Erasmus+

Development of innovative training solutions in the field of functional evaluation aimed at updating of the curricula of health sciences schools

MODULE BIOMECHANICS OF GAIT

Didactic Unit C: How Do I Assess Gait?

C.1 What methods may I apply to assess gait appropriately?

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AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE

C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

1. Introduction to gait assessment
2. Methods for gait evaluation
3. Gait assessment through clinical observation
4. Gait evaluation through standardized test and scales
5. Gait assessment through objective instruments

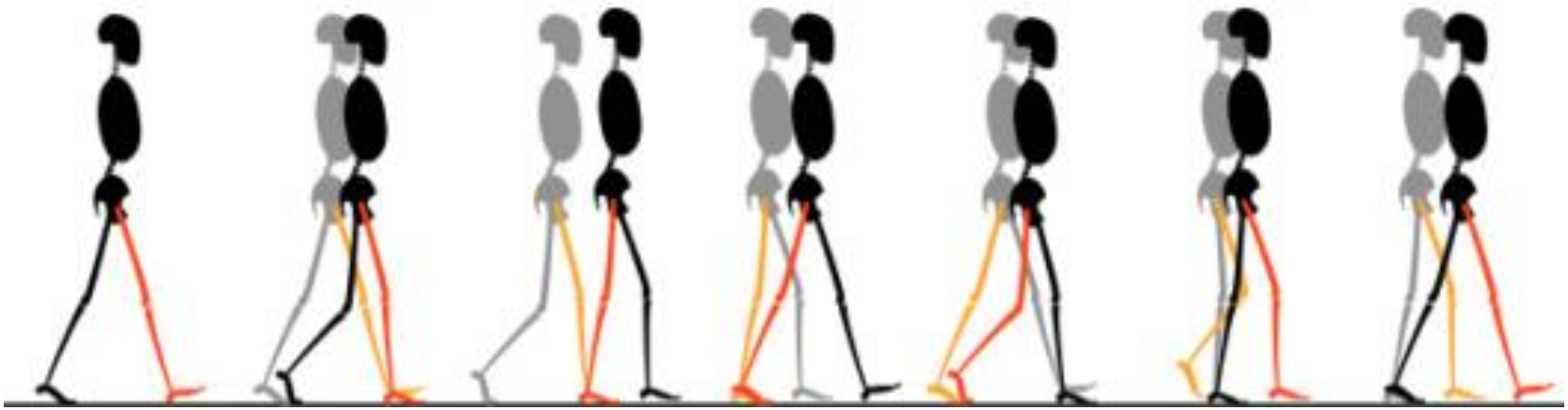
C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

1.Introduction to gait assessment

INTRODUCTION TO GAIT ASSESSMENT

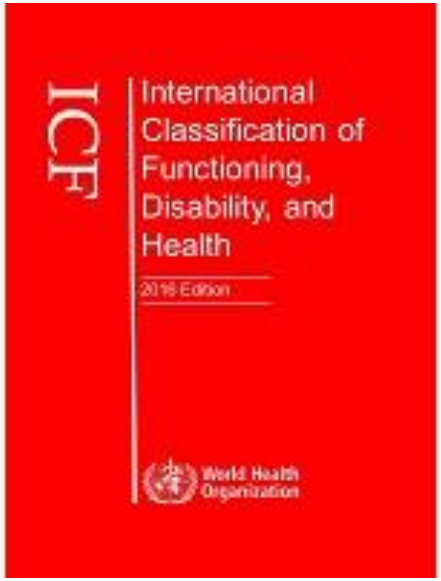
Gait is a complex behavior

→ Interaction of numerous body structures system



INTRODUCTION TO GAIT ASSESSMENT

Gait in the International Classification of Functioning, Disability and Health (ICF)



