08	0.05	0.05	0.01	0.01	0.01	0.02	0.01	0.05	0.01
Tosajidori	mean	0.09	0.24	1.23	0.24	0.26	0.52	0.97	1.34	0.18	0.18	0.09	0.25	0.39	1.40	0.14
	standard deviation	0.00	0.01	0.05	0.03	0.01	0.06	0.05	0.04	0.01	0.01	0.01	0.00	0.02	0.04	0.01
Totenko	mean	0.10	0.24	1.28	0.22	0.31	0.53	0.99	1.42	0.18	0.20	0.09	0.25	0.40	1.46	0.14
	standard deviation	0.00	0.01	0.06	0.03	0.02	0.03	0.05	0.09	0.01	0.01	0.01	0.02	0.01	0.06	0.01

Each alphabet indicates comparing pair with significant difference; See the caption of Table 2-4-2.

Table 2-4-2. Mean values and standard deviations for skeleton measurement ratios of forelimb, pectoral girdle and sternum in various breeds.

breed	measurements	Bdh	GLr	Bpr	SBr	Bdr	Bpc	Hcau	Wcau	Hcar	Wcar	Lm	GLcm	Didc
comparing pair with significant difference		abcdefg	bce	b	bcek	bcg	abcehkmo	abce	abcde	bc	abcem	bcef	b	abcdn
Chabo	mean	0.34	1.17	0.12	0.07	0.15	0.28	0.16	0.18	0.12	0.17	0.68	0.74	0.16
	standard deviation	0.02	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01
Ohshamo	mean	0.32	1.24	0.11	0.07	0.14	0.24	0.14	0.16	0.11	0.16	0.70	0.76	0.14
	standard deviation	0.02	0.08	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01
Onagadori	mean	0.30	1.30	0.10	0.06	0.13	0.24	0.14	0.16	0.11	0.15	0.75	0.80	0.15
	standard deviation	0.01	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01
Shokoku	mean	0.29	1.27	0.10	0.06	0.12	0.23	0.13	0.16	0.11	0.15	0.73	0.78	0.13
	standard deviation	0.01	0.05	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.03	0.03	0.01
Tosajidori	mean	0.30	1.20	0.10	0.07	0.14	0.26	0.14	0.16	0.11	0.16	0.71	0.77	0.14
	standard deviation	0.01	0.04	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.01
Totenko	mean	0.30	1.29	0.11	0.06	0.14	0.24	0.14	0.17	0.11	0.16	0.73	0.79	0.15
	standard deviation	0.02	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.04	0.04	0.01

Each alphabet indicates comparing pair with significant difference as follows; [a] Oh-Shamo - Chabo, [b] Onagadori - Chabo, [c] Shokoku - Chabo, [d] Tosajidori - Chabo, [e] Totenko - Chabo, [f] Onagadori - Oh-Shamo, [g] Shokoku - Oh-Shamo, [h] Tosajidori - Oh-Shamo, [i] Totenko - Oh-Shamo, [j] Shokoku - Onagadori, [k] Tosajidori - Onagadori, [l] Totenko - Onagadori, [m] Tosajidori - Shokoku, [n] Totenko - Shokoku and [o] Totenko - Tosajidori. - signified that every pair shows no significant difference.

Table 3-1. Specimens used in the Chapter 4.

breed	sex	specimen No.	growth stage	donor	depository	breed	sex	specimen No.	growth stage	donor	depository
Chabo	female	UMUT-15166	adult[1]	HU	UMUT	Onagadori	female	UMUT-14016	adult[1]	HU	UMUT
Chabo	female	UMUT-15167	adult[1]	HU	UMUT	Onagadori	female	UMUT-14015	adult[1]	HU	UMUT
Chabo	male	UMUT-15168	adult[1]	HU	UMUT	Shokoku	female	UMUT-15161	adult[1]	HU	UMUT
Chabo	male	UMUT-15169	adult[2]	TUA	UMUT	Shokoku	female	UMUT-15178	adult[2]	TUA	UMUT
Chabo	male	UMUT-14037	adult[2]	TUA	UMUT	Shokoku	male	UMUT-15162	adult[2]	TUA	UMUT
Chabo	female	UMUT-14036	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-1212	adult[2]	-	NUM
Chabo	female	UMUT-15170	adult[2]	TUA	UMUT	Shokoku	Male	NUM-ab1-220	adult[2]	-	NUM
Chabo	male	UMUT-14042	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-221	adult[2]	-	NUM
Chabo	male	UMUT-14041	adult[2]	TUA	UMUT	Shokoku	female	NUM-ab1-223	adult[2]	-	NUM
Chabo	female	UMUT-14035	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-226	adult[2]	-	NUM
Ohshamo	male	UMUT-15171	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-227	adult[2]	-	NUM
Ohshamo	male	UMUT-15172	adult[2]	HU	UMUT	Shokoku	male	NUM-ab1-234	adult[2]	-	NUM
Ohshamo	male	UMUT-15150	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-236	adult[2]	-	NUM
Ohshamo	male	UMUT-15151	adult[1]	HU	UMUT	Shokoku	male	NUM-ab1-237	adult[2]	-	NUM
Ohshamo	male	UMUT-15153	adult[1]	HU	UMUT	Shokoku	female	NUM-ab1-238	adult[2]	-	NUM
Ohshamo	female	UMUT-14018	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-57	adult[2]	-	NUM
Ohshamo	female	UMUT-14019	adult[2]	TUA	UMUT	Shokoku	male	NUM-ab1-224	adult[2]	-	NUM
Ohshamo	male	UMUT-15154	adult[2]	TUA	UMUT	Tosajidori	female	UMUT-14026	adult[1]	HU	UMUT
Ohshamo	-	UMUT-14023	adult[2]	TUA	UMUT	Tosajidori	female	UMUT-15163	adult[1]	HU	UMUT
Ohshamo	female	UMUT-14020	adult[2]	TUA	UMUT	Tosajidori	-	UMUT-15164	adult[2]	HU	UMUT
Ohshamo	male	UMUT-15174	adult[2]	TUA	UMUT	Tosajidori	female	NUM-ab1-1336	adult[2]	HU	NUM
Onagadori	male	UMUT-15175	adult[1]	HU	UMUT	Totenko	male	UMUT-14034	adult[2]	HU	UMUT
Onagadori	male	UMUT-15155	adult[1]	HU	UMUT	Totenko	male	UMUT-15165	adult[2]	TUA	UMUT
Onagadori	male	UMUT-15157	adult[1]	HU	UMUT	Totenko	male	UMUT-14031	adult[2]	TUA	UMUT
Onagadori	female	UMUT-15176	adult[1]	HU	UMUT	Totenko	female	UMUT-14030	adult[2]	TUA	UMUT
Onagadori	female	UMUT-15177	adult[2]	HU	UMUT	Totenko	male	UMUT-14033	adult[2]	TUA	UMUT
Onagadori	female	UMUT-15159	adult[1]	HU	UMUT	Totenko	female	UMUT-14029	adult[2]	TUA	UMUT
Onagadori	female	UMUT-15160	adult[1]	HU	UMUT						

UMUT indicates The University Museum, The University of Tokyo. NUM indicates Nagoya University Museum, Nagoya University. HU indicates Hiroshima University. TUA indicates Tokyo University of Agriculture. adult[1] indicates over one years old. adult[2] indicates completed ossification of hindlimb bones.

Table 3-2. The measurements used in the Chapter 4.

Abbreviation of measurements	Details	Abbreviation of measurements	Details
Dia	Diameter of one acetabulum; greatest distance including the labium acetabuli [a,b]	GLti	Greatest length of the tibiotarsus [a,b]
Hsp	Heighth between the spina iliolateralis and the processus terminalis ischii [c]	Lccl	Length of the crista cnemialis lateralis [c]
GDfi	Greatest diameter of the foramen ilioischiadicum [c]	Dip	Diagonal of the proximal end; from the condylus medialis femoralis to the crista lateralis [a,b]
SDfi	Smallest diameter of the foramen ilioschiadicum [c]	SBti	Smallest breadth of the tibiotarsus [a,b]
Hp	Heighth of the pelvis; from the processus dorsalis of the most cranial vertebrae to the processus ventralis of the most cranial vertabrae [c]	Bdti	Breadth of the distal end of the tibiotarsus [a,b]
GBpg	Greatest breadth across the partes glutaeae of the ilia [a,b]	Ddti	Depth of the distal end of the tibiotarsus [a,b]
SBpg	Smallest breadth of the partes glutaeae [a,b]	Lcf	Length of the crista febularis [c]
Btp	Breadth between the tuberculum preacetabulare [c]	Lf	Length of the fibula [c]
Bac	Breadth between the borders of the acetabula, measured at the narrowest part [a,b]	Bfaf	Breadth of the facies articularis femoralis [c]
Ba	Breadth in the middle; breadth across the two antitrochanter [a,b]	GLta	Greatest length of the tarsometatarsus [a,b]
Bcid	Breadth between the caudal crista iriaca dorsolateralis [c]	Bpta	Breadth of the proximal end of the tarsometatarsus [a,b]
Bsi	Breadth between the spina iliolateralis [c]	SBta	Smallest breadth of the tarsometatarsus [a,b]
Bpti	Breadth between the processus terminalis ischii [c]	Bdta	Breadth of the distal end of the tarsometatarsus [a,b]
Lrs	Length of the regio symsacrothoracolumbalis [c]	Bpfe	Breadth of the proximal end; caput femoris - most lateral point of the trochanter major [a,b]
Lv	Length along the vertebrae, centrally = length of the os lumbosacrale, from the most cranial (thoracic) vertebra fused with the os lumbosacrale to the most caudal (coccygeal) vertebra fused with the os lumbosacrale [a,b]	Dpfe	Depth of the proximal end of the femur [a,b]
Lcs	Length between the caudal crista iriaca dorsolateralis and the spina iliolateralis [c]	GLfe	Greatest length of the femur [a,b]
Ltpp	Length between the tuberculum preacetabulare and the processus dorsalis of the most cranial vertebrae [c]	Lmfe	Medial length of the femur [a,b]
Lrr	Length between the regio synsacrolumbalis and the regio synsacrocaudalis [c]	SBfe	Smallest breadth of the femur [a,b]
GLp	Greatest length of the pelvis (without pubis); cranial border of the ilia (= margo iliocranialis) - most caudal points of the ischia [a,b]	Ddfe	Depth of the distal end of the femur [a,b]
Ltp	Length between the tuberculum preacetabulare and the processus terminalis ischii [c]	Bdfe	Breadth of the distal end of the femur [a,b]

[a] Driesch (1976). [b] Samejima (1990). [d] Yasuda (2002).

Table 3-3-1. Mean values and standard deviations for skeleton of hindlimb, pelvic girdle and pelvis measurements in various breeds.

breed	measurements	Dia	Hsp	GDfi	SDfi	Hp	GBpg	SBpg	Btp	Bac	Ba	Bcid	Bsi	Bpti	Lrs
comparing pair with significant difference		ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIJMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCFGHIKM	ABEFGHIK	ABCEFGHIMO
Chabo	mean	5.57	22.60	9.73	6.80	15.32	24.98	21.39	34.05	28.63	40.26	34.81	17.98	32.85	13.61
	standard deviation	0.53	2.29	0.84	0.74	1.11	1.51	1.40	2.94	2.24	2.02	1.08	1.67	2.99	2.34
Ohshamo	mean	11.88	47.35	19.47	13.32	32.34	50.82	39.89	61.55	53.05	76.65	71.80	32.75	51.52	30.94
	standard deviation	1.27	5.10	1.85	1.70	3.60	4.28	3.21	4.22	5.61	7.20	6.62	3.81	5.38	3.16
Onagadori	mean	7.24	32.13	15.04	9.43	19.15	30.74	27.28	47.07	39.48	53.35	43.97	23.59	41.43	19.45
	standard deviation	0.80	2.99	1.06	1.77	1.64	2.20	2.10	3.91	3.45	4.59	3.94	2.32	2.28	2.56
Shokoku	mean	8.15	36.20	15.15	9.68	21.20	36.05	28.83	45.77	37.78	53.90	46.22	22.76	36.88	22.29
	standard deviation	0.98	4.62	1.29	0.88	2.72	2.72	1.95	3.58	2.69	4.17	3.76	2.78	4.44	3.11
Tosajidori	mean	5.46	21.53	11.68	6.79	13.64	26.39	22.70	35.84	30.18	41.13	35.61	16.51	34.25	14.90
	standard deviation	0.25	1.41	0.84	0.47	0.44	1.03	1.34	0.90	0.93	0.70	1.41	0.92	1.90	1.90
Totenko	mean	7.66	32.24	15.08	9.24	20.78	33.53	27.54	45.40	37.87	52.18	45.83	21.33	40.28	23.13
	standard deviation	1.21	3.72	2.09	1.14	2.93	3.08	2.11	5.80	4.21	4.80	5.56	4.87	3.74	4.91

breed	measurements	Lv	Lcs	GLp	Ltpp	Lrr	Ltp	GLti	Lccl	Dip	SBti	Bdti	Ddti	Lcf	Lf
comparing pair with significant difference		ABCEFGHIKMO	ACEFGHIJMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIK	ABCEFGHIKMO	ABCFGHI	ABCEFGHIKM	ACEFGHIMO	ABCEFGHIKMO	ABCEFGHIKMO
Chabo	mean	52.54	13.86	69.83	30.34	39.15	42.66	71.63	12.74	14.40	5.68	9.17	10.24	11.99	44.82
	standard deviation	5.53	1.34	5.37	2.09	3.94	4.02	8.19	0.99	1.40	0.50	0.63	0.92	2.37	4.46
Ohshamo	mean	105.12	30.50	137.29	55.37	78.24	90.39	167.24	28.24	31.09	11.11	18.85	20.13	28.80	118.19
	standard deviation	14.90	3.02	9.43	4.02	6.95	8.03	15.14	2.93	3.90	1.55	2.24	2.96	3.49	12.08
Onagadori	mean	73.99	15.67	94.89	42.46	55.24	58.12	119.42	20.74	18.52	7.03	12.47	12.48	20.94	78.17
	standard deviation	7.01	1.76	7.17	3.12	5.77	3.84	8.06	5.55	2.19	1.21	1.28	1.06	2.76	5.59
Shokoku	mean	80.13	18.46	102.98	44.51	58.38	63.94	121.85	19.40	19.37	6.94	12.61	12.90	21.31	79.18
	standard deviation	7.06	2.23	7.60	3.57	4.42	6.14	9.84	1.70	1.74	0.72	1.15	1.37	1.73	8.20
Tosajidori	mean	52.28	13.11	72.06	31.29	37.68	44.58	78.91	14.68	13.94	5.61	9.28	9.61	13.11	51.04
	standard deviation	1.42	1.18	3.11	0.89	1.13	2.32	1.95	0.81	0.85	0.33	0.24	0.48	1.07	1.29
Totenko	mean	78.28	18.62	99.52	43.38	55.86	60.26	120.84	19.34	18.70	6.84	11.91	12.88	20.18	74.82
	standard deviation	12.77	2.40	13.28	5.90	8.00	7.75	16.79	3.69	2.40	0.69	1.51	1.43	3.73	12.90

Each alphabet indicates comparing pair with significant difference; See the caption of Table 3-3-2.

Table 3-3-2. Mean values and standard deviations for skeleton of hindlimb, pelvic girdle and pelvis measurements in various breeds.

breed	measurements	Bfaf	GLta	Bpta	SBta	Bdta	Bpfe	Dpfe	GLfe	Lmfe	SBfe	Ddfe	Bdfe	GM
comparing pair with significant difference		ACFGHIM	ABCEFGHIKMO	ABCFGHIM	AFGHI	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCEFGHIKMO	ABCFGHIM	ACEFGHIM	ABCEFGHIKMO	ABCEFGHIKMO
Chabo	mean	7.61	45.65	10.98	5.79	10.11	11.17	10.31	54.00	49.46	5.90	11.20	12.29	31.84
	standard deviation	0.63	5.64	0.63	0.59	0.82	0.73	1.01	5.16	4.82	0.46	0.74	1.04	1.89
Ohshamo	mean	14.15	117.31	23.01	11.94	20.54	23.06	21.43	117.19	108.56	11.58	22.71	24.78	63.80
	standard deviation	2.00	10.84	2.99	1.81	2.41	2.57	2.19	9.64	8.65	1.42	3.18	3.58	7.02
Onagadori	mean	8.95	80.91	13.71	7.03	13.34	13.79	13.47	82.87	77.29	7.23	13.40	16.07	42.26
	standard deviation	0.97	7.87	1.47	1.88	1.32	1.30	1.68	5.31	4.69	0.67	1.18	1.80	3.46
Shokoku	mean	9.60	83.23	14.35	7.18	13.16	15.33	14.23	85.21	79.48	7.38	15.01	16.92	45.04
	standard deviation	1.02	7.68	2.10	0.94	1.67	1.58	1.27	6.57	6.00	0.67	1.63	1.72	4.19
Tosajidori	mean	7.20	51.99	10.64	5.24	10.13	10.53	10.23	57.34	53.38	5.86	11.14	11.78	30.83
	standard deviation	0.52	2.21	0.21	0.11	0.10	0.55	0.76	0.76	0.35	0.40	0.59	0.56	0.48
Totenko	mean	9.45	82.99	13.90	7.18	13.54	14.23	14.17	82.57	77.78	7.14	14.38	16.20	43.92
	standard deviation	1.15	12.89	1.58	1.19	1.61	1.64	1.66	9.61	9.38	0.66	1.97	1.88	5.78

Each alphabet indicates comparing pair with significant difference as follows; [A]Oh-Shamo - Chabo, [B]Onagadori - Chabo, [C] Shokoku - Chabo, [D]Tosajidori - Chabo, [E]Totenko - Chabo, [F]Onagadori - Oh-Shamo, [G] Shokoku - Oh-Shamo, [H] Tosajidori - Oh-Shamo, [I] Totenko - Oh-Shamo, [J] Shokoku - Onagadori, [K] Tosajidori - Onagadori, [L] Totenko - Onagadori, [M] Tosajidori - Shokoku, [N]Totenko - Shokoku and [O] Totenko - Tosajidrori.

Table 3-4-1. Mean values and standard deviations for skeleton of hindlimb, pelvic girdle and pelvis measurement ratios in various breeds.

breed	measurements	Dia	Hsp	GDfi	SDfi	Hp	GBpg	SBpg	Btp	Bac	Ba	Bcid	Bsi	Bpti
comparing pair with significant difference		f	cgmn	bcdefghim	-	abdfghi	fjk	hkmo	afhjm	fhjmo	hmo	cfgikmo	-	acfhjm
Chabo	mean	0.17	0.71	0.31	0.21	0.48	0.79	0.67	1.07	0.90	1.27	1.10	0.57	1.04
	standard deviation	0.01	0.05	0.01	0.01	0.02	0.05	0.04	0.07	0.06	0.07	0.07	0.07	0.12
Ohshamo	mean	0.19	0.74	0.31	0.21	0.51	0.80	0.63	0.97	0.83	1.21	1.13	0.52	0.82
	standard deviation	0.01	0.04	0.03	0.03	0.02	0.05	0.04	0.09	0.06	0.06	0.05	0.08	0.14
Onagadori	mean	0.17	0.76	0.36	0.22	0.45	0.73	0.65	1.12	0.94	1.26	1.04	0.56	0.99
	standard deviation	0.01	0.03	0.02	0.05	0.01	0.02	0.05	0.08	0.06	0.06	0.04	0.05	0.09
Shokoku	mean	0.18	0.80	0.34	0.22	0.47	0.80	0.64	1.02	0.84	1.20	1.03	0.51	0.83
	standard deviation	0.01	0.04	0.02	0.02	0.02	0.07	0.05	0.06	0.06	0.05	0.04	0.07	0.14
Tosajidori	mean	0.18	0.70	0.38	0.22	0.44	0.86	0.74	1.16	0.98	1.33	1.16	0.54	1.11
	standard deviation	0.01	0.04	0.02	0.01	0.01	0.03	0.06	0.05	0.05	0.04	0.05	0.04	0.06
Totenko	mean	0.17	0.74	0.34	0.21	0.47	0.77	0.63	1.03	0.86	1.19	1.04	0.48	0.92
	standard deviation	0.01	0.03	0.03	0.01	0.01	0.05	0.05	0.04	0.03	0.06	0.04	0.09	0.08

breed	measurements	Lrs	Lv	Lcs	GLp	Ltpp	Lrr	Ltp	GLti	Lccl	Dip	SBti	Bdti	Ddti
comparing pair with significant difference		ce	cegi	abfgil	gh	afghi	-	acd	abcdefk	b	afgi	cgm	gilo	bceg
Chabo	mean	0.43	1.65	0.44	2.19	0.95	1.23	1.34	2.24	0.40	0.45	0.18	0.29	0.32
	standard deviation	0.05	0.09	0.04	0.06	0.03	0.08	0.06	0.14	0.02	0.03	0.01	0.01	0.02
Ohshamo	mean	0.49	1.64	0.48	2.16	0.87	1.23	1.42	2.63	0.45	0.49	0.17	0.30	0.31
	standard deviation	0.06	0.12	0.03	0.13	0.07	0.08	0.07	0.10	0.04	0.03	0.01	0.02	0.02
Onagadori	mean	0.46	1.75	0.37	2.25	1.01	1.31	1.38	2.83	0.49	0.44	0.17	0.29	0.30
	standard deviation	0.05	0.06	0.03	0.10	0.03	0.07	0.05	0.11	0.11	0.02	0.03	0.01	0.01
Shokoku	mean	0.49	1.78	0.41	2.29	0.99	1.30	1.42	2.71	0.43	0.43	0.15	0.28	0.29
	standard deviation	0.04	0.06	0.02	0.07	0.03	0.06	0.06	0.10	0.02	0.02	0.01	0.01	0.02
Tosajidori	mean	0.48	1.70	0.43	2.34	1.01	1.22	1.45	2.56	0.48	0.45	0.18	0.30	0.31
	standard deviation	0.06	0.02	0.04	0.07	0.02	0.04	0.06	0.03	0.02	0.02	0.01	0.00	0.01
Totenko	mean	0.52	1.77	0.43	2.27	0.99	1.27	1.37	2.75	0.44	0.43	0.16	0.27	0.29
	standard deviation	0.05	0.08	0.05	0.04	0.02	0.05	0.04	0.12	0.05	0.01	0.02	0.00	0.01

Each alphabet indicates comparing pair with significant difference; See the caption of Table 3-4-2.

Table 3-4-2. Mean values and standard deviations for skeleton of hindlimb, pelvic girdle and pelvis measurement ratios in various breeds.

breed	measurements	Lcf	Lf	Bfaf	GLta	Bpta	SBta	Bdta	Bpfe	Dpfe	GLfe	Lmfe	SBfe	Ddfe	Bdfe
comparing pair with significant difference		abce	abcde	abce	abcdekmo	fgi	g	cgm	befgi	-	abcdef	abcdef	cegimo	bgk	-
Chabo	mean	0.37	1.41	0.24	1.43	0.35	0.18	0.32	0.35	0.32	1.69	1.55	0.19	0.35	0.39
	standard deviation	0.05	0.07	0.02	0.11	0.01	0.02	0.02	0.02	0.03	0.08	0.08	0.01	0.02	0.03
Ohshamo	mean	0.45	1.86	0.22	1.85	0.36	0.19	0.32	0.36	0.34	1.84	1.71	0.18	0.36	0.39
	standard deviation	0.04	0.17	0.02	0.12	0.03	0.02	0.01	0.01	0.01	0.08	0.08	0.01	0.02	0.04
Onagadori	mean	0.50	1.86	0.21	1.91	0.32	0.17	0.32	0.33	0.32	1.96	1.83	0.17	0.32	0.38
	standard deviation	0.07	0.16	0.01	0.07	0.02	0.04	0.02	0.01	0.03	0.06	0.06	0.01	0.02	0.02
Shokoku	mean	0.48	1.76	0.21	1.85	0.32	0.16	0.29	0.34	0.32	1.89	1.77	0.16	0.33	0.38
	standard deviation	0.05	0.12	0.01	0.08	0.04	0.01	0.03	0.01	0.02	0.05	0.05	0.01	0.02	0.01
Tosajidori	mean	0.43	1.66	0.23	1.69	0.35	0.17	0.33	0.34	0.33	1.86	1.73	0.19	0.36	0.38
	standard deviation	0.03	0.05	0.02	0.06	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01
Totenko	mean	0.46	1.70	0.22	1.88	0.32	0.16	0.31	0.33	0.32	1.88	1.77	0.16	0.33	0.37
	standard deviation	0.04	0.18	0.01	0.10	0.02	0.02	0.01	0.02	0.03	0.08	0.07	0.01	0.03	0.02

Each alphabet indicates comparing pair with significant difference as follows; [a] Oh-Shamo - Chabo, [b] Onagadori - Chabo, [c] Shokoku - Chabo, [d] Tosajidori - Chabo, [e] Totenko - Chabo, [f] Onagadori - Oh-Shamo, [g] Shokoku - Oh-Shamo, [h] Tosajidori - Oh-Shamo, [i] Totenko - Oh-Shamo, [j] Shokoku - Onagadori, [k] Tosajidori - Onagadori, [l] Totenko - Onagadori, [m] Tosajidori - Shokoku, [n] Totenko - Shokoku and [o] Totenko - Tosajidori. - signified that every pair shows no significant difference.

