Fiscal Year:	FY 2021	**Task Last Updated:**	FY 07/29/2020
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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City:	Winston-Salem	**State:**	NC
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:**	08/31/2021
No. of Post Docs:		**No. of PhD Degrees:**	0
No. of PhD Candidates:	2	**No. of Master' Degrees:**	1
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
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Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 8/31/2021 per NSSC information/S. Huppman/HRP (Ed., 2/25/2020) 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 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 older adults.
Task Progress:	The objectives of this project for the prior reporting year and the resulting progress on each objective is summarized below. Objective 1. Analyze retrospective pre- and post-flight medical images to quantify spinal muscle changes. Retrospective quantitative computed tomography (qCT) scans from 16 crewmembers were analyzed to characterize back muscle geometry, volume, and fat infiltration changes in crewmembers of long-duration spaceflight. This year, an additional analysis was added to examine abdominal muscle changes. Crewmember dual-energy x-ray absorptiometry (DXA) reports were also obtained from Lifetime Surveillance of Astronaut Health (LSAH) and used to compare skeletal muscle indexes between CT and DXA modalities. Retrospective magnetic resonance imaging (MRI) scans of the neck and lower back of six crewmembers were used to analyze size and fat infiltration changes in the muscles that support the spine. Correlations between muscle change and onboard exercise were also analyzed. Objective 2. Continue consenting crewmembers for the prospective arm of the study. Additional crewmember briefings took place this year and a total of nine crewmembers are currently enrolled to participate in the prospective portion of the study. Objective 3. Acquire, process, and begin analyzing prospective pre- and post-flight medical images. Prospective qCT and MRI data collection has continued for all nine of the enrolled subjects. Bone and muscle morphology and quality measures are underway and will continue as additional data become available. Objective 4. Prepare the prospective data for integration into human body finite element models. This year, a sensitivity analysis was conducted with the study's finite element human body model to investigate the effects of muscle activation on astronauts' kinematic and injury response under complex multi-directional loading conditions associated with spaceflight launch and landing. Considering the results of this sub-study, the available prospective qCT and MRI images are being used to create 3D computational models of the spine representative of each subject. With the help of computational algorithms, these subject-specific models are being used to customize existing finite element models of the spine to represent each crewmember.
Bibliography Type:	Description: (Last Updated: 08/02/2022)
Abstracts for Journals and Proceedings	Bonini MF, Greene KA, Lenchik L, Weaver AA. "DIXON Sequence MRI Pipeline for Measuring Prospective Changes in Spinal Muscle Size and Quality with Long-Duration Spaceflight." BMES 2019. 2019 Biomedical Engineering Society Annual Meeting, Philadelphia, PA, October 16-19, 2019. BMES 2019. 2019 Biomedical Engineering Society Annual Meeting, Philadelphia, PA, October 16-19, 2019. , Oct-2019
Abstracts for Journals and Proceedings	Greene KA, McNamara KP, Lenchik L, Weaver AA. "Quantifying Retrospective Lumbar Musculature Changes with Long-Duration Spaceflight using MRI." BMES 2019. 2019 Biomedical Engineering Society Annual Meeting, Philadelphia, PA, October 16-19, 2019. BMES 2019. 2019 Biomedical Engineering Society Annual Meeting, Philadelphia, PA, October 16-19, 2019. , Oct-2019
Abstracts for Journals and Proceedings	Greene KA, McNamara KP, Weaver AA. "Computationally Assessing Crewmember Musculoskeletal Health with Long-Duration Spaceflight." Tennessee Valley Interstellar Workshop, Wichita, KS, November 2019. Tennessee Valley Interstellar Workshop, Wichita, KS, November 2019. , Nov-2019

Abstracts for Journals and Proceedings	Greene KA, Weaver AA, Bonini MF, Lenchik L. "Measuring Cervical Muscle Size and Quality with Long-Duration Spaceflight." 2020 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 27-30, 2020. Abstracts. 2020 NASA Human Research Program Investigators' Workshop, Galveston, TX, January 27-30, 2020. , Jan-2020
Abstracts for Journals and Proceedings	Greene KA, Weaver AA, Bonini MF, Lenchik L. "Quantifying Lower Back Muscle Changes with Long-Duration Spaceflight using Biomedical Imaging." Society of Women Engineers WE Local, Raleigh, NC, February 21-22, 2020. Abstracts. Society of Women Engineers WE Local, Raleigh, NC, February 21-222, 2020. , Feb-2020
Abstracts for Journals and Proceedings	Lalwala M, Devane K, Johnson DR, Weaver AA. "Computational Assessment of the Effects of Muscle Activation on Body Kinematics and Injury Risks Associated with Spaceflight Loading Conditions." Ohio State University Injury Biomechanics Symposium, Columbus, OH, May 2020. Ohio State University Injury Biomechanics Symposium, Columbus, OH, May 2020. [Accepted; event cancelled due to COVID-19] , May-2020
Articles in Peer-reviewed Journals	McNamara KP, Greene KA, Tooze JA, Dang J, Khattab K, Lenchik L, Weaver AA. "Neck muscle changes following long-duration spaceflight." Front Physiol. 2019 Sep 13;10:1115. https:// ; PMID: 31572205; PMCID: PMC6753191 , Sep-2019
Dissertations and Theses	Greene KA. "Image-Based Analysis Reveals Detrimental Effects of Long-Duration Spaceflight on Trunk Muscles." Master's Thesis, Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences, July 2020. , Jul-2020