Developing a Methodology for Bidirectional Assisted Walking Testing
(Technical Paper)

The "Average Human":
Dangers of Homogeneity in Data Used to Construct Biomechanical Research Models
(STS Paper)

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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

Imagine the average human being. Picture the way they move, the way they look. What is their physique? What sex, race, and ethnicity are they? There is no way for you to accurately answer these questions because there is no "average human being." In fact, it is even difficult to say what "average" human movements, such as walking, should look like with any kind of specificity. Even so, we live in a world whose safety and function has been analyzed, most often, for the "average human being" performing "average human movements." We drive cars, use tools, and even design assistive devices, like walkers, tested with this mentality (Park et al., 2021; Vega & Arellano, 2021). So, who is the average human that researchers have been modeling in their work? Most often, it is a white man in his 20s or 30s who is in the 50th percentile for height and weight. And how have researchers been studying the average human movement, like walking? Most of the time, walking is studied on a treadmill, despite the fact that treadmill walking has been proven to be different from the walking we do on solid ground (Ahn & Hogan, 2012). The following prospectus details plans for two projects. First, a technical project is discussed that will address a difficulty that has previously prevented researchers from using overground walking in their studies. Second, a research paper will explore the dangers of using homogeneous data in the development of biomechanical computational models.

Technical Topic

In the design of assistive mobility devices that impart pulling forces on their users, such as motorized walkers, the ideal magnitude of the pulling force as a percentage of the user's body weight is a crucial value. The typical approach for finding this percentage has been to have a subject walk on a treadmill while wearing a belt that is tugged on by either a motor or a system of pulleys and weights. The subject wears a metabolic cost measuring device that monitors their carbon dioxide output and determines, from that, the amount of exertion their current movement is requiring of them. This approach has led to consistent results that pinpoint the ideal percentage of a subject's body weight that should be applied to them as a pulling force during treadmill walking to minimize metabolic cost.

However, the percentage of body weight value from this approach is being used in the development of assistive devices intended for overground (non-treadmill) walking. Overground walking and treadmill walking have been proven to elucidate differences in gait pattern that prevent them from being used interchangeably in biomechanical research (Fellin et al., 2010). Gait entrainment refers to the applied torque pulses and the stride period of a subject. For there to be gait entrainment, each pulse must occur at the same phase in the gait cycle. Gait entrainment occurs about 50% of the time in treadmill walking trials, but occurs over 90% of the time for overground walking (Ochoa et al., 2017). Therefore, it is necessary for the development of such devices to find this ideal pulling force value for overground walking. The goal of this work is to develop a system to allow for the identification of the ideal percentage of body weight to be used as an assistive pulling force during overground walking. In pursuit of this goal, we propose the following aims:

Aim 1: Develop a method for measuring the assistive value of pulling forces during overground walking relative to their magnitude as a percentage of subject body weight by:

A. Construct system to pull subject 50 feet using various pulleys
B. Ensure that force is constant and there is no variation during the gait pattern
C. Eliminate enough of the friction in the pulley system such that there is no statistically significant counter force

Aim 2: Ensuring continuity of data collection regardless of space constraints by:

A. Designing the aforementioned system to allow a subject to turn 180° and continue walking in the opposite direction while still experiencing the desired pulling force

Aim 3: Validate systems ability to be effectively implemented during data collection

A. Enabling the usage of a metabolic cost measurement system in conjunction with the system mentioned above
B. Perform preliminary testing and consult with motion capture experts to ensure usability

There have been several approaches in past biomechanical research to the concept of assistive walking by a pulling force. However, most of these approaches have utilized a treadmill. The treadmill approach poses several challenges, such as altered gait patterns (Fellin et al., 2010). There is also the potential for treadmill induced noise on the force plates from the treadmill belt and motor (Kram & Powell, 1989). Due to challenges such as these, it is imperative that a continuous overground assistive walking system is developed. The system must function in a way that the pulling force is able to be adjusted to the ideal body weight percentage and that continuous data collection is possible.

