Reasoning of dissertation topic and competency of potential supervisor for admission onto joint LSU and TU doctoral studies in 2022

Area of research (title and code)	**Natural science (N000)**
Field of research (title and code)	Biology (N010)
Topic of research	**Multi-joint control strategy**
Institution	**Lithuanian Sports University**

Potential supervisor

Pedagogical and scientific degree	Name, surname	Academic position
PhD	Danguole Satkunskiene	Professor

Short reasoning of proposed dissertation topic

Title

Neurophysiological and dynamical control of quick and fast movements

Short research description (including aims and objectives) (maximum 1500 characters).

Among various measures of motor performance, quickness of response and movement speed are often highly significant parameters for achieving athletic success [1]. To move more quickly, one has to shorten both preparation time and execution time for the movement. Changes in brain activities occur well before movement onset, and such preparatory activity is predictive of reaction time, movement variability[2] and its disruption delays movement onset[3]. Also, there are very important cognitive processes such as anticipation, attention, and planning in preparing for a quick motor response [4]. Mechanically, fast movement is difficult to control, especially when large degrees of freedom are involved in controlling the movement. For example, angular acceleration at a certain joint is affected not only by the torque at that joint but also by torques at other joints. Furthermore, velocity-dependent torque also induces angular acceleration. Joints link multiple limb segments, and the angular acceleration of a given joint in a multi-joint system at a certain instant is determined not only by the joint torques and gravity torque at that instant but also by the time series of the joint torques and gravity torque applied to the system in advance [5]. Therefore, it is difficult to intuitively understand how muscle forces produce joint rotations in multi-joint movements because of the complexity of inter-joint interactions, especially in three-dimensional (3D) movements.

The aims of the research are to properly understand how quick and fast movements are controlled and organized from dual neurophysiological and dynamical perspectives and to determine the cause and effect relationship between joint torques and rotations during sports movements.

We believe that understanding the neurophysiological and dynamical mechanisms underlying quick and fast movements can enhance sports performance and facilitate motor recovery and rehabilitation from neural damage.

References

1. Dawes J and Roozen M. 2011. Developing Agility and Quickness. Human Kinetics, IL, USA.

2. Churchland MM, Yu BM, Ryu SI, Santhanam G, Shenoy KV. Neural variability in premotor cortex provides a signature of motor preparation. *J Neurosci*

3. Churchland MM, Shenoy KV. Delay of movement caused by disruption of cortical preparatory activity. *J Neurophysiol.* 2007a;97:348–359

4. Hughes, G., & Dai, B. (2021). The influence of decision making and divided attention on lower limb biomechanics associated with anterior cruciate ligament injury: a narrative review. *Sports Biomechanics*, 1-16.

5. Hirashima M. 2011. Induced acceleration analysis of threedimensional multi-joint movements and its application to sports movements. In: Theoretical Biomechanics (Klika V, ed), 303-318, InTech, Rijeka, Croatia.

Relevance of the problem, its novelty at national and international level (maximum 1500 characters).

Knowledge of how muscle forces produce joint rotations is fundamental to the fields of sports biomechanics and rehabilitation medicine. Joint rotations occur sequentially from proximal joints to distal joints in fast sports movements. This kinematic sequence itself or the underlying kinetic mechanism is often called the "proximal-to-distal sequence," "kinetic chain," or "whip-like effect". However, the kinetic mechanism has not been properly understood because previous studies on sports movements have not focused on the fact that a joint rotation is caused by two different mechanisms: instantaneous and cumulative effects. The instantaneous effect is an instantaneous angular acceleration induced by a joint torque at that instant, whereas the cumulative effect is an angular acceleration induced by the entire joint torque and gravity torque history until that instant[6]. Because the mechanical causes are different between the two effects in terms of time, a clear differentiation is necessary to understand the original cause of each joint rotation and develop effective training programs. Whereas determining whether an instantaneous or cumulative effect causes a joint angular acceleration is very important for enhancing performance, by using induced acceleration analysis [7] we will determine the kinetic sources of each joint rotation and gain insight into the chain of causation of athletic movements and the control strategies adopted by high-performance athletes.

