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Beyond the Legs:
Leveraging Trunk and Driving Muscle EMG to Improve Gait Model Predictions

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Abstract

Traditionally, myographic gait prediction models tend to rely on EMG signals solely from the lower-limbs[1]. However, in addition to the legs, clinical gait research puts an emphasis on the role of the **trunk** during gait[2,3], which raises the question:

What if we could improve gait models by including muscles beyond those of the lower-limbs?

Using a Multi-Layer Perceptron (MLP), we compared the predictive power of EMG signals extracted from the trunk and driving muscles vs purely from the legs. We investigated this for the **hip, knee** and **ankle** joints across prediction horizons of **0.05ms** (one time-step ahead)**, 100ms** and **200ms**.

Our results show that including trunk muscles leads to more accurate gait models, and highlight the potential of targeting "drivers" to select more relevant EMG inputs for kinematic predictions.

Trunk and Drivers

The **trunk** plays a **dual role** during steady-state walking, focused on both **maintaining postural balance** and on **facilitating the movement of the lower-limbs**; the trunk can be perceived as **the centre of the kinematic chain**, providing a stable basis for control and the generation of movement during gait[3].

When performing a movement, such as gait, the muscles involved can be distinguished by their **task-specific role**[4]:

1. **Drivers:** Muscles responsible for movement generation.
2. **Stabilisers**: Muscles that provide stability and balance to facilitate the motion

Based on literature, some studies have classified the following muscles as **drivers:** the **Multifidus** (MF)[5] and **Erector Spinae** (ES)[6] muscles from the trunk, and the **Rectus Femoris** (RF) and **Soleus** (SO) muscles from the lower-limbs[7].

Methods

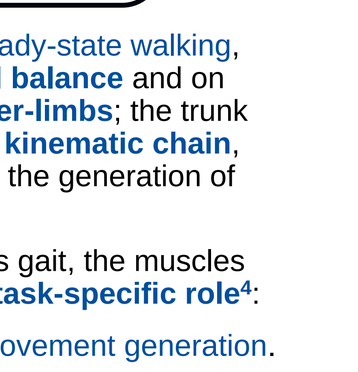
Subjects: 5 able-bodied participants

Experiment: Walking on a treadmill at speeds 0.4m/s to 0.8m/s with increments of 0.04m/s for a duration of 2 minutes per speed.

Model: 5-fold regressive Multi-Layer Perceptron

Inputs and Outputs: 250ms windowed EMG envelopes (4 muscles at a time) predicting the hip, knee and ankle joint angles, and gait cycle percentage (GC%)

Prediction horizons: 0.5ms, 100ms, 200ms



	Muscles included in each subset							
Subset	**ESL-L**	**ESL-R**	**MF-L**	**MF-R**	**RF**	**SO**	**BF**	**TA**
Trunk	✓	✓	✓	✓				
Leg					✓	✓	✓	✓
Drivers			✓	✓	✓	✓		

Results



Figure 1: *Cross-subject normalised RMSE for the one-step-ahead scheme*



Figure 2: *Cross-subject normalised RMSE using a 100 ms prediction horizon*



Figure 3*: Cross-subject normalised RMSE using a 200 ms prediction horizon*

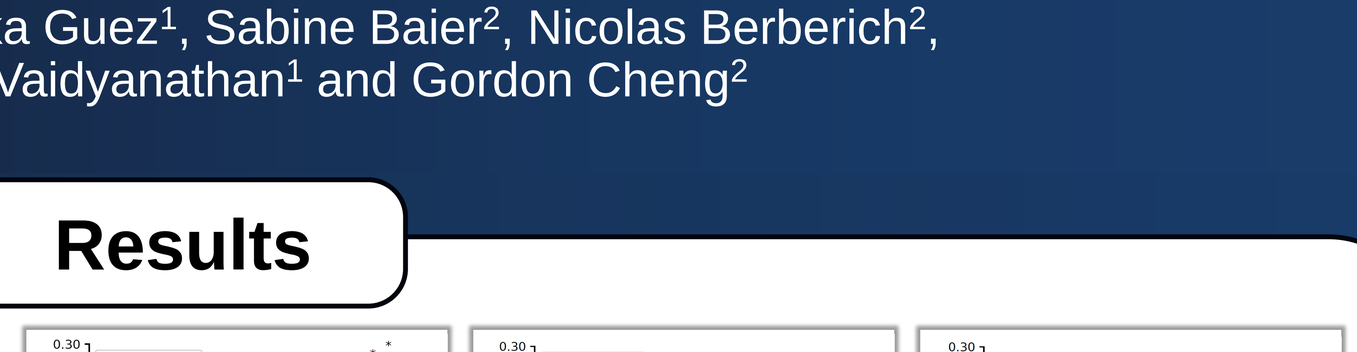


Figure 4*: Normalised validation RMSE of 3 example subjects in the one-step-ahead scheme*

