



# Smart Walker

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Client: Daniel Kutschera

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## Abstract

### Context

- Patients suffering from traumatic brain injury are often asked to perform a 10m walk test during each physio session to see their rehabilitation progress

### Problem

- There are no commercially available walker systems that provide real-time quantifiable metrics for rehabilitation monitoring

### Solution

- Development of an electronic system to be attached to the walker which will provide real-time rehabilitation metrics on the associated app

### Key Features

- Load cell embedded in a custom designed endcap to measure weight beared onto walker
- mmWave radar calibrated to measure distance walked and gait speed
- App developed to display data in real time via bluetooth connection with load cells and mmWave radar

### Testing & Analysis

- Total circuit was tested on breadboard to ensure all connections and components were working as necessary
- Load cell calibration factor found, and cells were against incremental weights and against body weight on walker
- mmWave radar distance accuracy were compared against known distances

## Background

### The Client

- Daniel Kutschera
- Physical therapist in neurorehabilitation

### Traumatic Brain Injury (TBI)

- TBI affects 50 million people worldwide and lead to 500,000 disabilities annually [1]
- Clinicians use standardized tests like 10-meter walk test through manual methods, but get subjective results
- Quantative measurements required: weight distribution, timing/speed, and distance traveled.
- Real-time metric collection can reduce documentation time, and help both patients and clinicians track progress.
- Past designs comprimised strutral integrity and not easily replicable



Figure 1: 2024 Final Design

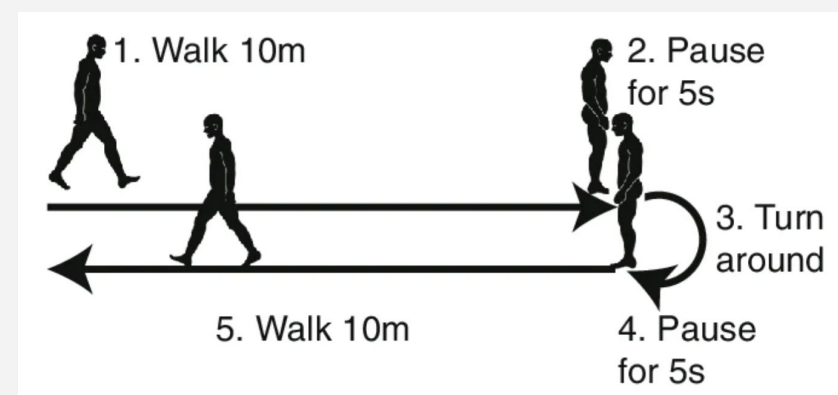


Figure 2: 2024 Final Design [2]



Figure 3: Bure Rise & Go Walker [3]

### Competing Designs

- Bure Rise & Go Walker has power standing and transfer assistance, lacks gait measurement capability [3]
- Research prototypes had FlexiForce™ sensors and IMUs, but not commercially available

## Fundamental Equations

$$R = \frac{c f_{IF}}{2S} \quad [5]$$

$$R_{max} = \frac{\sigma P_t G_{TX} G_{RX} \lambda^2 T_{meas}}{(4\pi^3 SNR_{min} kTF)^{\frac{1}{4}}} \quad [5]$$

R= Range  
c= Speed of light  
f<sub>IF</sub>= Frequency of IF signal  
S= Sweep rate  
σ= Target cross section  
P<sub>t</sub>= Transmitted Power  
G<sub>TX</sub>= TX antenna gain

G<sub>RX</sub>=RX antenna gain  
λ= Operating wavelength  
T<sub>meas</sub>= Total measurement time  
SNR= Signal-to-noise ratio  
k= Boltzmann constant  
T= Antenna temperature  
F= Receiver noise figure

## Problem Statement

- Clinicians lack objective tools to quantify walker use and track progress toward independence
- Limited mobility data makes Medicare/insurance documentation of functional improvement more difficult
- Device must measure load, gait speed, and walking distance
- Attachments must remain modular and compatible without compromising walker integrity
- System must be durable, compact, accurate, user-friendly, and provide real-time app-based data

## Design Criteria

- Must be able to withstand up to 100kg
- Record walking speed up to 10km/hr
- mmWave Radar must detect distances up to 45m
- Easy fixation and removal of electrical housing units
- Real-time display of data onto phone app
- System must be operable for a minimum of 45 minutes
- Electrical housing unit must stay at 45° to allow for accurate distance sensing
- System must be able to display data with a lag time of up to 500ms [4]

