This provided as an example proposal. it is important that you follow the current guidelines.

The mentor letter has been removed.

The John J. Kopchick Molecular and Cellular Biology/Translational Biomedical Sciences Research Fellowship Award

Cover Page Academic Year 2022-2023

NAME OF APPLICANT: HoWon Kim

NUMBER OF YEARS: Entering 3rd IN THE ☐ MCB OR ☑ TBS PROGRAM

E-MAIL ADDRESS: hk142717@ohio.edu

DEPARTMENT: School of Rehabilitation & Communication Sciences
Department of Athletic Training & Department of Physical Therapy

EXPECTED GRADUATION DATE (Month and Year): May 2024

TITLE OF PROJECT: The Effects of Virtual Reality Action Observation and Motor Imagery on Cortical Activity and Quadriceps Muscle Function.

FACULTY MENTOR INFORMATION:

NAME: Dustin R. Grooms

E-MAIL ADDRESS: groomsd@ohio.edu

DEPARTMENT: School of Rehabilitation & Communication Sciences, Physical Therapy

BUDGET: Total Request $ 15,000

STATEMENT OF HOW THE RESEARCH IS RELEVANT TO TRANSLATIONAL BIOMEDICAL SCIENCES* (500 character limit)

The following work will provide insight into the effects of virtual reality immersive exercise based with action-observation and motor imagery techniques on cortical activity and muscle function. These findings will immediately provide a novel therapeutic intervention that will help clinicians to effectively strengthen muscles after a musculoskeletal injury and potentially improve long-term patient outcomes.

*For the purposes of this program, translational biomedical sciences is defined as the translation of basic research effectively into enhanced healthcare outcomes for the entire population in fields such as biomedical research, bioengineering, drug development, informatics, communications, health policy and planning.

IRB AND IACUC APPROVAL:

To ensure that the University is in compliance with all federal regulations, complete the checklist below. *Note: your proposal can be approved prior to IRB or IACUC approval (put "pending" or "to be submitted" instead of approval number), but funding will be withheld until notification of approval or exemption.*

Yes	***No***	***Office of Research Compliance***	***Policy #***
✓		Human Subjects in Research: Institutional Review Board (IRB) Approval #: Expiration Date:	19.052
	✓	Animal Species: Institutional Animal Care & Use Committee (IACUC) Approval #: Expiration Date:	19.049

SIGNATURES

Applicant's Signature		**Faculty Mentor's Signature**	
Signature	HoWon Kim	Signature	Dustin R. Grooms
Name	HoWon Kim	Name	Dustin R. Grooms

Optional: ☑ Yes ☐ No

If selected for funding, I give permission to the Office of the Vice President for Research and Creative Activity to use my proposal as an example during training and workshop exercises.

Biographical Sketch

HoWon Kim, MS, AT

Personal Statement

My goal is to become a clinician-scientist investigating the neurophysiological alterations and psychological factors contributing to patient outcomes after musculoskeletal injuries. My long-term research goal is to advance rehabilitation and injury prevention programs to improve the quality of life and facilitate lifelong physical activity. This research proposal will provide an opportunity for novel scientific work and contribute to the body of knowledge via conference presentations and scientific journal publications. The foundational work proposed also will enable effect size computation for a future clinical trial and extramural grant submissions.

Education

Ohio University, *Doctor of Philosophy*, Expected Graduation Date: May 2024, GPA 3.68
Ohio University, *Master of Science in Athletic Training*, May 2020, GPA 3.91
Weber State University, *Master of Science in Athletic Training*, April 2018, GPA 3.97
Kyung Hee University, *Bachelor of Physical Education in Taekwondo*
Bachelor of Science in Sports Medicine, August 2014, GPA 3.04

Relevant Coursework

BIOS 5130 Neuroscience
PBIO 5170 Biologic Research Science Ethics
PSY 5110 Statistics in Behavior Science
AT 6310 Neuromechanics of Sport Injury
PSY 6100 Data Management
PT 7510 Neural Basis of Movement

Peer Reviewed Publications

- Farraye BT, Chaput M, Simon JE, **Kim HW**, Grooms DR, Monfort S. Development and reliability of a visual-cognitive medial hop for return to sport testing. *Physical Therapy in Sport*. Published online July 2022: S1466853X22000955. doi:10.1016/j.ptsp.2022.07.004
- **Kim H**, Lee D, Choi H-M, Park J. Joint Cooling does not Hinder Athletic Performance during High-intensity Intermittent Exercise. *International Journal of Sports Medicine*. 2016;37(08):641-646.