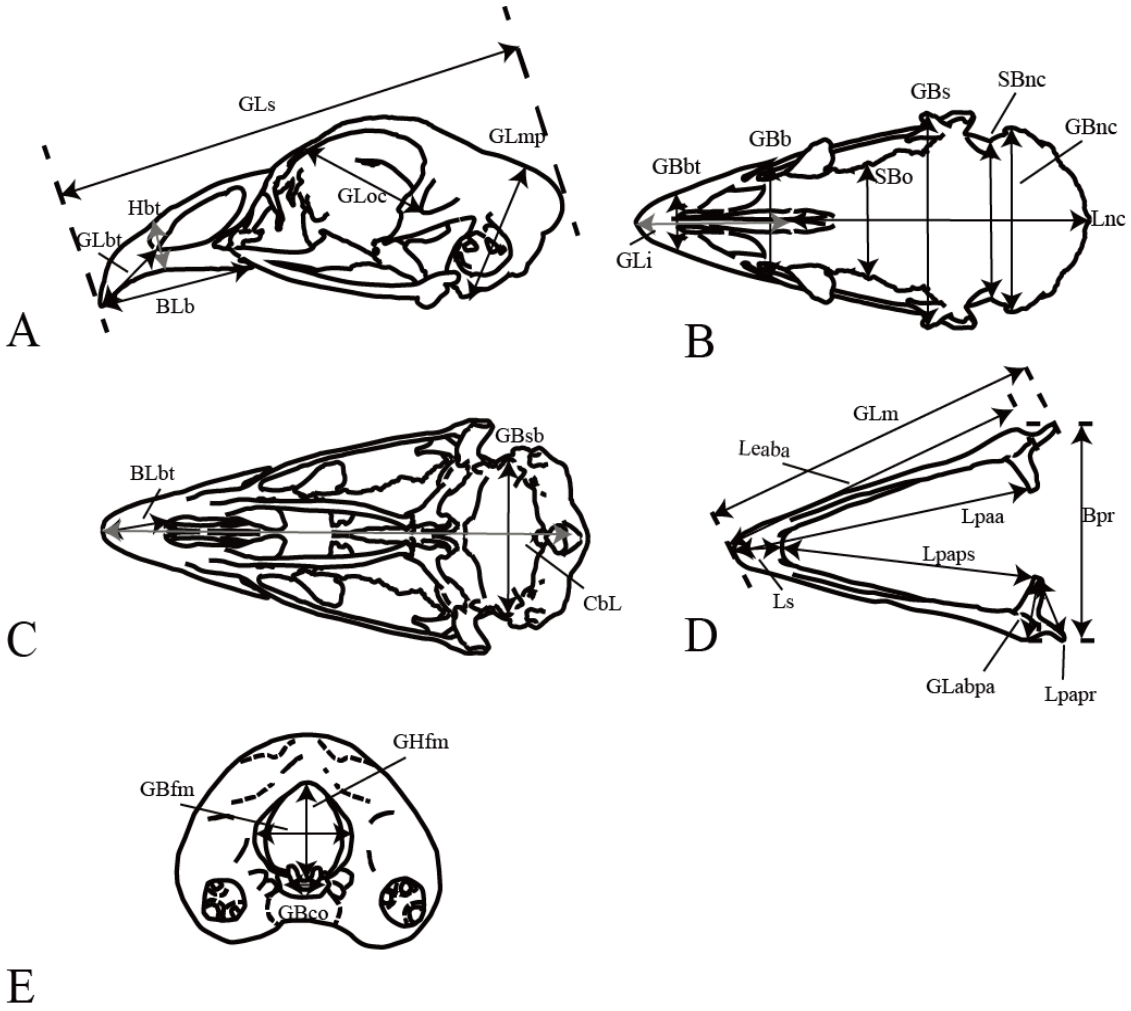

Fig. 1-1. The measurements in cranium and mandible. (A) Cranium of lateral view from left side. (B) Cranium from dorsal view. (C) Cranium from ventral view. (D) Mandible from dorsal view. (E) Cranium from caudal view. The abbreviated forms were remarked in Table 1-2.

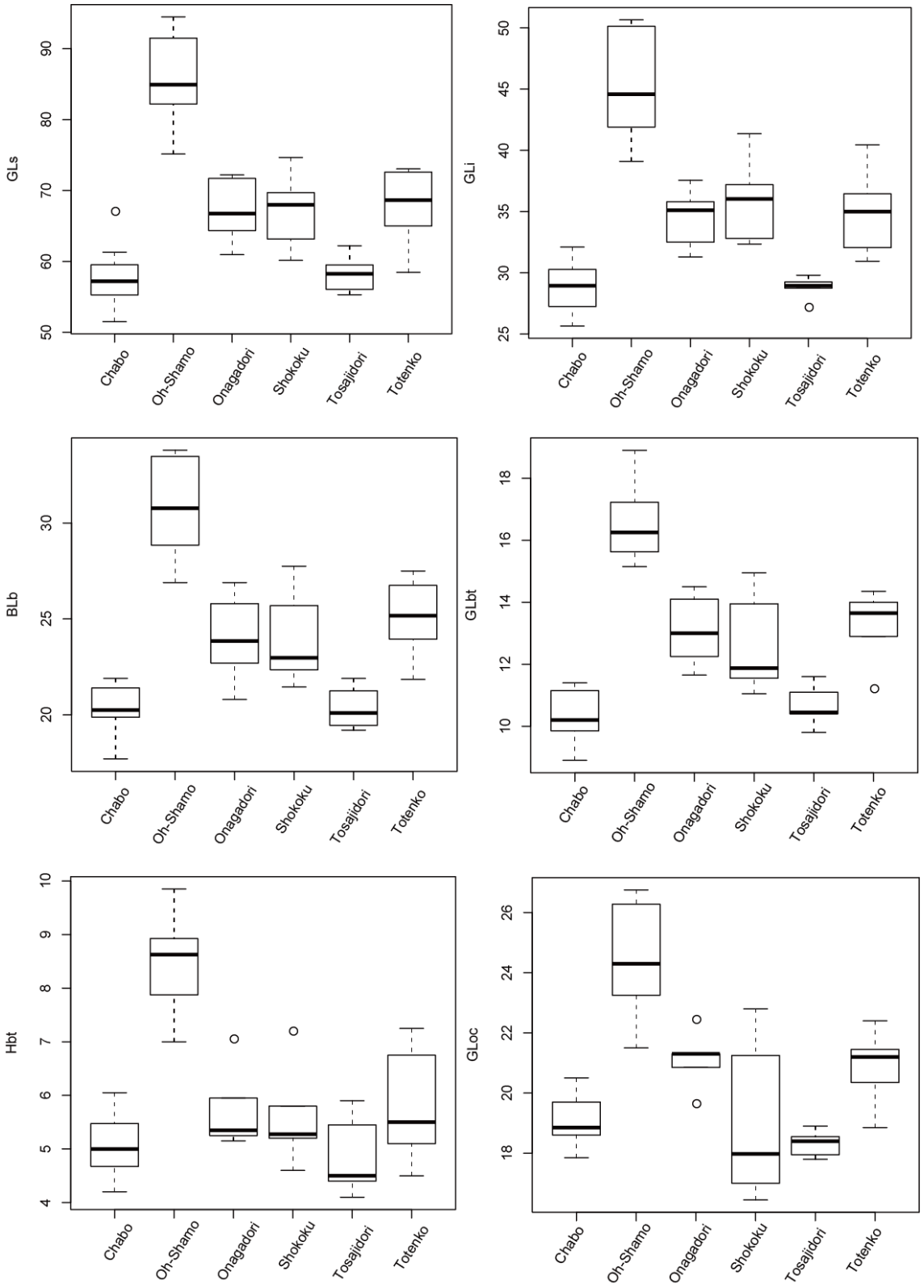

Fig. 1-1-1. The box plots in each measurement of skull. The abbreviated forms from GLs to GLco were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-3.

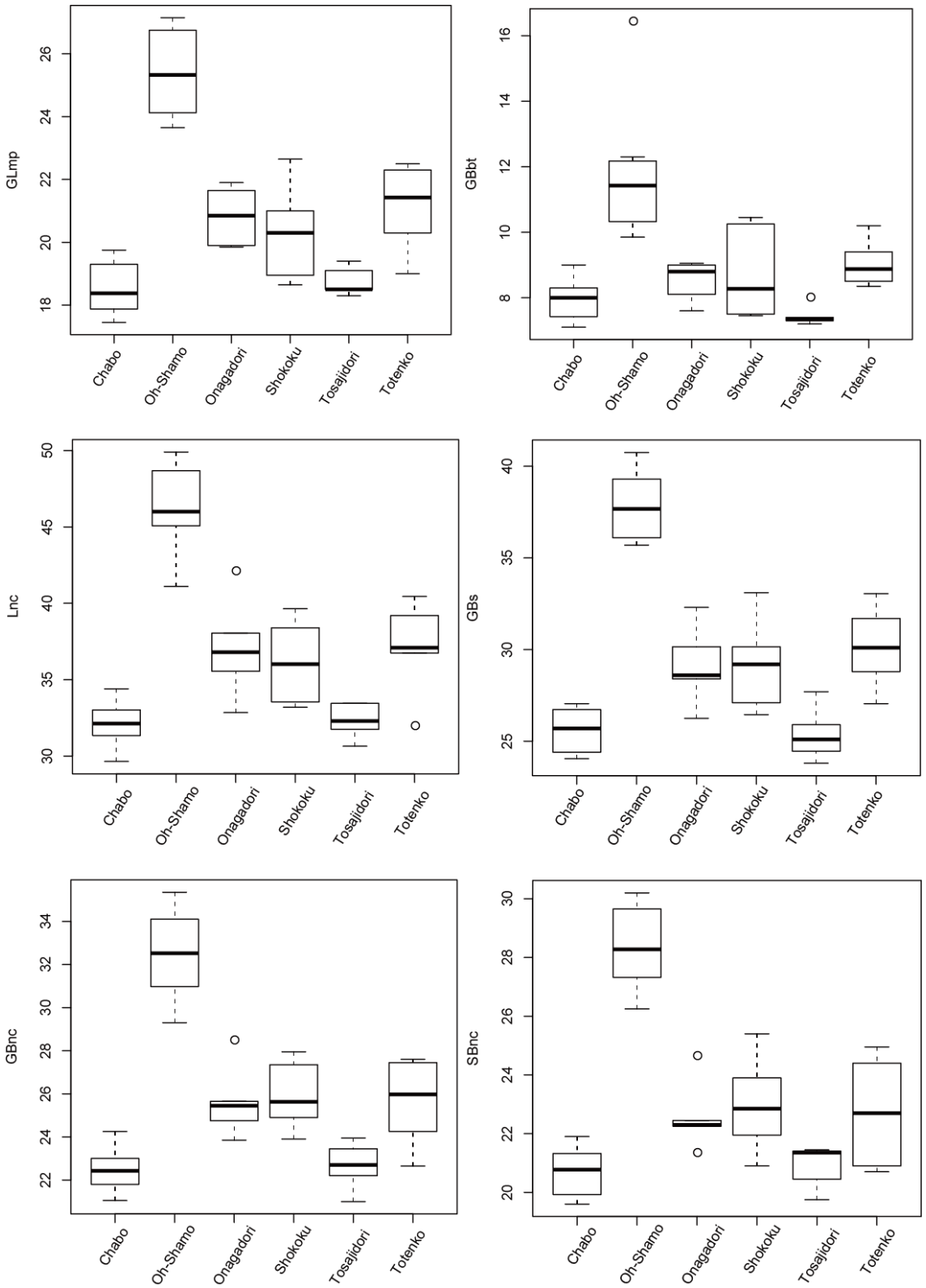

Fig. 1-1-2. The box plots in each measurement of skull. The abbreviated forms from GLmp to SBnc were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-3.

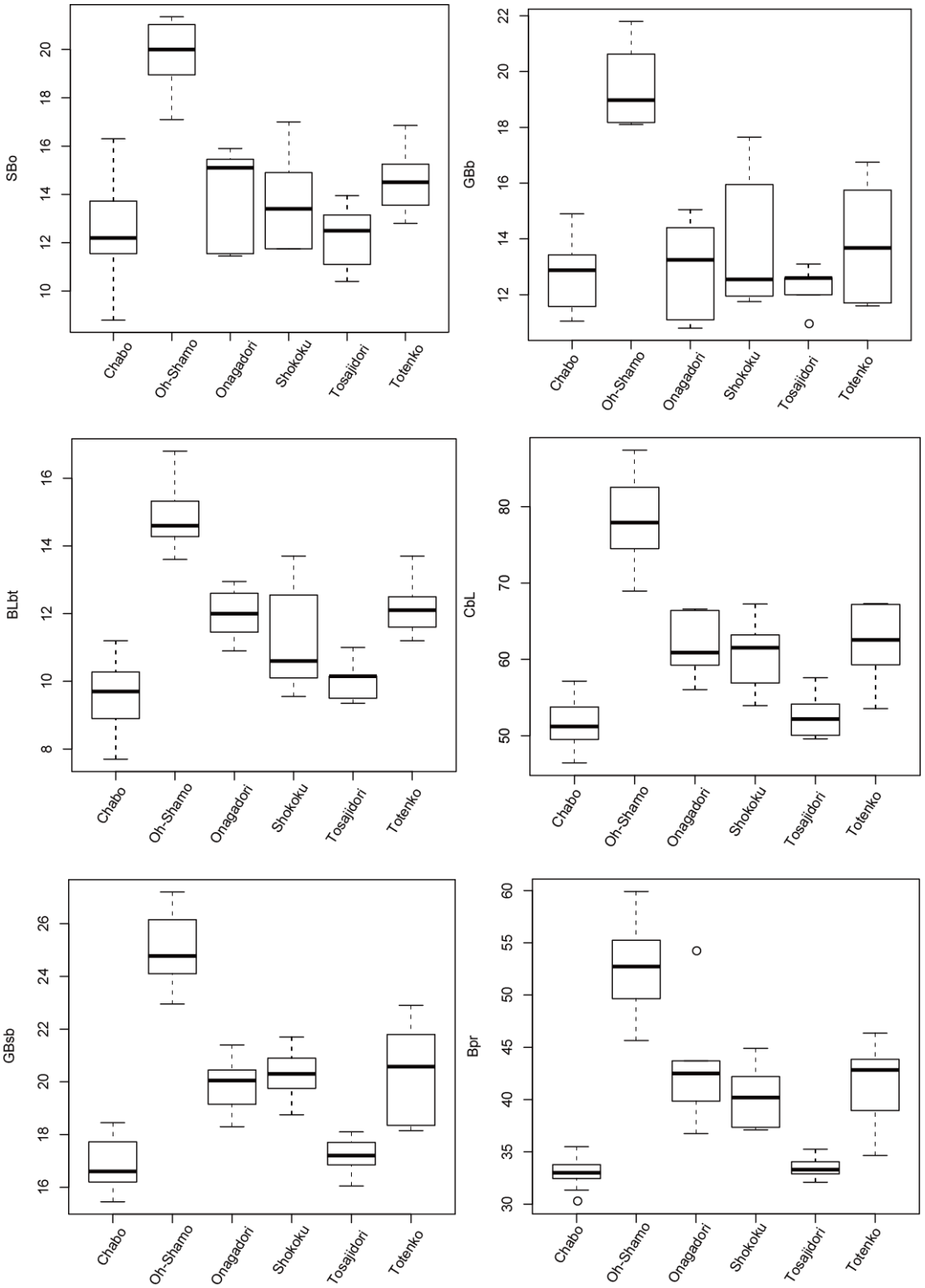

Fig. 1-1-3. The box plots in each measurement of skull. The abbreviated forms from SBo to Bpr were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-3.

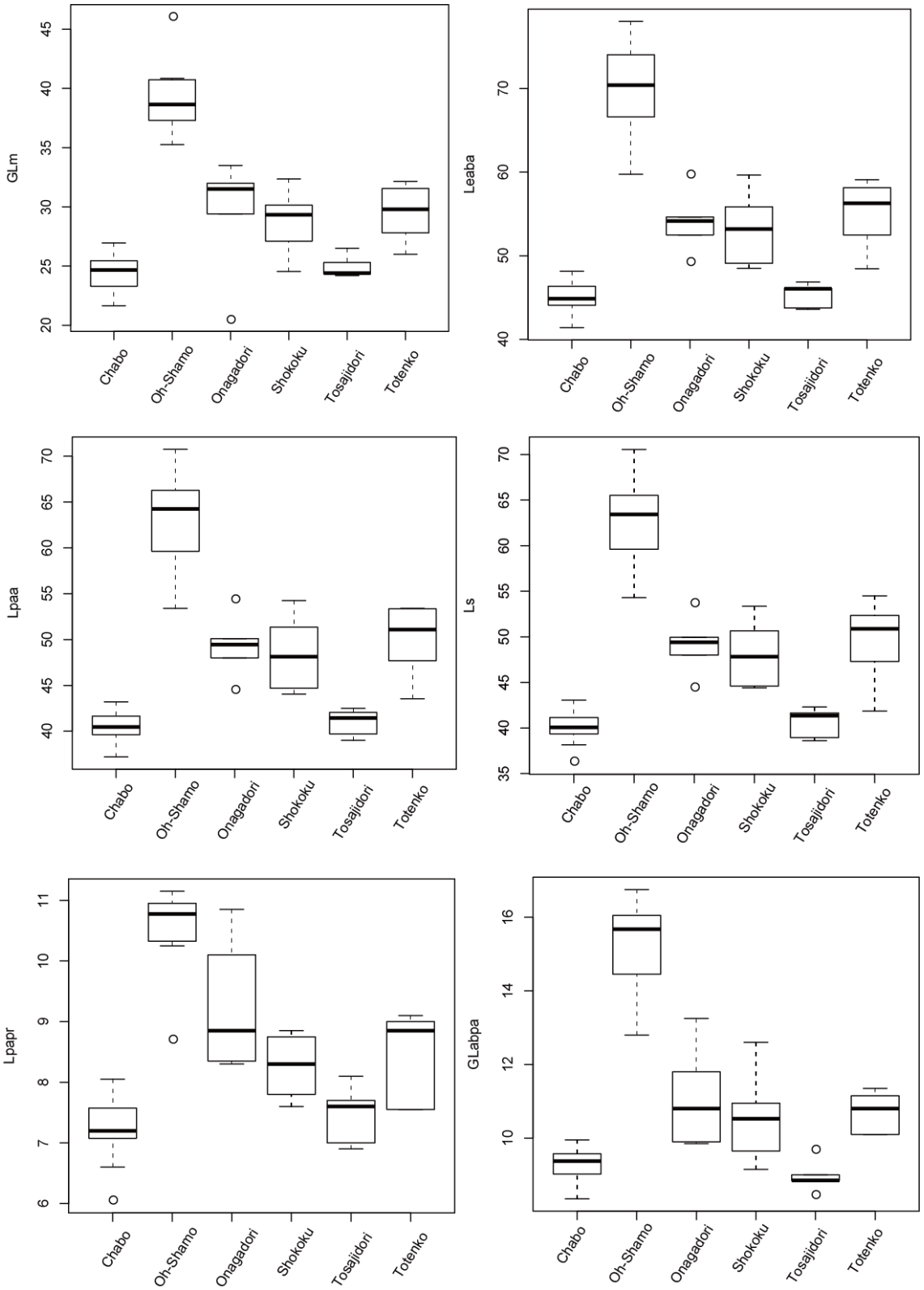

Fig. 1-1-4. The box plots in each measurement of skull. The abbreviated forms from GLm to GLabpa were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-3.

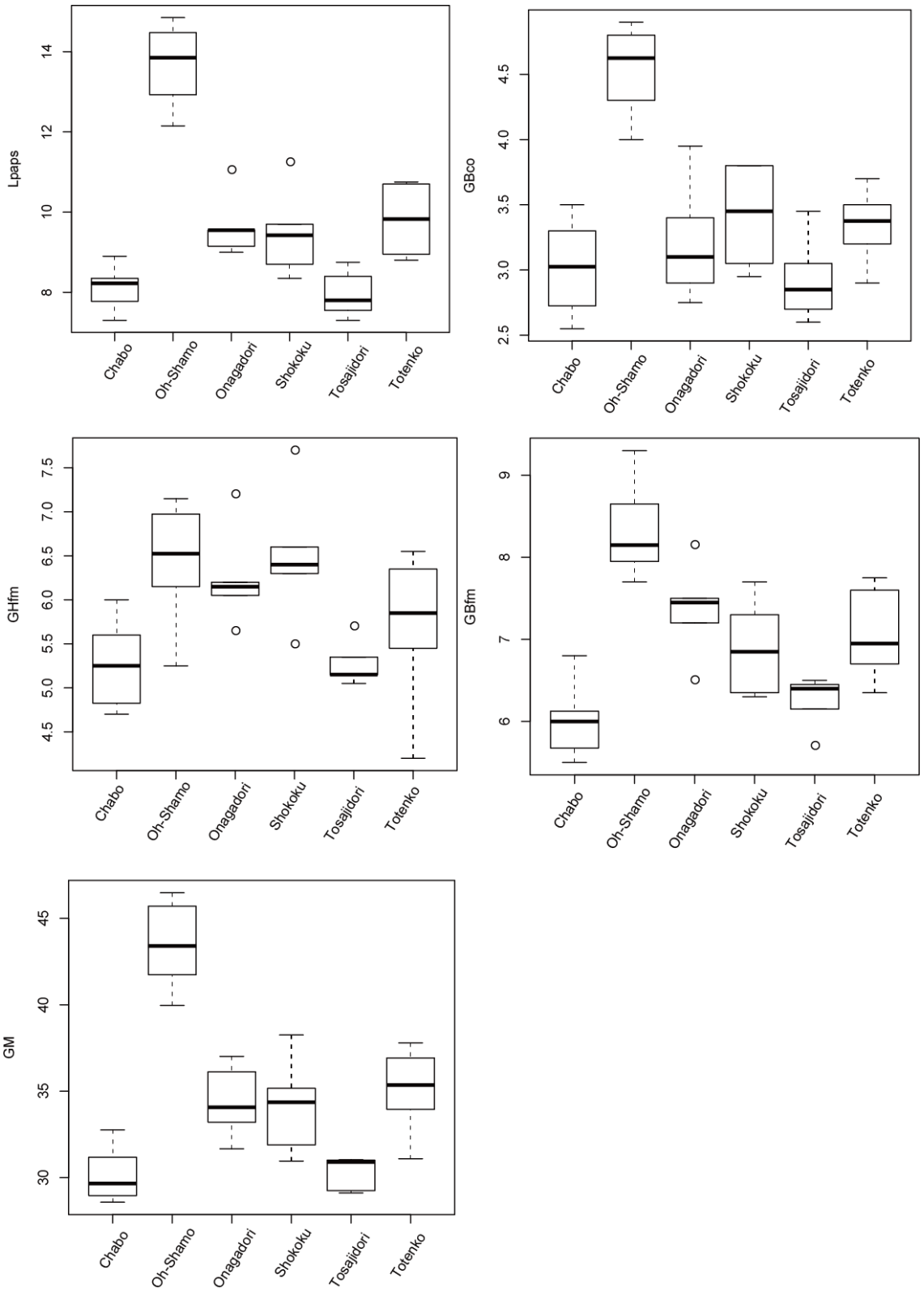

Fig. 1-1-5. The box plots in each measurement of skull. The abbreviated forms from Lpaps to GBfm were remarked in Table 1-2. GM shows the calculated geometric mean by using the measurement values of GLs, GBs and GLmp. The order of abbreviation follows the order of Table 1-3.

