Fiscal Year:	FY 2020	Task Last Updated:	FY 07/31/2019
PI Name:	Weaver, Ashley Ph.D.		
Project Title:	Quantitative CT and MRI-based Modeling Assess Long-Duration Spaceflight	sment of Dynamic Vertebral	Strength and Injury Risk Following
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline Element/Subdiscipline:	HUMAN RESEARCHSpace Human Factors Er	ngineering	
Joint Agency Name:		TechPort:	No
Human Research Program Elements:	(1) HFBP:Human Factors & Behavioral Performa	ance (IRP Rev H)	
Human Research Program Risks:	(1) Dynamic Loads:Risk of Injury from Dynamic	c Loads	
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	asweaver@wakehealth.edu	Fax:	FY
PI Organization Type:	UNIVERSITY	Phone:	336-716-0944
Organization Name:	Wake Forest University		
PI Address 1:	Biomedical Engineering/ Health Sciences		
PI Address 2:	575 N Patterson Ave.		
PI Web Page:			
City:	Winston-Salem	State:	NC
Zip Code:	27101-4101	Congressional District:	12
Zip Code: Comments:	27101-4101	Congressional District:	12
Zip Code: Comments: Project Type:	27101-4101 FLIGHT,GROUND	Congressional District: Solicitation / Funding Source:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus
Zip Code: Comments: Project Type: Start Date:	27101-4101 FLIGHT,GROUND 10/01/2016	Congressional District: Solicitation / Funding Source: End Date:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021
Zip Code: Comments: Project Type: Start Date: No. of Post Docs:	27101-4101 FLIGHT,GROUND 10/01/2016	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates:	27101-4101 FLIGHT,GROUND 10/01/2016 2	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates:	27101-4101 FLIGHT,GROUND 10/01/2016 2	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates: No. of Bachelor's Candidates:	27101-4101 FLIGHT,GROUND 10/01/2016 2 2	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 NASA JSC
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates: No. of Bachelor's Candidates: Contact Monitor:	27101-4101 FLIGHT,GROUND 10/01/2016 2 2 Williams, Thomas	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center: Contact Phone:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 NASA JSC 281-483-8773
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates: No. of Bachelor's Candidates: Contact Monitor: Contact Email:	27101-4101 FLIGHT,GROUND 10/01/2016 2 2 Williams, Thomas thomas.j.will1@nasa.gov	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center: Contact Phone:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 NASA JSC 281-483-8773
Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates: No. of Bachelor's Candidates: Contact Monitor: Contact Email: Flight Program:	27101-4101 FLIGHT,GROUND 10/01/2016 2 2 Williams, Thomas thomas.j.will1@nasa.gov ISS	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center: Contact Phone:	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 NASA JSC 281-483-8773
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Zip Code: Comments: Project Type: Start Date: No. of Post Docs: No. of PhD Candidates: No. of Master's Candidates: No. of Bachelor's Candidates: Contact Monitor: Contact Email: Flight Program: Flight Assignment: Key Personnel Changes/Previous PI:	27101-4101 FLIGHT,GROUND 10/01/2016 2 2 Williams, Thomas thomas,j.will1@nasa.gov ISS NOTE: End date changed to 8/31/2021 per NSSC NOTE: End date changed to 2/1/2020 per NSSC	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center: Contact Phone: Cinformation/S. Huppman/Fi	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 1 NASA JSC 281-483-8773 IRP (Ed., 2/25/2020)
Zip Code:Comments:Project Type:Start Date:No. of Post Docs:No. of PhD Candidates:No. of Master's Candidates:Contact Monitor:Contact Email:Flight Program:Flight Assignment:Key Personnel Changes/Previous PI:COI Name (Institution):	27101-4101 FLIGHT,GROUND 10/01/2016 2 2 Williams, Thomas thomas.j.will1@nasa.gov ISS NOTE: End date changed to 8/31/2021 per NSSC NOTE: End date changed to 2/1/2020 per NSSC	Congressional District: Solicitation / Funding Source: End Date: No. of PhD Degrees: No. of Master' Degrees: No. of Bachelor's Degrees: Monitoring Center: Contact Phone: Cinformation/S. Huppman/Finformation (Ed., 7/8/19)	12 2015-16 HERO NNJ15ZSA001N-Crew Health (FLAGSHIP, NSBRI, OMNIBUS). Appendix A-Crew Health, Appendix B-NSBRI, Appendix C-Omnibus 08/31/2021 1 1 NASA JSC 281-483-8773 IRP (Ed., 2/25/2020)
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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 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, 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.
	The objectives of this project for the prior reporting year and the resulting progress on each objective are summarized below.
	Objective 1. Analyze retrospective pre- and post-flight medical images to quantify spinal muscle changes.
	These retrospective analyses were continued from the previous year and completed. Retrospective quantitative computed tomography (qCT) scans from 16 crewmembers were received in March and July 2017. Pre-flight and post-flight qCT scans were used to characterize back muscle geometry, volume, and fat infiltration changes in crewmembers of long-duration spaceflight. Retrospective magnetic resonance imaging (MRI) scans of the neck and lower back of six crewmembers were received in June 2017. Pre-flight and a post-flight scans were used to analyze size and fat infiltration changes in the muscles that support the spine.
	Objective 2. Continue consenting crewmembers for the prospective arm of the study.
Task Progress:	Eleven crewmember briefings took place this year and a total of seven crewmembers have consented 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 begun for five of the enrolled subjects. Preliminary measures of muscle size and fat infiltration are underway and will continue as additional data becomes available.
	Objective 4. Prepare the prospective data for integration into human body finite element models.
	The available prospective qCT images are being used to create 3D computational models of the C3, T3, and L1 bones in the spine representative of each subject. With the help of computational algorithms, these subject-specific models of the bones are being used to customize existing finite element models of the spine to better represent each crewmember.
Bibliography Type:	Description: (Last Updated: 04/28/2023)
Abstracts for Journals and Proceedings	Greene KA, McNamara K, Moore A, Subramanian N, Maez L, Weaver AA. "Quantifying Lumbar Musculature and Adipose Tissue Changes with Spaceflight using qCT Analysis." BMES 2018. 2018 Biomedical Engineering Society Annual Meeting, Atlanta, GA, October 17-20, 2018. BMES 2018. 2018 Biomedical Engineering Society Annual Meeting, Atlanta, GA, October 17-20, 2018. , Oct-2018
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Dissertations and Theses	McNamara KP. "Spinal Muscle Changes and Occupant Injury Risk Prediction in Spaceflight." Doctoral Dissertation, Virginia Tech – Wake Forest University School of Biomedical Engineering and Sciences, Winston-Salem, NC, May 2019. , May-2019