Presentations and Published Abstracts

- **Kim HW**, Onate JA, Criss CR, Simon JE, Mischkowski D, Grooms DR. Action-Observation Brain Activity Associate with Kinesiophobia after Anterior Cruciate Ligament Reconstruction. National Athletic Trainers' Association Clinical Symposia & AT Expo, Philadelphia, PA. June 2022. Journal of Athletic Training. 2022; 57(6) S-18.
- **Kim HW**, Zuleger TM, Warren SM, Slutsky-Ganesh AB, Diekfuss JA, Anand M, Schlink BR, Barber Foss KD, Simon JE, Myer GD, Grooms DR. Relationship Between Brain Activity and Knee Biomechanics During a Bilateral Leg Press in Adolescent Female Athletes. ACL Research Retreat IX, Greensboro, NC. 2022; Will be published in Journal of Athletic Training.
- **Kim HW**, Onate JA, Simon JE, Mischkowski D, Grooms. Identifying Neural Activity Associated with Kinesiophobia after Anterior Cruciate Ligament Reconstruction. Great Lakes Athletic Trainers' Association Annual Meeting, Virtual. 2021
- **Kim HW**, Onate JA, Criss CR, Simon JE, Mischkowski D, Grooms DR. Identifying Neural Activity Associated with Kinesiophobia after Anterior Cruciate Ligament Reconstruction. National Athletic Trainers' Association Clinical Symposia & AT Expo, Virtual. June 2021. Journal of Athletic Training. 2021; 56(6) S-228.

Honor and Awards

- 2022 National Athletic Trainers' Association Free Communicating Award for Post-Professional Terminal Degree Student
- 1st place in medicine session for 2022 Ohio University Research Expo

BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. DO NOT EXCEED FIVE PAGES.

NAME: Grooms, Dustin

eRA COMMONS USER NAME (credential, e.g., agency login): grooms69

POSITION TITLE: Professor of Clinical Neuroscience

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Northern Kentucky University	B.S	05/2008	Athletic training & Mathematics
University of Virginia	M.Ed.	05/2009	Kinesiology
The Ohio State University	Ph.D.	08/2015	Neuroscience & Biomechanics

A. Personal Statement

I specialize in the neuroplastic and biomechanical changes associated with musculoskeletal injury and rehabilitative interventions, with a primary research focus on the development of novel paradigms to bridge neurophysiology and motor behavior. I am among the first to successfully quantify knee sensorimotor control neural activity with neuroimaging and have developed data collection and analysis methods to overcome limitations associated with fMRI studies of human movement. My previous work utilized neuroimaging to quantify the neural network for knee motor control across functional, resting, and diffusion neuroimaging (foundational to the methods proposed in this application). My prior work also employed advanced biomechanical methods to quantify the movement profile of gait, landing, and balance control under various cognitive-motor and visual-motor stressors to relate biomechanical measures of behavior to knee sensorimotor neural activity. This brain-behavior approach has translated to direct clinical impact with the development and implementation of novel therapies that can improve patient function by targeting the neural activity associated with musculoskeletal injury. This previous work has received several research awards and been selected for feature presentations at national and international scientific meetings and provided the preliminary data for federally funded Department of Defense and National Institutes of Health awards as Principal and Co-Investigator.

I have systematically established a track record of disseminating our novel methods with essential collaborations, including with Dr. Monfort (requested internship), that advance our lab's scholarly agenda. Specifically, Dr. Monfort and I collaborated on a successfully funded NIH R03 award and a prior successful Kopchick internship for Dr. Meredith Chaput. I have published more than 100 articles in high impact applied and clinical science journals (e.g., British Journal of Sports Medicine, American Journal of Sports Medicine, Sports Medicine, Journal of Neurotrauma, Journal of Neuroscience Methods, Experimental Brain Research, and Journal of Neuroimaging). Since establishing my research program at Ohio University, I have received substantive federal funding from the Department of Defense and National Institutes of Health that further advances sensorimotor control neuroimaging paradigm development and understanding of the neuroplasticity associated with orthopedic injury. These ongoing federal projects further support HoWon's scientific development and provide foundational data to support the new experiments proposed.

I look forward to continuing to work with the TBS program and supporting the excellent work enabled by the Kopchick funding opportunities.

1R01 AR077248-01A1, NIH\NIAMS
Grooms, Dustin (PI) 4/1/2021-4/1/2024
Discovery of the Neural Drivers Underlying Injury-Risk Biomechanics
Determine the brain activity associated with injury-risk motor control in standard and ecologically valid sport-specific virtual reality settings via key breakthroughs in the biomechanical instrumentation of knee motor control error in real-time during neuroimaging.
Role: PI

1R03 HD101093-01A1, NIH\NICHD
Monfort, Scott (PI) 1/1/2021-12/31/2023
Establishing Cognitive-Motor Function as a Missing Therapeutic Target after Anterior Cruciate Ligament Reconstruction
The proposed research is relevant to public health and the mission of
the NCMRR because it will provide new therapeutic targets and clinical tests of cognitive-motor function to improve rehabilitation outcomes from anterior cruciate ligament reconstruction that currently go undetected and unaddressed.
Role: Co-I

1R01 AR076153-01A1, NIH\NIAMS
Grooms, Dustin & Myer, Greg (MPI) 4/1/2020-4/1/2024
Neuroplastic Mechanisms for Acquisition and Transfer of Injury-Resistant Movement Patterns Assessed in VR Simulated Sport
The central hypothesis of this work is that changes in brain activity underlie the acquisition, retention and transfer of injury-resistant movement patterns and by determining those neural activity patterns augmented interventions can be employed to reduce injury risk during physical activity. This paradigm is tested with realistic sport-specific virtual reality to quantify movement pattern transfer, advanced augmented reality biofeedback training and neuroimaging to identify the neural correlates of each to inform future intervention development.
Role: MPI

