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TITLE: Rehabilitation 2.0: Addressing Neuroplasticity in the Musculoskeletal Rehabilitation Model

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CONTRACTING ORGANIZATION: Ohio University

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14. ABSTRACT

Musculoskeletal injuries such as to the knee's anterior cruciate ligament (ACL) degrade the operational readiness of our U.S. Service members. These injuries cause decreased physical ability that leads to reduced performance and high re-injury risk. Changes in brain activity as the result of the injury is directly related to the decreased physical performance, affecting the Service member's motor performance capability in complex or highly reactive military training and operations environments. Unfortunately, current treatments do not restore post-injury Service member's physical performance, especially when under stress. This deficit has clear consequences for military personnel, as the intense stress and constant need of situational awareness can impair physical performance when returned to active duty. To that end, new therapies are needed to restore Service member performance after injury. Thus, the purpose of this proposal is to quantify how the brain changes after injury across the typical 6-month window of physical therapy. We are also testing new functional assessments that target the brain changes that limit Service member performance. These assessments will support the transition of this research to clinical practice. This applied research award will provide the knowledge of the time course of brain changes that influence function to implement these new impactful interventions. These synergistic outcomes provide an immediate product that can be clinically implemented and propel further investigations to ensure truly restored functional capacity of our nations Service members.

15. SUBJECT TERMS

NONE LISTED

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2. Keywords

Neuroimaging, lower extremity, biomechanics, knee injury, anterior cruciate ligament, tactical performance, neural control of movement, neuromuscular control, cognitive motor interaction

3. Accomplishments

- Methods optimization and reliability experiments completed and published.
- Tactical cognitive-motor assessment development with ROTC completed and published.
- Primary study of longitudinal follow-up on neuroplasticity in knee anterior cruciate ligament injured patients is ongoing.
    - Local IRB and HRPO continuing review completed\approved.
    - Data collection (neuroimaging, virtual reality sensorimotor assessment, muscle strength, proprioception, postural control, neuromuscular control and patient outcomes) at 3 time points: 6 weeks, 3 months and 6-9 months post-surgery
        - ACL injured patients target sample size: 36
        - ACL injured patients enrolled to date: 27
        - Matched controls target sample size 36
        - Matched controls completed: 9 (of note, these are easier to enroll and are being completed now that most of the ACL cohort is completed to allow for matching)

4. Impact

- Preliminary, experimental optimization and reliability work completed, and studies published.
- ROTC arm of the study is complete and initial works published.
- The primary longitudinal study is currently in data collection for the ACL injured cohort.

5. Changes/Problems

No changes to the deliverables, general scope of work, expenditures or human subject experience were made during this reporting period.

The COVID related research shutdown did force us to lose follow-up on 15 recruited patients, nearly half of our study cohort requiring new subjects to be recruited and enrolled to replace them to meet the scope of work for 6-9 month longitudinal follow-up. We reduced charges to the grant and reduced personnel effort to allow for increased effort and charges once human subject research activity was allowed to resume.

A supplemental award was also granted to enable running the project for additional years to ensure the scope of work can be completed with these vital longitudinal follow-up visits. A second two year no-cost extension was granted to continue the work as the most vital outcome is the longitudinal data requiring patients to be tracked up to 9 months after enrollment.

We need to enroll 9 more ACL patients to achieve our target sample size, ideally 6 months before the award ends in October 2024 to allow for the longitudinal follow-up. We are a few subjects behind our target goals but remain optimistic to achieve the study aims.

We had some minor personnel effort changes over the year with some effort redistribution. The recently updated and approved no-cost extension budget has reallocated and accommodated all scope of work with minor effort adjustments.

6. Products

Currently in data collection on the primary longitudinal patient arm of the study.

*A project update was delivered at the MOMRP Musculoskeletal Research IRP meeting in September 2022

Several works have been published (highlight this year):

1) Neuroimaging paradigm development and validation studies

- Grooms DR, Criss CR, Simon JE, Haggerty AL, Wohl TR. Neural Correlates of Knee Extension and Flexion Force Control: A Kinetically-Instrumented Neuroimaging Study. *Front Hum Neurosci*. 2020;14. doi:10.3389/fnhum.2020.622637
- Grooms DR, Diekfuss JA, Criss CR, et al. Preliminary brain-behavioral neural correlates of anterior cruciate ligament injury risk landing biomechanics using a novel bilateral leg press neuroimaging paradigm. *PLOS ONE*. 2022;17(8):e0272578. doi:10.1371/journal.pone.0272578
- Kim H, Onate JA, Criss CR, Simon JE, Mischkowski D, Grooms DR. The relationship between drop vertical jump action-observation brain activity and kinesiophobia after anterior cruciate ligament reconstruction: A cross-sectional fMRI study. Brain Behav. 2023 Feb;13(2):e2879. doi: 10.1002/brb3.2879. Epub 2023 Jan 5. PubMed PMID: 36602922; PubMed Central PMCID: PMC9927857.

