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Changes of the red blood picture during nesting development of Wilson's storm petrel (*Oceanites oceanicus* Kühl)

ABSTRACT: The period of nesting development of Wilson's storm petrels (approx. 60 days) could be divided into three stages: first from hatching to 8th—10th day of development; second, from 10th to approx. 25th day and third from 25th day until nestlings leave the nests. During the first stage hemoglobin concentration in the blood decreases significantly while total surface of erythrocytes and the hematocrit increases. At that time nestlings do not grow very fast. In the second stage of development the values of all studied parameters do not change, while the growth of body weight is very intensive. The last stage is characterized by significantly reduced growth rate accompanied by important changes of all hematological parameters responsible for the respiratory function of blood volume unit.

Key words: Antarctic, Wilson's storm petrel, development, red blood picture, respiratory function.

Introduction

The results of hematological studies carried out over the nesting period of several species of flying birds suggest that the general mechanism determining the respiratory function of blood volume unit is the same in altricial birds of temperate as well as Arctic region (Kostelecka-Myrcha, Pinowski and Tomek, 1970, 1971, 1972, 1973, Kostelecka-Myrcha, Dąbrowska and Wieczorek, 1983, Kostelecka-Myrcha, 1987). The intensity of changes of the values of hematological indices determining the level of this function is higher in the species with the lower body weight. As a result the smaller birds have more efficient mechanism of providing oxygen to its tissues.

Adult Wilson's storm petrels seem to satisfy the general relation for flying birds between the values of red blood indices and body weight (Kostelecka-Myrcha, unpubl.), *O. oceanicus* is a non-specific altrical bird like all other Procellariiformes, characterized by a more advanced development at the moment of hatch. Nethertheless the period of the nesting development of these birds is longer than the similar period in typical altricial species with the same body weight. This phenomenon is belived to be the result of longer periods of parent birds' absence from the nest as they look for appropriate amount of food. Sometimes nestlings are fed even once only in several days (Beck and Brown 1972, Croxall and Prince 1982). It seems impossible for such a situation to occur in typical altricial birds since they must be warmed up for a longer period of time.

Wilson's storm petrel lays only one egg and this is characteristic for all representatives of Procellariiformes. Thus, the only nestling in the nest has to overcome low temperature of the environment and limited amount of food. Therefore, it is intersting to investigate whether characteristics of the mechanism responsible for respiratory function of blood volume unit during the nesting development of *O. oceanicus* are similar to typical altricial species of temperate zone and LIttle Auk. It is also interesting to follow the dynamics of changes of red blood indices during a longer period of development of Wilson's storm petrel.

Material and methods

The studies were carried out during 1984/85 breeding season in the region of Admiralty Bay, King George Island, South Shetland Islands. Examined nestlings belonged to a big breeding colony of Wilson's storm petrels localized on Rakusa Point rocks, 800 meters from Arctowski Station, in the immediate vicinity of Point Thomas pygoscelid penguins rookery. The highest concentration of Wilson's storm petrel nests in this region reached the value of $7 \times 100\,m^{-2}$ and was found on the area of stabilized andesite basalt rock debris (Wasilewski 1986).

250 nests were localized during the observation of birds flying in the evening and marked during December and January. The nests were visited every 2—3 days during the lying and incubation period. However, starting from January 20, the nests were checked every day since the nestlings usually start to hatch at that time (Wasilewski 1986). This allowed to determine the age of the nestlings with the accuracy of one day.

Hematological studies were carried out on 81 nestlings aged 1—61 days. Birds were brought to the Arctowski Station laboratory at midday hours. Blood was collected from antebrachial vein of etherized birds. Concentration of hemoglobin (Hb, g%) was determined in Zeiss hemometer and hematocrit value (Hct, %) was measured by the micromethod. Erythrocytes (RBC, mln/mm^3) in the blood diluted with Hayem fluid were counted in Thoma chamber. The width and length of 50 erythrocytes were measured for each individual on preparations stained by Pappenheim method using a micrometric ocular. Using the above measurements the mean cell hemoglobin (MCH, $\gamma\gamma$), mean cell hemoglobin concentration (MCHC, %), and the mean red blood cell volume (RBC vol., μm^3) were calculated. Total surface area of erythrocytes in 1 mm^3 of blood (TSAE) in units suitable for comparative analysis as well as the amount of Hb per unit of this surface (Hb/TSAE in mg$\times 10^{-9}$) were also estimated. As a measure of the surface area of a single red blood cell the product of its width and length multiplication was assumed. Total surface area of erythrocyte was calculated as the product of cell count in 1 mm^3 of blood and a single cell surface area (Kostelecka-Myrcha et al., in press). Constant proportions of erythrocyte and their nucleus dimensions in various bird species (Kostelecka-Myrcha, unpublished data) allowed us to apply calculated parameters as appropriate for comparative purposes.