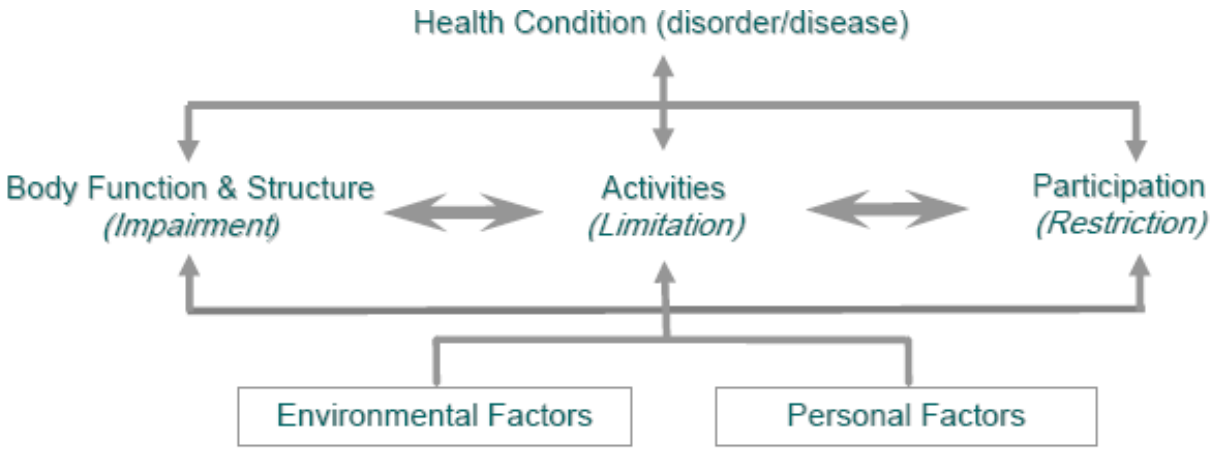
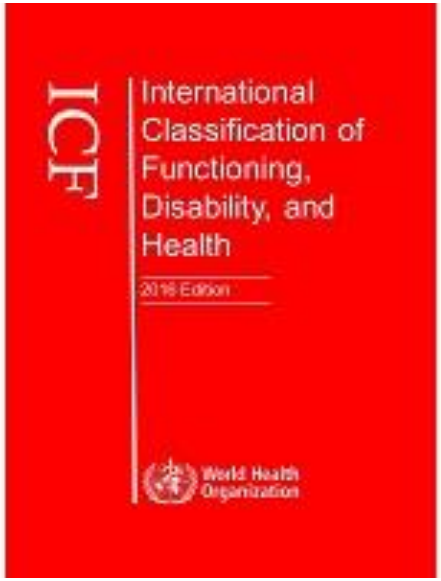
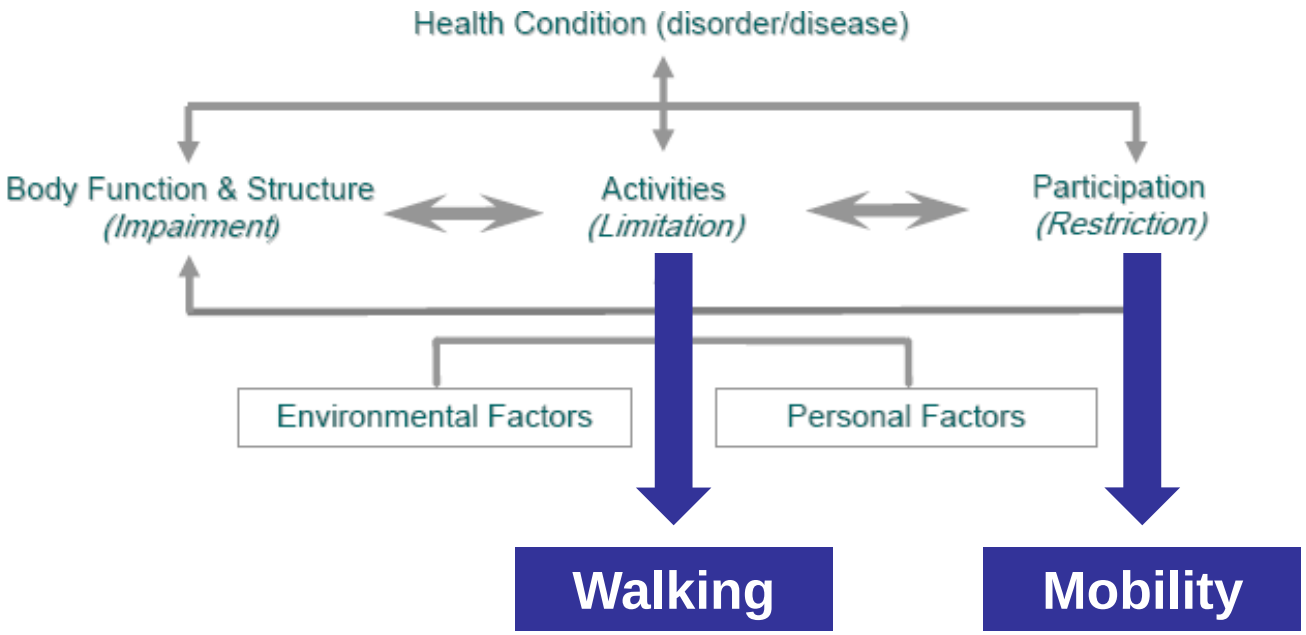


Figure 1. Model of ICF. Image from https://www.who.int

INTRODUCTION TO GAIT ASSESSMENT

Gait in the International Classification of Functioning, Disability and Health (ICF)





INTRODUCTION TO GAIT ASSESSMENT

Why we do assess the human gait?

1. to determine whether the gait pattern of a persona differs from "normal" pattern
2. to quantify the degree of impairment and to identify the causes of the abnormal gait patterns
3. to reassess and suggest an effective intervention plans to help patients improve their walking ability or to evaluate the efficacy of treatment
4. to give some information to the patients about his/her mobility state and recovery forecast

