Fiscal Year:	FY 2013	**Task Last Updated:**	FY 03/06/2014
PI Name:	Cavanagh, Peter R. Ph.D., D.Sc.		
Project Title:	Monitoring Bone Health by Daily Load Stimulus Measurement during Lunar Missions		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Musculoskeletal Alterations Team		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **Bone Fracture**:Risk of Bone Fracture due to Spaceflight-induced Changes to Bone (2) **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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City:	Seattle	**State:**	WA
Zip Code:	98195-6500	**Congressional District:**	7
Comments:	PI moved from Cleveland Clinic to University of Washington in June 2008 (8/08)		
Project Type:	GROUND	**Solicitation / Funding Source:**	2007 Crew Health NNJ07ZSA002N
Start Date:	10/01/2008	**End Date:**	09/30/2013
No. of Post Docs:	1	**No. of PhD Degrees:**	1
No. of PhD Candidates:	2	**No. of Master' Degrees:**	1
No. of Master's Candidates:	1	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	5	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: Risk and Gaps changed per IRP Rev E (Ed., 3/5/14) NOTE: End date changed to 9/30/2013 per NSBRI data submission (Ed., 3/4/2014)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Lang, Thomas (University of California, San Francisco) Grodsinsky, Carlos (ZIN Technologies, Inc.) Gilkey, Kelly (NASA Glenn Research Center) Hanson, Andrea (NASA Johnson Space Center)		
Grant/Contract No.:	NCC 9-58-MA01603		
Performance Goal No.:			
Performance Goal Text:			

Task Description:

1. Original project aims/objectives
One of the key questions that remains unanswered as we prepare to send humans to other planetary surfaces is the degree to which living and exercising in these reduced gravity environments will provide an osteoprotective stimulus to prevent the loss of bone mineral density (BMD) that has been observed in microgravity. The concept of daily load stimulus is useful in this regard since it has the potential to estimate the "dose" of load to the lower extremities that will maintain skeletal integrity even in the setting of concurrent therapeutic drug and exercise countermeasures. Most observers believe that some form of supplementary exercise will be required activity on the moon, Mars, or nearby asteroid, but this will need to be optimized to provide the most efficient use of crew time. Cavanagh et al. (J. Biomech., 2010) have published reports that, on average, only 43 minutes of the ~150 minutes assigned for exercise during a day resulted in loaded exercise. Given the continued loss of BMD observed in crew members after long-duration flights, this amount of loaded exercise is likely not enough to preserve an acceptable amount of bone strength.

The Specific Aims of the project were to:

1) Develop hardware based on Micro Electro Mechanical Systems (MEMS) technology that can unobtrusively monitor the accelerations applied to the body and interface with an ambulatory monitor.

2) Extend the Daily Load Stimulus Algorithm to account for recent developments in bone mechanobiology, to incorporate accelerometric signals, and to write software to perform this analysis in real-time.

3) Demonstrate the feasibility and validity of the approach in 1g, in 1/6g in the eZLS, and in another analog.

4) Integrate the hardware and software into a package suitable for flight development.

2. Key findings to date

• Foot forces suggest IVA lunar and Martian locomotion (walking, running, loping, hopping) alone may not be osteoprotective, and that a simulated lunar EVA (body weight plus ~200 Earth lbs of suit mass) locomotion may not be osteoprotective.

• Foot forces suggest that locomotion in a simulated Martian EVA (body weight plus ~200 Earth lbs of suit mass) may provide adequate loading under some locomotion conditions depending on the duration of the activities.

• Lunar and Martian hopping and loping result in higher foot forces than walking, while running provides the highest foot forces in any one environment.

• The Classification Trees developed can precisely recognize locomotor activity, which is useful during remote monitoring scenarios.

• Preliminary comparisons of tibial axial acceleration during parabolic flight to 1g confirm that tibial acceleration scales during the same activity in different gravity conditions.

• Preliminary results support the use of tibial acceleration as an indication of impact and therefore an effective tool for the examination of exercise regimens in reduced gravity.

3. Impact of key findings on hypotheses, technology requirements, objectives and specific aims of the original proposal

The wireless activity-tracking device has been designed, manufactured, and tested in a series of studies in 1g, 1/6g, and 3/8g simulated environments. Initial data analysis is starting to reveal potential crew health risks to bone health maintenance in reduced gravity environments. The sensor has been interfaced with a Smartphone to allow data collection in the field. This is an important step in moving towards flight readiness.

4. Future work

• Final parabolic flight campaign in April 2014.

