AGE-RELATED CHANGES IN THE ABSOLUTE AND RELATIVE WEIGHTS OF INTERNAL ORGANS OF THE PACIFIC WALRUS

G. A. Fedoseev, Yu. A. Bukhtiyarov,
V. N. Gol'tsev, and G. G. Shmakova

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The absolute and relative growth of internal organs of the Pacific walrus have been examined. In walrus pups, the growth of internal organs, which experience a heavy functional load from the first days of life, significantly exceeds the growth of the total body weight. The walrus internal organ indices remain stably high throughout the whole life span. The walrus differs in this from other arctic pinniped forms, which exhibit a clearly expressed fall in these indices with age. The enhanced development of internal organs is explained by the high level of metabolism, which is closely connected with the lower environmental temperature and the weak heat insulation properties of the subcutaneous fat.

In studying the morphoecological characteristics of animals, it is very important to know the absolute and relative weights of internal organs. It has long been noticed that species with relatively small body dimensions have relatively heavier internal organs and a higher metabolic level (Hesse, 1913; Bogolyubskii, 1939; Shvarts, 1954, etc.). At the same time, it has been established that in many cases this relationship is disturbed, and that animal internal indices are frequently determined exclusively by the specific conditions of existence. It is important to note that the ecological characteristics of individual species are demonstrated more clearly by the age-related changes of internal indices than by the characteristics of adult animals (Shvarts, 1956). Unfortunately, in the majority of investigations on marine mammals, the relative and absolute dimensions of internal organs are characterized only when individual or small numbers of animals are discovered, as for example, by Kleinenberg et al. (1964) and Yablokov (1966), and only certain workers have analyzed the age-related changes of internal indices (Fedoseev, 1971; Fedoseev and Gol'tsev, 1974; Potelov, 1972; Bryden, 1971).

We have therefore attempted a more detailed analysis of the internal indices of the walrus *Odobaenus rosmarus* and have compared the walrus indices with those of other pinniped species. We have measured the changes of body weight and internal organ weights in 167 females and 142 males, caught in the Bering and Chukotsk Seas from June to September in 1972 and 1973. The age of the animals was determined from the cement layers on the molars.

Age-related changes in the mass (weight) of the internal organs and body (expressed as a percentage of their masses in the adult animal) show (Tables 1 and 2) that in two- to three-month-old pups, the organs which are somewhat ahead in development are the heart and lungs (probably due to features of embryonic development) and also the kidney and pancreas which bear a heavy functional load from the first days of life. The diaphragm and liver are less well developed in pups than in adults, obviously because of the relatively weak functional activity of these organs during early life. Up to the age of one year the growth in mass of the internal organs directly associated with the metabolism of substances, significantly overtake the growth in body weight. At two to three years of age, the difference in the rates of increase in body mass and in the mass of the majority of internal organs becomes insignificant, i.e., the growth of internal organs becomes almost proportional to the growth of the whole organism.

The unique rate of growth of respiratory organs (lungs and diaphragm) is interesting. A sharp increase in the mass of these organs occurs at the age of two years when the young walruses become independent. With the changeover from milk feeding to catching food at the sea bed, the requirement for oxygen sharply increases because of the frequent, prolonged submersion.

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TABLE 1. Age-Related Changes of the Mean Weights of Male Walrus Organs Expressed as a Percentage of the Adult Weight at 21 to 37 Years

Age, years	Body weight	Heart	Liver	Lungs	Kidney	Diaphragm	Pancreas
This year	7,1	9,0	5,7	8,9	10,8	5,2	8,9
1	16,6	17,1	20,6	18,8	22,3	13,6	—
2	30,8	24,8	28,0	32,8	33,6	33,0	38,6
3	37,2	31,3	38,9	38,6	40,7	31,5	37,1
4	36,9	44,9	40,9	49,1	42,1	37,9	—
5	45,1	41,3	49,7	50,9	51,5	54,9	65,0
6	44,0	41,6	49,7	46,3	48,6	48,9	42,1
7	51,4	57,3	56,5	54,2	53,8	56,8	55,4
8	55,0	58,2	53,6	58,9	58,8	56,8	59,1
9	49,8	48,4	55,0	50,5	56,0	56,1	53,2
10	57,1	59,4	56,7	60,5	65,3	61,5	52,8
11	66,1	64,1	71,7	80,0	69,8	70,3	74,7
12	69,1	70,0	72,2	67,4	76,8	81,8	86,5
13	77,6	77,7	73,9	80,5	74,8	86,3	91,4
14	77,6	69,6	78,3	74,2	72,7	88,8	80,4
15—20	90,0	85,9	80,0	87,4	82,6	94,8	82,2
21—37*	100	100	100	100	100	100	100