INTRODUCTION TO GAIT ASSESSMENT

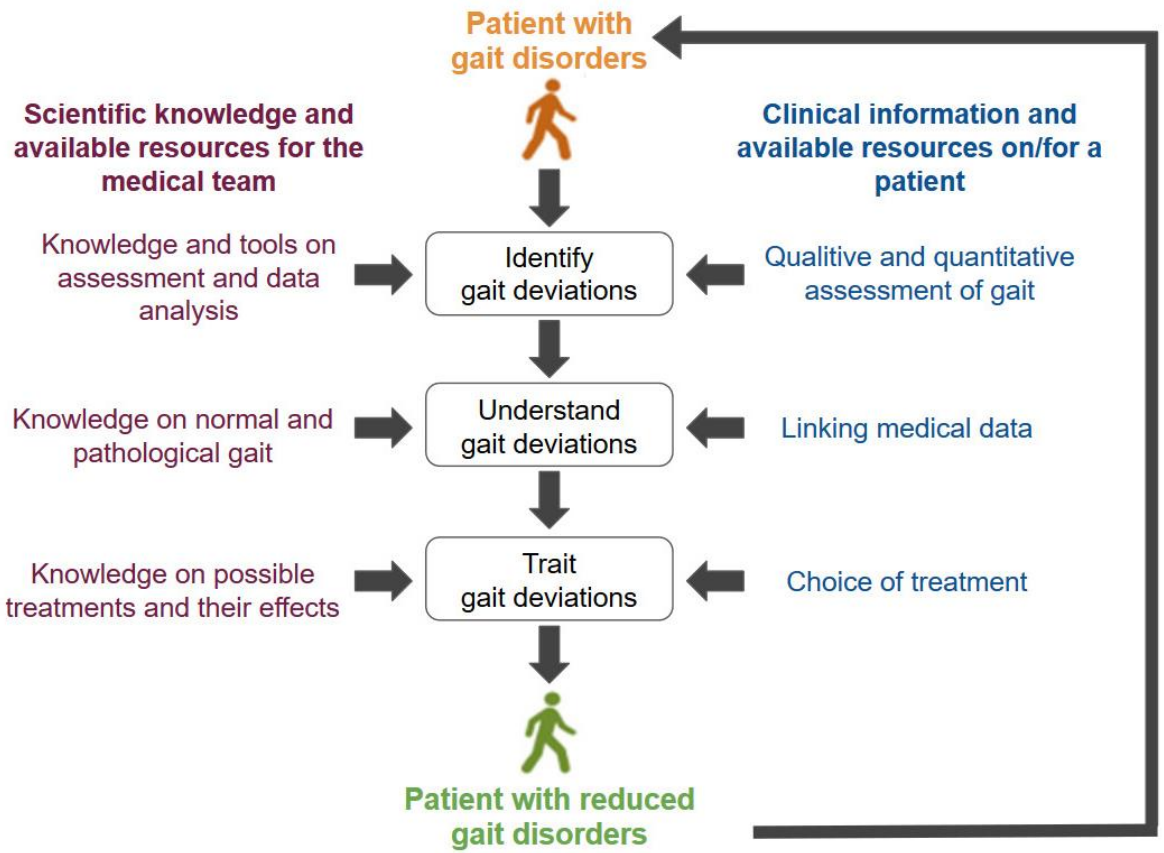
