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ALOMETRIC RELATIONSHIPS BETWEEN THE BODY-MASS INDEX, MASS TO SURFACE RATIO AND THE LENGTH OF PREGNANCY IN SOME MAMMALS (Metatheria and Placentalia)

A. Atanasov[1*], M. Todorova[2], D. Valev[3], R. Todorova[4]

[1]Department of Physics and Biophysics, Faculty of Medicine, Trakia University, Stara Zagora, Bulgaria
[2]Department of Obstetrics and Gynecology, Faculty of Medicine, Trakia University, Stara Zagora, Bulgaria
[3]Space Research and Technology Institute, Stara Zagora, Departments, Bulgarian Academy of Sciences, Bulgaria
[4]Institute of Biophysics and Biomedical Engineering, Bulgarian Academy of Sciences, Sofia

ABSTRACT
Body mass index (BMI) is characteristics in human physiology represented by the ratio between the body mass and the square of body height, i.e. BMI = Mass/Height^2. In the case of animals (mammals) the BMI can be defined by the length of the body i.e. BMI = Mass/Legth^2. In manuscript is showed existence of relationship between the body mass M(kg), length L(m), surface S(m^2), body mass to surface ratio M/S (kg/m^2) as well as body mass index BMI(kg/m^2) and the length of pregnancy T (days).

Key words: body mass index, length, surface, pregnancy, human, veterinary medicine.

INTRODUCTION

Body mass index (BMI) is a physiological characteristics represented by the ratio of body mass and the square of body height, i.e. BMI = Mass/Height^2. Body mass index is characteristics often used for purpose of diagnostics in Human medicine (1). But BMI is not well developed like prognostic characteristics in Veterinary medicine. In case of mammals the BMI can be defined by the length of the body i.e. BMI = Mass/Legth^2. The field of Veterinary medicine contained wide spectrum of animals (Poikilotherms, Mammals and Aves) with wide spectrum of characteristics: body mass, length and lifetime characteristics (lifespan, length of pregnancy, during puberty, during excretion of drugs) that differs some orders of magnitude between them. However, the connection between BMI and these characteristics is not study. The aim of the work is to investigate the alometric relationship between the body mass, body length, body surface, body mass to surface ratio and the body mass index and the length of pregnancy in Mammals.

***Correspondence to**: *Atanas Todorov Atanasov, Medical Faculty, Dept. Physics and Biophysics,Trakia University, Armeiska Str. 11, Stara Zagora, BULGARIA, E-mail: atanastod@abv.bg*

MATERIALS AND METHODS

The data for the 103 studied mammal species Metatheria and Placentalia (from Common shrew to Killer whale), their body mass, body length and pregnancy length were collected from the review papers (2-5). The body surface S (m^2) were calculated by formula S=0.1M$^{0.67}$, where the body mass M is given in kg (6, 7).The body length of animals H (m) was given to be from head to tail i.e. the length of head plus length of spinal cord, without length of the tail.

RESULTS

The relationships between the body mass M (kg), square of body length H^2 (m^2), body length H (m), body surface S (m^2), body mass to surface ratio M/S (kg/m^2) and body-mass index M/H^2) as a function of length of pregnancy T(d) are given on **Table 2**. On **Figure 1** are compared relationships of BMI, M/S ratio as functions of the length of pregnancy T.

