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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.					
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1. Introduction

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.

2. Keywords

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

3. Accomplishments

Project Goals

The project is split into 2 primary goals\aims.

Goal 1: To determine when the maladaptive neuroplastic sensory reweighting occurs following ACL injury.

Local IRB Approval: Achieved – Year 4 Continuing Review Completed

HRPO Approval: Achieved – Year 4 Continuing Review Completed

Equipment preparation: Completed

New technology integration and initial development studies

(Virtual reality and sensorimotor monitoring during neuroimaging): Completed (initial data published)

Participant recruitment: Ongoing

Injured cohort Neuroimaging data collection: Ongoing

(n=13 completed, n=6 recruited, enrolled or engaged in longitudinal follow-up) target sample size: 36

Control cohort Neuroimaging data collection: Ongoing (n=10 completed, paused till complete patient enrollment to allow patient matching on demographics) target sample size: 36

Goal 2: To determine the functional correlates of neuroplastic sensory reweighting for motor performance.

Local IRB Approval: Achieved – Year 4 Continuing Review Completed

HRPO Approval: Achieved – Year 4 Continuing Review Completed

Equipment preparation: Completed

New technology integration and initial development studies

(Functional virtual reality, proprioception, reactive motor control): Completed (initial data published)

Participant recruitment: Ongoing

Injured cohort Biomechanical data collection (muscle strength, proprioception, postural control, neuromuscular control and patient outcomes): Ongoing

(n=13 completed, n=6 recruited, enrolled or engaged in longitudinal follow-up target sample size: 36

Control cohort Biomechanics data collection: Ongoing (n=10 completed, paused till complete patient enrollment to allow patient matching on demographics) target sample size: 36

ROTC cohort tactical neuromuscular control performance data collection: Completed, published (n=33)

4. Impact

Work has completed development and methods optimization with studies published, the ROTC arm of the study is complete and initial works published. The primary longitudinal study is in 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-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.

Primary remaining challenge: The volume of orthopedic surgery has only this past August\September begun to reach pre-COVID levels in our area. However, we have had success recruiting at least 2 new subjects each month that have been engaged in the follow-up visits, and we are noticing a steady increase in patient recruitment. Over the last 3 quarters we have greatly expanded recruitment sites adding 6 outpatient physical therapy clinics, 2 orthopedic surgery groups, providing taxi and transport services and our project manager has taken on addition duties engaged in routine and regular communication with all recruitment sites within a 50-mile radius. We only need to increase recruitment by a few more patients a quarter to achieve the study timeline and are optimistic.

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](https://doi.org/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](https://doi.org/10.1371/journal.pone.0272578)
- 2) Virtual reality and functional performance testing under cognitive challenge with biomechanics data published reliability and validation studies
 - Farraye 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](https://doi.org/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>
 - 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:[10.3928/19425864-20210401-01](https://doi.org/10.3928/19425864-20210401-01)
- 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](https://doi.org/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. **In Review** *Military Medicine*

Presentations or abstracts 2022 only

- Grooms DR. Neuroplastic Optimization of ACL Injury Rehabilitation and Prevention. Colorado Children's Hospital; Denver, CO. October 2022
- Grooms DR. Clinical Virtual Reality To Augment Rehabilitation and Return-to Sport Testing. NATA. National Athletic Training Association 71st Annual Meeting; Philadelphia, PA. June 2022
- Chaput M, Farraye BT, Simon JE, Kim HK, Monfort SM, Grooms DR. Development and Reliability of a Gaze Controlled Visual-Cognitive Reactive Triple Hop Test. *American Physical Therapy Association Annual Combined Sections Meeting;* San Antonio, TX. 2022
- Farraye BT, Simon JE, Chaput M, Kim HK, Grooms DR, Monfort SM. Integrating Neurocognition into Clinical Single-Leg Hop Tests. *Combined Sections Meeting of the American Physical Therapy Association,* San Antonio, TX. Feb 2022

7. Participants & Other Collaborating Organizations

Name: Dustin Grooms

Role: PI

Research identifier: 0000-0001-6102-8224

Person month worked: 4

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: 9

Contribution: Data analysis, reporting and manuscript preparation on the phase 1 initial study data.

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