## Final Design

### 1. Load Detection: Load Cell

- Each load cell is embedded into a custom housing unit which slips into the walker leg
  - Material: Polylactic Acid (PLA)
  - Dimensions:
- End cap uses commercial walker-compatible tip for ground contact
- Change electrical resistance when deformed due to pressure which is measured and converted to voltage
  - Load capacity: 100kg per load cell [6]
  - Max Safe Overload: 150% of load capacity
- Signals amplified using HX711 load cell amplifier
- Signals read by Seed Studio microcontroller



Figure 4: ATO Miniature Compression Load Cell (5 kg–100 kg) [6]



Figure 5: 3D printed disk to hold load cell



Figure 6: Walker endcap [7]



Figure 7: Load cell housing

## Results and Discussion

### 1. Total Circuit

- End Caps**
  - XIAO ESP32S3 Arduino is the microsystem controller with Wi-Fi and bl
  - Microcontroller for system
  - Has Wi-Fi and Bluetooth capabilities
- mmWave Radar**
  - TI AWIR1843 Boost
  - RX and TX antennas for emitting and sending signals
  - Has Wi-Fi and Bluetooth capabilities
  - Emits frequency signal to measure range
  - Mathematically calculates range

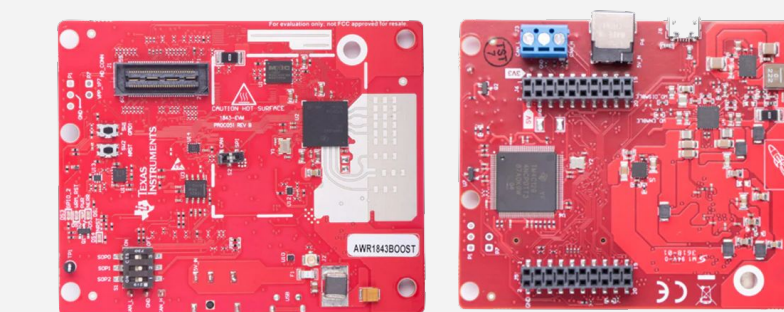


Figure 11: AWIR1843 Boost mmWave Radar [8]