***Table 1.**. Experimental and calculated data for Mammals.*

Animals	M (kg)*	T_{pr} (d)*	S (m^2)	M/S (kg/m^2)	H (m)*	BMI (kg/m^2)
1. Sorex araneus	0.008-0.015	20	5.00×10^{-3}	2.3	0.06-0.09	2.044
2. Mus musculus	0.021	19-20	7.514×10^{-3}	2.795	0.11	17.36
3. Cricetulus migratorius	0.021	20	7.514×10^{-3}	2.795	0.13	12.43
4. Myomimus personatus	0.024-0.025	20-25	8.33×10^{-3}	2.941	0.11	2.025
5. Mustela nivalis	0.1	54	0.0214	4.673	0.28	1.276
6.Rattus rattus	0.20-0.35	20-24	0.0421	6.535	0.13-0.24	8.041
7.Chinchilla laniger	0.30-0.60	108-112	0.0585	7.7	0.27	6.173
8.Rattus norvegicus	0.384	21-22	0.0526	7.3	0.18-0.25	8.312
9.Cricetus cricetus	0.40-0.50	30	0.0586	7.68	0.24-0.32	5.74
10.Gavia porcellus	0.51	68	0.0637	8	0.28-0.30	6.064
11.Sciurus vulgaris	0.18-1.0	38-44	0.0702	8.4	0.19-0.29	8.682
12.Mustela lutreola	1	42-46	0.1	10	0.43	5.408
13.Erinaceum europaeus	0.7-1.0	49	0.0897	9.48	0.20-0.30	13.6
14.Ondatra zibethica	0.95	25	0.0966	9.83	0.25-0.30	12.6
15.Citellus major	1.05	30	0.103	10.1	0.23-0.33	13.4
16.Mustela vison	1.5	34-78	0.312	11.43	0.4	9.375
17.Lepus tolai	3.0-4.0	50	0.231	15.12	0.4-0.53	7.527
18.Marmota bobac	4.5-6.0	30	0.304	17.28	0.5-0.7	14.58
19.Lepus europaeus	4.0-5.0	44	0.274	16.43	0.5-0.7	12.5
20.Lepus timidis	3.0-5.0	47-55	0.253	15.8	0.44-0.74	11.49
21.Felis libyca	5	60	0.294	17	0.7	10.2
22.Felis silvestris	6	63	0.332	18.06	0.75	10.67
23.Alopex lagopus	6	52	0.332	18.06	0.5-0.75	15.34
24.Marmota marmota	4.0-8.0	35	0.332	18.06	0.57	18.4
25.Urocyon cinereoargentus	7	63	0.372	18.81	0.5-0.8	16.59
26.Myocastor coypus	up to 6	130	0.332	18.06	0.6-0.8	12.24
27.Felis familiaris	up to 6	60-63	0.332	18.06	0.3-0.4	48.98
28.Dasypus novemcinctus	6	120	0.332	18.07	0.8	9.38
29.Vulpes vulpes	6-10	49-58	0.403	19.86	0.6-0.9	14.22
30.Nyctereutes procyonoides	6-10	65	0.403	19.86	0.65-08	15.22
31.Procyon lotor	7-8	63	0.386	19.44	0.5-0.6	24.8
32.Canis aureus	7-13	60-63	0.468	21.38	0.7-1	13.84
33.Hylobacter lar	10	210	0.468	21.38	1	10
34.Canis latrans	13	60-66	0.558	23.31	0.7-10	18
35.Capreolus capreolus	20-37	165	0.943	30.2	1.2	19.8
36.Gulo gulo	30	120	0.976	30.73	0.8	46.87
37.Lynx lynx	32	63-70	1.012	31.38	1.2	22.22
38.Gazella subgutturosa	33	150-180	1.04	31.7	1.16	24.52
39.Rupicapra rupicapra	25-45	180	1.083	32.17	1.2	24.3
40.Capra aegagrus	up to 38	150	1.144	33.21	1.5	16.9
41.Panthera pardus	32-40	90	1.103	32.63	1.8	11.11
42.Canis lupus	32-50	65-75	1.204	34.06	1.3	24.11
43.Ovis aries	49	148	1.356	36.12	1.3	28.8
44.Pan troglodytes	70	270	1.723	40.63	1.5	31.11
45.Homo sapiens	60	280	1.554	38.61	1.65	22
46.Saiga tatarica	60	150	1.554	38.61	1.14	46.5
47.Canis lupus	up to 65	60-65	1.64	39.65	1-1.6	38.23
48.Ovis orientalis	46-79	150	1.597	39.04	1.47	28.9
49.Delphinus delphis	53	300-330	1.43	37.07	2.5	8.48
50.Canis familiaris	65	64-68	1.64	39.65	1	65
51.Crocuta crocuta	59-82	110	1.731	40.73	1.3	41.47
52.Macropus rufus	80-150	275	2.403	47.87	2-3	18.4
53.Panthera pardus	75	90	1.804	41.57	1.8	23.15
54.Dama dama	100	240	2.188	45.71	1.4	51
55.Zalophus californianus	100	360	2.188	45.71	1.75	32.65
56.Felis concolor	up to 105	90	2.26	46.45	1.3	61.76
57.Sus scrofa	60-150	124-140	2.26	46.45	2	26.25
58.Ovis ammon	100-170	150-180	2.675	50.47	2	33.75
59.Capra falconeti	109	150-180	2.318	47.03	1.7	37.7
60.Capra ibex	110	154-161	2.332	47.17	1.6	43
61.Tursiops truncatus	120	330-360	2.472	48.54	3	13.33