Although muscle activities, joint torques, and joint rotations themselves have been examined extensively in sports medicine [8-10], a knowledge of the cause-and-effect relationships among these variables has not been fully understood. However, recent developments in the dynamical analysis of complex movements allow us to understand mechanisms and principles underlying fast multi-joint and multi-limb movements.

References

6. Kudo, K., Hirashima, M., & Miura, A. (2014). Preparation and control of quick and fast movements: Neurophysiological and dynamical perspectives. *The Journal of Physical Fitness and Sports Medicine, 3*(1), 73-83.

7. Hirashima M. 2011. Induced acceleration analysis of threedimensional multi-joint movements and its application to sports movements. In: Theoretical Biomechanics (Klika V, ed), 303-318, InTech, Rijeka, Croatia.
8. Hirashima M, Kadota H, Sakurai S, Kudo K and Ohtsuki T. 2002. Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. J SportsSci 20: 301-310
9. Alderink, G. J., Kepple, T., Stanhope, S. J., & Aguinaldo, A. (2021). Upper body contributions to pitched ball velocity in elite high school pitchers using an induced velocity analysis. *Journal of Biomechanics*, *120*, 110360.
10. Friesen, K. B., Saper, M. G., & Oliver, G. D. (2022). Biomechanics Related to Increased Softball Pitcher Shoulder Stress: Implications for Injury Prevention. *The American journal of sports medicine*, 03635465211055141.

Research methods and possibilities for conducting these studies (maximum 1500 characters).

Joint motion kinematics data will be obtained with a three-dimensional (3D) optical motion capture system SIMI Motion (Simi Reality Motion Systems GmbH, Germany), composed of eight video cameras in a semicircular arrangement. According to the specified human body model, 11 mm in diameter spherical reflective markers will be fixed to the subjects‘ bodies.

Four force plates system (BTS Bioengineering Corp., USA) synchronized with SIMI Motion system will be used for recording ground reaction force data required to calculate the net joint moment. The joint torques about the individual joint axes will be calculated using the inverse dynamics approach. In addition, muscle EMG signals will be recorded using a 16 channels wireless EMG system (Ultium EMG, Noraxon, USA) synchronized with SIMI Motion system and force plates. OpenSim software will be used for modelling, simulating, controlling, and analysing the neuromusculoskeletal system.

All necessary equipment is available at LSU laboratories**.**

Please indicate the links between the proposed topic for the doctoral thesis and biomechanics / physical therapy / sports study programs.

The topic is directly related to biomechanics teaching in undergraduate and graduate sports and physiotherapy programs. An accurate description of movement dynamics, and a better understanding of movement coordination and control, help professionals understand more clearly the causes of technical errors or movement disorders in athletes or patients.

The students will have the opportunity to learn the induced acceleration analysis method (used in this topic), which allows for determining the cause-and-effect relationships, helps identify the cause of the movement disorder, and create a targeted training program.

Is the proposed topic for the doctoral thesis related to currently funded research projects? Please indicate the links between the proposed topic for the doctoral thesis and funded research projects.

Is the proposed topic for the doctoral thesis related to joint research with a foreign institution? Please indicate the links between the proposed topic for the doctoral thesis and research with a foreign institution

The topic links to the research work in the School of Biological Sciences at Georgia Institute of Technology and in the Division of Physical Therapy at Emory University School of Medicine (Atlanta, USA). Prof. Boris Prilutsky supports this topic and is ready to consult on developing a research project (please see attached letter).

Currently I am supervisor of ____1__ doctoral students.

Supervisor _____ Danguolė Satkunskienė

(signature) (Name, surname)

Date 05 05 2022