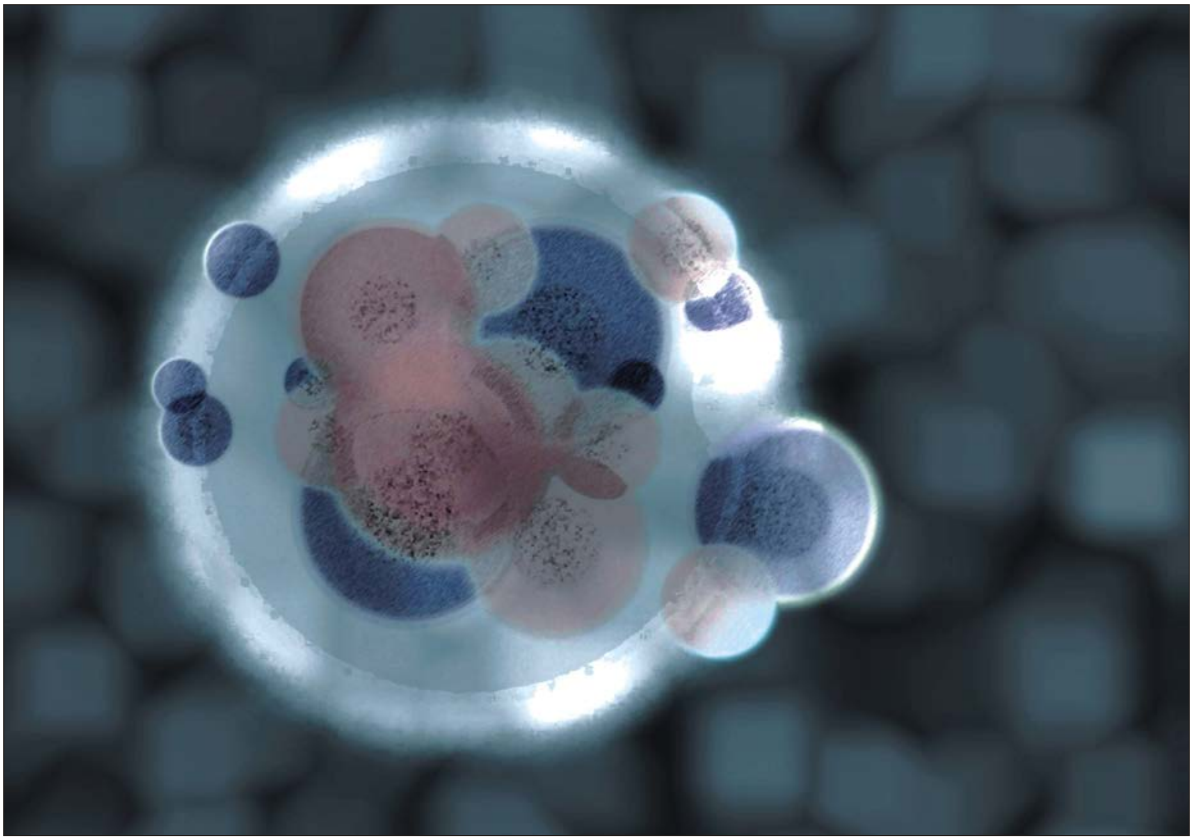

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 4 (4): 564-567, 2004
ISSN 1727-3048

Seasonal Variation in Basal Metabolic Rate and Body Composition Within Individual Sanderling Bird *Calidris alba*

Mansour I. AL-Mansour
Department of Zoology, College of Science, King Saud University,
P.O. Box 2455, Riyadh 11451, Saudi Arabia

Abstract: The magnitude of the seasonal variations in basal metabolic rate and body composition within individual Sanderling were investigated. Basal metabolic rate (BMR), an individual bird's minimum rate of energy expenditure, was followed in adult captive Sanderling throughout their annual cycle, in conjunction with measurements of body composition (lean mass and fat mass) as predicted using total body electrical conductivity (TOBEC). Adult captive Sanderling increased significantly in body mass (37%) during spring, primarily due to fat deposition (25%). A seasonal peak in BMR, often double the seasonal minimum, occurred during spring but typically took place several days (2-4) after the seasonal peaks in BM, lean mass (LM) and fat mass (FM). Little of the variation in BMR seen within captive Sanderling, irrespective of physiological state.

Key words: Basal metabolic rate, body composition, seasonal variation, *Calidris alba*

INTRODUCTION

Basal metabolic rate is the minimum rat of energy expenditure by a non-growing, non-reproductive homeotherm and is measured under post-absorptive and thermoneutral conditions, in the inactive phase of the circadian cycle[1-3].