2) Virtual reality and functional performance testing under cognitive challenge with biomechanics data published reliability and validation studies

- Burcal CJ, Haggerty A, Grooms DR. Using Virtual Reality to Treat Perceptual and Neurocognitive Impairments After Lower Extremity Injury. *Athletic Training & Sports Health Care*. Published online June 2021. doi:10.3928/19425864-20210401-01Farraye BT, Chaput M, Simon JE, Kim H, Grooms DR, Monfort SM. Development and reliability of a visual-cognitive medial side hop for return to sport testing. *Physical Therapy in Sport*. 2022;57:40-45. doi:10.1016/j.ptsp.2022.07.004

- Brazalovich P, Simon JE, Criss CR, Yom JP, Grooms DR. The effects of virtual reality immersion on drop landing mechanics. *Sports Biomechanics*. Published online February 9, 2022. Accessed February 10, 2022. https://www.tandfonline.com/doi/full/10.1080/14763141.2022.2035427
- Bendixen JB, Biddinger BT, Simon JE, Monfort SM, Grooms ADR. Effects of virtual reality immersion on postural stability during a dynamic transition task. Sports Biomech. 2023 Jan 4;:1-15. doi: 10.1080/14763141.2022.2162434. [Epub ahead of print] PubMed PMID: 36597788.
- Farraye BT, Simon JE, Chaput M, Kim H, Monfort SM, Grooms DR. Development and Reliability of a Visual-Cognitive Reactive Triple Hop Test. J Sport Rehabil. 2023 Jun 16;:1-8. doi: 10.1123/jsr.2022-0398. [Epub ahead of print] PubMed PMID: 37328155.
- Grooms DR, Chaput M, Simon JE, Criss CR, Myer GD, Diekfuss JA. Combining Neurocognitive and Functional Tests to Improve Return-to-Sport Decisions Following ACL Reconstruction. J Orthop Sports Phys Ther. 2023 Aug;0(8):1-5. doi: 10.2519/jospt.2023.11489. PubMed PMID: 37186672.

3) Initial report from the ROTC arm of the study

- Buckley S, Chaput M, Simon JE, et al. Cognitive Load Impairs Time to Initiate and Complete Shooting Tasks in ROTC Members. *Military Medicine*. Published online July 9, 2021:usab276. doi:10.1093/milmed/usab276
- McCarren G, Chaput M, Grooms DR, Criss CR, Buckley S, Brazalovich P, Yom J, Simon JE. Cognitive Load Influences Drop Jump Landing Mechanics During Cognitive-Motor-Simulated Shooting. Mil Med. 2023 Jan 31;. doi: 10.1093/milmed/usad003. [Epub ahead of print] PubMed PMID: 36722162.

7. Participants & Other Collaborating Organizations

Name: Dustin Grooms
Role: PI
Research identifier: 0000-0001-6102-8224
Person month worked: 3
Contribution: Coordinate overall project, IRB\HRPO approval, hire and train research assistants\project manager, secure technologies, patient and participant recruitment and data collection\analysis
Funding support: This award and university research release time

Name: Byrnadeen Farraye
Role: Project manager\research associate
Research identifier: *NA*
Person month worked: 10
Contribution: Undergo training in all data collection methods and CITI training for human subject interaction. Facilitate participant recruitment, data collection\analysis and manage research equipment.
Funding support: This award and university research support

Name: Janet Simon
Role: Co-I
Research identifier: *NA*
Person month worked: 1
Contribution: Project management, data analysis and experimental design, patient outcomes management
Funding support: This award and university research release time (in-kind)

Name: Brian Clark
Role: Co-I
Research identifier: *NA*
Person month worked: 0.5
Contribution: Strength and functional testing data collection and analysis.
Funding support: This award and university research release time (in-kind)

Name: Meredith Chaput
Role: Research assistant\PhD student
Person month worked: 6
Contribution: Data analysis, reporting and manuscript preparation on the phase 1 initial study data.
Funding support: This award and university

Name: Justin Rush
Role: Post-doctoral research associate
Person month worked: 2
Contribution: Data collection and analysis and processing pipeline development.
Funding support: This award and university

Name: Sergio Ulloa
Role: Physician
Person month worked: 0.5
Contribution: Patient recruitment
Funding support: This award and university and clinical practice

8. Special Reporting Requirements

Updated quad chart included

9. Appendices

Publications
Updated Scope of Work with percentage completed\ongoing