Wearable Textile-Integrated Functional Electrical Stimulation for In-Mission Mitigation of Musculoskeletal Back Strain in Naval Aircrew

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Introduction

- Musculoskeletal (MSK) neck and back pain is a recognized and prevalent problem among military aircrew across aviation platforms (Farrell et al. 2020; Harrison et al., 2015).
- Sustained seated posture, whole-body vibration, and prolonged helmet and equipment loading raise the mechanical demand and contribute to these conditions (Farrell et al. 2020; Harrison et al., 2015).
- Current in-mission countermeasures primarily consist of passive approaches such as ergonomic supports and seat modifications.
- An active, wearable intervention could extend these countermeasures beyond passive support by actively stimulating the target muscles.
- Functional Electrical Stimulation (FES) delivers controlled electrical stimulation to generate muscle contractions and is widely used to recover motor function (Peckham and Knutson, 2005).
- Adapting FES to a textile-integrated wearable form may provide active, in-mission muscle activation, while remaining compatible with flight operational requirements.

Objective

- To evaluate feasibility, safety, and performance of the BeHumyn textile-integrated FES prototype; designed to provide active in-mission MSK support during prolonged seated exposure.

Device Overview

- BeHumyn is developed through a Defense Health Agency (DHA) Phase II Small Business Innovation Research (SBIR) program.
- The garment incorporates embroidered conductive textile electrodes that deliver intermittent, low-level electrical stimulation.
- The textile-integrated design supports prolonged wear while maintaining comfort, electrode stability, and freedom of movement, providing continuous in-mission musculoskeletal support while remaining compatible with mission requirements (Figure 1).

Figure 1. Multi-view display of BeHumyn shirt and controller (front view, back view and attachment points, controller). Figure 1 is generated by Zansors.

Technical Approach

- A two-phase, IRB-approved study evaluated the feasibility, safety, and prolonged-wear performance of the textile-integrated FES garment.
- Phase I (n = 21) evaluated system discomfort during controlled stimulation sessions.
- Phase II (n = 3) evaluated feasibility during extended (15 h) seated exposure in a confined seating condition, during which participants received intermittent, low-level electrical stimulation to the upper/lower back, and trapezius musculature. Figure 2 illustrates the intermittent stimulation protocol, using predefined stimulation and rest intervals.

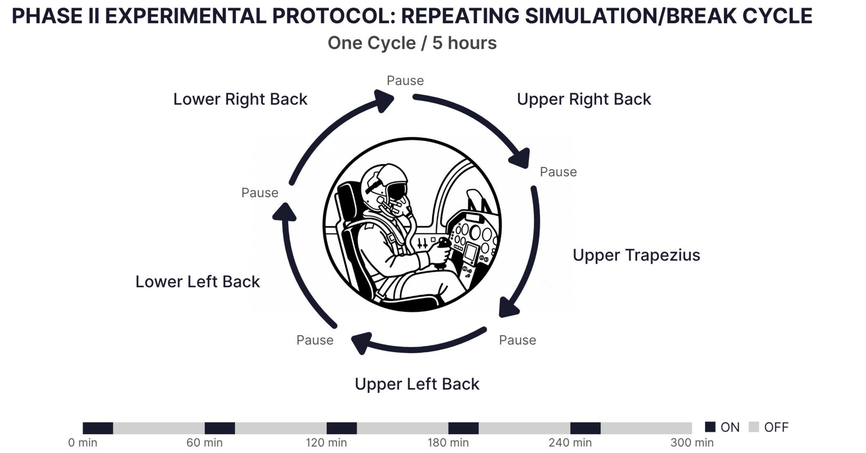

Figure 2. Experimental stimulation protocol used during the prolonged-wear evaluation (Phase II). Participants received intermittent, low-intensity FES in a repeating cycle consisting of 15-minute stimulation periods delivered sequentially to the lower/upper back, and trapezius regions, with 45-minute rest intervals between stimulation sessions. This cycle was repeated throughout the 15-hour evaluation. Figure 2 is generated by Zansors.

Results

- In Phase I (n = 21), mean of participant reported discomfort was lower in post assessment (2.29 to 1.86; $\Delta = -0.43$), but the change was not statistically significant (p = 0.37), Table 1.
- In Phase II (n = 3), across prolonged (15 h) wear, average comfort ratings remained between 4.0-5.0/5.0 apart from a transient low of 3.7/5.0 at hour 9 before stabilizing at 4.0/5.0, and average perceived stimulation strength remained between 4.7-5.0/5.0 throughout (Figure 3).
- No signal degradation, electrode migration, skin irritation, or device-related adverse events were reported.

Table 1. Phase I Participant-Reported Outcome Measures (n = 21)

Measure	Baseline Mean	Post-assessment Mean	Mean Δ	p-value
Discomfort	2.29	1.86	-0.43	0.37

Results

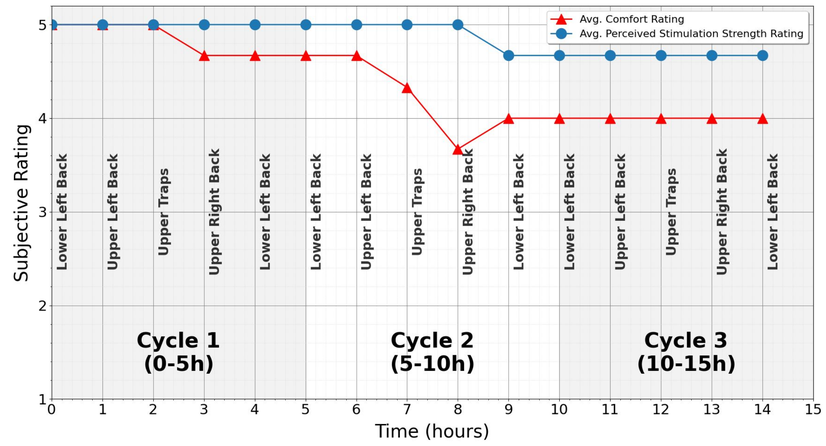

Figure 3. Phase II Participant-reported Outcome Measures (n = 3).

Discussion

- BeHumyn represents a novel wearable technology for in-mission mitigation of back strain, with the potential to improve aircrew comfort, sustain mission performance, and enhance operational readiness during prolonged flight operations.
- No device-related adverse events were reported.
- Larger studies in representative aviation environments are needed to further evaluate efficacy and support technology maturation.
- Future studies will advance technology maturation through environmental and airworthiness testing to support prototype transition.

Conclusion

- The study supports the feasibility and safety of BeHumyn textile-integrated FES prototype during prolonged wear under flight-representative seated conditions. These findings support further evaluation as a potential in-mission countermeasure for mitigating back strain in naval aviation.

References

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