Seasonal variation in BMR and body mass (BM) have been shown to take place in certain species of birds[4-7]. Daan *et al.*[4] followed variation in BMR in conjunction with BM of four captive Kestrels at fortnightly intervals throughout their annual cycle. They found that BMR to be high during moult. Variation in BMR has also been reported to occur within individual captive Knot during their annual cycle[5,6,8]. Measurements of BMR were taken by Piersma *et al.*[6] once every six weeks. Weber and Piersma[9] showed that a single individual captive Knot decreased from a peak body mass in spring 214 g to a BM of 98 g in only 24 days. It is more likely that all the previous studies missed out the real peak of BMR and BM due to infrequent measurements of the BMR and BM. Moreover, the findings by Daan *et al.*[4], Cadee[5] and Piersma *et al.*[6] have all been based on extremely small sample sizes and no attempts were made to monitor any seasonal changes within individuals in body composition, i.e. lean mass and fat mass. In this investigation measurements of basal metabolic rate (BMR) were followed in 17 adult captive Sanderling throughout their annual cycle, in conjunction with measurements of body composition (lean mass and fat mass) as predicted using total body electrical conductivity (TOBEC).

MATERIALS AND METHODS

Measurement of total body electrical conductivity (TOBEC) indices: Seventeen adult Sanderling, caught at Teesmouth (Northeast England) in 1998 using cannon nets and mist nets and held in captivity thereafter, were used for studies of seasonal variation in body composition and BMR.

Measurement of total body electrical conductivity (TOBEC) is now a popular technique among ornithologists for estimating fat reserves in birds[10]. This method was developed in the early 1970's and has recently been used widely in the agricultural and medical fields[11]. The machine must be calibrated for each species to be studied.

Predicted total lean mass (PTLM) for Sanderling can be obtained using the equation below:

$PTLM = (0.49 * I) + 20.4$ g (calibrated by the Author) for Sanderling *Calidris alba*.

Predicted mass of fat (PFM) is calculated by subtracting PTLM from body mass (BM):

$$PFM = BM - PTLM$$

TOBEC was measured using the EM-Scan (3420 Constitution Drive, Spring-field, Illinois 62707,

Corresponding Author: Mansour I. AL-Mansour, Department of Zoology, College of Science, King Saud University, P.O.Box 2455, Riyadh 11451, Saudi Arabia

USA) SA-1 Small Animal Body Composition Analyzer. The SA-1 was used in the laboratory and also in the field when it was powered by a 12V battery via an Oertling PC-01 converter to provide 240 V, 50 cycles AC. Each of the captive birds was weighed using a Pesola spring-balance to the nearest gram and its TOBEC index calculated at least once every week. Captive birds were isolated from the cage for 1 h before measuring TOBEC values.

Measurement of Basal Metabolic Rate: Open-flow respirometry: The metabolic heat production of each bird was estimated by determination of rates of oxygen consumption using a paramagnetic oxygen analyser (Servomex plc, Crowborough, East Sussex, Model1111D/000) and carbon dioxide production using an infrared analyser (Lira 3000, Mine Safety Appliances Company, Pennsylvania, USA) in an open-circuit system described by Scott *et al*.[12]. For measuring BMR, each bird was removed from the aviary at 08:00 GMT and kept isolated in a box for a minimum of 1 h without food or water. Around 10:00 GMT the bird was weighed using a Pesola spring-balance to the nearest g and then its TOBEC measurement taken. The bird was placed in one of the two identical metabolic chambers measuring 24.5 cm (height)x21 cm (diameter).