Department of Defense Peer Reviewed Orthopaedic Research Program
Grooms, Dustin (PI) 9/1/2018-9/1/2024
Rehabilitation 2.0: Addressing Neuroplasticity in the Musculoskeletal Rehabilitation Model
Anterior cruciate ligament (ACL) injuries cause decreased physical ability that leads to reduced performance and high re-injury risk. Injury-induced changes in brain activity are directly related to decreased physical performance. To that end, new therapies are needed to neural activity that drives motor performance after injury. This proposal will: 1) identify barriers to successful therapy via the longitudinal quantification of brain changes and 2) development of optimal treatment strategies via clinically testable and trainable correlates of the brain changes.
Role: PI

1R21AT009339-01, NIH/NCCIH
Clark, Brian (PI) 9/1/2016-9/1/2020 Completed
Innovative Neurophysiological Techniques for Assessing Trunk Muscle Control and Function
Due to limitations in technology and methodological development, examination of neural correlates of low back pain have been limited to resting or structural brain studies with limited data on how the nervous system generates stabilizing trunk contractions. This project will quantify whole brain activation patterns for trunk muscle contractions to determine how the nervous system reorganizes after low back pain to drive

therapy development.
Role: Co-I

Research Innovation and Pilot Fund Cincinnati Children's Hospital Medical Center
Myer/Diekfuss/Grooms/Yuan (MPIs) 01/01/2018 – 12/31/2019 Completed
Neural correlates of pain and sensorimotor control in patients with patellofemoral pain syndrome
To identify the neural correlates of pain and sensorimotor control in patients with patellofemoral pain using our novel imaging techniques described in the current proposal.
Role: MPI

Citations:

1. Anand M, Diekfuss JA, Slutsky-Ganesh AB, **Grooms DR**, Bonnette S, Barber Foss KD, DiCesare CA, Hunnicutt JL, & Myer GD. Integrated 3D motion analysis with functional magnetic resonance neuroimaging to identify neural correlates of lower extremity movement. J Neurosci Methods, 2021, May, 1; 355: 109108. doi: 10.1016/j.jneumeth.2021.109108. PubMed PMID: 33705853.
2. Barber Foss KD, Slutsky-Ganesh AB, Diekfuss JA, **Grooms DR**, Simon JE, Schneider DK, Jayanthi N, Lamplot JD, Hill D, Pombo M, Wong P, Reiter DA, Myer GD. Brain Activity During Experimental Knee Pain and Its Relationship With Kinesiophobia in Patients With Patellofemoral Pain: A Preliminary Functional Magnetic Resonance Imaging Investigation. J Sport Rehabil. 2022 Mar 12;:1-10. doi: 10.1123/jsr.2021-0236. [Epub ahead of print] PubMed PMID: 35279019.
3. Slutsky-Ganesh AB, Diekfuss JA, **Grooms DR**, Simon JE, Anand M, Lamplot JD, Jayanthi N, Wong PK, Lyle MA, Myer GD. A preliminary investigation of the effects of patellar displacement on brain activation and perceived pain in young females with patellofemoral pain. J Sci Med Sport. 2022 May;25(5):385-390. doi: 10.1016/j.jsams.2022.01.006. Epub 2022 Jan 31. PubMed PMID: 35219606.
4. Diekfuss JA, **Grooms DR**, Nissen KS, Coghill RC, Bonnette S, Barber Foss KD, Dudley JA, Berz K, Logan K, Gubanich P, Saltman AJ, Slutsky-Ganesh AB, Hansen E, Leach J, Yuan W, Myer GD. Does central nervous system dysfunction underlie patellofemoral pain in young females? Examining brain functional connectivity in association with patient-reported outcomes. J Orthop Res. 2022 May;40(5):1083-1096. doi: 10.1002/jor.25152. Epub 2021 Aug 11. PubMed PMID: 34379343.

B. Positions, Scientific Appointments, and Honors

Positions and Employment

2009 - 2011	Adjunct Faculty & Director of Rehabilitation, College of Mount Saint Joseph
2011 - 2015	Research Associate & Instructor, The Ohio State University
2015 - 2019	Assistant Professor, Ohio University
2016 - 2020	Visiting Professor, Cincinnati Children's' Hospital Medical Center
2019 - 2022	Associate Professor, Ohio University
2022 -	Professor, Ohio University
2019 -	Associate Director of OMNI, Ohio Musculoskeletal and Neurological Institute (OMNI), Ohio University, Athens, OH

Honors

2012	Travel Scholarship, American College of Sports Medicine
2012	Doctoral Scholarship, National Athletic Trainers' Association
2014	Distinguished Research Mentor, The Ohio State University
2014	Outstanding Graduate Student Award, The Ohio State University
2014	Research Award, American College of Sports Medicine
2014	Presidential Fellowship, The Ohio State University
2015	Doctoral Dissertation Award, National Athletic Trainers' Association
2016	Professional Original Research Award, Ohio Athletic Training Association
2017	Ohio University New Faculty Research Spotlight Award
2018	International Travel Award, National Athletic Trainers' Association
2019	Distinguished Research Award, Ohio University
2020	New Investigator Award, National Athletic Trainers' Association

