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**Letter to the Editor**

# Free Flight Physiology: Paragliding and the Study of Extreme Altitude

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Paragliding is one of the most widely practiced forms of free flight, with an estimated 127,000 active paraglider pilots worldwide (Paraglider Manufacturers Association, 2014). Suspended beneath an unpowered, but steerable aerofoil wing, paragliders gain altitude through thermaling in convective updrafts and by using wind-driven lift reflected from mountain surfaces. The current distance record stands at 564 km in a single 11-hour flight (World Airsports Federation, 2016), and high-altitude paragliding, a rapidly evolving subdiscipline, is pushing the boundaries of equipment design, human physiology, and skill. In the past 5 years, paraglider pilots have soared over Broad Peak, Pakistan (8051 m) from an initial altitude of 4700 m without supplemental oxygen (Ewing, 2016), and taken off from the summits of Mt. Kilimanjaro, Tanzania (5895 m), and Mt. Everest, Nepal (8848 m) (Ewing, 2011).

Paragliding presents a unique opportunity for altitude research. To date, the most accessible study locations have been the top of road heads such as Chacaltaya, Bolivia (5300 m), and Pikes Peak, United States (4302 m). To go higher, researchers have often turned to trekkers and mountaineers, hot air balloonists, and hypobaric or hypoxic chambers. However, paraglider pilots can reach these extreme altitudes without the need for roads or airfields, at a fraction of the cost and with none of the complex logistics of ballooning or the associated environmental pollution of powered aircraft. Like mountaineers (and unlike those at simulated altitude), paraglider pilots remain exposed to the cold, wind, noise, and anxiety that represent the reality of life at the extremes. Paraglider pilots even have potential advantages over high-altitude mountaineers as study subjects: they can ascend faster and carry more equipment, without the potentially confounding exertion of extreme climbing (and the selection bias inherent in studying only those individuals capable of such exertion).

Conducting research with paragliders also has its own challenges. We believe that from an ethical standpoint, study designs should not impede pilots from making the appropriate decisions in flight, tempt them to eschew oxygen, or to take unnecessary risks for the sake of research. This may lead to restricted or variable altitude exposures depending on flying conditions. Equipment should be carefully chosen to avoid impacting on the control of the paraglider: for example, by not requiring pilots to remove their hands from the controls for more than a brief period, and by evenly weighting the harness. Should that prove too restrictive, researchers could consider using tandem instead of solo paragliders, with the pilots controlling the wing and the passengers acting as the experimental subjects. Finally, although there are thousands of paraglider pilots flying at altitudes up to 4000 m every week worldwide (World XContest, n.d.), only a proportion can fly safely at the extremes, so the number of subjects may be limited depending on the scope of the research.

Paragliding has become safer over time as training and equipment have improved, but it remains, like climbing, a relatively high-risk pursuit: of the 22,345 registered pilots paragliding in France in 2015, there were 15 deaths (0.06%) and 515 reported injuries (2.3%) (Fédération Française de Vol Libre, 2015). Most accidents appear to be secondary to errors of piloting or judgment, rather than equipment failure. Understanding the physiological demands placed on pilots, particularly those imparted by the low partial pressure of oxygen, is therefore key to establishing systems to prevent injury or loss of life.

We propose a new field of study, *Free Flight Physiology* (www.freeflightphysiology.org), to investigate and compare the physiological mechanisms that permit extreme feats of free flight to take place in humans and nonhuman animals, integrating developments in wearable sensor technology with medicine, spatial ecology, and meteorology. As the closest human analogue to high-altitude bird flight, we believe that paragliding provides a versatile platform for interdisciplinary research into the comparative physiological responses of vertebrates in flight to high altitude, hypoxia, and extreme environments. After all, both paraglider pilots and birds launch from foot, ascend at similar rates and by similar

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means, and are subjected to similar environmental stressors. Free flight physiology research has the potential to benefit those in the mountaineering, general aviation, high-altitude parachuting, and space tourism communities, as well as others operating at extreme altitudes. Ultimately however, it will improve the safety and performance of the pilots venturing into a rarefied and exhilarating realm.

## Author Disclosure Statement

No competing financial interests exist.

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