Results

The 61 days long development of *O. oceanicus* nestling could be divided into three stages. The blood hemoglobin concentration decreases significantly during the first 10 days. Next 15 days are characterized by slow increase of Hb content. From the 25th day until the end of the nesting development an intensive increase of hemoglobin concentration was observed (Fig. 1A, Tab. 1). Erythrocyte count increases profoundly during first 8 days after which it stabilizes for the next two weeks of development. Renewed intensive increase of red blood cell number was observed from the 25th day until the end of the nestlings' stay in the nest (Fig. 1B, Tab. 1).

The fact that the dynamics of the heamtocrit changes (Fig. 1C, Tab. 1) is consistent with the pattern of the erythrocyte count changes in the blood of *O. oceanicus* nestlings testifies to a large intensity of the increase of this count, both in the first 8 days of the birds' development and after the 25th day of their lives. Hematocrit value depends also on the size of erythrocytes which decreases with statistical significance during the whole nesting development (Fig. 2A, B, C, Tab. 1).

The mean cell hemoglobin concentration decreases significantly during the first 8—10 days of young Wilson's storm petrel's life as the result of the above described changes of Hb concentration and the value of hematocrit. Then it increases until the nestlings leave the nest (Fig. 3A,

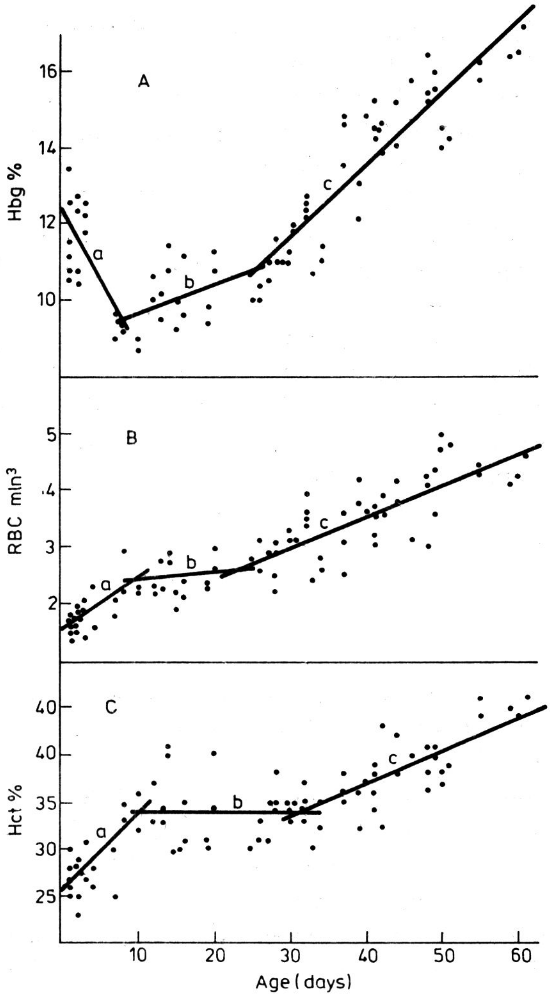

Fig. 1. Changes of the hemoglobin concentration, number of erythrocytes in 1 mm^3 of blood and hematocrit value during nesting development of Wilson's storm petrel

A. Amount of hemoglobin: a — 1—10 days, $y = 12.438 - 0.357x$, $r = -0,763$, $n = 20$, b — 7—25 days, $y = 8.903 + 0.075x$, $r = 0.443$, $n = 21$, c — 25—61 days, $y = 5.941 + 0.190x$, $r = 0.910$, $n = 47$;

B. Number of erythrocytes: a — 1—10 days, $y = 1.567 + 0.085x$, $r = 0.704$, $n = 20$, b — 8—25 days, $y = 2.250 + 0.041x$, $r = 0.215$, $n = 19$, c — 25—61 days, $y = 1.402 + 0.053x$, $r = 0.762$, $n = 47$;

C. Hematocrit: a — 1—14 days, $y = 25.44 + 0.824x$, $r = 0.834$, $n = 26$, b — 8—30 days, $y = 34.05 - 0.00089x$, $r = -0.064$, $n = 30$, c — 25—61 days, $y = 23.69 + 0.334x$, $r = 0.794$, $n = 46$.

