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Hematological studies on Antarctic birds II. Changes of the hematological indices during the development of the pygoscelid penguins *)

ABSTRACT: Changes in the red blood picture were studied during the development of *Pygoscelis adeliae, P. antarctica* and *P. papua*. It has been found that the respiratory function of a unit of the blood volume increases with the age of the investigated birds. The mechanism of this changes is described.

Key words: Antarctic, birds, blood indices

1. Introduction

Data referring to the values of hematological indices in various species of penguins are very scarse. In the greater part of the cases these are the results of the determinations supplementing other physiological studies (Lenfant et al. 1969, Milson, Johansen and Millard 1973, Douglas, Lockner and Murrish 1976). A more complete characteristic of the blood picture in *Eudyptes cristatus* is given by Koržuev, Aljakarinskaja and Glazova (1977), as well as by Myrcha and Kostelecka-Myrcha (1980) describing three species of the genus *Pygoscelis*.

As regards the changes in the blood picture of penguins during their development there are no available data, at all. The existence and development under the conditions of relatively low temperatures in their environment should lead these birds to the evolvement of the mechanism of adaptations, enabling a quick achievement of a high level of the respiratory function of a unit of blood volume. Moreover, it seems that considerable differences

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in oxygen uptake may occur between particular species, differing in the geographical range of distribution and living conditions.

On that account it appeared to be interesting to investigate changes in the red blood indices of three species of the genus *Pygoscelis* in the course of their development, at the place where they nest collectively in closely neighbouring colonies.

2. Material and methods

Altogether, 36 specimens of *Pygoscelis adeliae* (Hombron et Jacquinot), 47 — *Pygoscelis antarctica* (Forster) and 57 — *Pygoscelis papua* (Forster) were under examination from the first day after hatching till the day of the beginning of independent life (after moulting and first entering into water). Studies were carried out during antarctic summer 1977/78 in a large colony in the vicinity of the Arctowski Station (King George Island, South Shetland Islands).

Standard methods were used for: determination of the content of hemoglobin in the blood (*Hb* g %) and hematocrit (*Hct* %), erythrocyte count per 1 mm^3 of blood (*RBC* mln/mm^3), measurements of the length and width of erythrocytes and calculations of the mean cell hemoglobin content (*MCH* $\gamma\gamma$), the mean cell hemoglobin concentration (*MCHC* %), and the average volume of erythrocytes (μm^3).

3. Results and discussion

It has been found that the size of erythrocytes (length 13—14 μm, width about 8 μm, volume 220—240 μm^3) was very much alike in the three examined species and did not change during their development.

The highest hemoglobin content in 100 ml of blood at the moment of hatching was noted in *P. adeliae* (about 6.5—7.0 g %), but in the course of the nestlings development the quantity of this pigment increases less intensively than in the remaining two species and by the time the young birds leave their colony it amounts to about 14% (Fig. 1). The youngest nestlings of *P. antarctica* and *P. papua* the *Hb* content in blood is only about 4.5—5.0 g % and by the end of their development it is 14.5—15.5 g %.

At the end of the development the number of erythrocytes in 1 mm^3 of blood (about 1.8—1.9 mln/mm^3) of the three examined species is also similar (Fig. 2). The youngest nestlings of *P. adeliae* show not only the highest *Hb* content but also the highest number of erythrocytes in a unit of blood volume (about 1.8 mln/mm^3). However, this value decreases during the first 10—12 days of their development to 1.35 mln/mm^3, then it increases intensively up to about 1.9 mln/mm^3. A reversed process was observed in *P. papua*. In one-day nestlings the number of erythrocytes in 1 mm^3 of blood is only about 0.6 mln, then it increases intensively during the

