ACQUISITION OF A BIOMEDICAL DATABASE OF ACUTE RESPONSES TO SPACE FLIGHT DURING COMMERCIAL PERSONAL SUB-ORBITAL FLIGHTS.

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Introduction: There is currently too little reproducible data for a scientifically valid understanding of the initial responses of a diverse human population to weightlessness and other space flight factors. Astronauts on orbital space flights to date have been extremely healthy and fit, unlike the general human population. Data collection opportunities during the earliest phases of space flights to date, when the most dynamic responses may occur in response to abrupt transitions in acceleration loads, have been limited by operational restrictions on our ability to encumber the astronauts with even minimal monitoring instrumentation.

The era of commercial personal suborbital space flights promises the availability of a large (perhaps hundreds per year), diverse population of potential participants with a vested interest in their own responses to space flight factors, and a number of flight providers interested in documenting and demonstrating the attractiveness and safety of the experience they are offering.

Voluntary participation by even a fraction of the flying population in a uniform set of unobtrusive biomedical data collections would provide a database enabling statistical analyses of a variety of acute responses to a standardized space flight environment. This will benefit both the space life sciences discipline and the general state of human knowledge.

Discussion: The potential value of space life sciences research on suborbital flights has recently been reviewed [1, 2]. The physical aspects of the suborbital space flight environment are well-described in [3]. The environment of biomedical interest includes about four minutes of continuous weightlessness between two periods of about a minute each of high acceleration loading, first during powered flight and again during atmospheric entry, and the attendant physiological and psychological aspects of the experience, including the external view, the physical freedom offered by weightlessness and the personal realization of both the significance and the potential danger of the experience.

Several types of physiological adjustment to weightlessness can become well-established in four minutes. This is about eight times longer than the next nearest widely-available opportunity for such exposure, namely parabolic aircraft flight.

A preliminary set of hypotheses to be tested on such flights might include:

- Physiological responses to brief weightlessness, preceded and followed by brief, high acceleration loads, will be influenced by the presence and magnitude of the clinical and operational covariates (discussed below);
- Physiological responses will differ between populations exposed to the different launch and entry loads and flight profiles intrinsic to the variety of flight systems available from the providers;
- Repeat flyers will respond to flight stresses differently than novice flyers.

This last hypothesis illustrates an unprecedented opportunity offered by the approaching suborbital flight era. To date, only a few astronauts have flown as many as seven times. Nonetheless, there is evidence of less dramatic acute responses to repeated orbital flights in some areas (such as reported intensity of space motion sickness) but not others (such as postflight cardiovascular symptoms). In the suborbital era, it is entirely possible to expect that the spacecraft pilots, and possible some passengers, such as researchers, will fly dozens, perhaps a hundred times in a career, albeit on very short flights [2]. Documentation of the association between intensity of physiological response to flight factors and number of previous flights may provide insights into mechanisms of the human body's adaptability to space flight factors.

High-priority parameters to be recorded for analysis should change dramatically during suborbital space flights which provide physically dynamic phases as described above. These parameters should be readily perceptible to the volunteer participant, so as to provide the personal sensation context of the measurement. They should be amenable to unobtrusive and safe external detection, measurement and recording, and should have clinical relevance to the individual's experience and also be physiologically illuminating in the context of the accumulated database.

A preliminary list of such parameters might include:

Cardiovascular and cardiopulmonary changes including heart rate (from an electrocardiograph or a "pulse-meter"), arterial blood pressure (from continuous-sensing finger or wrist-mounted devices), thoracic blood volume, cardiac output and stroke volume (from impedance plethysmography and arterial waveform analysis), pulmonary function and arterial oxygen saturation (from a pulse oximeter), and regional (head and limb) blood volume from impedance plethysmography;

Sensory-motor changes inferred from cerebral function (by electroencephalography), cerebral blood flow (from near-infrared spectroscopy), visual-vestibular responses (by electrooculography), and behavioral strategies (by video and voice analysis)—and, of course, motion sickness;

Immunological and endocrinological changes documented in sample swabs and possibly automated venous sampling;

*Psychological response*s by video and voice recording, and possibly some brief tests of cognitive performance.

These should all be interpreted in the context of information from body-movement monitors and with spacecraft acceleration records and video- and voice-records assumed to be included in the services offered by the flight provider.

Physiological recordings will require the appropriate suite of sensors, presumably worn on the body. For greatest acceptability and thus use, they should be unobtrusive (non-contact sensors whenever possible), perhaps integrated into the flight clothing for ease of donning, doffing and sensor fixation, compatible with the spacecraft cabin environment, rugged, reusable, and inexpensive. The data recorder should have a low profile so as to be almost unnoticeable to the wearer, and battery-powered to avoid tethering the wearer to a spacecraft power supply. Wireless transmission of data and perhaps power are design features worthy of investigation.

The insights to be gained from the diverse population of expected volunteer participants can be inferred from consideration of the covariates of specific interest among common cardiovascular and cardiopulmonary risk factors, such as:

Uncontrollable risk factors including age, gender and hereditary factors;

Controllable risk factors such as history of tobacco use, cholesterol levels, hypertension, body mass index, history of physical activity or inactivity, behavioral responses to stress, and previous space flight history;

Operational or flight-related factors such as whether the individual is free-floating or restrained within the cabin, wearing a pressure suit or only lightweight clothing, the presence of motion sickness, changes in cabin atmospheric pressure and temperature, and the direction of acceleration loading (head-to foot if seated upright, chest-to-back if recumbent).

An effort to acquire a large and systematic database of human responses to space flight will have a variety of benefits. The quantitative assessment of risks on suborbital flights will permit an increase in passenger base as the flights become demonstrably safer; such data may also limit operator liability if untoward outcomes are shown to be independent of the flight itself. In addition, for what may be the first time in the era of human space flight, duplication of experiments may actually become encouraged instead of avoided, providing space life sciences research with a luxury that has heretofore been avoided as wasteful of limited opportunities and resources. Finally, the general increase in knowledge of the human effects of space flight may illuminate physiological knowledge in general, to the benefit of people in space and on the Earth.

In conclusion, every suborbital passenger will inevitably be the subject of an experiment that has not been possible throughout the evolution of life on Earth until the very recent past: exposure to weightlessness lasting more than a few seconds. The only question may be whether the data will be collected or lost.

References: [1] Stern A. *et al.*, Next-Generation Suborbital Spaceflight: A Research Bonanza at 100 Kilometers, *Space News*, Oct. 5, 2009, p. 19. [2] Wagner E. *et al.*, Opportunities for Research in Space Life Sciences Aboard Commercial Suborbital Flights, *Aviat. Space Environ. Med.* 80:984-6, 2009. [3] Sarigul-Klijn M. and Sarigul-Klijn N., Flight Mechanics of Manned Sub-Orbital Reusable Launch Vehicles with Recommendations for Launch and Recovery, AIAA 2003-0909, Jan. 2003 (rev. April 2003).