Subject Anxiety and Psychological Considerations for Centrifuge-Simulated Suborbital Spaceflight

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Introduction: Anxiety and psychological concerns may pose a challenge to future commercial spaceflight. To help identify potential measures of anxiousness and indicators of flight-related stress, the psychiatric histories and anxiousness responses of volunteers exposed to G forces in centrifuge-simulated spaceflight acceleration profiles were examined. ***Methods:*** Over 2 d, 86 individuals (63 men, 23 women), 20-78 yr old, underwent up to 7 centrifuge runs. Day 1 consisted of two $+G_z$ runs (peak = +3.5 G_z) and two $+G_x$ runs (peak = +6.0 G_x). Day 2 consisted of three runs approximating suborbital spaceflight profiles (combined $+G_x$ and $+G_z$). Hemodynamic data were collected during the profiles. Subjects completed a retrospective self-report anxiety questionnaire. Medical monitors identified individuals exhibiting varying degrees of anxiousness during centrifuge exposure, medical histories of psychiatric disease, and other potential indicators of psychological intolerance of spaceflight. ***Results:*** The retrospective survey identified 18 individuals self-reporting anxiousness, commonly related to unfamiliarity with centrifuge acceleration and concerns regarding medical history. There were 12 individuals (5 men, 7 women, average age 46.2 yr) who were observed to have anxiety that interfered with their ability to complete training; of these, 4 reported anxiousness on their questionnaire and 9 ultimately completed the centrifuge profiles. Psychiatric history was not significantly associated with anxious symptoms. ***Discussion:*** Anxiety is likely to be a relevant and potentially disabling problem for commercial spaceflight participants; however, positive psychiatric history and self-reported symptoms did not predict anxiety during centrifuge performance. Symptoms of anxiousness can often be ameliorated through training and coaching. Even highly anxious individuals are likely capable of tolerating commercial spaceflight.

Keywords: commercial spaceflight participant, motion sickness, psychology, G force, hypergravity.

ANXIETY AND psychological concerns may present challenges for future commercial spaceflight operations. Most of the psychological knowledge regarding humans in spaceflight is based upon studies of career astronauts selected under stringent medical and psychological standards. While there is limited study regarding chronic medical conditions and commercial spaceflight participant (SFP) tolerance of space vehicle acceleration profiles, there has been almost no investigation into anxiety and psychological elements related to commercial spaceflight (1,3). This is concerning as SFPs, unlike career astronauts, are not likely to experience a prolonged training program prior to launch, leaving them potentially unprepared for the psychological stressors of flight.

As with career astronauts, human centrifuge training can be used to prepare SFPs for the acceleration forces and general experience of commercial spaceflight. For many SFPs, centrifuge exposures may be the first opportunity to observe future passengers in a high-stress analogue environment and may elicit many of the anxious responses that could be anticipated in actual flight. To help identify useful measures of anxiety or stress during suborbital commercial spaceflight, as well as the potential for severe anxiousness to interrupt spaceflight operations, we examined the psychiatric histories as well as subjective and objective measures of nervous responses of volunteers to acceleration profiles of centrifuge-simulated spaceflight. We hypothesized that positive psychiatric history would correlate with anxiousness, but that most individuals could tolerate suborbital commercial spaceflight with appropriate coaching and training.

METHODS

Subjects

A prospective cohort study, approved by the University of Texas Medical Branch Institutional Review Board, was designed to recruit volunteers for physiological training at the National Aerospace Training and Research (NASTAR) Center centrifuge (2). Self-selected volunteers were assessed for inclusion in five cohorts of stable disease: hypertension; diabetes; cardiovascular disease; pulmonary disease, including chronic obstructive pulmonary disease, asthma, or similar obstructive or restrictive respiratory conditions; and spinal disease or injury. Volunteers with no known disease history were included in a control group. Participants were asked to complete a medical history survey regarding somatic and psychiatric conditions and undergo a physical examination by their personal physicians. These physicians were supplied with information regarding suborbital

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spaceflight and the expected physiological and psychological stressors that the participant would encounter (2).

