WHITEPAPER

MOBILITY LAB BY APDM

Mobility Lab provides sensitive, valid and reliable outcome measures.

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 Support
- Terminal Double Support
- Lateral Step Variability
- Circumduction
- Dorsiflexion
- Plantarflexion
- Stance
- Step Duration
- Stride Length
- Swing
- Toe Out Angle
- Stride Length Variability

Upper Limb

- Arm Swing Velocity
- Arm Range of Motion

Anticipatory Postural Adjustment

- APA Duration
- First Step Duration
- First Step Range of Motion
- Sagittal APA Peak
- Coronal APA Peak

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

Postural Sway

- 95% Ellipse Sway Area
- RMS Sway
- Centroidal Frequency
- Frequency Dispersion
- Jerk
- Mean Velocity
- Path Length
- Range

Sit to Stand

- Lean Angle
- Duration

Stand to Sit

- Lean Angle
- Duration

Turning

- Angle
- Duration
- Turn Velocity
- Steps in Turn

CLIENTS

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

MAYO CLINIC

NASA

Microsoft

intel

UT SOUTHWESTERN MEDICAL CENTER

NIH National Institutes of Health

NATIONAL PARKINSON FOUNDATION

HARVARD UNIVERSITY

USA GYMNASTICS.

THE MICHAEL J. FOX FOUNDATION FOR PARKINSON'S RESEARCH

KU MEDICAL CENTER The University of Kansas

Carolinas Medical Center Carolinas HealthCare System

McGill

P&G

Massachusetts Institute of Technology

PROVIDENCE Health & Services

University of Michigan

Stanford HEALTH CARE STANFORD MEDICINE

OREGON HEALTH & SCIENCE UNIVERSITY OHSU

JOHNS HOPKINS UNIVERSITY

VERTEX

St. Joseph Health St. Jude Heritage Medical Group A member of the St. Joseph Hoag Health alliance

RIC Rehabilitation Institute of Chicago

USA DIVING

Imperial College London

Barwon Health

The Children's Hospital of Philadelphia

Hebrew SeniorLife

Shriners Hospitals for Children

DEPARTMENT OF THE NAVY · UNITED STATES OF AMERICA

DEPARTMENT OF VETERANS AFFAIRS · UNITED STATES OF AMERICA

DEPARTMENT OF THE AIR FORCE · UNITED STATES OF AMERICA

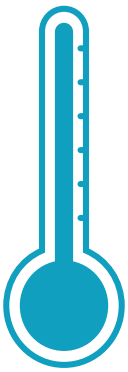
UNITED STATES ARMY

PORTABLE

Set up in any location with our lightweight, wireless system

RELIABLE

Numerous clinical studies have proven high test-retest reliability

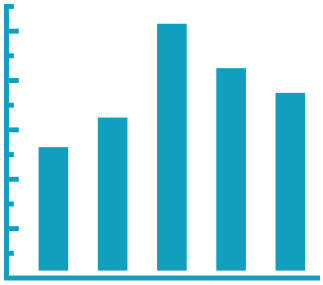


SENSITIVE

Accurately measure minimally detectable changes

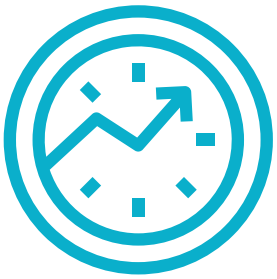
VALID

Algorithms validated against gold standard motion capture systems



MEASURE OBJECTIVELY

Easily interpret and export data automatically broken into gait cycles



LONGITUDINAL STUDIES

Precisely see asymmetries and minimal detectable changes over time

REDUCE COSTS

Save time and perform complete movement analysis without a motion capture lab

NO LIMITS

Long battery life and synchronized logging for continuous monitoring outside the lab

DEFINITIONS

Lower Limb	
Cadence	The number of steps per minute, counting steps made by both feet
Gait Cycle Duration	The duration of a full gait cycle, measured from the left foot's initial contact to the next initial contact of the left foot
Gait Speed	The forward speed of the subject, measured as the forward distance traveled during the gait cycle divided by the gait cycle duration
Foot Clearance	The height of the foot sensor measured at midswing, relative to its start position while standing
Double Support	The percentage of the gait cycle in which both feet are on the ground
Lateral Step Variability	In a series of 3 consecutive foot placements of the same foot, the variability of perpendicular deviations of the middle foot placement from the line connecting the first and third
Circumduction	The amount that the foot travels perpendicular to forward movement while swinging forward during an individual stride
Foot Strike Angle	The angle of the foot at the point of initial contact. The pitch of the foot when flat is zero and positive when the heel contacts first.
Toe Off Angle	The angle of the foot as it leaves the floor at push-off. The pitch of the foot when flat is zero.
Stance	The percentage of the gait cycle in which the foot is on the ground
Step Duration	The duration of a step, measured as the period from initial contact of one foot to the next initial contact of the opposite foot
Stride Length	The forward distance travelled by a foot during a gait cycle
Swing	The percentage of the gait cycle in which the foot is not on the ground
Toe Out Angle	The lateral angle of the foot during the stance phase, relative to the forward motion of the gait cycle. Positive angle is outward rotation.
Upper Limb	
Arm Swing Velocity	The maximum rotational velocity of the arm swing
Arm Swing Range of Motion	The angular range of the arm swing
Trunk Range of Motion	
Coronal	The angular range of the thoracic spine in the coronal plane (roll)
Sagittal	The angular range of the thoracic spine in the sagittal plane (pitch)
Transverse	The angular range of the thoracic spine in the transverse plane (yaw)
Lumbar Range of Motion	
Coronal	The angular range of the lumbar spine in the coronal plane (roll)
Sagittal	The angular range of the lumbar spine in the sagittal plane (pitch)
Transverse	The angular range of the lumbar spine in the transverse plane (yaw)
Sit To Stand	
Duration	The duration of the sit to stand transition
Lean Angle	The angular range of motion of the trunk during the sit to stand transition
Stand To Sit	
Duration	The duration of the stand to sit transition
Lean Angle	The angular range of motion of the trunk during the stand to sit transition
Turning	
Angle	The rotational angle of the turn
Duration	The duration of the turn
Velocity	The peak angular velocity of the turn
Postural Sway	
Sway Area	The area of an ellipse covering 95% of the sway angle in both the coronal and sagittal planes
RMS Sway	The root mean square (RMS) of the sway angle in both the coronal and sagittal planes
Coronal RMS Sway	The root mean square (RMS) of the sway angle in the coronal plane
Sagittal RMS Sway	The root mean square (RMS) of the sway angle in the sagittal plane
Anticipatory Postural Adjustment	
Duration	The duration of the period starting from the first measurable change of the lateral lumbar acceleration from baseline, to the return to baseline
First Step Duration	The duration of the period spanning from the end of the APA to the initial contact of the first step
First Step Range of Motion	The integrated angular velocity of the stepping foot from the end of the APA to the initial contact of the step
Forward APA Peak	The peak forward lumbar acceleration during the APA
Lateral APA Peak	The peak lateral lumbar acceleration during the APA

PUBLICATIONS

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- Espay, et al. "**Technology in Parkinson's Disease: Challenges and Opportunities**." *Movement Disorders*. 2016
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- Horak, et al. "**Potential of APDM Mobility Lab for the Monitoring of the Progression of Parkinson's Disease**." *Expert Review of Medical Devices*. 2015
- Hollman, et al. "**A Comparison of Variability in Spatiotemporal Gait Parameters Between Treadmill and Overground Walking Conditions**." *Gait and Posture*. 2015