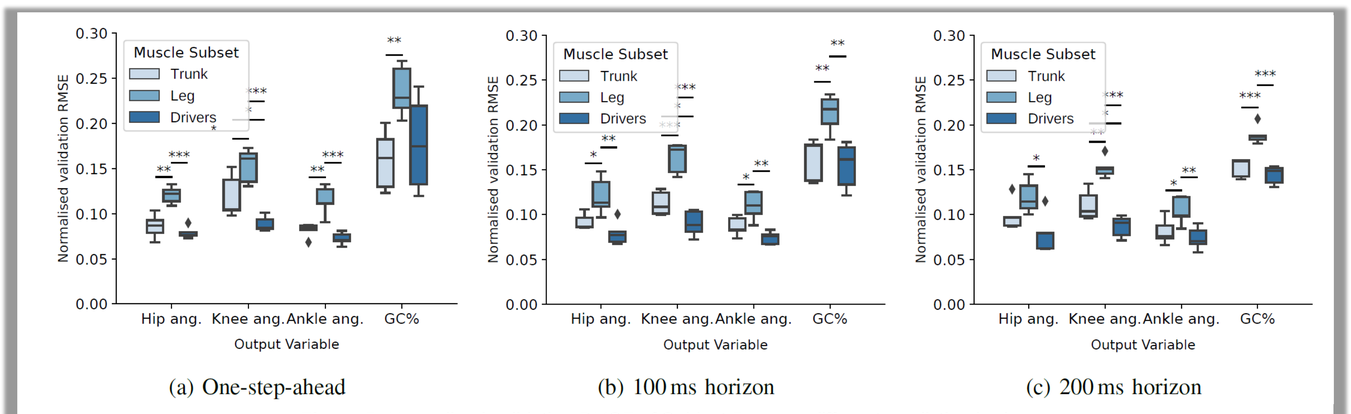


Figure 5: *Normalised validation RMSE of Subject 5 across different prediction horizons*

Discussion

One-step-ahead

For all predicted outputs, the *Trunk* consistently outperformed the *Leg* subset. Furthermore, for the knee and ankle joints, the *Drivers* outperformed the *Trunk*.

→ The ***Trunk* and *Drivers* EMG provide valuable information** compared to only the *Leg*.

100 and 200 ms prediction horizon

Both the *Trunk* and *Drivers* outperform the *Leg* subset, however there is greater significance between the *Leg* and *Drivers* at 100 ms, which shifts to the *Leg* and *Trunk* at 200 ms.

→ This reveals **the importance of the trunk in performing anticipatory postural adjustments** in preparation for the lower-limb movement.

Balancing strategies and task-specific muscle roles

The performances of the *Trunk* and *Drivers* alternate across subjects (Fig. 4), which could be related to the subjects' balancing strategies[8]: **hip-strategy** (focus on trunk extension) or **ankle strategy** (sway about the ankle joint). Furthermore, the improved performance of the *Drivers* suggest **better EMG signals** (clear concentric contraction) and a **more direct relationship to the observed kinematic outputs** (role in motion generation).

Conclusion

The **dual role of *Trunk* muscles** in both postural balance and motion generation makes them **a reliable EMG input** for gait prediction and should be incorporated in future works.

Furthermore, the increased performance of **the *Drivers*** relative to the *Leg* reveal **the importance of muscle functionalities** in gait, and should be further investigated.

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[1] N. Amrani El Yaakoubi, C. McDonald, and O. Lennon, "**Prediction of gait kinematics and kinetics: A systematic review of EMG and EEG signal use and their contribution to prediction accuracy,**" Bioengineering, vol. 10, no. 10, 2023.
[2] J. D. Willson, C. P. Dougherty, M. L. Ireland, and I. M. Davis, "**Core stability and its relationship to lower extremity function and injury**," Journal of the American Academy of Orthopaedic Surgeons, vol. 13, no. 5, pp. 316–325, 2005.
[3] E.-J. Chung, J.-H. Kim, and B.-H. Lee, **"The effects of core stabilization exercise on dynamic balance and gait function in stroke patients,"** Journal of physical therapy science, vol. 25, pp. 803–806, 2013.
[4] T. E. Flaxman, A. D. Speirs, and D. L. Benoit, "**Joint stabilisers or moment actuators: The role of knee joint muscles while weightbearing**," Journal of Biomechanics, vol. 45, no. 15, pp. 2570–2576, 2012.
[5] C. Anders, H. Wagner, C. Puta, R. Grassme, A. Petrovitch, and H.-C. Scholle, "**Trunk muscle activation patterns during walking at different speeds**," Journal of Electromyography and Kinesiology, vol. 17, no. 2, pp. 245–252, 2007.
[6] G. Li, D. Ao, M. M. Vega, M. S. Shourijeh, P. Zandiyeh, S.-H. Chang, V. O. Lewis, N. J. Dunbar, A. Babazadeh-Naseri, A. J. Baines, and B. J. Fregly, "**A computational method for estimating trunk muscle activations during gait using lower extremity muscle synergies**," Frontiers in Bioeng. and Biotech., vol. 10, 2022.
[7] R. Chiba, K. Takakusaki, J. Ota, A. Yozu, and N. Haga, "**Human upright posture control models based on multisensory inputs; in fast and slow dynamics,"** Neuroscience Research, vol. 104, pp. 96–104, 2016, body representation in the brain.
[8] A. D. Kuo and F. E. Zajac, "**Chapter 31 human standing posture: multi-joint movement strategies based on biomechanical constraints**," in Natural and Artificial Control of Hearing and Balance, ser. Progress in Brain Research, Eds. Elsevier, 1993, vol. 97, pp. 349–358.