

SEQUENCE AND ATTENTION MODELS FOR PREDICTING LOWER LIMB MUSCLE FORCES FROM GROUND REACTION FORCES

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1. Introduction

Portable force plates enable ground reaction force (GRF) measurements outside the lab [1]. However, estimating muscle forces from these external forces alone remains a challenge due to the complexity of musculoskeletal dynamics. Traditional methods rely on electromyography (EMG), kinematics, and time-consuming modelling pipelines, limiting clinical use. This study explores a deep learning approach for directly predicting lower limb muscle forces from GRFs collected during gait, using models that can support future integration with portable force measurement technologies.

2. Materials and Methods

We trained 4 deep learning architectures, LSTM, CNN-LSTM, LSTM with Attention (LSTM+ATTN), and Transformer, on publicly available treadmill walking data from 10 healthy adults. GRFs from over 13,000 stance phases were used as input, while muscle forces from 9 lower limb muscles were computed via OpenSim static optimization and used as ground truth [3, 4]. Models were implemented in PyTorch. Mean average error (MAE) and coefficient of determination (R^2) were evaluated on the validation set.

3. Results

All models effectively predicted muscle forces from GRFs alone (**Figure 1**). Attention-based models, particularly the Transformer, achieved the best performance (MAE: 13.69 N, R^2 : 0.996), followed closely by the LSTM+ATTN model (MAE: 14.67 N, R^2 : 0.996). All models predicted Achilles muscle force trends the best compared to muscles with lower force magnitudes. These findings demonstrate that GRFs alone can reliably estimate internal muscle forces using attention-based models.

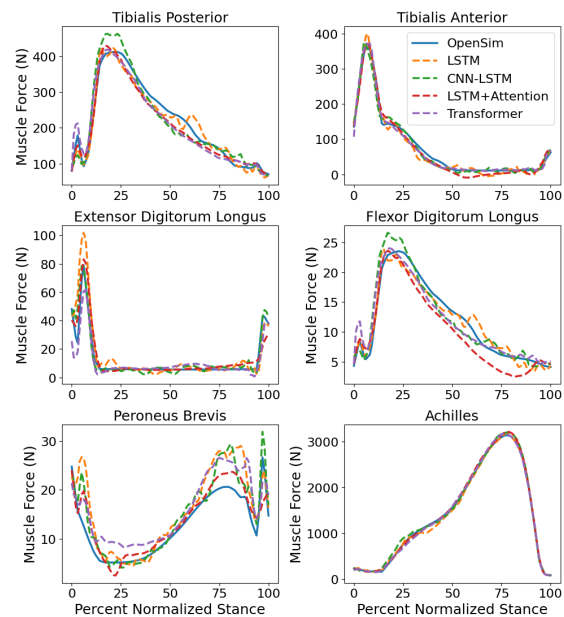


Figure 1: Predicted lower limb muscle forces (excluding 3 muscles) from models compared to OpenSim estimates for a representative stance phase.

4. Discussion and Conclusions

This work demonstrates that lower limb muscle forces can be predicted from GRFs alone, supporting the use of portable force plates in clinical or athletic settings where motion capture or EMG may not be feasible. Hybrid and attention-based models outperformed sequence-based models, which are more commonly used for this task [5], demonstrating strong performance with minimal inputs. Future work will extend to pathological and diverse populations to improve generalizability.

5. References

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