Fiscal Year:	FY 2019	**Task Last Updated:**	FY 07/28/2018
PI Name:	Weaver, Ashley Ph.D.		
Project Title:	Quantitative CT and MRI-based Modeling Assessment of Dynamic Vertebral Strength and Injury Risk Following Long-Duration Spaceflight		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **Dynamic Loads**:Risk of Injury from Dynamic Loads		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Zip Code:	27101-4101	**Congressional District:**	12
Comments:			
Project Type:	FLIGHT,GROUND	**Solicitation / Funding Source:**	2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus
Start Date:	10/01/2016	**End Date:**	02/01/2020
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:	2	**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	1
No. of Bachelor's Candidates:	3	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 2/1/2020 per NSSC information (Ed., 7/8/19)		
Key Personnel Changes/Previous PI:	None		
COI Name (Institution):	Stitzel, Joel Ph.D. (Wake Forest University) Tooze, Janet Ph.D. (Wake Forest University)		
Grant/Contract No.:	NNX16AP89G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Prolonged periods of near weightlessness can cause damage to astronauts' musculoskeletal system. This damage can increase the risk of skeletal tissue failure (e.g., fractures, tears) when experiencing forceful, dynamic loads. Fractures of the spine during dynamic conditions such as launch or landing could cause a mission to fail. This study will measure this degradation of astronauts' vertebrae and spinal muscles during missions aboard the International Space Station (ISS). We will then determine the extent of vertebral weakening of crewmembers during long-duration missions. Changes in pre- and post-flight vertebral geometry, volume, cortex thickness, and bone mineral density will be measured from existing lumbar quantitative computed tomography (qCT) scans, as well as from planned qCT scans of the cervical, thoracic, and lumbar spine from nine ISS crewmembers. Likewise, the pre- and post-flight spinal muscle volumes will be analyzed using both existing magnetic resonance imaging (MRI) scans and planned MRI scans from nine ISS crewmembers. The qCT and MRI scans will be analyzed to determine structural and material changes in the cervical, thoracic, and lumbar vertebrae and the spinal muscles that indicate damage which could weaken these tissues. Our unique engineering approach will measure the loss of vertebral strength during spaceflight conditions and predict the risk of failure during traumatic, dynamic loading conditions such as launch or landing. Vertebral strength and risk for vertebral fracture and injury will be quantified in 900 dynamic simulations using a full human body model that is constructed using structural and material data gathered from the pre- and post-flight medical images for each astronaut. This study has significance in quantifying and addressing risks of long-duration spaceflight, including vertebral injury from dynamic loads, vertebral fracture, early onset vertebral osteoporosis due to spaceflight, and impaired performance due to reduced spinal muscle mass, strength, and endurance.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Microgravity induces similar spinal changes to those seen in the aging population and people with limited mobility. Demonstrating how the vertebral column changes in response to microgravity can aid in refining the diagnostic and treatment protocols of physicians on Earth. Additionally, assessing vertebral column strength using finite element modeling can provide future techniques for assessing the efficacy of osteoporosis treatments, which would particularly benefit the elderly.
Task Progress:	The objectives of this project for the second year and the resulting progress on each objective are summarized below. Objective 1. Acquire and analyze retrospective pre- and post-flight medical images to quantify spinal muscle changes. Retrospective quantitative computed tomography (qCT) scans from 16 crewmembers were received from the LSDA (Life Sciences Data Archive)/LSAH (LSAH (Lifetime Surveillance of Astronaut Health) in March and July 2017. Pre-flight and post-flight qCT scans were available for 16 subjects, and the psoas, paraspinal, and quadratus lumborum muscle groups were segmented and analyzed from the retrospective qCT scans to characterize muscle geometry, volume, and fat infiltration changes in crewmembers of long-duration spaceflight. Retrospective magnetic resonance imaging (MRI) scans of the cervical spine and lumbar spine of 6 crewmembers were received from the LSDA/LSAH in June 2017. All crewmembers underwent both a pre-flight and a post-flight scan. The psoas, paraspinal, and quadratus lumborum muscle groups were segmented to characterize full-length volume changes in these lumbar muscles. Select cervical muscles were measured at pre-determined axial slices in order to characterize changes in the cross-sectional areas of the cervical muscles. Objective 2. Modify a finite element human body model to mimic the musculoskeletal changes seen in imaging. Using the outputs from the MRI scans, a finite element model has been modified to better represent the back and neck musculature of crewmembers both before and after spaceflight. A total of 10 models have been generated to date (pre- and post-models for 5 crewmembers). Objective 3. Create an injury risk prediction post-processor for the spine. Cross sections were implemented in the finite element models along all cervical, thoracic, and lumbar vertebrae. This allowed us to extract information on stresses, strains, axial forces, and bending moments experienced at each vertebra to calculate injury risk. Objective 4. Begin running simulations of landing conditions. A total of six 10G deceleration simulations were created by varying loading direction. Each astronaut model was subjected to this test matrix creating a total of 60 launched simulations. Of these 60 simulations, the clear majority have completed without errors. Objective 5. Continue consenting crewmembers for the prospective arm of the study. Ten crewmember briefings have taken place this year and four crewmembers have consented to participate in prospective portion of the study. Additional consent briefings are tentatively planned for the Fall of 2018.
Bibliography Type:	Description: (Last Updated: 08/02/2022)
Abstracts for Journals and Proceedings	Subramanian N, McNamara K, Weaver AA. "Cortical Thinning in Lumbar Vertebrae of Astronauts on Long-Duration Spaceflight Missions." Abstract for poster presentation at the 2017 Biomedical Engineering Society Annual Meeting, Phoenix, AZ, October 11-14, 2017. 2017 Biomedical Engineering Society Annual Meeting, Phoenix, AZ, October 11-14, 2017. , Oct-2017
Abstracts for Journals and Proceedings	Weaver AA, McNamara KP, Greene KA, Subramanian N. "Spaceflight-Induced Changes in the Lumbar Vertebrae and Musculature." Presented at the 2018 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2018. 018 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 22-25, 2018. http://cdn-uploads.preciscentral.com/ ; accessed 7/30/2018. , Jan-2018

Abstracts for Journals and Proceedings	McNamara KP, Greene KA, Weaver AA. "THUMS Modeling to Assess Dynamic Vertebral Strength Changes Pre- vs Post-Spaceflight on Long-Duration ISS Missions." Presented at the 2018 THUMS (Total Human Model for Safety) USA Users' Meeting, Dearborn, MI, June 13, 2018. 2018 THUMS (Total Human Model for Safety) USA Users' Meeting, Dearborn, MI, June 13, 2018. https:// ; accessed 7/30/2018. , Jun-2018