C. Contribution to Science

1. **Neuroplasticity of Musculoskeletal Injury and Sensorimotor Control.** My primary research has focused extensively on neuroimaging to advance sensorimotor control assessment paradigms. Due to many technical restraints, there is a paucity of research exploring the neural activity associated with human movement of the lower extremity. This research line developed techniques to adapt fMRI for the assessment of lower extremity motor control. This success has allowed the exploration of the neuroplastic effects of lower extremity injury and given insight into novel therapeutic targets. Specifically, the brain increases activation of cross-model sensory-visual integration regions in response to musculoskeletal injury. This visual-motor adaption causes behavior alterations in terms of maintaining neuromuscular control and mitigating injury risk as demonstrated with further studies exploring how brain changes relate to movement mechanics. **This work (including publications in the complete bibliography in addition to those below) provides foundational support for the novel neuroimaging experiments proposed.**

    a. **Grooms DR**, Diekfuss JA, Ellis JD, Yuan W, Dudley J, Foss KDB, Thomas S, Altaye M, Haas L, Williams B, Lanier JM, Bridgewater K, Myer GD. A Novel Approach to Evaluate Brain Activation for Lower Extremity Motor Control. J Neuroimaging. 2019 Sep;29(5):580-588. doi: 10.1111/jon.12645. Epub 2019 Jul 3. PubMed PMID: 31270890; PubMed Central PMCID: PMC6731137.

    b. Lepley AS, Ly MT, **Grooms DR**, Kinsella-Shaw JM, Lepley LK. Corticospinal tract structure and excitability in patients with anterior cruciate ligament reconstruction: A DTI and TMS study. Neuroimage Clin. 2020;25:102157. doi: 10.1016/j.nicl.2019.102157. Epub 2019 Dec 27. PubMed PMID: 31901791; PubMed Central PMCID: PMC6948362.

    c. **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;14:622637. doi: 10.3389/fnhum.2020.622637. eCollection 2020. PubMed PMID: 33613205; PubMed Central PMCID: PMC7890238.

    d. **Grooms DR**, Diekfuss JA, Slutsky-Ganesh AB, Ellis JD, Criss CR, Thomas SM, DiCesare CA, Wong P, Anand M, Lamplot J, Simon JE, Myer GD. Preliminary Report on the Train the Brain Project: Sensorimotor Neural Correlates of Anterior Cruciate Ligament Injury Risk Biomechanics - Part I. J Athl Train. 2022 Mar 10;. doi: 10.4085/1062-6050-0547.21. [Epub ahead of print] PubMed PMID: 35271712.

2. **Neuromuscular Adaptations after Injury and Interventions to Promote Improved Motor Control.** In conjunction with neuroimaging, I have worked with the biomechanics of human movement ranging from strength, electromyography, kinematic, kinetic, 3D motion capture as well as clinical tools to assess human motor control. This work has extended from injury risk screening, development of metrics to translate from the laboratory to the clinic, and exploration of novel interventions involving sensory-visual-motor integration and cognitive challenges in the rehabilitation of musculoskeletal injury. This work has extended into more advanced assessments of neuromuscular control, including the development of novel therapies for inducing adaptive neuroplasticity after injury with augmented and virtual reality as well as low-tech methods to optimize clinician feedback. **This research line provides support to the proposed project focusing on sensorimotor control and orthopaedic condition assessment.**

    a. Diekfuss JA, **Grooms DR**, Yuan W, Dudley J, Barber Foss KD, Thomas S, Ellis JD, Schneider DK, Leach J, Bonnette S, Myer GD. Does brain functional connectivity contribute to musculoskeletal injury? A preliminary prospective analysis of a neural biomarker of ACL injury risk. J Sci Med Sport. 2019 Feb;22(2):169-174. doi: 10.1016/j.jsams.2018.07.004. Epub 2018 Jul 10. PubMed PMID: 30017465; PubMed Central PMCID: PMC6311430.

b. Diekfuss JA**,** Rhea CK, Schmitz RJ, **Grooms DR**, Wilkins RW, Slutsky AB, & Raisbeck LD. The influence of attentional focus on balance control over seven days of training. J Mot Behav, 2019, 51(3), 281-292. doi: 10.1080/00222895.2018.1468312. PubMed PMID: 29792580

c. Miko SC, Simon JE, Monfort SM, Yom JP, Ulloa S, **Grooms DR**. Postural stability during visual-based cognitive and motor dual-tasks after ACLR. J Sci Med Sport. 2021 Feb;24(2):146-151. doi: 10.1016/j.jsams.2020.07.008. Epub 2020 Jul 28. PubMed PMID: 32773174.

d. Diekfuss JA**, Grooms DR**, Bonnette S, DiCesare CA, Thomas S, MacPherson R, Ellis JD, Kiefer AW, Riley MA, Schneider DK, Gadd B, Kitchen K, Barber Foss KD, Dudley JA, Yuan W, & Myer GD. Real-time biofeedback integrated into neuromuscular training reduces high-risk knee biomechanics and increases functional brain connectivity: A preliminary longitudinal investigation. Psychophysiology, 2020, May, 57(5): e13545, doi: 10.1111/psyp.13545. PubMed PMID: 32052868.