PUBLICATIONS

- Curtze, et al. "**Levodopa is a Double Edged Sword for Balance and Gait in People with Parkinson's Disease**." *Movement Disorders*. 2015
- Coulthard, et al. "**Evaluation of an Inertial Sensor System for Analysis of Timed-Up-and-Go Under Dual-Task Demands**." *Gait & Posture*. 2015
- Cohen, et al. "**Lighten Up: Specific Postural Instructions Affect Axial Rigidity and Step Initiation in Patients with Parkinson's Disease**." *NeuroRehabilitation and Neural Repair*. 2015
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- King, et al. "**Exploring Outcome Measures for Exercise Intervention in People with Parkinson's Disease**." *Parkinson's Disease*. 2013
- Fling, et al. "**Asymmetric Pedunculopontine Network Connectivity in Parkinsonian Patients with Freezing of Gait**." *Brain - A Journal of Neurology*. 2013
- Beach. "**Effect of Compliant Flooring on Postural Stability in an Older Adult Population and in Individuals with Parkinson's Disease**." University of Dayton. 2013.
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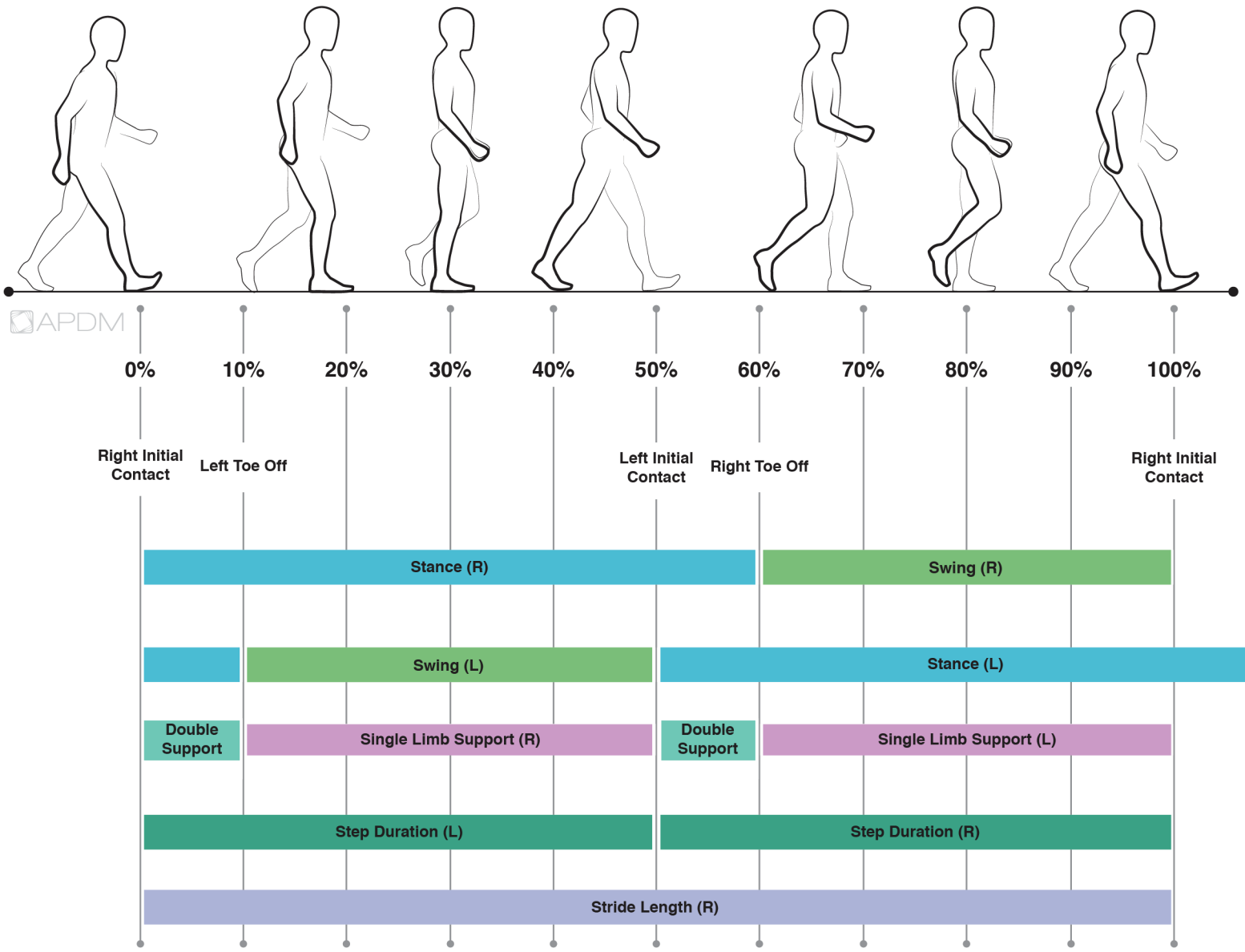
- Simoes. "**Feasibility of Wearable Sensors to Determine Gait Parameters**." University of South Florida. 2011

CONTENTS

GAIT CYCLE ANALYSIS



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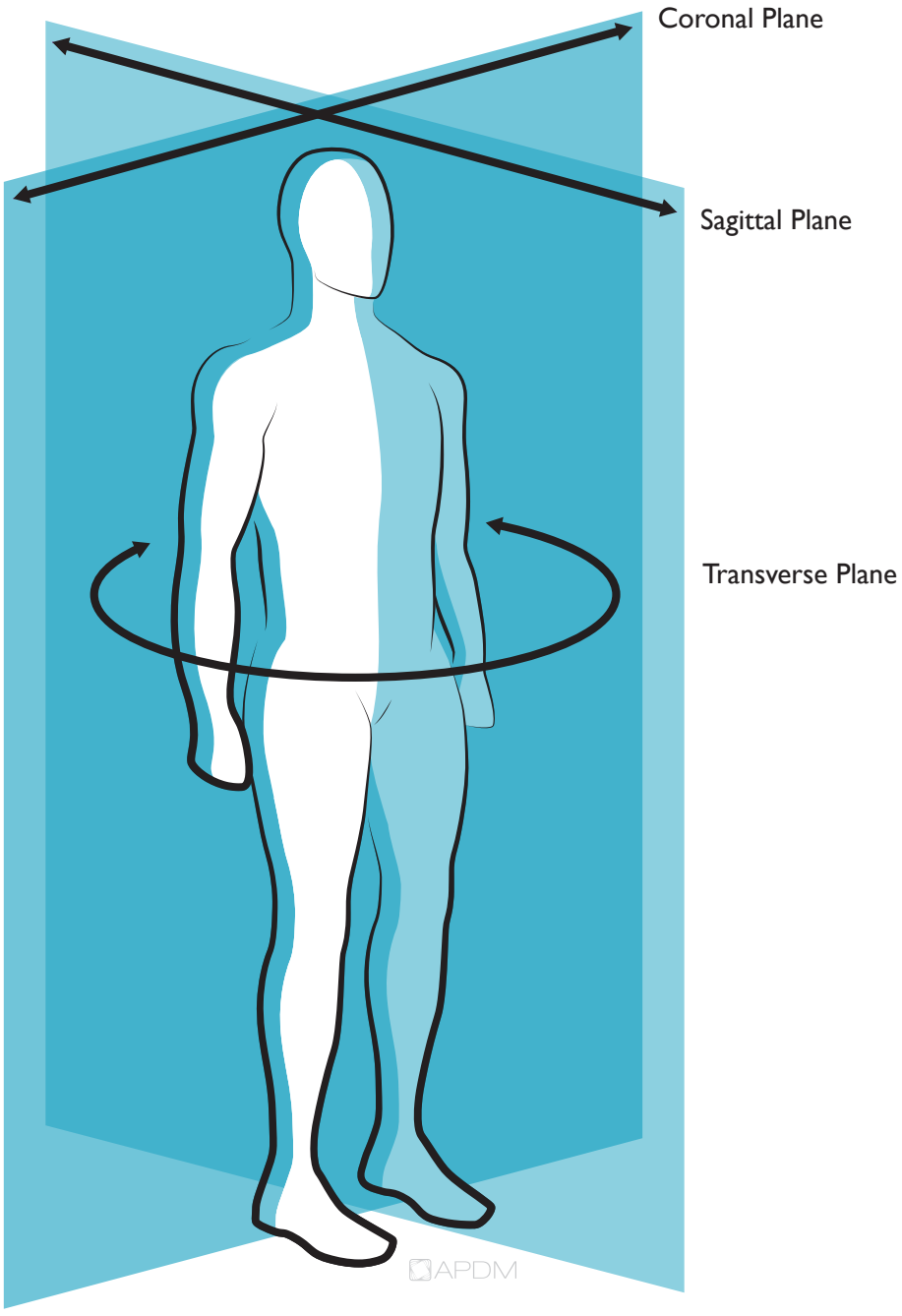
BODY PLANES



