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Original Article

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Abstract

Accurate estimation of body weight is useful for feeding program evaluation, assessing nutritional status and general health, and for accurate dose calculation in medical treatment. However, it is impractical to weigh elephants due to their enormous size and tremendous weight, and also due to the lack of a suitable weighing machine. The objective of the present study was to correlate various body measurements and actual body weight of the elephant in order to formulate a regression model to approximate the body weight of the elephant from body measurements. Seventy-eight Asian elephants *(Elephas maximus indicus)* comprising 18 males and 60 females, from 9 months to 57 years in age were used. Body weight, girth measurements (heart, neck and flank), shoulder height, and circumference of feet and elbows were measured. All possible linear regressions of body weight were calculated. The most accurate model when using one parameter for domestic elephants is the flank girth (R^2 = 0.939), although the body weight of domestic Asian elephants can be reliably calculated from various body measurements ($R^2 \geq 0.813$). For wild elephants, we suggested that shoulder height and circumference of feet are more practical ($R^2 \geq 0.839$). Inclusion of sex and age group (< 10 years, 10 to < 20 years, and ≥ 20 years) in the statistical model increased the R^2.

Keywords : Asian elephant, body weight, body measurements, regression model

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บทคัดย่อ

การคำนวณสูตรน้ำหนักตัวของช้างเอเชีย

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การทราบน้ำหนักที่แท้จริงของช้างจะเป็นประโยชน์ในหลายๆ ด้าน ทั้งโปรแกรมการให้อาหาร สุขภาพโดยทั่วไป หรือการคำนวณปริมาณยา แต่เนื่องจากตัวช้างมีขนาดใหญ่และน้ำหนักมาก รวมทั้งการหาเครื่องชั่งที่เหมาะสมก็เป็นไปได้ยาก วัตถุประสงค์ของการศึกษาครั้งนี้เพื่อหาความสัมพันธ์ระหว่างตำแหน่งของร่างกายและน้ำหนักตัวเพื่อใช้ในการคำนวณน้ำหนักโดยศึกษาในช้างเอเชียจำนวน 78 เชือก เป็นช้างเพศผู้ 18 เชือก และช้างเพศเมีย 60 เชือก อายุตั้งแต่ 9 เดือนถึง 57 ปี วัดน้ำหนัก ความยาวรอบอก คอ และสะโพก ความสูงบริเวณไหล่ความยาวรอบวงเท้าและข้อศอกเพื่อหาความสัมพันธ์ในการคำนวณสูตรน้ำหนักให้ใกล้เคียงกับน้ำหนักจริงมากที่สุด โดยใช้สมการเชิงเส้นแบบถดถอย สำหรับช้างเลี้ยงค่าที่ดีที่สุดคือความยาวรอบสะโพก (R^2 = 0.939) ส่วนตำแหน่งอื่นก็สามารถใช้ได้ ($R^2 \geq 0.813$) สำหรับช้างป่า ตำแหน่งที่แนะนำ คือ ความสูงบริเวณไหล่ ความยาวรอบวงเท้า ($R^2 \geq 0.839$) การเพิ่มตัวแปร (เพศ และอายุ) จะช่วยเพิ่มค่า R^2

คำสำคัญ : ช้างเอเชีย น้ำหนักตัว การวัดร่างกาย สมการแบบถดถอย

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Introduction

Elephants (order Proboscidia) have an aquatic ancestry (Gaeth et al., 1999) and are classified in the superorder Afrotheria (Carter, 2001). The Asian elephant is divided to 3 subspecies, and the Thai elephant belongs to *Elephas maximus indicus*. One hundred years ago, there was about 100,000 domesticated elephants in Thailand. In 1998, the number of domestic elephant declined to 2,257, a decrease of 3 percent per year (Prasob, 2001). In 1997, there were only 1,700 domesticated elephants left in Thailand; most are females and young males without tusks (Lohanan, 2001). An elephant can produce only 3-4 offspring during its entire life (Lekakul and MacNeely, 1977). This is due to the long gestation period (18-22 months) and 2-3 years of calf nursing after parturition (resulting in lactational anestrous). Good veterinary care, animal husbandry, and management can be very meaningful in elephant conservation and can decrease the untimely loss caused by illness or accident. Apart from the problem of having medical equipment that is suitable for veterinary use in elephant treatment, knowledge of proper medical dosage and health care are still inadequate. Inaccurate estimation of an elephant's body weight can hamper appropriate medical treatment, cause unpleasant results, and in some instant, can even cause death. Too low or too high a dosage can be the cause of unsuccessful treatment, development of drug resistant and side effects (Pugh, 1991). Accurate body weight is needed for correct dosages (anaesthetics, antibiotics, anthelmintics etc.) and for feeding programs.

