NEXT GENERATION EXERCISE DEVICE (NGED): ADVANCING EXERCISE CAPABILITIES FOR FUTURE SPACE MISSIONS THROUGH BIOMECHANICAL MODELING

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BACKGROUND

As space exploration extends to long-duration missions on the Moon and Mars, maintaining astronaut health and fitness becomes increasingly critical. The Next Generation Exercise Device (NGED), developed and tested by the HumanWorks Lab in NASA Johnson Space Center's (JSC) Software, Robotics, and Simulation Division, aims to address this challenge through innovative approaches. This study presents the development and evaluation of an NGED system, focusing on its adaptability to various mission scenarios, including prospective use in a Lunar Pressurized Rover (LPR). Central to this project is the application of biomechanical modeling to optimize exercise efficacy and safety in microgravity and partial gravity environments. The project is a collaborative effort with the Human Health and Performance group at Johnson Space Center, ensuring a comprehensive approach to astronaut well-being that integrates biomechanical principles with practical exercise solutions. The NGED represents the next generation of exercise capabilities for missions in space, on the Moon and Mars, with a specific focus on applications such as the LPR.

METHODS AND RESULTS

Data collection for NGED development was conducted with two motor-driven Beyond Power Voltra I [1] systems and a custom test structure to allow placement of the cable-based devices on the ground, at shoulder height, and overhead. The collection was performed in JSC's Prototype Immersive Technology (PIT) Lab, utilizing an OptiTrack motion capture system and AMTI force platform, to enable detailed biomechanical analysis via OpenSim [2,3]. Motion capture data were collected for three subjects representing different body types and statures. The marker set used was an enhanced version of the full-body Plug-in Gait marker set [4], with additional markers strategically placed for the primary objective of informing exercise volume requirements. Subjects performed a series of 17 exercises, carefully selected to engage various muscle groups, including novel spaceflight exercises such as skiing (ergometer style), lateral pulldowns, wood chops, triceps extensions, and flies, with load variations ranging from 10 to 90 pounds to maintain kinematic form. This comprehensive approach allowed for a thorough evaluation of the NGED's performance across a wide range of motions and loads. The biomechanical modeling and analysis were conducted using a modified OpenSim Full Body Rajagopal Model [4,5] and also scaled to the maximum and minimum anthropometry provided in NASA-STD-3001 [6]. Volumetric convex hulls were generated based on model marker trajectories and aggregated into geometric assemblies. These can be placed in models of vehicle designs to assess fit to protect for exercise as well as to adapt NGED exercise to fit available space. Preliminary findings from the collection indicate that the NGED prototype demonstrates significant adaptability across varying user anthropometrics and exercise types. The device showed consistent performance in load-bearing exercises, with subjects able to perform exercises effectively while maintaining proper biomechanical form.

CONCLUSION

NGED represents a forward-looking advancement in exercise capabilities for future space missions. In the future, this system can be used to capture valuable metrics (e.g., isometric mid-thigh pull for force output measurements, assessments of postural muscle strength, overall isometric strength). Its versatility in accommodating various exercises and user physiques, coupled with the ability to provide targeted biomechanical loading, makes it a promising approach for maintaining astronaut health during long-duration missions to the Moon and Mars. Future work will focus on refining the NGED based on initial biomechanical findings, leveraging the detailed insights provided by motion capture and analysis techniques. Particular emphasis will be placed on optimizing its use within the confined spaces of a LPR and other space habitats. This work contributes significantly to NASA's goals of supporting human health and performance in deep space exploration, paving the way for sustainable long-term presence beyond Low Earth Orbit through advanced, biomechanically-informed exercise solutions.

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