Fiscal Year:	FY 2017	**Task Last Updated:**	FY 07/18/2017
PI Name:	Jagodnik, Kathleen Ph.D.		
Project Title:	Improving the Efficacy of Resistive Exercise Microgravity Countermeasures for Musculoskeletal Health and Function using Biomechanical Simulation (Postdoctoral Fellowship)		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Musculoskeletal Alterations Team		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	kathleen.jagodnik@nasa.gov	**Fax:**	FY
PI Organization Type:	NASA CENTER	**Phone:**	440-729-4113
Organization Name:	NASA Glenn Research Center		
PI Address 1:	9240 Winchester Valley		
PI Address 2:			
PI Web Page:			
City:	Chesterland	**State:**	OH
Zip Code:	44026	**Congressional District:**	10
Comments:	NOTE (Ed., May 2016): Administrative affiliation is Baylor College of Medicine, Center for Space Medicine, which administers the fellowship. Fellowship work is being performed at NASA Glenn.		
Project Type:	GROUND	**Solicitation:**	2014 NSBRI-RFA-14-02 First Award Fellowships
Start Date:	03/01/2015	**End Date:**	03/31/2017
No. of Post Docs:	0	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	3	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 3/31/2017 (previously 5/31/2017) per NSBRI (Ed., 4/1/17) NOTE: End date changed to 5/31/2017 per NSBRI (Ed., 3/8/17) NOTE: Start/End dates changed to 3/1/2015 and 2/28/2017, respectively (original start/end dates were 12/1/2014 and 11/30/2016, respectively) per NSBRI (Ed., 7/27/15)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Lewandowski, Beth (MENTOR/ NASA Glenn Research Center)		
Grant/Contract No.:	NCC 9-58-PF04105		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	POSTDOCTORAL FELLOWSHIP Original Project Aims/Objectives: This project aims to develop a biomechanical model of a human performing the deadlift exercise on the Hybrid Ultimate Lifting Kit (HULK) device in order to inform exercise prescriptions for astronauts so that their musculoskeletal health can be maintained during extended periods of spaceflight. To create this model, which has been developed using the OpenSim software platform, it was necessary to collect data (including motion capture, ground reaction force, and EMG) from human subjects performing the deadlift exercise. Trials using different combinations of load, load configuration, exercise cadence, and stance width were performed. Inverse kinematics and inverse dynamics analyses have been performed and are ongoing, and subsequent steps of analysis include residual minimization and potentially static optimization. Key Findings: To date, we have collected motion capture, electromyography (EMG), force plate, and device load cell data from 5 human subjects performing 73 trials of the deadlift exercise with varying load, load configuration, stance width, and exercise cadence. We report the joint angle characteristics resulting from inverse kinematics analysis for selected joints in the biomechanical model, inverse dynamics analyses reporting joint moments, as well as EMG results for 16 muscles recorded. We are currently able to draw tentative conclusions about how the exercise configuration parameters affect the kinematic and kinetic properties of a subset of the subjects being modeled, but more extensive analyses of the collected data (and, potentially, additional data collection) will be necessary before stronger conclusions can be reached. Impact of Key Findings on Hypotheses, Technology requirements, Objectives and Specific Aims of the Original Proposal: As previously mentioned, the current set of key findings includes the kinematic, kinetic, and muscle activity properties of the human subjects being modeled as the deadlift load, load configuration, stance width, and cadence are varied. Based on the analyses completed to date, we are able to draw tentative relationships between these deadlift exercise parameters and the joint angles, joint moments, and EMG activities that result. This will eventually permit our Digital Astronaut Project team to make predictions about how particular exercise devices and prescriptions are likely to benefit the musculoskeletal health of the astronauts performing these exercises. This will assist us in optimizing exercise prescriptions for astronauts exposed to microgravity environments for extended periods. Research Plan for Coming Year: Not applicable since this is the final report for this 2-year project. The Digital Astronaut Project's Biomechanics team will continue data collection and analysis pursuant to the objectives described above.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	Astronauts who are exposed to microgravity environments for extended durations during spaceflight experience declines in musculoskeletal health. Similarly, elderly and disabled people can experience losses of mobility that prevent them from participating in an active lifestyle that allows them to maintain optimal musculoskeletal health. Those who lack the balance or strength required for steady gait, who are bedbound, or who otherwise cannot remain sufficiently active, face a number of risks related to such inactivity. We are studying resistive exercises that serve to benefit not only astronauts during spaceflight, but inactive Earthbound individuals, as well. Our work aims to gain a solid understanding of the resistive exercise prescriptions required to maintain musculoskeletal health in the absence of gravity-based activity. Providing effective resistive exercise prescriptions for impaired Earthbound individuals will help them to optimize their health despite their existing physical limitations.
