Estimation of Lower Extremity Muscle electromyographic Activities during Gait Using an Artificial Neural Network

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Summary

Artificial neural networks (ANNs) were trained and tested to predict electromyographic (EMG) activities of lower-limb muscles during walking. EMG activities of six muscles as well as gait data were used for training. The developed ANN proved to be robust (R>0.88 and normalized root-mean-squared-error < 2%).

Introduction

Walking, one of the most common daily activities, can be affected by musculoskeletal disorders [1]. Surface EMG measurement of muscles is a widely-used technique to analyze the human locomotion condition and muscular function. Collecting and processing EMG signals is, however, time-consuming and challenging [1]. Artificial intelligence, especially artificial neural networks (ANNs), are newly flourishing tools in biomechanics, that when trained based on measured data, can easily and robustly predict (generalize) the target outputs [2]. The present study aims to develop ANNs that can effectively predict EMGs activities of lower-limb muscles using a minimal number of gait inputs.

Methods

Ten healthy men, with 179.7±6.7 cm height, 69.5±7.4 kg weight, and 23.6±1.6 kg/m^2 BMI, participated in this study. Each subject was tested at least 6 times during a four-meter walking activity at two distinct gait speeds. First, they were asked to walk at their preferred/comfortable speed, then, to walk at a faster pace. All experiments were conducted after approval from the institutional ethics committee (approval ID: IR.IOMS.REC.1401.740) and with the informed consent of all participants. Full-body kinematic data were recorded using a 10-camera Vicon motion capture system at a sampling rate of 120 Hz. Full-body plug-in gait marker placements with thirty-nine passive reflective skin markers were used. Surface EMG electrodes were recorded activities of Tibialis anterior, Gastrocnemius Medius, Gastrocnemius lateral, Rectus femoris, Semitendinosus, Vastus lateralis at a sampling rate of 1200 Hz. While performing each gait activity, the anatomical angles of both right and left hip, knee, and ankle joints were calculated. EMG data were first high-pass filtered at 30Hz, then detrended and rectified respectively, and finally followed by a low-pass filter at 10 Hz.

An ANN was trained using the measured data to predict the EMG activity of the foregoing muscles with minimal and readily measurable inputs, i.e., gait percentage, body weight, body height, gait speed, ankle angle, knee angle, and hip angle in the sagittal plane. A time series ANN was trained using 80% of the measured data while the remaining 20% of data were used for validation and test. Moreover, Leave-one-subject-out (LOSO) technique was used as an additional validation strategy in which each time the training dataset excludes all observations of one participant, i.e., the ANN is trained on the remaining dataset of nine subjects, and finally it is tested on the excluded subject.

Results and Discussion

Our preliminary results shows that an ANN with 7 inputs, 4 hidden layers, and 1 output could be trained to predict EMG activities of the Vastus Lateralis muscle during gait (Figure 1). Great coefficients of determination (R = 0.89 and 0.88 for normal and fast speeds, respectively) and small normalized root-mean-squared errors (1.22 and 0.59% for normal and fast speeds, respectively) were obtained. These preliminary results suggest that the proposed method is a promising step forward for using ANNs to predict EMG activities of muscles from kinematic data.

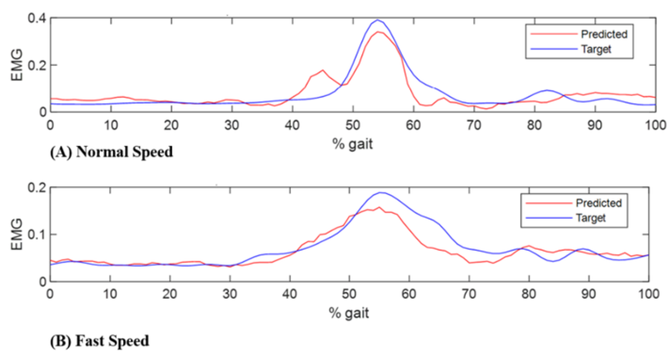

Figure 1: The predicted and measured EMG activities of Vastus Lateralis muscle during normal speed (A) and fast speed (B) gait.

Conclusions

ANNs can predict muscle EMG activities using readily-measurable gait data. This method is accurate and can help analysis of EMG data easier and more practical.

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References

[1] Moreira, L., Figueiredo, J., Fonseca, P. *et al.* Lower limb kinematic, kinetic, and EMG data from young healthy humans during walking at controlled speeds. *Sci Data* **8**, 103 (2021). https://doi.org/10.1038/s41597-021-00881-3

[2] Khant M, Gouwanda D, Gopalai AA, Lim KH, Foong CC. Estimation of Lower Extremity Muscle Activity in Gait Using the Wearable Inertial Measurement Units and Neural Network. Sensors (Basel). 2023 Jan 3;23(1):556.