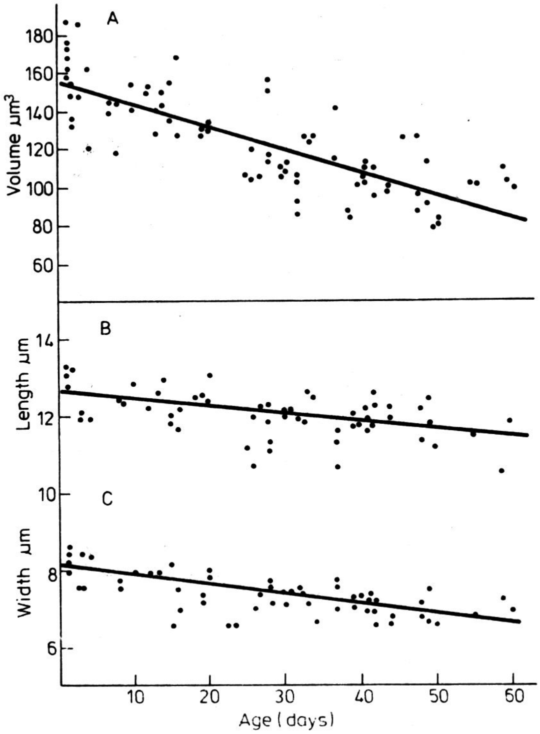

Fig. 2. Changes of erythrocyte size during nesting development of Wilson's storm petrel
A. Volume: 1—61 days, $y = 156.70 - 1.19x$, $r = -0.794$, $n = 81$;
B. Length: 1—61 days, $y = 12.68 - 0.021x$, $r = -0.537$, $n = 57$;
C. Width: 1—61 days, $y = 8.08 - 0.024x$, $r = -0.696$, $n = 57$.

Tab. 1). The mean cell hemoglobin decreases rapidly during the first 10 days of development (Fig. 3B, Tab. 1) since the Hb concentration also decreases (Fig. 1A) and the erythrocyte count per 1 mm³ increases (Fig. 1B). In nestlings older than 10 days MCH stabilizes.

Total surface area of erythrocyte depends mainly on its count in 1 mm³ of blood. During the first 8—10 days of Wilson's storm petrel development increase of TSAE is intensive and statistically significant. Later it does not change until the 25th day and than TSAE decreases rapidly until the end of the birds' stay in the nest (Fig. 3C, Tab. 1). The amount of Hb calculated for the assumed surface area unit does not change from 8th day until the end of development (Fig. 3D, Tab. 1). Only during the first days of Wilsons storm petrel life Hb/TSAE value was found to be higher since total surface area of erythrocytes is the lowest (Fig. 3C) and the Hb concentration is relatively high (Fig. 1A).

Table 1

Changes of hematological values during nesting development of Wilson's storm petrel

Age days	n	Body weight g	Hb %	RBC mln/mm³	Hct %	MCHC %	MCH γγ	RBC vol μm³	Erythrocytes measurements		TSAE μm²	Hb / TSAE mg·10⁻⁹μm²
									Length μm	Width μm		
1	6	7.45	11.7	1.60	27.3	43.03	73.86	171.2	13.14	8.39	181.4	0.68
2	4	8.02	11.6	1.82	26.2	44.96	64.08	143.9	—	—	—	—
3	2	9.25	12.0	1.76	29.0	41.69	70.39	167.9	12.11	8.52	146.4	0.80
4	2	10.50	12.5	1.96	27.0	46.34	66.03	142.3	12.02	8.39	160.4	0.77
7	2	13.95	9.3	1.92	27.5	34.40	48.94	142.6	—	—	—	—
8	2	15.40	9.3	2.60	34.0	27.37	36.28	132.3	12.46	7.63	259.2	0.38
10	2	24.25	8.8	2.27	34.0	26.09	38.90	149.3	12.86	7.88	233.2	0.38
12	2	34.85	10.3	2.31	35.0	29.72	44.98	151.4	12.28	7.97	236.9	0.43
13	2	38.25	9.8	2.51	33.5	29.39	39.30	133.8	12.87	7.95	257.3	
14	2	25.75	11.2	2.76	40.5	27.52	40.33	146.6	—	—	—	—
15	2	40.60	9.6	2.08	30.0	31.99	46.49	144.8	11.95	7.41	186.3	0.54
16	2	42.00	10.4	2.27	33.5	31.04	46.17	148.7	11.96	7.23	198.1	0.54
19	2	49.00	9.6	2.35	30.5	31.48	40.76	129.8	12.66	7.27	216.2	0.44
20	2	40.75	11.0	2.77	37.0	30.00	39.95	133.2	12.79	7.95	281.4	0.40
25	1	49.00	10.0	2.78	30.0	33.33	35.97	107.9	11.25	6.62	207.9	0.48

