Fiscal Year:	FY 2022	**Task Last Updated:**	FY 07/19/2021
PI Name:	Koehne, Jessica Ph.D.		
Project Title:	Printed Electrochemical Sensor Strip for Quantifying Bone Density Loss in Microgravity		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:			
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:	Moffett Field	**State:**	CA
Zip Code:	94035	**Congressional District:**	18
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2019 HERO 80JSC019N0001-FLAGSHIP & OMNIBUS: Human Research Program Crew Health. Appendix A&B
Start Date:	10/01/2020	**End Date:**	09/30/2021
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:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Brocato, Becky	**Contact Phone:**	
Contact Email:	becky.brocato@nasa.gov		
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:	July 2021 report: Milton Cordeiro is now Co-Investigator on the project.		
COI Name (Institution):	Graf, John Ph.D. (NASA Johnson Space Center) Cordeiro, Milton Ph.D. (USRA)		
Grant/Contract No.:	Internal Project		
Performance Goal No.:			
Performance Goal Text:			

Task Description:

The Human Research Program has outlined risks associated with human spaceflight within the Human Research Roadmap. One such risk is listed as the risk of bone fracture due to spaceflight-induced changes to bone. Our objective to create a printed amino-terminal collagen crosslinks (NTX) quantification sensor strip coupled with a facile urine collection and volume measurement device. The proposed project will be a ground-based study with the potential to be further developed for spaceflight. To accomplish the proposed objective, we will complete the following Aims.
Aim 1: Develop conductive, telopeptide selective, and dielectric inks for printed sensor.

Aim 2: Print and electrochemically characterize 3-electrode device for NTX detection.

Aim 3: Integrate sensor with urine collection device and handheld potentiostat hardware.

If successful, the proposed project will reduce risk of crew bone fracture by continuously evaluating bone health by monitoring mineral metabolism as excreted NTX for bone reabsorption. Future studies could expand the scope of health monitoring to include interferon gamma, tumor necrosis factor-alpha, 25 OH-vitamin B, and bone specific alkaline phosphatase, and/or other molecules of interest. Additionally, these sensors will be manufactured entirely by printing technology. It is anticipated that they can eventually be manufactured in an in-space environment, which directly compliments Space Technology Mission Directorate's In-Space Manufacturing project. By relying on simple printing technology, analytical sensors can be fabricated in space, which would enable adaptive crew health monitoring on long-duration space mission and future habitation.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

This research has benefits for both humans involved in space travel and for humans on Earth. A sensor that monitors bone health has great benefit for our aging adult population. Osteoporosis is the most common bone disease and affects an estimated 10.2 million Americans leading to increased risk of bone fracture. Point-of-care sensors can be useful to monitor bone density loss and onset of osteoporosis, improving the patient experience by lowering the time required for an auxiliary diagnostic while also reducing healthcare costs, since a specialized operator is not required to perform the measurement.

Task Progress:

This project addresses the topic: "Lab Analysis Point-of-Care Device Evaluation and Downselect" of the Human Research Roadmap (HRR) gap Osteo 5 that states, "we need an in-flight capability to monitor bone turnover and bone mass changes during spaceflight." One bone remodeling biomarker that can be directly correlated with bone resorption from a non-invasive urine specimen is NTx, a degradation by-product of type I collagen (Kuo and Chen, 2017). NTx levels in urine were recently used to evaluate bone health during the NASA Twin Study (Garrett-Bakelman et al., 2019) and is a biomarker of interest, referred to in the Human Research Roadmap (HRR) Osteo 5 gap (as noted above). To address this HRR gap, we have developed a methodology using a printed electrochemical sensor capable of detecting NTx in urine. Our goal is to create a highly adaptable and versatile approach that utilizes fabrication processes consistent with in-space manufacturing, thus enabling the manufacture of point-of-care devices during flight. Going forward, we plan to expand the sensor's capability to measure a variety of bone remodeling biomarkers simultaneously. However, NTx serves as our initial target for this project and as a proof-of-concept for our approach.
The project objective is to create a space-suitable, printed sensor strip for quantifiable NTx detection coupled to a urine collection device. To accomplish this objective, we have focused on the following Aims.

Aim 1: Develop conductive, telopeptide selective and dielectric inks for printed sensor.

Aim 2: Print and electrochemically characterize 3-electrode device for NTx detection.

Aim 3: Integrate sensor with urine collection device and handheld potentiostat hardware

This project was heavily impacted due to the COVID-19 shutdown and laboratory access has not yet been granted for this project.

During this period of performance, we have generated, optimized, and selected conductive and dielectric inks for the printed electrochemical sensor. We have evaluated commercial inks and homemade inks and selected the most suitable for this application. For example, it was determined that further processing of carboxylic acid functionalized multiwalled carbon nanotube (MWCNT-COOH) was required to create stable aqueous inks suitable for inkjet printing. Commercial silver nanoparticle (AgNP) and dielectric inks were used for the remaining circuitry of the sensor. Additional ink development to produce telopeptide selective inks is currently underway.

Using those optimized and pre-screened electronic inks, 3-electrode electrochemical sensors have been printed using inkjet and precision microdispense instrumentation with two unique device designs. Both devices were characterized for their electrochemical performance and robustness. Fluid delivery was designed to carry the urine specimen to the sensor surface. Finally, sensors were packaged into reusable cassette holders for simple and reliable operation. Development and characterization of NTx sensing is currently underway.

It is envisioned that the printed sensor will be integrated with commercially available handheld potentiostat hardware and a previously developed urine collection device. The design of these interfaces require easy assembly and disassembly for non-cumbersome overall sensor operation. Significant effort is required of this Aim as the project moves forward.

References

Kuo, T. R.; Chen, C. H. Bone Biomarker for the Clinical Assessment of Osteoporosis: Recent Developments and Future Perspectives. Biomark. Res. 2017, 5 (1), 5–13.

Garrett-Bakelman, F. E.; Darshi, M.; Green, S. J.; Gur, R. C.; Lin, L.; Macias, B. R.; McKenna, M. J.; Meydan, C.; Mishra, T.; Nasrini, J.; et al. The NASA Twins Study: A Multidimensional Analysis of a Year-Long Human Spaceflight. Science (80). 2019, 364.

Bibliography Type: Description: (Last Updated: 04/14/2023)