Validating Postural Sway Measurements: Aspire Motion® IMU vs. Bertec® Force Plate

Abstract

Aspire Motion® utilizes a single Inertial Measurement Unit (IMU) worn near the body's center of mass (CoM) and measures body movement. This study evaluates the Aspire sensor's accuracy in assessing postural stability compared to measurements obtained from a Bertec® force plate. Specifically, it examines the correlation between sway length recorded by the Aspire sensor and postural length derived from Center of Pressure (CoP) data.

The study involved 190 samples from 19 individuals aged 28 to 72. Each subject performed 10 trials: 5 with eyes open and 5 with eyes closed. The results demonstrate a high Pearson correlation coefficient of r = .93 between Aspire sensor sway length and Bertec COP sway length.

This strong correlation suggests that the Aspire sensor provides a reliable alternative for postural control assessment in both clinical and research contexts. These findings underscore the Aspire sensor's potential for efficient and effective evaluation of postural stability.

Introduction

Balance is a fundamental aspect of daily living, essential for maintaining independence and quality of life as we age. Postural balance control is a multifactorial process that relies on the integration of motor, sensory, visual, cognitive, and vestibular neural networks. This complex system enables us to maintain stability and navigate our environment effectively. Any disruption in these interconnected systems can lead to postural instability, increasing the risk of falls[1,2].

Traditional balance assessments often rely on visual observation by clinicians or therapists, which can lead to subjective results. These assessments may vary based on the clinician's experience and interpretation. On the other hand, more precise evaluations are performed in clinical labs using force plates and optical systems. While these tests provide objective, detailed data, they are typically confined to specialized settings and are not accessible to most people in the community.

The Aspire sensor addresses these limitations by offering a portable and user-friendly solution for balance assessment. It brings clinical-grade accuracy to a broader audience, allowing for accurate, real-time assessments of postural stability in everyday settings. The Aspire sensor bridges the gap between subjective visual assessments and sophisticated clinical evaluations, making effective balance monitoring accessible to everyone.

Method

19 healthy adults of diverse ages and genders participated in the study (age = 52.0 ± 13.6 years; height = 164.6 ± 9.1 cm; weight = 67.5 ± 11.0 kg). Table 1 shows the gender and age breakdown. Each participant wore the Aspire

sensor around their waist, positioned near the L5 vertebra, and stood on a Bertec force plate with their feet together. Due to difficulties in maintaining the insides of the feet touching, a 28 cm x 28 cm box was marked on the force plate. Participants were instructed to keep the outer edges of their feet within this box.

Female	8
Male	11
25-35 years old	2
36 - 49 years old	4
50-64 years old	10
> 65 years old	3

Table 1. Breakdown of participant gender and age

Each balance test lasted 40 seconds. Participants performed 5 eyes open tests consecutively. They were then given 5 minutes to rest, then performed 5 eyes closed tests. For each test, they were asked to hold as still as possible. The Aspire Motion app recorded the movements detected by the Aspire sensor. An operator initiated the recording for both the Aspire sensor and the force plate simultaneously. However, due to some latency in the connection between the Aspire sensor and the app, the data from the two systems were not always perfectly synchronized. To address this, participants were asked to perform a small movement, such as a partial knee bend followed by standing up. This movement created a noticeable spike in data on both the Aspire sensor and the force plate. This spike was used to synchronize the data during post-processing.

Results

The raw data from the Aspire sensor and the Bertec force plate were processed using Butterworth filters, which are designed to provide a flat frequency response within the passband. This helps in removing high-frequency noise while preserving the core signal. In this study, a low-pass Butterworth filter was applied to smooth the data and reduce noise of the postural sway measurements.

Analysis of 190 sway measurements from the two systems revealed a Pearson correlation coefficient of $r = .93$ (Figure 1), indicating a strong correlation and similar sway measurements between the Aspire sensor and the force plate. Although the relationship is nearly linear, it does not align perfectly with a 1:1 ratio. The Aspire sensor’s sway measurements were approximately 10-12% higher than those recorded by the force plate, likely due to the sensor capturing small dynamic trunk movements that the force plate does not.

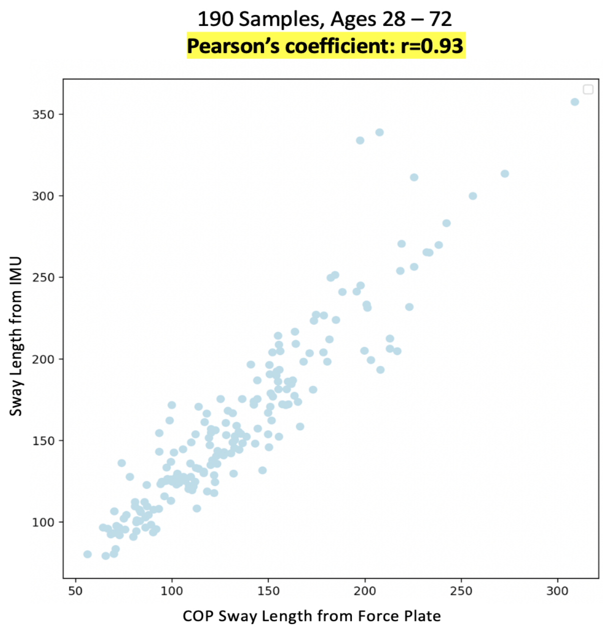

Figure 1. Calculated sway length of Aspire sensor near body center of mass versus Bertec center of pressure (CoP)