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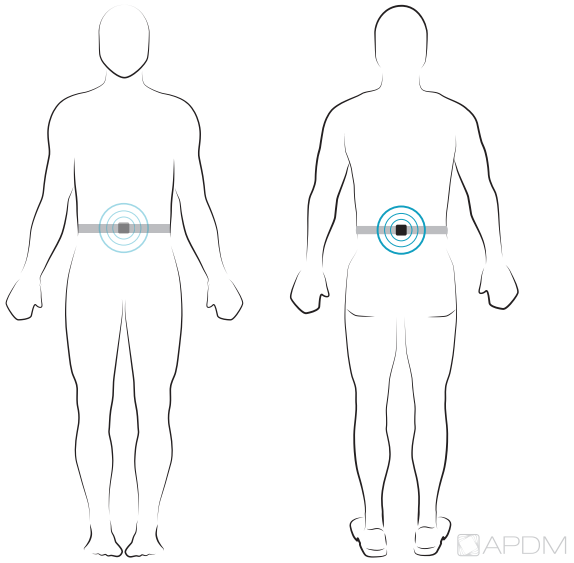
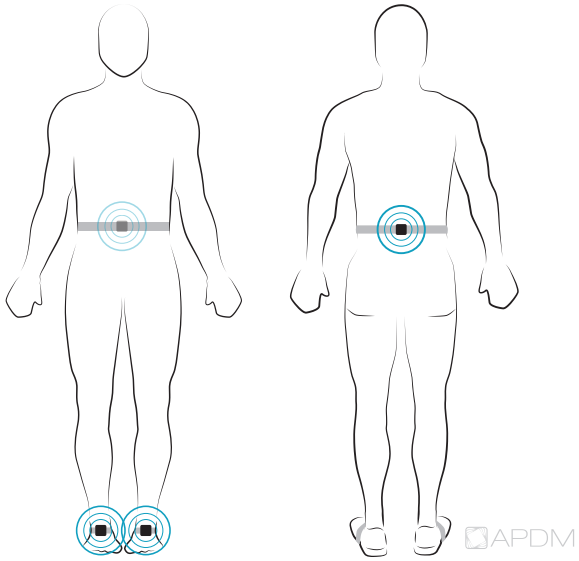
SENSOR CONFIGURATIONS AND MEASURES

BALANCE



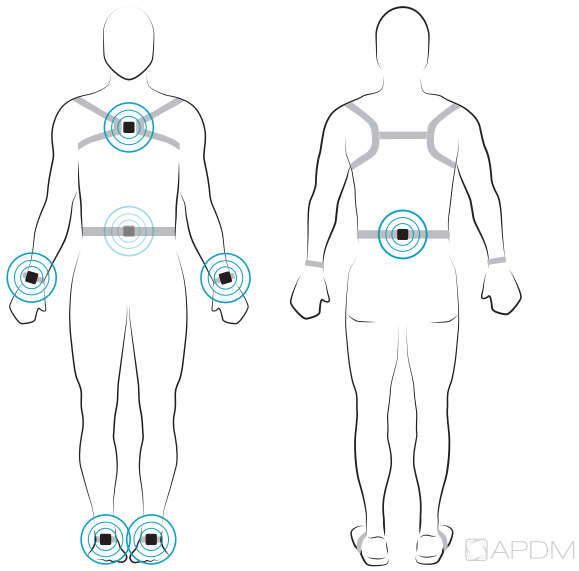
1 OPAL

BALANCE, LOWER LIMB GAIT, TURNING



3 OPALS

BALANCE, LOWER LIMB GAIT, UPPER LIMB GAIT, TURNING, SIT TO STAND



6 OPALS

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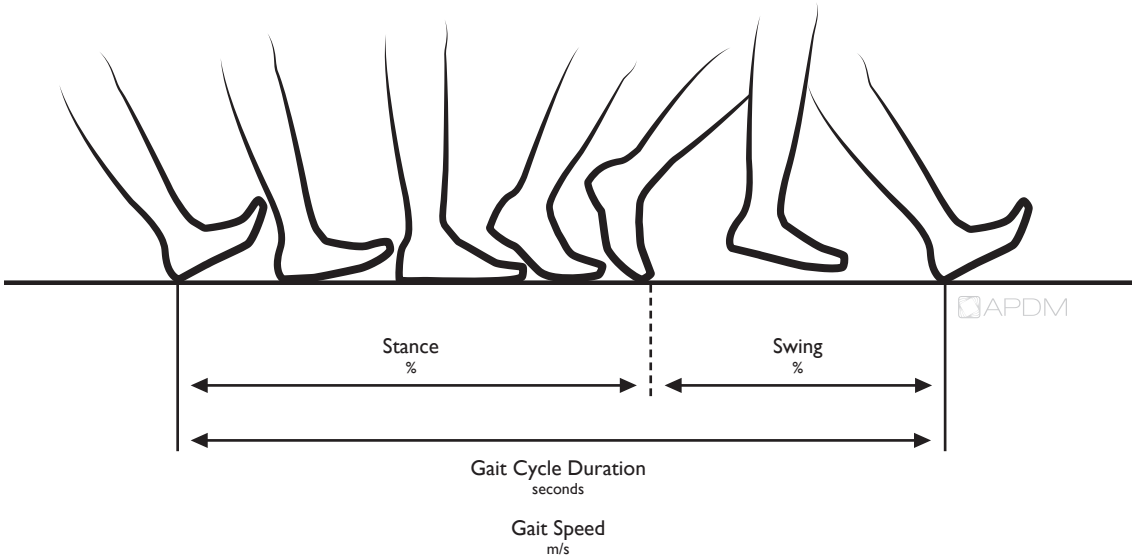
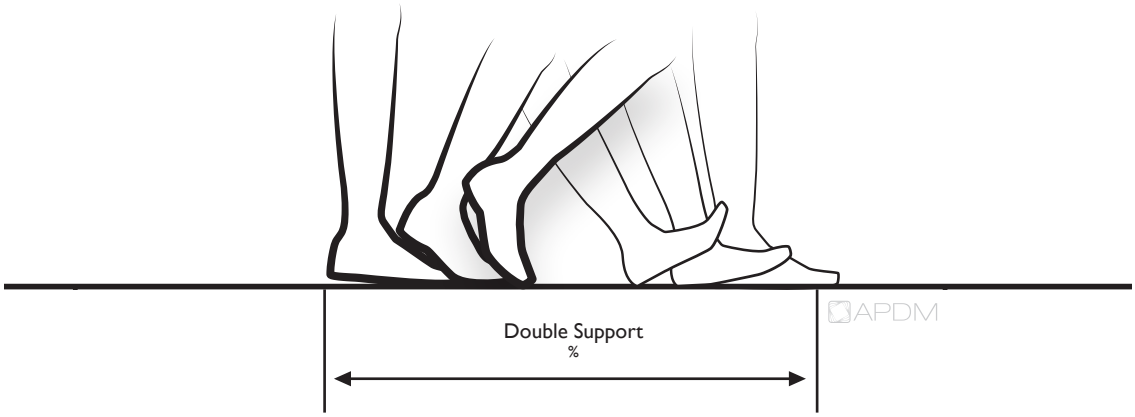
FULL BODY GAIT MEASURES

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.