62.Ursus thibetanus	140	210	2.741	51.07	2	35
63.Capra sibirica	100-130	170-180	2.4	47.87	1.65	42.3
64.Phoca vitulina	150	270-300	2.87	52.25	1.8	42.3
65.Lama glama	up to 101	330-397	2.202	45.86	1.6	39
66.Ovis ammon	100-170	150-180	2.675	47	2	33.75
67.Pagopoca groenlandica	170	330	3.122	54.46	2	42.5
68.Cervus nippon	148	240	2.845	52.02	1.18	106
69.Panthera leo	180-240	105-112	3.596	58.39	2.7	28.8
70.Gorilla gorilla	110-300	270	3.539	57.93	2	51.25
71.Tapirus terrestris	200	390-400	3.481	57.45	1	200
72.Panthera tigris	227-272	95-154	4.037	61.81	2.9	29.73
73.Ursus arctos	250	180-240	4.042	61.85	2	62.5
74.Pongo pigmaeus	up to 250	270	4.042	61.85	1.5	111.1
75.Monachus monachus	300	315	4.567	65.68	2.75	39.7
76.Cervus elaphus	300-340	165-224	4.77	67.1	2.4	55.55
77.Ovibos moschatus	up to 300	270	4.567	65.68	2.4	52.08
78.Equus burchelli	up to 350	361-390	5.064	69.11	2.5	56
79.Cystophora cristata	400	330	5.535	66.74	2.8	51
80.Kogia breviceps	400-500	270	5.993	75.087	3	50
81.Camelus bactrianus	450-490	365-440	6.17	76.175	3	52
82.Ursus maritimus	700	230-250	8.058	86.87	2.5	112
83.Bison bonasus	600-800	270	8.058	86.87	3.5	57.14
84.Poephagus gruniens	up to 720	255-304	8.211	87.69	4	45
85.Equus cabalus	up to 700	350	8.058	86.87	3	77.8
86.Ursus horribilis	up to 800	250	8.812	86.87	2.75	105.8
87.Bubalus caffer	800-1000	270-280	9.535	90.78	2.75	132.3
88.Giraffa camelopardalis	1000	420-446	10.23	94.4	4	62.5
89.Bison bison	1000	265-270	10.23	97.75	3	111.1
90.Delphinapterus leucas	1000	330-360	10.23	97.75	5	40
91.Bubalus aranee	1000-1200	300-328	10.9	97.75	1.9	160.34
92.Syncerus caffer	1000-1200	330	10.9	100.92	2.2	227
93.Tapirus indicus	1500	390-395	13.43	100.92	2.5	240
94.Diceros bicornis	up to 2000	450-548	16.28	111.7	3.8	138.5
95.Rhinoceros unicornis	up to 2000	484.5	16.28	122.85	3.15	201.5
96.Hippopotamus amphibius	3200	210-240	22.31	143.43	4.5	158
97.Ceratotherium simum	3000	540	21.36	140.45	4.5	148.14
98.Elephas maximum	5000	607-641	30.08	166.2	5	200
99.Loxodonta africana	7500	660	39.47	190	5	300
100.Orcinus orca	12500	480	55.58	224.9	8	195.3
101.Balaenoptera physalus	100000	360	223.87	446.69	25	160
102.Balaena mysticetus	100000	360	223.87	446.69	21	226
103.Balaenoptera musculus	160000	420	306.73	521.68	32	161.24

The correlation coefficients R^2 of relationships given on **Table 2** vary between 0.612 and 0.941. This shows that the relationships are not random. The power and linear coefficients in the relationships for body surface and the square of body length differ negligible i.e. these relationships are nearly equivalently in relation to the length of pregnancy.

