WHITEPAPER

MOBILITY LAB BY APDM

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
- Saggital Range of Motion
- Transverse Range of Motion

Lumbar

- Coronal Range of Motion
- Saggital Range of Motion
- Transverse Range of Motion

Head

- Coronal Range of Motion
- Saggital Range of Motion
- Transverse Range of Motion

Postural Sway

- 95% Ellipse Sway Area
- RMS Sway
- Coronal RMS Sway
- Saggital RMS Sway

Turning

- Angle
- Duration
- Maximum Velocity

Sit to Stand

- Lean Angle
- Duration

Stand to Sit

- Lean Angle
- Duration

DEFINITIONS

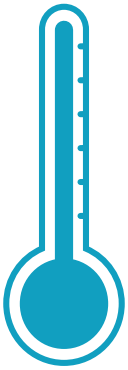
Lower Limb	
Cadence	The number of steps per minute, counting steps made by both feet
Gait Cycle Duration	The duration of the gait cycle (one left plus right step duration)
Gait Speed	The forward distance (2 step lengths) travelled during the gait cycle divided by the gait cycle duration
Foot Clearance	The height of the sensor on the foot, relative to its start position during standing and measured at mid-swing
Double Support	The percentage of the gait cycle in which both feet are on the ground
Lateral Step Variability	In three consecutive steps, the perpendicular deviation of the middle foot placement from the line connecting the first and the third step
Lateral Swing Max	The amount that the foot travels perpendicular to forward movement while swinging forward during an individual stride
Pitch at Initial Contact	The dorsiflexion of the foot at initial contact (typically heel strike)
Pitch at Toe Off	The plantar flexion of the foot just as it leaves the floor at push off
Stance	The percentage of the gait cycle in which the foot is on the ground
Step Duration	The duration of a step
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
Upper Limb	
Maximum Velocity	The maximum rotational velocity of the arm swing
Range of Motion	The angular range of the arm swing
Sternum 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	
95% Ellipse Sway Area	The area of an ellipse covering 95% of the sway angle in both the coronal and sagittal planes
RMS Sway	The extent of postural sway calculated as the root mean square (RMS) of the sway angle in both the coronal and sagittal planes
Coronal RMS Sway	The extent of postural sway calculated as the root mean square (RMS) of the sway angle in the coronal plane
Sagittal RMS Sway	The extent of postural sway calculated as the root mean square (RMS) of the sway angle in the sagittal plane

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

PUBLICATIONS

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- Spain, et al. "**Body-worn Motion Sensors Detect Balance and Gait Deficits in People with Multiple Sclerosis who have Normal Walking Speed**." *Gait & Posture*. 2012
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- Horak, et al. "**Role of Body-Worn Movement Monitor Technology for Balance and Gait Rehabilitation**." *Physical Therapy*. 2014
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- King, et al. "**Instrumenting the Balance Error Scoring System for Use with Patients Reporting Persistent Balance Problems After Mild Traumatic Brain Injury**." *Archives of Physical Medicine and Rehabilitation*. 2014
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- Weiss, et al. "**Long-term Outcome of Deep Brain Stimulation in Fragile X-associated Tremor/Ataxia Syndrome**." *Parkinsonism and Related Disorders*. 2014
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- Mancini, et al. "**Continuous Monitoring of Turning in Parkinson's Disease: Rehabilitation Potential**." *NeuroRehabilitation*. 2015
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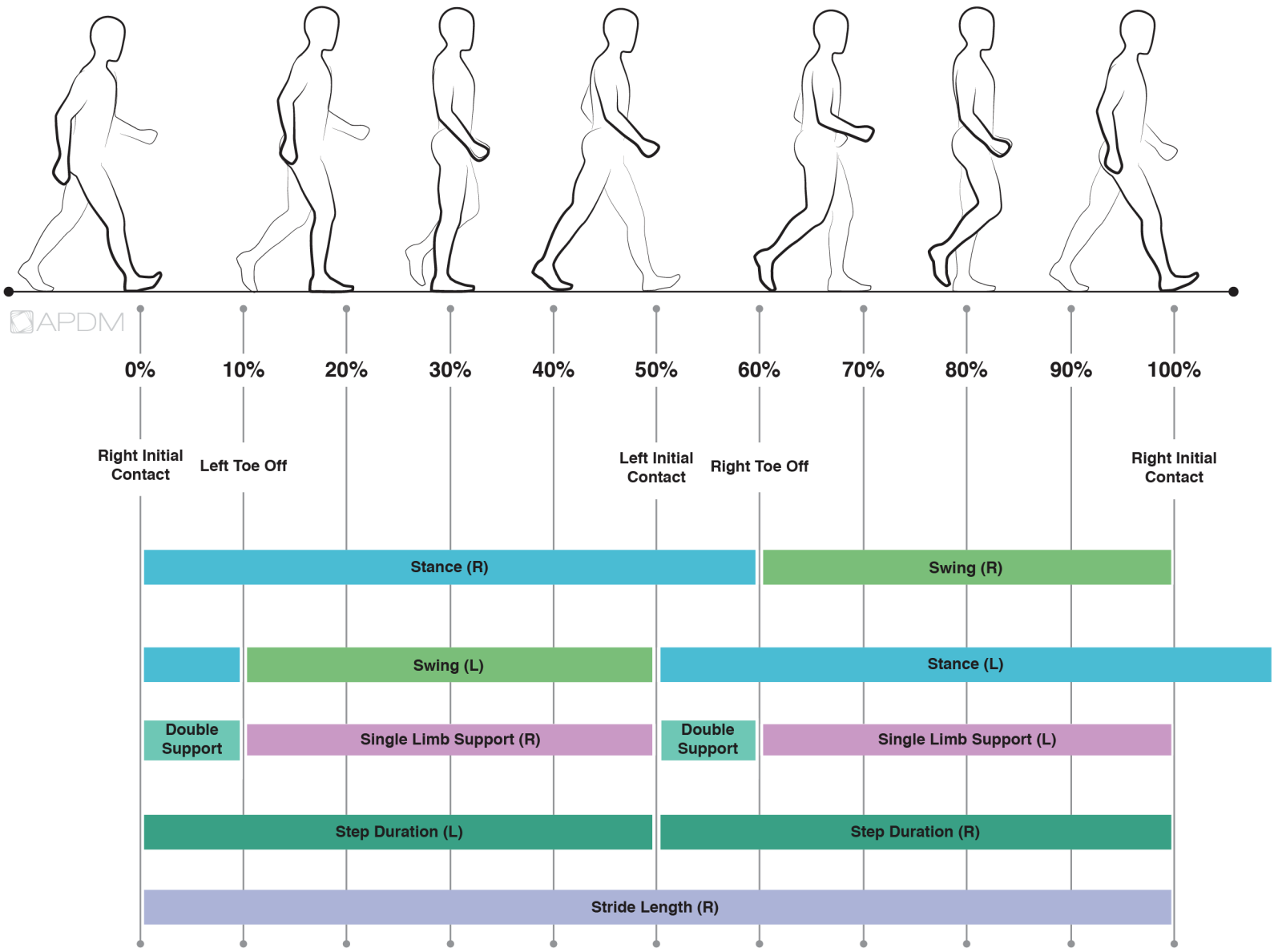
CONTENTS