26	2	45.50	10.2	2.86	32.0	31.88	35.86	112.4	11.35	6.82	220.1	0.46
27	1	55.50	10.5	2.92	31.0	33.87	35.96	106.2	12.30	7.42	266.4	0.39
28	4	48.37	11.1	2.62	35.5	31.43	42.32	134.9	11.71	7.50	236.9	0.49
30	4	45.37	11.5	3.13	34.2	33.50	36.72	109.6	12.12	7.32	278.2	0.51
32	4	52.00	12.4	3.60	34.7	35.80	34.63	96.9	11.98	7.44	306.7	0.41
33	1	45.00	10.6	2.38	30.0	35.33	44.54	126.0	12.66	7.08	213.3	0.50
34	2	45.50	11.2	2.67	33.5	33.47	41.99	125.4	12.48	6.70	232.4	0.48
37	3	57.00	14.3	2.96	36.3	39.45	48.97	123.9	11.14	7.43	244.8	0.59
39	2	59.50	12.5	3.98	34.0	36.96	31.50	85.3	11.89	7.25	343.2	0.36
40	1	61.00	14.8	3.64	37.0	40.00	30.66	101.6	11.81	7.37	316.6	0.47
41	4	54.50	14.6	3.38	36.7	39.76	43.41	109.0	11.92	7.20	289.3	0.50
42	2	52.50	14.2	3.60	37.5	38.69	39.78	103.6	12.50	6.90	309.4	0.46
44	2	49.50	14.6	3.99	40.0	36.51	36.55	100.1	12.21	6.72	328.3	0.44
46	1	60.00	15.8	3.16	40.0	39.50	50.00	126.6	—	—	—	—
48	3	51.67	15.7	3.78	38.3	41.00	42.65	103.7	11.84	7.02	297.3	0.53
49	2	55.50	15.7	3.97	40.5	38.88	40.10	103.1	12.02	7.12	339.4	0.46
50	2	55.00	14.2	4.83	37.5	38.00	29.47	78.5	11.24	6.59	366.7	0.40
51	1	62.00	14.2	4.80	39.0	36.41	29.58	81.2	—	—	—	—
55	2	57.00	16.0	4.36	45.0	34.65	36.67	103.0	11.51	6.84	336.2	0.47
59	1	60.00	16.4	4.10	45.0	36.44	40.00	109.7	10.56	7.31	316.5	0.51
60	1	50.00	16.5	4.26	44.0	36.36	38.73	103.3	11.88	6.96	352.1	0.46
61	1	62.00	17.2	4.59	46.0	37.39	37.47	100.2	—	—	—	