The **Figure 1** shows that the scaling exponent of relationships: $M/S = 0.3474\ T^{0.9768}$ and $M/H^2 = 0.2184\ T^{0.9968}$ differ negligible (0.9768 and 0.9968), as well as the linear coefficient (0.3474 and 02184), and corresponding coefficients (0.753 and 0.612) in two relationships. Thus, the BMI and M/S ratio are equivalently in relation to the length of pregnancy too.

***Table 2**. Alometric relationships between the body parameters and the length of pregnancy*

n	EQUATIONS	Correlation coefficient R^2
1.	$M = 2.248\times10^{-5}\ T^{2.9744}$	$R^2 = 0.7553$
2.	$H^2 = 9.85\times10^{-5}\ T^{1.9864}$	$R^2 = 0.7244$
3.	$H = 9.81\times10^{-3}\ T^{0.9931}$	$R^2 = 0.7283$
4.	$S = 8.093\times10^{-5}\ T^{1.9844}$	$R^2 = 0.7539$
5.	$M/S = 0.3474\ T^{0.9768}$	$R^2 = 0.7534$
6.	$M/H^2 = 0.2184\ T^{0.9968}$	$R^2 = 0.612$
7.	$H^2 = 1.123\ S^{0.9906}$	$R^2 = 0.941$

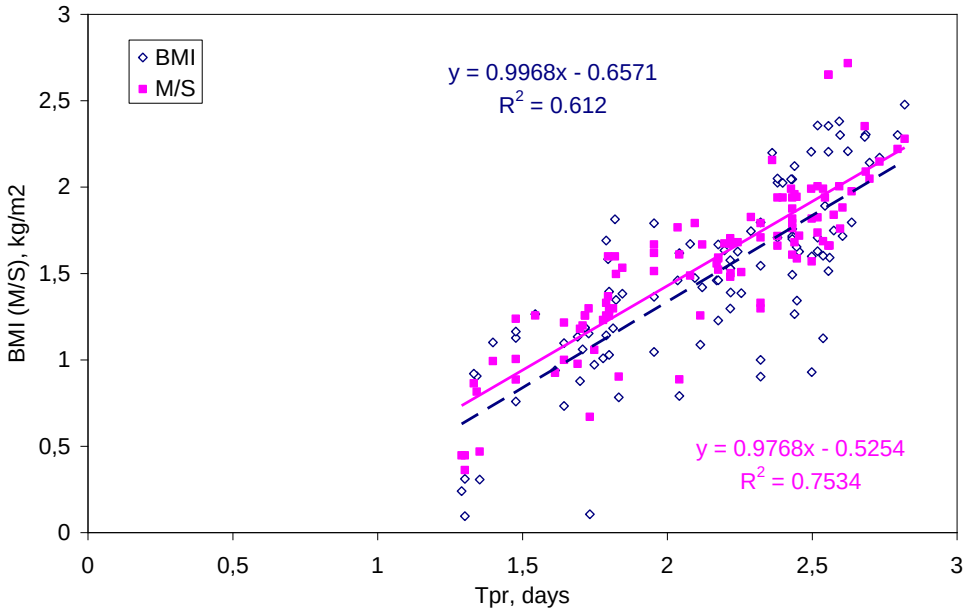

Figure 1. Linear relationships between BMI, M/S ratio and length of pregnancy T in 103 Metatheria and Placentalia. The power coefficients 0.9968 and 0.9768 in two relationships are very near to 1.0.

The found relationships can be used for prognostic purpose in the human and the veterinary medicine.

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