Body measurements as parameters in predicting body weight have been studied in many kinds of animals such as cows (Heinrichs et al., 1992), horses (Jones et al., 1989), giraffes (Hall-Martin, 1977) and elephants (Ananthasubramaniam et al., 1982; Sreekumar and Nirmalan, 1989; Hile et al., 1997). Ananthasubramaniam et al. (1982) predicted the body weight of 20 elephants (various ages) using chest and neck girths. Sreekumar and Nirmalan (1989) used 6 parameters to estimate the weight of 39 Indian elephants of both sexes and of various ages. The best estimation was obtained by using two parameters (body length and heart girth). Hile et al. (1997) estimated the body weight of 75 Asian elephants using 4 parameters. Heart girth gave a high R^2 and the correlation coefficient was increased when the body length and pad circumferences were added.

The aim of this study was to correlate various body measurements and actual body weight of the elephant in order to formulate a regression model to estimate the body weight of the elephant from body measurements.

Materials and Methods

Animals

Fifty-five Asian elephants (9 males and 46 females) from Ayudthya Elephant Palace and Royal Kraal, Ayudthya province and 23 Asian elephants (9 males and 14 females) from Elephant Playground and Crocodile Farm, Nakornpathom province, age from 9 months to 57 years were used in this study. Elephants were divided into 3 groups (A: < 10 years; B: 10 to < 20 years; C: ≥ 20 years, Table 1).

Body measurements

Eight parameters were obtained using a measuring tape (m.). The flank girth (F) was measured infront of the wing of ilium. The heart girth (G) was measured around the chest, just behind the elbow. The neck girth (N) was measured at base of the neck, infront of the shoulders. The right and left forefoot circumferences (FR, FL) were measured at the widest of point of the front feet including nails, at the level of sole. The shoulder height (H) was measured from the withers to the ground (Hile et al., 1997). The right and left elbow circumferences (ER, EL) were measured above the elbow joint (Fig.1).

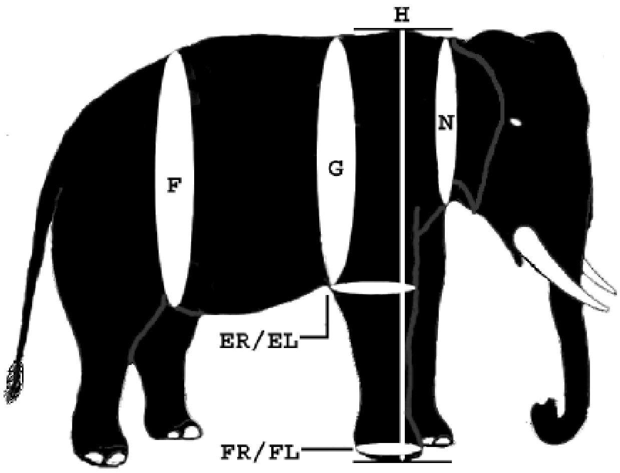

Figure 1 Elephant body measurements.

Weighing

Manual and digital weighing machines [Dietham Trading (Thailand) Co. Ltd.] were used to weigh the elephants from Ayudthya and Nakornpathom respectively. All elephants were weighed in the morning before eating, standing with all four legs on the weighing machine and the weight recorded in kilograms.

Table 1 Age group and number of female and male elephant.

Age group	Female	Male
A (< 10 yrs.)	6	9
B (10 to < 20yrs.)	12	5
C (≥ 20 yrs.)	42	4
	60	18

Statistical analyses

The data were analysed using the statistical software package, SAS (SAS, 1996). The correlation between each body measurement (F, G, N, FR, FL, H, ER, and EL) as an independent variable and the weight of each elephant was evaluated with Pearson's correlation coefficient. The variable parameters that were significantly ($p < 0.05$) related to the weight of elephant were calculated using a linear regression model. The dependent variables (age group, sex) were also added to the models by adapting to two and three way linear regression models respectively (y = a + bx) (y = weight of the elephant in kg, a = intercept point on y-axis, b = regression coefficient, and x = measurement parameter).

Results

Using F, G, and N as body measurements gave an R^2 higher than 0.90 (Table 2) as F has the highest R^2 (0.939) while EL gave the lowest R^2 (0.813).