GAIT CYCLE ANALYSIS



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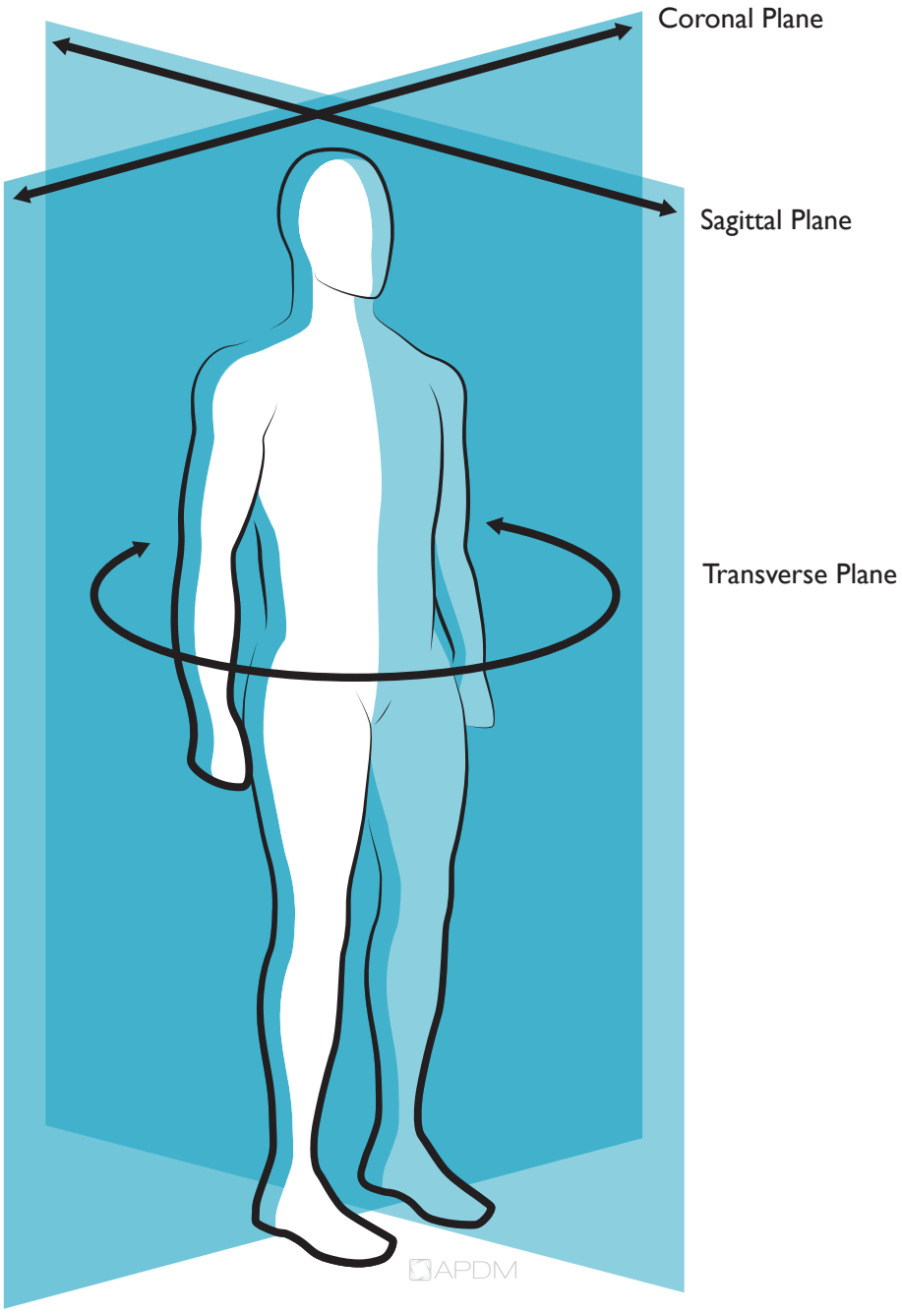
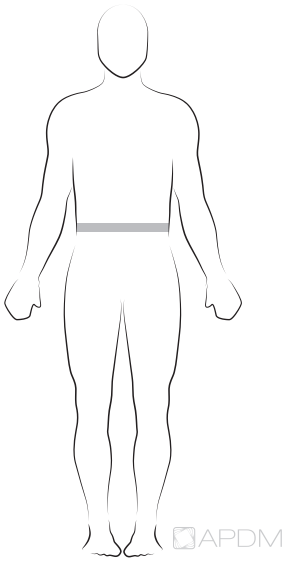
BODY PLANES



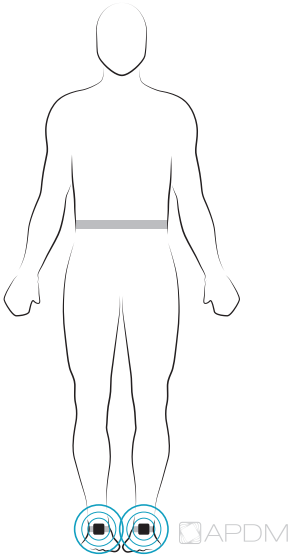
SENSOR CONFIGURATIONS AND MEASURES

BALANCE



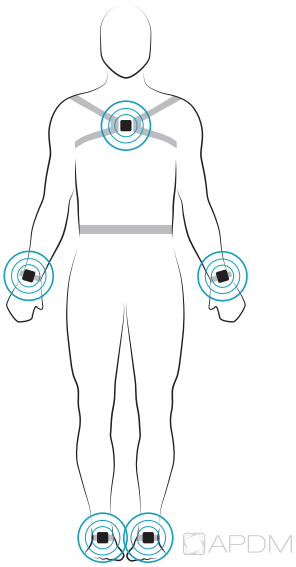
1 OPAL

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

- W — Walk
- T — TUG
- S — Sway
- C — CTSIB
- B — BESS
- mB — mBESS
- 360 — 360° Turn
- sS — Sit to Stand

Lower Limb	Tier 1 1 Opal sensor	Tier 2 3 Opal sensors	Tier 3 6 Opal sensors
Cadence		W	W
Gait Cycle Duration		W	W
Gait Speed		W	W
Foot Clearance		W	W
Double Support		W	W
Lateral Step Variability		W	W
Circumduction		W	W
Foot Strike Angle		W	W
Toe Off Angle		W	W
Stance		W	W
Step Duration		W	W
Stride Length		W	W
Swing		W	W
Toe Out Angle		W	W
Upper Limb			
Maximum Velocity		W	W
Range of Motion		W	W
Sternum Range of Motion			
Coronal			W
Sagittal			W
Transverse			W
Lumbar Range of Motion			
Coronal		W	W
Sagittal		W	W
Transverse		W	W
Sit To Stand			
Duration			sS
Lean Angle			sS
Stand To Sit			
Duration			sS
Lean Angle			sS
Turning			
Angle		W T	W T 360
Duration		W T	W T 360
Velocity		W T	W T 360
Steps in Turn		W T	W T 360
Postural Sway			
95% Ellipse Sway Area	S	S C B mB	S C B mB
RMS Sway	S	S C B mB	S C B mB
Coronal RMS Sway	S	S C B mB	S C B mB
Sagittal RMS Sway	S	S C B mB	S C B mB

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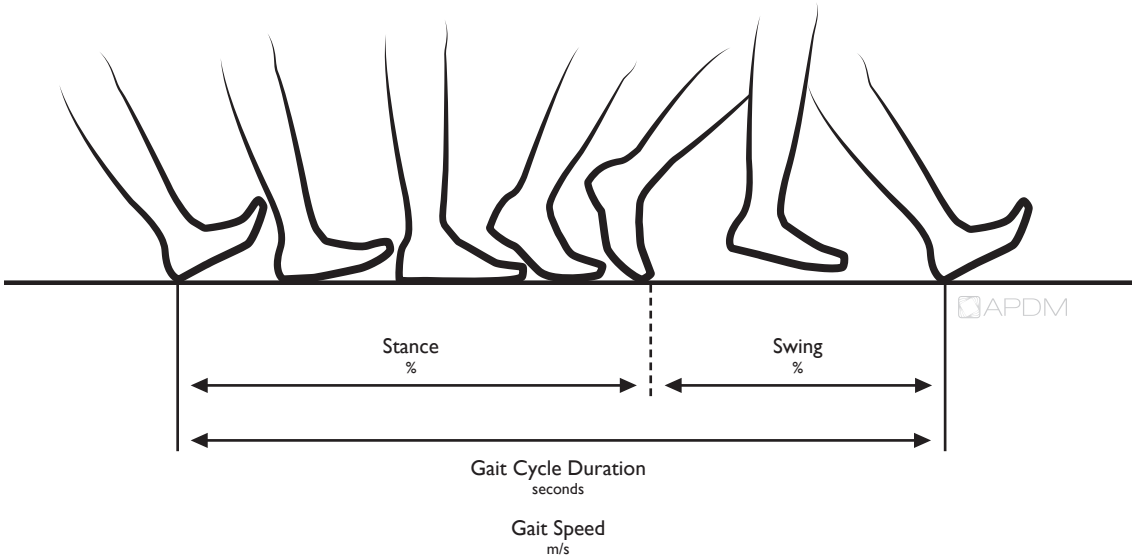
FULL BODY GAIT MEASURES

