

Modified Formulas for Calculation of Encephalization Quotient in Dogs

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Research note

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Abstract

Objective

Dogs are a breed of animals that play important roles, ranging from security passing through companionship to models of research for application in humans. Intelligence is the key factor to success in life, most especially for dogs that are used for security purposes at the airports, seaports, public places, houses, schools and farms. However, it has been reported that there is correlation between intelligence, body weight, height and craniometry in human. In view of this, literatures on body weight, height and body surface areas of ten dogs were assessed with a view to determining their comparative level of intelligence.

Results

Findings revealed that dogs share brain common allometric relationships with human as shown by Encephalization Quotient (EQ) = Brain Mass/0.14 x Body weight^{0.528} as compared with Brain Mass /0.12 x Body Weight^{0.66} and Brain Mass (E) = $k p^\beta$, where p is the body weight, $k=0.14$ and $\beta=0.528$ which yielded better results as compared with the other formulas. Dogs with BSA, weight and height similar to that of human are the most intelligent. Doberman Pinscher is the most intelligent followed by German Shepherd, Labrador Retriever, Golden Retriever, respectively.

Introduction

The neural basis of human intelligence in relation to brain weight, head circumference as identified by computed tomography (CT) or magnetic resonance imaging (MRI) is 0 to 0.6 with verbal ability correlating with cerebral volume, and each hemi-sphere volume in women and in right handed men accounting for 36% of the variation in verbal intelligence [1]. But body temperature, digestive state, and phylogeny does not support the scaling of basal metabolic rate (BMR) to $\frac{3}{4}$ but support the scaling to $\frac{2}{3}$ [2]. Lack of support for a single exponent model suggest that there is no universal accepted allometry [3]. Geometrical similar objects exhibit isometry, whereas geometrically dissimilar objects exhibit allometry. Brain weight is an index of intelligence [4]. Relative low birth weight is related to intelligence in 3-5-year-old children [5] and variation in brain size is related to intellectual achievement [6]. Numerical comparison of relative brain to body size is called encephalization quotient (EQ) [7]. The EQ for pig and sheep (0.6), giraffe (0.7), Bactrian camel (0.8), Llama and guinea pig (0.9), European cat (1.1), dog (1.2), vicuna (1.4), ring-tailed lemur (1.5), gorilla (1.4 – 1.7), fox (1.6), Asian elephant (2.3), chimpanzee (2.2. – 2.5) and human (7.3 – 7.7) have been established, respectively [7-10]. The efficiency of brain structural organization could be an important biological basis for intelligence [11]. Metabolic resources and brain size share same relationship with body size across mammals. Hence, lean body mass is the more appropriate scaling parameter for comparing brain size across species than is the overall body weight [12]. The EQ for dolphin (5.3) and monkey (4.8) suggest that intelligence may depend on the amount of neural reserve after the brain's menial chores and brain size [13]. Placental brain size evaluation cannot

be generalized to mammals [14]. Human evolution expanded brains to increase expertise capacity not intelligence quotient [15]. Expansion and differentiation of neocortex increases brain size and complex function of the brain [16], but carnivores have intermediate values of K [17]. In humans brain volume, grey matter, white matter, cortical thickness, cortical convolution and neural efficiency are used to measure intelligence [18]. Since different formulas used to calculate EQ provided different values, there is need for modification of the formulas with a view to providing formula that would provide efficient EQ.

Materials And Methods

Relationship between brain mass and body height in man is:

Brain Mass = 920g (± 113) + 2.70 (± 0.65) x body height and in woman is:

Brain Mass = 748g (± 104) + 3.10 (± 0.64) x body height [19]. But for animals the Eencephalization