Tables 3 and 4 demonstrate regression models using two parameters (body measurements/age group and body measurements/sex) for body weight calculation. The regression models using two parameters resulted in a higher R^2 than the model using one parameter. The highest R^2 (0.944) was obtained when using F as the body measurement and the least R^2 (0.87) occurred when H was used with age group as a dependent variable (Table 3).

Table 2 Formulas for estimating elephant body weight using single parameter.

Parameters	Formulas	R^2	Mean ± SD
F	-2881.6 + 1402.4F	0.939	2331.5 ± 207
G	-2493.4 + 1484G	0.936	2331.5 ± 211.9
N	-1776.5 + 1937.3N	0.917	2331.5 ± 242
FR	-2577.4 + 4553.9FR	0.855	2331.5 ± 319
FL	-2676.3 + 4630.7FL	0.839	2331.5 ± 335.5
H	-2850.8 + 2462.3H	0.85	2331.5 ± 324.3
ER	-3222.9 + 5203.4ER	0.846	2331.5 ± 328.5
EL	-2898.2 + 4872.9EL	0.813	2331.5 ± 362.3

Tables 3 and 4 demonstrate regression models using two parameters (body measurements/age group and body measurements/sex) for body weight calculation. The regression models using two parameters resulted in a higher R^2 than the model using one parameter. The highest R^2 (0.944) was obtained when using F as the body measurement and the least R^2 (0.87) occurred when H was used with age group as a dependent variable (Table 3).

Table 3 Formulas for estimating elephant body weight using two parameters: body measurements and age group.

Parameters	Age group	Formulas	R^2	Mean ± SD
F	A	-2635.8 + 1304.8F	0.944	2331.5 ± 200.5
	B	-2579.8 + 1304.8F		
	C	-2448.3 + 1304.8F		
G	A	-2277.3 + 1382G	0.941	2331.5 ± 206.9
	B	-2214.8 + 1382G		
	C	-2094.9 + 1382G		
N	A	-1454.7 + 1661.1N	0.932	2331.5 ± 211.6
	B	-1203.6 + 1661.1N		
	C	-1078.5 + 1661.1N		
FR	A	-1933.5 + 3588.1FR	0.892	2331.5 ± 278.7
	B	-1544 + 3588.1FR		
	C	-1371.2 + 3588.1FR		
FL	A	-1956.9 + 3555.7FL	0.888	2331.5 ± 283.9
	B	-1516.9 + 3555.7FL		
	C	-1331.2 + 3555.7FL		
H	A	-2296.4 + 2071.3H	0.87	2331.5 ± 306
	B	-2101.4 + 2071.3H		
	C	-1891.2 + 2071.3H		
ER	A	-2384.4 + 3988.7ER	0.90	2331.5 ± 267.9
	B	-1930.6 + 3988.7ER		
	C	-1737.3 + 3988.7ER		
EL	A	-2050.9 + 3612.7EL	0.879	2331.5 ± 295.3
	B	-1537.3 + 3612.7EL		
	C	-1342.1 + 3612.7EL		

As sex was used as one of the two parameters (Table 4), F also gave the highest R^2 at 0.944 and EL the lowest at 0.83.

Table 4 Formulas for estimating elephant body weight using two parameters: body measurements and sex.

Parameters	Sex	Formulas	R^2	Mean ± SD
F	F	-3127.4 + 1458.3F	0.944	2331.5 ± 198.6
	M	-2962.3 + 1458.3F		
G	F	-2723.6 + 1543.2G	0.942	2331.5 ± 203.9
	M	-2559.1 + 1543.2G		
N	F	-1623.5 + 1883.1N	0.923	2331.5 ± 234
	M	-1789.6 + 1883.1N		
FR	F	-2378.6 + 4408.3FR	0.863	2331.5 ± 312.6
	M	-2560 + 4408.3FR		
FL	F	-2390.7 + 4486.3FL	0.846	2331.5 ± 330.5
	M	-2651.4 + 4486.3FL		
H	F	-2738.6 + 2418.6H	0.852	2331.5 ± 324.6
	M	-2825.8 + 2418.6H		
ER	F	-2994.6+5030.5ER	0.855	2331.5 ± 321.6
	M	-3183.7+5030.5ER		
EL	F	-2616.3+4667.2EL	0.83	2331.5 ± 347.9
	M	-2881.2+4667.2EL		

Table 5 shows results obtained when three parameters were included (body measurements, sex, and age group). The R^2 using three parameters was highest when F was used (0.952) while H gave the lowest R^2 at 0.87.

Table 5 Formulas for estimating elephant body weight using three parameters: body measurements, sex and age group.