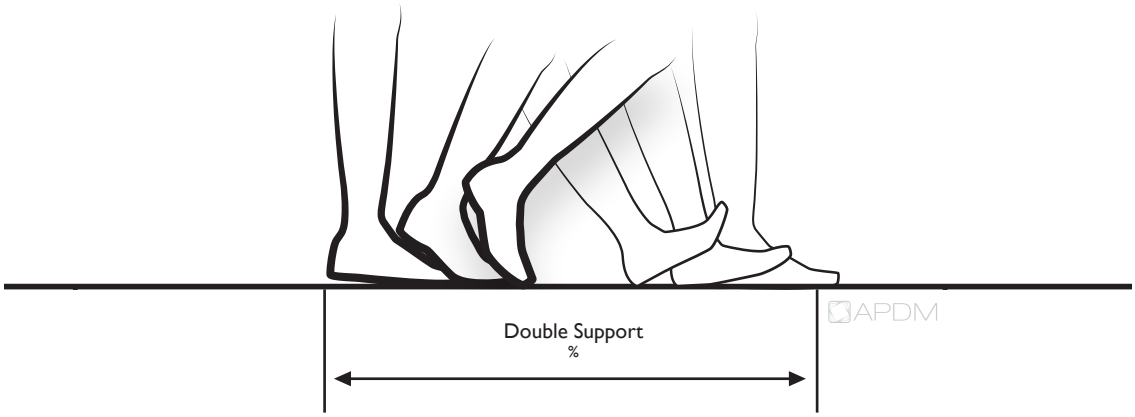
Gait measures are detected, analyzed, and averaged over the extent of the walking duration of the subject. All measures are assessed for asymmetry and variability.

