"*Skywalker: A New Hope for Reducing Muscle Atrophy in Astronauts*"

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Background & Significance

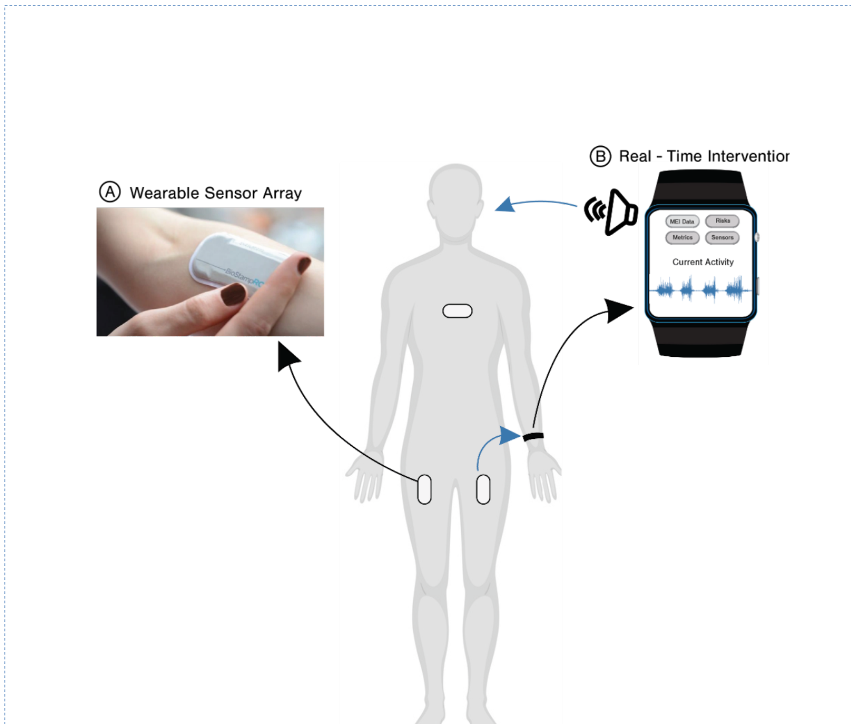
NASA's upcoming missions include returning astronauts to the moon (*Artemis*) and the continued exploration of Mars (*Mars and Beyond*) [1], which demand increased levels of muscular fitness yet require longer exposure to micro-gravity than ever before. As micro-gravity induced muscular atrophy remains an unresolved challenge despite current countermeasures [2], NASA's Human Research Program outlined several knowledge gaps that, if addressed, could further reduce muscular atrophy in astronauts. These knowledge gaps include metrics to quantify individual baseline for crewmembers that describe their own functional performance, real-time quantification of muscle loss in relation to baseline, and quantification of the physical demand of specified tasks [2,3]. A solution that is able to continuously monitor and quantify direct muscular response to stress, and to resolve that response relative to a muscle health baseline, may address these knowledge gaps and improve our understanding of the amount of muscular stress required in space to eliminate atrophy.

Project Goals

Our long-term goal is to develop *Skywalker*, a connect health system for reducing muscle atrophy in astronauts. The system will continuously monitor muscle loading (via surface electromyography (sEMG)) and provide automated biofeedback interventions, based on social cognitive theory. Our hypothesis is that this system will help astronauts identify the shortcomings in muscle use that lead to atrophy and engage in associated mitigation behaviors. The aims for this project are a first step toward development of the *Skywalker* system. Aim 1: *Define normalization guidelines for long-duration unsupervised sEMG*. Current sEMG guidelines are optimized for short-duration supervised recordings, but due to the time-varying nature of sEMG, these guidelines may not remain valid for long-duration use. Aim 2: D*evelop an sEMG-based measure of muscle stress, and demonstrate its ability to resolve acute and daily muscle loading.* Aim 3: E*xplore user response to acute and daily biofeedback for adapting behavior to reduce muscle atrophy.*

Summary of Key Findings

Skywalker depends on accurate analysis of unsupervised long-duration sEMG data recording. Thus, the key outcomes of this work focus on Aim 1, to define guidelines for deploying long-duration sEMG. Due to the time-varying nature of sEMG signals, standard procedure for sEMG analysis is to normalize the signal by a reference value. However, long-duration sEMG recordings are not considered in recent consensus on the appropriate methods for sEMG normalization [4]. To address this limitation, we examined the suitability of using the gold standard sEMG normalization method (e.g. the mean sEMG amplitude collected from a maximum voluntary contraction (MVC)) to normalize unsupervised sEMG data collected over 24-hours. It was found that when comparing sEMG data from two similar walking bouts performed at the beginning and at the end of the 24-hour period, the mean sEMG amplitude resulted in an unsupported increase of 456% when normalized to MVC. However, when the two walking bouts were normalized by the mean sEMG amplitude of their respective walking bouts, the difference in amplitude was insignificant and could be explained by variation in stride time. These results indicate that normalization values should be updated throughout a recording period. Thus, we propose a new adaptive method for sEMG normalization that leverages data collected during typical daily activities (ADLs). We explored several candidate ADLs for performing this normalization, and their ability to respond to expected sEMG amplitude changes with stride time and activity intensity. It was found that normalization to walking, and particularly to a self-selected comfortable speed, yields the best results. Thus, Skywalker could detect when a specific ADL was performed and use that to adaptively update the normalization reference value. Next steps include further testing and validation of the suggested adaptive update methodology in a microgravity environment. We can then progress to aims 2 and 3.



Visual description of *Skywalker*. Wearable sensors (sEMG) are placed on the quadricep muscles and heart rate is measured from the chest sensor. Data is sent in real-time to a smart watch that provides acute alerts and daily SCT-based messages to reduce atrophy.

References

[1] National Aeronautics and Space Administration,"AboutNasa,"*What'sNextForNASA?*[Online].Available: https://www.nasa.gov/about/whats_next.html.

[2] B. H. Dobkin and C. Martinez, "Wearable Sensors to Monitor, Enable Feedback, and Measure Outcomes of Activity and Practice," *Curr. Neurol. Neurosci. Rep.*, vol. 18, no. 12, p. 87, Dec. 2018, doi: 10.1007/s11910-018-0896-5.

[3] R. D. Gurchiek, C. P. Garabed, and R. S. McGinnis, "Gait event detection using a thigh-worn accelerometer," *Gait Posture*, vol. 80, pp. 214–216, Jul. 2020, doi: 10.1016/j.gaitpost.2020.06.004.

[4] M. Besomi *et al.*, "Consensus for experimental design in electromyography (CEDE) project: Amplitude normalization matrix," *J. Electromyogr. Kinesiol.*, vol. 53, p. 102438, Aug. 2020, doi: 10.1016/j.jelekin.2020.102438.