Overlaying the data from both systems shows that the sensor and force plate measurements closely follow each other. Figure 2 presents the medio-lateral (ML) and anterior-posterior (AP) movements from the sensor (pink) and force plate (blue) for two different individuals. The left panel (a) displays measurements from a 70-year-old female with eyes closed, while the right panel (b) shows measurements from a 61-year-old male with eyes open. The data indicate that performing the feet together balance test with eyes open or closed does not significantly alter the movements at the body's center of mass and center of pressure, demonstrating that the balance and postural sway remain synchronized regardless of visual input.

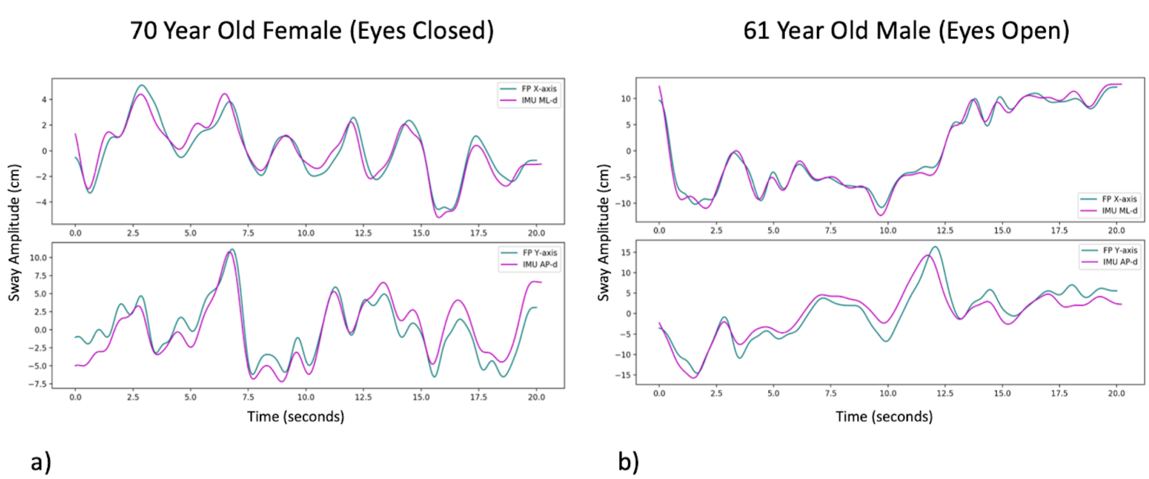

Figure 2. Medio-lateral (ML) and anterior-posterior (AP) data from the sensor and force plate over time from two individuals

Discussions & Conclusion

This study assessed the Aspire sensor's effectiveness in measuring postural sway compared to the Bertec force plate, and the results highlight its robustness and accuracy. The strong Pearson correlation coefficient of $r = .93$ between the Aspire sensor and the force plate underscores the sensor's accuracy. The observed 10-12% higher measurements from the Aspire sensor can be attributed to its capability to capture additional dynamic trunk movements, which the force plate does not measure.

One important distinction is that while the force plate measures center of pressure (CoP) shifts, which are indicative of weight distribution changes at the base of support, the Aspire sensor, placed at the center of mass (CoM), detects more direct trunk movements. This difference becomes particularly pronounced in more challenging balance stances such as tandem or single-leg positions, where trunk bending and compensatory movements can cause significant deviations from CoP measurements. In such cases, the Aspire sensor's ability to capture trunk movement provides a complementary perspective to traditional CoP measurements.

A reference study utilizing both IMUs and force plates to measure dynamic balance and fatigue in athletes found that both systems yielded similar predictive values for fatigue[3]. This supports the notion that while IMUs and force plates measure different aspects of balance, they can provide complementary insights into dynamic stability and fatigue. The Aspire sensor, through its detailed measurement of trunk movements, offers a valuable addition to balance assessment tools, particularly in capturing dynamic aspects of postural control that may not be fully represented by force plates alone.

The validation of the Aspire sensor in the feet-together stance demonstrates its accuracy in capturing trunk movements. The consistency in measurements with eyes open and closed further confirms the sensor's reliability and effectiveness in various conditions. This suggests that the Aspire sensor is a valuable tool for assessing postural stability, as it provides a comprehensive view of balance by capturing both subtle and dynamic movements.

The Aspire sensor's portability and ease of use make it a significant advancement in balance assessment, extending its application beyond traditional clinical settings. Its clinical-grade accuracy and ability to deliver real-time measurements in everyday environments enhance its utility for both clinical and community-based monitoring.

In conclusion, the Aspire sensor offers an accurate, reliable, and accessible solution for postural stability assessment. It also captures a broader spectrum of movement dynamics than traditional force plate measurements. Its accuracy in measuring trunk movement and stability in various conditions underscores its potential as a valuable tool for comprehensive balance evaluation.

References

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