Ankle Joint Kinematics and Muscle Activations during Ankle Exercise Using a Biomechanic Measurement Tool: Honest Measure

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Summary

This study analyzed ankle kinematics and muscle activation during a dynamic balance exercise using Honest Measure, a smartphone-based tool. Six participants controlled ankle movement to align with a target, while motion capture and IMU data were recorded. Significant differences in fibularis longus activation and ankle joint angles indicate that Honest Measure promotes muscle engagement and movement coordination. As a cost-effective alternative for balance training and rehabilitation, it supports neuromuscular and joint control. Future studies should explore its use in ankle instability and post-injury rehabilitation.

Introduction

Assessing balance is crucial for evaluating functional stability and informing rehabilitation programs [1]. While sophisticated tools (e.g., force platform and NeuroCom) provide accurate measurements in research settings, their high cost restricts widespread clinical use. In contrast, commonly used clinical methods, such as stopwatch-based single-leg stance tests, fail to quantify sway or capture precise motion data. To bridge this gap, we developed "Honest Measure", a smartphone app that utilizes smartphone IMU data to assess and train balance ability. This study aimed to quantify the ankle joint angle and muscle activations during exercise using Honest Measure.
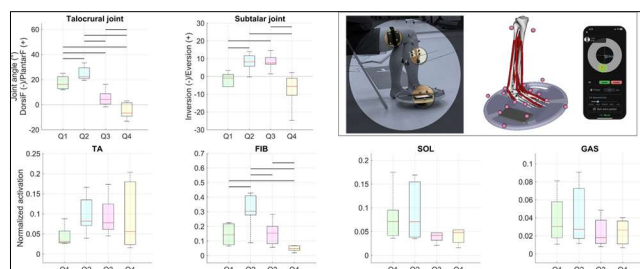

Figure 1: Ankle joint kinematics, muscle activations, and the experiment setup. The horizontal lines represent the pairwise significant differences. Q: quadrant

Methods

Six subjects performed the dynamic exercise while seated with the hip and knee flexed at 90 degrees, placing his dominant foot on a balance board. A smartphone was positioned 5 cm laterally from the foot on the board. Reflective markers were attached to the balance board, and their 3D positions were recorded using nine motion capture cameras. 3D orientation data from the smartphone (iPhone 7S) were recorded using MATLAB. Honest Measure displayed a target circle moving clockwise through four quadrants (Q1-Q4), alongside a real-time orientation dot representing smartphone IMU data, which was mirrored onto a TV screen. The participant adjusted the orientation dot to align with the target circle by controlling the ankle joint. Orientation data from the motion capture system and smartphone IMU were synchronized using cross-correlation. The angles of the talocrural and subtalar joints, along with muscle activations, were measured and compared across different quadrants using Kruskal Wallis test and Wilcoxon Signed-Rank Test.

Results and Discussion

The Kruskal-Wallis test showed significant differences across quadrants in fibularis longus activation ($\chi^2(3) = 14.87$, $p = 0.0019$, $\eta^2 = 0.65$), talocrural joint angle ($\chi^2(3) = 18.51$, $p = 0.0003$, $\eta^2 = 0.80$), and subtalar joint angle ($\chi^2(3) = 14.77$, $p = 0.002$, $\eta^2 = 0.64$). Post-hoc Wilcoxon tests revealed significant pairwise differences ($p = 0.031$) in all cases except for Q1–Q3 in fibularis longus activation ($p = 0.688$) and Q2–Q3 in subtalar joint angle ($p = 0.563$, $r = -0.12$).

The findings suggest that dynamic ankle exercises using Honest Measure effectively engage the fibularis longus, which plays a key role in lateral ankle stability and functional movement control. The results indicate that Honest Measure promotes active muscle engagement, making it beneficial for improving dynamic balance.

Additionally, the coordination of talocrural and subtalar joint angles during the exercise suggests that ankle movement is systematically adjusted in response to the task. The consistent changes in talocrural joint angles highlight controlled dorsiflexion and plantarflexion, while variations in subtalar joint movement indicate adaptive inversion and eversion. The lack of significant differences in some comparisons suggests that stability is maintained in certain movement phases, which may contribute to smoother transitions during the exercise.

Conclusions

Overall, Honest Measure appears to facilitate targeted neuromuscular activation and controlled joint coordination, making it a valuable tool for balance training, rehabilitation, and performance enhancement. Future research should explore its applications in populations with ankle instability, neuromuscular deficits, or post-injury rehabilitation to further assess its clinical effectiveness.

References

[1] Brachman et al. (2017). J Hum Kinet, 58: 45-6