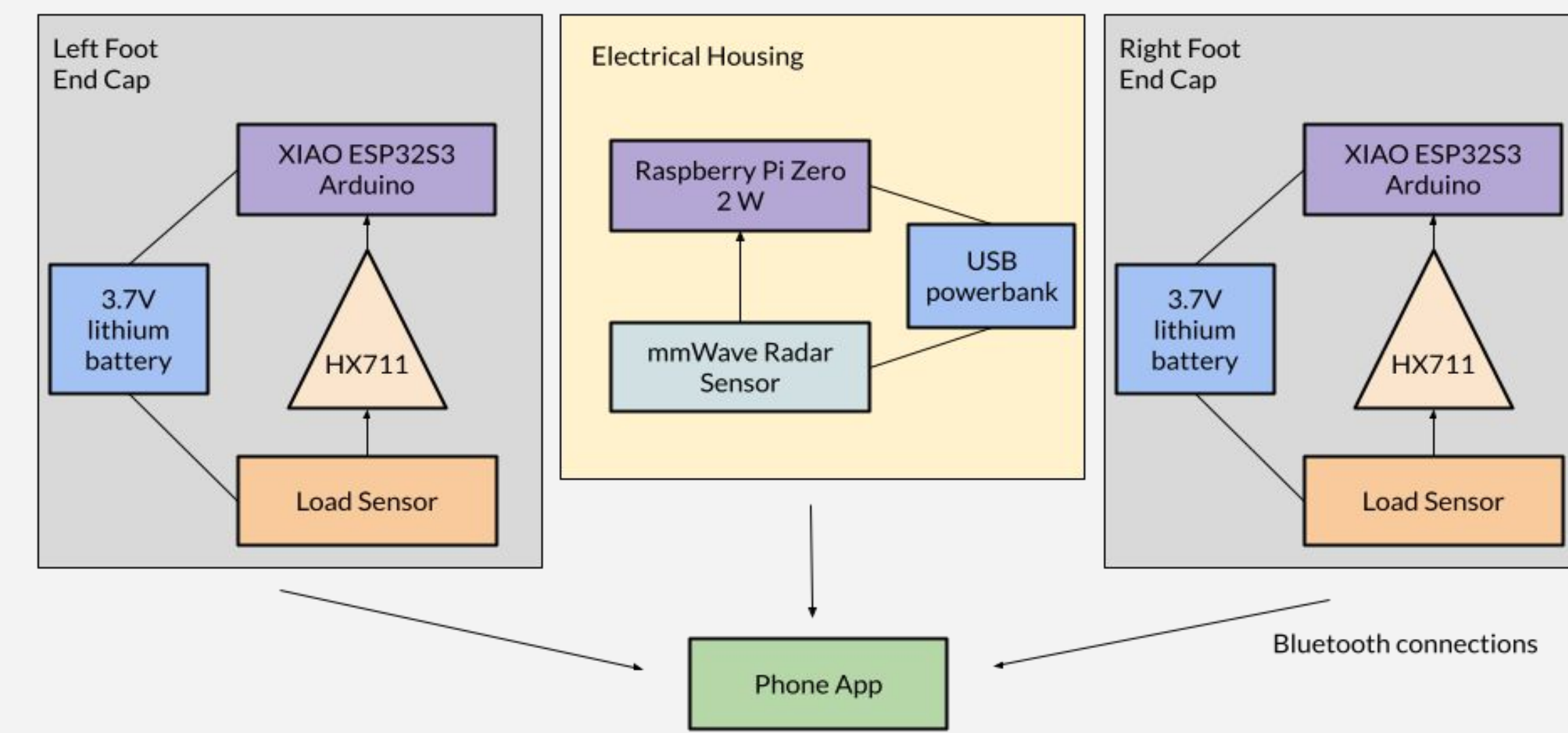


Figure 12: Electrical Workflow

### 2. Load Cell

- 10 reference loads from 20–180 lb were applied to the load cell
- Measured load cell values recorded on the app
- The load cells remained accurate until 120 lbs where the readings leveled off
- Average load error: 14.7% lb/lb
- The load cell exhibited systematic offset prior to calibration with linear response.

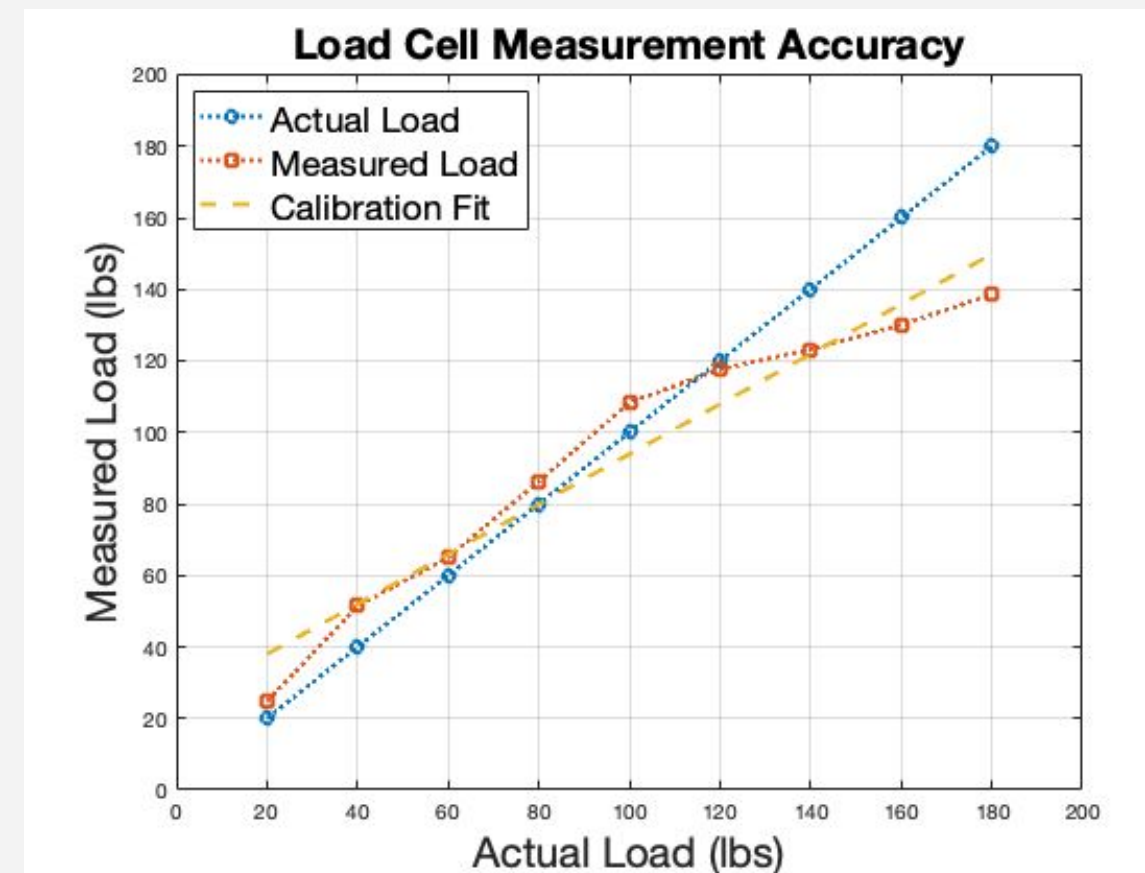


Figure 13: Load-cell measured vs actual load across the 20–180lb showing linear response.

