Fiscal Year:	FY 2012	**Task Last Updated:**	FY 11/14/2011
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
Start Date:	11/01/2008	**End Date:**	08/31/2013
No. of Post Docs:	3	**No. of PhD Degrees:**	0
No. of PhD Candidates:	4	**No. of Master' Degrees:**	3
No. of Master's Candidates:	2	**No. of Bachelor's Degrees:**	4
No. of Bachelor's Candidates:	6	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:	NOTE: End date changed to 8/31/2013 (from 10/31/2013) per NSBRI (Ed., 5/14/2013) NOTE: Extended to 10/31/2013 per NSBRI (Ed., 2/22/2013)		
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 (University of Kentucky) Gelato, Marie (University of Kentucky)		
Grant/Contract No.:	NCC 9-58-SMST01603		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Using a newly developed noninvasive Scanning Confocal Acoustic Navigation (SCAN) technology, strong correlations between SCAN determined data and bone 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 SCAN 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. The team is continuing the technology development of a new generation of the SCAN device to access the bone quality at multiple skeletal sites, and use ultrasound to treat the bone fracture in this year. A demo device was shown at the NSBRI 5-year review in Houston in January, 2011. A combined mechanical and electrical array scan modality has been initiated, which can complete the SCAN time at the particular skeletal site less in 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) Development of electronic array SCAN for bone imaging. The objective for this project is to develop computer-controlled phase delay and sequence of acoustic excitation energy for electronic focusing in the 3-D object. An accelerated continuous scan mode is further designed and built including rapid A/D data acquisition, microprocessor control synchronizing (for scanning, transmit signal, and A/D trigger) and control algorithm. A high-resolution ultrasound image array with 60x60 (mm2) and 0.5 mm resolution results in scan times of less than 2.5 minutes in the region of interest (ROI). 2) Development of SCAN for multi-site quantitative ultrasound measurement. The team is continuing to develop an image based SCAN technology for enhanced diagnostic readings at multiple anatomical sites, e.g., wrist region for distal radius and ulna. A soft contact transducer holder was designed to provide acoustic coupling free of water. The design was validated using 2D SCAN imaging system, and evaluated with its performance at the distal radius. Strong correlation between H2O and gel coupling (R2=0.89), and high repeatability (95%) were observed at the tested site. Results indicated that there was an excellent relationship between ultrasound imaging and microradiographic image. These data demonstrated feasibility of ultrasound imaging in multiple critical skeletal sites, i.e., wrist. 3) Characterization of cortical bone fracture with SCAN and longitudinal acoustic velocity. The objectives of this study were to evaluate the cortical fracture gap size using quantitative ultrasound imaging, and the longitudinal ultrasound velocity in bone to predict the fracture gap size. Strong correlations were observed between ultrasound and X-ray images in fracture size (R2=0.91). High correlation was found between gap size and the longitudinal velocity from 4000 m/s to 3000 m/s for 0-5 mm gaps (R2=0.93). These results suggest that ultrasound is capable to predict bone fracture, and provide useful information for longitudinal assessment of complications, such as non-union fracture, and for evaluating healing. 4) Improving ultrasound sensitivity with phase cancellation method. Phase cancellation in ultrasound due to large receiver size has been proposed as a contributing factor to the inaccuracy of estimating broadband ultrasound attenuation (BUA). In vitro ultrasound measurements were conducted on 54 trabecular bone samples (harvested from sheep femurs) in a confocal configuration with a focused transmitter and synthesized focused receivers of different aperture sizes. Phase sensitive (PS) and phase insensitive (PI) detections were performed. The results indicate that the receiver aperture size used in the confocal configuration with PI detection should at least equal the aperture of the transmitter to capture most of the energy redistributed by the interference and diffraction from the trabecular bone. 5) Mitigation of bone loss using guided therapeutic ultrasound in osteopenia. The objective of this project is to evaluate the capability of guided ultrasound in generating dynamic mechanical signal to inhibit bone loss in an estrogen deficient model of osteopenia. Specimen specific, voxel based, finite element (FE) models (E=18GPa & v=0.3), were generated using µCT image data and 1% axial compressive strain was simulated using a nonlinear FE solver (ABAQUS). US treatment significantly increased BVF compared to OVX controls for the 100mW/cm2 treated group. This study suggests that there exists a minimum intensity threshold below which US in less effective at maintaining bone's microstructural and mechanical characteristics. The paper is published in BONE. 6) Acceleration of fracture healing in vivo in a disuse animal model using guided ultrasound. Long duration microgravity not only induces bone loss, but also increases risk of fracture. The aim of this project is to evaluate the potentials of low-intensity guided therapeutic ultrasound on acceleration of fracture healing under delayed union model using hindlimb suspension (HLS) rats. The results have revealed that 6% less bone volume was observed in HLS alone group than the normal fracture (i.e., normal non-HLS condition). Ultrasound treatment on HLS fracture accelerated the healing with significant higher bone volume (25% than the HLS alone group. These data imply that guided ultrasound can speed up the healing and mineralization in the fracture callus, while disuse may delay the fracture healing.