3. **Applied Science Translation to Clinical Practice from Prevention to Rehabilitation.** As a practicing clinician before starting PhD studies, I strive for our research to have clear and direct translational potential to clinical practice. To that end my lab has continually pushed our mechanistic neuroscience breakthroughs into implemental clinical solutions. We have achieved this through a variety of novel technology adaptations as well as simple conceptual, low-cost additions or repurposed available technology to facilitate clinical implementations that can address the maladaptive neuroplasticity associated with orthopedic trauma. Then during PhD studies I was extensively involved in two initiatives to improve healthcare via injury risk reduction and prevention interventions. One, as project manager for the NIH R01-funded nationwide functional pre-participation physical exam project – to determine the ability of an orthopedic physical exam to quantify injury risk and if the addition of functional clinical tests can enhance injury risk detection. Two, as project manager for a Navy Special Warfare initiative – to develop a screening algorithm for performance across physical, mental, emotional, exposure and genetic metrics to ensure long-term success and health of our nations combat operators. These projects reinforced the need for research to have an applied, clinical endpoint to be impactful. Since the completion of those projects, I have strived to consistently translate my applied research into clear and implemental clinical applications. These experiences provided extensive project management experience for large-scale and multi-center nationally-funded research programs that will help to ensure the success of the proposed study. **This work contributes to the present proposal with extensive project, grant management, and clinical translation experience.**

   a. Simon JE, Millikan N, Yom J, **Grooms DR**. Neurocognitive challenged hops reduced functional performance relative to traditional hop testing. Phys Ther Sport. 2020 Jan;41:97-102. doi: 10.1016/j.ptsp.2019.12.002. Epub 2019 Dec 6. PubMed PMID: 31837629.

   b. Kim KM, Kim JS, Oh J, **Grooms DR**. Stroboscopic Vision as a Dynamic Sensory Reweighting Alternative to the Sensory Organization Test. J Sport Rehabil. 2020 May 29;:1-7. doi: 10.1123/jsr.2019-0466. [Epub ahead of print] PubMed PMID: 32473585.

   c. Criss CR, Melton MS, Ulloa SA, Simon JE, Clark BC, France CR, **Grooms DR**. Rupture, reconstruction, and rehabilitation: A multi-disciplinary review of mechanisms for central nervous system adaptations following anterior cruciate ligament injury. Knee. 2021 Apr 15;30:78-89. doi: 10.1016/j.knee.2021.03.009. [Epub ahead of print] Review. PubMed PMID: 33873089.

   d. **Grooms DR**, Diekfuss JA, Slutsky-Ganesh AB, DiCesare CA, Bonnette S, Riley MA, Kiefer AW, Wohl TR, Criss CR, Lamplot J, Thomas SM, Barber Foss KD, Faigenbaum AD, Wong P, Simon JE, Myer GD. Preliminary Report on the Train the Brain Project: Neuroplasticity of Augmented Neuromuscular Training and Improved Injury Risk Biomechanics - Part II. J Athl Train. 2022 Mar 10;. doi: 10.4085/1062-6050-0548.21. [Epub ahead of print] PubMed PMID: 35271709.

Complete List of Published Work in Pubmed MyBibliography:
https://www.ncbi.nlm.nih.gov/myncbi/dustin.grooms.1/bibliography/public/

Project Narrative

Objective and Scope

Problem to be addressed: The knee is the second most injured joint in the young athletic populations (19.32% of total injuries). However, the risk of developing knee osteoarthritis after injury is high. In the United States, 15.1 million people suffer from knee osteoarthritis which amounts to $16,581 of annual average financial burden per person.[1] The quadriceps muscle group located on the front of the thigh has a crucial role in knee joint health and adequate strength is required to maintain fundamental life activities such as rising from a chair, walking, and balance. Quadriceps muscle weakness is a common impairment in individuals with a wide range of knee injuries (i.e. ligamentous, osteoarthritis, meniscal).[2] Additionally, after knee injury, failure to recover quadriceps muscle strength can result in movement compensation that increases the risk of rapid osteoarthritis development.[3] Our lab and others have shown that quadriceps deficit after injury are due in part to central nervous system (CNS) alterations to control the knee joint.[4] However, despite compelling data indicating quadriceps deficits after injury are to neurological factors, there are limited treatment pathways targeting the CNS to improve muscle function.

What has previously been done: Previously, action-observation (viewing movement) and motor imagery (imagining movement) techniques (AO+MI) have been utilized to restore motor function in patients with the associated neural activity.[5] Previous studies employing AO+MI have successfully targeted the neural mediators of muscle strength[6,7] and are able to increase strength without physical exercise[8]. AO+MI take advantage of the mirror neuron system (MNS) to improve muscle function by engaging the nervous system, as similar cortical areas activate when a person executes, imagines, and/or observes a movement.[9] Building on these prior works, the proposed research project will evaluate the effects of virtual reality (VR) immersive functional movement

AO+MI combined with exercise (VRE) on muscle function and cortical activity. The VRE may provide a means to enhance the AO+MI effect and assist clinicians to implement the therapy to strengthen a muscle after injury by targeting both peripheral muscle and central neural pathways.