• One of the next steps will be to repackage the system hardware into a final configuration including design considerations for deep space missions.

• Further enhance the Activity Recognition algorithms.

• Continue to test the interface between our wireless sensors and the BioNet software framework in the laboratory setting, for future automated data management aboard the International Space Station (ISS).

• Utilize the Smartphone platform as a portable data logger that is capable of communicating with the wireless sensors and the BioNet software framework.

• Review results from a data-sharing arrangement with the Integrated Medical Model team at NASA Glenn who received Jump Down data from this study, and with colleague Joern Rittweger who received static hopping data to assess the loss of energy during a stiff legged hop at 1g, 3/8g, and 1/6g.

• Prepare manuscripts for publication to peer reviewed journals.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Accurate and detailed ambulatory activity monitoring with the added benefit of software predicting bone health is a tool that would be highly sought after by athletic communities, the aging population, osteoporotic patients, and elderly care personnel. This project has the potential to produce a NASA spinoff that would benefit the mentioned populations through personal bone health monitoring systems. In 2005, osteoporosis-related fractures in the US were responsible for an estimated $19 billion in medical expenses. This estimate is expected to rise to $25.3 billion by 2025. The personal monitoring system being developed under this grant can help individuals manage their bone health based on personal exercise goals and real-time feedback. Use of this hardware could help significantly decrease medical costs related to osteoporotic fracture.
The small wireless sensors developed in this study have been useful in other research efforts. Attached to the ankle, the sensor is currently being used in a study examining gait characteristics of female runners engaged in regular, long-distance training programs who are prone to injury. The goal is to reduce the rate of loading during running. A

	program has been developed to provide real-time feedback from the sensors as displayed on a screen in front of the runner. The runner can adjust their gait to a desirable data point in real-time, or take a portable data logger with them into the field and analyze the data post-run to see how the in-lab training has helped to re-train their running gait. Additional work has been proposed to use the sensors to assess the trade-off between hardware complexity and information density in comparing activity data from patients with bilateral osteoarthritis of the knee and unilateral trans-tibial amputations. Applications in the military are also envisaged where activity recognition in a large group of military personnel could be performed. We believe there are many other applications as well.
Task Progress:	1) COMPLETE DATA COLLECTION IN eZLS FACILITY: The largest human study to date has been completed in the Exercise Countermeasures Laboratory utilizing the eZLS facility at NASA Glenn Research Center. The activity monitoring system was tested at 1g, 3/8g, and 1/6g gravity loads in the eZLS during a variety of locomotor activities and functional tasks, including walking, running, loping, hopping, ladder climb, platform jump down, rock carry, obstacle course, static hopping, and squat exercise. 2) DEPLOY SOFTWARE UPDATES & INCREASE DATA THROUGHPUT: A comprehensive analysis of the wireless communication protocol and software configuration was conducted. Software updates have resulted in more reliable communication and more consistent data logging. 3) COMPLETE DATA COLLECTION IN PARABOLIC FLIGHT: Data was successfully collected on 9 subjects during parabolic flight campaigns in October 2012 and April 2013. However, neither campaign yielded a complete and successful data set. We are tentatively approved for another flight campaign in 2014 where we hope we can get a full complement of parabolas and activities/configurations with all data components. In depth analyses of the data collected is currently underway. 4) CONTINUED DATA ANALYSIS: Data analysis has been an on-going effort over the life of the project. Analysis of the data continues to suggest that the partial gravity environments of the moon or Mars will not alone be osteoprotective. Exercise will remain a necessary countermeasure in these environments. It is unclear what amount of loaded exercise is necessary to maintain optimal bone health. On-going work in this study will utilize the enhanced Daily Load Stimulus theory to help answer this question. It is certain that running in reduced gravity will still benefit from use of a subject load device to increase impact during locomotor exercises. Enhancements have been made to our activity programs to allow real-time reporting of daily activity and progress toward individual daily load stimulus target goals. NASA Glenn's Integrated Medical Model (IMM) team is exploring input of the jump down data into their bone fracture risk model, and with Joern Rittweger of the German Aerospace Association to explore the energy losses experienced during static, stiff-legged hopping in 1g, 3/8g, and 1/6g environments. We will be following their progress in analysis of these data. 5) FLIGHT READINESS: The system performed well during parabolic flight testing. The sensors have successfully been interfaced with the Smartphone platform which can be used as a portable data logging system. Currently one sensor communicates with the phone at a time, and the feasibility of connecting two Bluetooth devices to one phone is being explored.
Bibliography Type:	Description: (Last Updated: 03/08/2018)
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