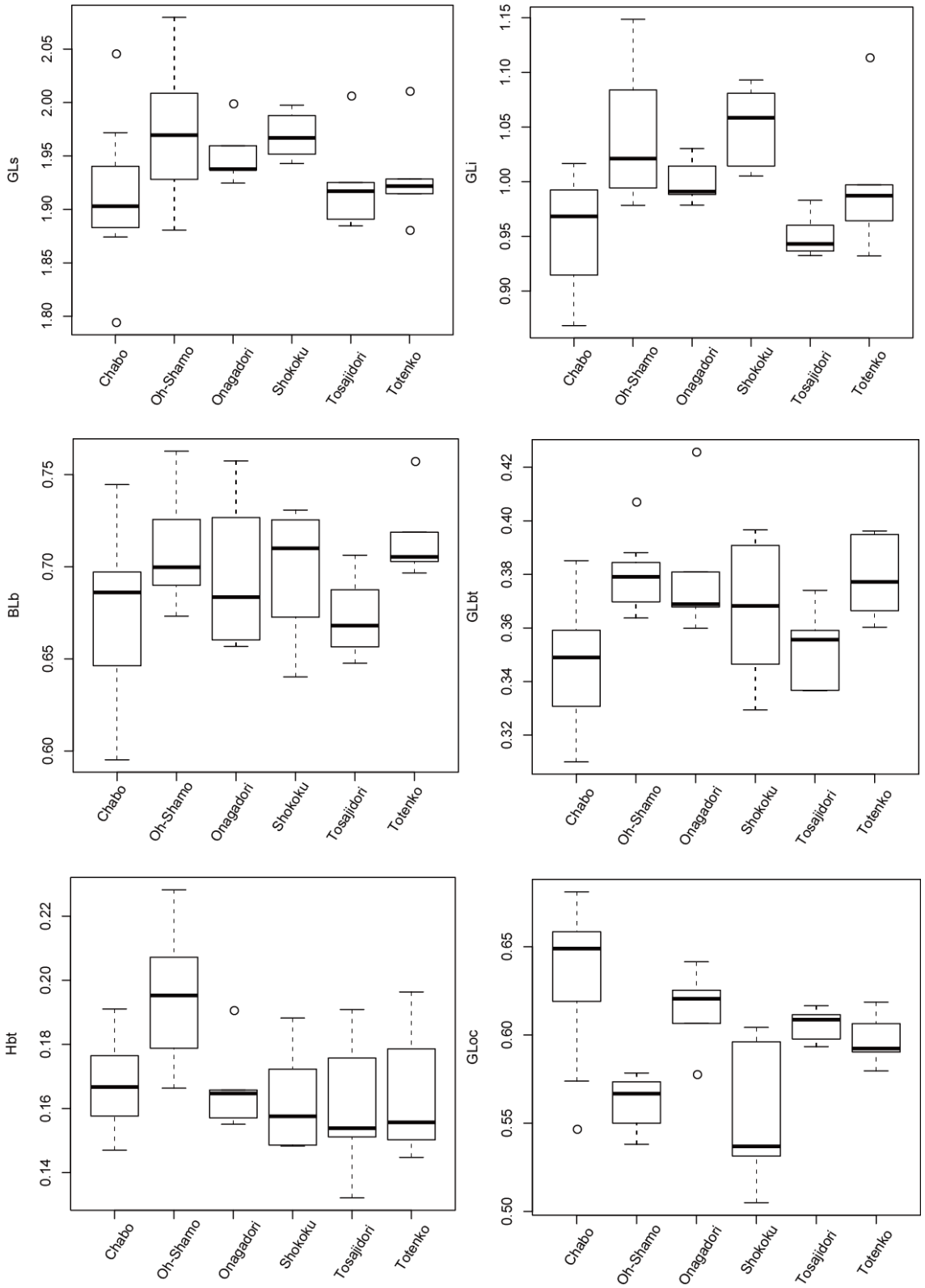

Fig. 1-1-6. The box plots in each measurement ratio of skull. The abbreviated forms from GLs to GLoc were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-4.

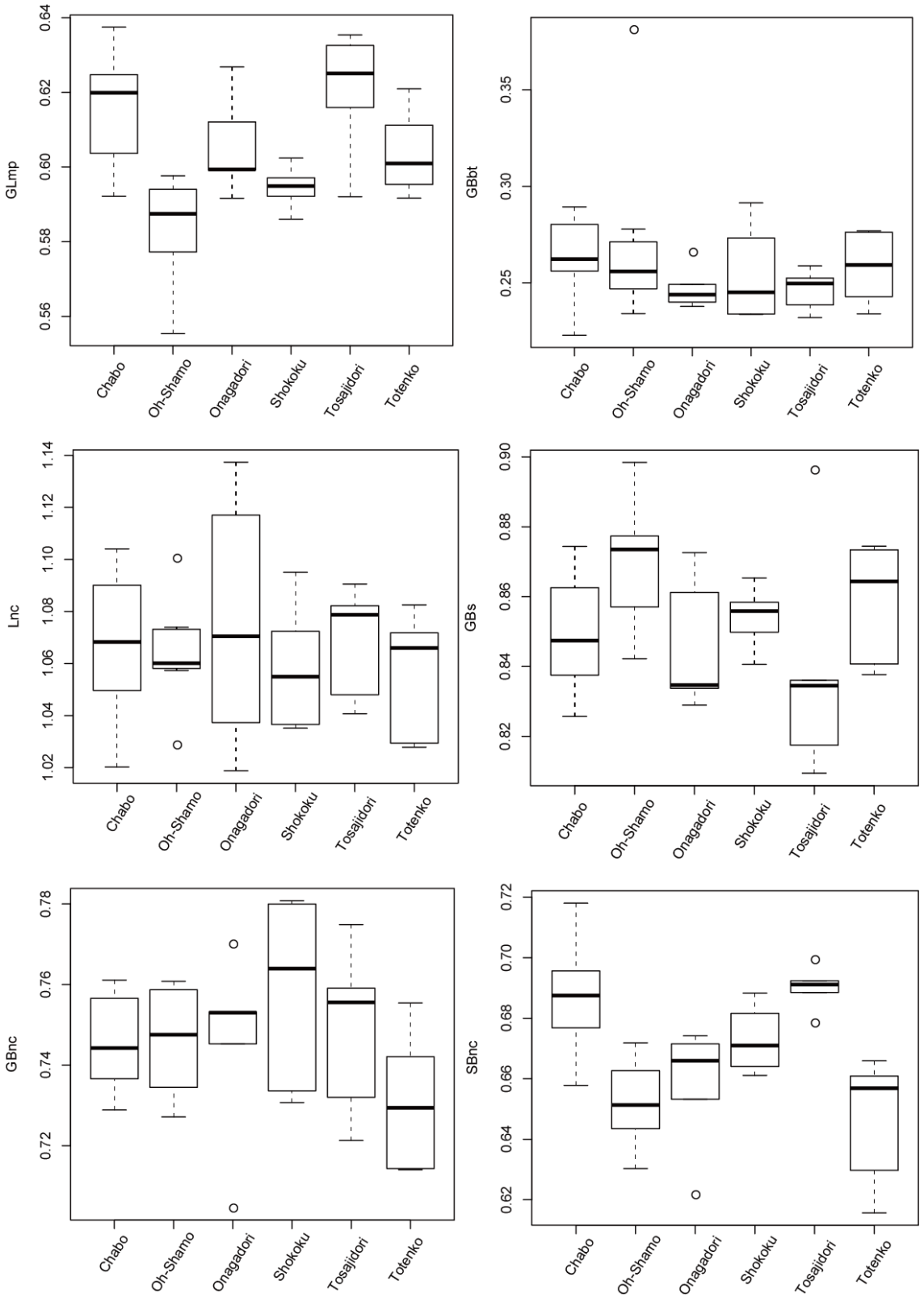

Fig. 1-1-7. The box plots in each measurement ratio of skull. The abbreviated forms from GLmp to SBnc were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-4.

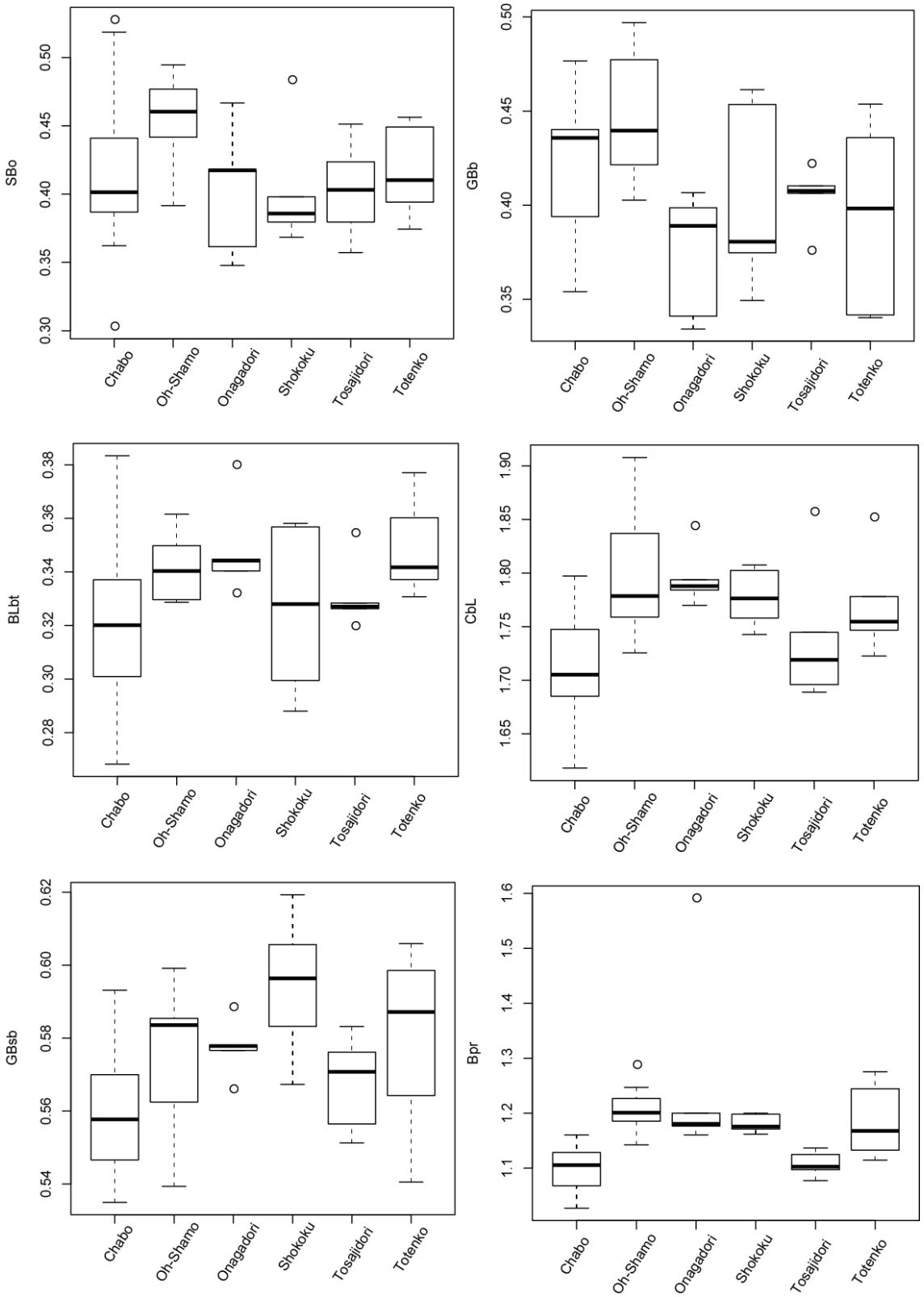

Fig. 1-1-8. The box plots in each measurement ratio of skull. The abbreviated forms from SBo to Bpr were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-4.

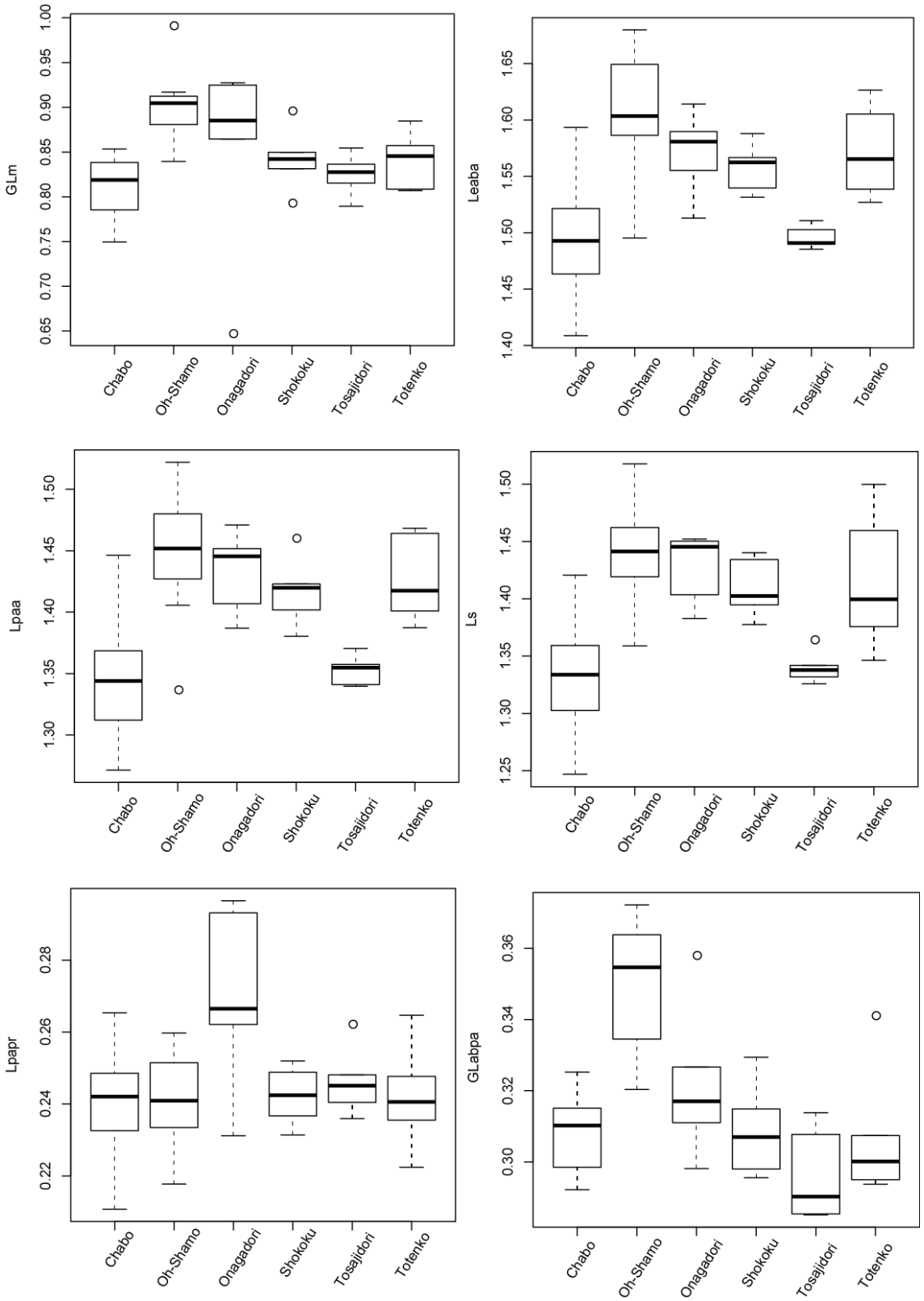

Fig. 1-1-9. The box plots in each measurement ratio of skull. The abbreviated forms from GLm to GLabpa were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-4.

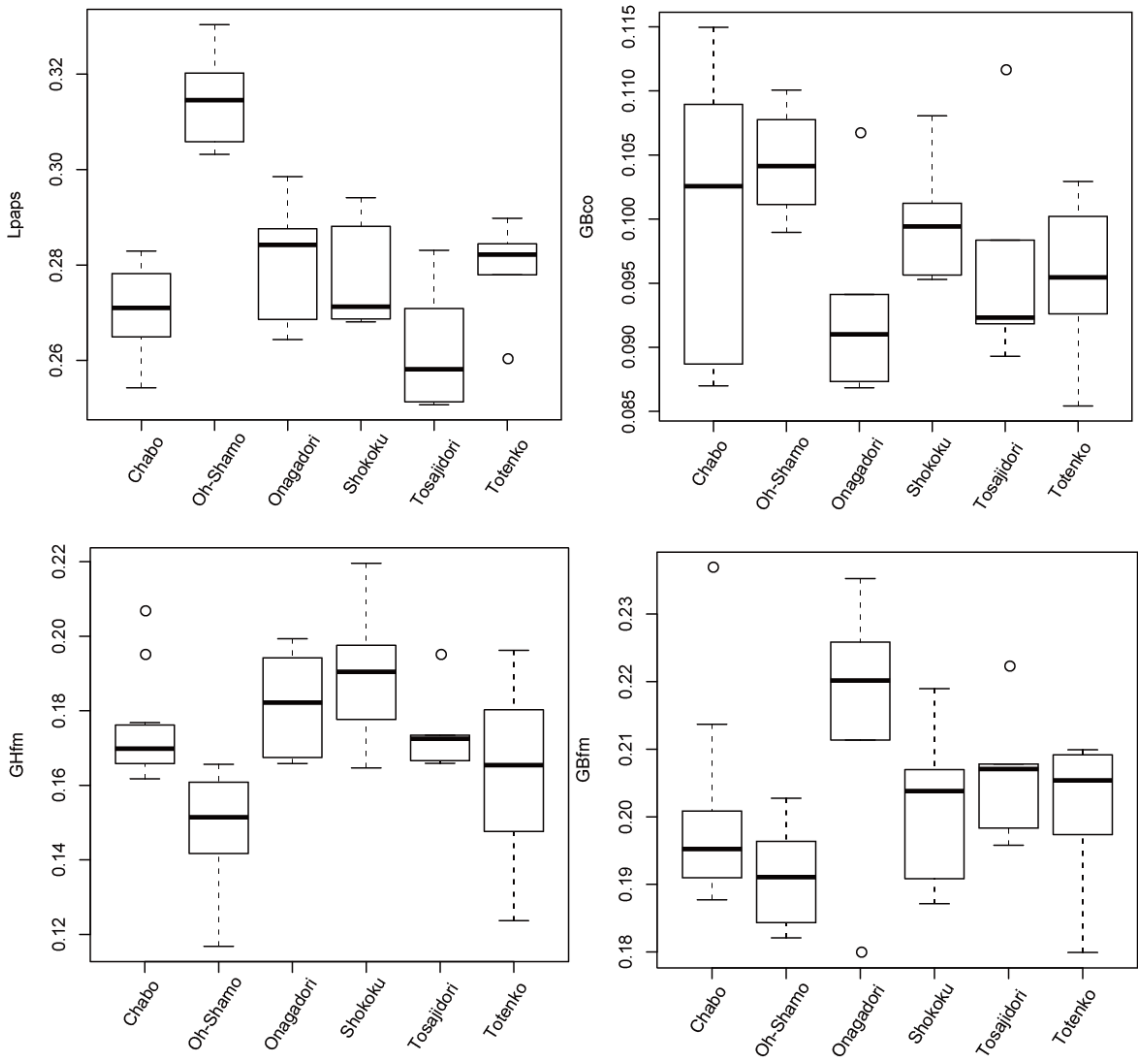

Fig. 1-1-10. The box plots in each measurement ratio of skull. The abbreviated forms from Lpaps to GBfm were remarked in Table 1-2. The order of abbreviation follows the order of Table 1-4.

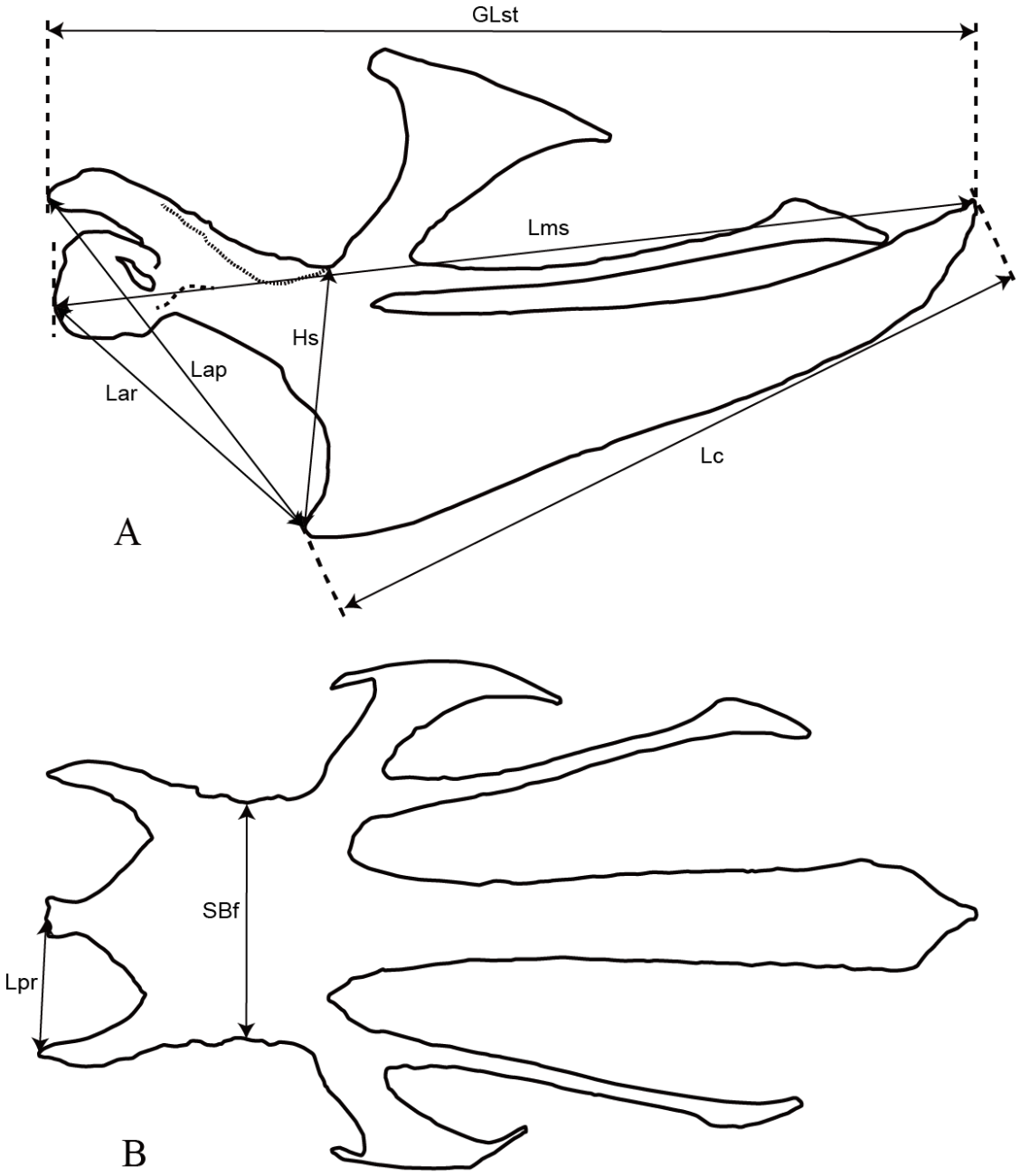

Fig. 2-1-1. The measurements in sternum. (A) Sternum of lateral view from left side. (B) Sternum from dorsal view. The abbreviated forms were remarked in Table 2-2.

