Mobility Lab provides sensitive, valid and reliable outcome measures.

With hundreds of universities and hospitals using this system worldwide, Mobility Lab is the most trusted wearable gait and balance system on the market.

Using APDM’s advanced wearable sensors (Opals), Mobility Lab makes it easy to collect, analyze, and store outcome measures. Attach sensors to your subject, and instruct them to perform a standardized test. A report is then automatically generated to compare against normative values. This process takes less than five minutes.

What Can You Measure?

**GAIT**

**Lower Limb**
- Cadence
- Foot Clearance
- Gait Cycle Duration
- Gait Speed
- Double Limb Support
- Lateral Step Variability
- Lateral Swing Max
- Pitch at Initial Contact
- Pitch at Toe Off
- Stance
- Step Duration
- Stride Length
- Swing
- Toe Out Angle

**Upper Limb**
- Maximum Velocity
- Range of Motion

**BALANCE**

**Trunk**
- Coronal Range of Motion
- Sagittal Range of Motion
- Transverse Range of Motion

**Lumbar**
- Coronal Range of Motion
- Sagittal Range of Motion
- Transverse Range of Motion

**Head**
- Coronal Range of Motion
- Sagittal Range of Motion
- Transverse Range of Motion

**Postural Sway**
- 95% Ellipse Sway Area
- RMS Sway
- Coronal RMS Sway
- Sagittal RMS Sway

**Turning**
- Angle
- Duration
- Maximum Velocity

**Sit to Stand**
- Lean Angle
- Duration

**Stand to Sit**
- Lean Angle
- Duration
### Lower Limb

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadence</td>
<td>The number of steps per minute, counting steps made by both feet</td>
</tr>
<tr>
<td>Gait Cycle Duration</td>
<td>The duration of the gait cycle (one left plus right step duration)</td>
</tr>
<tr>
<td>Gait Speed</td>
<td>The forward distance (2 step lengths) travelled during the gait cycle divided by the gait cycle duration</td>
</tr>
<tr>
<td>Foot Clearance</td>
<td>The height of the sensor on the foot, relative to its start position during standing and measured at mid-swing</td>
</tr>
<tr>
<td>Double Support</td>
<td>The percentage of the gait cycle in which both feet are on the ground</td>
</tr>
<tr>
<td>Lateral Step Variability</td>
<td>In three consecutive steps, the perpendicular deviation of the middle foot placement from the line connecting the first and the third step</td>
</tr>
<tr>
<td>Lateral Swing Max</td>
<td>The amount that the foot travels perpendicular to forward movement while swinging forward during an individual stride</td>
</tr>
<tr>
<td>Pitch at Initial Contact</td>
<td>The dorsiflexion of the foot at initial contact (typically heel strike)</td>
</tr>
<tr>
<td>Pitch at Toe Off</td>
<td>The plantar flexion of the foot just as it leaves the floor at push off</td>
</tr>
<tr>
<td>Stance</td>
<td>The percentage of the gait cycle in which the foot is on the ground</td>
</tr>
<tr>
<td>Step Duration</td>
<td>The duration of a step</td>
</tr>
<tr>
<td>Stride Length</td>
<td>The forward distance travelled by a foot during a gait cycle</td>
</tr>
<tr>
<td>Swing</td>
<td>The percentage of the gait cycle in which the foot is not on the ground</td>
</tr>
<tr>
<td>Toe Out Angle</td>
<td>The lateral angle of the foot during the stance phase, relative to the forward motion of the gait cycle</td>
</tr>
</tbody>
</table>

### Upper Limb

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Velocity</td>
<td>The maximum rotational velocity of the arm swing</td>
</tr>
<tr>
<td>Range of Motion</td>
<td>The angular range of the arm swing</td>
</tr>
</tbody>
</table>

### Sternum Range of Motion

<table>
<thead>
<tr>
<th>Plane</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>The angular range of the thoracic spine in the coronal plane (roll)</td>
</tr>
<tr>
<td>Sagittal</td>
<td>The angular range of the thoracic spine in the sagittal plane (pitch)</td>
</tr>
<tr>
<td>Transverse</td>
<td>The angular range of the thoracic spine in the transverse plane (yaw)</td>
</tr>
</tbody>
</table>

### Lumbar Range of Motion

<table>
<thead>
<tr>
<th>Plane</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>The angular range of the lumbar spine in the coronal plane (roll)</td>
</tr>
<tr>
<td>Sagittal</td>
<td>The angular range of the lumbar spine in the sagittal plane (pitch)</td>
</tr>
<tr>
<td>Transverse</td>
<td>The angular range of the lumbar spine in the transverse plane (yaw)</td>
</tr>
</tbody>
</table>

