

<b>Fiscal Year:</b>	FY 2011	<b>Task Last Updated:</b>	FY 11/09/2010
<b>PI Name:</b>	Qin, Yi-Xian Ph.D.		
<b>Project Title:</b>	Combined Scanning Confocal Ultrasound Diagnostic and Treatment System for Bone Quality Assessment and Fracture Healing		
<b>Division Name:</b>	Human Research		
<b>Program/Discipline:</b>	NSBRI		
<b>Program/Discipline--Element/Subdiscipline:</b>	NSBRI--Smart Medical Systems and Technology Team		
<b>Joint Agency Name:</b>	<b>TechPort:</b>	<b>Yes</b>	
<b>Human Research Program Elements:</b>	(1) <b>ExMC</b> :Exploration Medical Capabilities		
<b>Human Research Program Risks:</b>	(1) <b>Bone Fracture</b> :Risk of Bone Fracture due to Spaceflight-induced Changes to Bone (2) <b>Medical Conditions</b> :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) <b>Osteo</b> :Risk Of Early Onset Osteoporosis Due To Spaceflight (4) <b>Renal Stone</b> :Risk of Renal Stone Formation		
<b>Space Biology Element:</b>	None		
<b>Space Biology Cross-Element Discipline:</b>	None		
<b>Space Biology Special Category:</b>	None		
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<b>Zip Code:</b>	11794-5281	<b>Congressional District:</b>	1
<b>Comments:</b>			
<b>Project Type:</b>	GROUND	<b>Solicitation / Funding Source:</b>	2007 Crew Health NNJ07ZSA002N
<b>Start Date:</b>	11/01/2008	<b>End Date:</b>	10/31/2012
<b>No. of Post Docs:</b>	3	<b>No. of PhD Degrees:</b>	2
<b>No. of PhD Candidates:</b>	4	<b>No. of Master' Degrees:</b>	2
<b>No. of Master's Candidates:</b>	3	<b>No. of Bachelor's Degrees:</b>	3
<b>No. of Bachelor's Candidates:</b>	3	<b>Monitoring Center:</b>	NSBRI
<b>Contact Monitor:</b>	<b>Contact Phone:</b>		
<b>Contact Email:</b>			
<b>Flight Program:</b>			
<b>Flight Assignment:</b>			
<b>Key Personnel Changes/Previous PI:</b>			
<b>COI Name (Institution):</b>	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 )		
<b>Grant/Contract No.:</b>	NCC 9-58-SMST01603		
<b>Performance Goal No.:</b>			
<b>Performance Goal Text:</b>			

	<p>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. Advances in quantitative ultrasound (QUS) techniques can characterize both BMD and the material properties. Using a newly developed noninvasive Scanning Confocal Acoustic Navigation (SCAN) technology, strong correlations between SCAN 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 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, 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 NASA HRP risks related to bone loss monitoring, prevention and recovery, and acceleration of fracture healing.</p> <p>In this year's research, the team is continuing the development of a new generation of the prototype SCAN system to access the bone quality at 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 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). The team has achieved several milestones:</p> <ol style="list-style-type: none"> <li>1) Continuing development of SCAN for multi-site quantitative ultrasound measurement. The objective of this project is to develop an image based SCAN technology for enhanced diagnostic readings at multiple anatomical sites, e.g., wrist region for distal radius and ulna. Strong correlation between H2O and gel coupling (<math>R^2=0.89</math>), and high repeatability (95%) were observed at the tested site. Results indicated that there was an excellent relationship between ultrasound imaging and microradiographic image.</li> <li>2) Characterization of cortical bone fracture with SCAN and longitudinal acoustic velocity. A real-time scanning confocal ultrasound image was developed to evaluate bone defect and bone loss. 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 (<math>R^2=0.91</math>). 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.</li> <li>3) Continuing development of electronic SCAN with array ultrasound transducer. 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 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 2-D ultrasound image array with <math>60 \times 60</math> (mm<sup>2</sup>) and 0.5 mm resolution results in scan times of less than 2.5 minutes in the region of interest (ROI), i.e., in calcaneus, wrist, and knee.</li> <li>4) Guided low-energy therapeutic ultrasound in an OVX rat model of osteopenia. The objective of this project is to evaluate the capability of therapeutic ultrasound in mitigation of bone loss in an estrogen deficient model of osteopenia. US treatment significantly increased BVF compared to OVX controls for the 100mW/cm<sup>2</sup> treated group. This study suggests that there exists a minimum intensity threshold below which US is less effective at maintaining bone's microstructural and mechanical characteristics.</li> <li>5) Bone fracture healing using low-energy guided ultrasound. 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 (femur) 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.</li> </ol>
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	<p>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.</p> <p>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.</p> <p>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.</p> <p>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 <math>\mu</math>CT 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.</p>

<b>Task Progress:</b>	<p>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.</p>
<b>Bibliography Type:</b>	Description: (Last Updated: 02/17/2021)
<b>Articles in Peer-reviewed Journals</b>	Cheng J, Lu JY, Lin W, Qin YX. "A new algorithm for spatial impulse response of rectangular planar transducers." Ultrasonics. 2010 Sep 4. [Epub ahead of print] <a href="#">PMID: 20863543</a> , Sep-2010
<b>Articles in Peer-reviewed Journals</b>	Lam H, Hu M, Qin YX. "Alteration of contraction-to-rest ratio to optimize trabecular bone adaptation induced by dynamic muscle stimulation." Bone. 2010 Sep 17. [Epub ahead of print] <a href="#">PMID: 20850577</a> , Sep-2010
<b>Articles in Peer-reviewed Journals</b>	Lin W, Xia Y, Qin YX. "Characterization of the trabecular bone structure using frequency modulated ultrasound pulse." J Acoust Soc Am. 2009 Jun;125(6):4071-7. <a href="http://dx.doi.org/10.1121/1.3126993">http://dx.doi.org/10.1121/1.3126993</a> ; <a href="#">PMID: 19507988</a> , Jun-2009
<b>Articles in Peer-reviewed Journals</b>	Qin YX, Lam H, Ferreri S, Rubin C. "Dynamic skeletal muscle stimulation and its potential in bone adaptation." J Musculoskelet Neuronal Interact. 2010 Mar;10(1):12-24. <a href="#">PMID: 20190376</a> , Mar-2010
<b>Awards</b>	Qin Y-X. "NYSTAR Distinguished Faculty Development Award, October 2009." Oct-2009
<b>Patents</b>	US Patent 7,727,152 B2. Patent awarded June 1, 2010. Jun-2010 Qin Y, Rubin C, Lin W. "Method and apparatus for scanning confocal acoustic diagnostic for bone quality."