Fiscal Year:	FY 2010	**Task Last Updated:**	FY 12/09/2009
PI Name:	Qin, Yi-Xian Ph.D.		
Project Title:	Combined Scanning Confocal Ultrasound Diagnostic and Treatment System for Bone Quality Assessment and Fracture Healing		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Smart Medical Systems and Technology Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **ExMC**:Exploration Medical Capabilities		
Human Research Program Risks:	(1) **Bone Fracture**:Risk of Bone Fracture due to Spaceflight-induced Changes to Bone (2) **Medical Conditions**:Risk of Adverse Health Outcomes and Decrements in Performance Due to Medical Conditions that occur in Mission, as well as Long Term Health Outcomes Due to Mission Exposures (3) **Osteo**:Risk Of Early Onset Osteoporosis Due To Spaceflight (4) **Renal Stone**:Risk of Renal Stone Formation		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	yi-xian.qin@stonybrook.edu	**Fax:**	FY 631-632-8577
PI Organization Type:	UNIVERSITY	**Phone:**	631-632-1481
Organization Name:	SUNY- The State University of New York		
PI Address 1:	Orthopaedic Bioengineering Research Laboratory		
PI Address 2:	Room 215, Bioengineering Bldg		
PI Web Page:			
City:	Stony Brook	**State:**	NY
Zip Code:	11794-5281	**Congressional District:**	1
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2007 Crew Health NNJ07ZSA002N
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No. of Post Docs:	3	**No. of PhD Degrees:**	1
No. of PhD Candidates:	4	**No. of Master' Degrees:**	1
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	2
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Rubin, Clinton (Research Foundation of SUNY) Lin, Wei (SUNY- The State University of New York) Mirza, Naureen (SUNY- The State University of New York) Gelato, Marie (SUNY- The State University of New York)		
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Task Description:

Musculoskeletal complications, i.e., osteoporosis, induced by microgravity during extended space mission and age-related disorders represent a key health problem. Osteoporosis will diminish both the structure and strength of bone, each considered critical in defining the ability of the bone to resist fracture. Early diagnosis of such progressive bone loss would allow prompt treatment, and thus inherently reduce the risk of fracture. Bone mineral density (BMD) measurement is a well-accepted, standard assessment used for the diagnosis of osteopenia and osteoporosis, using dual-energy X-ray Absorptiometry (DXA) in the clinic. However, it is limited to a BMD index and insensitive to bone's physical properties. Advents in quantitative ultrasound (QUS) techniques can characterize both BMD and the material properties. Using a newly developed noninvasive Scanning Confocal Acoustic Diagnostic (SCAD) technology, strong correlations between SCAD determined data and bone's structural and strength parameters were observed. Ultrasound has also been shown therapeutic potentials to accelerate fracture healing. The objectives of this study are to develop a combined diagnostic and treatment ultrasound technology for early prediction of bone disorder and guided acceleration of fracture healing, using SCAD imaging and low-intensity pulse ultrasound. The technology will target to the critical skeletal sites, where may be significantly affected by disuse osteopenia and potentially at the risk of fracture, i.e., hip, long bone and wrist regions. We will evaluate bone's quality in clinical human subjects, and at the JSC/UTMB bedrest facility. Animal models and cadaver will be used for testing feasibility of identifying bone loss, fracture, and longitudinally treatment and monitoring. A noninvasive diagnostic and treatment technology using ultrasound will have significant potentials to prevent and treat bone fracture, and will address critical questions in the HRP Bioastronautics Roadmap related to bone loss monitoring, prevention and recovery.

In this year's research, the research team is continuing in development of a new generation of the prototype of scanning confocal acoustic navigation (SCAN) system to access the bone quality at the multiple skeletal sites, and use ultrasound to detect bone fracture. A combined mechanical and electrical array scan modality has been initiated, which can complete the SCAN time at the particular skeletal site less than 2.5 minutes. The new development is capable of generating non-invasive, high-resolution quantitative ultrasound (QUS) attenuation and velocity maps of bone for determining the relationship between ultrasonic specific parameters and bone mineral density (BMD) and bone's physical properties (i.e., stiffness). Several studies were conducted.

(1) Multi-Site Quantitative Ultrasound Scanner for Osteoporosis Diagnostics - Evaluated at the Distal Radius. The objective of this study was to provide validation of the new mechanical setup for the 2D scanning confocal acoustic diagnostic (SCAD) system, and evaluate its performance at the distal radius.

(2) Non-invasive assessment of long bone fracture and its potential healing process using quantitative ultrasound.

In this study, we evaluated a hypothesis that the ultrasonic velocity drop is dependent on the fracture gap size. A three transducers ultrasound system was setup to measure fracture gap size. This was verified by both experiment and mathematical simulation.

