Fiscal Year:	FY 2018	**Task Last Updated:**	FY 08/02/2017
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:**	09/30/2019
No. of Post Docs:		**No. of PhD Degrees:**	
No. of PhD Candidates:	1	**No. of Master' Degrees:**	
No. of Master's Candidates:		**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:	1	**Monitoring Center:**	NASA JSC
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Flight Program:	ISS		
Flight Assignment:			
Key Personnel Changes/Previous PI:	None		
COI Name (Institution):	Stitzel, Joel Ph.D. (Wake Forest University) Tooze, Janet Ph.D. (Wake Forest University)		
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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 first year and the resulting progress on each objective is summarized below. Objective 1. Obtain study approvals for the retrospective and prospective arms of the study. Approvals for the retrospective and prospective arms of the study were obtained this year, including LSAH (Lifetime Surveillance of Astronaut Health), IRB (Institutional Review Board), and Flight Investigation approvals. Objective 2. Acquire and analyze retrospective pre- and post-flight medical images to quantify vertebral and spinal muscle changes. Retrospective quantitative computed tomography (qCT) scans from 16 crewmembers were received from the LSDA (Life Sciences Data Archive)/LSAH in March and July 2017. Pre-flight and post-flight qCT scans were available for 16 subjects, with follow-up qCT scans at 1, 2, 3, and 4 years for select subjects. The 16 pre-flight,16 post-flight, and 27 annual follow-up qCT scans of L1 and L2 vertebrae were segmented using a semi-automated process to create 3D models of the vertebrae. Each qCT scan was processed with an algorithm to quantify the cortical thickness of the L1 and L2 vertebrae, mapping these thicknesses onto the 3D vertebral surface models. Analysis of the cortical thickness data is ongoing. The psoas, paraspinal, and quadratus lumborum muscle groups are in the process of being segmented and analyzed from the retrospective qCT scans to characterize muscle geometry, volume, and fat infiltration changes in crewmembers of long-duration spaceflight. Segmentation of the psoas, paraspinal, and quadratus lumborum muscles, including fat infiltration, has been completed for 16 of the 59 qCT scans. Analysis of muscle geometry, volume, and fat infiltration changes for pre-flight, post-flight, and follow up scans is in progress. 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. Analysis of these scans to quantify spinal muscle changes from pre- to post-flight is in progress. Objective 3. Prepare the medical image protocols and procedures for the prospective arm of the study. A parametric experiment with a cadaver was conducted to vary qCT scan parameters and examine the resulting image quality and radiation dosage. The objective was to determine a set of scanning parameters that produced adequate image quality to measure bone outcomes, while reducing the radiation exposure to the research participant. The cadaver underwent 14 qCT scans of the C1-L5 region and the following scan parameters were varied: tube voltage, tube current, and pitch. Volumetric bone mineral density measures from each of these scans were compared to a qCT scan acquired with standard parameters that are used clinically to assess accuracy. Using this data, we have finalized a qCT protocol to scan the C3, T3, and L1 vertebrae that produces accurate volumetric bone mineral density measurements with minimal radiation exposure (The MRI scan protocol was also finalized for the prospective arm of the study. T1 and T2 weighted MRI scans of the cervical, thoracic, and lumbar spine regions will be acquired to capture the spinal musculature surrounding the vertebral column. Objective 4. Begin consenting crewmembers for the prospective arm of the study. Consent briefings for potential crewmembers for the prospective arm of the study began in July 2017 and we are actively enrolling participants. To date, four consent briefings have been held or are scheduled.
Bibliography Type:	Description: (Last Updated: 08/02/2022)

Abstracts for Journals and Proceedings	Weaver AA, Stitzel JD. "Imaging and Modeling Techniques for Assessing Dynamic Vertebral Strength and Injury Risk in Long-Duration Spaceflight." Presented at the 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. 2017 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 23-26, 2017. https:// , Jan-2017