Quotient (EQ) is: $\frac{\text{Brain Mass}}{0.12 \times \text{Body weight}^{2/3}}$ [17], modified as $\left(\frac{\text{Brain Mass}}{0.14 \times \text{Body weight}^{0.528}}\right)$ and used for the present study. The majority of animals are expected to have an EQ of 1. Therefore a value higher than 1, may suggest higher than average intelligence [7]. However, percent body fat (%bf): $0.339 + 2.942$ (logWT) [12] should be considered when the dogs are either obese or over weight. The formula for linking hominal skull volume to brain volume is: $\log_{10}(B) = 3.015 + 0.986 \log_{10}(C)$, where B (total brain size in mm^3) and C (internal cranial capacity in cubic centimeter) is expressed as $y = 0.39x^{0.27}$, where 0.39 (integral constant), X (bw mean) and 0.27 (allometric exponent) are considered as potency associated with the intraspecies ratio of body weight and body weight means [20]. Also brain weight is calculated as $E = k\rho\beta$ where E is the brain weight, ρ is the body weight, k and β are determined from log – log plot of brain weight to body weight. Log k is the log E intercept and β is the slope [17]. Whereas $k = 0.18$ and $\beta = 0.66$ respectively [21]. However $k = 0.16$ and $\beta = 0.67$ have also been reported [17]. The dogs classified according to Coren [22] as brightest are: Border Collie, Standard Poodle, German Shepherd, Golden Retriever, Doberman Pinscher, Shetland, Labrador Retriever, Papillion, Rottweiler and Australian Cattle Dog were used for the study. Their body weight, body surface area, height, $k = 0.14$ and $\beta = 0.528$ were considered as reported by Saganuwan [23].

Results

The body weight, brain weight, body surface area, height and encephalization quotient of the ten dogs are presented in Table 1 below.

The calculated brain masses for all the dogs using von Bronin's formula are higher than the masses yielded by Jerison's and Saganuwan's formulas. Saganuwan's formula yielded highest EQ for Border Collie (2.3), Standard Poodle (2.2), German Sheperd (3.1), Golden Retriever (2.8), Doberman Pinscher (3.1), Labrador Retriever (2.) and Australian Cattle Dog (2.7) as compared to the other formulas. However von Bronin's formula yielded highest EQ for Rottweiler (2.5) as Jerison's formula yielded highest EQ for

Shetland Sheep Dog (1.4) and Papillon (1.2). German Shepherd had highest TBS/ICC ratio (1.4) followed by Labrador Retriever, Doberman Pinscher, Golden Retriever (1.3), Border Collie, Standard Poodle, Papillon (1.2) and Shetland Sheep Dog (1.1), respectively. The calculated ICC parameter showed that Rottweiler and German shepherd scored highest, 11 (Table 1).

Discussion

The obtaining of EQ (1.0-3.1) for dogs in the present study disagrees with the report that, the EQ for dogs is 1.2 [7-10]. EQ calculated from Saganuwan's formula developed for both dog and human shows that Doberman Pinscher has the highest EQ hence, considered the most intelligent followed by German Shepherd, Labrador Retriever, Golden Retriever, Australian Cattle Dog, Rottweiler, Border Collie, Standard Poodle, Shetland Sheep Dog and Papillon, respectively. The EQ value indicates larger brain ($EQ > 1$), equal ($EQ = 1$) and smaller ($EQ < 1$) than expected for its body mass, respectively [24]. Each of the formulas used to calculate EQ yields different values, but the formula developed by Saganuwan may be more reliable. The TBS/ICC value higher than 1 and EQ value of 1.0-3.1 show that even Papillon is intelligent. Intelligence, learning, awareness and the welfare are closely related. Self-aware animals should be able to deduce mental states of other animals [25] which is classified as a form of complex learning [26] signifying that the level of intelligence is directly proportional to the level of awareness [7]. However, awareness is a state that comprises conscious thought and unanxious responses [27]. However, learning and awareness are connected with environment, past experiences, relationships between old and new information and action to produce a positive outcome [28]. Latent is the acquisition of neutral information with no immediate effects on behavior [29] as seen between a naive and experienced animal [7]. But dog's intelligence is of three components; instinctive intelligence, adaptive intelligence as well as working and obedience intelligence [22]. Therefore the intelligence of dogs may be classified according to their functions as working (e.g. Doberman Pinscher, German Shepherd, Border Collie), hunting (Labrador Retriever, Golden Retriever), companion (Standard Poodle) and toying (Papillon) intelligence [23]. But nutrition, genetics, environment, diseased condition inter alia, may affect EQ. However, study on evolution of encephalization quotient revealed that carnivore and other mammals showed abrupt increase in median log- encephalization quotients, indicating higher brain volume relative to body mass, at the end – Midcene, but gradual increases in the variance of log EQs. By Akaike Information Criterion, evolution of canid encephalization proposed plesiomorphic and apomorphic allometries [30]. Hence increased canid encephalization coincides with reorganization of the brain, which reflects complex social behaviour overtime [31]. But the reported value of EQ (0.4) for African grass cutter [32] shows that the animal's level of intelligence is quite low as compared to that of dog which may allow for easy predation by dog on the grass cutter. However the therapeutic implication of $EQ > 1$ and $EQ < 1$ is that, central nervous system acting drug which has fulfilled the condition of CSF penetration in animals having $EQ > 1$, may have high chance of accumulating the drugs compared to animals with $EQ < 1$.