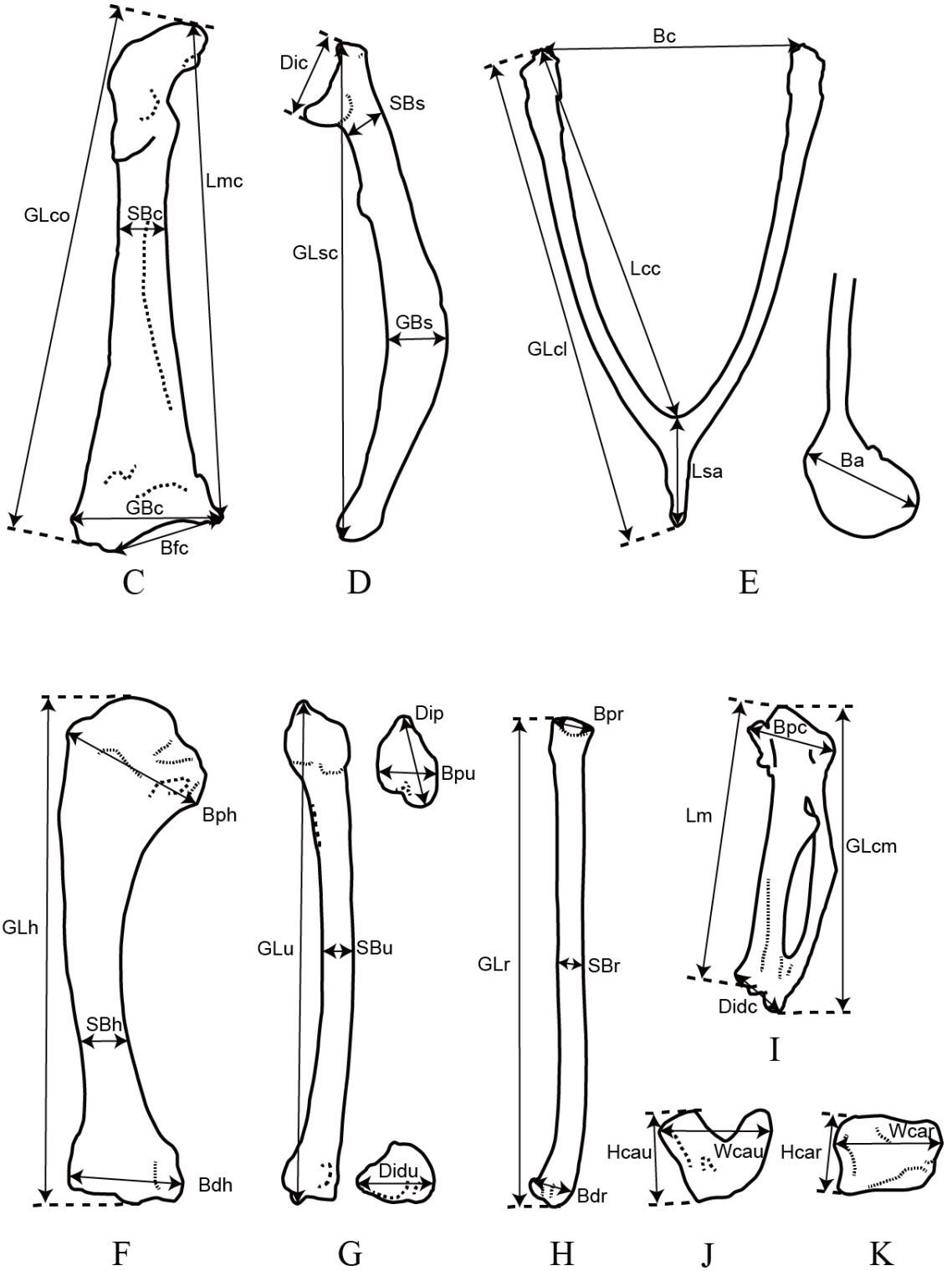

Fig. 2-1-2. The measurements in skeleton of forelimb, pectoral girdle. (C) Coracoid from dorsal view. (D) Scapula from ventromedial view. (E) Clavicula from cranial view and Acromion of clavicula from lateral view. (F) Humerus from medial or ventral view. (G) Ulna from cranial, proximal and disral view. (H) Radius from cranial view. (I) Carpometacarpus from caudal view. (J) Os carpi alulae ulnare from dorsal view. (K) Os carpi alulae radiale from dorsal veiw. The abbreviated forms were remarked in Table 2-2.

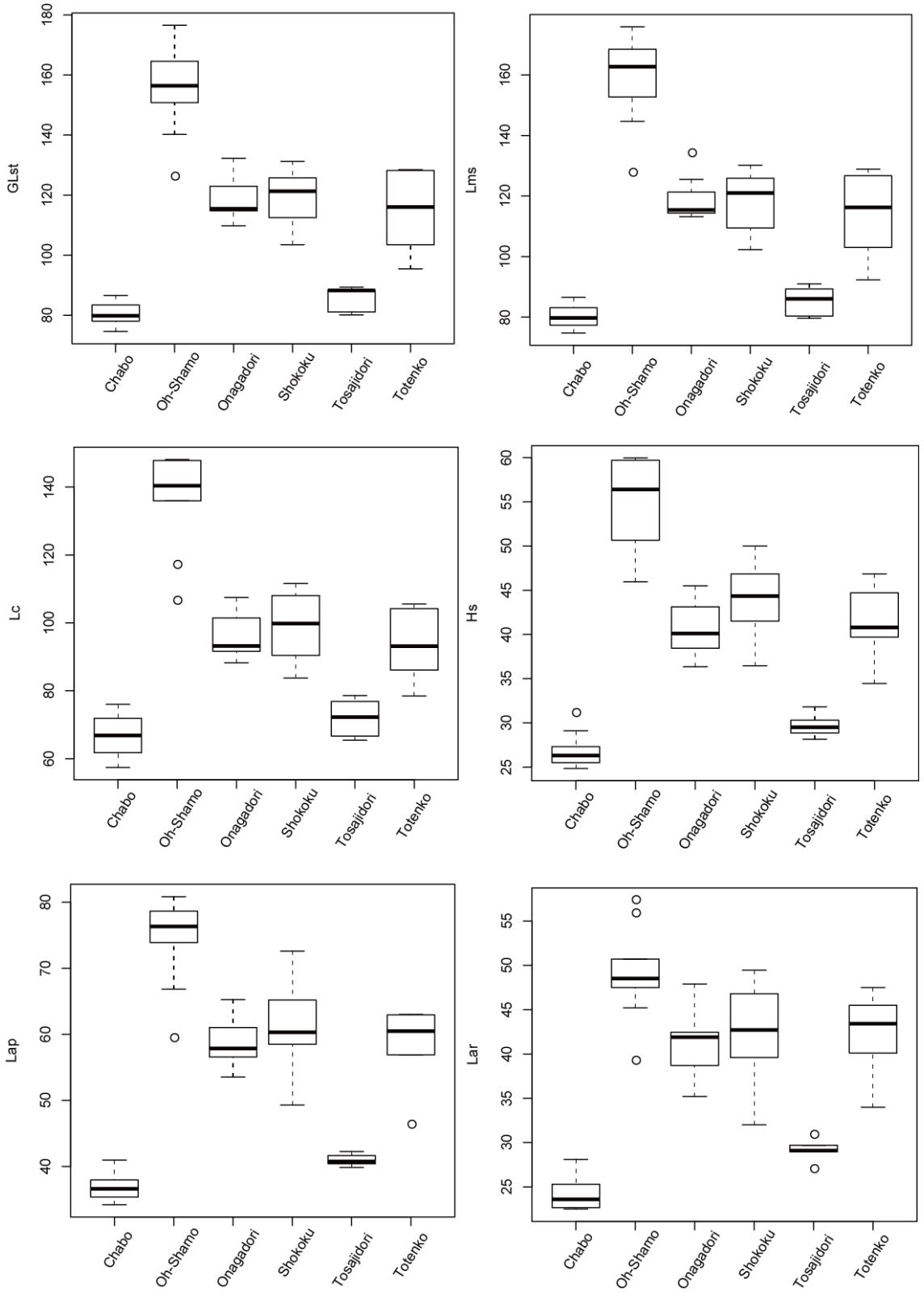

Fig. 2-2-1. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from GLst to Lar were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-1.

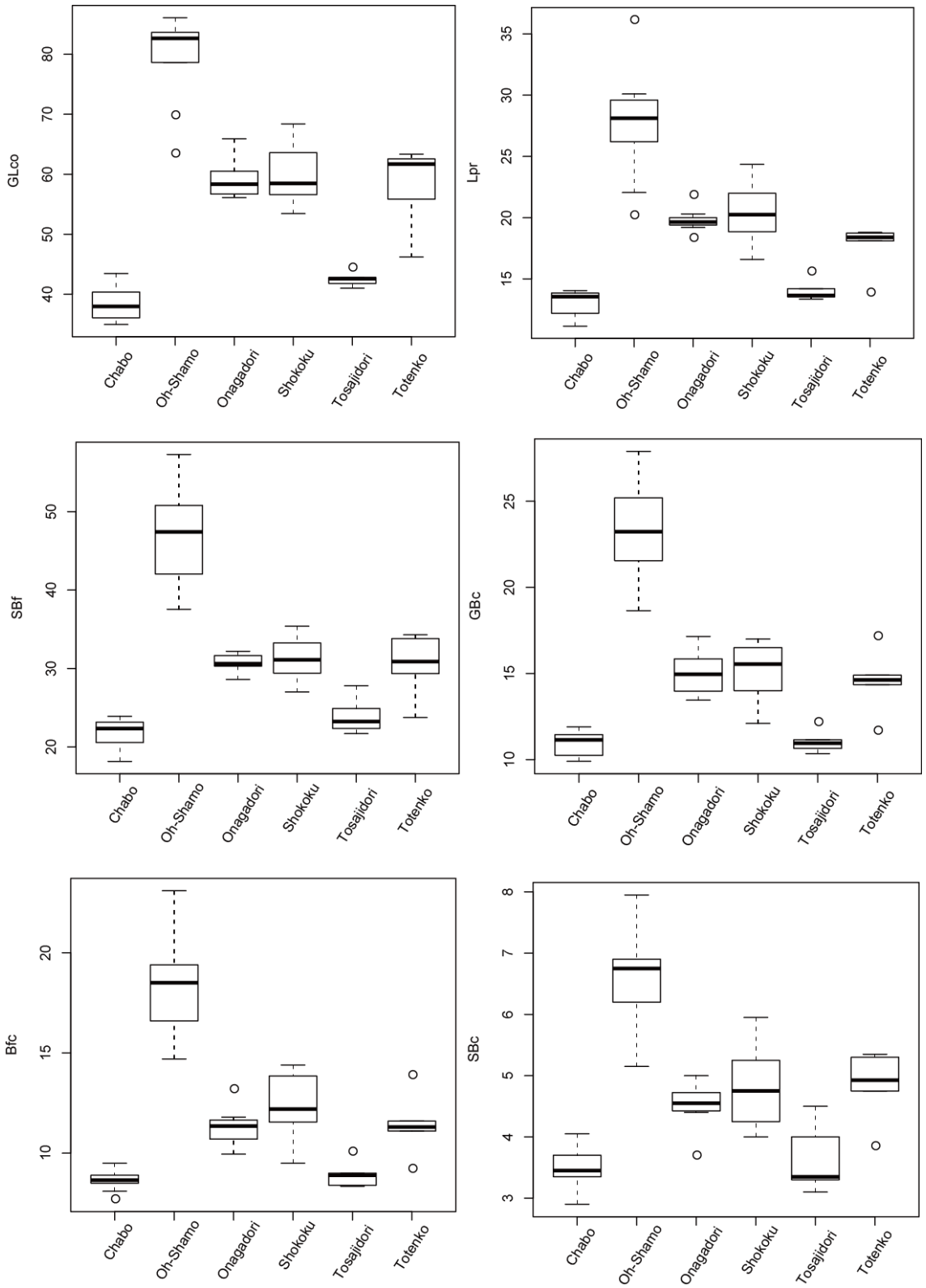

Fig. 2-2-2. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from GLco to SBc were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-1.

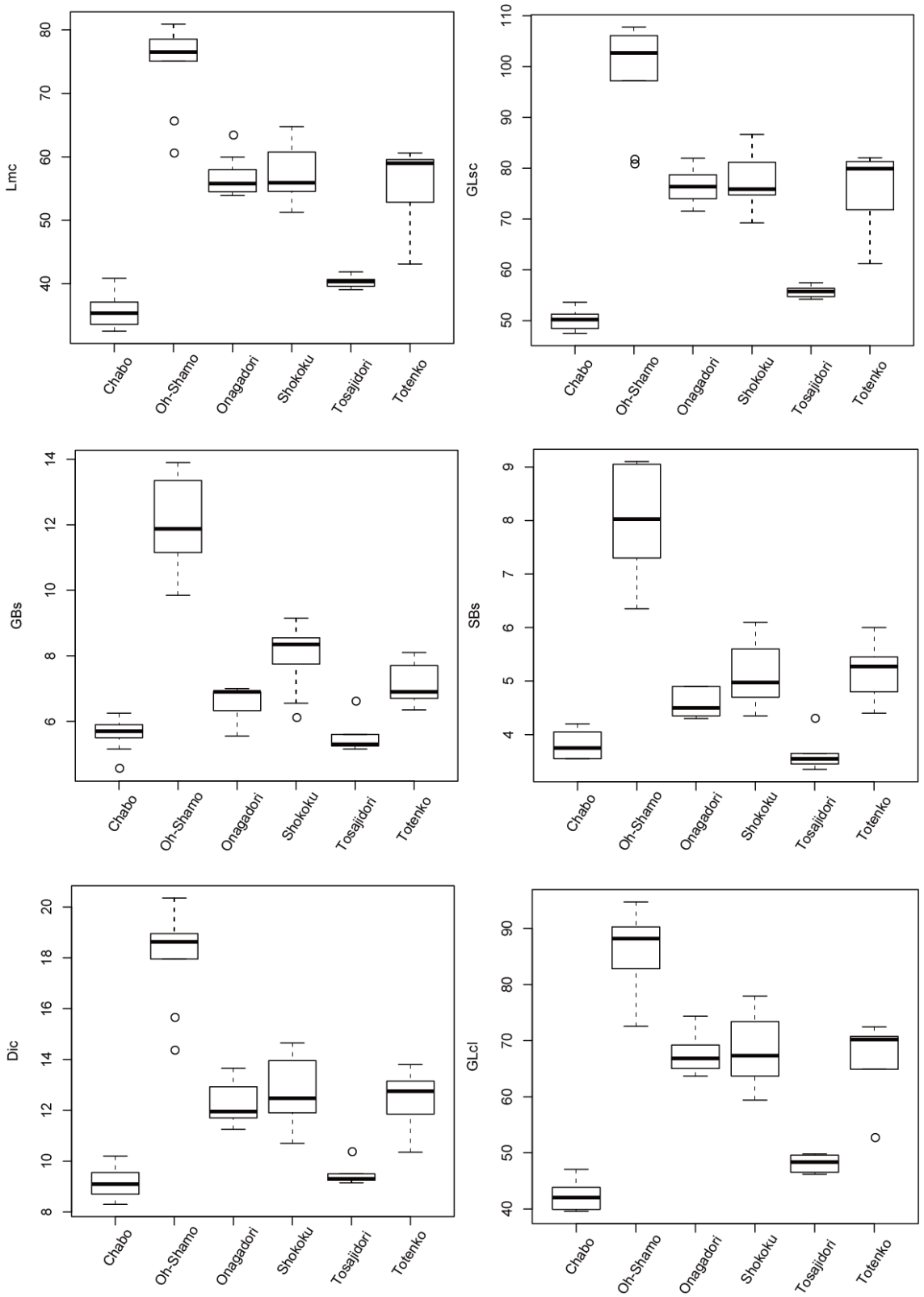

Fig. 2-2-3. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from Lmc to GLcl were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-1.

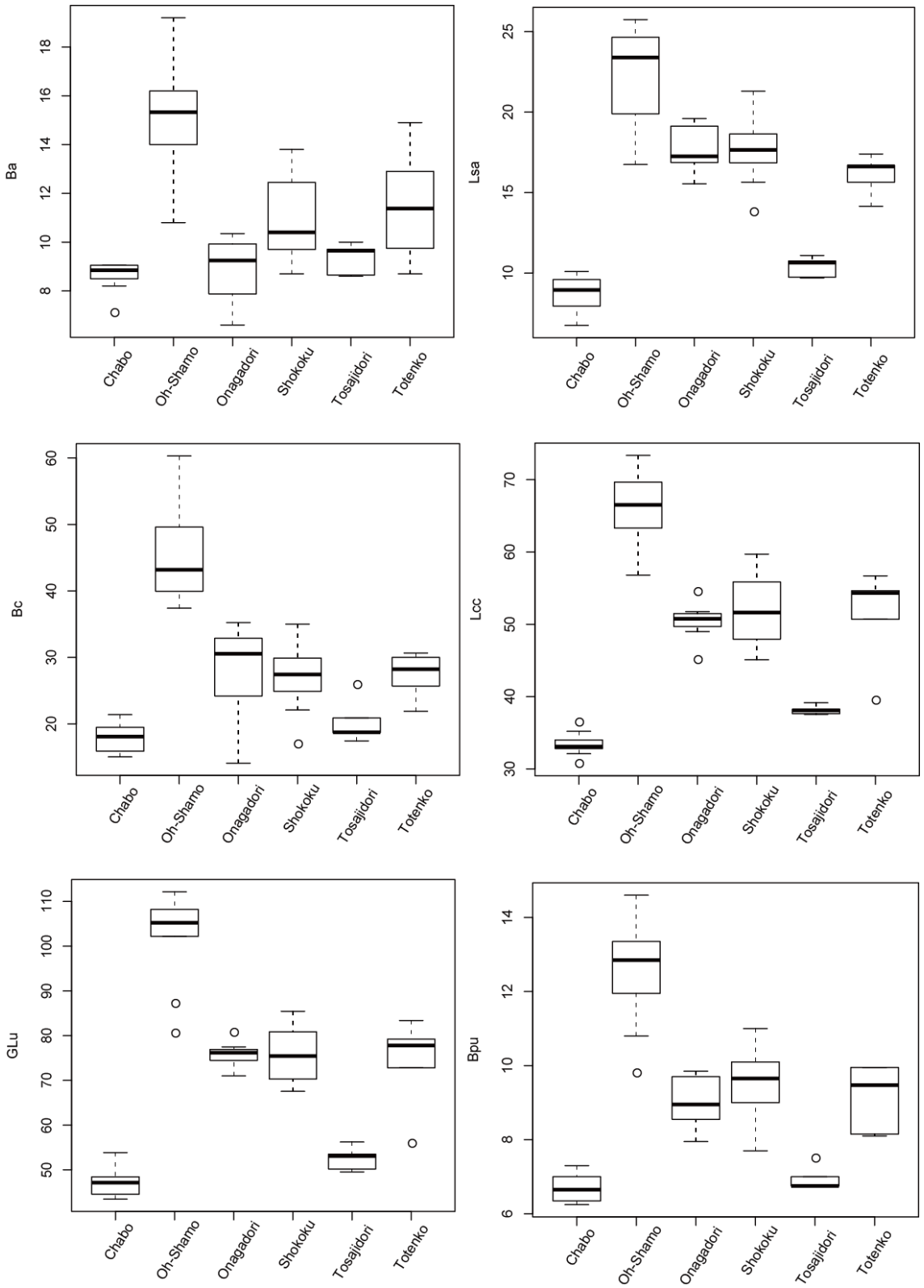

Fig. 2-2-4. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from Ba to Bpu were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-1.

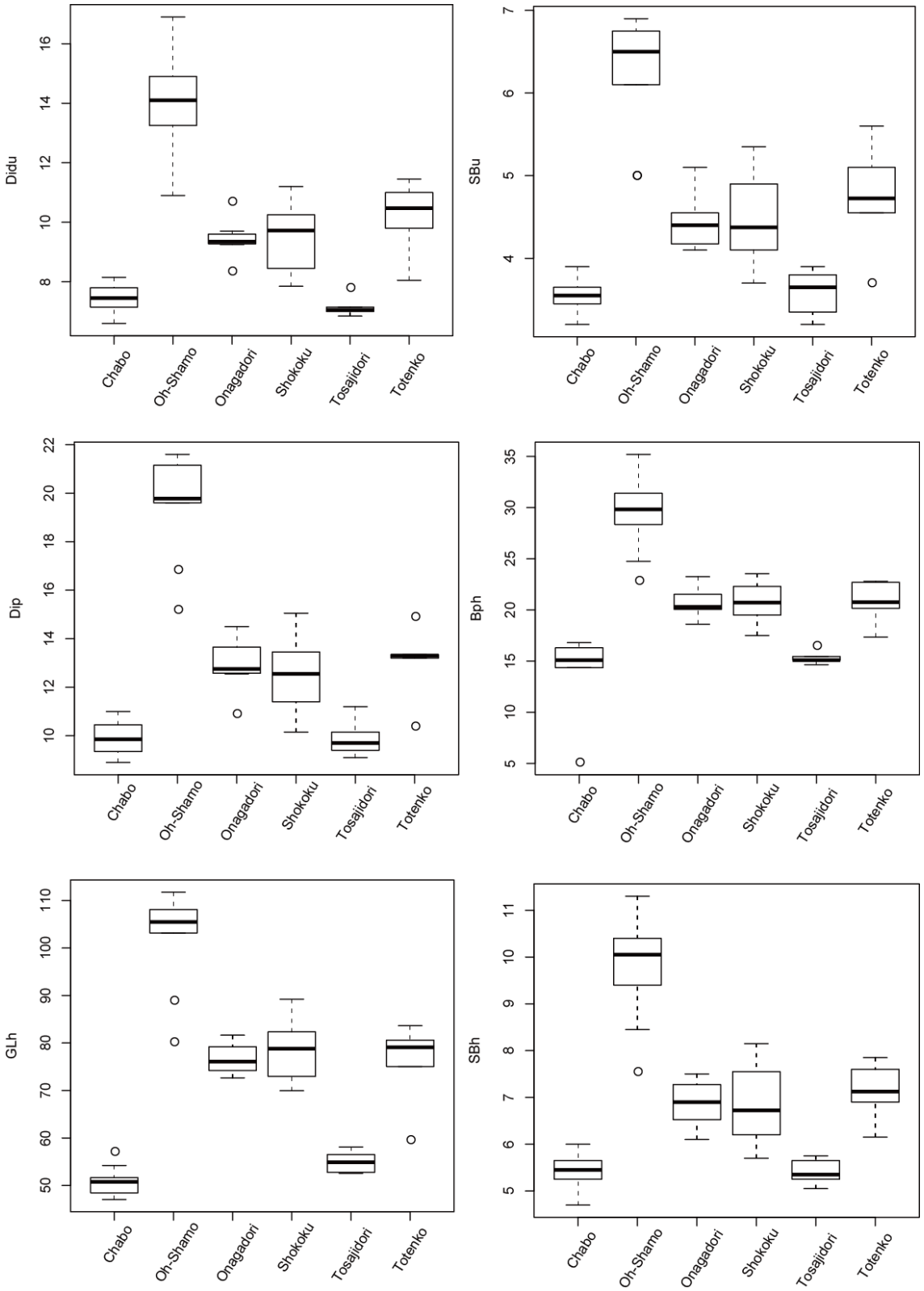

Fig. 2-2-5. The box plots in each measurement of forelimb, pectoral girdle and sterum. The abbreviated forms from Didu to SBh were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-1.

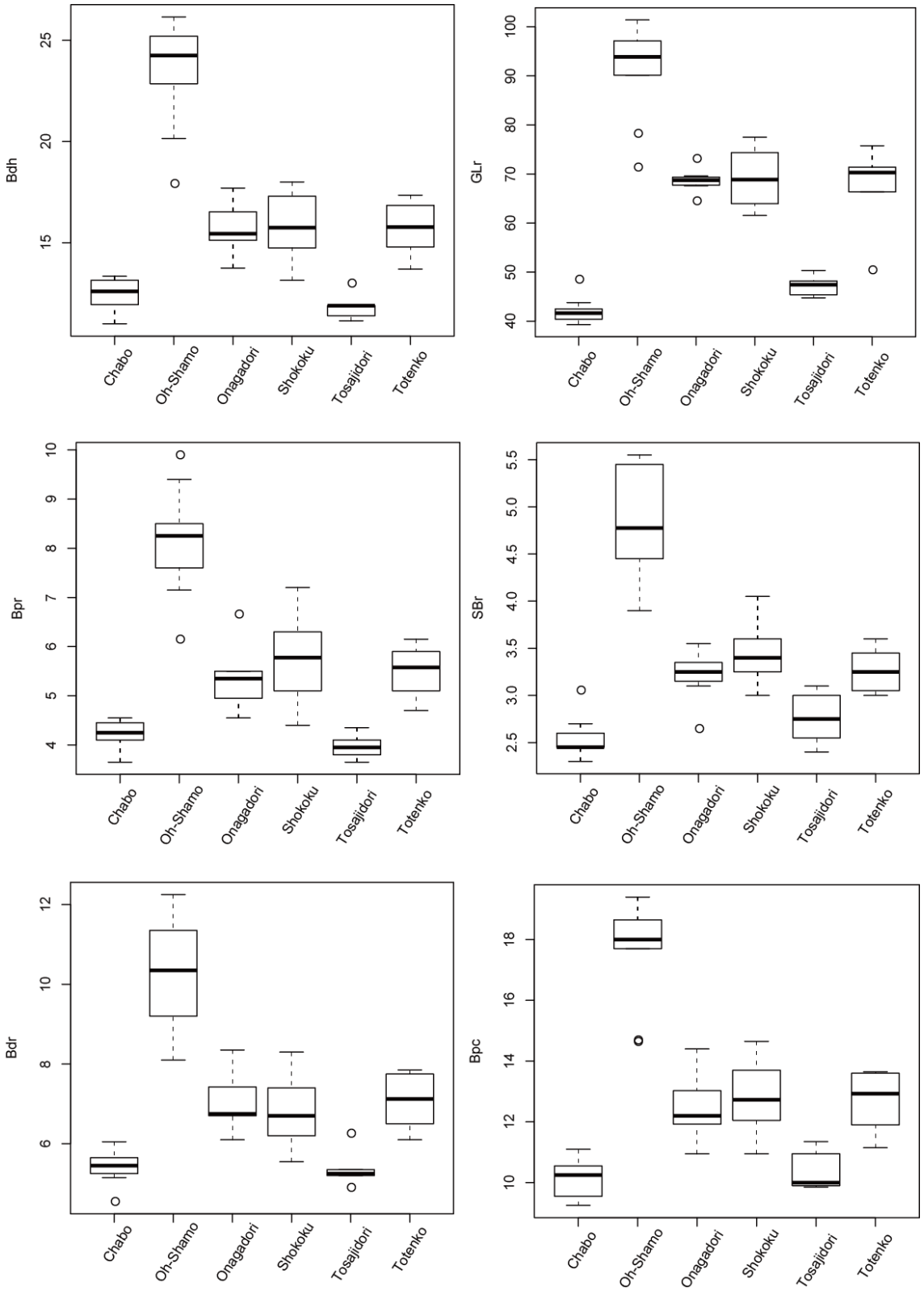

Fig. 2-2-6. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from Bdh to Bpc were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-2.