### Sit To Stand

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>The duration of the sit to stand transition</td>
</tr>
<tr>
<td>Lean Angle</td>
<td>The angular range of motion of the trunk during the sit to stand transition</td>
</tr>
</tbody>
</table>

### Stand To Sit

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>The duration of the stand to sit transition</td>
</tr>
<tr>
<td>Lean Angle</td>
<td>The angular range of motion of the trunk during the stand to sit transition</td>
</tr>
</tbody>
</table>

### Turning

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>The rotational angle of the turn</td>
</tr>
<tr>
<td>Duration</td>
<td>The duration of the turn</td>
</tr>
<tr>
<td>Velocity</td>
<td>The peak angular velocity of the turn</td>
</tr>
</tbody>
</table>

### Postural Sway

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% Ellipse Sway Area</td>
<td>The area of an ellipse covering 95% of the sway angle in both the coronal and sagittal planes</td>
</tr>
<tr>
<td>RMS Sway</td>
<td>The extent of postural sway calculated as the root mean square (RMS) of the sway angle in both the coronal and sagittal planes</td>
</tr>
<tr>
<td>Coronal RMS Sway</td>
<td>The extent of postural sway calculated as the root mean square (RMS) of the sway angle in the coronal plane</td>
</tr>
<tr>
<td>Sagittal RMS Sway</td>
<td>The extent of postural sway calculated as the root mean square (RMS) of the sway angle in the sagittal plane</td>
</tr>
</tbody>
</table>
PORTABLE
Set up in any location with our lightweight, wireless system

RELIABLE
Numerous clinical studies have proven high test-retest reliability

SENSITIVE
Accurately measure minimally detectable changes

VALID
Algorithms validated against video motion capture and force plate systems
• Simoes. “Feasibility of Wearable Sensors to Determine Gait Parameters.” University of South Florida. 2011
• Beach. “Effect of Compliant Flooring on Postural Stability in an Older Adult Population and in Individuals with Parkinson’s Disease.” University of Dayton. 2013.
• Martori. “A Wearable Motion Analysis System to Evaluate Gait Deviations.” University of South Florida. 2013
• Balasubramanian. “Age Related Changes in Balance and Gait.” Arizona State University. 2014
• Curtze, et al. “Levodopa is a Double Edged Sword for Balance and Gait in People with Parkinson’s Disease.” Movement Disorders. 2015
• Mancini, et al. “Continuous Monitoring of Turning in Parkinson’s Disease: Rehabilitation Potential.” NeuroRehabilitation. 2015
• McConnell & Silverman. “Comparing Usability and Variance of Low and High Technology Approaches to Gait Analysis in Healthy Adults.” University of Nevada. 2015
GAIT CYCLE ANALYSIS 1

BODY PLANES 2

SENSOR CONFIGURATIONS AND MEASURES 3

MOBILITY LAB TEST MEASURES 4

FULL BODY GAIT MEASURES 5

• Gait Cycle Analysis
  Stance
  Swing
  Gait Cycle Duration
  Gait Speed

• Double Support

• Spatial Analysis
  Cadence
  Step Duration
  Stride Velocity
  Stride Length
  Toe Out Angle

• Lateral Step Variability

• Circumduction
  Lateral Swing Max

• Clearance

• Heel Pitch

• Toe Pitch

• Arm Range Of Motion
  Arm Swing Velocity

POSTURAL TRANSITION MEASURES 8

• Turning Analysis
  Turn Angle
  Turn Duration
  Turn Velocity

• Sit To Stand Analysis
  Lean Angle
  Duration

• Turn To Sit Analysis
  Turn duration
  Turn Velocity

• Trunk Range Of Motion

POSTURAL SWAY MEASURES 10

• Postural Sway
  95% Ellipse Sway Area
  95% Ellipse Rotation
  RMS Sway
  Mean Velocity

MOBILITY LAB FOOTPLATE 11

TESTS 12

• Walk Test
• Timed Up and Go Test
• Postural Sway Test
• mCTSIB Test
• BESS Test
• mBESS Test
• 360º Turn Test
• 5x Sit To Stand
BODY PLANES

Coronal Plane

Sagittal Plane

Transverse Plane
SENSOR CONFIGURATIONS AND MEASURES

BALANCE
1 OPAL

BALANCE, LOWER LIMB GAIT, TURNING
3 OPALS

BALANCE, LOWER LIMB GAIT, UPPER LIMB GAIT, TURNING, SIT TO STAND
6 OPALS
# MOBILITY LAB TEST MEASURES

**TESTS**

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Opal sensor</td>
<td>3 Opal sensors</td>
<td>6 Opal sensors</td>
</tr>
</tbody>
</table>

- **Lower Limb**
  - Cauter
  - Gait Cycle Duration
  - Gait Speed
  - Foot Clearance
  - Double Support
  - Lateral Step Variability
  - Circumduction
  - Foot Strike Angle
  - Toe Off Angle
  - Stance
  - Step Duration
  - Stride Length
  - Swing
  - Toe Out Angle

