# Stance Leg Sagittal Power as a Predictor of Whole Body Energy Expenditure in Walking

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## Summary

In this study, we identified the linear correlation between $P_{sag}^{SL}$ and $P^{WB}$ during walking, and based on this, we estimated $\dot{E}^{WB}$ from the weighted sum of $P_{sag.}^{SL}$. The estimation error was about 0.95W/kg, and CoV of estimation parameter was 2.96%.

## Introduction

Estimating energy expenditure ($\dot{E}$) in the field using wearable devices is challenging due to the trade-off between accuracy and convenience. Since $\dot{E}$ correlates with mechanical power ($P$), estimating whole body $\dot{E}$ ($\dot{E}^{WB}$) requires whole body $P$ ($P^{WB}$). While sagittal plane $P$ of stance leg ($P_{sag}^{SL}$) can be estimated using a single IMU [1], its significant difference from $P^{WB}$ limits its direct use for $\dot{E}^{WB}$ estimation.

Therefore, in this study, we estimate the whole body energy expenditure during walking using only sagittal plane mechanical power of stance leg, based on the correlation between the stance leg and whole body, mechanical power and energy expenditure.

## Methods

$P^{WB}$ and $\dot{E}^{WB}$ were measured experimentally, revealing a correlation between $P^{WB}$and $P_{sag}^{SL}$ . $\dot{E}^{WB}$ was estimated using a linear regression of the weighted sum of $P_{sag}^{SL}$. Data from 4 adult males were collected at 5 walking speeds of 70~130% of their self-selected pace (8 min per trial). Additional data from 11 males were gathered at speeds of 1.0~1.75 m/s (6 min per trial), measuring GRF, kinematics, and $\dot{E}^{WB}$. 3 subjects were randomly assigned to the estimation group (EG), and the remaining 8 to the validation group (VG). The proposed estimation equation is as follows:

$$\dot{E}_{est.}^{WB} = c\sum \eta^{+}\left(P_{sag}^{SL}\right)^{+} - \eta^{-}\left(P_{sag}^{SL}\right)^{-}, \eta^{+} = 4, \eta^{-} = 0.83$$

The estimation parameter $c$ was derived from EG data via linear regression and applied to VG using leave-3-out cross-validation to evaluate performance.

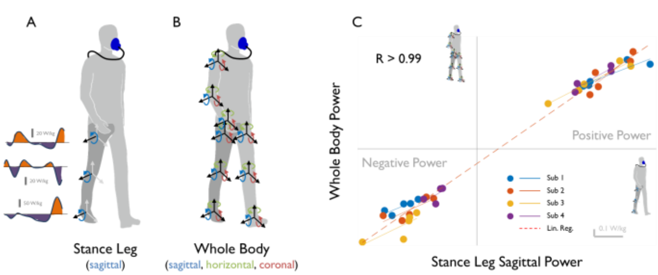


**Figure 1:** (A) $P_{sag}^{SL}$ Model (B) $P^{WB}$ Model (C) Linear correlation of $P^{WB}$ and $P_{sag}^{SL}$

## Results and Discussion

A strong linear correlation (R>0.99) was observed between $P^{WB}$ and $P_{sag}^{SL}$ (Fig. 1.C). The first experiment showed consistent linearity, with $P^{WB}$ being about 2~2.5 times $P_{sag}^{SL}$. This suggests that body segments other than the stance leg move like a pendulum, where the rate of $P$ and $\dot{E}$ during movement is proportional to frequency [3]. This allows $P_{sag}^{SL}$ to represent $P^{WB}$ and enables $\dot{E}^{WB}$ estimation.

$\dot{E}^{WB}$ estimated from $P_{sag}^{SL}$ showed high accuracy, with an RMSE within 0.95W/kg. In the VG with median error, bias stayed below 1W/kg, and all points were within the limits of agreement (Fig. 2.B). RMSE was 0.87 (0.33)W/kg for EG and 0.95 (0.36)W/kg for VG. The parameter $c$ was 1.35 (0.04) with a CoV of 2.96%, indicating high stability. The value 1.35 appears to be a valid constant linking the weighted sum of $P_{sag}^{SL}$ to $\dot{E}^{WB}$, aligning with prior studies suggesting a muscle work fraction of 0.5~0.55 for $\dot{E}$ estimation [2].

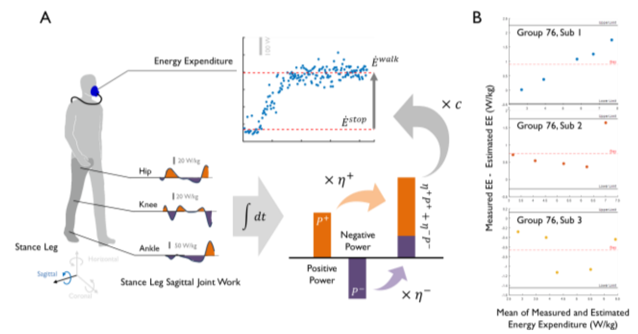


**Figure 2**: (A) Schematic of $\dot{E}^{WB}$ estimation (B) Bland-Altman Plot of 76th validation group

## Conclusions

This study demonstrated that stance leg's sagittal plane can represent whole body mechanical power due to the coordinated movement of body segments during walking, enabling whole body energy expenditure estimation with an RMSE within 0.95W/kg. This suggests that $\dot{E}^{WB}$ could be estimated with a single IMU by applying previous study [1].

## Acknowledgments

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## References

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