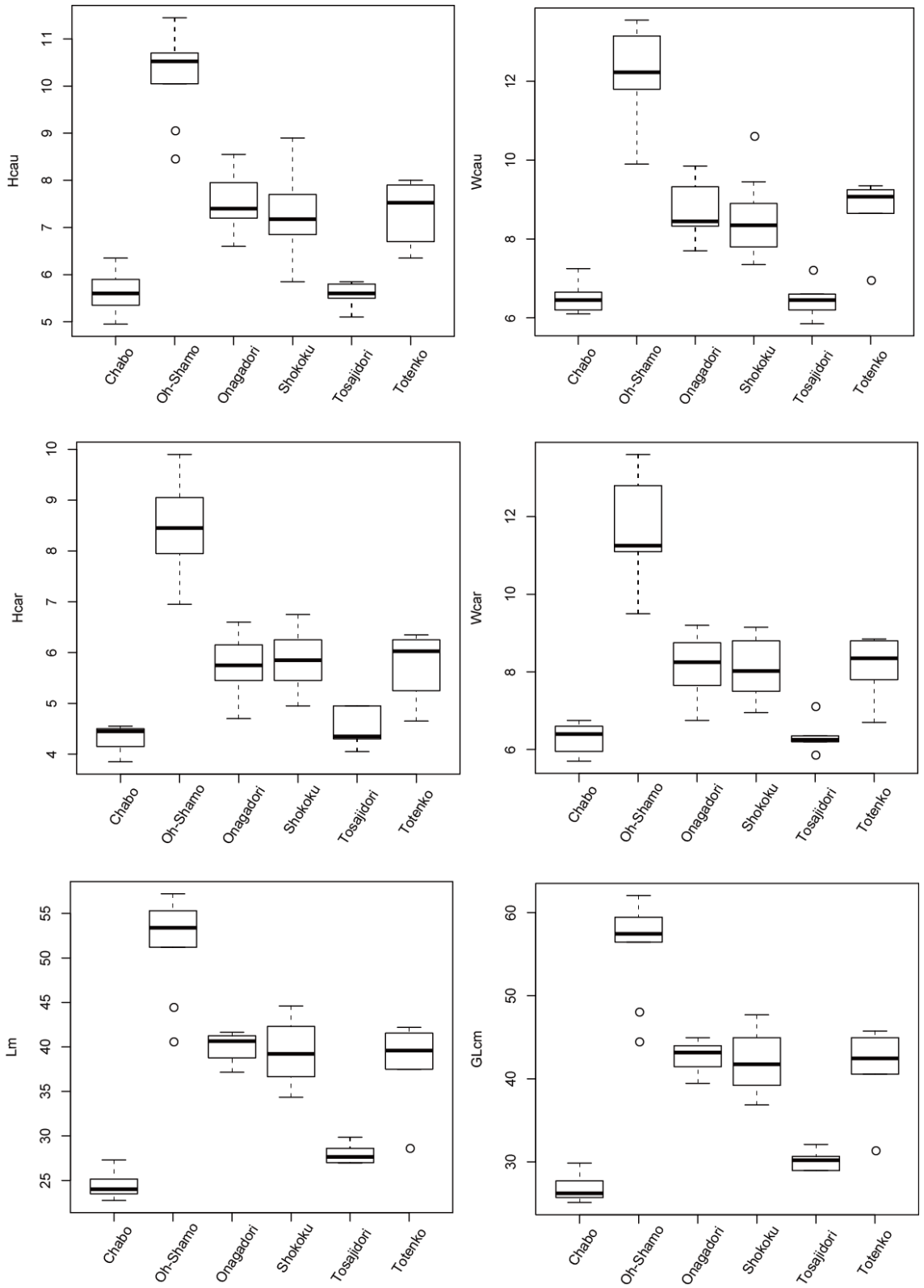

Fig. 2-2-7. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated forms from Hcau to GLcm were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-3-2.

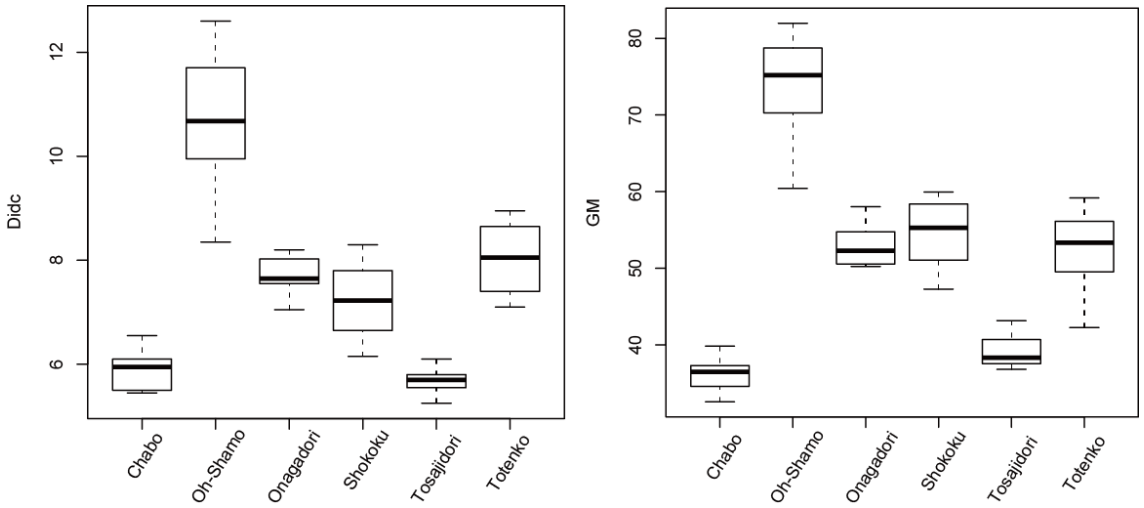

Fig. 2-2-8. The box plots in each measurement of forelimb, pectoral girdle and sternum. The abbreviated form of Didc was remarked in Table 2-2. GM shows the calculated geometric mean by using the measurement values of Lms, Hs and SBf. The order of abbreviation follows the order of Table 2-3-2.

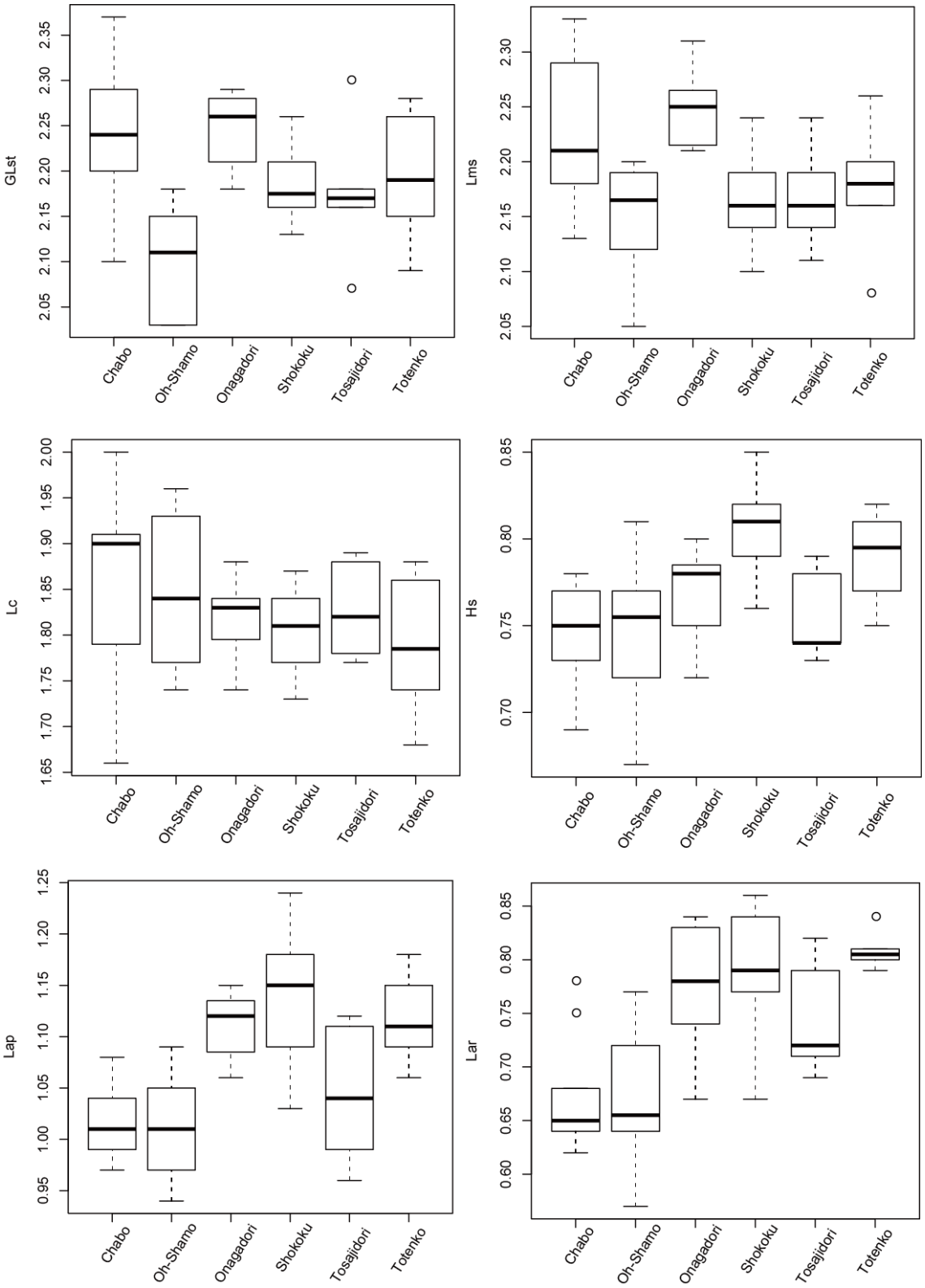

Fig. 2-2-9. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from GLst to Lar were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-1.

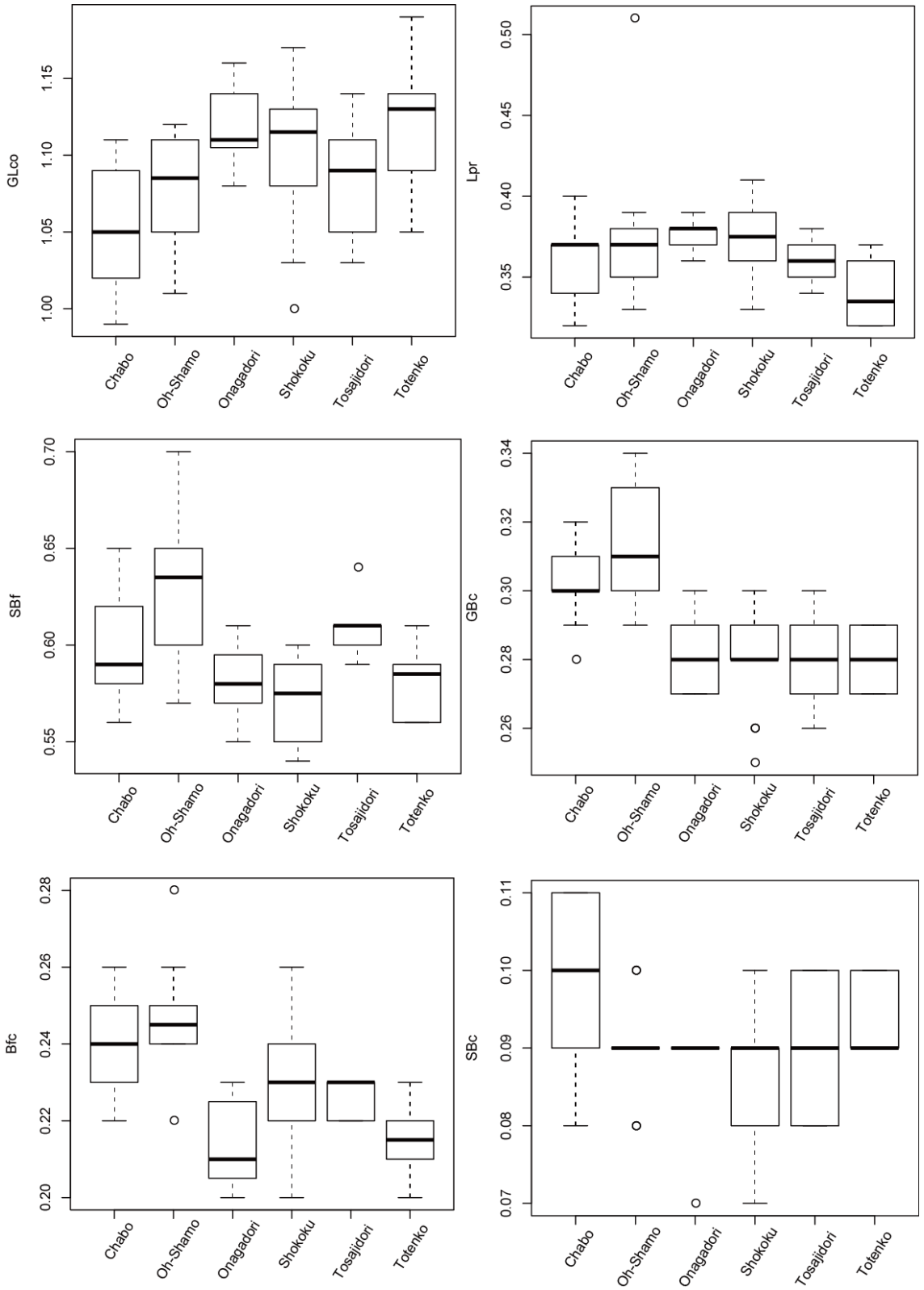

Fig. 2-2-10. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from GLco to SBc were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-1.

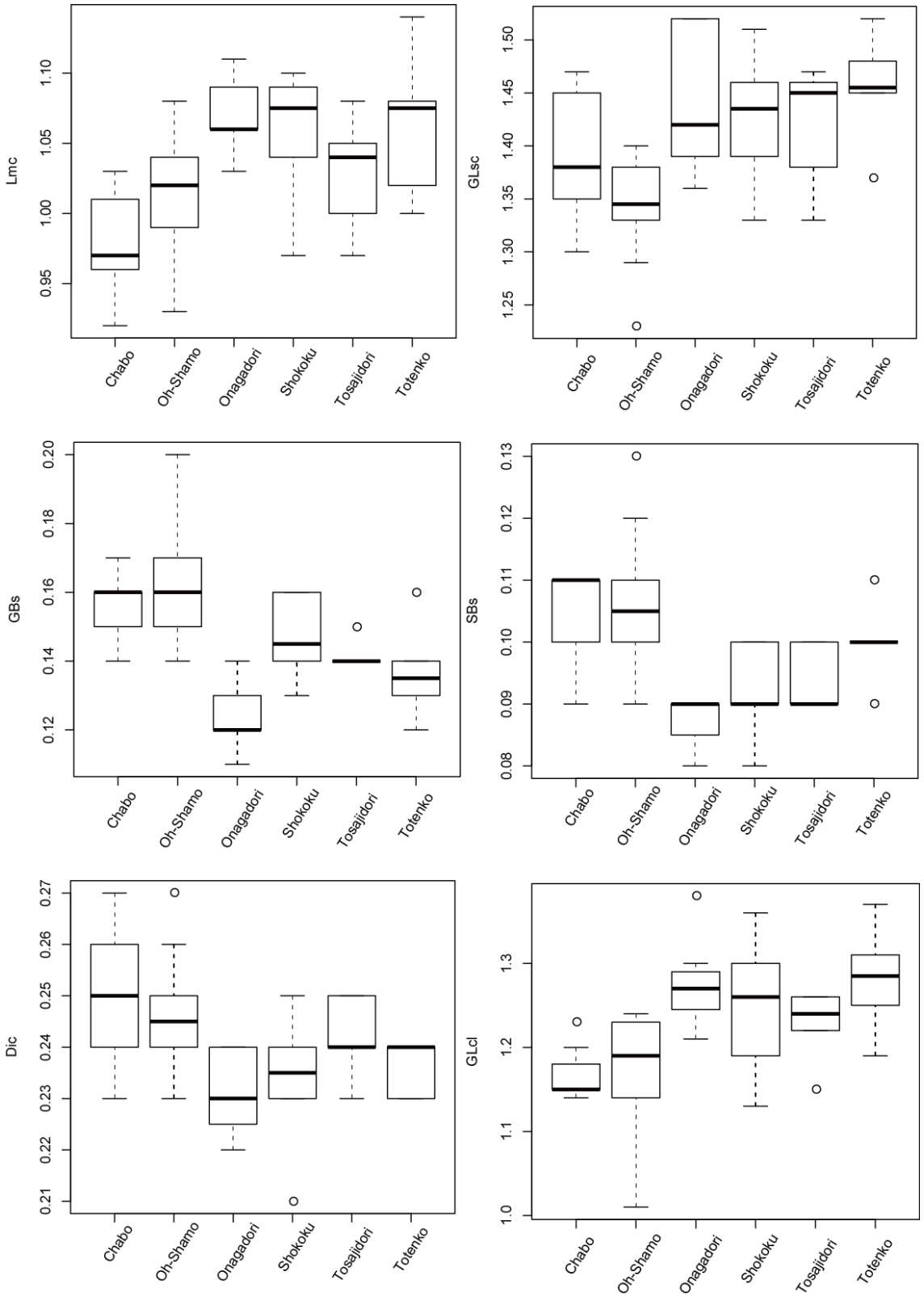

Fig. 2-2-11. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from Lmc to GLcl were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-1.

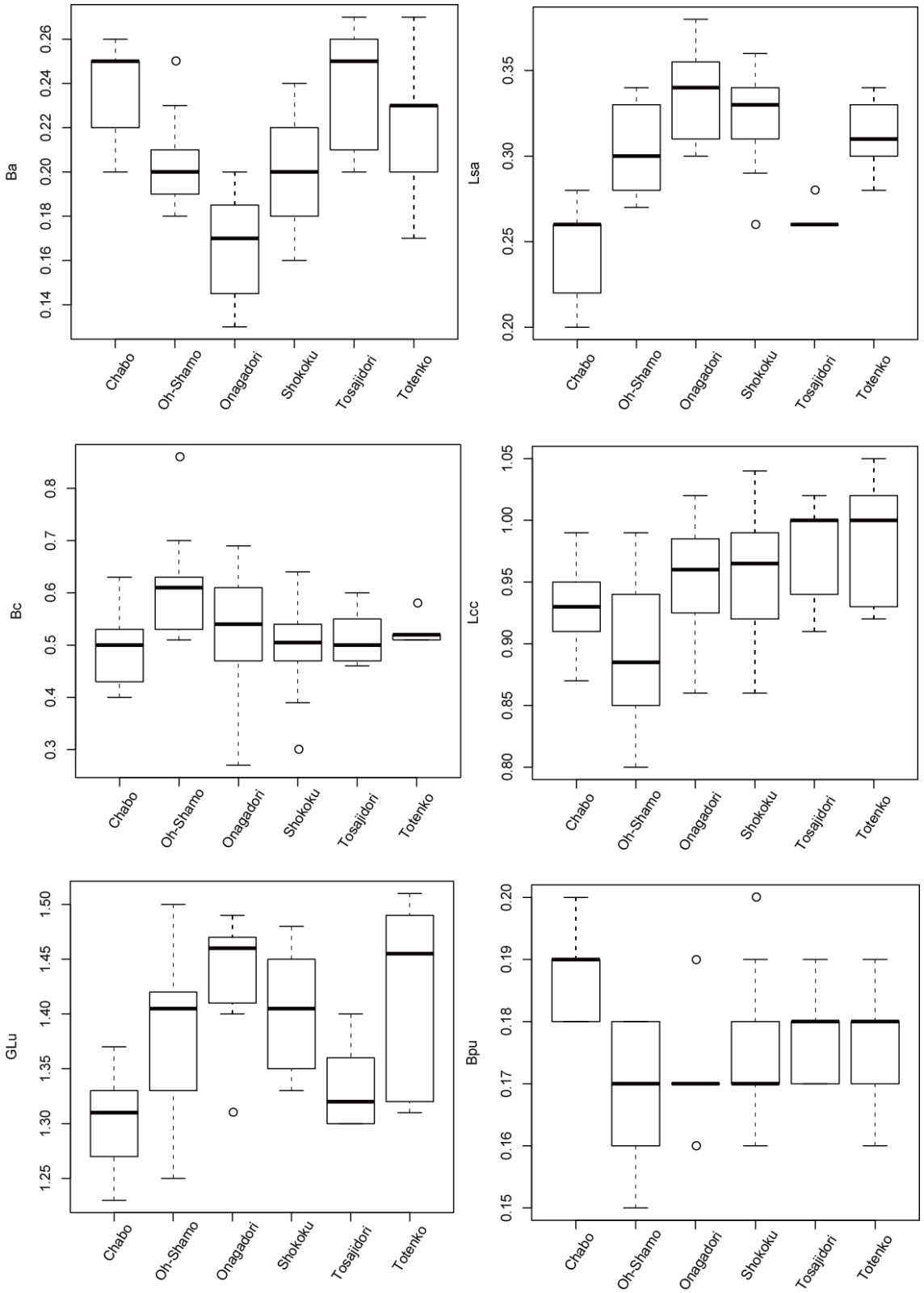

Fig. 2-2-12. The box plots in each measurement ratio of forelimb, pectoral girdle and sternunm. The abbreviated forms from Ba to Bpu were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-1.