Parameters	Sex	Age group	Formulas	R^2	Mean ± SD
F	F	A	-2872.5 + 1348.4F	0.952	2331.5 ± 187.3
		B	-2796.9 + 1348.4F		
		C	-2641.2 + 1348.4F		
	M	A	-2674.7 + 1348.4F		
		B	-2599.2 + 1348.4F		
		C	-2443.4 + 1348.4F		
G	F	A	-2498.9 + 1427.6G	0.948	2331.5 ± 194.6
		B	-2417.1 + 1427.6G		
		C	-2273.6 + 1427.6G		
	M	A	-2304 + 1427.6G		
		B	-2222.2 + 1427.6G		
		C	-2078.64 + 1427.6G		

Parameters	Sex	Age group	Formulas	R^2	Mean ± SD
N	F	A	-1409.2 + 1664.2N	0.934	2331.5 ± 220.3
		B	-1187.8 + 1664.2N		
		C	-1077.5 + 1664.2N		
	M	A	-1499.9 + 1664.2N		
		B	-1278.5 + 1664.2N		
		C	-1168.1 + 1664.2N		
FR	F	A	-1901.7 + 3587.2FR	0.893	2331.5 ± 279.7
		B	-1529.1 + 3587.2FR		
		C	-1365.1 + 3587.2FR		
	M	A	-1957.5 + 3587.2FR		
		B	-1584.8 + 3587.2FR		
		C	-1420.8 + 3587.2FR		
FL	F	A	-1939.9 + 3553FL	0.888	2331.5 ± 285.6
		B	-1507.3 + 3553FL		
		C	-1325.7 + 3553FL		
	M	A	-1966.3 + 3553FL		
		B	-1533.7 + 3553FL		
		C	-1352 + 3553FL		
H	F	A	-2291.3 + 2070.6H	0.87	2331.5 ± 308.1
		B	-2098.1 + 2070.6H		
		C	-1889 + 2070.6H		
	M	A	-2298.3 + 2070.6H		
		B	-2106 + 2070.6H		
		C	-1896 + 2070.6H		
ER	F	A	-2364 + 3985.8ER	0.901	2331.5 ± 269.4
		B	-1920 + 3985.8ER		
		C	-1731 + 3985.8ER		
	M	A	-2397 + 3985.8ER		
		B	-1952 + 3985.8ER		
		C	-1763.9 + 3985.8ER		
EL	F	A	-2009 + 3619.4EL	0.881	2331.5 ± 295.4
		B	-1524 + 3619.4EL		
		C	-1342 + 3619.4EL		
	M	A	-2096 + 3619.4EL		
		B	-1610 + 3619.4EL		
		C	-1428.4 + 3619.4EL		

Table 6 reveals that the R^2 of all formulas are higher than 0.80. Three body measurements including F, G, and N gave an R^2 greater than 0.90. Using EL in all calculations resulted in the lowest R^2, except when age group was used or included with shoulder height (H) in the formulas.

Table 6 Summary of R^2 from linear regression models using body measurements, body measurements and age group, sex, and age group with sex for body weight calculation.

Parameters	R^2			
	Body measurements	**Body measurements and age group**	**Body measurements and sex**	**Body measurements age group with sex**
F	0.939	0.944	0.944	0.952
G	0.936	0.941	0.942	0.948
N	0.917	0.932	0.923	0.934
FR	0.855	0.892	0.863	0.893
FL	0.839	0.888	0.846	0.888
H	0.85	0.87	0.852	0.87
ER	0.846	0.90	0.855	0.901
EL	0.813	0.879	0.83	0.881

Discussion

Body measurement in elephants can be managed more readily than weighing the animal on a weighing machine (Hile et al., 1997). All parameters from this study can be easily obtained, though the feet (FR and FL) were slightly difficult to manipulate due to the risk of being accidentally stepped on while measuring. From this study, all body measurements can be used to reliably calculate the elephant body weight. Any single body measurement used as the sole parameter to calculate weight gives an R^2 of at least 0.80, flank girth (F) gives the best R^2 at 0.939 (-2881.6+1402.4F, Table2). Heart and neck girths (G and N) are also reliable, with R^2 values of more than 0.90 (-2493.4+1484G and -1776.5 +1937.3N respectively, Table 2). On the other hand, Hile et al. (1997) found that the heart girth was the best single parameter to estimate elephant body weight. The difference in findings may be due to fact that elephants in this study were measured and weighed in the morning before their meal, resulting in less variation when using flank girth as the sole parameter in calculating the elephant body weight.