All submitted medical records were examined by a study investigator and aerospace medicine specialist. Applicants could be approved, asked to undergo further testing or provide additional records, or be excluded based upon reported history or findings. In addition to severe or uncontrolled somatic conditions, uncontrolled psychiatric disease was grounds for exclusion from the trial. Study medical monitors were responsible for final decision making regarding any subject's participation. All participants signed informed consent and liability release forms prior to participation (2).

Procedures

Medical monitors reviewed submitted medical documentation with participants upon arrival at the centrifuge facility to ensure accuracy and completeness, and baseline vital signs were obtained at this time. Participants were advised to take all medications as scheduled, with the exception of peripheral vasodilators that could blunt their ability to tolerate acceleration. Prior to centrifuge runs, subjects were educated in basic anti-G straining and "hook" maneuvers (2).

Participants underwent seven centrifuge runs over 2 d (2). Apart from the final run (Run 7), each profile was executed first at 50% G force intensity and followed by a full-intensity run after a brief pause. Run 7 was executed at full intensity only. Day 1 consisted of two $+G_z$ (head-to-toe) runs with a peak of $+3.5\ G_z$ lasting 15 s in the second run and two $+G_x$ (front-to-back) runs with a peak of $+6.0\ G_x$ lasting 15 s in the second run. Day 2 consisted of three runs simulating future suborbital spaceflight profiles with combined $+G_x$ and $+G_z$. The first two runs approximated the Virgin Galactic spaceflight profile as estimated based on acceleration profiles from test flights, where passengers would be seated upright during launch and supine during re-entry, and includes consecutive $+G_z$ and $+G_x$ components with maximums of $+6.0\ G_x$ and $+3.8\ G_z$ in Run 6. The final run was designed to simulate the acceleration anticipated in a generic suborbital flight with the spaceflight participant seated upright, resulting in combined and simultaneous $+G_x$ and $+G_z$ exposures during launch and re-entry. Maximum exposure was $+4.5\ G_x$ and $+4.0\ G_z$, with a resultant vector maximum of +6.0 G. Exposure to each phase of acceleration for all three of the final runs did not exceed 2 min and onset rates always remained less than $1.5\ G \cdot s^{-1}$ in the $+G_x$ direction and $0.5\ G \cdot s^{-1}$ in the $+G_z$ direction. The duration of time at the peaks of $+G_x$ and $+G_z$ was less than 5 s (2).

Audiovisual simulation was included during each run via the multimedia system of the centrifuge gondola to create an experience as similar as possible to actual suborbital flight. In addition to simulated spacecraft views of Earth and space, instrumentation displayed the flight profile and acceleration measurements in real time (2).

Vitals signs were monitored during and after flight. Immediately postflight, subjects completed a subjective questionnaire regarding physiological symptoms such as occurrence of motion sickness, spatial disorientation, greyout, or other centrifuge-related conditions. Postflight survey questions are provided below:

Did you experience:

1. Tumbling
2. Spinning
3. Disequilibrium
4. Nausea
5. Yawning
6. Claustrophobia
7. Greyout or tunnel vision
8. Increased work of breathing or shortness of breath
9. Palpitations
10. Presyncope (feeling like you might faint) or light-headedness
11. Loss of consciousness or awareness
12. Chest discomfort
13. Headache
14. Back or neck discomfort
15. Surprises, or unexpected events

Subjects completed this survey after the conclusion of each centrifuge run. Subjects provided answers of yes or no, and were given the opportunity to leave comments regarding issues not addressed by the survey. Throughout the visit at the centrifuge facility, participants were monitored by proctors for evidence of anxiety related to the simulated spaceflight experience. Coaching and education were provided as needed.