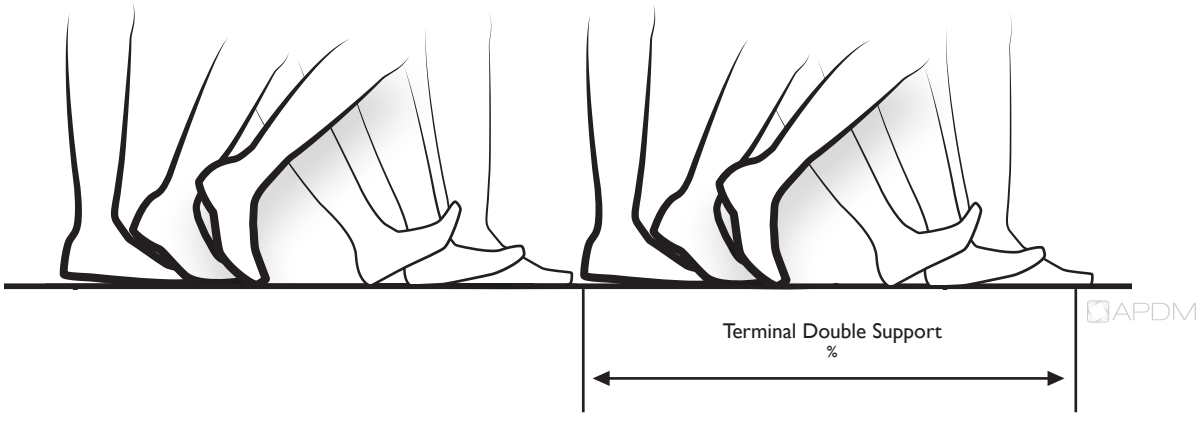
GAIT CYCLE ANALYSIS



DOUBLE SUPPORT



TERMINAL DOUBLE SUPPORT



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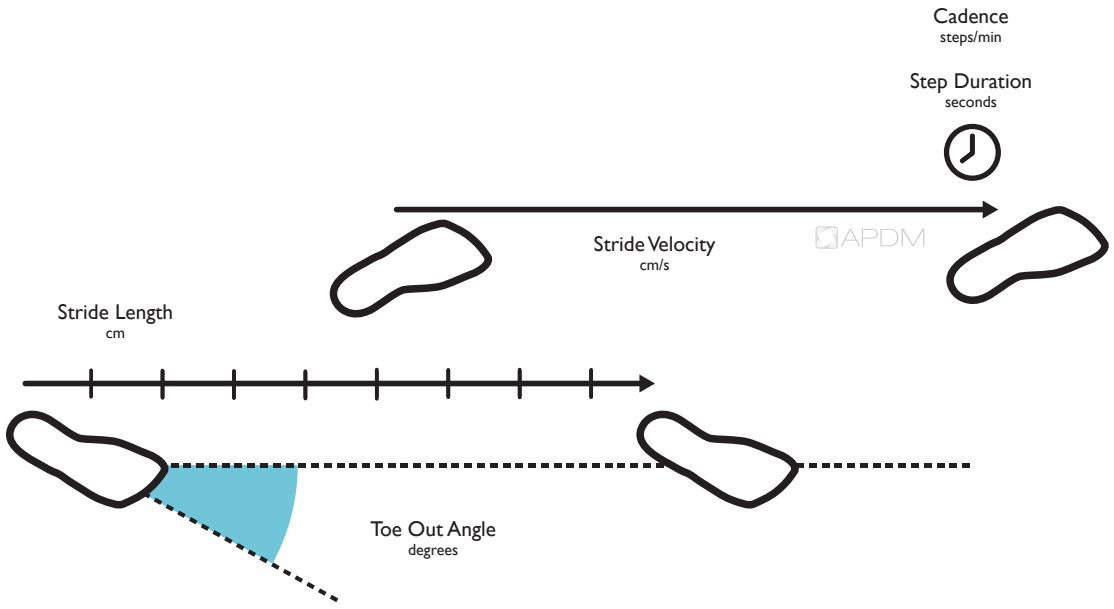
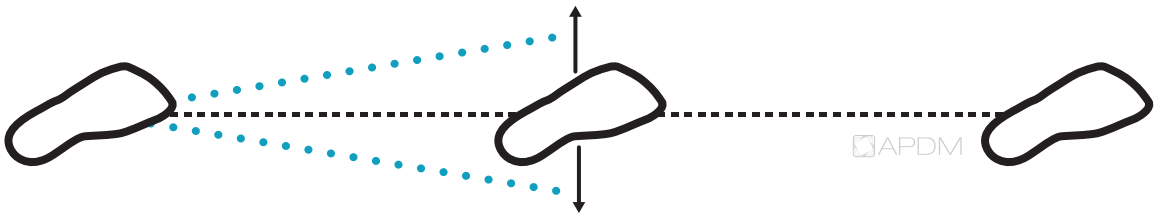
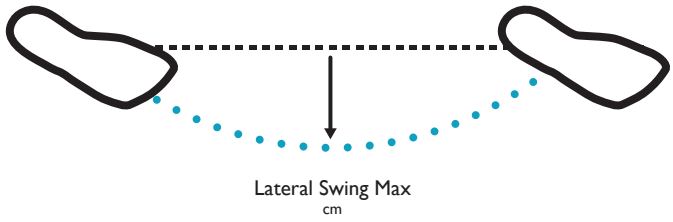
SPATIAL ANALYSIS



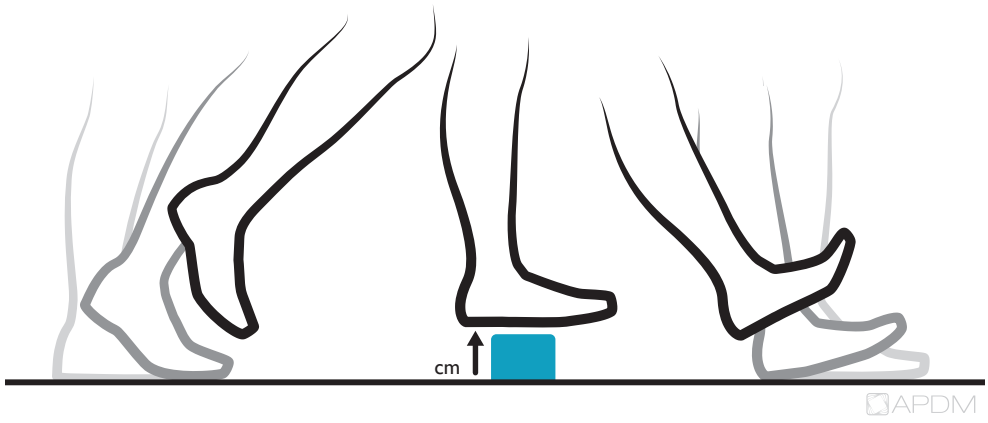
LATERAL STEP VARIABILITY



CIRCUMDUCTION



ELEVATION AT MIDSWING



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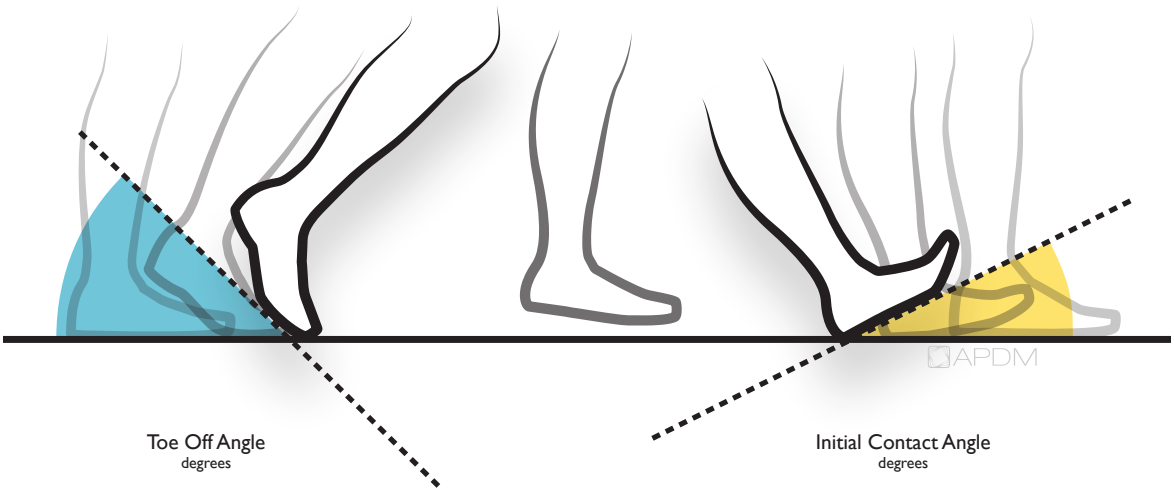
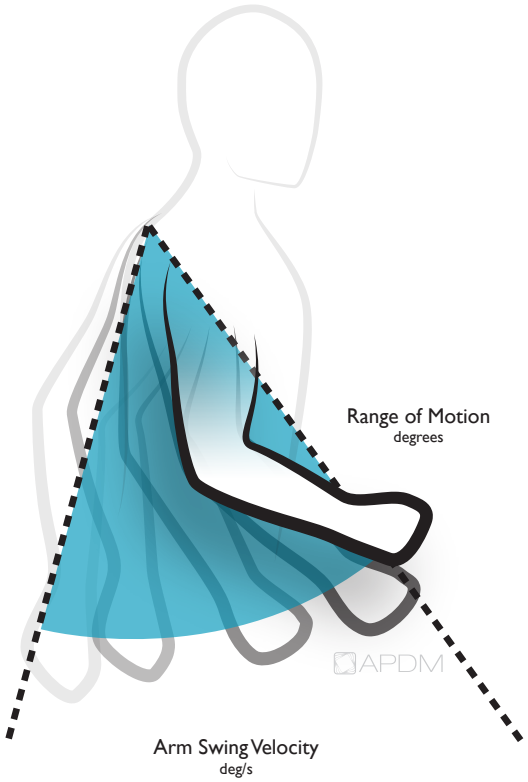
FOOT CONTACT ANGLES