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 SCAN 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. The results have demonstrated the feasibility and efficacy of SCAN for assessing bone's quality in bone. We have been able to demonstrate that the bone quality is predictable via non-invasive scanning ultrasound imaging in the ROI, and to demonstrate the strong correlation between SCAN

	determined data and microCT identified BMD, structural index, and mechanical modulus. These data have provided a foundation for further development of the technology and the clinical application in this research. Our principal goal is to continue the development and evaluation of the SCAN system for ground-based determination of bone's physical properties, and for determining even subtle changes of bone during extended flights.
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 critical 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 SCAN system combined with therapeutic ultrasound capable of generating acoustic images at the regions of interest 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 SCAN 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	Cheng J, Lin W, Qin YX. "Extension of the distributed point source method for ultrasonic field modeling." Ultrasonics. 2011 Jul;51(5):571-80. Epub 2010 Dec 30. http://dx.doi.org/10.1016/j.ultras.2010.12.011 ; PubMed PMID: 21269654 , Jul-2011
Articles in Peer-reviewed Journals	Cheng J, Lu JY, Lin W, Qin YX. "A new algorithm for spatial impulse response of rectangular planar transducers." Ultrasonics. 2011 Feb;51(2):229-37. Epub 2010 Sep 4. http://dx.doi.org/10.1016/j.ultras.2010.08.007 ; PMID: 20863543 , Feb-2011
Articles in Peer-reviewed Journals	Ferreri SL, Talish R, Trandafir T, Qin YX. "Mitigation of bone loss with ultrasound induced dynamic mechanical signals in an OVX induced rat model of osteopenia." Bone. 2011 May 1;48(5):1095-102. Epub 2011 Jan 15. http://dx.doi.org/10.1016/j.bone.2011.01.002 ; PubMed PMID: 21241838 , May-2011
Articles in Peer-reviewed Journals	Lam H, Hu M, Qin YX. "Alteration of contraction-to-rest ratio to optimize trabecular bone adaptation induced by dynamic muscle stimulation." Bone. 2011 Feb;48(2):399-405. Epub 2010 Sep 17. http://dx.doi.org/10.1016/j.bone.2010.09.018 ; PubMed PMID: 20850577 , Feb-2011
Articles in Peer-reviewed Journals	Qin YX. "Challenges to the musculoskeleton during a journey to Mars: Assessment and counter measures." J Cosmol. 2010 Oct- Nov;12:3778-80. http://journalofcosmology.com/Mars148.html , Oct-2010
Articles in Peer-reviewed Journals	Serra-Hsu F, Cheng J, Lynch T, Qin YX. "Evaluation of a pulsed phase-locked loop system for noninvasive tracking of bone deformation under loading with finite element and strain analysis." Physiol Meas. 2011 Aug;32(8):1301-13. http://dx.doi.org/10.1088/0967-3334/32/8/019 ; PubMed PMID: 21765205 , Aug-2011
Articles in Peer-reviewed Journals	Zia Uddin SM, Cheng J, Lin W, Qin YX. "Low-intensity amplitude modulated ultrasound increases osteoblastic mineralization." Cellular and Molecular Bioengineering. 2011 Mar;4(1):81-90. http://dx.doi.org/10.1007/s12195-010-0153-8 , Mar-2011
Awards	Qin YX. "Elected College Fellow, American Institute for Medical and Biological Engineering (AIMBE), February 2011." Feb-2011