### 3. mmWave Radar

- 5 distances between 2m to 10m were tested
- Measured distances of mmWave radar recorded on the app
- Actual distances recorded manually, and through Tracker Analysis app
- Measurements collected across 3 trials per distance
- Average distance error: 5.7% m/m

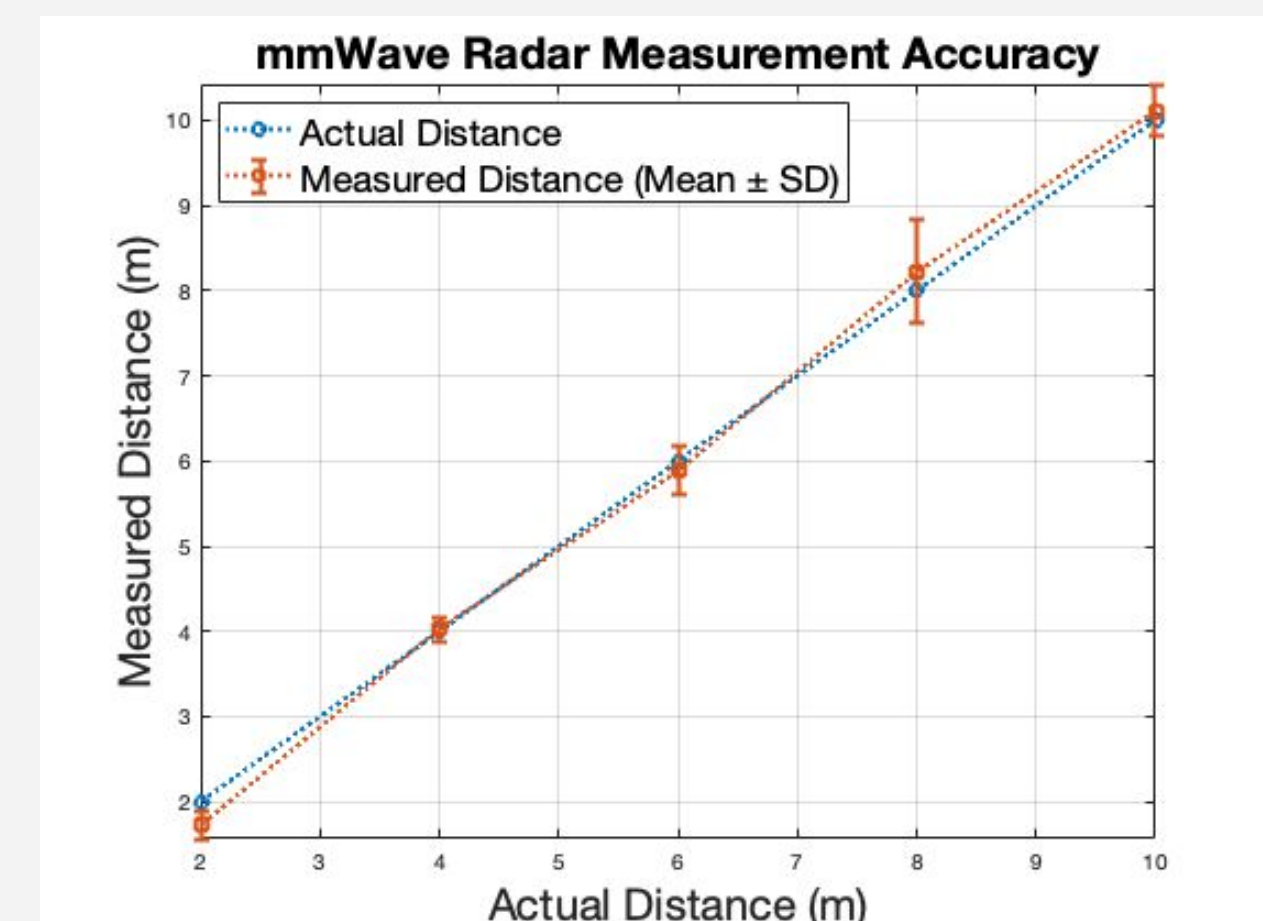


Figure 14: mmWave radar measured vs actual distance (mean ± SD) across the 2–10m

## Conclusion

The Smart Walker system integrates with any clinical walker while providing real-time data for patients through an mobile app. The modular design embeds dual load cells within custom end caps and an with a mmWave radar to quantify weight-bearing, distance, and speed.