GAIT CYCLE ANALYSIS

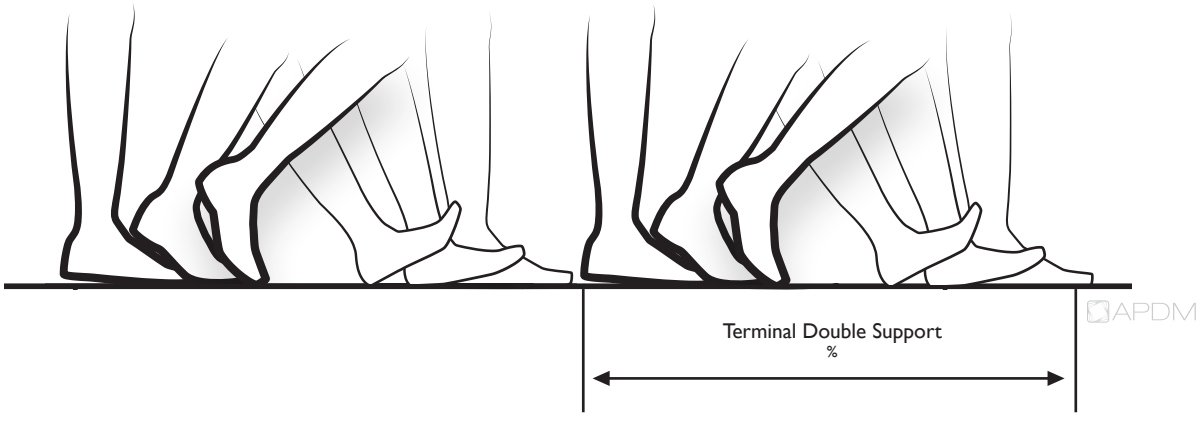


Gait Speed
m/s

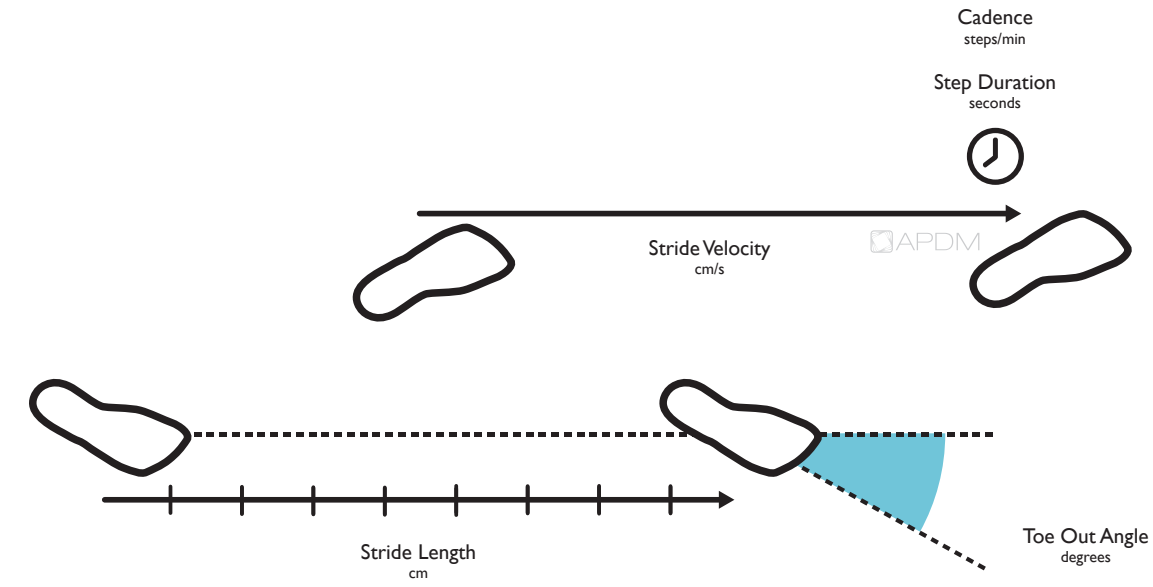
DOUBLE SUPPORT



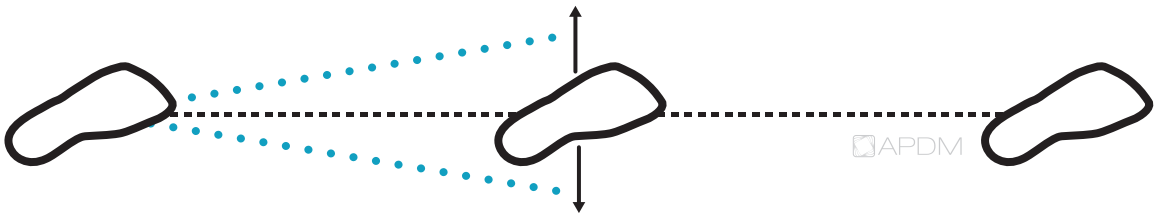
TERMINAL DOUBLE SUPPORT



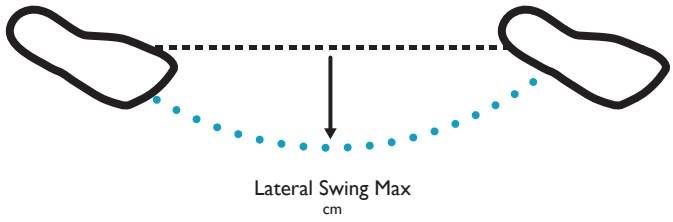
SPATIAL ANALYSIS



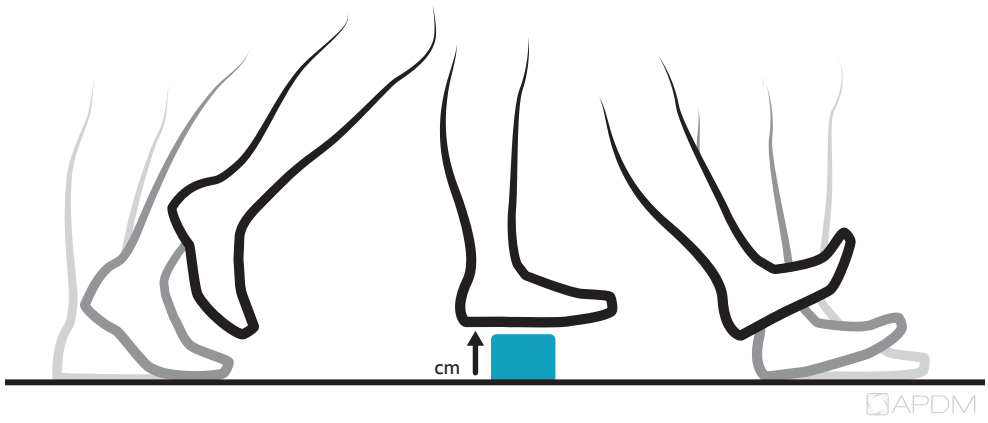
LATERAL STEP VARIABILITY



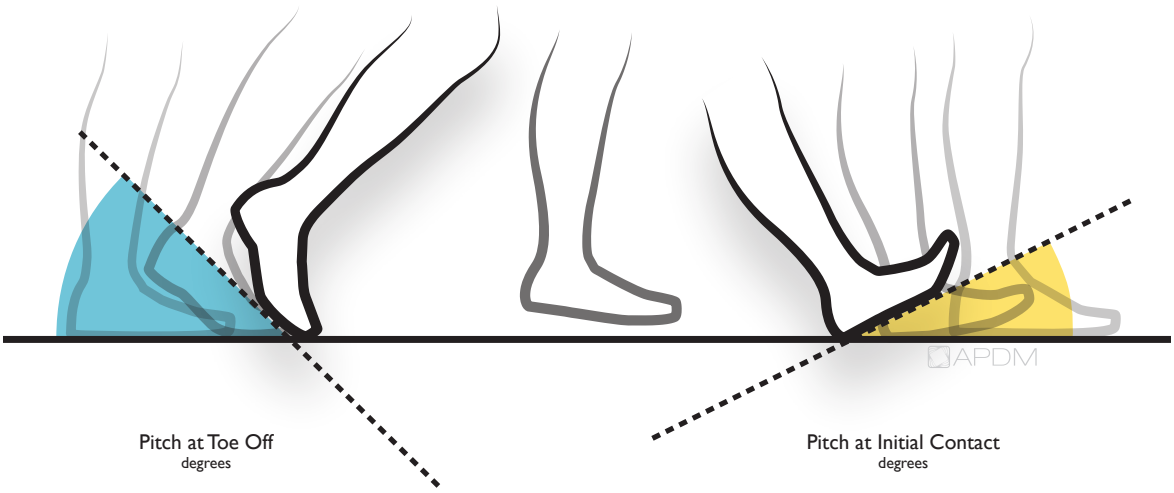
CIRCUMDUCTION



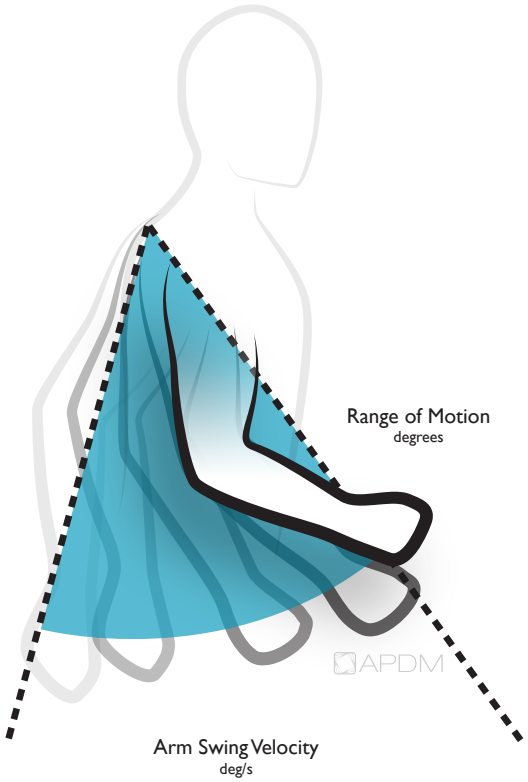
CLEARANCE



HEEL/TOE PITCH



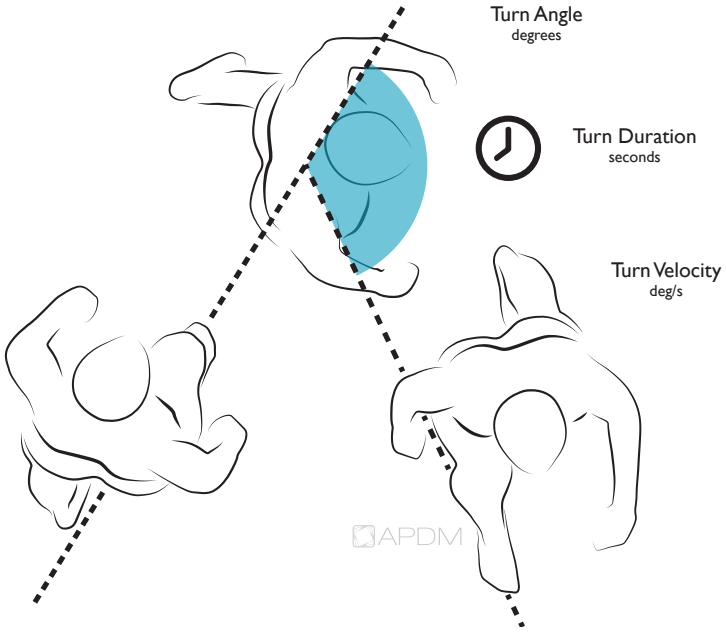
ARM RANGE OF MOTION



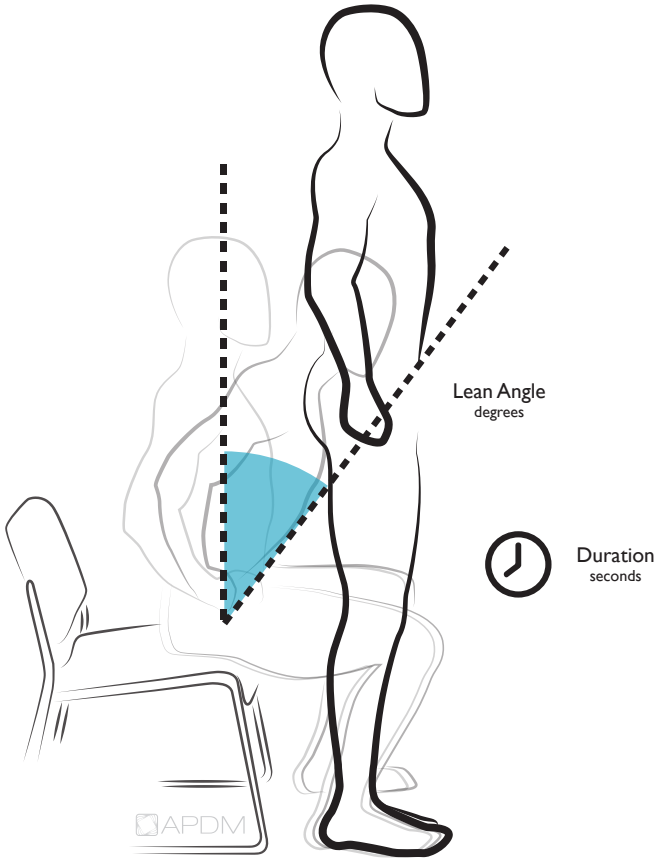