Upon conclusion of all centrifuge runs, subjects completed a retrospective postflight anxiety questionnaire based upon an established validated air-travel anxiety questionnaire (The Flight Anxiety Modality Questionnaire by Van Gerwen et al., 1999), designed to assess anxiety-related symptoms during the experience (4,6). The retrospective survey is provided below:

1. I felt sick or had stomachache or belly complaints
2. I had a fear of dying
3. I had chest discomfort
4. I couldn't tell what was going to happen and that made me feel very anxious
5. I was sweating
6. The idea that something would go wrong was constantly on my mind
7. I attended to every sound or movement of the centrifuge and wondered whether everything was ok
8. I was afraid that I was losing control of the situation or felt nervous trusting the staff
9. I had a dry mouth
10. I thought the gondola was going to malfunction and injure me
11. I thought that I would faint from fear
12. I was very nervous on arrival to the facility
13. The staff helped to relieve my anxiety
14. I considered withdrawing from the study
15. I became more comfortable with later runs because of the experience
16. I would consider participating again

Subjects completed this survey after the conclusion of the entire centrifuge experience or after withdrawal from the study. Subjects rated their answers on a scale of 1 to 5, with 1 being minimal and 5 being significant. Subjects were also given the opportunity to leave comments regarding issues not addressed by the questionnaire.

Questions covered stomach upset, fear of dying, chest discomfort, fear of the unknown, dry mouth, diaphoresis, concerns about potential gondola malfunction, thoughts of withdrawal from the study, and fear regarding loss of control. Responses were given on a scale of 1-5 and the sum total of points from all questions was calculated and converted into a quaternary score from 0 to 3 (least to most anxious). Subjects were also rated by monitors on a quaternary scale based upon how significantly their anxiety impacted the workflow during study days or the experience of the other subjects in the study group. Specific indicators of anxiousness identified by staff included subjects reporting nervousness to monitors, reluctance to enter the gondola at the time of their runs, tearfulness, and observations of reliance upon stress-mitigation techniques such as yoga, prayer, and similar activities.

Statistical Analysis

Data collection was followed by statistical analysis using descriptive statistics, linear regression modeling, and student *t*-tests. Free-response comments from the questionnaire were analyzed for common themes.

RESULTS

A total of 335 individuals registered to take part in the study. The prescreening medical questionnaire was completed by 179 volunteers and 124 provided adequate medical documentation to be considered. Two subjects were excluded due to uncontrolled psychiatric disease; both were disqualified after being identified as unfit to participate by their personal physician prior to requests for additional information by study personnel. Included in the study population were six participants with depression, four with generalized anxiety disorder, and three with bipolar disorder, all of which were reported mild and well-controlled.

Of 86 participants, 85 completed the retrospective anxiety questionnaire, including 11 of the 12 noted by study personnel as exhibiting symptoms of anxiousness during their time at the centrifuge facility. The questionnaire identified 18 individuals who self-reported anxiety symptoms. These were commonly related to unfamiliarity with centrifuge acceleration and concerns regarding medical history. Noted by study personnel were 12 individuals (5 men, 7 women, average age 46.2 yr) who had anxiousness that interfered with their ability to complete the trials. Of these, four reported significant anxiousness on their retrospective questionnaire and nine eventually completed their centrifuge profiles. The three subjects who withdrew before completion of all spins noted medical concerns (motion sickness or discomfort) as the source of nervousness and the reason for withdrawal. One complained of a history of motion sickness with prior centrifuge training, citing concerns that further spins could trigger nausea or vomiting; a second complained of chest discomfort with $+G_x$ exposure and concerns regarding potentially worsening symptoms with further spins (though symptoms had been, per the subject, easily tolerable to that point); and the final subject withdrew due to worsening dizziness and disequilibrium that, while tolerable, caused concerns over the potential for significant discomfort with additional spins. While these symptoms were minimal at the time of withdrawal for each subject, concern over progression of symptoms with continued participation prompted their early departure.

There was a significantly higher reported reliance upon peer (group) support in the retrospective questionnaire by participants who were rated anxious by staff [on a 1-5 scale, not anxious 0.05 ± 0.2, anxious 0.25 ± 0.5, $t(84) = 1.99$, $P = 0.02$] and those that self-reported being anxious [not anxious 0.04 ± 0.2, anxious 0.2 ± 0.4, $t(84) = 1.99$, $P = 0.01$] than those that were not staff- or self-rated as anxious. Here, peer support specifically referred to the support from the group of other study participants, not family or staff. In contrast, there was no significant difference between both staff- and self-rated anxious and nonanxious subjects and reported reliance upon family, staff, or monitor support.