(3) Mediation of Bone Loss with Ultrasound Induced Dynamic Mechanical Signals in an OVX Rat Model of Osteopenia.

This study tests the hypothesis that an ultrasound generated dynamic mechanical signal can inhibit bone loss in an estrogen deficient model of osteopenia.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

Musculoskeletal decay due to a microgravity environment has greatly impacted the nation's civil space missions and ground operations. Such musculoskeletal complications are also major health problems on Earth, i.e., osteoporosis, and the delayed healing of fractures. About 13 to 18 percent of women aged 50 years and older and 3 to 6 percent of men aged 50 years and older have osteoporosis in the US alone. One-third of women over 65 will have vertebral fractures and 90% of women aged 75 and older have radiographic evidence of osteoporosis. Thus, approximately a total of 24 million people suffer from osteoporosis in the United States, with an estimated annual direct cost of over $18 billion to national health programs. Hence, an early diagnosis that can predict fracture risk and result in prompt treatment is extremely important.

Ultrasound has also demonstrated its therapeutic potentials to accelerate fracture healing. The objectives of this study are focused on developing a combined diagnostic and treatment ultrasound technology for early prediction of bone disorder and guided acceleration of fracture healing, using SCAD imaging and low-intensity pulse ultrasound.

Development of a low mass, compact, noninvasive diagnostic and treatment modality will have great impacts as early diagnostic to prevent bone loss and accelerate fracture healing. This research will address critical questions in the Bioastronautics Roadmap related to non-invasive assessment of the acceleration of age-related osteoporosis and the monitoring of fractures and impaired fracture healing.

Task Progress:

Musculoskeletal complications induced by age-related diseases like osteoporosis, and in long-term disuse osteopenia such as a lack of microgravity during extended space missions and long-term bed rest, represent a key health problem. Such a skeletal disorder changes both the structural and strength properties of bone, and the latter plays a critic role in ultimately leading to fracture. Early diagnosis of progressive bone loss or poor bone quality would allow prompt treatment and thus will dramatically reduce the risk of bone fracture. While most of the osteoporotic fractures occur in cancellous bone, non-invasive assessment of trabecular strength and stiffness is extremely important in evaluating bone quality. Ultrasound has also been shown therapeutic potentials to accelerate fracture healing. We are able to develop a scanning confocal acoustic diagnostic (SCAD) system capable of generating acoustic images at the regions of interest (e.g., in the human calcaneus) for identifying the strength of trabecular bone, in which the system is capable of generating non-invasive, high-resolution ultrasound (US) attenuation and velocity maps of bone, and thus determining the relationship between ultrasonic specific parameters and bone mineral density (BMD), and bone strength and bone's physical properties (i.e., stiffness and modulus). The ultrasound resolution and sensitivity are significantly improved by its configuration, compared to the existing technology. Developed prototype of SCAD is successfully used in the bedrest subjects and clinical test (Stony Brook University). A fast scan mode (~2.5 min) and a surface topology mapping technology using scanning ultrasound are developed and capable of determining calcaneus bone thickness accurately and hence enhancing the accuracy of UV measurement. Ultrasound treatment for progressive bone loss is also initiated in this year's research.

Bibliography Type:	Description: (Last Updated: 02/17/2021)
Articles in Peer-reviewed Journals	Lam H, Qin YX. "The effects of frequency-dependent dynamic muscle stimulation on inhibition of trabecular bone loss in a disuse model." Bone. 2008 Dec;43(6):1093-100. http://dx.doi.org/10.1016/j.bone.2008.07.253 ; PMID: 18757047 , Dec-2008
Articles in Peer-reviewed Journals	Mittra E, Rubin C, Gruber B, Qin YX. "Evaluation of trabecular mechanical and microstructural properties in human calcaneal bone of advanced age using mechanical testing, microCT, and DXA." J Biomech. 2008;41(2):368-75. PMID: 17953972 , Oct-2008
Articles in Peer-reviewed Journals	Qin YX, Lam H. "Intramedullary pressure and matrix strain induced by oscillatory skeletal muscle stimulation and its potential in adaptation." J Biomech. 2009 Jan 19;42(2):140-5. http://dx.doi.org/10.1016/j.jbiomech.2008.10.018 ; PMID: 19081096 ; PMID: 19081096 , Jan-2009
Awards	Ferreri S, Qin YX. "2nd Place Paper Award for: Ultrasound Mitigating Bone Loss, ASME Bioengineering Annual Summer Conference, June 2009." Jun-2009
Awards	Qin YX. "NYSTAR Distinguished Professor--Development Award, May 2009." May-2009