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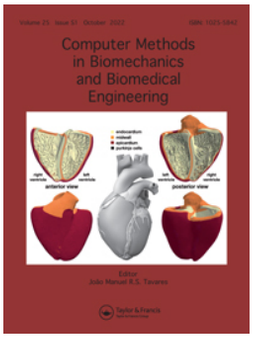

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Predicting shear force in wheelchair at body-seat interface with machine learning

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1. Introduction

As the number of wheelchair users increase with the improvement of life expectancy (Kaye et al. 2000), it is mandatory to further explore their risk of medical complication such as pressure ulcers.

The aetiology of pressure ulcers is well documented since Bennett's work (Bennett et al. 1979): mechanical loads (normal and shear forces) on soft tissues can induce deep tissue strains and lead to hypoxia and/or tissue cells death (Loerakker 2007). Normal seating forces are usually studied with force sensor array (FSA) (Stinson et al. 2003) for both laboratory and ecological experimentations. Shear forces are less studied and mainly in laboratory conditions (Hobson 1992; Kobara et al. 2008) since shear sensors could not be as easily used as FSA. Recently, a portative device has been developed to measure shear forces, the iShear® wich measure the shear force between the seat and the cushion. (Redwood-Thomas et al. 2020).

Since both normal and shear forces are of importance in pressure ulcer formation, the purpose of the study is to develop and validate a model able to provide total shear forces estimated from Machine Learning results based on FSA parameters. Thus, with a single tool pressure measurement such as FSA, total shear forces could be studied in future work.

2. Methods

2.1. Experimental protocol

An experimental seat (Beurier et al. 2017) was used to measure total shear forces under the seatpan and normal force under the footpan, with force sensors. The seat was equipped with a wheelchair backrest. On the seat and backrest surfaces, two Texisense® FSA (1024 sensors each) were placed.

The seatpan includes a matrix of 52 height adjustable cylinders allowing to provide a flat seating surface or a curved one (called ergonomic seating surface, built by minimizing the maximal pressure). To cause a dynamic activity resembling to wheelchair propulsion while seating on this experimental seat, a handcycling activity was chosen. The hand peddler was positioned in a table in front of the participant (Figure 1).

A sample of 38 able-bodied participants (27 women and 11 men, 35.1 ± 11.8 yo, 168.7 ± 8.1 cm and 63.4 ± 10.3 kg) was recruited.

The computer clock was used to synchronize the experimental seat with both FSA at 10 Hz.

Measurements were made during static postures when seating on both the flat and ergonomic surfaces. For the dynamic activity, they were asked to pedal for 10s when seating on both the flat and ergonomic surfaces.

The protocol has been reviewed by both the LBMC and Eiffel University ethical committees.

2.2. Machine learning preparation

A supervised Machine Learning algorithm was used with the Scikit Learn, Python library (Pedregosa et al. 2011)

First, different models (Linear Regression, SVM and Random Forest Regressor) were tested to choose the one that fit the best our data.

Thus, in order to find the best dataset, the algorithm was trained with different combinations of the following features:

- From the seat pressure measurements on the seatpan: contact area, total normal force (Fs), position of the center of pressure (COP) in the antero-posterior direction, depth of contact (distance between the most posterior FSA sensors activated and the most anterior sensors), distance between the ischial tuberosity (IT) and COP in the antero-posterior direction (COPs).
- From the backseat pressure measurement: contact area, total normal force (Fb), position of the COP in the upward-downward direction (COPb).
- From the participants: weight, sex, height; once in the experimental seat: seating depth, thigh-trunk angle (TT), seat-back angle (SB).
- From the sensor under the footpan: normal force.
- A new feature, calculated with some parameters above: named KAE (Eq. (1)) adapted from Kobara's (2008) work.

$$KAE = Fb * \sin(TT) * Cos\beta^2 + Fs * \tan(Ta)$$

Ta for seat tilt angle and with:

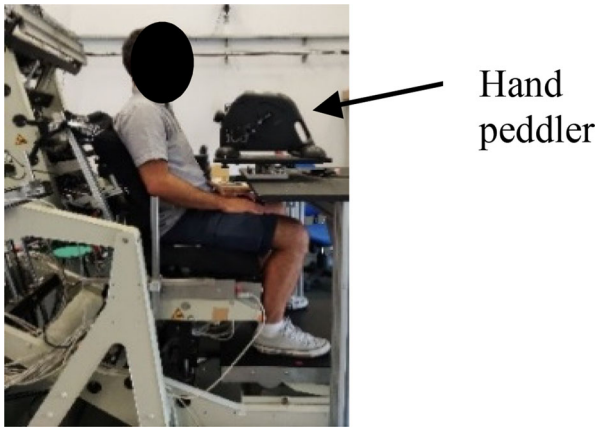

Figure 1. Picture of the set up with participant.

$$Cos\beta = \frac{COPs}{\sqrt{(COPb * \cos(SB - 90))^2 + COPs^2}}$$

Equation (1): the KAE feature. The different parameters are defined in the list just above the formula.

