Figures and figure supplements

Reduced metabolism supports hypoxic flight in the high-flying bar-headed goose (*Anser indicus*)

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Figure 1. CO₂ production versus heart rate in F_iO₂=0.21 (black), F_iO₂=0.105 (blue), and F_iO₂=0.07 (red). Normoxia and moderate hypoxia data from this study shown in (A), inset shows expansion of data at rest. N=7 birds for all data, n=89 sessions for rest in normoxia, n=113 flights in normoxia, n=54 sessions for rest in moderate hypoxia, n=74 flights in moderate hypoxia, n=13 flights in severe hypoxia (note that only one bird flew consistently in severe hypoxia), n=29 sessions for rest in severe hypoxia. In (B) oxygen consumption versus heart rate for bar-headed geese from three studies, Hawkes et al. (2011) (running, filled triangles), Ward et al. (2002) (open circles are flight and open triangles are walking), and the present study (filled circles are flight data, filled squares are rest). Note that $\dot{V}_{\text{O}_2}$ values for the current study have been calculated from $\dot{V}_{\text{CO}_2}$ values, assuming an RER=1.

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Figure 1—figure supplement 1. CO₂ production versus heart rate for rest and preflight (squares), as well as steady-state flight (circles) separated by individual birds in F₉O₂ = 0.21 (black), F₉O₂ = 0.105 (blue), and F₉O₂ = 0.07 (red).

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Figure 1—figure supplement 2. Means and standard errors in CO₂ production and heart rate are plotted for flight data of individual birds, indicated by bird number.

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Figure 2. Heart rate during flights of bar-headed geese. Line histogram distribution of heart rate measurements during flight for the present study (A) and measurements taken from wild, migrating birds by Bishop et al. (2015) (B). Dashed line shown to indicate 300 beats per minute in each plot (for aid in visual comparison only). Note that only one bird flew consistently in severe hypoxia (red trace in panel A).

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Figure 3. Mixed venous PO₂ and temperature during flight. Mixed venous PO₂ (A) and temperature (B) in F_iO₂=0.21 (black, n=4 birds, 13 flights), F_iO₂=0.105 (blue, n=2 birds, 6 flights), and F_iO₂=0.07 (red, n=1 bird, 3 flights). Time points shown along x-axis: ‘pre-flight’ is steady state before flight begins, ‘start’ at the start of the flight, ‘steady state’ is steady state in flight, ‘end’ at the end of the flight, ‘recovery’ is steady state after the bird lands. Asterisks indicate significant difference from normoxia (* indicates p<0.05; ** indicates p<0.01; *** indicates p<0.001, § indicates difference from pre-flight value, # indicates difference from recovery value, and $ indicates difference from start value).

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Figure 4. Examples of blood $P_{O_2}$ (black) and temperature (red) recordings during flight (gray shaded area) in normoxia (venous (A), arterial (C)) and hypoxia (venous (B), arterial (D)) for bird 45. Flight duration of (A) 3.3 minutes, (B) 4.2 minutes, (C) 5.7 minutes, and (D) 5.5 minutes.

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Figure 5. Flight tunnel experimental set up. (A) Schematic and (B) photo showing the set up in the wind tunnel. The goose flew in center of wind tunnel test section while person one encouraged flight and person two supported tubing. Tubes ran from mask out of the tunnel, one introducing a calibrated amount of dry nitrogen into the mask, and the other pulling from the mask by way of an air pump. A subsample of the outflow was pulled into the field metabolic system (FMS). Person three operated the tunnel and equipment. DOI: https://doi.org/10.7554/eLife.44986.011
Figure 5—figure supplement 1. Flight training with goose and foster parent (JUM) on a motor scooter, undertaken as the wind tunnel was undergoing repair at the time of fledging. Photo credit: K. Kuker.
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