POSTURAL TRANSITION MEASURES

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

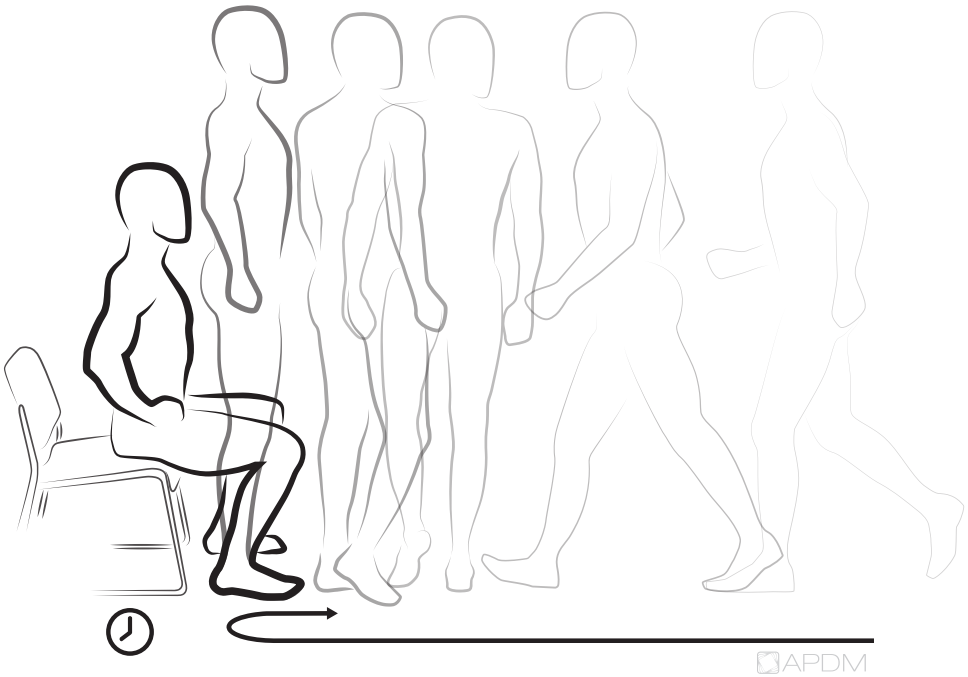
TURNING ANALYSIS



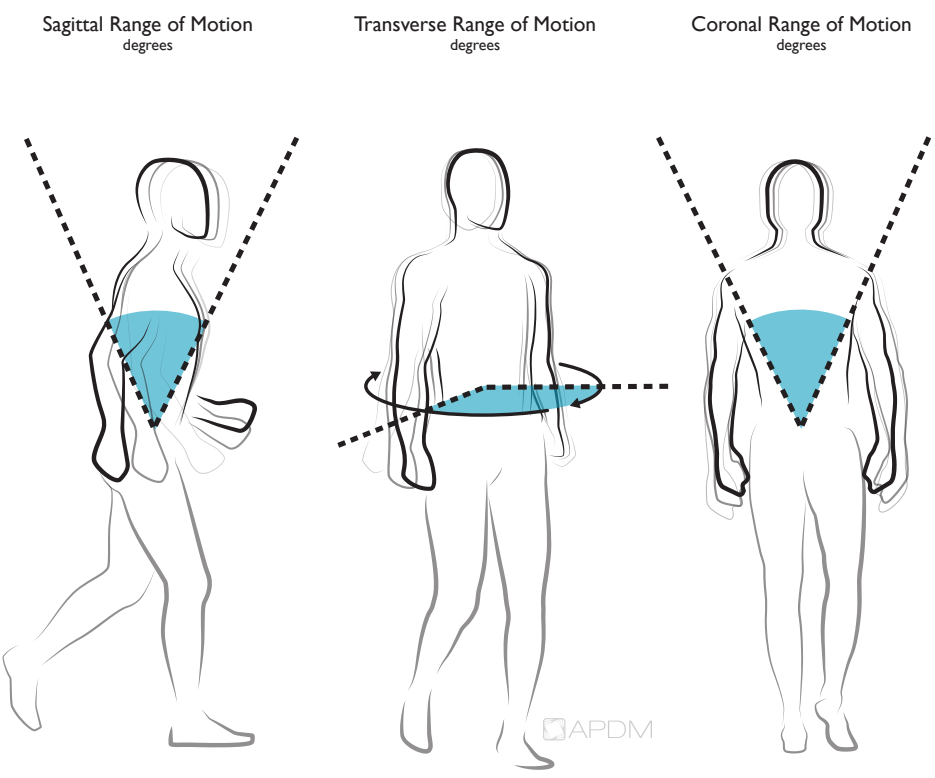
SIT TO STAND ANALYSIS



TURN TO SIT ANALYSIS

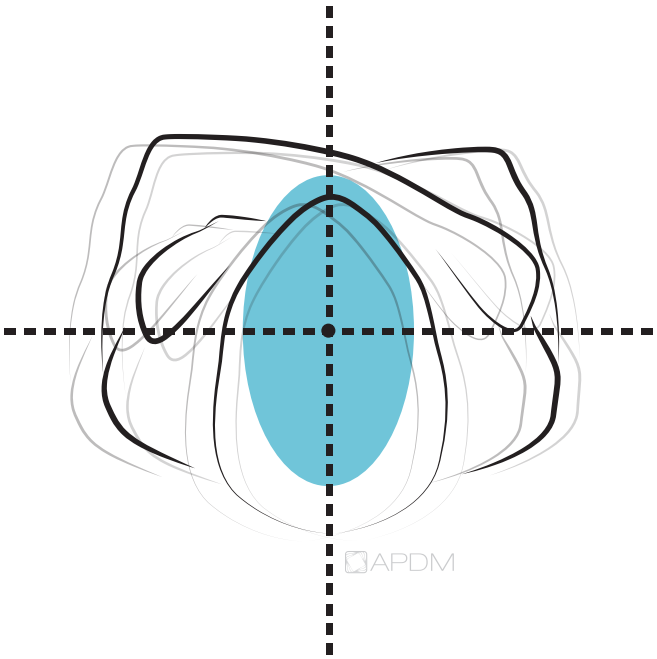


TRUNK RANGE OF MOTION



POSTURAL SWAY MEASURES

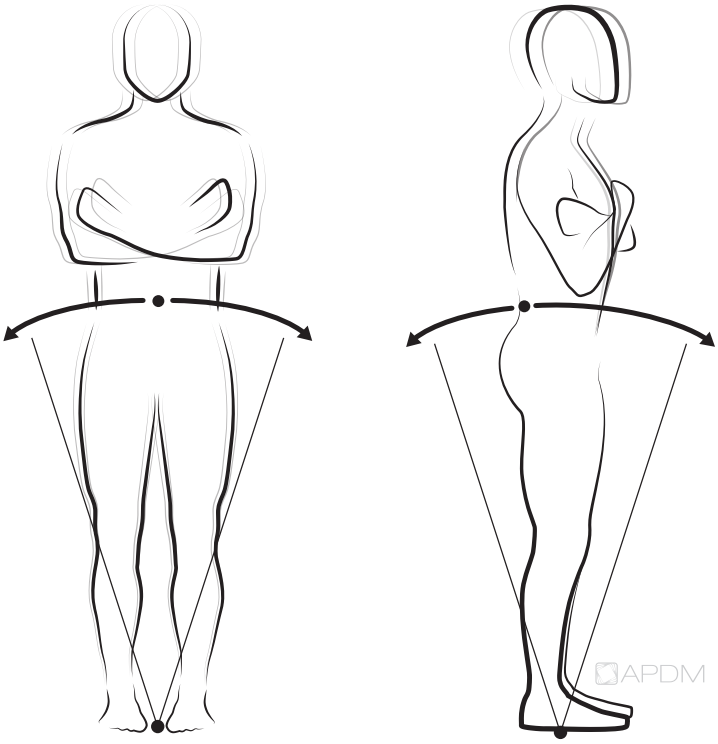
All postural sway measures are assessed using the Opal movement sensor placed on a subject's lumbar. All metrics are reported in Coronal, Sagittal and Transverse planes.



