Classification of Wheelchair Pressure Reliefs Using Changes in Center of Pressure

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BACKGROUND

There are over 5.5 million wheelchair users in the United States [1], and over half of wheelchair users will develop a pressure injury (PI) [2]. The risk of PI is especially high for individuals with impaired sensation in a variety of spinal cord injuries (SCI), diabetes, or multiple sclerosis [3]. Each year one in four individuals with an SCI is likely to develop a PI [4].

The pressure exceeding about 30% of a person’s body weight seen only 8% of the body's surface area. Pressures that exceed the threshold of mechanical loading at which PI formation begins, particularly over the sacrum and ischial tuberosities [6], may cause capillary pressure and cause tissue damage.

Current clinical practice guidelines recommend periodic repositioning exercises and pressure distribution reducing seating to relieve the sitting pressure [5, 6]. Individuals who have strength and trunk stability are asked to perform pressure reliefs (PR) such as wheelchair pushups, wheelies, leaning forward and backward to minimize the duration of pressure acting on the same region of the body every 15 to 30 minutes [6, 7]. Studies show that manual wheelchair users (MWC) rarely follow the advice [6, 8, 9].

Studies have used the displacement of the center of pressure (CoP) for examining dynamic sitting behavior [11] of able-bodied participants [8] and people with spinal cord injuries (SCI) [11]. However, none of these studies specifically related changes in center of pressure to clinically accepted pressure-relieving maneuvers. Furthermore, our interviews with clinicians suggest that it is difficult for a system to not only identify the type of PR, but also to provide an easily interpretable measure of its degree to train MWC to what constitutes an effective PR.

In this study, we describe a system that measures and classifies common PR maneuvers (e.g. seated push-up, wheelie, rightward, and forward lean) and provides a description of a dynamic sitting behavior, providing feedback to the clinician and user, and defining thresholds to identify when an effective PR has been performed.

OBJECTIVES

- To obtain center of pressure measurements while wheelchair users performed a variety of pressure reliefs
- To develop a classification algorithm that can discriminate between neutral sitting and various pressure reliefs
- To assess the validity of such an algorithm for use in an artificial intelligence coaching system for pressure reliefs

RESULTS

• The MW-VC consisted of a custom-designed fabricated cross-shaped bending beam load cell instrumented with strain gauges. Three 305 D gauge strain gauges positioned to detect forces in the vertical direction, allowing for the calculation of CoP in both the left-right and the fore-aft directions.

• Twenty individuals were recruited at the National Disabled Veterans Winter Sports Clinic to complete the study protocol. Participants were 18 men, and two women, with an average age of 51 ± 9.8 years, average height 177.6 ± 7.2 cm, and average weight 77.0 ± 15.4 kg. Diagnoses were spinal cord injury (7), traumatic brain injury (1), Multiple Sclerosis (2), and Fragile X-Myotonia (1).

• After obtaining informed consent, clinicians experienced in the provision of wheelchairs and seating systems trained study participants in proper PR techniques including forward, leftward, rightward, and backward leans as well as seated push-ups. Following training, force measurements were recorded as participants practiced the various PR maneuvers.

• CoP in X and Y were converted to a vector quantity. The CoP in X and Y magnitude, angle, and weight were analyzed by two different approaches: cluster analysis and a decision tree algorithm.

• K-Means clustering analysis performed on the data in MATLAB. The X-ordinate and Y-ordinate, and percent seated weight variables were the inputs to the function, and it was prompted to return clusters that corresponded to neutral sitting and the 5 types of pressure reliefs.

• The angle and magnitude values, along with percent seated weight, were used in a variety of parameter combinations to either reposition or stop the movement. The percent seated weight drops below a threshold—representing a push-up—or the center of pressure moves out of a neutral area at the center and center back of the wheelchair’s seat—representing some type of lean.

• For each cluster, the percentage of data points that were found in each trial type—e.g., forward lean—was calculated by the cluster dividing the number of samples from each PR trial by the total number of samples in that cluster. The same approach was taken with the decision tree classifications.

• For all trials, data could be expected to consist of samples representing the wheelchair user in the neutral seated position. Samples taken while executing the forward lean, and some number of samples recorded during the transition from a neutral position to forward lean, then back to neutral. Other PR trial data was collected similarly. Wheelie and rightward leaning PR maneuvers were recorded in a single trial.

• The locations of the clusters centroids. Figure 1 shows the CoP (left) and weight righted data points categorized using the deterministic algorithm. The points inside the circular boundary near the center of the wheel were labeled as neutral sitting. The weight below 20% was labeled as push up.

• All data points with the X—Y center of pressure on the left and weight on the right with the centroids from the K-Means clustering analysis. Different colors represent different cluster assignments resulting from the K-Means algorithm.

MATERIALS & METHODS

• The MW-VC consisted of a custom-designed fabricated cross-shaped bending beam load cell instrumented with strain-gauges. These 305 D gauge strain gauges positioned to detect forces in the vertical direction, allowing for the calculation of CoP in both the left-right and the fore-aft directions.

• The results of this research were performed as well as machine learning, more computationally efficient, and may require less set-up time for each user in the data.

• Future work will focus on refining the parameters and calibration routine for the decision tree algorithm.

CONCLUSIONS

Wheelchair users’ seated center of pressure and seated weight can be used to evaluate sitting behavior. In their decision tree analysis and the deterministic decision tree are capable of discriminating between neutral sitting and various pressure reliefs. The K-Means decision tree approach has the advantage of computational efficiency, potential to reflect dynamic movement in a control group, and the ability to describe the degree of pressure relief with a single number magnifying the amount of time in the case of push-up, which may help coach wheelchair users to perform effective pressure reliefs.

REFERENCES


KEY FINDINGS

- Both cluster analysis and decision trees are able to distinguish between neutral sitting and various pressure reliefs.

- The times at which PI formation begins, particularly over the sacrum and ischial tuberosities may overcome capillary pressure and cause tissue damage.

- Through training, force measurements were recorded as participants practiced the various PR maneuvers.

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