STS Topic

Biomechanical research requires large sums of data to be properly conducted. This data can often be obtained through subject-based studies like those described above, where tools like motion capture systems and force plates are used to gather data from individual trials. Another method for data generation that is growing in popularity is computational modeling, an approach in which the human body is reproduced in a computer so that it may be manipulated and studied more easily. This method reduces the need for patient trials and increases the efficiency and precision with which biomechanical research can be conducted. However, computational modeling as a research method is certainly still fallible. Creating biomechanical computational models involves taking the measurements of a set of subjects and averaging them to create the models. Like all computational models, they are only as accurate as the data used to train them.

Using a diverse data set to create a single biomechanical model leads to an averaging of varying characteristics that results in a model that does not properly represent any of the groups that it is based upon (Smith, 1996, p. 199). On the other hand, choosing only one group from which to construct a biomechanical model becomes problematic when that model is then said to be representative of the "average human," as has been historically the case. Research covering everything from the prevention of car accidents (Bose et al., 2011; Yu et al., 2020) to the design of surgical tools (Tröster et al., 2020) has been conducted using models created from data sets of exclusively males, often in the 50th percentile for height and weight, and frequently all white.

The study of sex-based differences in biomechanics has led to a definitive understanding of the presence of musculoskeletal distinctions between men and women (Blemker, 2021; Claiborne, 2008). By using all-male data sets in studies that claim their results apply to all humans, researchers exclude women from life-altering and often even life-saving research findings. Most people are not the "average person," so 50th percentile models are not as universal as they might seem (Haden, 2018) and variation in height and mass can have a huge impact on biomechanical results. Lastly, homogeneity of subject pools in categories like race and ethnicity threaten to further diminish the population that will benefit from biomechanical research. While both race and ethnicity are social—not biological—constructs, there are observable biomechanical differences across subjects based on race and ethnicity that cannot be overlooked (Gasperino, 1996; Pierce, 1966).

To better understand the issue of data homogeneity in biomechanical model construction, it will be analyzed through the lens of the Political Technologies Theory. This theory, famously argued by Langdon Winner, posits that technology itself can be political. According to Winner, there are two ways in which this can occur; First, the technology itself can be the answer to a political argument, effectively representing a victory for one side of a debate. Second, the technology can be inherently political such that any decision about its design will ultimately make a political statement. Those who critique this theory claim that technology itself holds no political power and is instead solely a manifestation of the political intentions of its creator, offering no influence outside of those intentions. Hopefully, this topic will serve as a counterpoint to that notion as it is a prime example of political power residing within a technology itself and influencing the population in ways that were not intended by the technology's creator and were instead a consequence of carelessness.

Research Question and Methods

The question of this research is: How does the demographically homogeneous data used to construct biomechanical models impact their efficacy? To answer this question, a literature review will be conducted alongside a series of interviews. The following keywords will be used when searching for sources: biomechanics, sex, race, ethnicity, models, female. Given the significant underrepresentation of words such as "sex," "race," and "ethnicity" in current biomechanical research papers, the use of these keywords will isolate papers focusing on populations currently underserved by such research. Even so, there are not a vast quantity of papers covering this subject, so interviews with subject matter experts like Dr. Silvia Blemker, Dr. Shawn Russell, and the graduate students at their labs will further the understanding of the topic and steps that can be taken to improve the situation.

Conclusion

Upon the completion of the technical project, it is expected that a physical system will have been developed that will allow for a constant pulling force to be applied to a subject performing bidirectional overground walking in a motion capture laboratory. As a result, the percentage of a subject's body weight that can be applied as a pulling force to most reduce the metabolic cost of their walking will be accurately determined. This value will be crucial to the development of assistive devices that impart pulling forces, such as motorized walkers. The results of the STS research paper will inform a specific call to action for all biomechanists. This will involve the usage of an in-depth understanding of the problem to generate a set of recommendations for steps to take towards the improvement of biomechanical modeling accuracy for all populations.

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