95% Ellipse Sway Area
degrees^2

95% Ellipse Rotation
degrees

POSTURAL SWAY

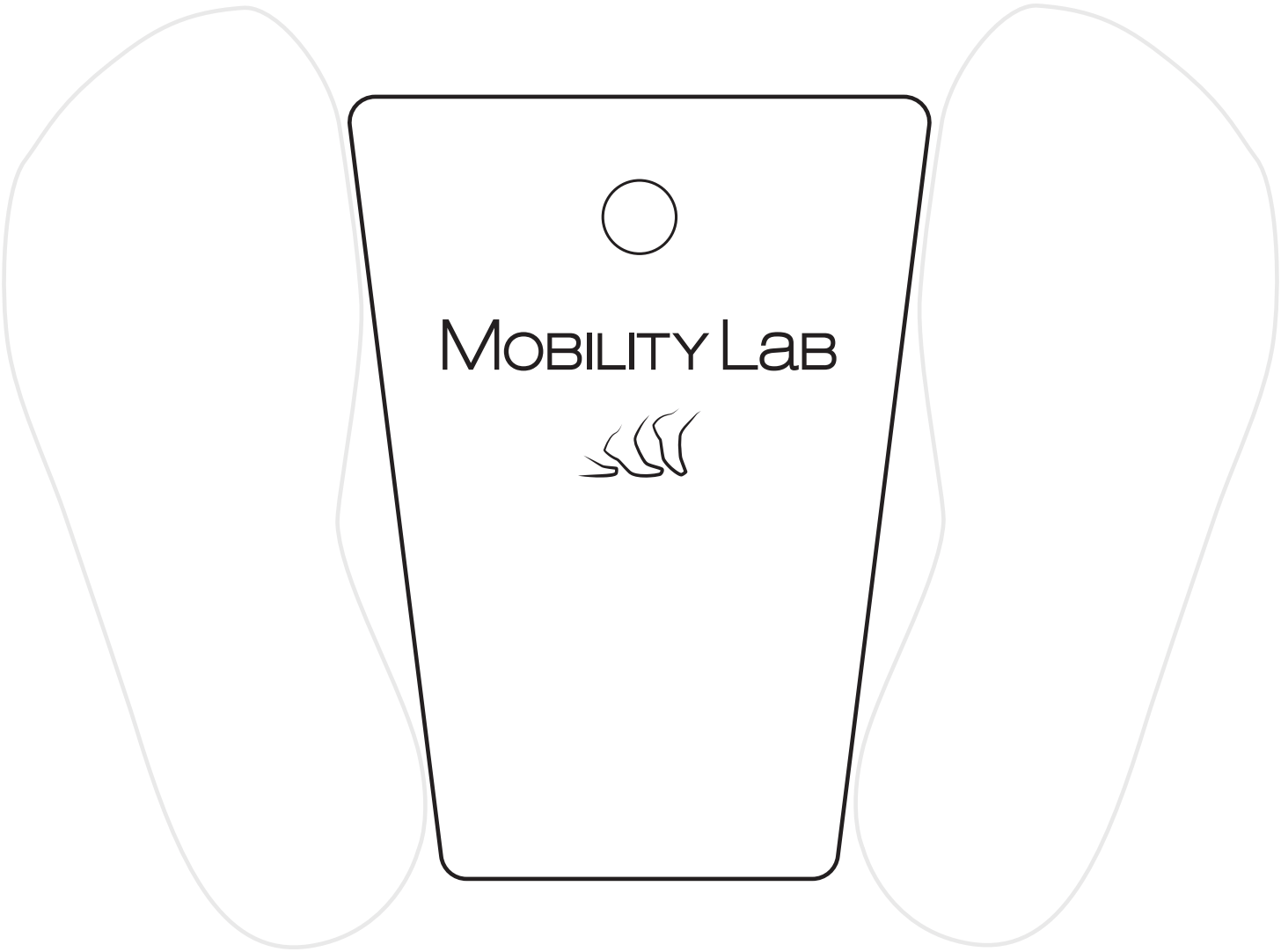


RMS Sway
m/s^2

Mean Velocity
m/s^3

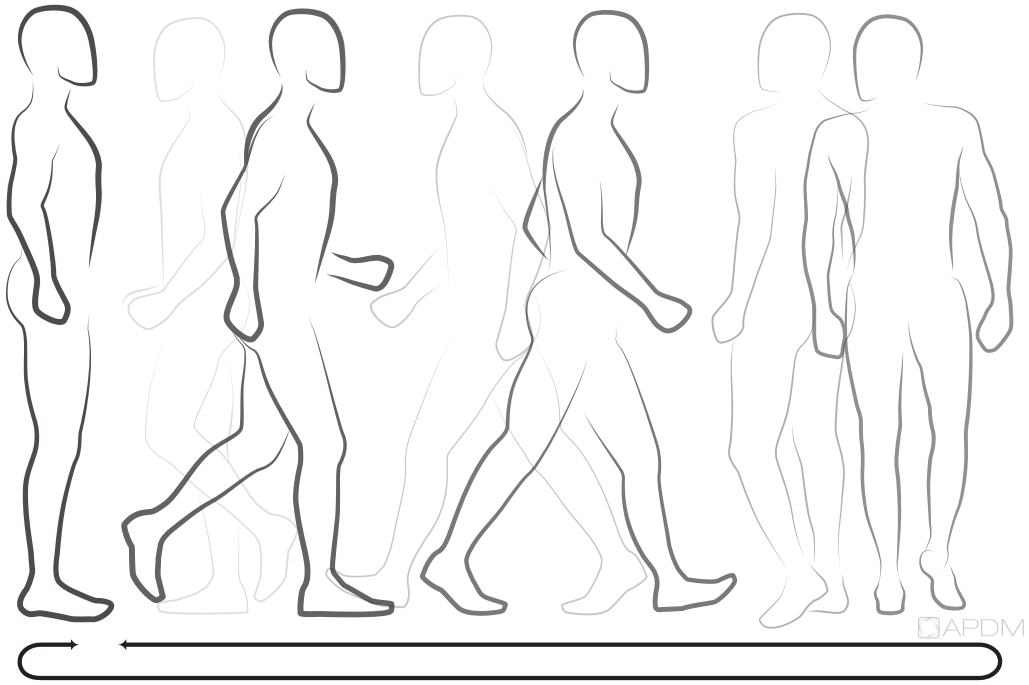
FOOTPLATE

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. 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.