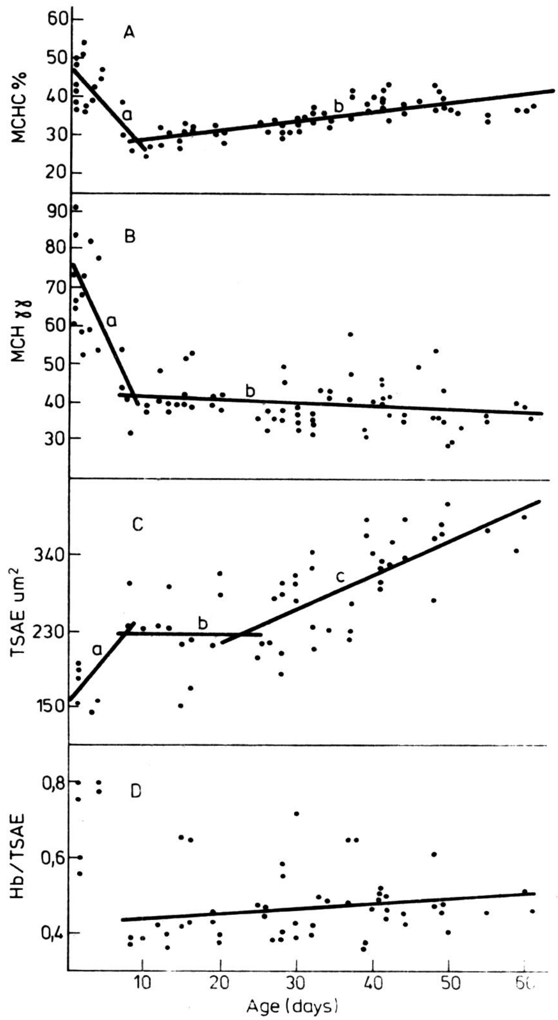

Fig. 3. Changes of the mean cell hemoglobin concentration, mean cell hemoglobin, total surface area of erythrocytes and amount of hemoglobin per unit of erythrocyte surface area during nesting development of Wilson's storm petrel

A. MCHC: a — 1—10 days, $y = 47.55 - 2.067x$, $r = -0.761$, $n = 20$, b — 7—61 days, $y = 27.44 + 0.220x$, $r = 0.740$, $n = 67$

B. MCH: a — 1—10 days, $y = 77.32 - 4.178x$, $r = -0.799$, $n = 20$, b — 10—61 days, $y = 42.58 - 0.081x$, $r = -0.189$, $n = 63$;

C. TSAE: a — 1—10 days, $y = 160.97 + 9.068x$, $r = 0.734$, $n = 9$, b — 10—25 days, $y = 226.40 + 0.058x$, $r = 0.006$, $n = 13$, c — 25—61 days, $y = 146.90 + 3.615x$, $r = 0.704$, $n = 37$;

D. Hb/TSAE: 8—61 days, $y = 0.432 + 0.001x$, $r = 0.187$, $n = 51$.

Discussion

The analysis of the changes of hematological parameters describing the respiratory function of blood volume unit during the nesting development of *O. oceanicus* lasting approximatelly 60 days (Beck and Brown 1972, Wasilewski 1986) suggests that this period could be divided into three stages. The first 8—10 days of nestling life are characterized by statistically significant decrease of Hb concentration that is accompanied by profound increase of erythrocyte count in 1 mm^3 of blood. In turn this results in statistically significant increase of Hct and TSAE although the erythrocyte size decreases in this period. Finally, mean cell hemoglobin concentration as well as MCH profoundly decreases. During the first stage of birds development the amount of hemoglobin calculated per unit of surface area of erythrocytes decreases also as the effect of the decrease of Hb concentration in blood accompanied by the inrease of total surface area of erythrocytes.

Various bird species were studied with respect to changes of the red blood picture during nesting development but none of them is comparable to that of *O. oceanicus*. Increase rather than decrease of blood Hb concentration accompanied by the increase of total surface area of erythrocytes was observed in the representatives of all studied species. Therefore, the value of Hb/TSAE index does not change in 5 bird species of temperate zone as well as in Little Auk from Arctic. Moreover, calculated value is almost the same as obtained for temperate zone birds and Little Auk, the species of different body weight, biology and environmental conditions (Kostelecka-Myrcha, unpubl.). Present knowledge on the biology of *O. oceanicus* does not allow to explain the phenomenon of hemoglobin concentration decrease during first days of life.

The values of all tested red blood parameters responsible for respiratory function of blood volume unit did not change during second stage of *O. oceanicus* development lasting about two weeks i.e. until the 25th day.

The changes of hematological parameters appeared again during the third period of *O. oceanicus* development, lasting about 35 days. The mechanism responsible for respiratory function of blood volume unit of nestlings between the 25th and the last day of their stay in the nest is characteristic for typical altricial birds (Kostelecka-Myrcha, 1985). Increasing value of hemoglobin concentration matches the increase of total surface area of erythrocytes in 1 mm^3 since the value of Hb/TSAE is stable over this stage. This last value is similar to that obtained for previously studied birds. The precisely defined increase of total surface area of erythrocytes is a result of very intensive increase of erythrocytes number in 1 mm^3 of blood, which causes, despite significant decrease of their size, statistically noticeable hematocrit increase. The increase of the hemoglobin content changes was found to be of the same rate as the increase of erythrocyte count since MCH is stable, but more profound than the increase of hematocrit since statistically significant increase of MCHC was observed.