ARM RANGE OF MOTION



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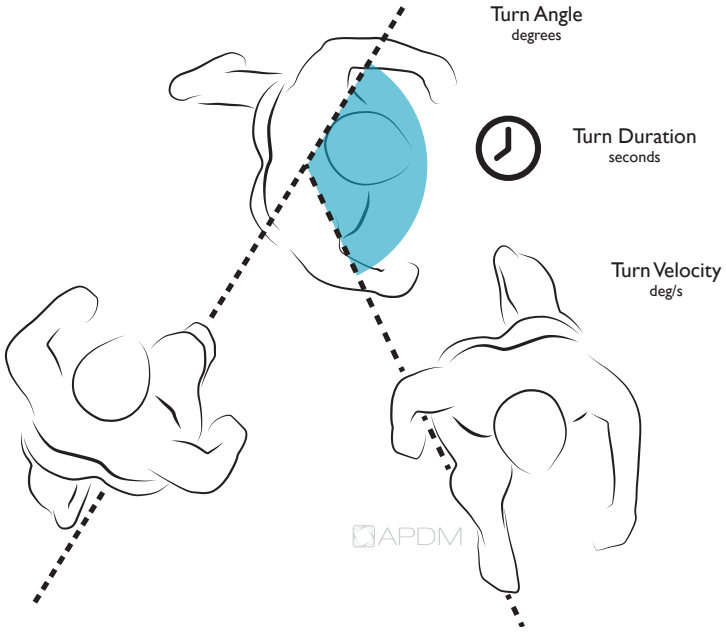
POSTURAL MEASURES

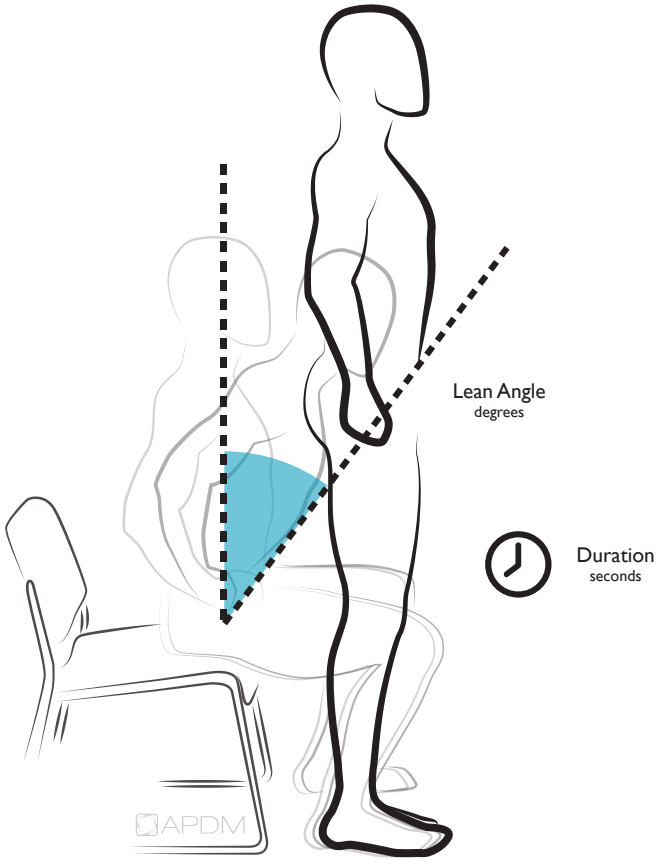
Postural measures are detected, analyzed, and averaged over the extent of the walking duration of the subject.

TURNING ANALYSIS



SIT TO STAND ANALYSIS

STAND TO SIT ANALYSIS



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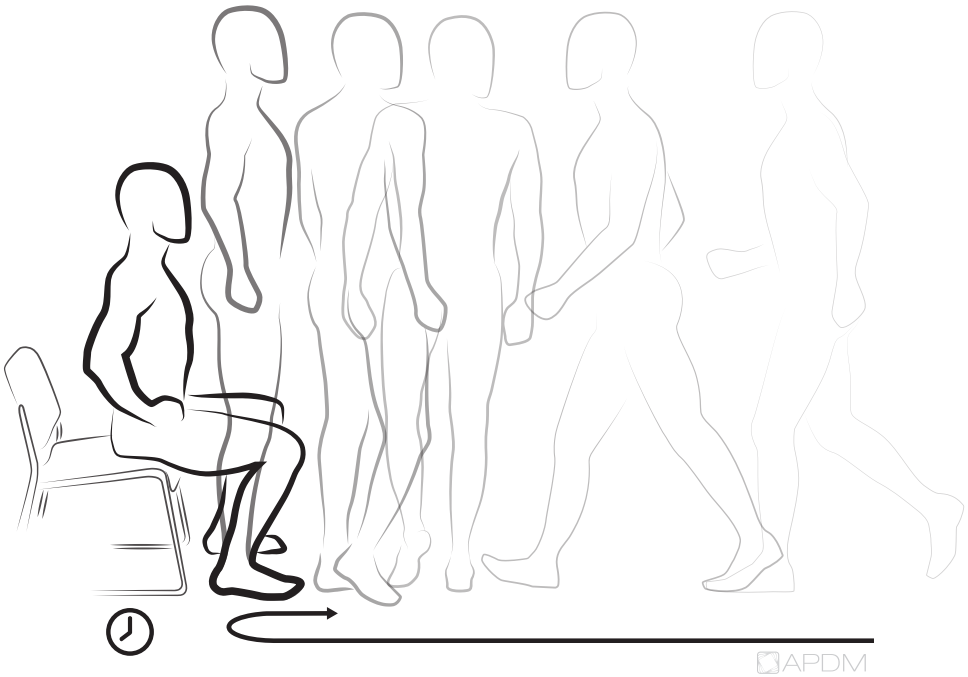
TURN TO SIT ANALYSIS