- **Upper Limb**
  - Maximum Velocity
  - Range of Motion

- **Sternum Range of Motion**
  - Coronal
  - Sagittal
  - Transverse

- **Lumbar Range of Motion**
  - Coronal
  - Sagittal
  - Transverse

- **Sit To Stand**
  - Duration
  - Lean Angle

- **Stand To Sit**
  - Duration
  - Lean Angle

- **Turning**
  - Angle
  - Duration
  - Velocity
  - Steps in Turn

- **Postural Sway**
  - 95% Ellipse Sway Area
  - RMS Sway
  - Coronal RMS Sway
  - Sagittal RMS Sway

- **Walking**
  - TUG
  - Sway
  - CTSIB
  - BESS
  - mBESS

- **360° Turn**

- **Sit to Stand**
Gait measures are detected, analyzed, and averaged over the extent of the walking duration of the subject. All measures are assessed for asymmetry and variability.

**FULL BODY GAIT MEASURES**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Cycle Duration</td>
<td>seconds</td>
</tr>
<tr>
<td>Gait Speed</td>
<td>m/s</td>
</tr>
</tbody>
</table>

**GAIT CYCLE ANALYSIS**

- **Stance %**
- **Swing %**

**DOUBLE SUPPORT**

- **Double Support %**

**TERMINAL DOUBLE SUPPORT**

- **Terminal Double Support %**
HEEL/TOE PITCH

- Pitch at Toe Off degrees
- Pitch at Initial Contact degrees

ARM RANGE OF MOTION

- Range of Motion degrees
- Arm Swing Velocity deg/s
POSTURAL TRANSITION MEASURES

Postural transitions are detected, analyzed, and averaged over the extent of the walking duration of the subject.

TURNING ANALYSIS

SIT TO STAND ANALYSIS
TURN TO SIT ANALYSIS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn Duration</td>
<td>Time taken to turn</td>
<td>seconds</td>
</tr>
<tr>
<td>Turn Velocity</td>
<td>Angular velocity of turn</td>
<td>deg/s</td>
</tr>
<tr>
<td>Sagittal Range of Motion</td>
<td>Anterior-posterior movement</td>
<td>degrees</td>
</tr>
<tr>
<td>Transverse Range of Motion</td>
<td>Lateral movement of trunk</td>
<td>degrees</td>
</tr>
<tr>
<td>Coronal Range of Motion</td>
<td>Front-back movement of trunk</td>
<td>degrees</td>
</tr>
</tbody>
</table>

TRUNK RANGE OF MOTION
All postural sway measures are assessed using the Opal movement sensor placed on a subject’s lumbar. All metrics are reported in Coronal, Sagittal and Transverse planes.
The Mobility Lab Footplate is designed to standardize stance width for each Mobility Lab test. All norms are derived from subjects using the standardized stance width measured by the Footplate. Standard instructions for some tests instruct the subject stand with their feet together to induce instability, but research has shown that using Mobility Lab with a wider stance is equally as sensitive and puts the subject at less of a risk of falling during the tests.
The Walk test is the most comprehensive test to measure a subject’s gait. We recommend that your subject walks for at least 2 minutes in order to collect a sufficient amount of gait cycles to accurately measure variability and asymmetry.

**TEST MEASURES:**
Full body gait (legs, arms, and trunk), asymmetry, variability and turning

**NUMBER OF SENSORS:** 3 or 6

**SETUP:**
1. Walking corridor must be at least 7 meters in length

**PROTOCOL:**
1. Select Walk and press start trial.
2. Subject should stand comfortably and wait for instruction to begin walking.
3. When the subject is ready, press record and instruct the subject to walk.
4. The subject can walk freely in a straight path and perform 180 degree turns when necessary.
5. Terminate the trial at any point.

**NORMATIVE VALUES:**
Normative values were collected using a 2 minute walk in a corridor 7 meters or longer with 180 degree turns at both ends.
Timed Up and Go (TUG) is a common test to assess a subject’s mobility. APDM has made it more valuable by giving you the ability to precisely measure all of the components of mobility, rather than just duration.

**TEST MEASURES:**
Postural transitions (sit, stand, and turning)

**NUMBER OF SENSORS:** 3 or 6

**SETUP:**
1. Measure 7 meters, placing tape at the two ends.
2. Place an armless chair at the start before the tape.

**PROTOCOL:**
1. Select TUG and press start test.
2. Subject should sit comfortably in the chair with their arms on their legs, and back against the seat.
3. When the subject is ready, press record and the test will begin to count down from 3 seconds.
4. The subject should rise from the chair without using their arms and begin walking. If the subject is unable to rise from the chair with arms, reset the test and allow them to use their arms to stand.
5. After the subject walks passed the 7m end tape, they should turn 180 degrees and walk back.
6. Once they arrive at the chair they should turn 180 degrees, and sit down.
7. Terminate the trial when the subject rests their back against the back of the seat.