Motion sickness was significantly correlated with anxiety. Motion sickness reported immediately following each spin was correlated with those rated anxious by staff [not anxious 0.2 ± 0.4, anxious 0.9 ± 0.3, $t(84) = 1.99$, $P < 0.001$]; this did not hold true for those self-rating as anxious. On the retrospective questionnaire there was a significantly higher reported rate of motion sickness in both the staff- [not anxious 0.05 ± 0.2, anxious 0.5 ± 0.5, $t(84) = 1.99$, $P < 0.001$] and self-reported [not anxious 0.07 ± 0.3, anxious 0.3 ± 0.5, $t(84) = 1.99$, $P < 0.02$] anxious groups as compared to the nonanxious group.

Chest discomfort was similarly correlated with anxiety. There was a significantly higher reported rate of chest discomfort in the staff-rated anxious group immediately following each spin [not anxious 0 ± 0, anxious 0.08 ± 0.3, $t(84) = 1.99$, $P < 0.02$] compared to nonanxious subjects, though this did not hold true for self-rated anxious subjects. In contrast, there was a significant correlation between self-rated anxious subjects who reported chest discomfort on the retrospective questionnaire, but not for those that were staff-rated as anxious.

There was no correlation between staff- or self-rated anxiousness and any of the following: age, body mass index (BMI), sex, psychiatric disease history, use of psychotropic medications, or hemodynamic variables, including blood pressure, heart rate, or pulse oximetry. Further, there was no correlation between nervousness and any questionnaire-reported fear of the unknown or confidence gained by education or experience in the centrifuge.

DISCUSSION

This study investigated anxiousness in study participants using centrifuge-simulated spaceflight experiences. As there are little data addressing anxiety in a commercial spaceflight participant, this study may provide insight into what may become a significant concern for

future commercial spaceflight operations. From a psychological standpoint, the cohort as a whole completed centrifuge training without significant difficulty. However, 12 volunteers were noted by staff as having anxious responses that interfered with their ability to complete centrifuge trials or disrupted the experience of those around them. Of these, only nine were able to complete the runs. The effect of these individuals on the study ranged from minimal interruption of operations to significant utilization of resources, including time spent isolated in a room with staff members to provide support or disruption to other participants' enjoyment. Of note, of the 18 individuals that self-reported nervous symptoms, only 4 were in the staff-rated anxious group, demonstrating poor correlation between self-awareness of (or willingness to report) anxiety and staff recognition of disruptive symptoms. Finally, it is worth noting that only 3 of 86 subjects failed to complete the demanding series of acceleration exposures for psychological reasons; most subjects performed both psychologically and physiologically well during the trials.

In general, subjects that staff rated as more anxious were concerned over potential medical issues that the participant had previously experienced. Motion sickness has been correlated with anxiety in other studies (5,10). Many participants who experienced anxiousness had a history of significant motion sickness. While symptoms were minimal or absent when nervousness occurred, subjects expressed concern that these symptoms could develop, diminishing the positive nature of the centrifuge experience. Of the subjects who withdrew prior to completion of their centrifuge runs, discomfort prompted early withdrawal from the centrifuge trials in order to prevent worsening of symptoms and development of an overall negative experience. As this study was not originally designed to evaluate the difference between anxiety directed at motion sickness and other physiological complaints or anxiety concerning the experience itself, it is difficult to delineate the weight of the different stressors on the overall psychological response of the subjects.

Peer support from accompanying participants appeared to soothe anxiousness. Subjects often indicated in retrospective surveys that their ability to rely upon their peer group, or learn from the actions of other flyers, was particularly helpful and occasionally even prevented subjects from withdrawing from the study for anxiety-related reasons. It is likely that encouragement of peer-support relationships in groups of SFPs could similarly mitigate anxiousness and provide comfort during commercial spaceflight operations. Interestingly, subjects did not indicate the same reliance upon family or staff support during times of anxiousness. Additionally, there was no significant correlation between nervousness and confidence gained during training or experience. While many subjects anecdotally reported improvement in mild anxiousness after experiencing preliminary runs, those that were the most nervous were not ameliorated with increasing exposure to the centrifuge.