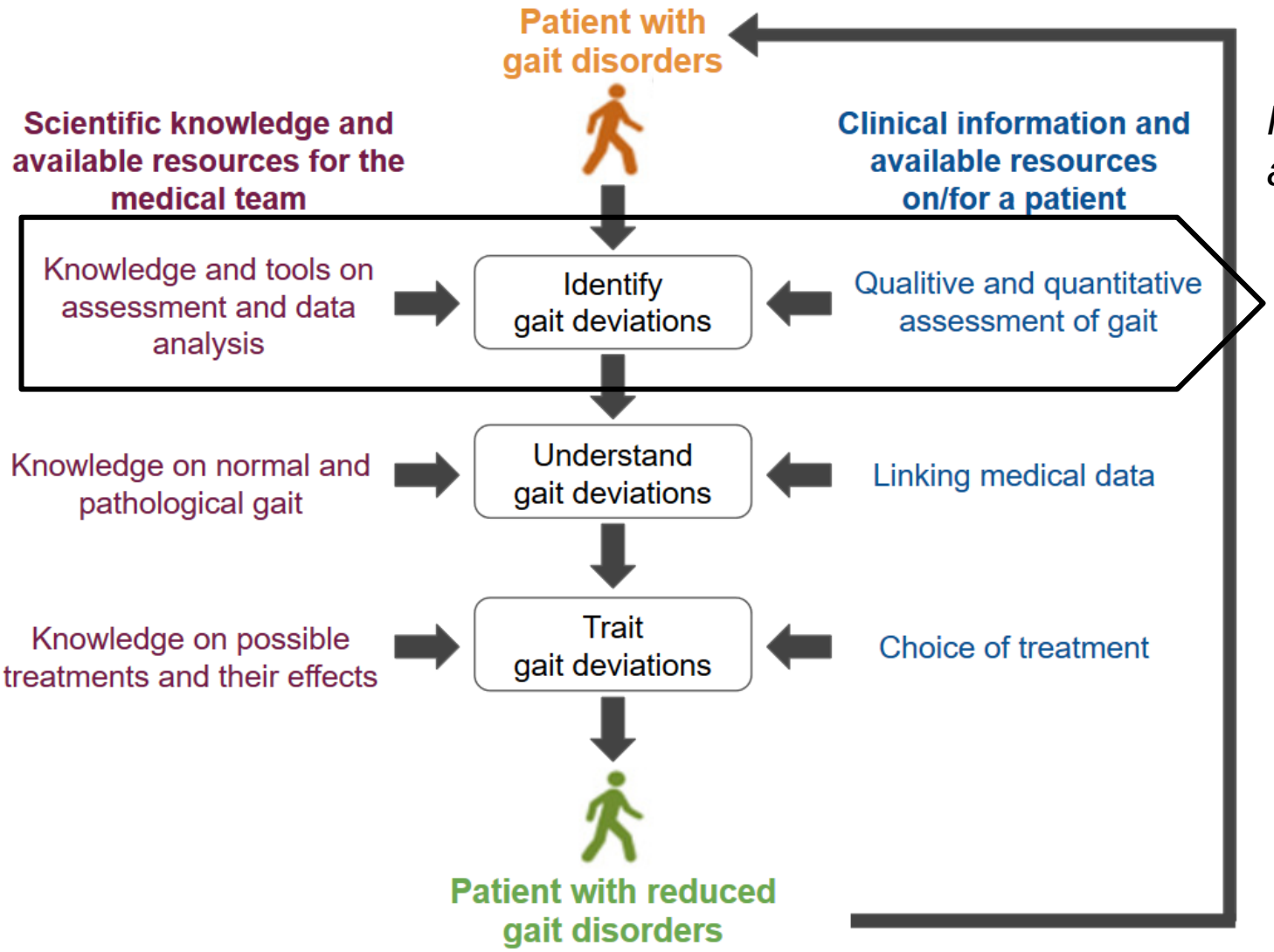
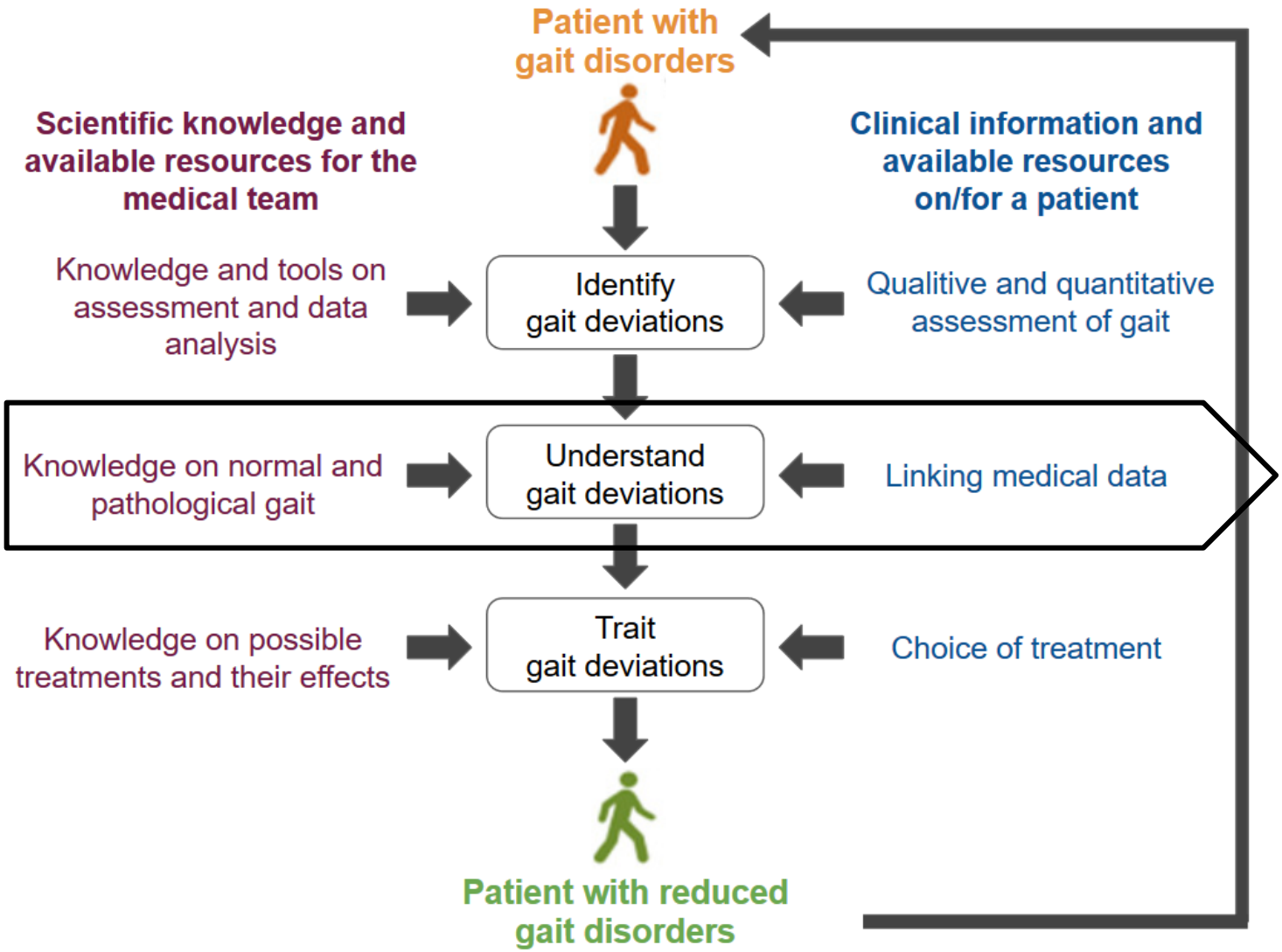