BMR measurement started at or after 12:00 h, after a period of at least 2 h of acclimation by birds to the metabolic chamber and 4 h of fasting to ensure that the individual was post-absorptive. The chamber was in complete darkness and was placed in a controlled temperature cabinet (LMS, Sevenoaks, Kent) at a constant temperature of 25°C (within the thermoneutoral zone of Sanderling). Dry air was drawn through the chamber at a rate of 60 L h^{-1}. Gas analyses were performed on samples taken from both the inlet and outlet gases via gas mass-flow controllers (Brooks Instruments, Netherlands, 5878 and 5850 TR series) at rates of 3.6 L h^{-1} for O_2 and 4.8 L h^{-1} for CO_2. Both inlet and outlet gases were dried prior to measurement by passing them over columns of dried coarse mesh silica gel. A measurement of BMR on a single individual was taken over a period of time ranging from between 90-120 min to ensure that a stable measurement of BMR was obtained for each run. If any periods of raised metabolic rate (MR) occurred during a measurement these were assumed to be periods of activity and the measurements were not used, although this was rare (Author, pers. Obs.). Under normal circumstances, birds remained at rest throughout the measurements, as proven by the lack of traces on activity-recording paper used to line the floor of the chamber. A period of 15-20 min was necessary between the first and second individual's BMR measurements when measurements were carried out on two birds on the same day, to enable the levels of O_2 and CO_2 to return to the pre-measurement baseline levels. To avoid CO_2 building up in the metabolic chamber not undergoing a BMR measurement, a constant flow of dry air was provided through this metabolic chamber using a simple diaphragm pump. Calibration was performed before each day's measurements, using dry, oil-free 100%N_2 and then a certified mixture of 21% O_2, 0.03% CO_2 in N_2 (SIP Analytical Ltd.). During each analysis, measurements were taken every minute over a ten-minute period in which O_2 consumption and CO_2 production were appeared to be stabilised at a basal level. The means of O_2 and CO_2 levels over these ten-minute periods were used to calculate RQ (CO_2 production/O_2 consumption) and BMR expressed in W (using an energy value per litre O_2 consumed appropriate for the RQ). The levels of O_2 and CO_2 were recorded onto a flatbed recorder (Kipp and Zonen, Delft, Netherlands, Model BD 112). Measurements of BMR were taken at least once every month but every three days when BM start rising i.e. during fat deposition in spring.

RESULTS

Figure 1 shows that captive Sanderling exhibited seasonal cycles in BM similar to those measured in wild birds in the non-breeding areas, in both terms of timing and mass[12]. It also shows that adult captive Sanderling increased significantly in body mass (37%) during spring. It can also be seen that increases in BM were due primarily to the deposition of fat (25%), although peaks in predicted total lean mass (13%) also occurred during the same time (Fig. 1). The mean (SE) time from the start of body mass gain in spring to peak mass and then through mass lose to stabilization of body mass at a level similar to that measured before spring mass increase was 27 (±4.3) days in the seventeen Sanderling.

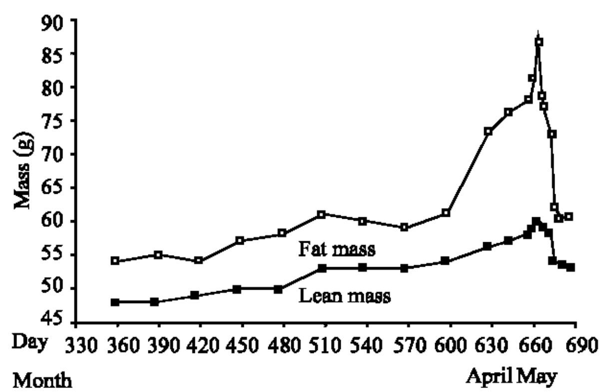

Fig. 1: Average of body compositions for seventeen adult Sanderling throughout captivity

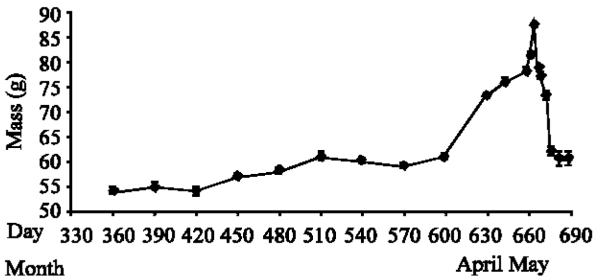

Fig. 2: Average of Basal Metabolic rate for seventeen Sanderling throughout captivity. Bars indicate SE

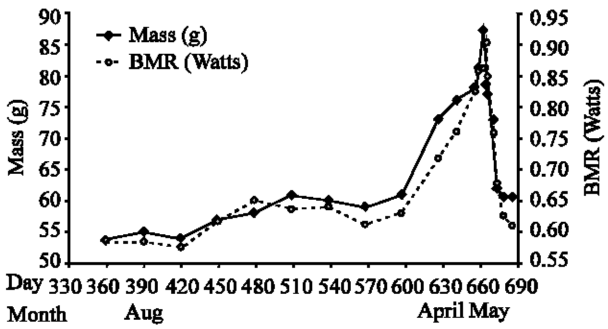

Fig. 3: Seasonal variation in Basal Metabolic rate and Body Mass in seventeen Sanderling

Table 1: Timing of peak of basal metabolic rate (BMR) in relation to timing of peak body mass (BM) and predicted total lean mass (PTLM) and Predicted fat mass (PFM)