Objective: This study will aim to understand the effects of VRE on quadriceps muscle strength and cortical activity in young physically active individuals. This will be accomplished by using a fully immersive VR environment with a functional movement (soccer kicking) while performing a knee extension task. Cortical activity (hemodynamic response) and quadriceps muscle function (surface electromyography [EMG] and strength) will be measured during VRE. This research proposal will accomplish filling a gap in the literature by 1) understanding the neural mechanism of VRE and 2) evaluating the effectiveness of VRE to improve cortical activation strategies and quadriceps muscle function.

Materials and Methods

Hypothesis: We hypothesize that VRE will increase quadriceps force production and electrical activity during the seated knee extension task via increased cortical activity in brain regions associated with motor execution (primary motor cortex) and motor planning (premotor cortex).

Data Collection: Data collection will occur in a single session at a biomechanics lab in Grover center (Ohio University). Maximum quadriceps strength will be collected on an isokinetic dynamometer (Humac Norm, Stoughton, MA, USA). Simultaneously, cortical activity (change in oxy- and deoxy-hemoglobin) will be collected using functional near-infrared spectroscopy (fNIRS) (Octamon Plus, Artinis Medical Systems, Netherlands). Eight channels will be used to measure the cortical activity in two different brain regions (bilateral primary motor somatosensory cortices and left prefrontal cortex, 4 channels per region). Quadriceps EMG will be measured via the Tringo research System (Delsys, Natick, MA, USA). Three wireless sensors will measure

electrical activity from the rectus femoris, vastus lateralis, and vastus medialis muscles of the quadriceps. An Oculus Quest (Oculus VR, Irvine, CA, USA) immersive VR headset will be used to immerse individuals for the VRE task. The experimental paradigm requires an individual to perform 50 knee extensions per condition. There will be two conditions (regular knee extension [no VRE] and VRE knee extension [which will be randomized and counterbalanced]). Each condition will consist of alternating resting (20 seconds each) and movement periods (10 seconds each). During each movement period, individuals will complete 5 maximum effort isokinetic knee extensions (2 seconds duration each [120 degree/second for knee extension and 500 degree/second for knee flexion]). A total of 50 maximum effort extensions for each condition will be recorded (100 total maximal effort contractions for a session).

Session Set-up: All participants will complete a medical history questionnaire, Tegner activity scale (measuring physical activity level), movement imagery questionnaire-3 (measuring motor imagery skill level), and demographics. Next, participants will have a VR acclimation period to ensure participants are familiar with the VR environment. The acclimation process will be performed while participants are seated on an isokinetic dynamometer. EMG sensors and an fNIRS head cap will be placed, and participants will be secured on an isokinetic dynamometer with multiple straps. After acclimation, data collection will start with maximum voluntary isometric contraction (3 reps of 5 sec and 30 sec resting between reps), followed by the isokinetic knee extension conditions (regular knee extension [no VRE], VRE with a soccer kicking video) (**Figure 1**). The order of the conditions will be randomized and counterbalanced to control a learning effect. There will be 2 minutes of rest between conditions, and the NASA task load index will be measured after each condition to monitor fatigue level. To estimate sample size

Figure 1. Participant set-up and video setting in VRE condition.

a power analysis was conducted. A sample size of 34 achieves 80% power to reject the null hypothesis of zero with a medium effect size (d=0.5) and alpha set at 0.05 using a two-sided paired t-test. To be included in the study individuals will be age between 18-30, free from any musculoskeletal injury, and engaged in recreational sports (Tegner activity scale > 5).

Statistical Analysis: fNIRS data preprocessing and statistical analysis will be performed using HOMER 3 software. The data will undergo standard preprocessing to increase the signal to noise ratio. Only the oxyhemoglobin signals will be analyzed as it is the most sensitive indicator for hemodynamic response in brain.[10] Paired sample t-tests will be conducted to determine whether there are statistically significant differences in isokinetic strength, EMG data, and oxyhemoglobin signal between conditions. Alpha will be set at 0.05 for all analyses.

Significance

A therapeutic intervention that can target the CNS to overcome quadriceps muscles weakness after knee injury or in those with osteoarthritis is needed. Our experimental design will determine the potential efficacy of a new intervention (VRE) to target the CNS and provide fundamental knowledge regarding the underlying neurophysiologic mechanism (cortical activity and EMG signals) of VRE.

Intellectual Property

The proposed project will lead to development of clinical interventions to improve muscle function by targeting a novel nervous system pathway. By identifying the neurophysiologic effects of VRE in healthy individuals, clinicians can implement this intervention in rehabilitation to improve quadriceps muscle function and patient mobility. This project directly supports our lab's recently developed smart phone application that will allow a clinician to easily apply VRE in the clinical setting without technical or financial difficulty.