Start/Turn Walk Any Distance or Duration Turn

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

NUMBER OF SENSORS: 3 or 6

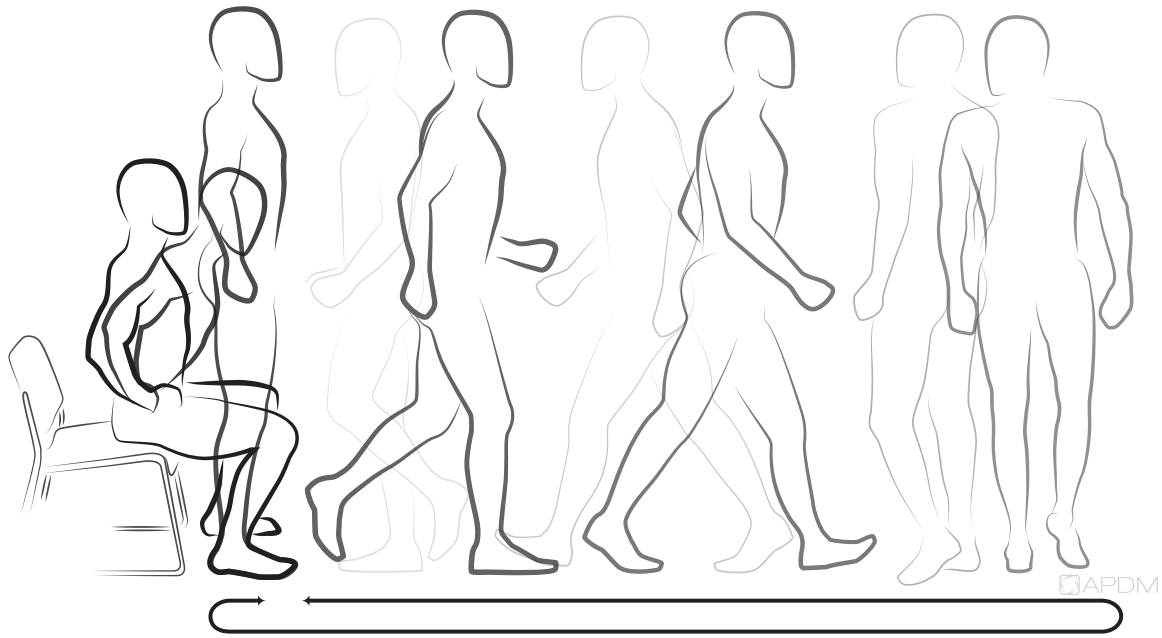
SETUP:
1. Walking corridor must be at least 7 meters in length

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 preform 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 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 7 Meters** **Turn**

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

NUMBER OF SENSORS: 3 or 6

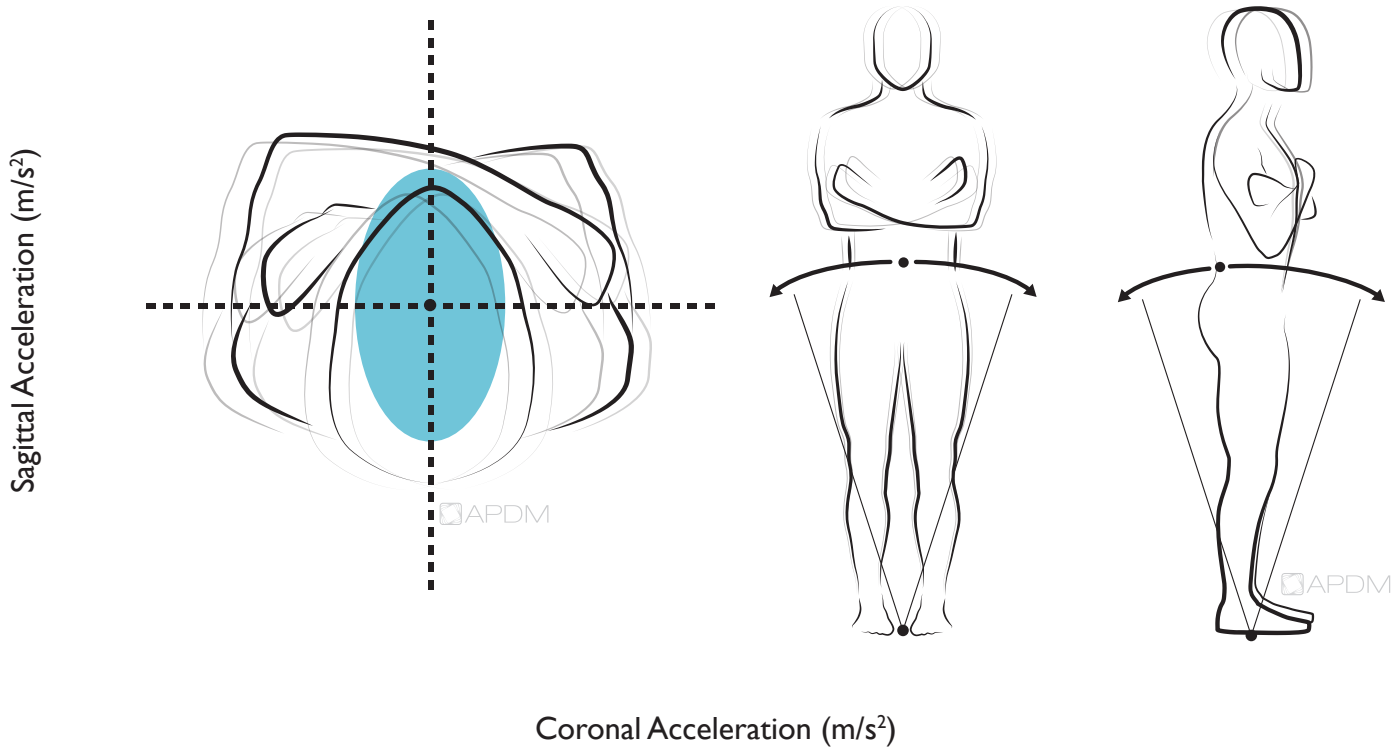
SETUP:
1. Measure 7 meters, placing tape at the two ends.
2. Place an armless chair at the start before the tape.

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.

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

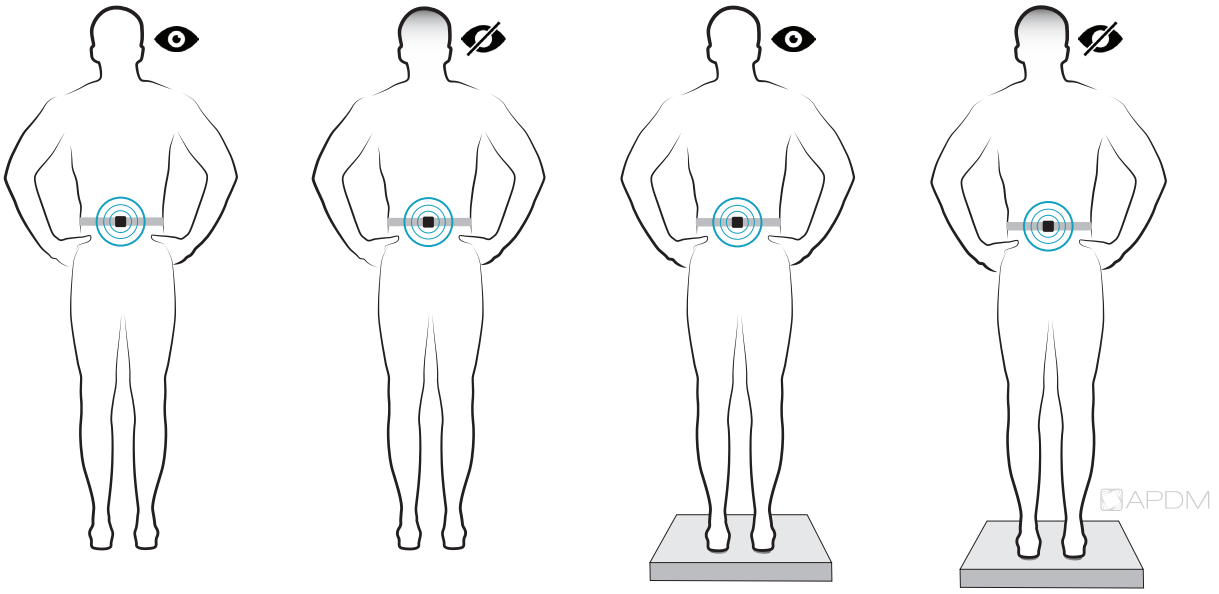
SETUP:
1. Have the subject fit their feet around the foot template provided with the Mobility Lab system (to normalize foot placement).