In order to assess the model, a cross validation (GroupK-fold approach (Pedregosa et al. 2011)) was performed using static experimental data, ergonomic and flat seatpans. This cross validation evaluates the model on the training set (static data used to train the model) and on the test set (another set of new data).

The metrics chosen to assess the model was the mean absolute percentage error (MAPE) between the experimental and predicted shear forces. The final model was tested with the dynamic results. The average over 10s during handcycling of the measured shear force (from the experimental seat) and of the predicted shear force (from the model and the measured pressure) were used to compute the MAPE.

3. Results and discussion

Several models built with different parameters were tested until the best set of parameters was obtained.

The model fitting the best our data is the Random Forest Regressor model with the following parameters and their weights: total force of the back (0.46), COPs (0.26), total normal force under the feet (0.13), KAE (0.08) and seat contact area (0.07). The MAPE were 5.99% ± 0.28 and 15.47% ± 4.02 on the training set and the testing set, respectively (Figure 2).

The MAPE in 'dynamic' condition is close to the MAPE of the testing cross-validation performed on static data, showing that our model could be used in dynamic condition even though its standard deviation is higher in dynamic condition.

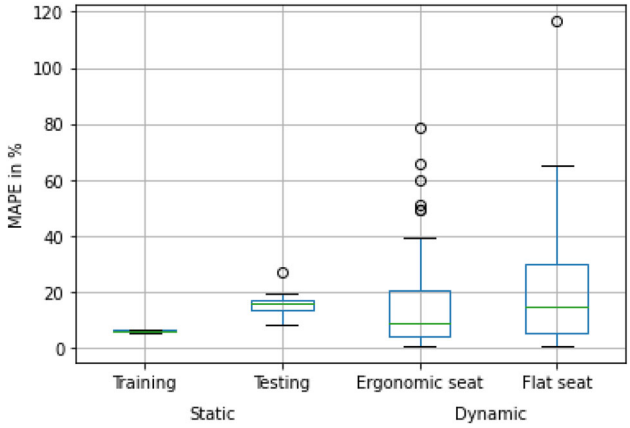

Figure 2. Model's errors (MAPE) between the experimental and predicted shear forces, averaged over 10s for the dynamic conditions.

In 'dynamic' conditions, the model provides better results for the ergonomic condition with 16.9% versus 22.1% for the flat seatpan.

It can be noted that the parameters used to build the model come from FSA measurements. FSA measurement errors can go up to 10%, this could explain the order of magnitude of the error of the model. Nevertheless, our model's errors in static are of the same order of magnitude than the only ecological available tool, the iShear® (Redwood-Thomas et al. 2020) also assessed in static condition, which is encouraging.

One of the limits of the 'dynamic' evaluation is the handcycling activity rather than propulsion, since the experimental seat could not be equipped with wheelchair wheels.

4. Conclusions

We developed a model abled to predict the total shear force at body – seat interface based on the participant's posture and on FSA measurements. The average error of the model prediction is less than 16% in static condition, but it can also be used in dynamic with less than 17% of error. Future works is needed to assess this model with data from pathological wheelchair users as well as its use during wheelchair propulsion.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

Bennett L, Kavner D, Lee BK, Trainor FA. 1979. Shear vs pressure as causative factors in skin blood flow occlusion. Arch Phys Med Rehabil. 60(7):309–314.

Beurier G, Cardoso M, Wang X. 2017. A new multi-adjustable experimental seat for investigating biomechanical factors of sitting discomfort.

Hobson DA. 1992. Comparative effects of posture on pressure and shear at the body-seat interface. J Rehabil Res Dev. 29(4):21–31.

Kaye HS, Kang T, LaPlante MP. 2000. Mobility device use in the United States.

Kobara K, Eguchi A, Watanabe S, Ishiura Y, Fujita D, Nishimoto T, Shinkoda K. 2008. Investigation of the validity of an experimental model for the estimated shear force on buttocks in a comfortable sitting posture. J Phys Ther Sci. 20(3):157–162.

Loerakker S. 2007. Aetiology of pressure ulcers. Eindhoven: Eindhoven University of Technology (TU/E), 31.

Pedregosa F, Varoquaux G, Gramfort A, Michel V, Thirion B, Grisel O, Blondel M, Prettenhofer P, Weiss R, Dubourg V, et al. 2011. Scikit-learn: machine learning in Python. J Mach Learn Res. 12(85):2825–2830.

Redwood-Thomas J, Bowtell M, Graham S, William I, Tasker L. 2020. The effect of seating setup on shear forces experienced at the seating interface. Vancouver; p. 109.

Stinson MD, Porter-Armstrong AP, Eakin PA. 2003. Pressure mapping systems: reliability of pressure map interpretation. Clin Rehabil. 17(5):504–511.

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