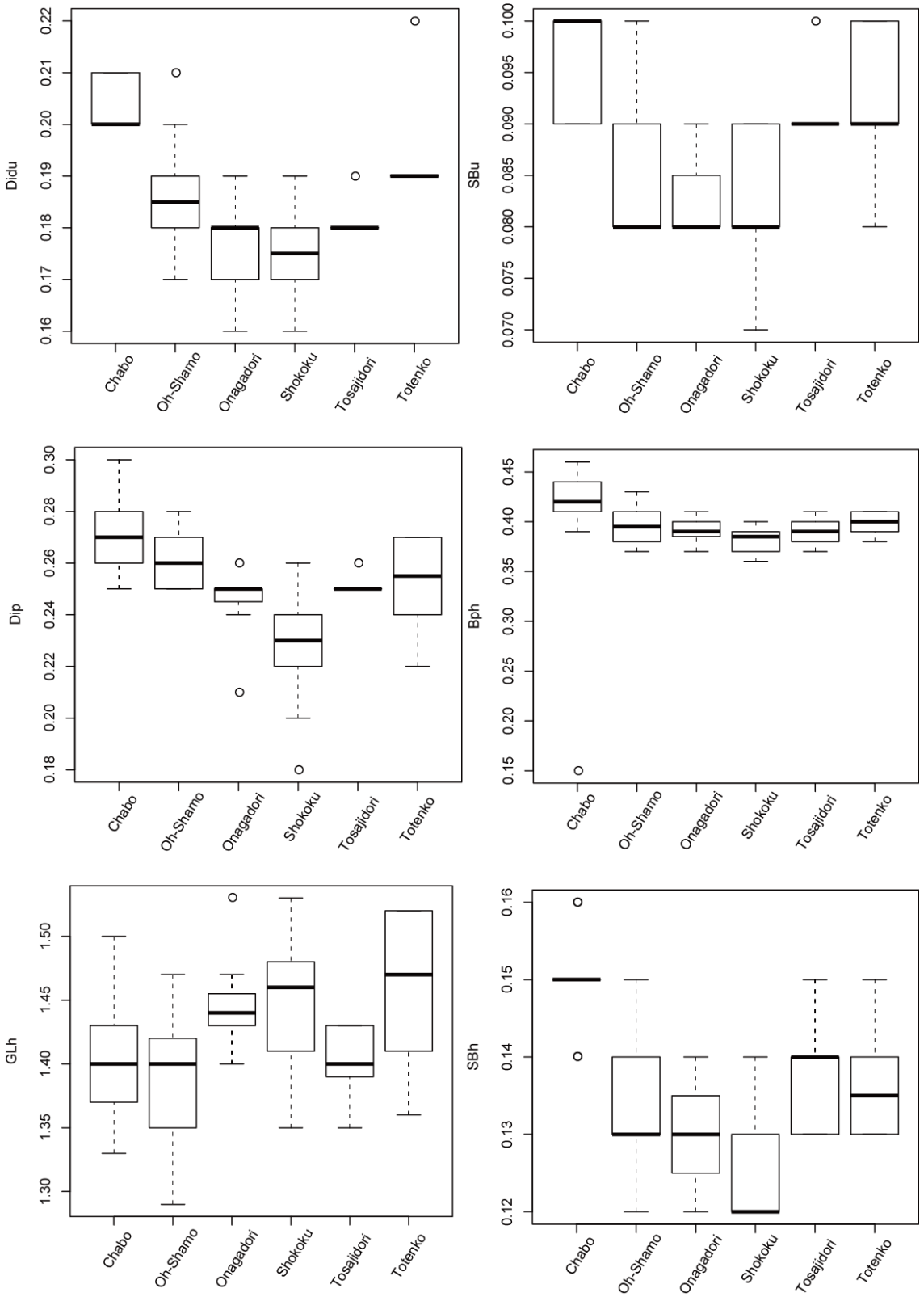

Fig. 2-2-13. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from Didu to SBh were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-1.

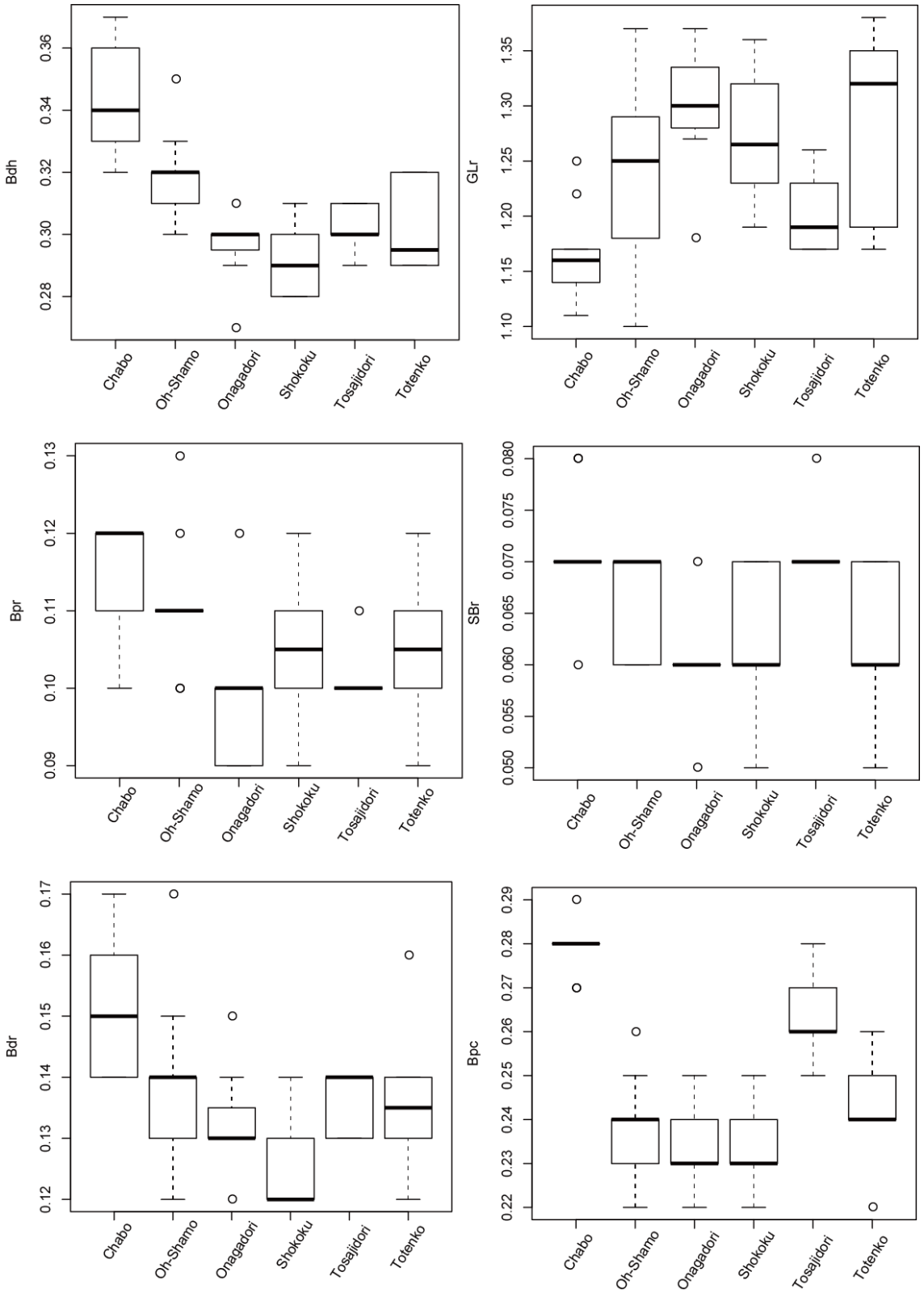

Fig. 2-2-14. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from Bdh to Bpc were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-2.

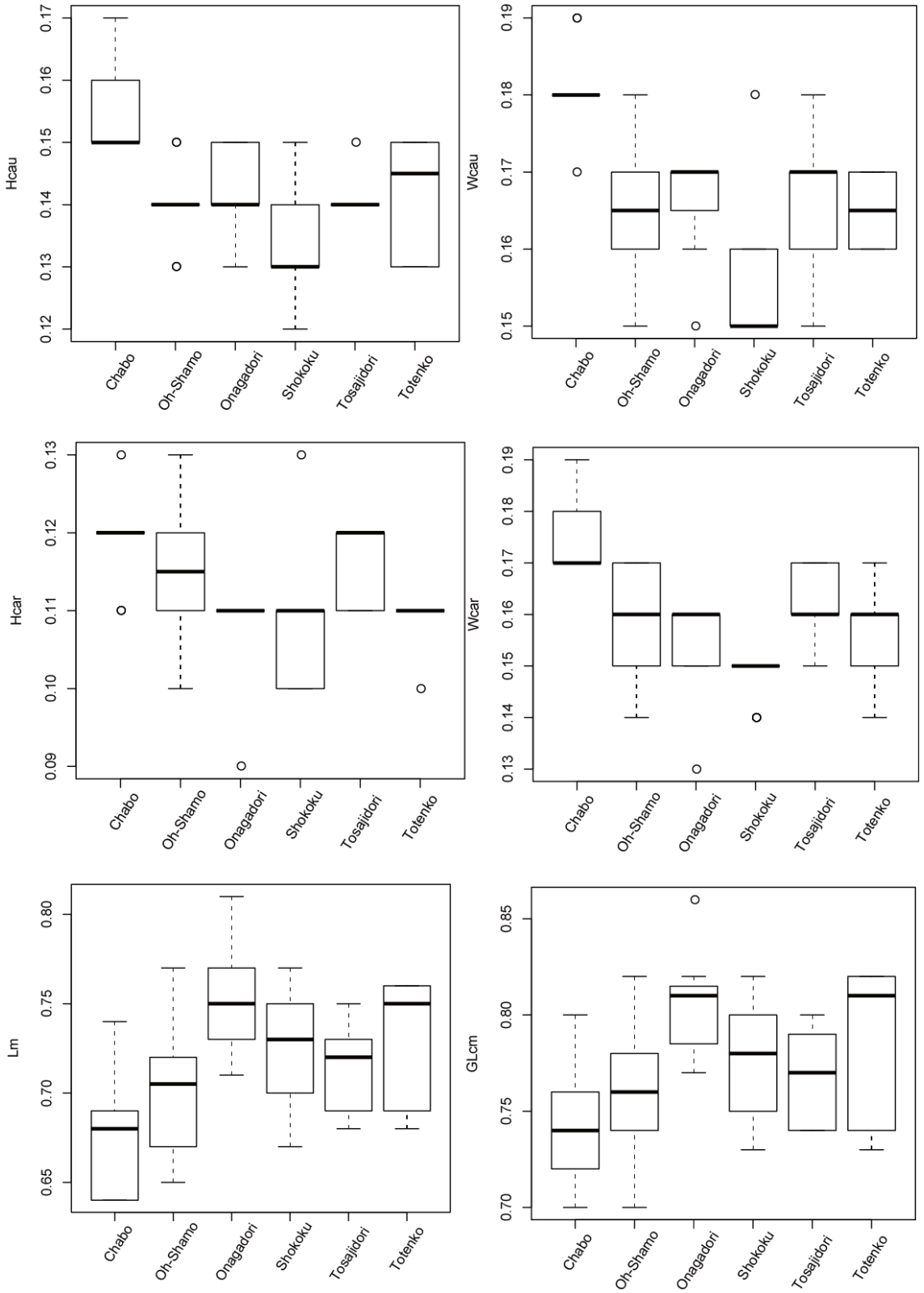

Fig. 2-2-15. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated forms from Hcau to GLcm were remarked in Table 2-2. The order of abbreviation follows the order of Table 2-4-2.

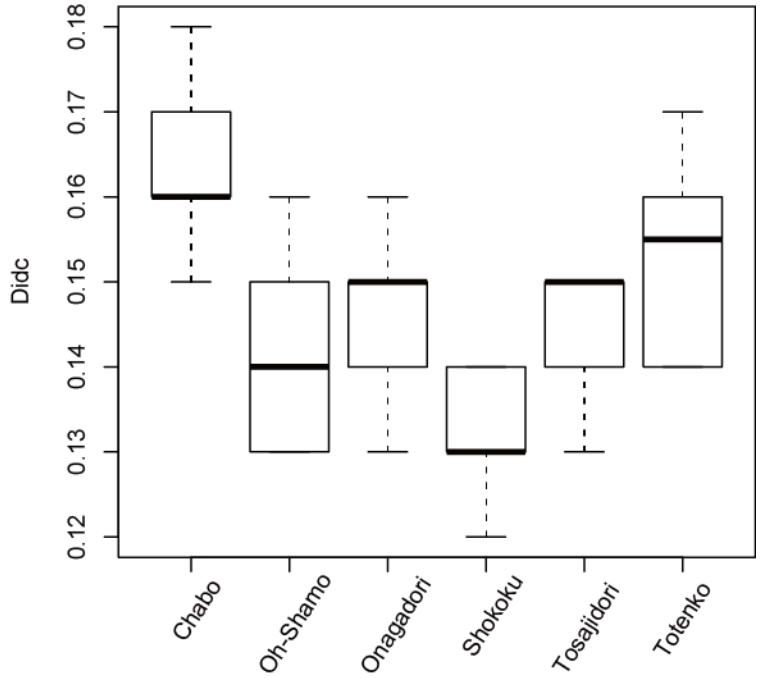

Fig. 2-2-16. The box plots in each measurement ratio of forelimb, pectoral girdle and sternum. The abbreviated form of Didc was remarked in Table 2-2.

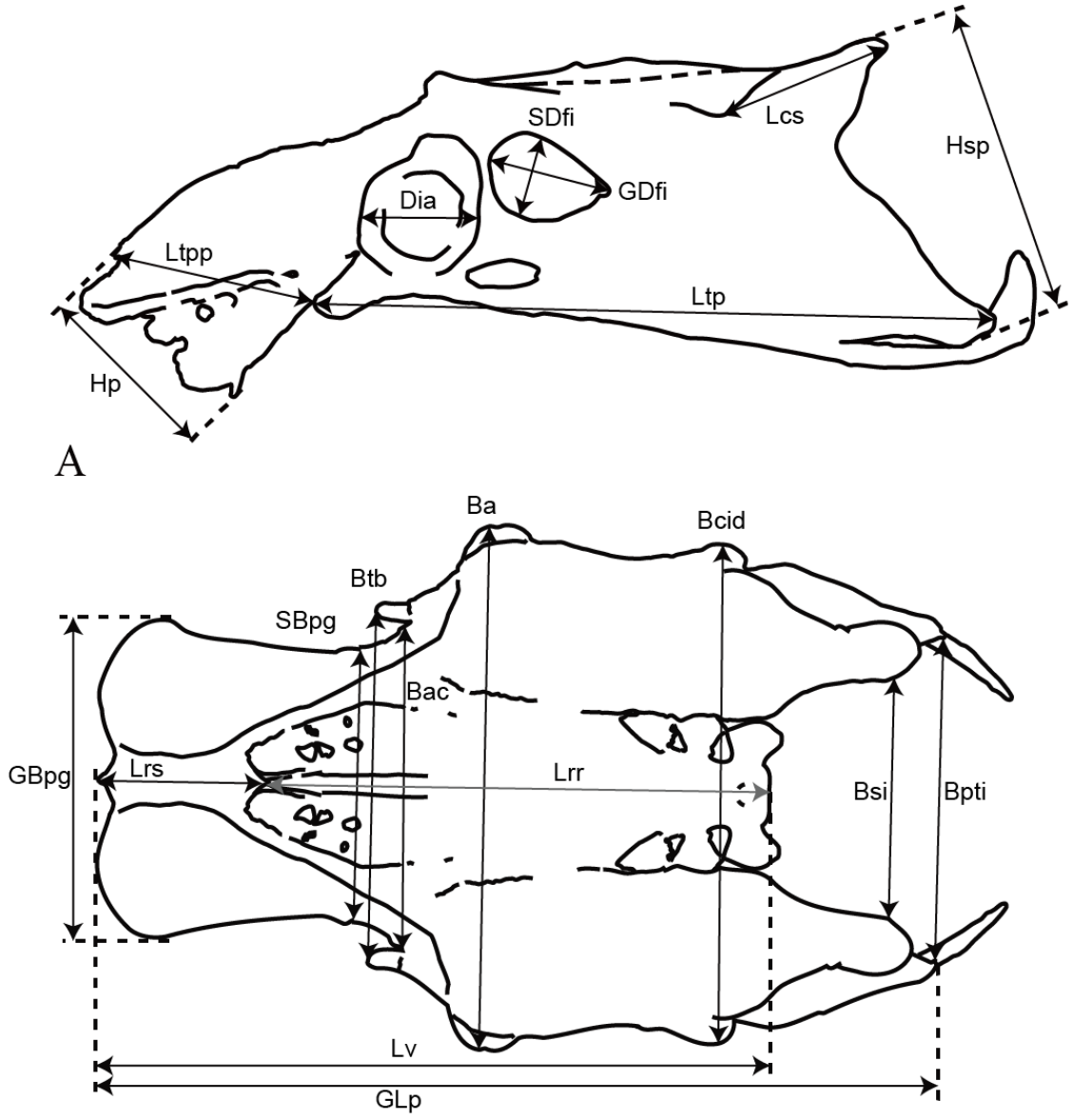

Fig. 3-1-1. The measurements of pelvis. (A) Pelvis of lateral view from left side. (B) Pelvis from dorsal view. Bv The abbreviated forms were remarked in Table 3-2. In this Chapter 4, the coalesced vertebrae, ilium, ischii and pubis were defined as pelvis.

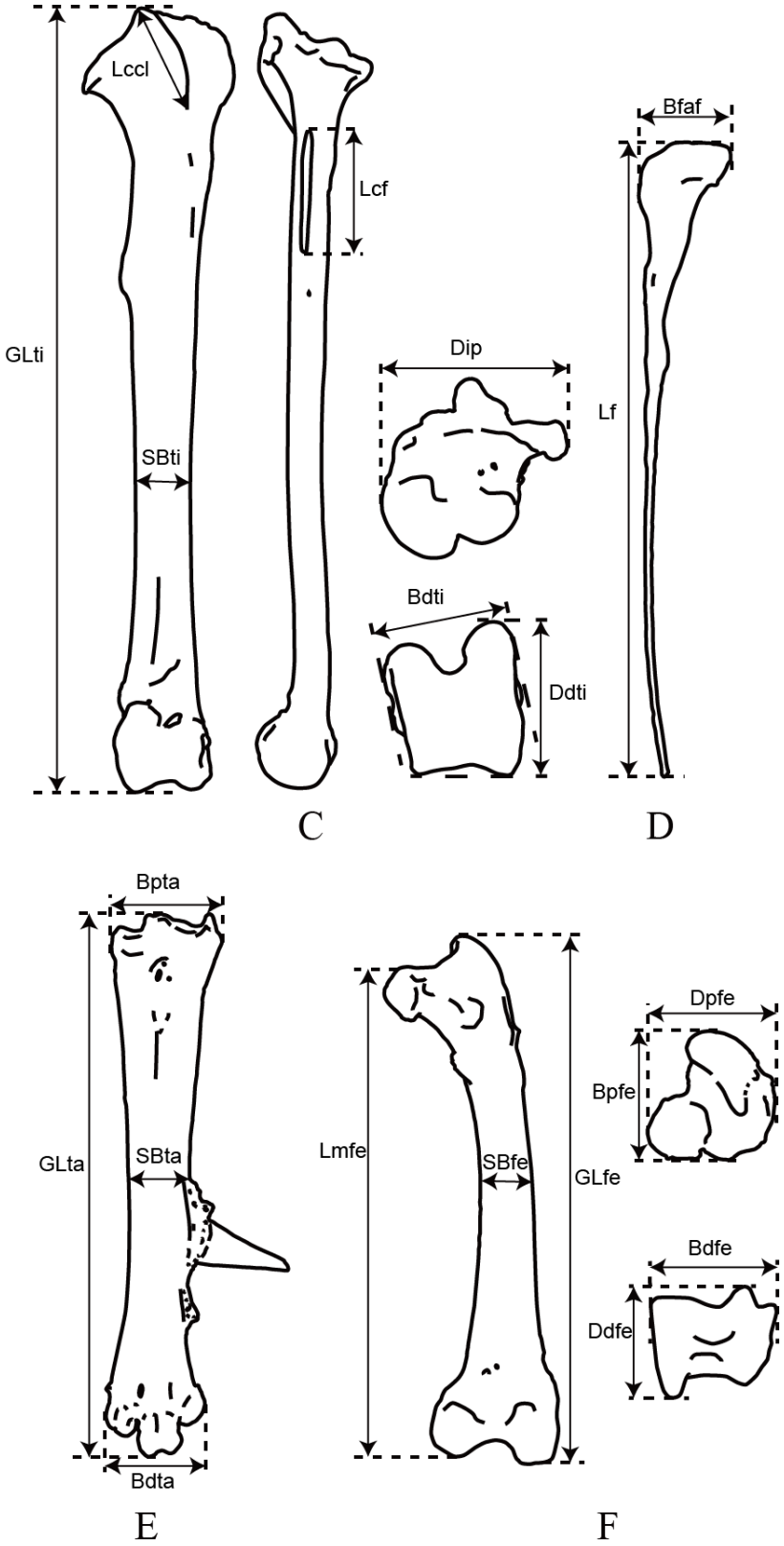

Fig. 3-1-2. The measurements in skeleton of hindlimb. (C) Tibiotarsus from cranial, lateral, proximal and distal view. (D) Fibula from cranial view. (E) Tarsometatarsus from cranial view. (F) Femur from caudal, proximal and distal view. The abbreviated forms were remarked in Table 3-2.

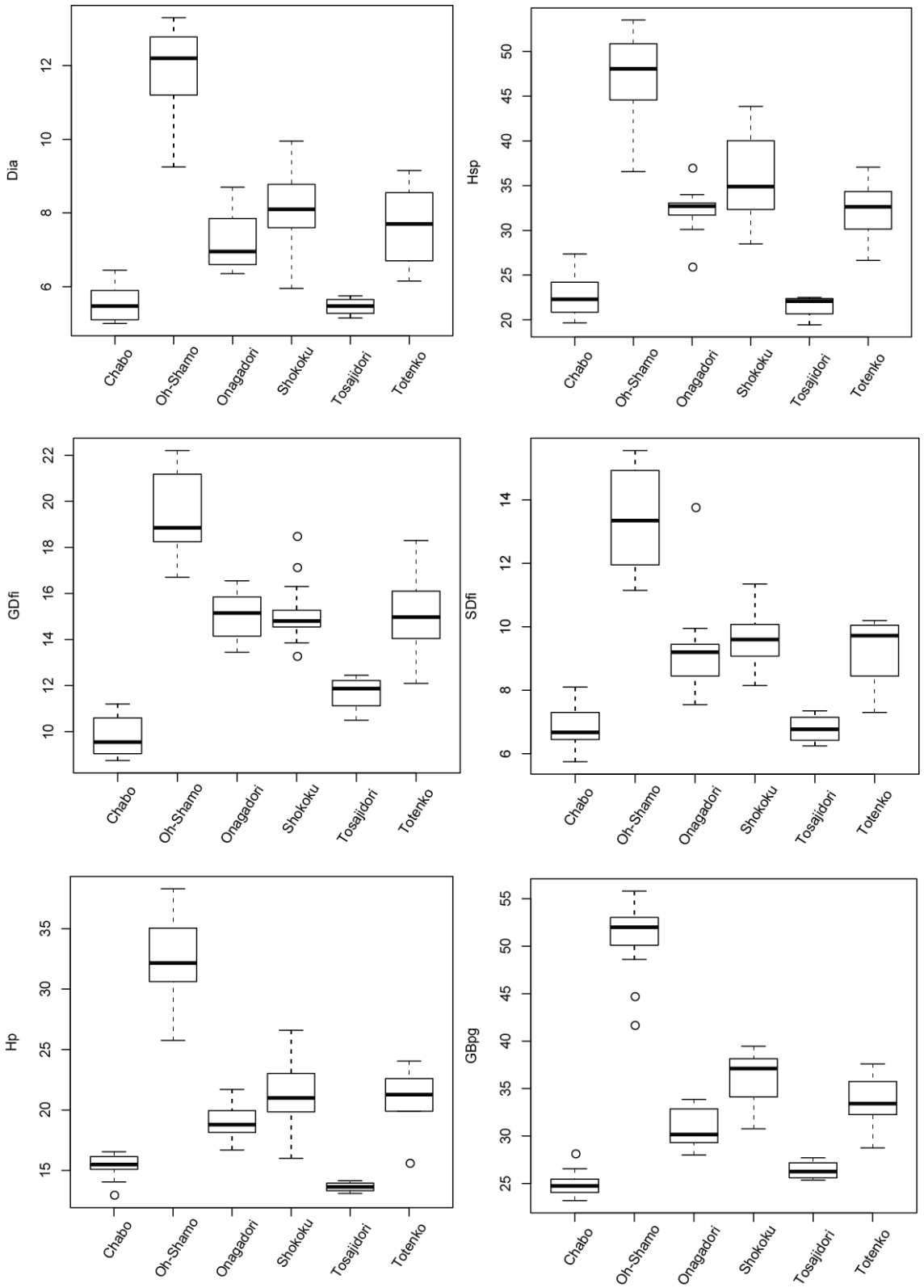

Fig. 3-2-1. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Dia to GBpg were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-1.