*The following weights, kg, are taken to be 100%; body 1201; heart 8.09; liver 36.1; lungs 19.0; kidney 3.63; diaphragm 8.98; pancreas 2.28.

TABLE 2. Age-Related Changes in the Mean Weight of Female Walrus Organs as a Percentage of the Organ Weight of Adults (14 to 30 years)

Age, years	Total body weight	Heart	Liver	Lungs	Kidney	Diaphragm	Pancreas
This year	10,3	11,4	9,5	10,9	12,8	8,1	10,0
1	15,0	24,5	29,3	44,8	26,1	21,6	—
2	—	—	—	—	—	—	—
3	54,4	53,6	64,4	77,6	44,2	48,0	56,8
4	54,4	55,3	64,9	63,8	55,1	55,4	73,5
5	66,8	51,9	74,1	60,1	70,7	58,6	55,0
6	80,9	74,5	92,4	79,3	80,3	82,0	91,0
7	67,9	64,3	72,7	64,8	72,3	65,6	79,0
8	90,1	96,6	99,0	100,0	90,6	98,4	90,7
9	88,8	84,0	95,6	84,5	85,2	91,4	79,8
10	94,9	88,8	100,0	95,7	96,5	100,0	101,1
11	94,5	93,5	94,1	97,4	92,3	100,0	84,3
12	96,6	95,3	100,0	88,8	92,0	100,0	98,4
13	100,0	97,8	100,0	100,0	94,7	100,0	95,9
14—30*	100	100	100	100	100	100	100

*The following weights, kg, are taken to be 100%: body 698.1; heart 4.699; liver 20.5; lungs 11.6; kidney 2.488; diaphragm 5.318; pancreas 1.496.

In six-year-old females and seven-year-old males there was a sharp increase in body mass and in the weights of all internal organs, associated with the onset of sexual maturity. In the first years of sexual maturity, the kidney, liver, pancreas, and body weights noticeably increased.

In the majority of cases the relative dimensions of internal organs, expressed as parts per thousand of the body mass (see Fig. 1), remain stable almost throughout the whole life span, apart from the first two years, especially in sexually mature animals. The exceptions are the heart and kidney weights of pups under two years, which on average are greater than they are in the remaining groups. Diaphragm weights have a clear tendency to increase up to the period of sexual maturity. The indices show sexual differences in that the amplitude of the individual variation is greater in females than in males. Moreover, in sexually mature females the kidney index is noticeably higher. This apparently indicates a higher level of metabolism due to gravidity.