**NORMATIVE VALUES:**
Normative values were collected using the protocol listed above.
The instrumented Postural Sway (Sway) test is a common test of quiet stance balance. It is a very simple test comprising of only one sensor on the lumbar. The test takes only 30 seconds to administer.

**TEST MEASURES:**
Postural sway

**NUMBER OF SENSORS:** 1 or 3 or 6

**SETUP:**
1. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

**PROTOCOL:**
1. Select Sway and press start test.
2. Subject should stand comfortably with their hands at their side or across their chest.
3. Press start and wait for the test to count down from 30 seconds.

**NORMATIVE VALUES:**
Normative values were collected with eyes open on a hard surface with arms crossed.
The modified Clinical Test of Sensory Interaction and Balance (mCTSIB) is a composite test to assess a subject’s balance under different test conditions.

**TEST MEASURES:**
Postural sway, visual dependence, proprioceptive dependence, and vestibular loss

**NUMBER OF SENSORS:** 1 or 3 or 6

**SETUP:**
1. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

**PROTOCOL:**
1. Select CTSIB and press start test.
2. Subject should stand comfortably with their feet together and hands at their side.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the next test condition.

**TEST CONDITIONS:**
1. Eyes Open, Hard Surface
2. Eyes Closed, Hard Surface
3. Eyes Open, Foam Surface
4. Eyes Closed, Foam Surface

**NORMATIVE VALUES:**
Normative values were collected following the protocol listed above.
The Balance Error Scoring System (BESS) test is a measure of assessing static postural stability. It is designed for the mild head injury population, and to assist in return to sports play decisions.

**TEST MEASURES:**
Postural stability in varying conditions

**NUMBER OF SENSORS:** 1 or 3 or 6

**SETUP:**
1. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

**PROTOCOL:**
1. Select BESS and press start test.
2. Subject should stand according to the test condition with their hands on their hips, and their eyes closed.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the next test condition.

**TEST CONDITIONS:**
1. Eyes Closed, Double Support, Hard Surface
2. Eyes Closed, One Leg, Hard Surface
3. Eyes Closed, Tandem Stance, Hard Surface
4. Eyes Closed, Double Support, Foam Surface
5. Eyes Closed, One Leg, Foam Surface
6. Eyes Closed, Tandem Stance, Foam Surface

**NORMATIVE VALUES:**
Normative values were collected following the protocol listed above.
The modified Balance Error Scoring System (mBESS) test is a shortened version of the BESS test. It is a measure of assessing static postural stability, designed for the mild head injury population, and to assist in return to sports play decisions.

**TEST MEASURES:**
Postural stability in varying conditions

**NUMBER OF SENSORS:** 1 or 3 or 6

**SETUP:**
1. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

**PROTOCOL:**
1. Select mBESS and press start test.
2. Subject should stand according to the test condition with their hands on their hips, and their eyes closed.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the next test condition.

**TEST CONDITIONS:**
1. Eyes Closed, Double Support, Hard Surface
2. Eyes Closed, One Leg, Hard Surface
3. Eyes Closed, Tandem Stance, Hard Surface

**NORMATIVE VALUES:**
Normative values were collected following the protocol listed above.
**360° TURN**

The 360 degree Turn Test is a measure of dynamic balance. The subject turns in a complete circle (360 degrees) while time to complete and/or number of steps to complete the turn are recorded.

**TEST MEASURES:**

Turn velocity, time, number of steps

**NUMBER OF SENSORS:** 6

**SETUP:**

1. Place a piece of masking tape on the floor to mark the start/stop position. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

**PROTOCOL:**

1. Select 360° Turn and press start test.
2. Subject should stand with their toes aligned with the tape.
3. Press start and wait for the subject to complete a full turn. Press stop when the subject’s shoulders are back in the start position.

**NORMATIVE VALUES:**

Normative values were collected following the protocol listed above.
The 5 Times Sit to Stand (5xSTS) test is a measure of functional lower limb muscle strength. It is useful in quantifying functional change of transitional movements.

TEST MEASURES:
Trunk excursion, stand time, cadence, total time

NUMBER OF SENSORS: 6

SETUP:
1. It is preferable to use a chair with no armrests, to ensure that subjects stand without assistance.

PROTOCOL:
1. Select 5x Sit to Stand and press start test.
2. Subject should sit with their back against the back of the chair.
3. Press start and wait for the subject to stand up completely, then return to the sitting position. Press stop when the subject has returned to the sitting position the 5th time.

NORMATIVE VALUES:
Normative values were collected following the protocol listed above.