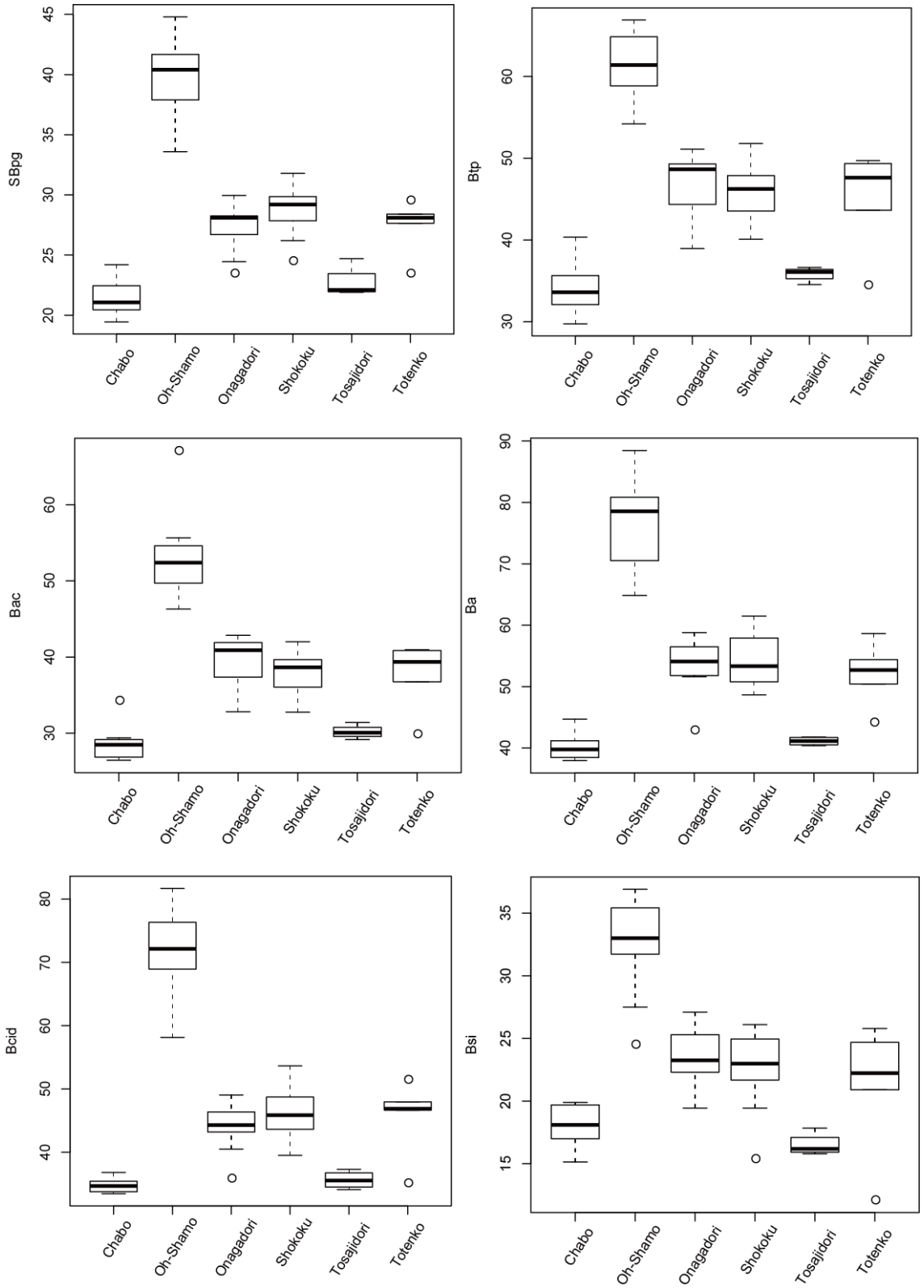

Fig. 3-2-2. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from SBpg to Bsi were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-1.

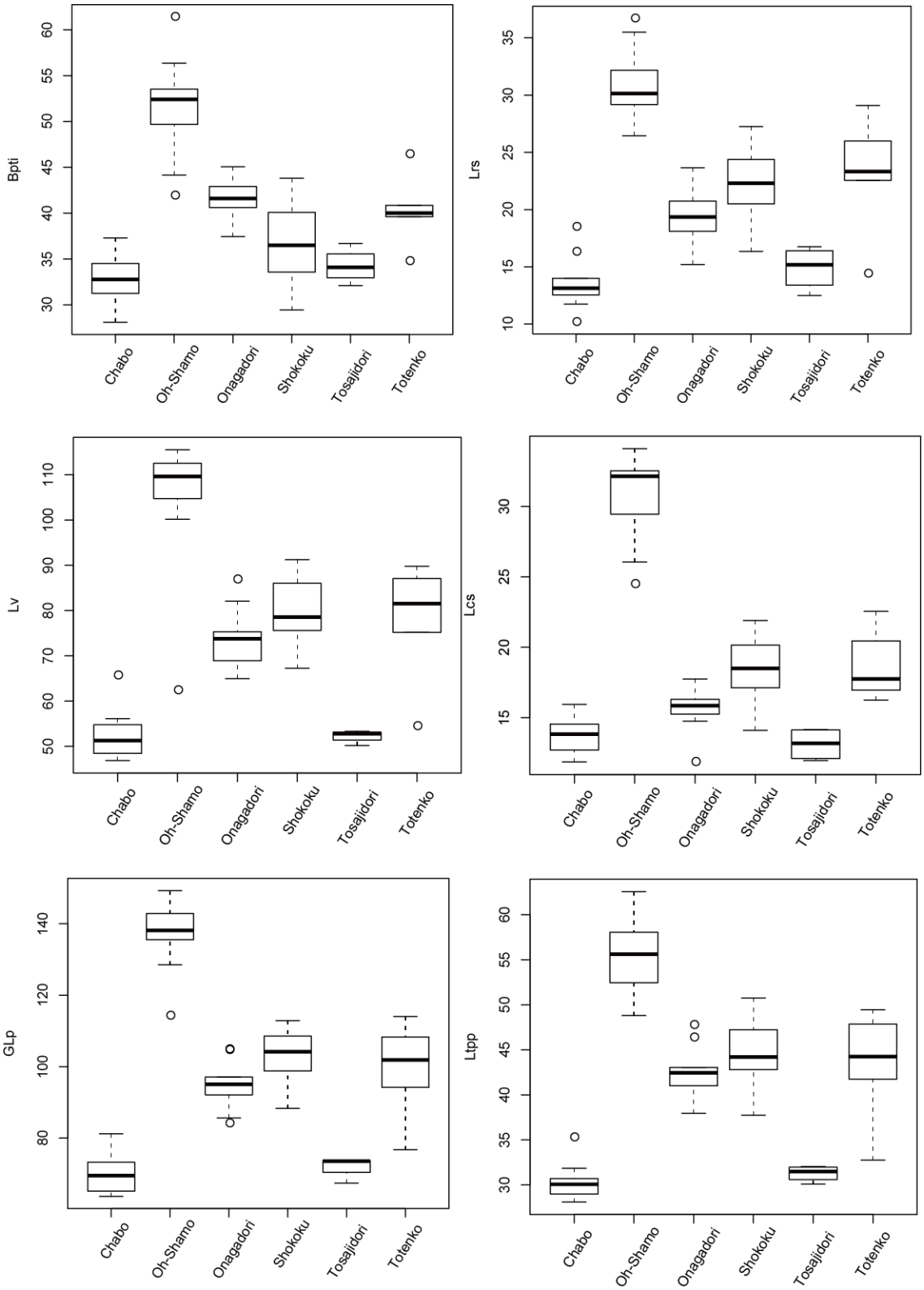

Fig. 3-2-3. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bpti to Ltpp were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-1.

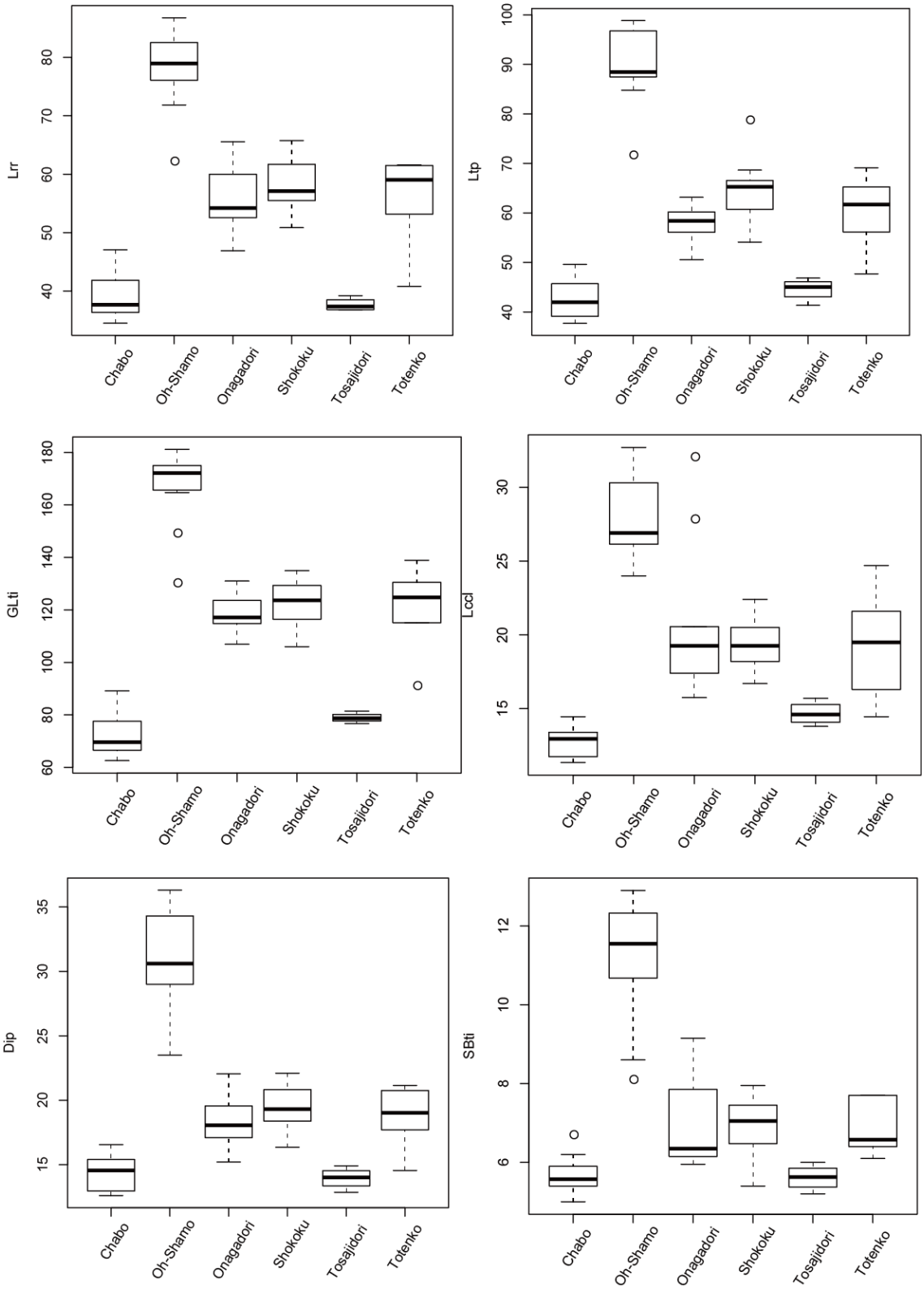

Fig. 3-2-4. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Lrr to SBti were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-1.

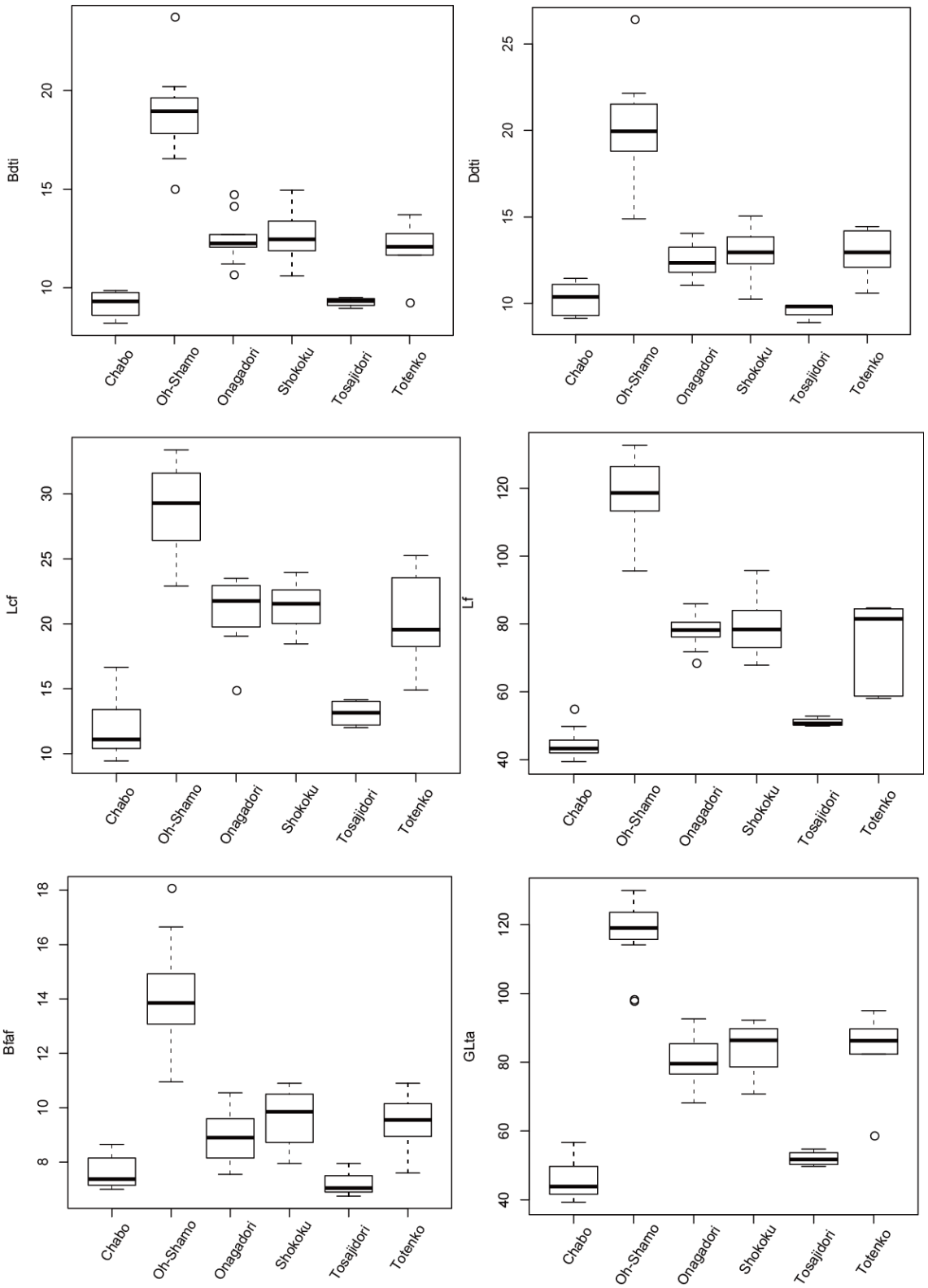

Fig. 3-2-5. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bdti to GLta were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-1 and 3-3-2.

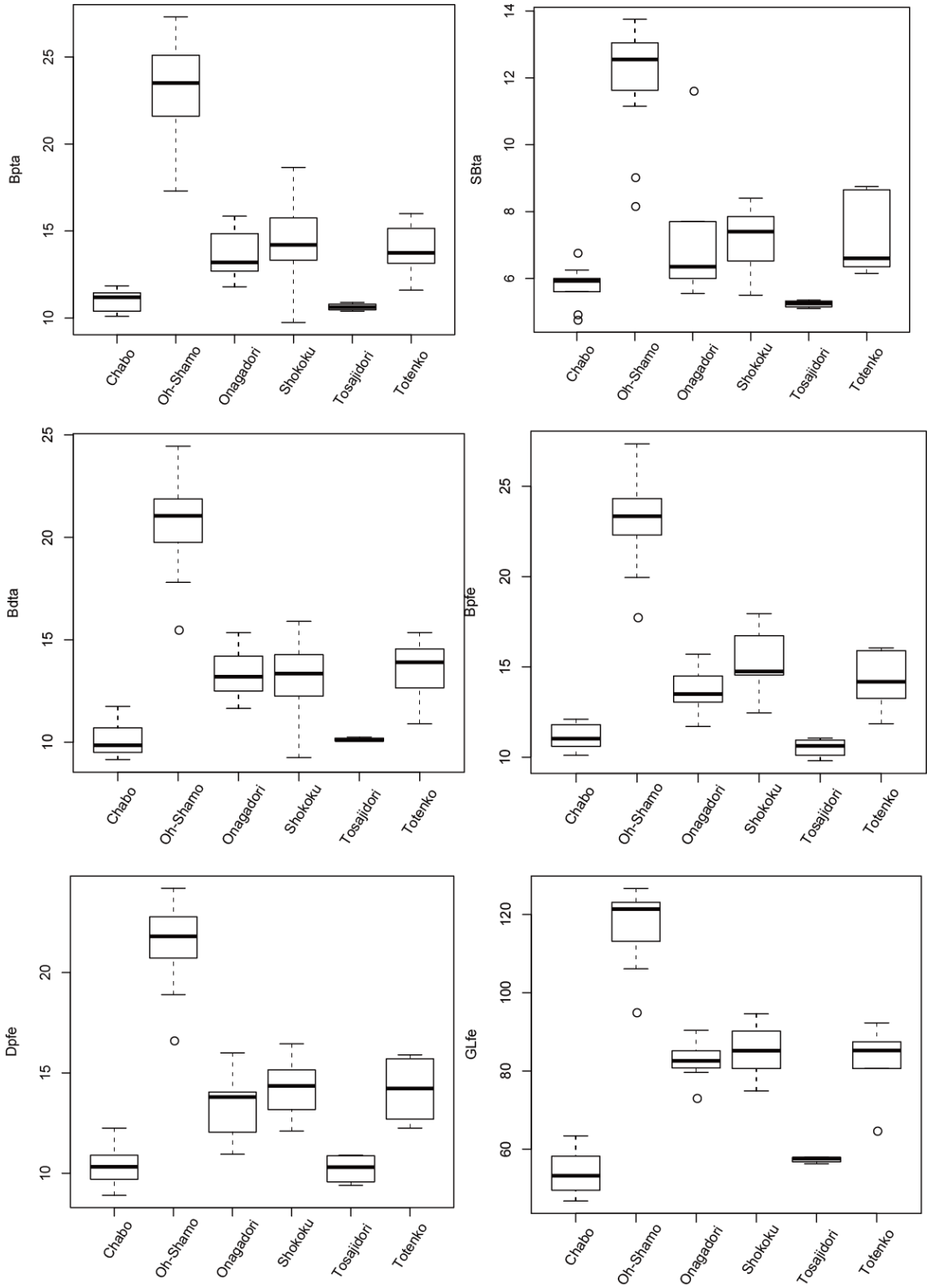

Fig. 3-2-6. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bpta to GLfe were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-3-2.

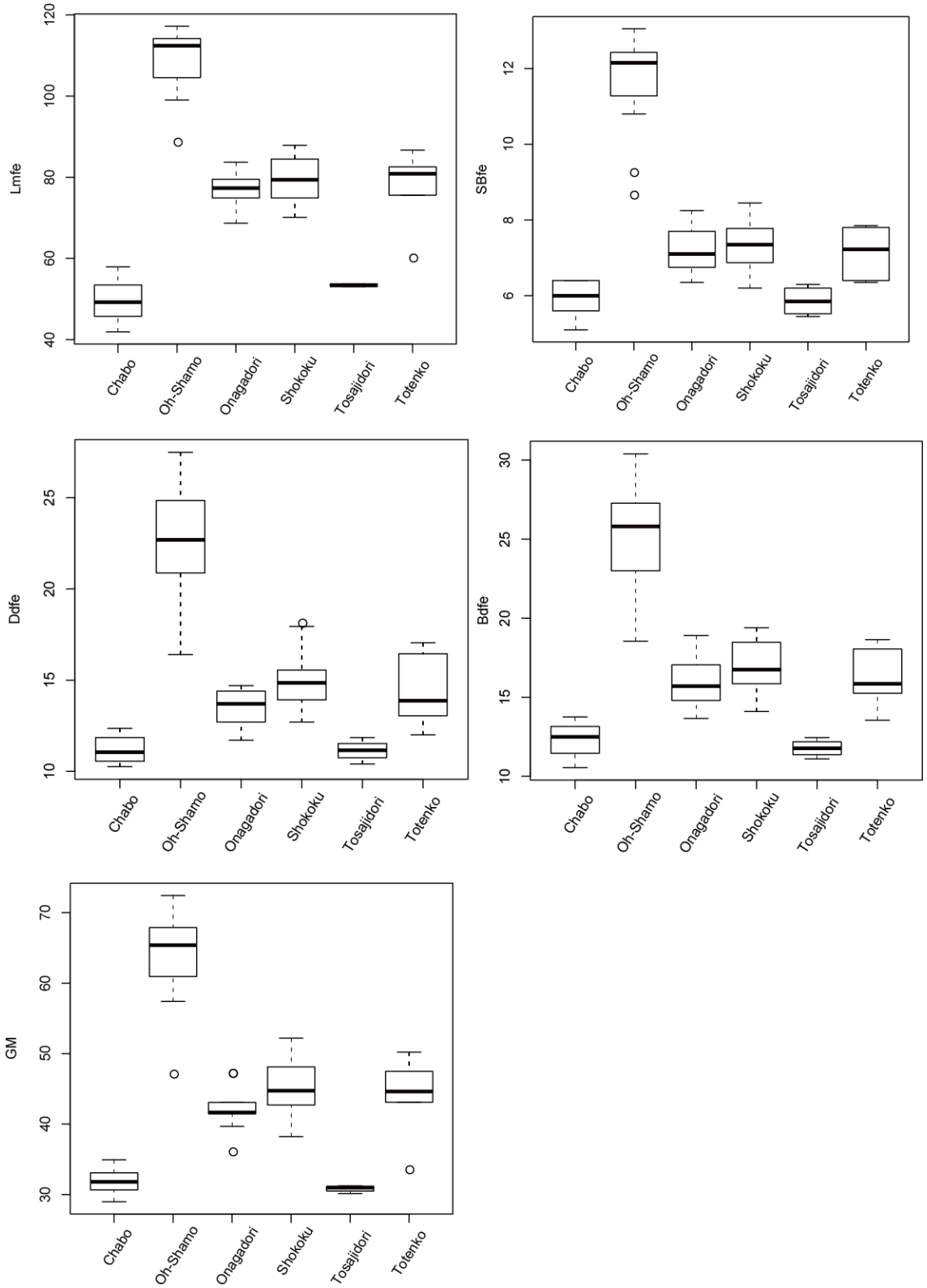

Fig. 3-2-7. The box plots in each measurement of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Lmfe to Bdfe were remarked in Table 3-2. GM shows the calculated geometric mean by using the measurement values of Ba, Hp and Lv. The order of abbreviation follows the order of Table 3-3-2.

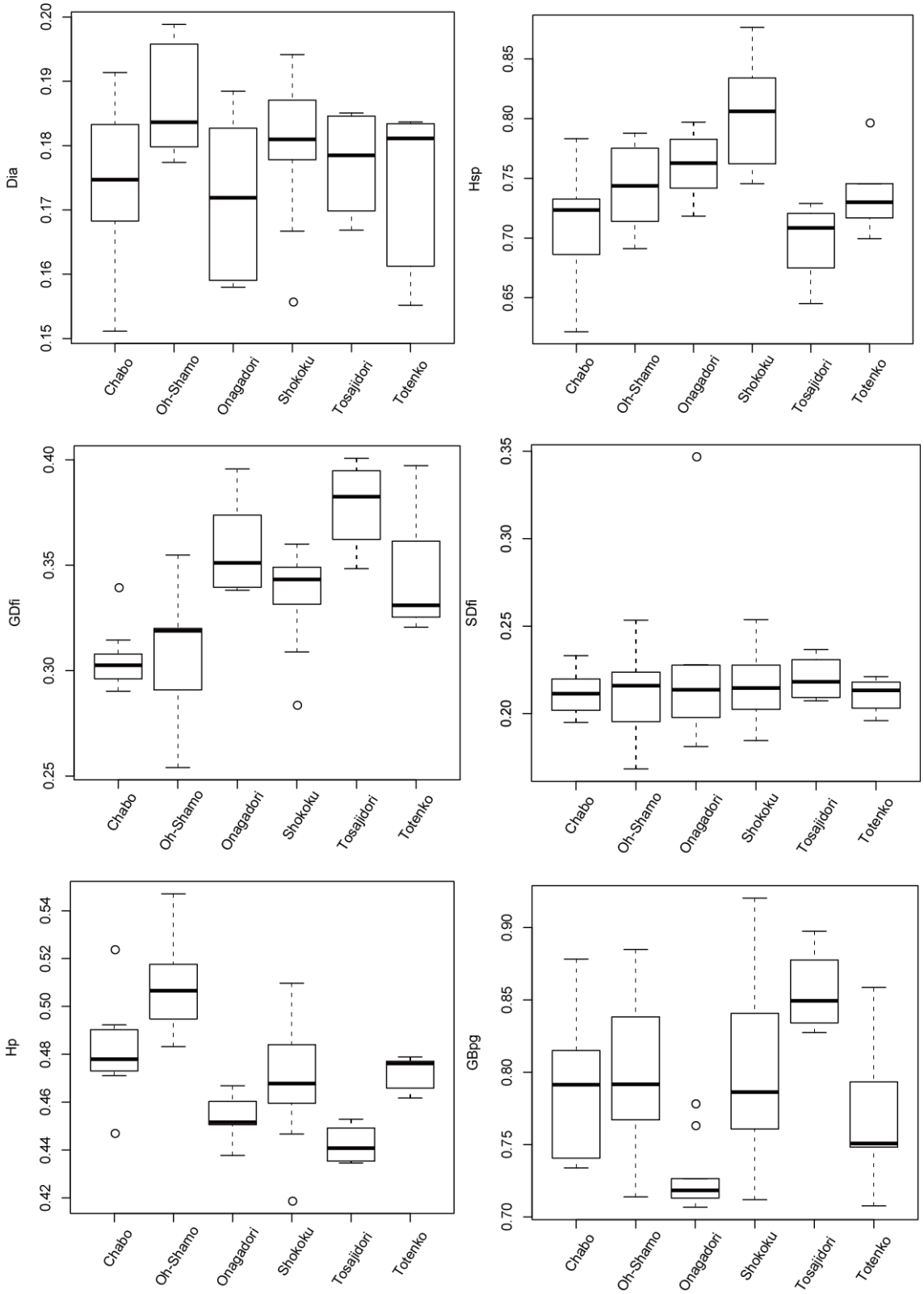

Fig. 3-2-8. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Dia to GBpg were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-1.

