Fiscal Year:	FY 2016	**Task Last Updated:**	FY 05/09/2016
PI Name:	Gernhardt, Michael Ph.D.		
Project Title:	Mechanisms of Musculoskeletal-Induced Nucleation in Altitude Decompression Stress		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:			
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **DCS**:Risk of Mission Impacts and Long-Term Health Issues due to Decompression Sickness		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	michael.l.gernhardt@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	281-244-0125
Organization Name:	NASA Johnson Space Center		
PI Address 1:	2101 NASA Parkway, Code ER		
PI Address 2:	EVA Physiology Laboratory / Advanced Exploration Systems		
PI Web Page:			
City:	Houston	**State:**	TX
Zip Code:	77058	**Congressional District:**	22
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	Directed Research
Start Date:	02/07/2013	**End Date:**	02/28/2016
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:		**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:		**Monitoring Center:**	NASA JSC
Contact Monitor:	Norsk, Peter	**Contact Phone:**	
Contact Email:	Peter.norsk@nasa.gov		
Flight Program:			
Flight Assignment:	NOTE: End date changed back to 2/28/2016 as work ended at that time, per PI and K. George/JSC (Ed., 3/14/17) NOTE: Extended to 2/28/2017 (original end date was 2/28/2016) per K. George/JSC (Ed., 2/9/16)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Pollock, Neal (Duke University Medical Center) Vann, Richard (Duke University Medical Center) Conkin, Johnny (Universities Space Research Association)		
Grant/Contract No.:	Directed Research		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Musculoskeletal activity has the potential to both improve and compromise decompression safety, depending on the intensity, sequence, and level of tissue supersaturation. Exercise enhances inert gas elimination during oxygen breathing prior to decompression, but it may also promote bubble nuclei formation, which can lead to gas phase separation and growth resulting in increased decompression sickness (DCS) risk. The timing, sequence, and intensity of musculoskeletal activity may be critical to the net effect, but there are limited data available. This study will help determine the cost/benefit relationship of exercise, describe underlying mechanisms of nucleation in exercise prebreathe protocols and quantify variable risk in gravity and microgravity environments when musculoskeletal effort can differ substantially. Data gathered during prebreathe reduction program (PRP) studies combined multiple variables (prebreathe exercise and microgravity simulation) to produce a procedure now used by astronauts preparing for extravehicular activity (the PRP Phase II protocol). The PRP results will serve as control data for this NASA/Duke multi-center study to investigate the influence of individual variables (exercise and ambulation) on bubble formation and the subsequent risk of decompression sickness. METHODS: Four separate experiments would replicate the PRP Phase II protocol, each with a different exception. A minimum of 25 and a maximum of 50 subjects would be tested. A Fisher's exact test would be used to compare the results of the test and control groups. Each experiment will be stopped when pre-defined accept/reject criteria are met. Experiment I – Subjects would be ambulatory during both preflight and at altitude instead of non-ambulatory throughout. Experiment 2 - Subjects would remain non-ambulatory during the preflight period and ambulatory at altitude. Experiment 2 would use the same statistical design, as experiment I. Experiment 3 – Subjects would be ambulatory during the preflight period and non-ambulatory at altitude. Experiment 4 - The order of heavy and light exercise would be reversed, with the light exercise occurring first. For experiment 4, all subjects will be nonambulatory during the pre extravehicular activity (EVA) and simulated EVA phases to match the phase II control group. Blood collection - Venous blood will be collected via needlestick at three points to investigate whether the concentration of microparticles is associated with the presence of venous gas emboli (VGE) or DCS. EXPECTED RESULTS. It is anticipated these experiments will show that for exercise prebreathe protocols, decompression stress is related to musculoskeletal nucleation, and that nucleation can be controlled to reduce decompression stress. Specifically, ambulation during the altitude exposure results in increased decompression stress, but that ambulation prior to altitude exposure does not. Additionally, the results will show that reversing the order of light and heavy exercise will result in higher decompression stress, suggesting that light exercise facilitates the removal of heavy exercise induced nucleation. These results will demonstrate that the degree, sequence, and level of supersaturation under which musculoskeletal activity is performed are important in controlling nuclei generation and subsequent decompression stress. Finally, there will be a correlation in the microparticle concentration observed prior to the decompression and the occurrence of decompression stress during the simulated EVA.
