Fiscal Year:	FY 2018	**Task Last Updated:**	FY 10/08/2018
PI Name:	Bouxsein, Mary Ph.D.		
Project Title:	Vertebral Strength and Fracture 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:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **Bone Fracture**:Risk of Bone Fracture due to Spaceflight-induced Changes to Bone (2) **Dynamic Loads**:Risk of In-Mission Injury and Performance Decrements and Long-term Health Effects due to Dynamic Loads (3) **Osteo**:Risk Of Early Onset Osteoporosis Due To Spaceflight		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:			
Project Type:	Flight,Ground	**Solicitation / Funding Source:**	2014-15 HERO NNJ14ZSA001N-Crew Health (FLAGSHIP & NSBRI)
Start Date:	01/01/2016	**End Date:**	07/01/2018
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	1	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Williams, Thomas	**Contact Phone:**	281-483-8773
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Flight Program:			
Flight Assignment:	NOTE: End date change to 7/1/2018 per NSSC information (Ed., 5/3/18) NOTE: Element change to Human Factors & Behavioral Performance; previously Space Human Factors & Habitability (Ed., 1/19/17) NOTE: Period of performance changed to 1/01/2016-12/31/2017 (originally 11/16/2015-11/15/2017) per NSSC information and B. Gore/JSC (Ed., 9/13/16)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Kopperdahl, David Ph.D. (O.N. Diagnostics)		
Grant/Contract No.:	NNX16AC15G		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Mechanical loading is required for maintenance of the musculoskeletal system. Thus, exposure to microgravity induces marked bone loss in both humans and animals, and is a major concern for astronauts exposed to long-duration spaceflight, as they may be at increased risk for skeletal fragility and bone fractures. Most prior studies have relied on dual-energy X-ray absorptiometry (DXA), a 2D technique used to assess bone mass at different skeletal sites, to assess effects of spaceflight on bone strength and fracture risk. However, DXA-based measurements are limited in several regards. Newer technologies, including 3D quantitative computed tomography (QCT) are able to overcome the limitations of DXA. Moreover, QCT images can be used to estimate bone strength using a standard engineering approach called finite element analysis. Indeed, QCT images have been used successfully to demonstrate negative effects of spaceflight on hip bone density and strength. However, a similar examination of the effects of spaceflight on vertebral strength has not been performed. Thus the degree of spinal deconditioning and subsequent risk of vertebral fracture following long-duration spaceflight remains unknown. Specific Aims: 1) Determine changes in bone density and vertebral strength following long-duration spaceflight in astronauts and cosmonauts, including pre-flight, post-flight, and one-year after return to Earth 2) Use musculoskeletal modeling to compute subject-specific spinal loading and estimate the risk of vertebral fracture (as the load-to-strength ratio) following long-duration spaceflight 3) Determine changes in trunk muscle size and density following long-duration spaceflight.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	This research will help us to better understand risk factors for vertebral fracture. Vertebral fractures are the most common fracture among older adults on Earth, with a prevalence of 30-50% among those over age 50. Improved insight into the factors that increase risk for vertebral fracture could advance the clinical management of older adults and inform better approaches to prevent these fractures.
Task Progress:	The impact of long-duration (i.e., 6 months) spaceflight on vertebral bone strength, trunk muscle atrophy, and risk of spine fracture has not previously been investigated. We used previously collected computed tomography (CT) scans of the lumbar spine taken pre-flight, immediately post-flight, and one to four years after return to Earth in 17 crewmembers with long-duration service on the International Space Station. We used CT-based finite element analysis (CT-FEA) to estimate vertebral compressive strength and subject-specific musculoskeletal models to estimate the compressive forces applied to the vertebral bodies during routine activities as well as a few spaceflight-specific tasks. We found that 6 months of spaceflight led to a mean (±SD) 5.6±4.3% decline in lumbar vertebral strength compared to baseline, with 65% of subjects experiencing deficits of greater than 5%. Notably, vertebral strength remained at this level after one to four years of recovery on Earth. The decline in vertebral strength was greater than the decline in bone mineral density (BMD) assessed by DXA (-3.6 ± 3.0%) and not associated with the decline in spine DXA-BMD. The cross-sectional area and density of paraspinal muscles were also reduced after spaceflight, with consistent recovery of muscle area but not density after one-year readaptation on Earth. Musculoskeletal models of the trunk showed a very slight increase in spinal loading post-flight, but in all individuals and for all simulated activities the ratio of vertebral compressive load to vertebral compressive strength remained well below one, indicating a low risk of vertebral fracture. Additional analyses simulating vertebral strength changes in high-loading rate simulations showed similar results. Altogether our findings confirm and extend previous studies showing significant declines in bone strength due to 6 months of spaceflight. This study was limited to examining crewmembers with mission durations of only 4-7 months, was conducted prior to availability of iRED (Interim Resistive Exercise Device), and none of the subjects used bisphosphonates. Thus, future studies should investigate whether exercise and/or pharmacologic interventions can mitigate the bone and muscle losses we observed, and should determine nature of bone loss and trunk muscle atrophy in longer-duration missions. In particular, it is important to determine whether bone loss continues at the same rate, accelerates, or plateaus with longer exposure to microgravity. The following manuscript is in review ; other manuscripts are in preparation for submission: Burkhart K, Allaire B, Bouxsein ML. Negative Effects of Long-Duration Spaceflight on Paraspinal Muscle Morphology, Spine (in review 2018).
Bibliography Type:	Description: (Last Updated: 06/11/2025)
Articles in Peer-reviewed Journals	Burkhart K, Allaire B, Bouxsein M. "Negative effects of long-duration spaceflight on paraspinal muscle morphology." Spine (Phila Pa 1976). 2019 Jun 15;44(12):879-86. https://doi.org/10.1097/BRS.0000000000002959 ; PubMed PMID: 30624302 , Jun-2019
Articles in Peer-reviewed Journals	Burkhart K, Allaire B, Anderson DE, Lee D, Keaveny TM, Bouxsein ML. "Effects of long-duration spaceflight on vertebral strength and risk of spine fracture." J Bone Miner Res. 2020 Feb;35(2):269-76. https://doi.org/10.1002/jbmr.3881 ; PubMed PMID: 31670861 , Feb-2020