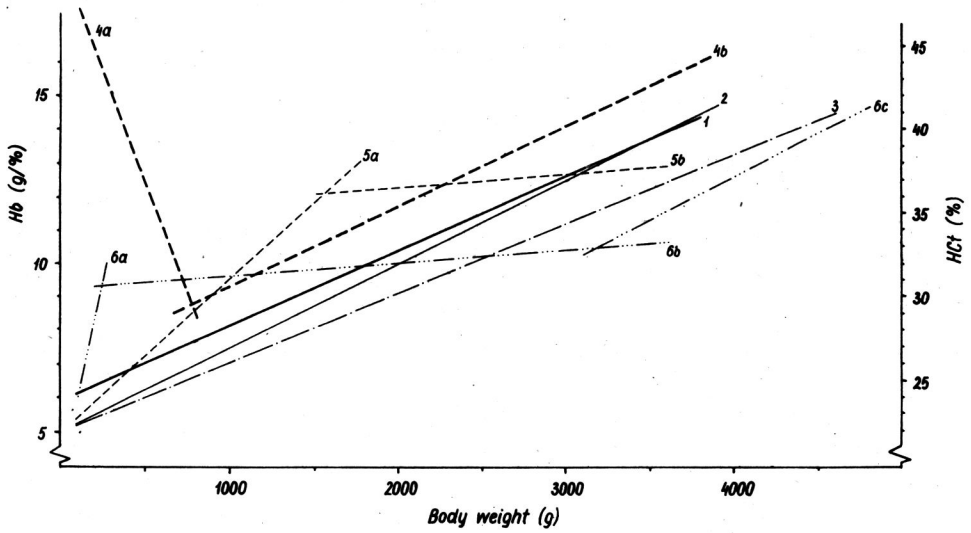

Fig. 1. Changes in the hemoglobin concentration and hematocrit during the development of pygoscelid penguins

Hemoglobin: 1. *P. adeliae:* $y = 0.0022x + 6.006$, $r = 0.81$; 2. *P. antarctica:* $y = 0.0025x + 5.055$, $r = 0.99$; 3. *P. papua:* $y = 0.00205x + 5.053$, $r = 0.97$

Hematocrit: 4. *P. adeliae:* 4a $-y = -0.042x + 56.62$, $r = -0.88$; 4b $-y = 0.0048x + 25.97$, $r = 0.54$; 5. *P. antarctica:* 5a $-y = 0.009x + 21.85$, $r = 0.54$; 5b $-y = 0.0013x + 33.19$, $r = 0.14$; 6. *P. papus:* 6a $-y = 0.044x + 19.77$, $r = 0.78$; 6b $-y = 0.00076x + 30.62$, $r = 0.20$; 6c $-y = 0.0053x + 15.97$, $r = 0.57$

following ten days (body weight 600—700 g) of their development (up to 1.5 mln/mm^3), then it increases slowly reaching the value of 1.8 mln/mm^3 in the individuals starting an independent life.

The one-day nestlings of *P. antarctica* have about 0.9 mln erythrocytes in 1 mm^3 of blood. During the first 20—25 days of their life (body weight 1400—1700 g) this value increases intensively to the level of about 1.7 mln/mm^3 and further on it does not change, practically.

The values of hematocrit changed during the development of the examined penguins in exactly the same way as the number of erythrocytes in 1 mm^3 of blood (Fig. 1), which seems comprehensible since the size of red cells did not change at all. During the first three weeks of the life of *P. antarctica* nestlings (body weight about 1500—1600 g) the *Hct* value increases much more intensively (from about 22% to about 37%) than in the later period of their development (up to about 38—39%). In *P. adeliae* the value of this index is initially high (about 43%), then it decreases to about 34%, and later increases again up to about 44%, at the end of the development period. In *P. papua* the initially very low value of hematocrit (about 24%) increases intensively during the first week of the nestlings development (30—31%), then until the end of the 5th week of their life (body weight about 3200 g) the increase in the *Hct* value is very slow (up to about 33%). Afterwards the next phase of a quicker increase in the *Hct* values occurs, reaching after the moulting the level of about 42%.

