

# The effect of fixation location and footwear type on peak impact accelerations from a consumer-grade IMU during running



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## Summary

Biomechanical loads (e.g., vertical peak positive acceleration; PPA) from research-grade inertial measurement units (IMUs) have been correlated with lab-based metrics (e.g., ground reaction force loading rate) and running-related injuries (e.g., tibial stress fracture). Most commercially available IMUs are mounted either on the shoelaces or embedded in the insole and their validity has not been investigated. The purpose of this study was to assess the validity of two commercially available IMUs during running when compared to a research-grade tibia-mounted IMU. A secondary aim was to determine the effect of footwear on validity. We found poor to moderate validity between a tibia-mounted IMU and two commercially available IMUs located on the shoelaces and insole. Footwear (level of cushioning) also influenced the degree of validity, suggesting that both location of fixation and type of footwear should be taken into account in future research and in clinical applications.

## Introduction

Wearable technology has made it possible for runners to quantify biomechanical loads (e.g., peak positive acceleration; PPA) using commercially available inertial measurement units (IMUs). Vertical PPA of the tibia has been associated with running-related injuries (e.g., tibial stress fracture) [1] and has been correlated with the vertical ground reaction

force loading rate [2]. However, while PPA is often measured in a lab setting at the tibia, consumer-grade IMUs are often fixated on the shoelaces or embedded in the insole. The effect of these fixation locations on the magnitude of the PPA is unknown. Therefore, we aimed to assess the validity of two commercially available IMUs during running when compared to a tibia-mounted IMU. A secondary aim was to determine the effect of footwear on validity.

## Results and Discussion

Using the IMU-tibia as the criterion reference for PPA, ICC<sub>2,1</sub> values for the RunScribe and Plantiga IMUs were significant in neutral and maximalist footwear conditions only, ranging from 0.60 to 0.74 (Table 1), representing poor to moderate validity [3]. ICC values of >0.90 are considered desirable for clinical measurements [3]. As such, both devices may have some clinical limitations for use as a proxy for vertical PPA at the tibia. Further, footwear had a clear effect on the validity of the signal from both devices, with the minimalist footwear resulting in insignificant correlations and the maximalist condition resulting in the highest correlations.

## Conclusion

Our findings indicate that two commercially available IMUs located on the shoelaces and insole represent poor to moderate validity when acting as a surrogate for a tibia-mounted IMU for vertical PPA. Footwear (level of cushioning) also influences the degree of validity. Location of fixation and type of footwear, therefore, should be taken into account in future research and in clinical applications.

**Figure 1**

Tibia-mounted (IMeasureU), lace-mounted (RunScribe), and insole-embedded (Plantiga) inertial measurement units.



**Table 1**

Validity of peak positive acceleration (PPA) from a lace-mounted and insole-embedded inertial measurement unit (IMU) in three different footwear conditions. Values represent ICC<sub>2,1</sub> with 95% confidence interval. † p < .05

Criterion Reference	Footwear Condition	Plantiga Insole (PPA)	RunScribe (Impact)
Tibia-mounted IMU	Neutral	0.62 (-0.08, 0.87) <sup>†</sup>	0.60 (-0.06, 0.85) <sup>†</sup>
	Minimalist	0.31 (-0.90, 0.75)	-0.72 (-3.46, 0.34)
	Maximalist	0.74 (0.24, 0.91) <sup>†</sup>	0.72 (0.24, 0.90) <sup>†</sup>

## Methods

Healthy runners ran on a treadmill at their preferred speed in three footwear conditions (neutral, minimalist, maximalist). Three IMUs were affixed at the distal tibia (IMeasureU, Vicon, Oxford, UK), shoelaces (RunScribe, San Francisco, USA), and insole (Plantiga, Vancouver, Canada). Intraclass correlation coefficients (ICC<sub>2,1</sub>) were calculated for PPA between the tibia-mounted IMU (IMU-Tibia) and the commercially available IMUs for each footwear condition. Significance was set at p < 0.05.

## References

- [1] Milner CE et al (2006). Med Sci Sports Exerc, 38:323-28.  
 [2] Hennig EM & Lafortune MA. (1991) IJSB, 7:303-09.  
 [3] Portney LG and Watkins MP (2009). Foundations of Clinical Research; FA Davis Company.

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