Figure 2. Gait assessment within the management patient with gait disorders. Image from Moissener F. et al. 2015

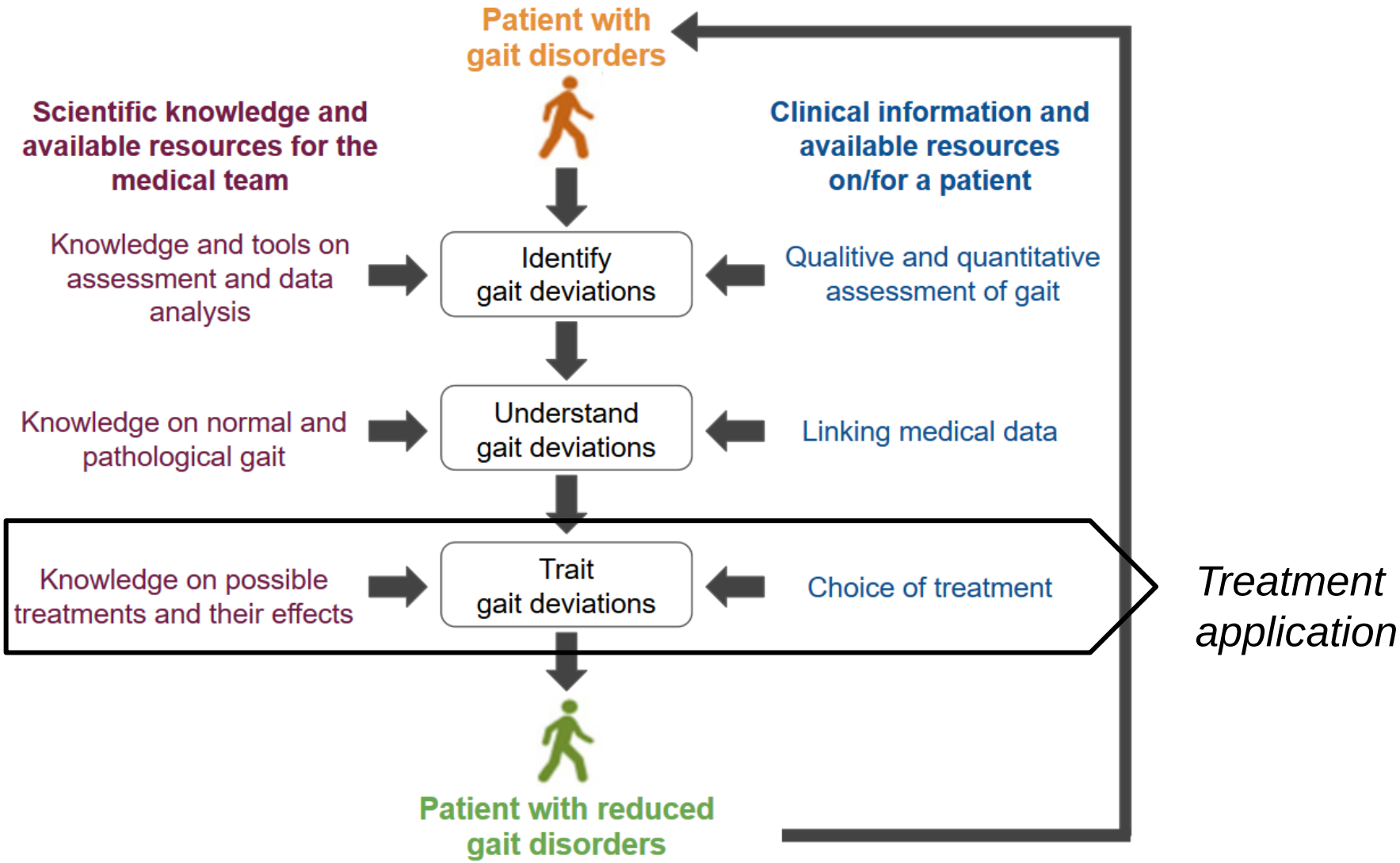


Factors to choose a technique:

- Complexity of disorders
- Available resources
- Capacity of patient
- Desired level of precision
- Evaluator experience