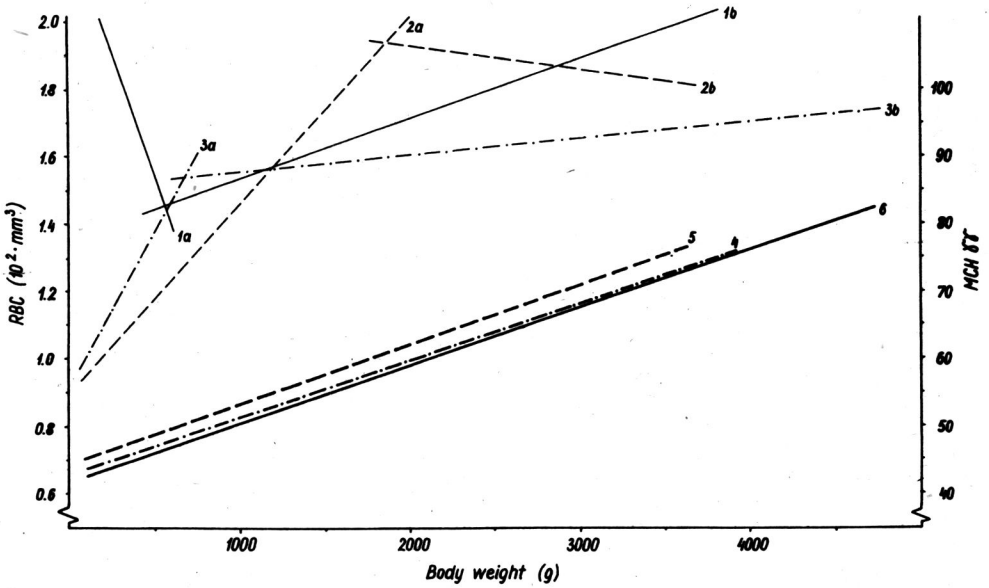

Fig. 2. Change in the number of erythrocytes and the *MCH* during the development of pygoscelid penguins

RBC: 1. *P. adeliae:* 1a $-y = -0.00151x + 2.33$, $r = -0.82$; 1b $-y = 0.00018x + 1.37$, $r = 0.47$. 2. *P. antarctica:* 2a $-y = 0.00063x + 0.896$, $r = 0.86$; 2b $-y = 0.000107x + 2.16$, $r = -0.26$; 3. *P. papua:* 3a $-y = 0.00083x + 0.984$, $r = 0.67$; 3b $-y = 0.000049x + 1.509$, $r = 0.37$

MCH: 4. *P. adeliae:* $y = 0.00794x + 43.47$, $r = 0.74$; 5. *P. antarctica:* $y = 0.00864x + 44.78$, $r = 0.68$; 6. *P. papua:* $y = 0.00848x + 42.25$, $r = 0.83$

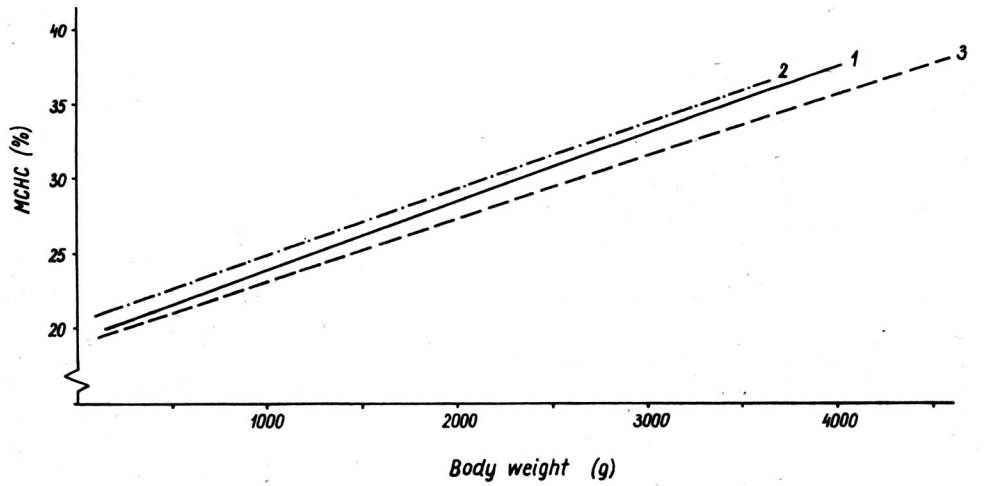

Fig. 3. Changes in the *MCHC* values during the development of pygoscelid penguins 1. *P. adeliae:* $y = 0.00453x + 19.36$, $r = 0.79$; 2. *P. antarctica:* $y = 0.00419x + 20.99$, $r = 0.84$; 3. *P. papua:* $y = 0.00416x + 18.81$, $r = 0.85$

The above described changes in the *Hb* and *RBC* content in a unit of blood volume and in hematocrit values find consequently their expression in the changes of the *MCH* and *MCHC* indices, which take a similar course in all of the three examined species (Figs. 2 and 3). During the development of the nestlings of penguins of the genus *Pygoscelis* the *MCH* increases from about 45 $\gamma\gamma$ up to about 75—80 $\gamma\gamma$ and *MCHC* from about 18—21% up to about 36—40%.