Turn Duration
seconds

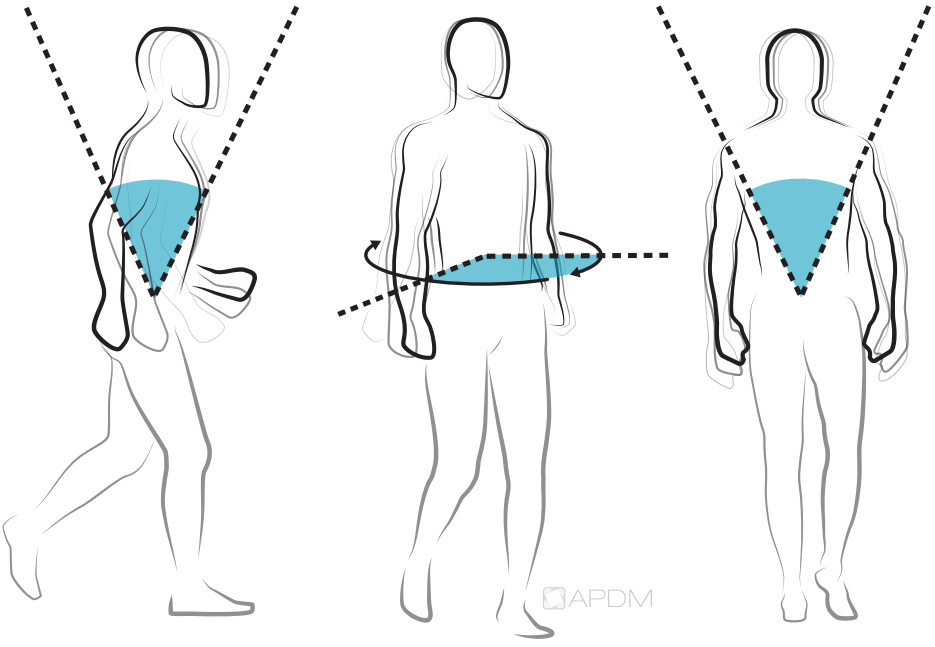
Turn Velocity
deg/s

TRUNK RANGE OF MOTION

Sagittal Range of Motion
degrees

Transverse Range of Motion
degrees

Coronal Range of Motion
degrees



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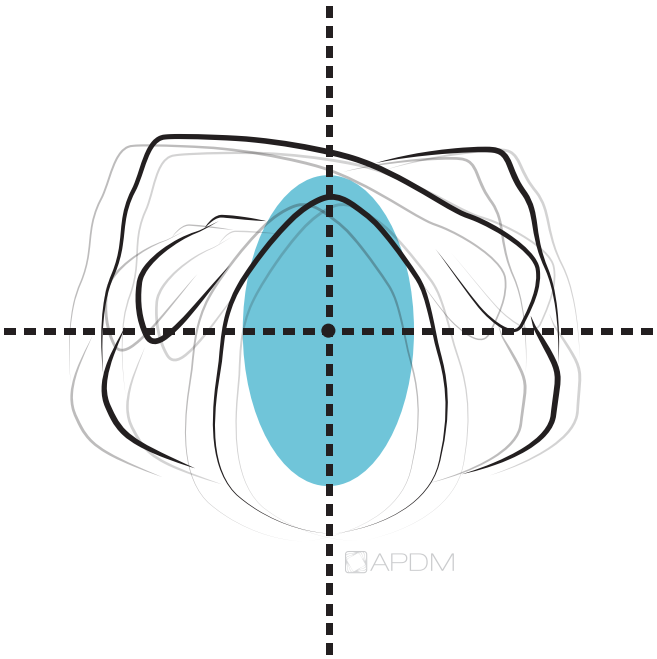
POSTURAL SWAY MEASURES

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.

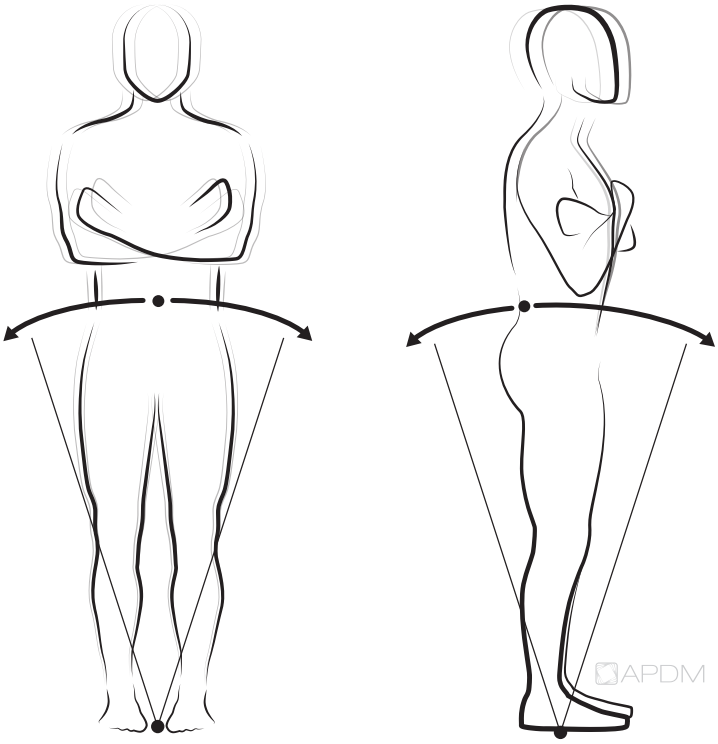


Planar Acceleration
degrees^2

Sway Area
m^2/s^4

Rotation
degrees

POSTURAL SWAY



RMS Sway
m/s^2

Mean Velocity
m/s^3

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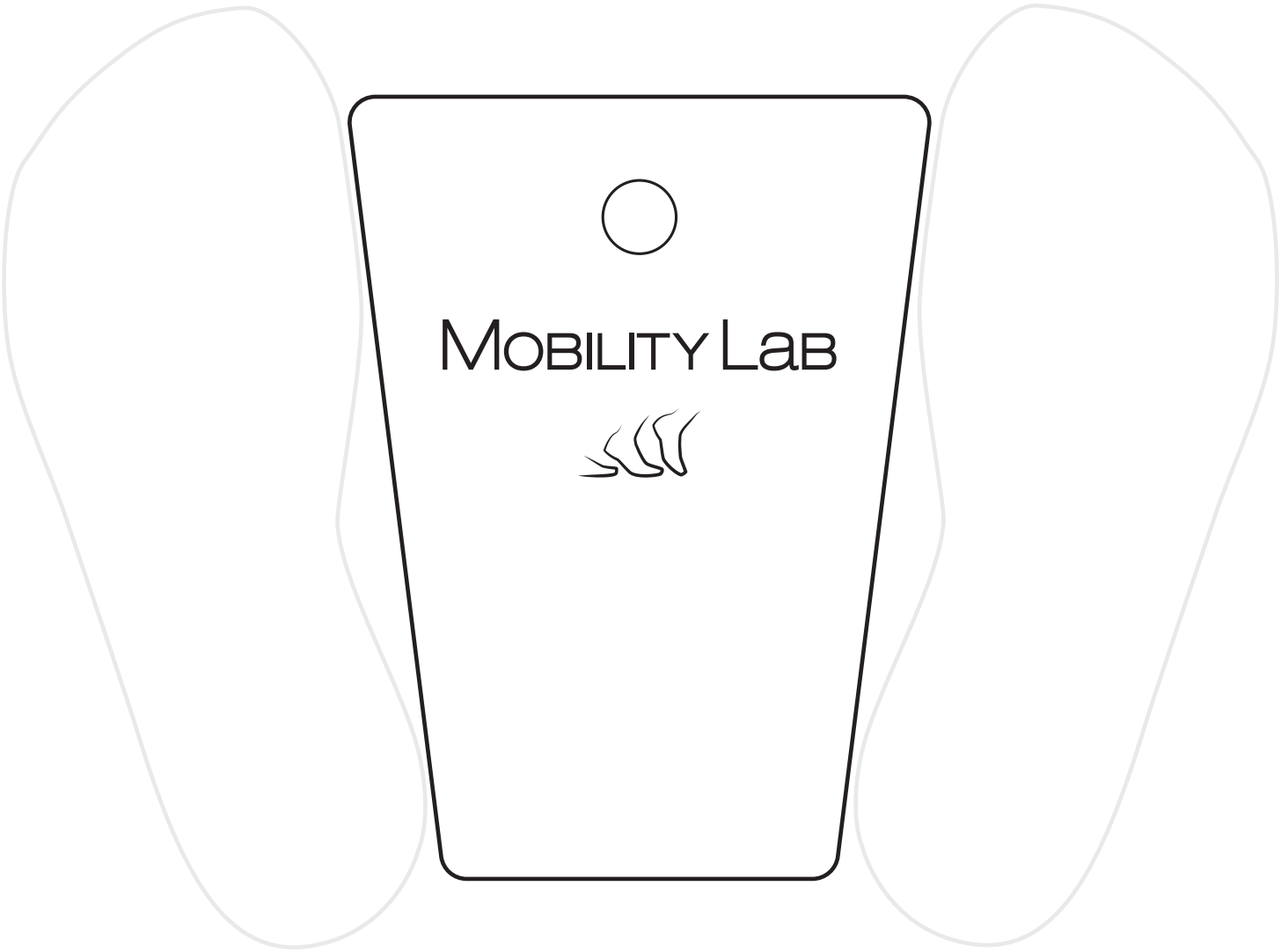
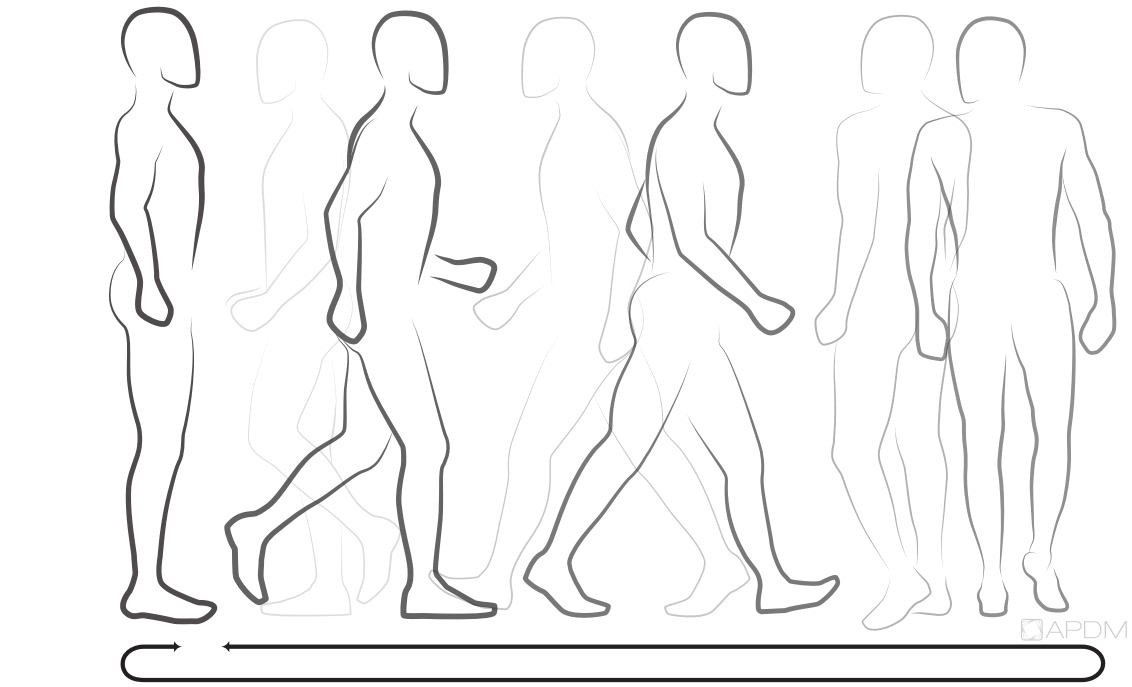
FOOTPLATE