Interpretation of gait information and medical data

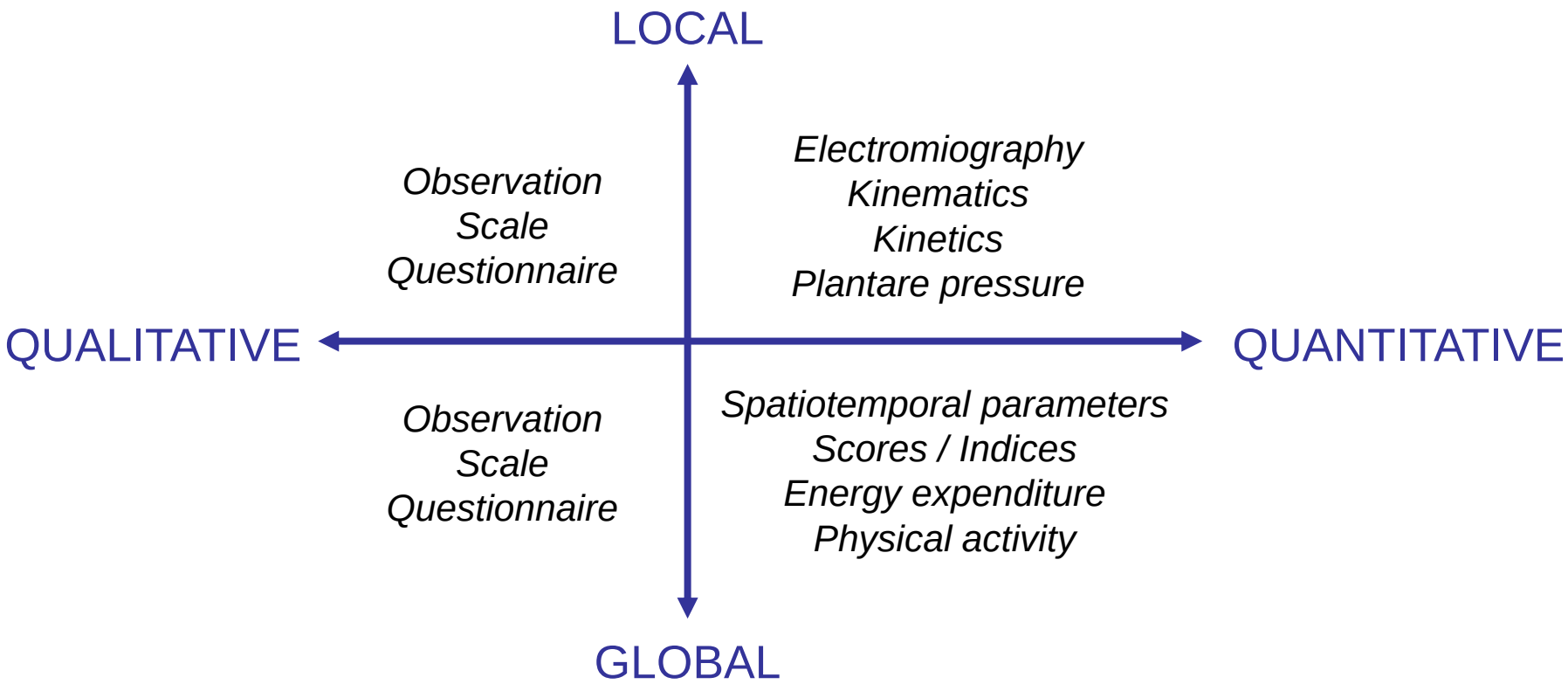

Patient with gait disorders
Scientific knowledge and available resources for the medical team
Clinical information and available resources on/for a patient
Knowledge and tools on assessment and data analysis
Identify gait deviations
Qualitive and quantitative assessment of gait
Knowledge on normal and pathological gait
Understand gait deviations
Linking medical data
Knowledge on possible treatments and their effects
Trait gait deviations
Choice of treatment
Treatment application
Patient with reduced gait disorders