Task Progress:	Of the 10 proposed steps, Step 1, Collect Data using Human Subjects Performing Movements on the HULK Device, has been completed in collaboration with my lab members. A total of 5 human subjects performed the deadlift exercise using a variety of loads, load configurations, cadences, and stance widths; a total of 73 trials were collected. Data include motion capture, EMG, device load cell, and force plate data; anthropometric measurements; and photographic and video data. I completed Step 2, Perform Data Processing and Reduction, on the collected data. This processing included data filtering, interpolation, tracking, and downsampling. In Step 3, with members of the Digital Astronaut Project, three different versions of a biomechanical model of the human body performing the deadlift exercise were developed on the OpenSim software platform; one version excludes arms and represents the upper-extremity forces as being concentrated in the shoulders; the second version includes full musculature in the arms; and the third version simplifies the arms by including torque actuators rather than muscles. The latter two models address Step 4. We selected the third model for use in subsequent analyses due to its computational efficiency and the requirement when modeling in OpenSim that the deadlift, which is a closed-kinetic-chain exercise, include arms in its model to enable attachment to the model's bar. In Step 5, I performed Inverse Kinematics analysis to yield descriptive kinematics. For selected trials and subjects, progress has been made on Step 6, Inverse Dynamics (ID) analysis, which involves formulating and solving the system's equations of motion, to determine the generalized forces (e.g., net joint forces and torques, ground reaction forces, and residual forces and moments on the pelvis) that produce the deadlift movement; this permits the inference of how muscle groups are activated in order to produce this movement. Work is ongoing to complete ID analyses. Step 7, minimizing the residuals (errors resulting from the process of computational modeling) of the system, is performed following ID analysis, which still remains to be completed for all subjects and trials. Step 8, performing static optimization, will require modifications to the model to allow it to accurately predict muscle force values at joints where extreme flexion occurs during the exercise. Part of Step 9, creating data reports, has been completed, while its other component, performing sensitivity analysis, will follow once the preceding steps have been completed. Finally, Step 10 involves conducting verification and validation (V&V) analyses for this modeling effort. I have created a detailed verification and validation plan for this project, which has been and will be implemented as the stages of the project are completed. My lab members plan to use this deadlift modeling V&V plan as the reference for their own V&V planning work when studying other exercises.

Bibliography Type:	Description: (Last Updated: 09/01/2017)
Abstracts for Journals and Proceedings	Jagodnik K, Thompson W, Gallo C, DeWitt J, Funk J, Funk N, Perusek G, Sheehan C, Lewandowski B. "Biomechanical Modeling of the Deadlift Exercise to Improve the Efficacy of Resistive Exercise Microgravity Countermeasures." 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. , Jan-2017
Abstracts for Journals and Proceedings	Jagodnik KM, Thompson WK, Gallo CA, DeWitt JK, Funk JH, Funk NW, Perusek GP, Sheehan CC, Lewandowski BE. "Biomechanical Modeling of the Deadlift Exercise to Improve the Efficacy of Resistive Exercise Microgravity Countermeasures." 32nd Annual Meeting of the American Society for Gravitational and Space Research, Cleveland, OH, October 26-29, 2016. 32nd Annual Meeting of the American Society for Gravitational and Space Research, Cleveland, OH, October 26-29, 2016. , Oct-2016
Awards	Digital Astronaut Project Team. "NASA Human Research Program Group Peer Award: Recognition for Exceptional Work in Computational Modeling, October 2015." Oct-2015
Awards	Jagodnik K. "Winner (tie) of Most Inquisitive Award at the OpenSim Virtual Workshop, April 25 – May 6, 2016." May-2016