It is noteworthy that the third stage of the nesting development is the most important from the point of view of the organization level of respiratory function of blood volume unit. This period starts after the most intensive growth of the nestlings has been finished (Fig. 4). The highest rate of young *O. oceanicus* growth occurs during the second stage of nesting development characterized by the lack of changes of hematological indices. Growth of Wilson's storm petrel nestlings was slightly slower during the first stage. However, the general shape of the growth curve fits well the one obtained for this species by Beck and Brown (1972) and Wasilewski (1986).

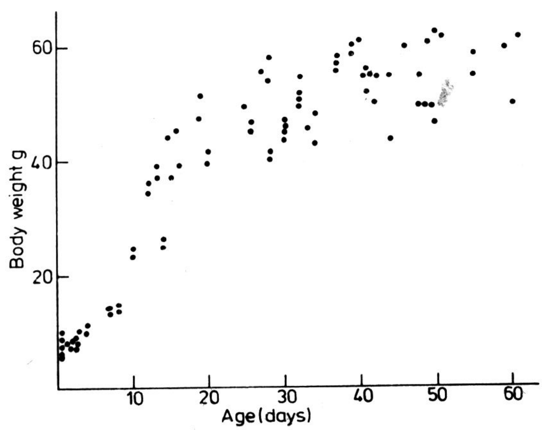

Fig. 4. Changes of the body weight during nesting development of Wilson's storm petrel.

Different developmental processes of *O. oceanicus*, found not to occur parallel in time, but following each other, seem to result from a limited amount of food delivered by parents to the nest at time intervals even longer than one day, accompanied by their absence and insufficient warming of nest. The situation is typical for many sea bird species and particularly for Procellariiformes (Lack 1968, Ricklefs 1983). The chicks of storm petrels are the smallest among them and only after several days from the moment of hatching young birds are able to keep constant body temperature in quite range of environmental temperatures (Ricklefs, White and Cullen 1980). Probably the amount of energy assimilated from food by the developing Wilson's storm petrels is not enough to provide efficient thermoregulation, storage of adequate amount of fat as a reserve material which allows them to survive the long periods of starvation, intensive growth and development of various physiological processes e.g. blood respiratory function. It is suggested that the time separation of these different developmental proceses in non-specific altricial birds is the reason of their prolonged development period as compared with typical altricials of similar body weight.

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Streszczenie

Zbadano zmiany wartości wskaźników czerwonokrwinkowych w rozwoju gniazdowym nawałników Wilsona, *Oceanites oceanicus* (Kühl). Pisklęta pochodziły z kolonii lęgowej położonej w rejonie Zatoki Admiralicji na Wyspie Króla Jerzego, Antarktyka. Stwierdzono, że trwający około 60 dni rozwój gniazdowy tych ptaków można podzielić na trzy okresy: 1) od wyklucia do 8—10 dnia, 2) od 10 do ok. 25 dnia, 3) od ok. 25 dnia do wylotu z gniazda. W pierwszym okresie stężenie Hb we krwi istotnie maleje, podczas gdy sumaryczna powierzchnia erytrocytów i hematokryt zwiększają się. Pisklęta w tym czasie rosną jeszcze niezbyt szybko. U dotychczas badanych ptaków nie stwierdzono zmniejszania się stężenia Hb podczas rozwoju gniazdowego. W drugim okresie wartości wszystkich badanych wskaźników nie zmieniają się, natomiast wzrost piskląt jest bardzo szybki. W trzecim okresie tempo wzrostu znacznie maleje i wkrótce młode nawałniki uzyskują ciężar ciała typowy dla dorosłych osobników. Jednocześnie rozpoczynają się bardzo intensywne zmiany wszystkich parametrów hematologicznych, kształtujących funkcję oddechową jednostki objętości krwi. Kierunek tych zmian i wzajemne relacje są takie same, jak stwierdzone w całym okresie rozwoju wcześniej zbadanych typowych gniazdowników. Długi okres rozwoju gniazdowego nawałników można tłumaczyć tym, że różne procesy rozwojowe, kształtujące różne funkcje, odbywają się niejednocześnie (np. wzrost i oddechowa funkcja krwi). Konieczność taka wynika prawdopodobnie z ograniczonej ilości pokarmu dostarczanego młodym ptakom przez rodziców.