Prospectus

Brave: Implementation of Motion Capture Methodologies for Predictive and Preventative ACL Rehabilitation
(Technical Topic)

Biological Citizenship: How the Ease of Motion Data Accessibility Affects the Social and Political Foundations of a Citizen
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The technical research project aims to focus on presenting a new methodology to predict and classify injurious movement patterns that may lead to anterior cruciate ligament (ACL) injuries. This includes studying the dynamic knee valgus collapse with an on-body motion capture system using easy to use custom 9-axis sensor technology paired with various machine learning classification tools to determine which has the highest predictive accuracy.

This methodology provides greater access to human movement data to multiple stakeholders. These include not just a professional such as a physical therapist or athletic trainer, but also the patient or athlete. With the power of their own data, patients or athletes are able to perform "citizen science" principles that may contribute to their biological citizenship status. "Citizen science" is simply defined as the interaction of non-professionals with scientific data and the way they contribute to its evaluation. This places more power in the hands of an individual to now present the way they move and interact with their surroundings in any situation imaginable.

The STS research thesis presents itself as the effects of how having access to one's own movement data influences their bio-citizenship status. The ability of an individual to now see how they move, whether it is during a workout or even just their daily activities, they now hold evidence of where they are and what they are doing in a much more quantitative manner. Furthermore, due to individuals having easy access to such data, they are the deciding entity of what to do with it. This includes maintaining the privacy of the data, sharing it with other individuals, or even using it as a tool to validate actions such as exercising. In terms of an individual's biological citizenship, with motion data they now hold the potential to modify what it entails in both a positive and negative way.

Technical Topic

The ability to track and monitor injurious biomechanical movement patterns has become a critical area of development in the fields of sports and rehabilitation. Lower extremity injurious movements have been linked as risk factors associated with anterior cruciate ligament (ACL) injuries (Kiapour et al., 2015). With an annual incidence rate of 200,000 to 400,000 cases in the US, ACL rupture is a common problem in younger populations participating in medium to high intensive activities. Some repercussions of ACL injury include temporary or long-term disability, absence from other activities, high costs from operative or rehab treatment, and early onset osteoarthritis (OA) (Cesar et al., n.d.; Utturkar et al., 2013). However, through the study of ACL injury mechanisms, there may be the development of a process to design training programs aimed at prevention This involves objective observation of contributing motions that occur causing an ACL rupture. One common example is the dynamic knee valgus collapse, which is usually described as excessive medial collapse of the knee (Utturkar et al., 2013).

The current treatment recommended following ACL rupture is surgical reconstruction in order to facilitate a return to desired daily activities, including sports. However, the estimated annual health-care cost of these surgeries is approximately $3 billion in the U.S. alone. The decision to recommend this operative reconstruction is multi-factorial and individualized to each patient (Murawski et al., 2014). Still, following ACL reconstruction many athletes fear return back to their intensive sports activities due to reinjury concerns . Thus, a new focus has developed to potentially track and prevent lower extremity injurious movement patterns that may be a cause of future ACL rupture. A gold-standard method seen today is using reflective anatomical markers which are then recorded using high-speed motion analysis camera systems which are commonly referred to as optical motion capture (OMC) systems (Ali et al., 2012). However, these systems have the following drawbacks: expensive, unable to use in real-time on the field analysis, and inaccurate sense of joint angle measurements in 3D (*Survey of Motion Tracking Methods Based on Inertial Sensors: A Focus on Upper Limb Human Motion*, n.d.). Thus, the following aims are proposed.

Aim 1: Implement an on body motion capture device to measure specific 3D kinematics of the dynamic knee valgus collapse

This entails establishing a protocol of exercises used to measure normal knee motion and the occurrence of the valgus collapse. Next, data parsing scripts in Python must be designed to obtain real-time quaternion data from the motion capture system to then be transformed into 3D coordinate data. Finally, it must be ensured that the angular data of the upper leg and lower leg are able to be recorded to assist in classification of valgus collapse.

Aim 2: Determine predictive capability of real-time data collection to detect knee valgus collapse in action

The first step is to research various machine learning algorithms that can be used to classify and predict future events of the real-time measurements. These include logistic regression, k-nearest neighbors, convolutional neural networks (CNN), and recurrent neural networks (RNN). Then, each model must be tested to determine bias and variance error to select the best one that is able to accurately fit the data for better predictive capabilities.

Aim 3: Ensure seamless integration of motion capture system and associated software within professional workflow

Within this aim, a partnership will be developed with Mary Baldwin University to conduct an Institutional Review Board (IRB) approved study. This will entail working with a physical therapy group to test the results of the technical capstone on female subjects susceptible to exhibiting dynamic knee valgus collapse. This will be conducted to ensure technical viability but also ease of adoption into a professional workflow.