Inclusion of the dependent variables (age group, sex, and age group with sex) results in an increase in R^2 (Tables 3,4,5 and 6). Hile et al. (1997) reported that R^2 is slightly increased when body length or pad circumference is added. This is in accordance with the report from Sreekumar and Nirmalan (1989) that a more accurate prediction of body weight can be obtained by using more than one parameter. It is interesting to note that R^2 were the least when age group was used or included with shoulder height (H) to calculate the elephant body weight (Table 3,5 and 6). This may reflex the various stages of malnutrition or improper diets of elephant in captivity, that height are not corresponding to age.

Weight approximation in wild elephants needs further consideration, as most body measurements are not possible, except for H, FL, and FR. The height of an elephant can be estimated while FL and FR can be measured from the footprints. The height at the shoulder of an elephant is approximately twice the circumference of the right forefoot (Sreekumar and Nirmalan, 1989). However, Hile et al. (1997) revealed that this approximation is only valid for immature elephants.

Based on the results from our study, we suggest one of the following models be used to approximate the weight of wild elephants according to the specific circumstances: -2850.8 + 2462.3H, -2676.3 + 4630.7FL, or -2577.4 + 4553.9FR. The R^2 for H and FR are ≥ 0.85 while FL is 0.839. This is in agreement with the report that height at the shoulder was the third best parameter (Sreekumar and Nirmalan, 1989) and that pad circumference was the second best single parameter for body weight estimation (Hile et al., 1997). A more accurate body weight calculation for wild elephants can be obtained if age group and sex can be determined and introduced into the model.

Conclusion

1. Asian elephant body weight can be predicted from various body measurements including F, G, N, H, FR, FL, ER, and EL. All R^2 values for each of these measurements were above 0.80 in our study. The best parameter for approximating domestic elephant weight is flank girth, F (-2881.6 + 1402.4F). Sex, age group or sex with age group can be used to improve the accuracy of the approximation.

2. On the other hand H, FL, and FR are more practical for wild elephants (-2850.8 + 2462.3H, -2676.3 + 4630.7FL or -2577.4 + 4553.9FR). Determination of sex, age group or sex with age group can also be used for a more accurate weight approximation.

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References

Ananthasubramaniam, C.R., Chandrasekharan, K. and Surendran, P.U. 1982. Prediction of the body weight from body measurements. Indian Vet. J. 59: 227-232.

Carter, A.M. 2001. Evolution of the placenta and fetal membranes seen in the light of molecular phylogenetics. Placenta. 22: 800-807.

Gaeth, A.P., Short, R.V. and Renfree, M.B. 1999. The developing renal, reproductive, and respiration systems of the African elephant suggest an aquatic ancestry. PNAS. 96(10): 5555-5558.

Hall-Martin, A.J. 1977. Giraffe weight estimation using dissected leg weight and body measurements. J. Wildlife Management. 41(4):740-745.

Heinrichs, A.J., Roger, G.W. and Cooper, J.G. 1992. Predicting body weight and wither height in Holstein heifers using body measurements. J. Dairy Sci. 75(12): 3576-3581.

Hile, M.E., Hintz, H.F. and Erb, H.N. 1997. Predicting body weight from body measurements in Asian Elephants *(Elephas maximus)*. J. Zoo Wildlife Med. 28(4): 424-427.

Jones, R.S., Lawrence, T.L.J., Veevers, A., Cleave, N. and Hall, J. 1989. Accuracy of prediction of live weight of horses from body measurements. Vet. Rec. 125(22): 549-553.

Lekakul, B. and MacNeely, J.A. 1977. Elephant in Thailand: Importance, Status and Conservation. Tiger paper. 4(3): 22-25.

Lohanan, R. 2001. The elephant situation in Thailand and a plea for co-operation. In: Giants on Our Hands. Proceeding of the International Workshop on the Domesticated Elephant. Bangkok, Thailand. 5-10 February: 231-237.

Prasob, T. 2001. Elephant and ecotourism in Thailand. In: Giants on Our Hands. Proceeding of the International Workshop on the Domesticated Elephant. Bangkok, Thailand. 5-10 February: 157-171.

Pugh, D.M. 1991. Introduction and general pharmacology. In:Veterinary Applied Pharmacology and Therapeutics. 5th ed. G.C. Brander, D.M. Pugh and R.J. Bywater (eds). London:Bailliere Tindall. 3-4.

SAS.1996. The SAS system for Windows, version 6.12. SAS Institute Inc, Cary NC, USA.

Sreekumar, K.P. and Nirmalan, G. 1989. Estimation of body weight in Indian Elephants *(Elephas maximus indicus)*. Vet. Res. Com.13: 3-9.