Bibliography

1. Lo J, Chan L, Flynn S. A Systematic Review of the Incidence, Prevalence, Costs, and Activity and Work Limitations of Amputation, Osteoarthritis, Rheumatoid Arthritis, Back Pain, Multiple Sclerosis, Spinal Cord Injury, Stroke, and Traumatic Brain Injury in the United States: A 2019 Update. *Arch Phys Med Rehabil*. 2021;102(1):115-131. doi:10.1016/j.apmr.2020.04.001

2. Myer GD, Martin L, Ford KR, et al. No Association of Time From Surgery With Functional Deficits in Athletes After Anterior Cruciate Ligament Reconstruction: Evidence for Objective Return-to-Sport Criteria. *Am J Sports Med*. 2012;40(10):2256-2263. doi:10.1177/0363546512454656

3. Hart JM, Turman KA, Diduch DR, Hart JA, Miller MD. Quadriceps muscle activation and radiographic osteoarthritis following ACL revision. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(4):634-640. doi:10.1007/s00167-010-1321-z

4. Neto T, Sayer T, Theisen D, Mierau A. Functional Brain Plasticity Associated with ACL Injury: A Scoping Review of Current Evidence. *Neural Plast*. 2019;2019:1-17. doi:10.1155/2019/3480512

5. Caligiore D, Mustile M, Spalletta G, Baldassarre G. Action observation and motor imagery for rehabilitation in Parkinson's disease: A systematic review and an integrative hypothesis. *Neurosci Biobehav Rev*. 2017;72:210-222. doi:10.1016/j.neubiorev.2016.11.005

6. Kaneko, Masugi, Usuda, Yokoyama, Nakazawa. Muscle-Specific Modulation of Spinal Reflexes in Lower-Limb Muscles during Action Observation with and without Motor Imagery of Walking. *Brain Sci*. 2019;9(12):333. doi:10.3390/brainsci9120333

7. Wright DJ, Wood G, Eaves DL, Bruton AM, Frank C, Franklin ZC. Corticospinal excitability is facilitated by combined action observation and motor imagery of a basketball free throw. *Psychol Sport Exerc*. 2018;39:114-121. doi:10.1016/j.psychsport.2018.08.006

8. Scott M, Taylor S, Chesterton P, Vogt S, Eaves DL. Motor imagery during action observation increases eccentric hamstring force: an acute non-physical intervention. *Disabil Rehabil*. 2018;40(12):1443-1451. doi:10.1080/09638288.2017.1300333

9. Taube W, Mouthon M, Leukel C, Hoogewoud HM, Annoni JM, Keller M. Brain activity during observation and motor imagery of different balance tasks: An fMRI study. *Cortex*. 2015;64:102-114. doi:10.1016/j.cortex.2014.09.022

10. Hoshi Y. Functional near-infrared spectroscopy: current status and future prospects. *J Biomed Opt*. 2007;12(6):062106. doi:10.1117/1.2804911

Research Internship Description at Montana State university

In order to enhance and strengthen knowledge on the principles of Functional Near-InfraRed Spectroscopy (fNIRS) and Isokinetic Strength Testing techniques, a 4-week research internship will take place at the neuromuscular biomechanics laboratory at Montana State University (MSU). This research internship opportunity will provide technical experience with data analysis of human brain activity (indirectly measured by oxygen concentration changes) and human kinetics (measured by isokinetic quadriceps strength) that are complimentary to the research proposal. The neuromuscular biomechanics laboratory at MSU is conducting ongoing studies to 1) understand the relation between additional cognitive task and human movement (cognitive-motor function) and 2) investigate the effects of impaired peripheral nervous system on gait and brain activity. To conduct their ongoing research projects, the laboratory at MSU is equipped with fNIRS, isokinetic dynamometer, overground motion analysis, and an instrumented treadmill with motion analysis. Dr. Scott Monfort who is a co-director of the neuromuscular biomechanics laboratory at MSU will oversee the research internship. Dr. Monfort's research interest is to understand the influence of neurological factors on human movement. His research works are based on his strong foundation in engineering mechanics and human biomechanics (engineering approach of human movement). Together the research laboratory and personnel resources at MSU make it a premier location to complete a research internship focused on neurological factors related to human movement. Therefore, this research internship will provide an intensive experience in computing and programming of fNIRS and strength data with an engineering approach to the analysis of the data collected in this proposal. This opportunity will provide a strong and fundamental base for completing the research proposal and with my future studies.

Budget and Justification

Budget for Academic Advancement and Achievement

Professional Membership	
• National Athletic Trainers Association Student Member Fee	$ 75
• Board of Certification for the Athletic Trainer Fee	$ 39
• Society for Neuroscience Graduate Student Member Fee	$ 75
Purchase of Scholarly Supplies	
• MacBook Pro 13- inch (Apple Inc) with software for fMRI analysis	$ 1,499
• MATLAB Student License	$ 99
• MATLAB Wavelet Toolbox Add-on Product	$ 10
Stipend for the Applicant	$ 703
Total Budget Requested	**$ 2,500**

Part of the budget for academic advancement and achievement will be used to keep processional memberships for National Athletic Training Association and Society for Neuroscience. Both organizations have annual meeting which will provide an opportunity to submit and present abstract from this proposed study. Rest of the budget will be used as stipend to purchase a MacBook laptop. This laptop will be used for fMRI and fNIRS data analyses. For analysis fNIRS data, MATLAB program with wavelet Toolbox is required to run HOMER3 program (Open-source MATLAB application). This laptop will allow me to efficiently learn the data analysis for the duration of my PhD studies and during the research internship period.