The use of on-body motion capture permits the ability to collect real-time valgus collapse data without the need of heavy equipment or reliance on only 2D kinematic analysis joint motion. For the motion capture, 9-axis sensor fusion (accelerator, magnometer, and gyroscope) technology or inertial motion units (IMUs) will be developed via a separate ECE capstone team. The data analysis platform will be developed using Python obtaining data from a secure database. This will all tested with a research group at Mary Baldwin University to determine real-world efficacy.

STS Topic

With the merging of medicine and politics, the main stakeholder to be affected is the citizen. The introduction of a new factor of citizenship means an additional set of rules and regulations on how someone interacts with politics. With the new wave of data-driven approaches to medicine this presents a more quantifiable manner of defining this relationship between an individual's biological traits and political standing. Shifting this approach of quantifying the health of an individual to human motion presents a whole new way of assessing and evaluating the physical abilities of a person. This further increases the complexity of how to define biological citizenship due to now adding in data that represents how someone moves, where they are, and what are they physically able to perform.

Background

Introduced in the early 2000s, the concept of biological citizenship presented a new way to collectively identify an individual on their biological traits. Adriana Petryna first introduced this term following the aftermath of the Chernobyl disaster in Ukraine. Following the explosion of the Chernobyl nuclear reactor in 1986, the negative health impact on Ukrainian citizens was assessed with a scientific and political lens (Petryna, 2004). Petryna elucidated in her studies that politics and science were constantly engaged to mutually stabilize the aftermath of such a large scale disaster that helped define post-Soviet Ukraine as well. This event brought forth the role of considering “at-risk” populations and its relationship to defining the norms of citizenship. Another major treatment of the term biological citizenship was brought forth by Rose and Novas in 2005. They coin a more broader look at the term to view how citizenship projects links conceptions of citizens to the biological background of an individual. Explicitly, they state how the globally this term can come to have different meanings. For example, in post-Soviet Ukraine, this term came to be correlated to receiving financial support from political authorities. However, in the West, biological citizenship is taking the shape of a new kind of value provided to individuals, “biovalue”, to tailor the political climate as more ethical and moral (Novas, n.d.). However, it is interesting to note that biological citizenship has existed prior to its coining by Petryna under different terminology. Rabinow in 1996 and Clarke, et al. in 2003 have come up with the terms biosociality and biomedicalization respectively which come to hold similar meanings to biological citizenship. These terms however are much more broad to encompass all social processes and relationships to define political acts of organizing and advocating for access to medical knowledge or treatment (*Biological Citizenship*, n.d.).

Biological Citizenship and Data

The cross-section of Big Data and healthcare has brought forth a novel way of perceiving one's health. The use of metrics that are tailored to each individual provides another layer of complexity when it comes to assessing their biological background. The integration of such data has begun to make its way into political contexts. This is primarily attributed to help define future imaginaries of medical treatment such as personalized medicine versus stratified medicine. However, this clearly demonstrates the relationship between a data-driven approach to a citizen's health and what it means to a political actor (Erikainen & Chan, 2019).

Specific factors to consider when it comes how biomedical data affects the biological citizenship is the change in social interactions of an individual along with their classification by political entities. These modifications to a citizen's lifestyle denote how their personal health data affects their standing as a citizen of a nation and what resources and rights are either offered or taken away following assessment of said data. One example that supports this framework is the study conducted by the New Zealand Organization for Rare Disorders (NZORD) in 2008 on the familial accounts of children with incurable genetic disorders. This study exemplified the growth of political activism by the parents with children exhibiting such disorders on healthcare reform policies that transcended national boundaries. Through the constant journey of the parents to find treatment and cures for their children, their social interactions began to change with a continuous engagement with healthcare workers and public genetic medicine campaigns. This led to them being regarded as "genetic political activists" by the local government in New Zealand (Fitzgerald, 2008).

The above framework can also be seen when looking at how autism today is seen as a way of determining the biological citizenship standing of an individual. The biological explanation of autism demonstrates how their different social interactions has led to them be different classified and provided additional rights when it comes to performing daily activities such as in school or the workplace, an exemplary notion of empowerment. Through the use of newer data-driven approaches to defining autism has led to the creation of sub-levels which then correlates to biological sub-citizenship based on severity of a condition (Brownlow & O'Dell, 2013).

Thus the above framework and following examples can be applied to determine the effect personalized motion data can have on the social and political standing of a citizen or individual. This entails studying the different actors, both political and social, that may influence the biological citizenship of an individual based on the assessment of their motion data.

Next Steps

Overall, it can be seen how the inclusion of biomedical data affects the biological citizenship of an individual. This relationship can either empower or degrade an individual's access to specific citizen rights depending on their biological standing. In this following thesis, I will explore precedent of specific cases where biological citizenship has changed based on the health or medical data utilized to assess a citizen. This includes analyzing the case of Immigration policies affected via usage of DNA analysis for family reunification in Germany and policies set forth by the food and drug administration (FDA) that have been influenced via disruption of biosocial networks. These cases will provide an in-depth framework of how to assess the results of the technical capstone presented in the thesis, which is how real-time motion data of an individual affects the biopolitical and biosocial aspects that define biological citizenship.

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