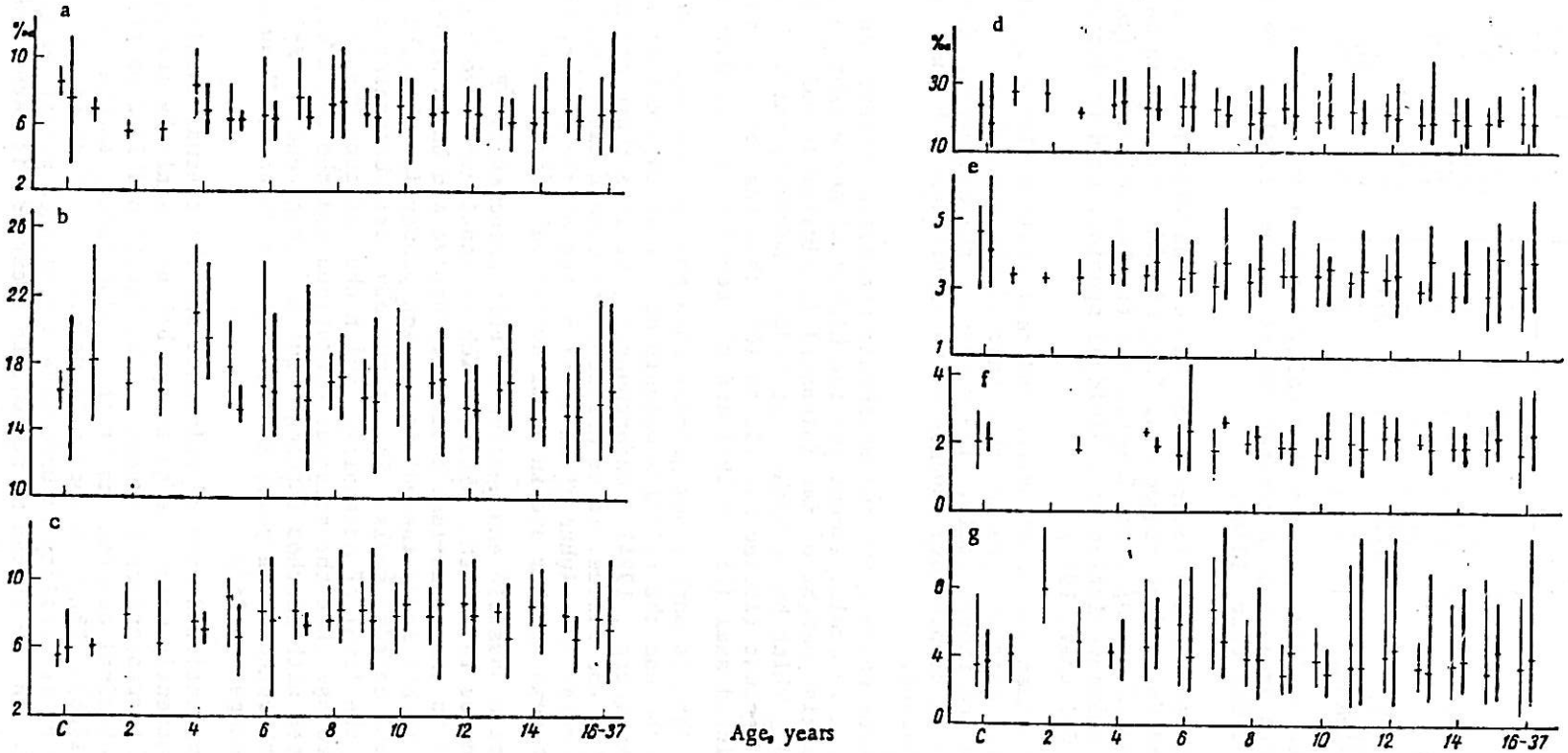

Fig. 1. Age-related changes in the indices of internal organs of the Pacific walrus; vertical lines show the range of the various indices and horizontal lines show their mean values; thin lines represent males and thick lines females: a) heart; b) lungs; c) diaphragm; d) liver; e) kidney; f) pancreas; g) spleen.

TABLE 3. Relative Internal Organ and Body Weights of Arctic Pinniped Forms (expressed in ‰ mean values)

Organ	*Pusa hispida*	*Histriophoca fasciata*	*Ph. vitulina largha*	*Erignathus barbatus*	*Odobaenus rosmarus*
Heart	7,8	8,1	7,5	4,7	6,8
Lungs	20,0	17,3	16,0	14,0	16,7
Diaphragm	5,7	6,7	5,5	4,9	7,6
Kidney	4,5	2,8	3,3	4,0	3,4
Pancreas	3,0	1,8	—	1,8	2,1
Liver	30,5	23,5	28,5	30,9	30,0
Blubber %	40,0	31,3	32,0	30,0	31,5
Body weight, kg	37	72	89	216	977
No. of individuals	64	33	29	31	76

Note. These data apply to physically mature animals (the results are presented in greater detail in the article of Fedoseev and Gol'tsev, 1974).

The age-related changes in the internal indices of the walrus differ sharply from those of other Arctic pinniped forms (the ringed seal *Pusa hispida*, the ribbon seal *Histriophoca fasciata*, the common seal *Phoca vitulina largha*, and the bearded seal *Erignathus barbatus*), which, in spite of the characteristics of individual species, tend to decrease more clearly with age (Fedoseev and Gol'tsev, 1974).