Budget for Translational Biomedical Sciences Research

Research Supplies and Equipment

Research Participant Incentives ($ 30/person)	
• 40 participants	$ 1,200
3D Digitizer: Polhemus Patriot (Artinis Medical System)	$ 4,400
EMG Sensors Preparation Equipment	$ 50
Personal Protective Equipment	$ 50
Sanitizing Equipment	$ 50
Total Research Cost	**$ 5,750**

Conference Travel

National Athletic Trainers' Association Clinical Symposia	
• Registration	$ 155
• Airfare	$ 250
• Per Diem ($69/day in Indianapolis Indiana)	$ 241
• Lodging ($127/night) (4-night)	$ 508
Society for Neuroscience Annual Meeting	
• Registration	$ 240
• Airfare	$ 300
• Per Diem ($79/day in Washington DC)	$ 355
• Lodging ($188/night) (5-nights)	$ 940
• Abstract Submission	$ 145

Total Conference Travel Cost	**$ 3,134**
Total Budget for Translational Biomedical Sciences Research	$ 8,884
Total Budget Requested	**$ 7,500**

Research Materials

My mentor Dr. Grooms will provide any additional laboratory supplies required for fNRIS, EMG, Isokinetic strength data collection and analysis. Additionally, the remaining cost of supplies and conference travel ($1,084) will be supplemented by his available funding (start-up or research incentive accounts). The proposed research will require 1 visit (1 hour and 30 minutes). Because the proposed research involves an invasive procedure, a monetary intensive will be provided. The 3D Digitize is required to individualize the fNIRS's sensor location based on participant's unique head size and shape. To obtain individualized sensor locations will help to determine precise locations of underlying brain structures and improve the quality of fNIRS data.

Conferences

The purpose of attending the National Athletic Training Association Annual Clinical Symposia is to present the work that understanding underlying neurophysiologic mechanism of the VRE during knee extension task. This conference will be held in Indianapolis, IN and is the main conference for athletic trainers. To attend this conference and sharing the results of the proposed research will introduce a novel rehabilitative intervention to improve outcomes in athletic population. The purpose of attending the Society for Neuroscience is to present the work that identifying underlying neurophysiologic mechanism based on different movement during the VRE. This conference will be held in Washington, DC and is the main conference for neuroscientists. Attending this conference will help me to understand basic scientific knowledge in the field of neuroscience.

Budget for Research Internship

The Neuromuscular Biomechanics Laboratory at Montana State University	
• Travel/Airfare	$ 300
• Rideshare and Ground Transportation	$ 100
• Lodging ($124/night) (4-week)	$ 3,472
• Per Diem ($79/day in Bozeman Montana)	$ 2,054
Total Budget for Research Internship	$ 5,926
Total Budget Requested	**$ 5,000**

The following budget is to support a research internship at the Neuromuscular Biomechanics Laboratory at Montana State University. This research internship will include 4-week of intensive learning not only in fNRIS and strength data analysis techniques and but also in engineering approach of the human movement. This research internship will provide opportunity to participate in ongoing research with Dr. Scott M Monfort and stimulate a collaborative work between the Neuromuscular Biomechanics Laboratory at Montana State University and the Neuromuscular Biomechanics and Health Assessment laboratory at Ohio University.

MONTANA STATE UNIVERSITY
NORM ASBJORNSON College of ENGINEERING

Department of Mechanical & Industrial Engineering

August 10, 2022

Re: Research Internship for John J. Kopchick Award

To HoWon Kim and John J. Kopchick Award committee:

I would like to take this opportunity to express my support for HoWon Kim's John J. Kopchick proposal and 4-week internship at the Neuromuscular Biomechanics Laboratory at Montana State University (MSU). Prolonged quadriceps weakness is a significant health problem that can lead to adverse health outcomes after a knee injury and this proposal has the potential to provide a novel therapeutic intervention to strengthen the quadriceps muscle after knee injury. I strongly believe the proposed novel approach of using virtual reality to immerse individuals along with the use of action observation and motor imagery as a therapeutic intervention will improve outcomes after a knee injury. The knowledge gained from this research proposal will fill a key knowledge gap in understanding the neural mechanism of virtual reality exercise for muscle strengthening and introduce a novel therapeutic method to the rehabilitation field.

I am co-director of the Neuromuscular Biomechanics Laboratory at MSU. My background in engineering mechanics and human biomechanics (engineering approach of human movement), as well as my experience in using functional near-infrared spectroscopy (fNIRS) position me to assist Mr. Kim's development as an independent clinician-scientist. Specific to the current proposal, my copious experience with fNIRS data analysis and engineering approach to human movement will ensure that Mr. Kim can complete the proposal with the appropriate rigor for high quality research presentations and publications.

The opportunity to collaborate on the proposal and contribute to Mr. Kim's training in fNIRS and strength data analyses is an exciting endeavor. I confirm and support Mr. Kim's education and training through this intensive internship to ensure his ability to analyze the requisite data in a rigorous and independent manner.

Mr. Kim has assembled a strong, interdisciplinary team that will help to ensure project success and effectively contribute to his research training to become an independent clinician-scientist. I look forward to furthering his development as a researcher and collaborating with him on this proposal.

Respectfully,

Scott M. Monfort, PhD
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