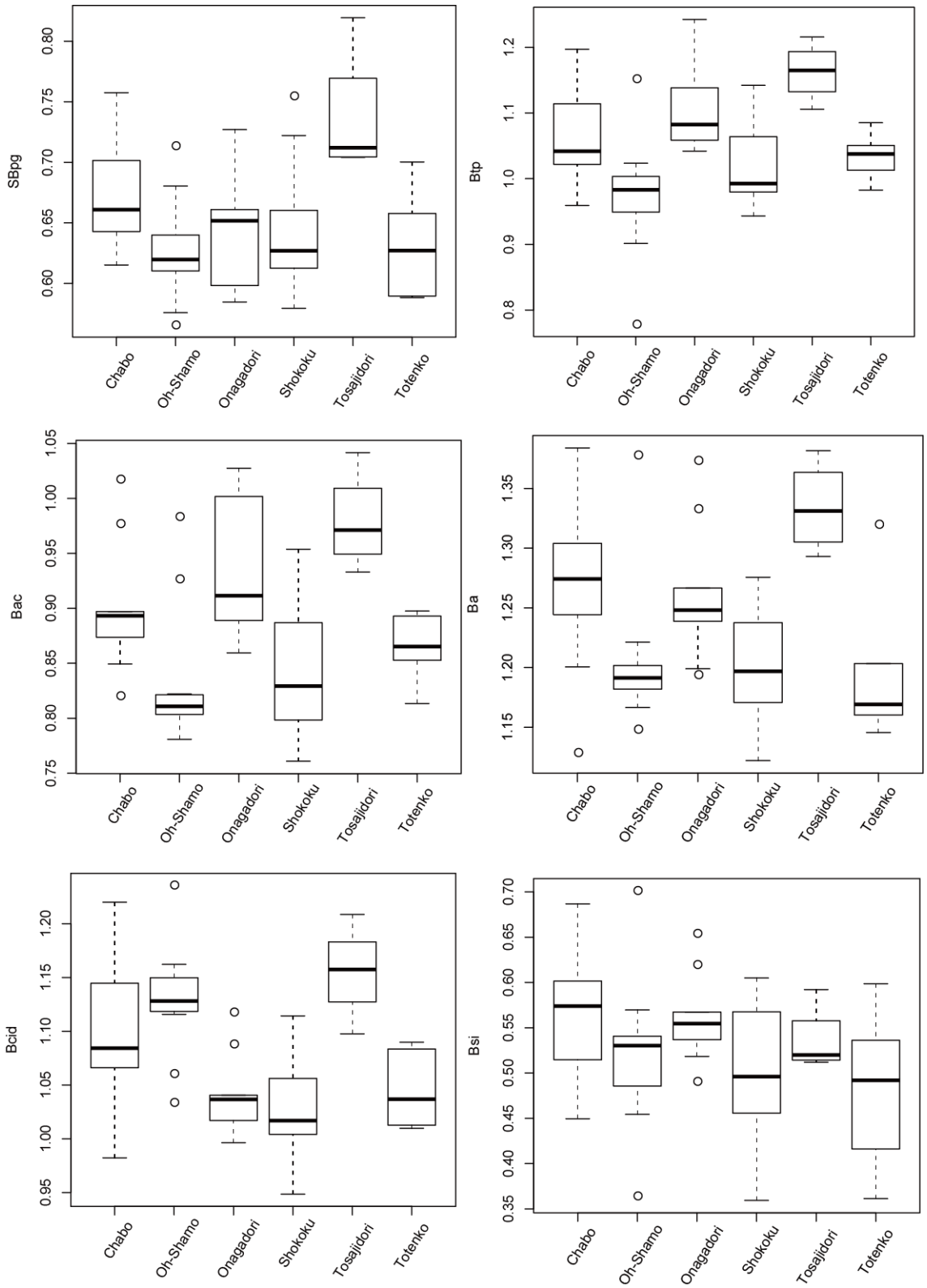

Fig. 3-2-9. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from SBpg to Bsi were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-1.

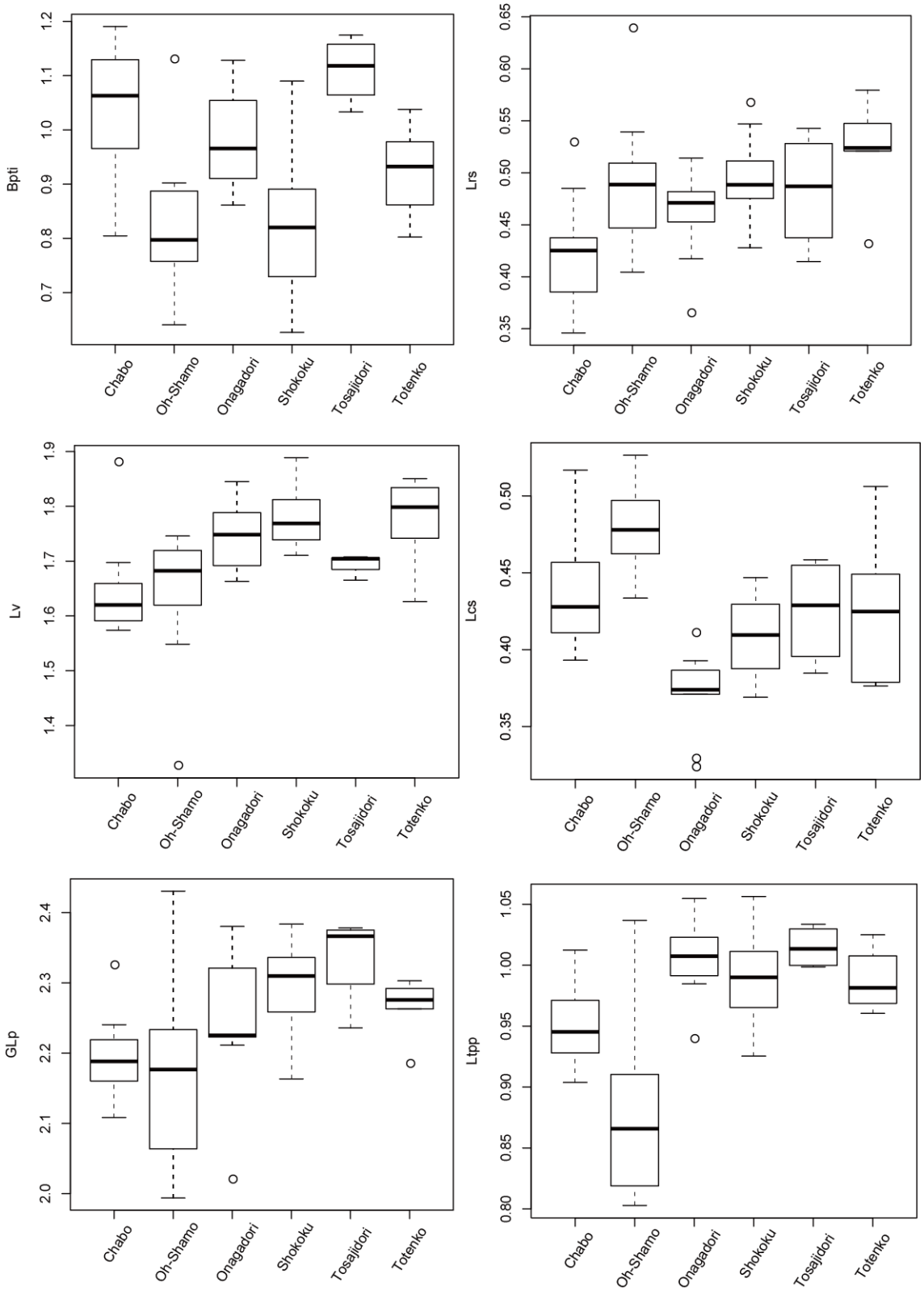

Fig. 3-2-10. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bpti to Ltpp were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-1.

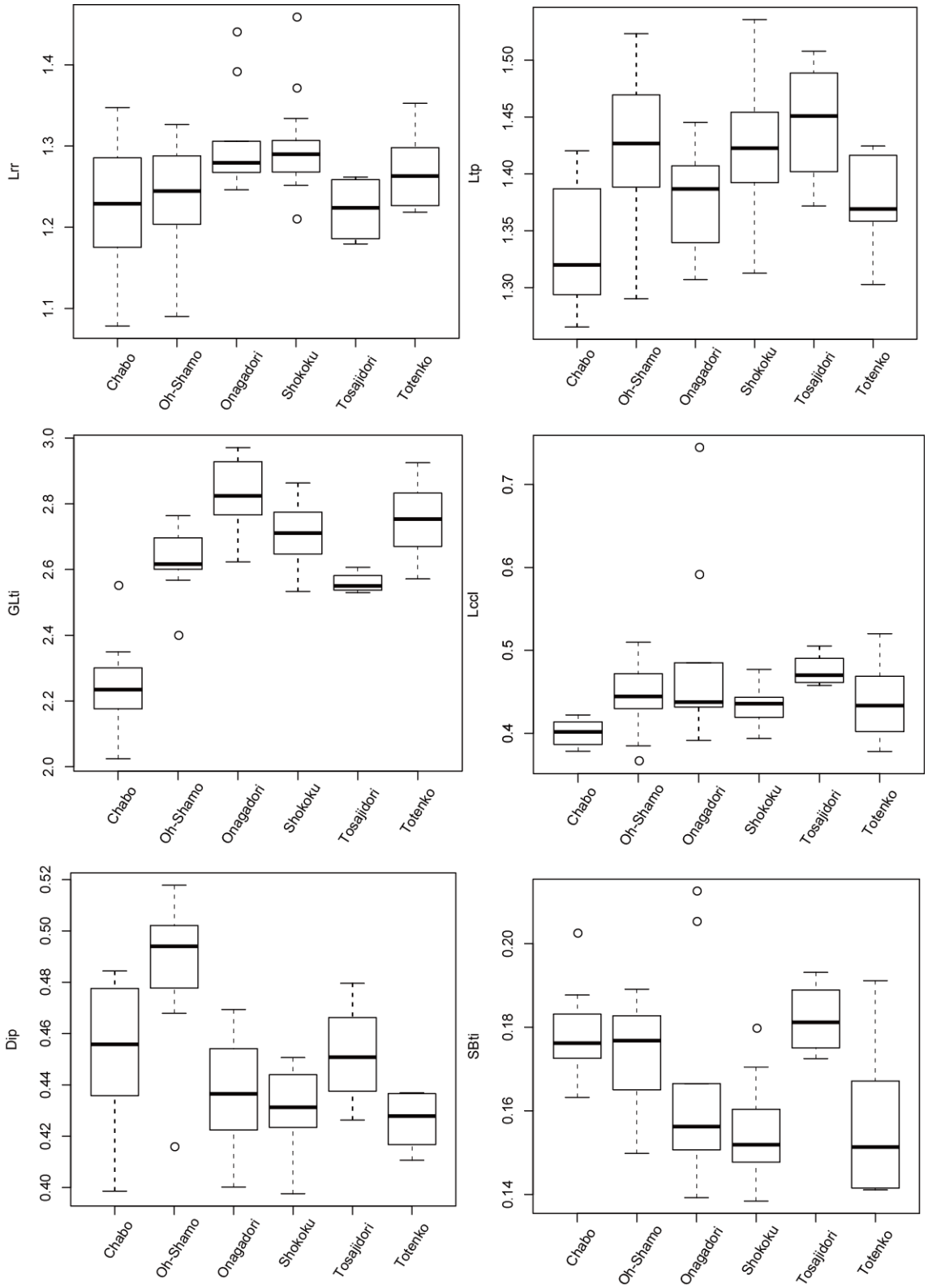

Fig. 3-2-11. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Lrr to SBti were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-1.

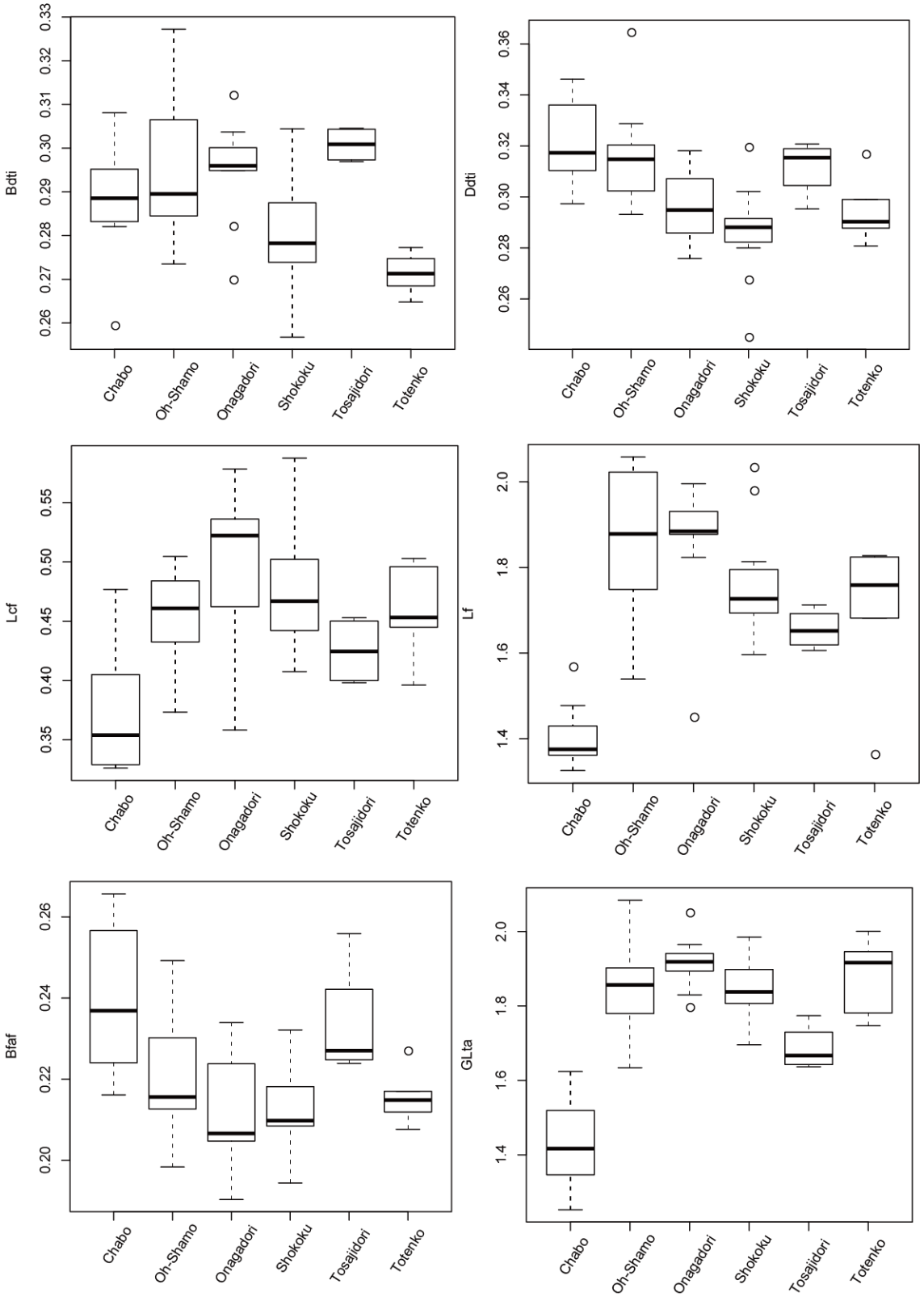

Fig. 3-2-12. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bdti to GLta were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-1 and 3-4-2.

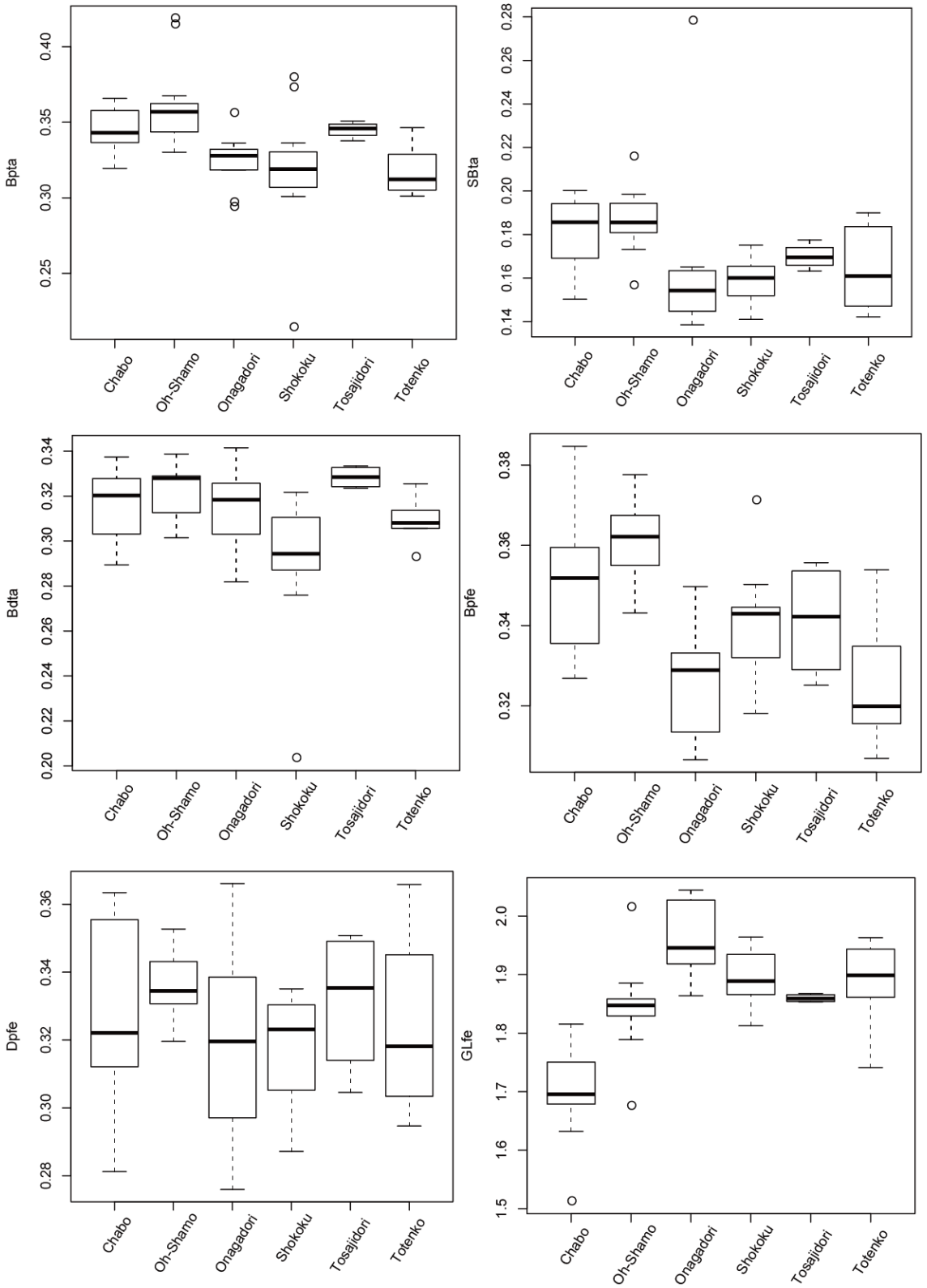

Fig. 3-2-13. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Bpta to GLfe were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-2.

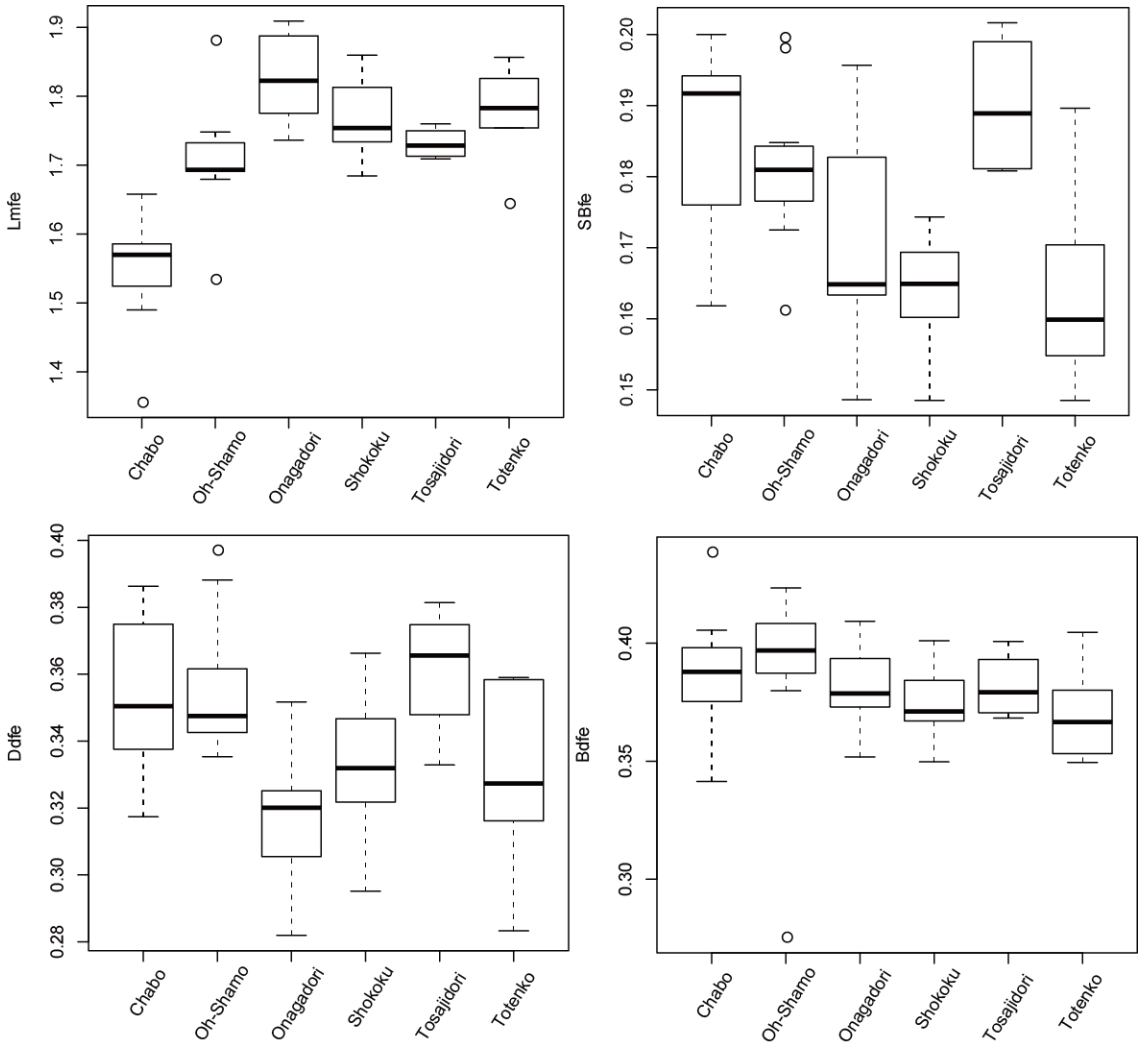

Fig. 3-2-14. The box plots in each measurement ratio of hindlimb, pelvic girdle and pelvis. The abbreviated forms from Lmfe to Bdfe were remarked in Table 3-2. The order of abbreviation follows the order of Table 3-4-2.