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 unless otherwise noted in the test instructions. 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.



WALK TEST

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, turning, and anticipatory postural adjustments

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.

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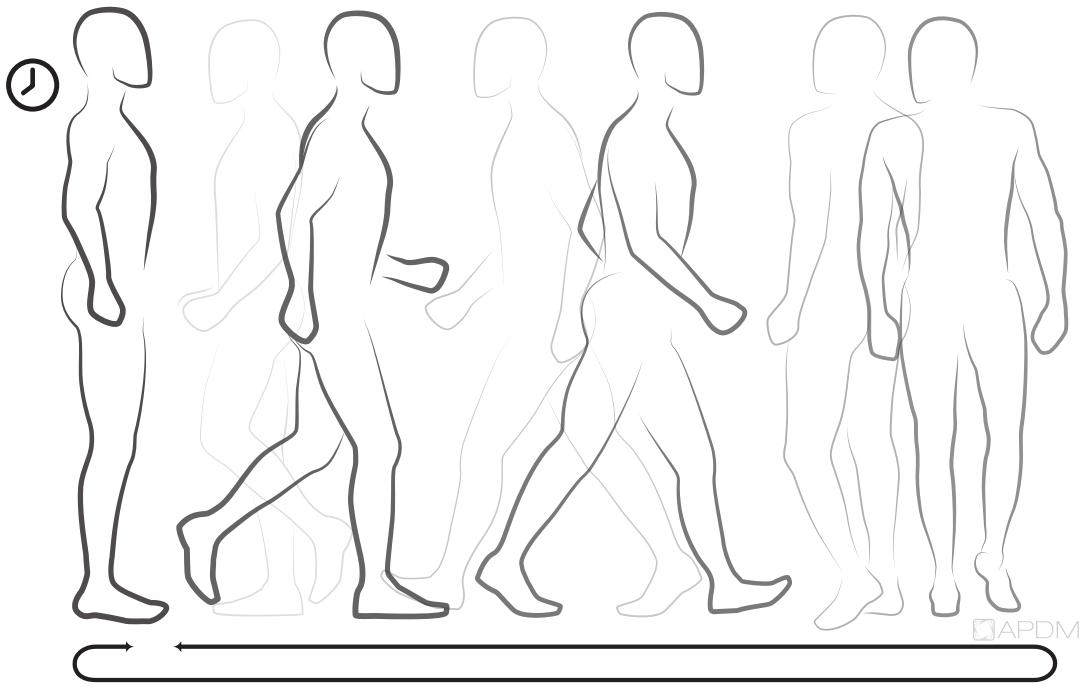
STAND AND WALK TEST

The Stand and Walk (SAW) test allows clinicians and nonexperts to quickly obtain objective measures of standing balance, step-initiation, gait, and turning.



TEST MEASURES:
Full body gait (legs, arms, and trunk), asymmetry, variability, turning, postural stability, and anticipatory postural adjustments

NUMBER OF SENSORS: 3 or 6

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

PROTOCOL:
1. Select SAW and press start trial.
2. When the subject is ready, press record and instruct the subject to stand quietly for 30 seconds.
3. Instruct the subject to walk 7 meters, turn around, and return to the starting point.

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

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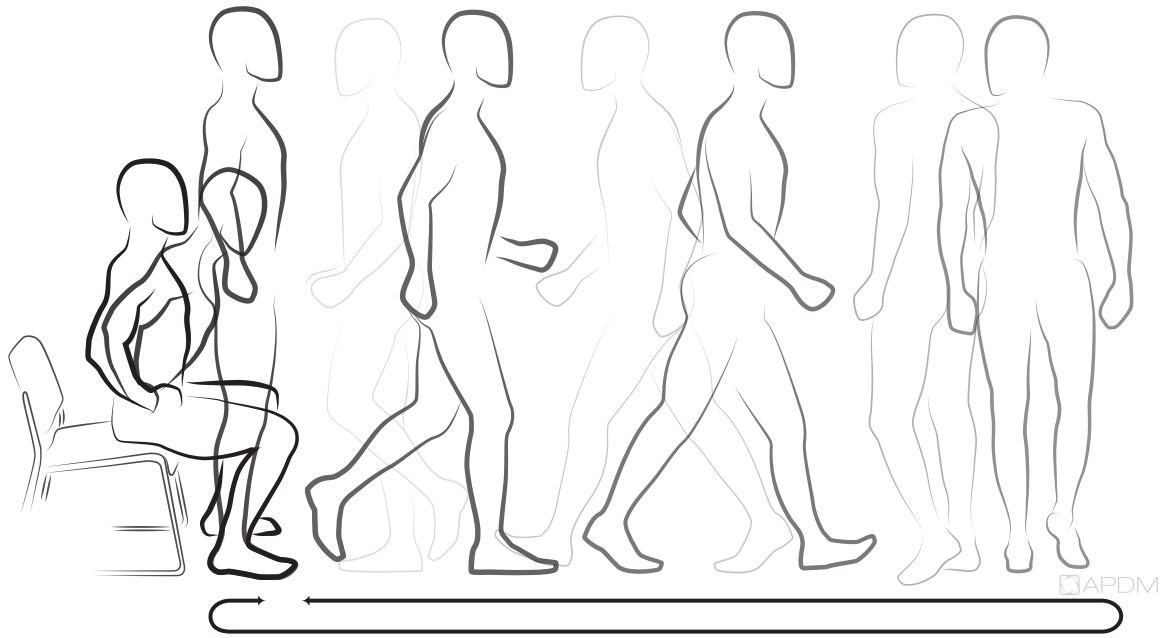
TIMED UP AND GO TEST

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.



Stand/Sit **Walk 3 Meters** **Turn**

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

NUMBER OF SENSORS: 3 or 6

SETUP:
1. Measure 3 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 3m 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.

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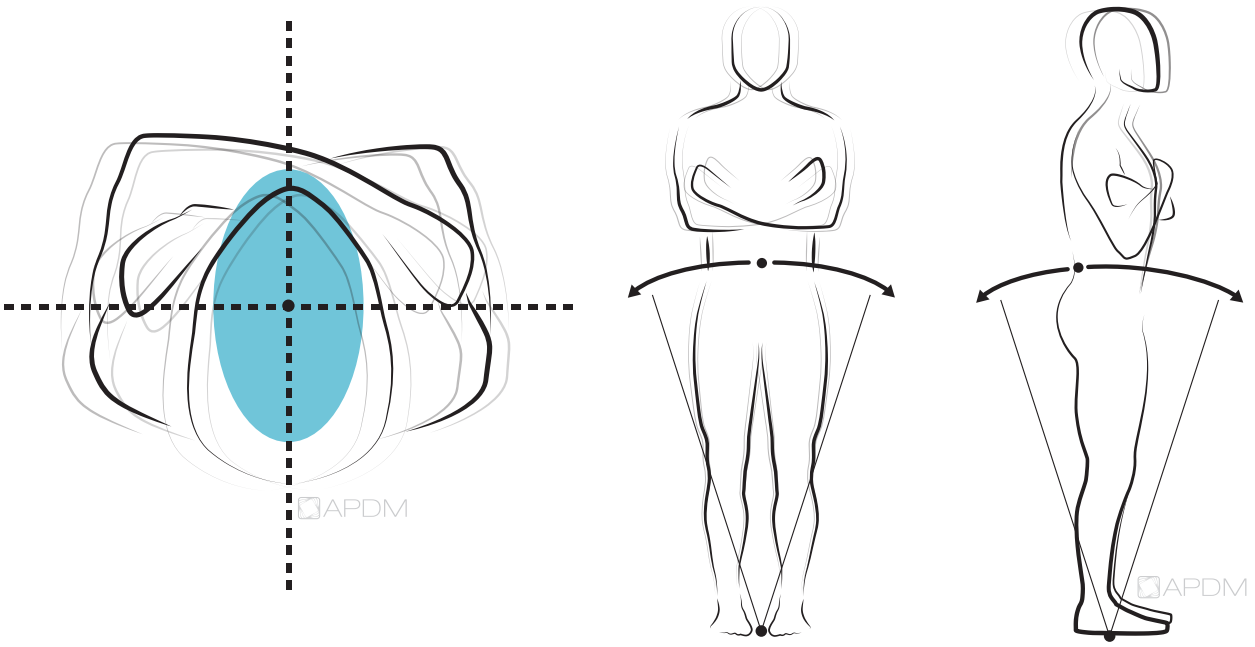
POSTURAL SWAY

