Predicting intra-abdominal pressure during walking and running

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Summary

Intra-abdominal pressure (IAP) is an important physiological parameter, which is difficult to measure during physical activity. In this study, motion capture, musculoskeletal modeling and a transformer encoder model are used to predict IAP during walking and running. The model showed promising results with an overall mean percentage error of 13.5% and a Pearson correlation coefficient of 0.85. Minor challenges included the lower accuracy for fast walking and running and the limited amount of data. All in all, the prediction of IAP was successful, which opens up prospects for further applications.

Introduction

Intra-abdominal pressure (IAP) is an important physiological parameter associated with pelvic floor health [1]. Since measuring IAP is difficult [2], the use of motion capture (MoCap) and musculoskeletal (MSK) modeling can help to gain an understanding of IAP during movement but is computationally expensive [3]. Machine learning methods provide an efficient tool for predicting IAP and enable real-time applications. In this study, a transformer encoder is used to predict IAP during walking and running.

Methods

The transformer encoder model originally described by Vaswani et al. [4] was adapted to time-series data and combined with a feed-forward neural network architecture.

The dataset comprised MoCap recordings from 211 subjects performing three activities: walking, fast walking and running. MSK modeling was conducted using the AnyBody™ Modeling System. 28 major physiological angles as well as the subjects' weight and height were selected as features. The corresponding IAP values were used as labels.

The recordings were segmented into individual gait cycles, which were interpolated to a length of 50 timesteps. Data cleaning included the removal of outliers in terms of gait cycle duration, maximal muscle activity and hip reaction forces. The data was split into training, test and validation dataset in a subject-naïve fashion and normalized using z-score normalization. For evaluation the mean absolute error (MAE), the mean absolute percentage error (MAPE) and Pearson correlation coefficient (r) were used.

Results and Discussion

The model performs well with an overall MAPE of 13.5% (Table 1). The performance differences between the different activities can likely be explained by the higher complexity of fast walking and running.

Table 1: Performance of the model

	Mean ± MAE in kPa	MAPE in %	r
overall	2.59 ± 0.33	13.5	0.85
walking	2.46 ± 0.24	9.8	0.88
Fast walking	2.71 ± 0.47	19.4	0.78
running	2.92 ± 0.49	19.7	0.86

A visualization of the gait cycles with highest and lowest MAE shows a high qualitative agreement between predicted values and labels for the best-case plots. In the worst-case plots the overall pattern is still matched, despite an observable offset (Figure 1). Limitations include possible MSK modeling errors and relatively small dataset size.

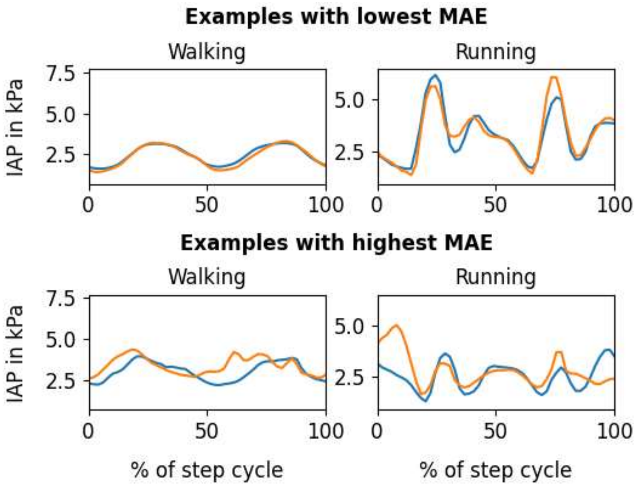

Figure 1: Examples of the performance on individual gait cycles. Labels in orange, predictions in blue.

Conclusions

The successful application of a transformer encoder to predict IAP during walking and running enhances the understanding of IAP during movement and highlights the potential of using machine learning models for biomechanical regression tasks.

References

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