A comparison of the mean values of walrus and seal indices (Table 3) shows that the relative weight of the walrus heart is greater than that of the bearded and common seals and less than that of the ringed and ribbon seals. The weight of the diaphragm, which characterizes the depth and frequency of respiratory movements, is significantly higher in the walrus than in any of the seals examined.

The weights of organs which carry out metabolic processes (kidneys and liver) are almost the same in the walrus as in seals, except for the higher kidney weight in the ringed and bearded seals. The relative weight of fat (blubber) is similar in walrus and seals, except for the ringed seal, which has a higher fat index. However, the walrus fat has a lower unsaturated fatty acid content (iodine No. 132 to 168) than that of the other circumpolar species, such as the ringed seal (154 to 198) and the bearded seal (150 to 174).

The walrus body weight is many times greater than that of any comparable North Pacific pinniped species; nevertheless the relative weights of walrus internal organs are high, despite Hesse's serial law (Hesse, 1924). Unfortunately, because there are no data on the metabolism and ecology of the walrus, it is difficult to give a direct explanation of such a paradox, i.e., why the relative weights of internal organs of the walrus, in spite of its huge body size, are the same as they are in small Arctic seal forms.

We will now propose a possible explanation of this phenomenon. Firstly we should note the quality of subcutaneous fat in the walrus, which as mentioned above has a lower unsaturated acid content. It is therefore less chemically active and has a higher solidification point; because of this it has lower thermal insulation properties that the fat of such Arctic species as the ringed and bearded seals. The walrus obviously maintains a constant body temperature by increasing the level of metabolism, which thus affects the development of the internal organs. We propose that the seasonal migrations and the continual existence under icy conditions associated with benthos feeding require a large energy expenditure. Such loads remain constant throughout the year, so that the functional load on the internal organs remains stable at all stages of life.

Thus with the aforementioned type of existence and the thermal insulation properties of the fat, the walrus apparently maintains an energy balance mainly by its relatively large demand for food and by a corresponding increase in the functional load on the internal organs, rather than by any biochemical adaptations at the tissue level, as are observed in some animals (Shvarts et al., 1968). The "uneconomical" maintenance of an energy balance in the walrus is compensated for by its ability to undertake a prolonged migration (from May to November) in search of food. In the fattening period, this extends its area from the Bering to the Chukotsk, Eastern Siberian, and Beaufort seas.

However it arises, the fact of the relatively high level of metabolism in the walrus in connection with the proposed features of maintaining an energy balance, is in itself especially interesting, since it may be one of the principal factors which limit the possibilities of a growth in population numbers. This is extremely important to know, so that special care can be taken to avoid using walruses on a large scale.

An analysis of age-related changes of body weight and internal organ weights in the Pacific walrus has therefore shown that in spite of a certain decrease in the relative weights of some organs during the first three years, their indices remain quite high and constant throughout the subsequent years of life. This indicates that the degree of the functional load on walrus internal organs and correspondingly the level of metabolism remain stable at all stages of life, except for the first three years.

The morphoecological characteristics of the walrus are somehow interrelated with its type of energy exchange. Some of the possible factors which determine the type of energy exchange and the internal features of these animals are: the extensive biocenotic links caused by the migration for food over long distances; their frequent existence in water at low temperatures; and the relatively weak thermal insulation properties of the subcutaneous fat, in comparison with such other Arctic pinniped species as the ringed and bearded seals.

The age-related changes noted for the internal organs, apparently associated with metabolism, suggest that the food requirement in walruses per unit body weight is more or less constant at all stages of life, after three years. Such a type of energy balance maintenance limits the possibilities for an increase in the number of animals in a population. However, this "lack" is possibly compensated for by another ecological adaptive property, i.e., the ability to undertake long migrations for food, which extend the territory of the walruses.