C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

2. Methods for gait evaluation

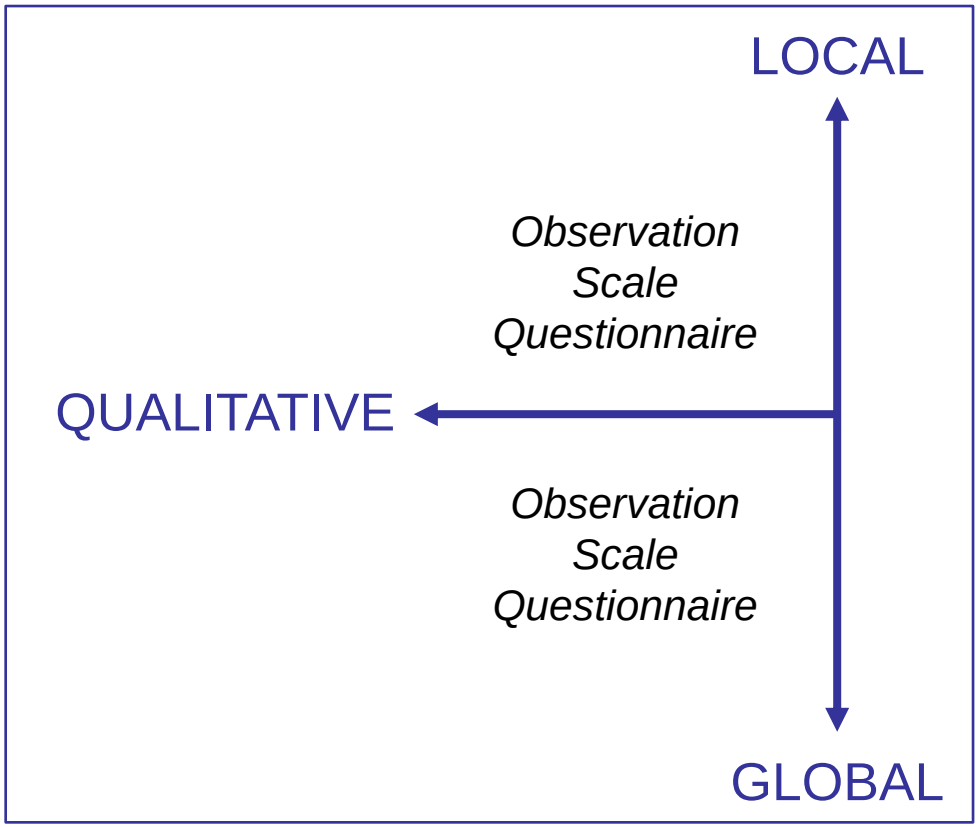
METHODS FOR GAIT EVALUATION

Methods to assess gait



METHODS FOR GAIT EVALUATION

Methods to assess gait

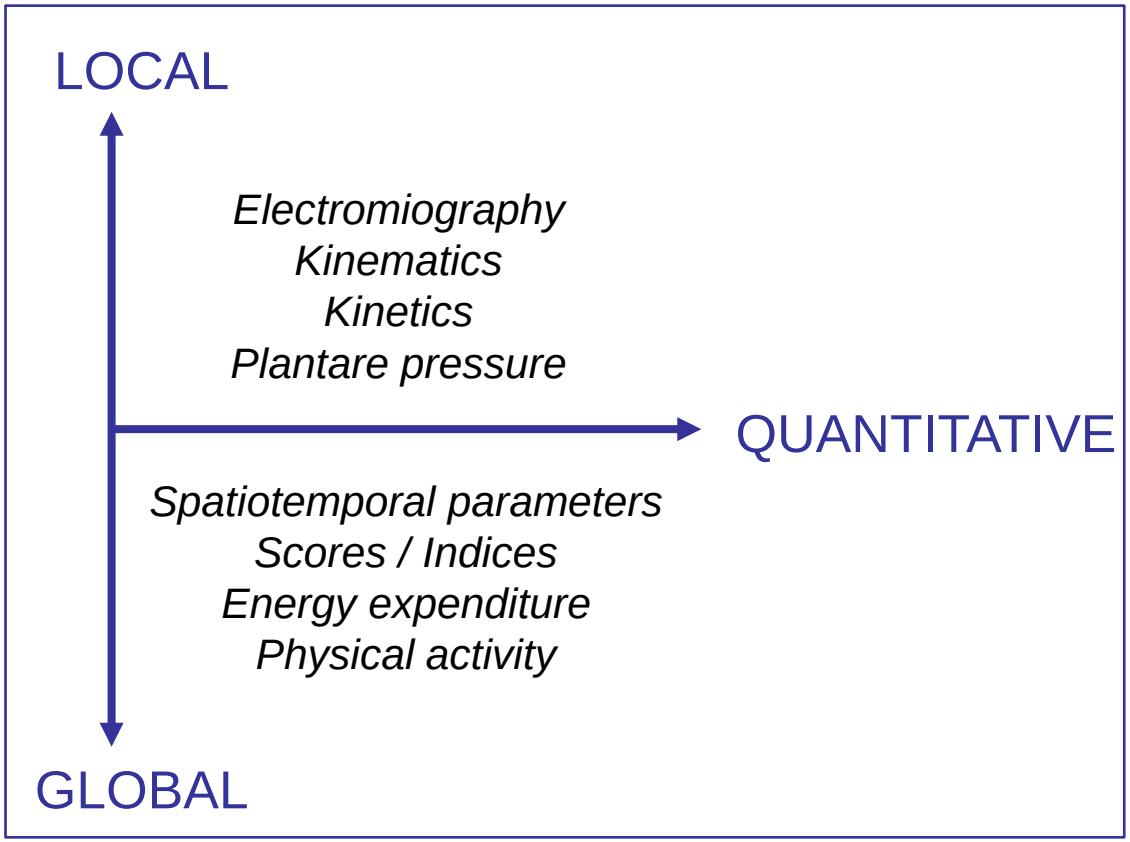


- To observe and interpret the gait performance.
- Subjective evaluation methods.
- Useful in clinical practice.