## Future Works

- Alter load cell housing unit to minimise friction between the components
- Develop an algorithm to track non-linear motion through the mmWave radar
- Record gait speed

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- Dr. Tracy Puccinelli
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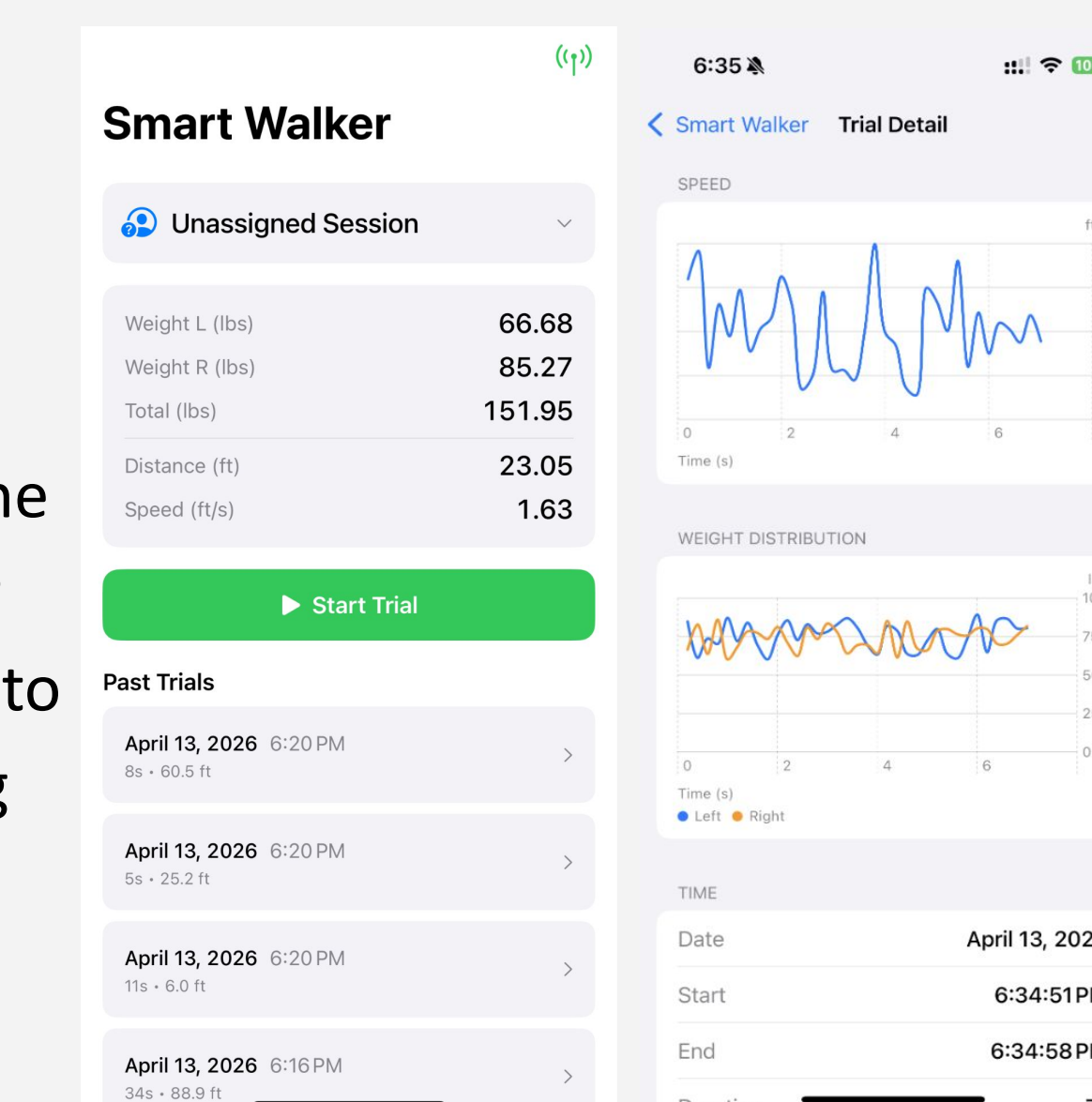


Figure 9 and 10: IOS App UI and Data Display