Based on the in-study observations and the responses to the retrospective anxiety questionnaire, motion sickness and chest discomfort were significantly correlated with both staff- and self-reported anxiousness. Chest discomfort is thought to induce anxiousness during high acceleration due to the sensation of struggling to breathe, particularly during $+G_x$ acceleration where acceleration forces a limit to inspiratory ability. Similarly, neurovestibular dysfunction, including motion sickness, is a known effect of spaceflight (9). The prevalence of motion sickness susceptibility in the general population and the link between motion sickness and anxiousness may make these issues a concern for commercial SFPs (10). However, there is evidence to suggest that acclimatization procedures may mitigate the effects of neurovestibular dysfunction and physiological discomfort during spaceflight (11). Of note, there was no correlation between anxiety symptoms and any hemodynamic parameters, including blood pressure, heart rate, and pulse oximetry. This suggests that hemodynamic alteration may not be a useful marker to identify those at high risk for nervousness about centrifuge exposure (and, likely, commercial spaceflight), even when anxiety is prompted by a somatic source such as motion sickness or other bodily discomfort. Further studies are warranted to further address this issue.

While it was hypothesized that a history of psychiatric disease may help identify candidates prone to anxiety, psychiatric history was not correlated with symptoms of anxiety. There were several participants with psychiatric diagnoses; these subjects tolerated centrifuge exposure with no more difficulty than any other subject. As there were subjects excluded from the study due to uncontrolled psychiatric disease, there may be a correlation between severe psychiatric conditions and anxiety during flight. However, these individuals are likely to be excluded from commercial spaceflight due to psychiatric instability. The well-controlled psychiatric conditions present in this study may not pose any further risk for commercial spaceflight.

Anthropomorphic data revealed that anxiety did not significantly vary in prevalence by sex or age. Given the association between chest discomfort and anxiety, it was postulated that BMI may play a role because subjects with higher BMI and larger torso mass may experience a higher degree of chest pressure during the runs. However, data did not support this conclusion. Further research with a larger subject pool may identify anthropomorphic parameters that could place an individual at higher risk for nervousness.

One limitation of this investigation is the subjective nature of both the participant-reported anxiety symptoms and staff-identified signs of anxiousness. Additionally, as uncontrolled psychiatric disorders were grounds for exclusion, this study included only well-controlled Axis I disorders. Another limitation lies in the potential motivation of subjects to hide nervousness in order to complete the experience. The study is further limited as it was not originally intended to evaluate subject anxiety, leading some of the self-reported anxiety data to be

collected and analyzed retrospectively. The fact that each questionnaire was administered only once limits the ability to discern training effects on diminution of anxiety and the ability to draw conclusions over time. Additionally, there were a limited number of individuals identified as anxious during the runs (12 identified by staff, 18 by self). Even so, the data here suggest interesting correlations with statistical significance despite the small population. Future studies specifically designed to evaluate the etiology of anxious responses, develop more efficacious preflight screening modalities, and identify effective and individualized mitigation strategies would be particularly useful for commercial spaceflight applications. For example, mind-body relaxation techniques have shown promise in reduction of anxiety, but more research is needed (8). Additional options warranting investigation include familiarization (such as preflight centrifuge training), counseling, or group support. Peer support in particular has demonstrated a robust impact on stress reduction (7,12). Similarly, medical and pharmacological amelioration strategies should be examined to provide guidance into which individuals require prophylactic treatment and to assess whether medications disrupt performance or enjoyment of the commercial spaceflight experience.

Anxiety may be a relevant and potentially disabling problem for commercial spaceflight participants; however, positive psychiatric history and self-reported symptoms do not appear to predict anxiety during spaceflight simulation. Significant symptoms of anxiousness disrupted study monitors, other participants, operational timelines, and at times required all available attention from staff to be focused on a single individual. In commercial spaceflight, nervous reactions of participants may have detrimental effects on the experience of other flyers and the flight as a whole, while reducing anxiety in susceptible SFPs could increase their enjoyment of the unique experience. Further research is indicated to develop a more complete understanding of anxiety in commercial SFPs as there remains much to be learned in this novel area. Our data indicates that anxiousness can often be ameliorated through coaching and support, and that most individuals reporting anxiousness are likely capable of tolerating commercial spaceflight.

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