ID	BM	PTLM	PFM
AA	+ 4	+6	+ 4
AB	+ 2	+2	0
AC	0	4	4
AD	+ 2	+4	+2
AE	+2	+3	+3
AF	0	+6	+6
AH	+3	+6	+3
AI	+3	+6	+3
AJ	0	0	0
AK	+1	+1	+6
AL	+3	+3	+3
AM	+2	+2	+4
AN	+2	+5	+2
AO	-1	+2	-1
AP	+3	+7	+3
AQ	+4	+7	+4
AR	+3	+3	+5
Mean(±SE)	+2 (±0.36)	+4 (±0.52)	+3 (±0.47)

- Days before peak in BM components, + Days after peak in BM components, 0 Peak in BMR occurs on same day as peak in BM components

Figure 2 shows that Sanderling did exhibit seasonal variation in basal metabolic rate. Seasonal peaks in BMR can clearly be seen during spring. This seasonal peak in BMR, nearly double the seasonal minimum.

The average of BMR (Watts) in conjunction with measurements of body composition (lean mass and fat mass) as predicted using TOBEC for seventeen Sanderling are shown in Fig. 3. It also shows that seasonal peaks in BMR generally did not occur on the same date as seasonal peaks in body mass but slightly later as body mass fell (Table 1).

Table 1 confirms that the peak BMR during the period of fat deposition rarely coincided with the period of peak BM, peak PTLM or predicted fat mass (PFM) but, on average occurred 2 days after peak body mass, 3 days after peak fat mass and 4 days after the peak in PTLM. As mentioned earlier the change in PTLM (48 to 60 g) was generally less than the change in PFM (6 to 27 g). The data indicated that the metabolic intensity of the lean tissue was altering on seasonal basis.

DISCUSSION

Seasonal variation in body composition: Sanderling in captivity exhibited and maintained annual cycles in body mass (BM) very similar in timing, duration and intensity to those seen during non-breeding seasons in wild conspecifics[12]. These variations in BM of captives, that had access to food *ad libitum,* suggest that seasonal variation in BM may be under some pre-programmed endogenous control[14] and not due directly to seasonal fluctuations in food availability. The environmental factors in this study under experimental control were photoperiod and temperature (set to imitate the external day-length and follow the ambient temperature as closely as possible in Durham) and it seems likely that photoperiod is involved in the synchronization and timing of the clear annual cycles in body mass seen in captive Sanderling.

Significant increases in BM generally occurred during late April early May in all captive Sanderling. This is the period in the wild when fat deposition occurs to fuel long-distance migration to the breeding grounds. No captive Sanderling exhibited autumnal peak in mass or in BMR. The probable explanation for this was that the photoperiod that wild birds experience on breeding grounds at this time, was not replicated in captivity.

Captive Sanderling show significant increase in BM (33 g), PTLM (12 g) and PFM (27 g). The deposition of fat is achieved mainly by an increase in adipocyte volume without an increase in adipocyte cell number[15,16]. PTLM increases as BM rising in spring, may indicate a period of gut hypertrophy which may aid food uptake and assimilation[17]. TOBEC, unfortunately cannot differentiate between the different tissues and organs that contribute to PTLM. Therefore it is possible that the flight muscle may actually hypertrophy in captive Sanderling at peak BM[9]. Such hypertrophy in the flight muscle will increase the power output of the muscles which, in turn, will enable a migrating bird to carry a larger load of fat (fuel) at the start of a long flight[18-21].

Seasonal variation in basal metabolic rate (BMR): The results in this investigation clearly show that seasonal peaks in BMR in captive Sanderling did not coincide with and therefore are not necessarily a consequence of seasonal peaks in BM, PTLM or of PFM. This finding is in direct contrast of those of Cadee[5], Piersma *et al.*[6] and Piersma[7]. The peak of BMR tended to occur soon after body compositions began to fall in spring (2-4 days). The rapid rate at which body mass is lost during this time may be due in part to the elevated BMR but it also requires a voluntary reduction in food intake[22]. The 3-4 day duration for which BMR is at a peak is assume to be the time that take a wild Sanderling to fly from the final staging post to the breeding grounds. The peaks of BMR may have been missed by Cadee[5] and Piersma[6] because they did not measure BMR in their individual birds as frequently as in this study; Piersma[7] for example, used measurements at 6-week intervals.

ACKNOWLEDGMENT

The author of this study is very grateful to the group of Lab 16 of Durham University for their help and support throughout this project.

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