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.

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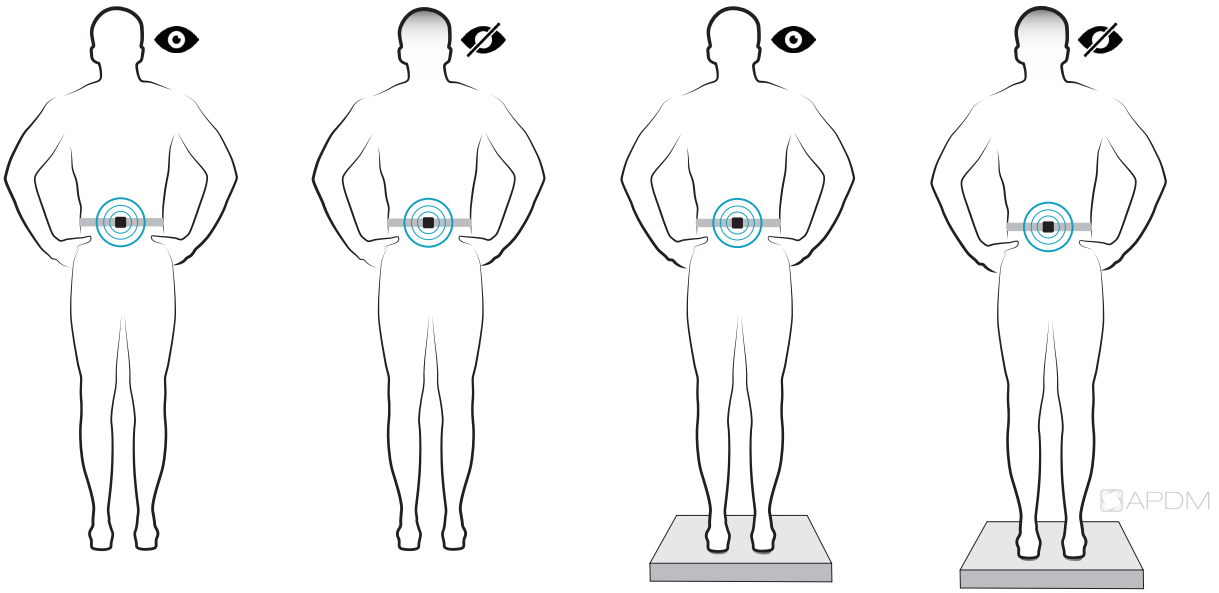
mCTSIB

The modified Clinical Test of Sensory Interaction and Balance (mCTSIB) is a composite test to assess a subject's balance under different test conditions.



Eyes Open, Firm Surface | Eyes Closed, Firm Surface | Eyes Open, Foam Surface | Eyes Closed, Foam Surface

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

NUMBER OF SENSORS: 1 or 3 or 6

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, Firm Surface
2. Eyes Closed, Firm Surface
3. Eyes Open, Foam Surface
4. Eye Closed, Foam Surface

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

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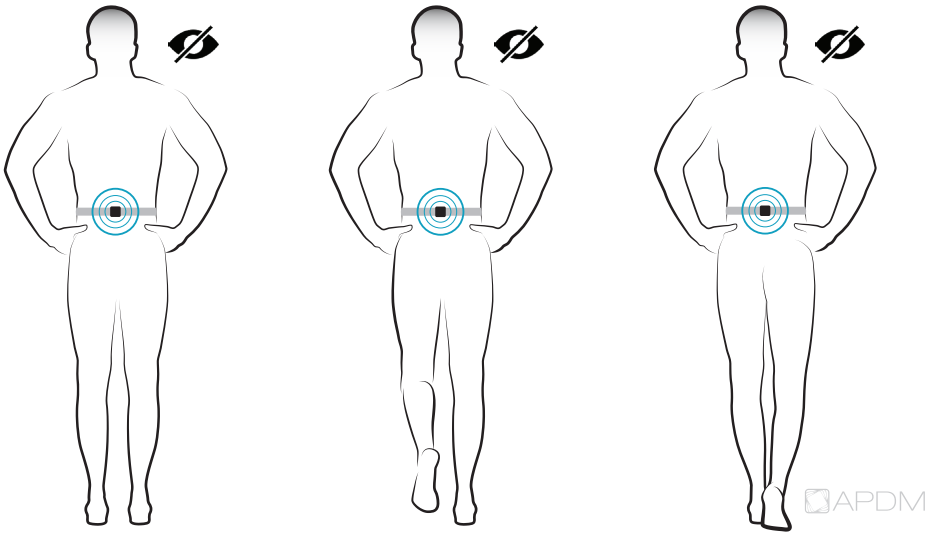
mBESS

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.



Eyes Closed, Firm Surface

Eyes Closed, One Foot, Firm Surface

Eyes Closed, Tandem Stance, Firm Surface

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.

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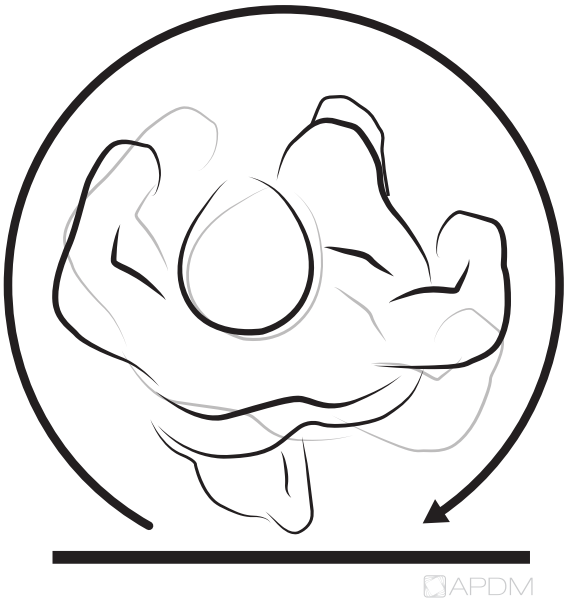
360° TURN

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: 1 or 3 or 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.

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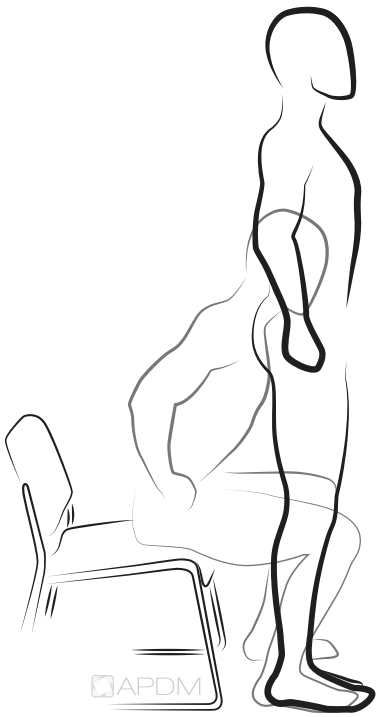
5x SIT TO STAND

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:
Lean angle, duration

NUMBER OF SENSORS: 1 or 3 or 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.

CONTACT US

info@apdm.com
503.445.7757
apdm.com/mobility

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