Conclusion

Body weight, body mass, height and body surface area can be used to estimate encephalization quotient of dogs, which can vary according to formulas, nutrition, environment and diseased conditions. The calculated parameters showed that Doberman Pinscher is the most intelligent followed by German Shepherd, Labrador Retriever, Golden Retriever, Australian Cattle Dog, Rottweiler, Border Collie, Standard Poodle, Shetland Sheep Dog and Papillon, respectively.

Limitations

The calculations were based on different formulas generated for different or similar purposes in dog and human. Intelligence in dogs and human is used for different assignments even within canine species. More so difference in physiology, anatomy and biochemistry count for differences in the calculated values.

Abbreviations

P=Body weight; $k=0.14$; $\beta=0.528$; EQ=Encephalization quotient

Declarations

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Author's contribution

SAS designed, carried out the work, analyzed data, wrote and proof read the manuscript.

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Availability of data and materials

Availability of data and analyzed data are included in this article.

Ethics approval and consent to participate

Not applicable, because neither human nor animal was used for the study.

Consent to publish

Not applicable.

Competing interest

The author declares no competing interest.

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Tables

Table 1. Body weight, brain weight, body surface area, height and encephalization, quotient of the reported brightest dogs

S/No	Breed of dog	BW (kg)	BSA (m ²)	Height (m)	Measurement of Encephalization Quotient						Ranking	ICC	TBS	$\frac{TBC}{ICC}$
					EvB	ES	EJ	EQJ	EQvB	EQS				
1.	Border Collie	23.0	1.12	0.78	2.7	1.7	1.8	1.8	1.9	2.3 ^a	7 th	9	10.8	1.2
2.	Standard Poodle	22.0	0.62	0.76	2.6	1.6	1.8	1.9	1.9	2.2 ^a	8 th	9	10.8	1.2
3.	German Shepherd	40.0	1.13	1.30	4.8	3.0	3.2	2.3	2.1	3.1 ^a	2 nd	11	15.4	1.4
4.	Golden Retriever	34.0	1.22	1.00	4.0	2.5	2.7	2.1	2.2	2.8 ^a	4 th	10	12.9	1.3
5.	Doberman Pinscher	40.6	1.42	1.18	4.8	3.0	3.3	2.3	2.3	3.1 ^a	1 st	10	12.9	1.3
6.	Shetland Sheepdog	7.0	0.82	0.35	0.8	0.5	0.6	1.4 ^a	1.2	1.3	9 th	7	8.0	1.1
7.	Labrador Retriever	36.0	1.14	1.00	4.3	2.7	2.9	2.2	2.2	2.9 ^a	3 rd	10	12.9	1.3
8.	Papillon	4.5	0.23	0.56	0.5	0.3	0.4	1.2 ^a	1.0	1.0	10 th	6	6.9	1.2
9.	Rottweiler	50.0	1.36	1.30	5.9	3.7	4.02	2.4	2.5 ^a	1.8	6 th	11	15.4	1.4
10.	Australian Cattle Dog	33.0	0.96	0.87	3.9	2.4	2.7	2.2	2.2	2.7 ^a	5 th	10	12.9	1.3

Keys: BW = Body Weight; BSA = Body Surface Area; E = Brain Mass; EQ = Encephalization Quotient; TBV = Total Brain Volume; ICC = Internal Cranial Capacity; J = Jerison; vB = Von Bronin; S = Saganuwan; TBS=Total Brain Size; ICC=Internal Cranial Capacity;a=Highest EQ in the row