It may be said generally that the values of the investigated indices in all of the three species are similar at the endstage of their development. Whatsoever, it seems that during the first few days following the hatch *P. adeliae* nestlings have more favourable conditions for securing their oxygen demand, which gives evidence of the highest degree of their metabolic cold adaptation. The basic mechanism in the development of the examined penguins leading to intestification of the respiratory function of a unit of blood volume depends on the increase in the number of erythrocytes and *Hb* content in this unit of blood volume. The hemoglobin content increases incommesurably more than the number of the erythrocytes, which is reflected in the increase in the *MCH* and *MCHC* indices. Thus, the total surface of the erythrocytes increases only due to an increase in the number of red cells and the hemoglobin content per a unit of that surface is higher and higher.

In the nestlings of the temperature zone the process of intensification of the respiratory function in a unit of blood volume is more complex (Kostelecka-Myrcha, Pinowski and Tomek 1970, 1972). The total surface of erythrocytes may increase in these birds more intensively than in penguins, since due to a decrease of the size of the red blood cells during their development the increment in number of erythrocytes may be considerably higher (at a restricted possibility of an increase in the *Hct* value). However, in the nestlings of the temperate zone such a high increase in *MCHC* was never observed. It seems that utilization of this high content of hemoglobin per a unit of the surface of erythrocytes in penguins is possible while diving, when the rate of blood flow is lower, and consequently the duration of the contact of the respiratory pigment with the air in lungs is sufficiently long to be saturated with oxygen.

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4. Summary

Changes of the erythrocytes image of blood were studied during the development of three species of penguins of the genus *Pygoscelis* from the first day after hatching to the beginning of self-depended life (change of plumage and immersion in water).

It was found that the basic mechanism leading to the intensification of the respiratory function of a volume unit of blood during the development of penguins depends on an increase of the erythrocyte number and of the amount of hemoglobin (Figs. 1 and 2). The amount of hemoglobin increases more intensively than the erythrocyte number, thus *MCH* and *MCHC* increase, too (Fig. 2 and 3). The size of erythrocytes does not change,

thus they total area increases only due to the rise of the erythrocytes number, and there is more and more of hemoglobin per unit of this surface.

The observed differences in the changes of the blood image during the development of studied penguin species can suggest their uneven adaptation to thermal conditions.

5. Резюме

Провндено исследования изменений красных кровяных шариков в развитии трёх видов пингвинов рода *Pygoscelis* с первого дня от вылупления до начала самостоятельной жизни (оперение, вход в воду).

Констатировано, что основной механизм ведущий к интенсификации дыхательной функции единицы объёма крови в развитии пингвинов состоит в увеличении количества эритроцитов и гемоглобина (рис. 1 и 2). Количество гемоглобина растёт интенсивнее чем число красных кровяных шариков. Благодаря этому увеличивается также *MCH* и *MCHC* (рис. 2 и 3). Величина эритроцитов не подвергается изменению, значит их общая поверхность увеличивается путём роста количества красных кровяных шариков. И так в единице этой поверхности выступает всё больше гемоглобина.

Замеченные разницы в изменениях образа крови во время развития исследованных видов пингвинов могут свидетельствовать о их неодинаковом приспособлении к термическим условиям.

6. Streszczenie

Zbadano zmiany czerwonokrwinkowego obrazu krwi w rozwoju trzech gatunków pingwinów z rodzaju *Pygoscelis* od pierwszego dnia po wykluciu się z jaja do momentu rozpoczęcia samodzielnego życia (zmiana upierzenia i wejście do wody).

Stwierdzono, że podstawowy mechanizm prowadzący do intensyfikacji oddechowej funkcji jednostki objętości krwi w rozwoju pingwinów polega na zwiększeniu się liczby erytrocytów i ilości hemoglobiny (rys. 1 i 2). Ilość hemoglobiny wzrasta intensywniej niż liczba czerwonych krwinek, dzięki czemu zwiększa się również *MCH* i *MCHC* (rys. 2 i 3). Wielkość erytrocytów nie ulega zmianie, a więc sumaryczna ich powierzchnia zwiększa się tylko dzięki wzrostowi liczby czerwonych krwinek i na jednostkę tej powierzchni przypada coraz więcej hemoglobiny.

Zaobserwowane różnice w zmianach obrazu krwi w czasie rozwoju badanych gatunków pingwinów mogą świadczyć o ich niejednakowej adaptacji do warunków termicznych.

7. References

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