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.

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, Hard Surface | **Eyes Closed, Hard 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

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

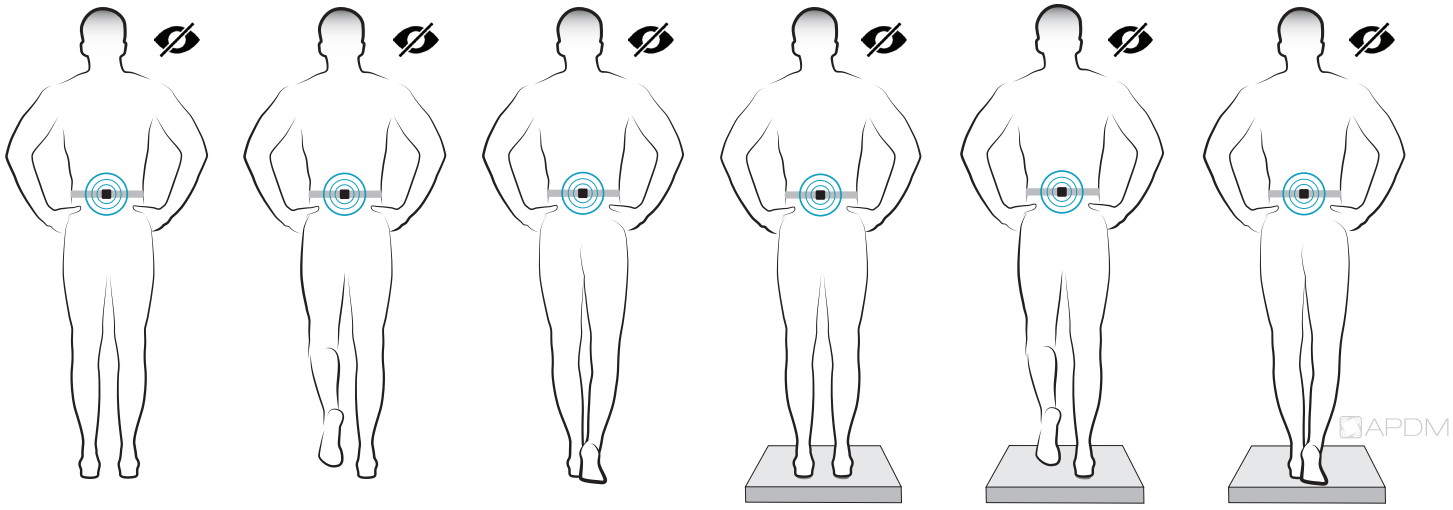
PROTOCOL:
1. Select CTSIB and press start test.
2. Subject should stand comfortably with their feet together and hands at their side.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the next test condition.

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

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

BESS

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.



Eyes Closed, Hard Surface | Eyes Closed, One Leg, Hard Surface | Eyes Closed, Tandem Stance, Hard Surface | Eyes Closed, Foam Surface | Eyes Closed, One Leg, Foam Surface | Eyes Closed, Tandem Stance, Foam 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).

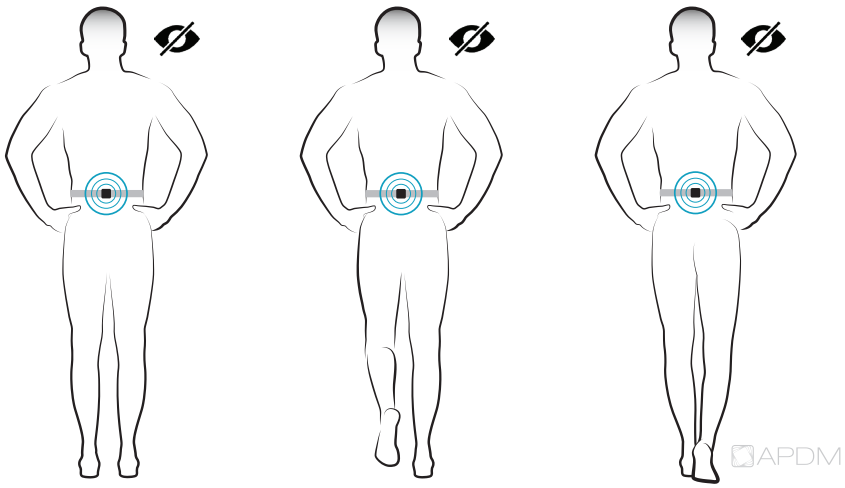
PROTOCOL:
1. Select BESS and press start test.
2. Subject should stand according to the test condition with their hands on their hips, and their eyes closed.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the next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

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, Hard Surface

Eyes Closed, One Leg, Hard Surface

Eyes Closed, Tandem Stance, Hard 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).

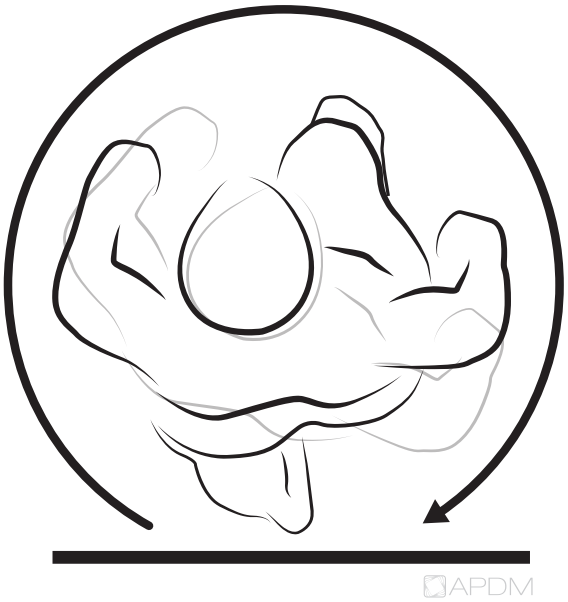
PROTOCOL:
1. Select mBESS and press start test.
2. Subject should stand according to the test condition with their hands on their hips, and their eyes closed.
3. Follow the conditions outlined in the test description.
4. Press start and wait for the test to count down from 30 seconds. Move on to the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

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).

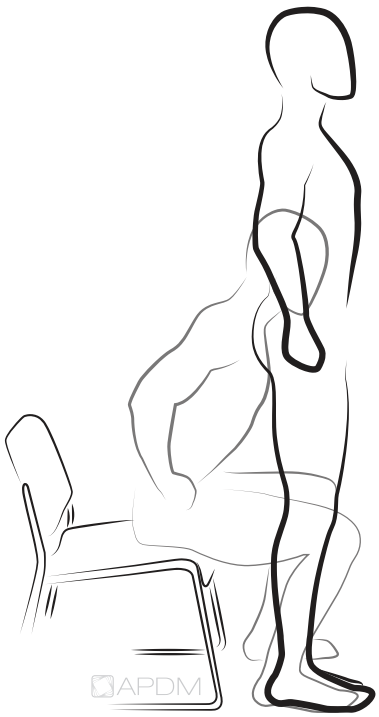
PROTOCOL:

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.

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:
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.

CONTACT US

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