Rationale for HRP Directed Research:	This research is directed because it contains highly constrained research, which requires focused and constrained data gathering and analysis that is more appropriately obtained through a non-competitive proposal.
Research Impact/Earth Benefits:	Results indicate the prebreathe protocols validated for the microgravity environment are not likely to work in a planetary gravity environment such as the Moon or Mars.
Task Progress:	Experiment I with ambulation both pre-EVA and during EVA simulation had significantly higher DCS and VGE than the Phase II control group. The decision was made to perform Experiment 3 next, with the rationale that if there were not a significant difference between Experiment 3 and the PRP Phase II control, then it could be concluded that ambulation during the EVA exposure was the cause of the increased decompression stress in Experiment I, and that there would then be no need to perform Experiment 2. Experiment 3 results then showed that there was not a significant difference with the PRP Phase II control, but there was significantly less DCS and grade IV VGE in Experiment 3 than Experiment I. These results suggest that pre-EVA ambulation with under-saturated tissues does not increase the risk of DCS, but ambulation during the EVA exposure with supersaturated tissues does increase the risk of DCS and VGE. The precise mechanism(s) for ambulation-induced DCS and VGE outcomes is still elusive, but possibly related to tribonucleation combined with micronuclei stabilized in hydrophobic crevices. One limitation to this conclusion is that these results are contingent on the inclusion of the 10.2 psia depressurization and repressurization back to 14.7 psia during the prebreathe timeline. Therefore, controlling ambulation during the pre-EVA period may still be required if there is not a similar partial depressurization prior to the full EVA depressurization. Several journal manuscripts are in process to document and share the results of the Nucleation Mechanism study.
Bibliography Type:	Description: (Last Updated: 10/31/2019)
Abstracts for Journals and Proceedings	Pollock NW, Natoli MJ, Conkin J, Wessel JH, Gernhardt ML. "Ambulation increases decompression sickness in altitude exposure." 85th Annual Scientific Meeting, Aerospace Medical Association, San Diego, CA, May 10-15, 2014. Aviation, Space, and Environmental Medicine. 2014 Mar;85(3):329. , Mar-2014
Abstracts for Journals and Proceedings	Pollock NW, Natoli MJ, Martina SD, Conkin J, Wessel JH 3rd, Gernhardt ML. "Ambulation increases decompression sickness in altitude exposure." 86th Annual Scientific Meeting, Aerospace Medical Association, Lake Buena Vista, FL, May 10-14, 2015. Aerosp Med Hum Peform. 2015 Mar;86(3):474. , Mar-2015
Abstracts for Journals and Proceedings	Conkin J, Pollock NW, Natoli MJ, Martina SD, Wessel JH 3rd, Gernhardt ML. "Venous gas emboli and ambulation at 4.3 psia." 87th Aerospace Medical Association Annual Meeting, Atlantic City, NJ, April 24-28, 2016. Aerosp Med Hum Peform. 2016;87(3):079. , Mar-2016

Abstracts for Journals and Proceedings	Pollock NW, Natoli MJ, Martina SD, Conkin J, Wessel JH 3rd Gernhardt ML. "Decompression sickness during simulated low pressure exposure is increased with mild ambulation exercise." 87th Aerospace Medical Association Annual Meeting, Atlantic City, NJ, April 24-28, 2016. Aerosp Med Hum Peform. 2016;87(3):080. , Mar-2016
Articles in Peer-reviewed Journals	Conkin J, Pollock NW, Natoli MJ, Martina SD, Wessel JH 3rd, Gernhardt ML. "Venous gas emboli and ambulation at 4.3 psia." Aerosp Med Hum Perform. 2017 Apr;88(4):370-6. https://doi.org/10.3357/AMHP.4733.2017 ; http://www.ingentaconnect.com/content/asma/amhp/2017/00000088/00000004/art00003 , Apr-2017