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ВОЗРАСТНЫЕ ИЗМЕНЕНИЯ АБСОЛЮТНЫХ И ОТНОСИТЕЛЬНЫХ ПОКАЗАТЕЛЕЙ ВНУТРЕННИХ ОРГАНОВ ТИХООКЕАНСКОГО МОРЖА

Г. А. Федосеев, Ю. А. Бухтияров, В. Н. Гольцев, Г. Г. Шмакова

Рассматривается абсолютный и относительный рост внутренних органов тихоокеанского моржа. У щенков моржа рост внутренних органов, испытывающих высокую функциональную нагрузку с первых дней жизни, значительно опережает рост общего веса тела. Индексы внутренних органов моржа остаются стабильно высокими на протяжении всей жизни. Этим морж отличается от других ледовых форм ластоногих, у которых четко выражено падение индексов с возрастом. Особенность сильного развития внутренних органов объясняется высоким уровнем метаболизма, который находится в тесной связи с низкой температурой окружающей среды и слабыми термоизоляционными свойствами подкожного жира.

При изучении морфо-экологической специфики животных большое значение имеют данные, характеризующие абсолютный и относительный вес внутренних органов. Уже давно было отмечено, что виды с относительно мелкими размерами тела обладают относительно большим весом внутренних органов и более высоким уровнем метаболизма (Гессе, 1913; Боголюбский, 1939; Шварц, 1954 и др.). В то же время установлено, что во многих случаях эта зависимость нарушается и интерьерные показатели животных нередко определяются исключительно специфическими условиями существования. Важно отметить, что экологическая специфика отдельных видов более отчетливо проявляется в характере возрастных изменений интерьерных показателей, а не в признаках взрослых особей (Шварц, 1956). К сожалению, в большинстве работ по исследованию морских млекопитающих относительные и абсолютные размеры внутренних органов характеризуются на основе вскрытий отдельных или небольшого числа животных, на что обращали внимание С. Е. Клейненберг и др. (1964), А. В. Яблоков (1966), и только в некоторых анализируются возрастные изменения интерьерных показателей (Федосеев, 1971; Федосеев, Гольцев, 1974; Потелов, 1972; Bryden, 1971).

В связи с этим нами предпринята попытка более детального анализа интерьерных показателей моржа и сравнения их с аналогичными материалами по другим видам ластоногих. В основу настоящей работы положены изменения веса тела и внутренних органов 167 самок и 142 самцов, добытых в Беринговом и Чукотском морях в июне—сентябре 1972—1973 гг. Возраст животных определялся по слоям цемента коренных зубов.

Возрастные изменения массы (веса) внутренних органов и тела (выраженных в процентах от их массы у взрослых животных) показывают (табл. 1, 2), что у двух-трехмесячных щенков несколько большего развития достигают сердце и легкие (что, вероятно, обусловлено особенностями эмбрионального развития), а также почки и поджелудочная железа, которые получают сильную функциональную нагрузку с первых дней жизни. Диафрагма и печень у щенков менее развиты, чем у взрослых, очевидно, из-за относительно слабой функциональной деятельности этих органов на первых порах жизни. До годовалого возраста нарастание массы внутренних органов, непосредственно связанных с обменом

Возрастное изменение
в % от веса органов

Возраст, годы	Вес тела	Сердце
Сеголетки	7,1	9,0
1	16,6	17,1
2	30,8	24,8
3	37,2	31,3
4	36,9	44,9
5	45,1	41,3
6	44,0	41,6
7	51,4	57,3
8	55,0	58,2
9	49,8	48,4
10	57,1	59,4
11	66,1	64,1
12	69,1	70,0
13	77,6	77,7
14	77,6	69,6
15—20	90,0	85,9
21—37*	100	100

* За 100% принят вес, *кг*: тела — 1
почки — 3,63; диафрагмы — 8,98; по

Возрастное изменение
в % от веса органо

Возраст, годы	Общий вес тела	Сердце
Сеголетки	10,3	11,4
1	15,0	24,5
2	—	—
3	54,4	53,6
4	54,4	55,3
5	66,8	51,9
6	80,9	74,5
7	67,9	64,3
8	90,1	96,6
9	88,8	84,0
10	94,9	88,8
11	94,5	93,5
12	96,6	95,3
13	100,0	97,8
14—30*	100	100

* За 100% принят вес, *кг*: тела —
почки — 2,488; диафрагмы — 5,318

веществ, значительно опере
возрасте разница в темпе у
ренних органов становится
ганов становится почти про

Привлекает внимание с
(легкие и диафрагма). Резк