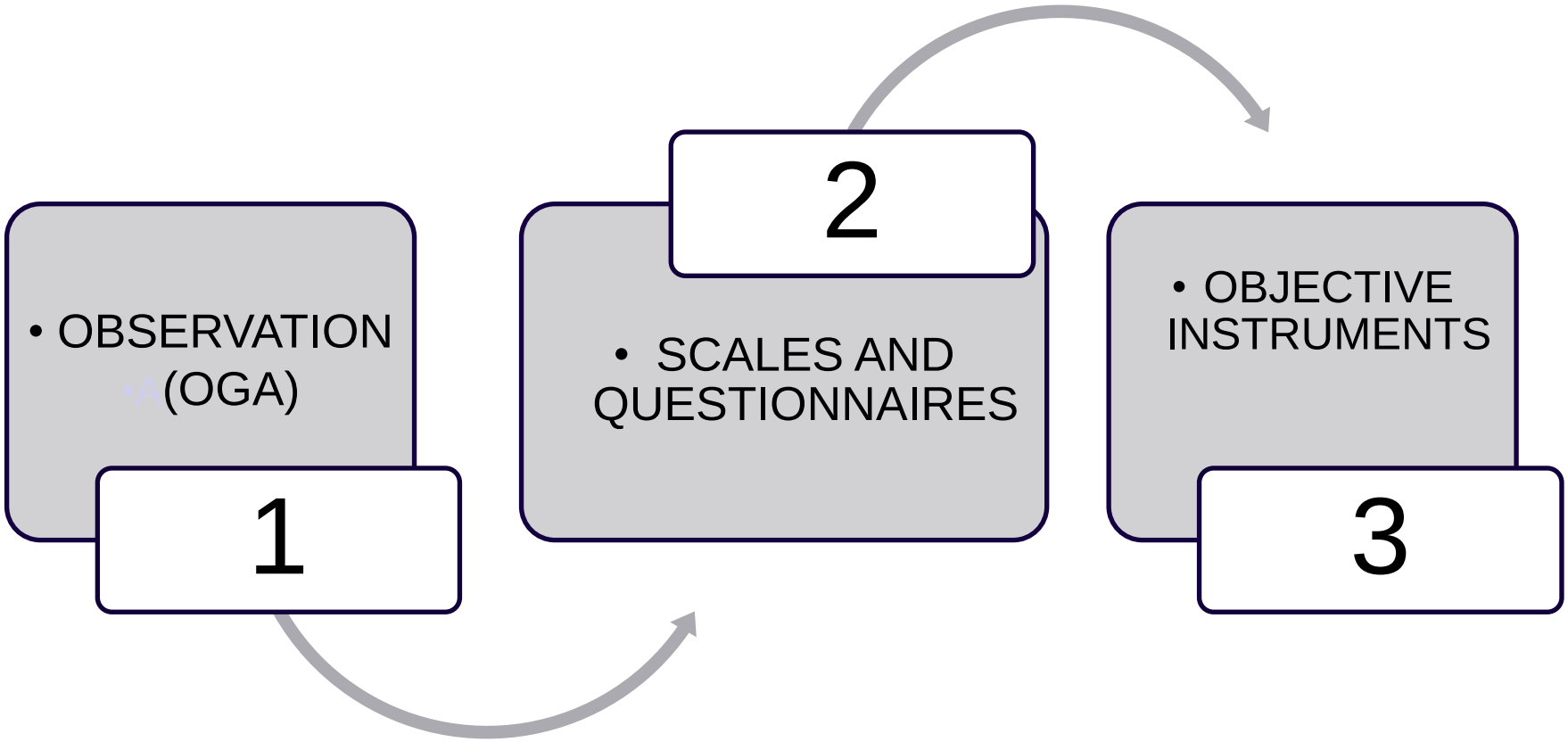
METHODS FOR GAIT EVALUATION

Methods to assess gait

- Objective instrument.
- Well-defined, limited and quantified result.
- Numerical magnitude.



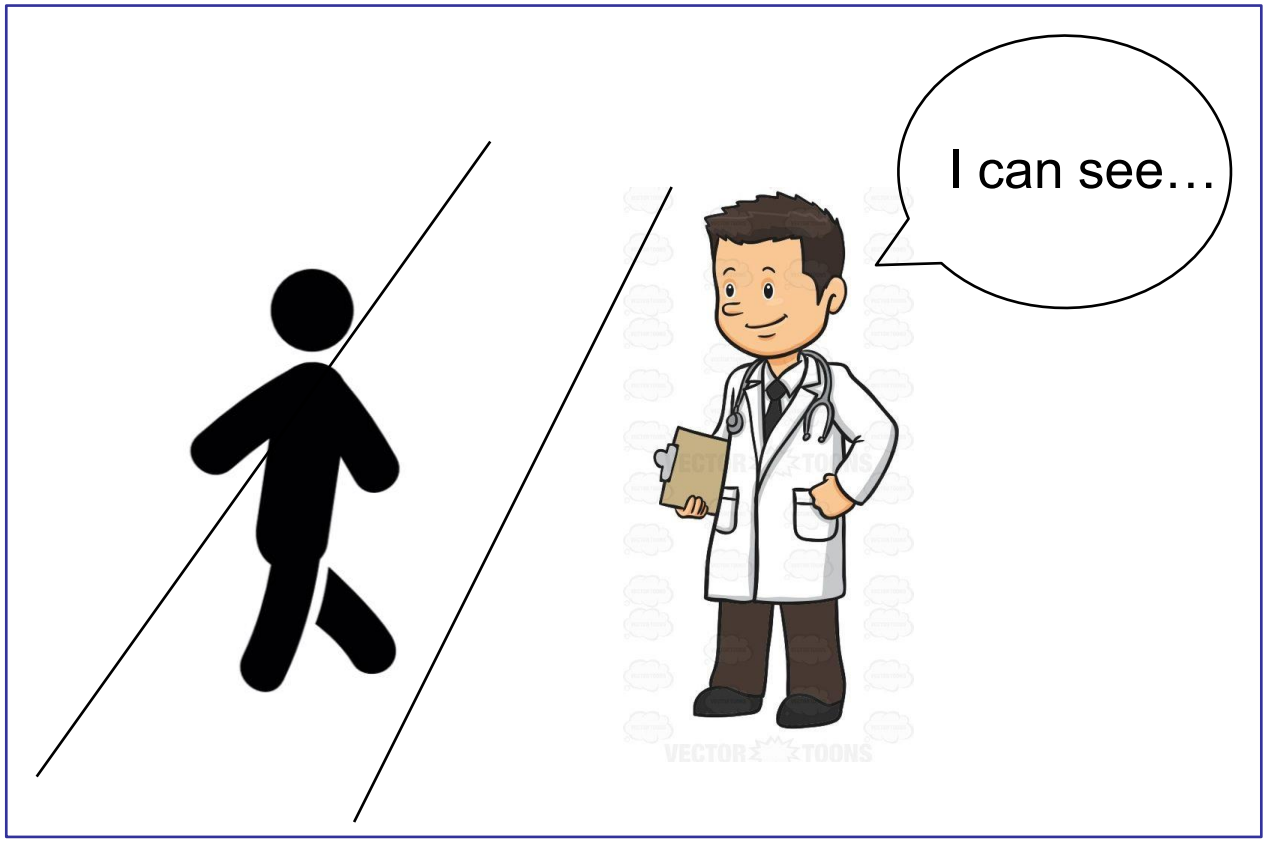
METHODS FOR GAIT EVALUATION



C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

3. Gait assessment through clinical observation

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION



To observe and register gait characteristics

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

When do we only use observation for gait evaluation?

Daily clinical setting

First consultation

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Following process

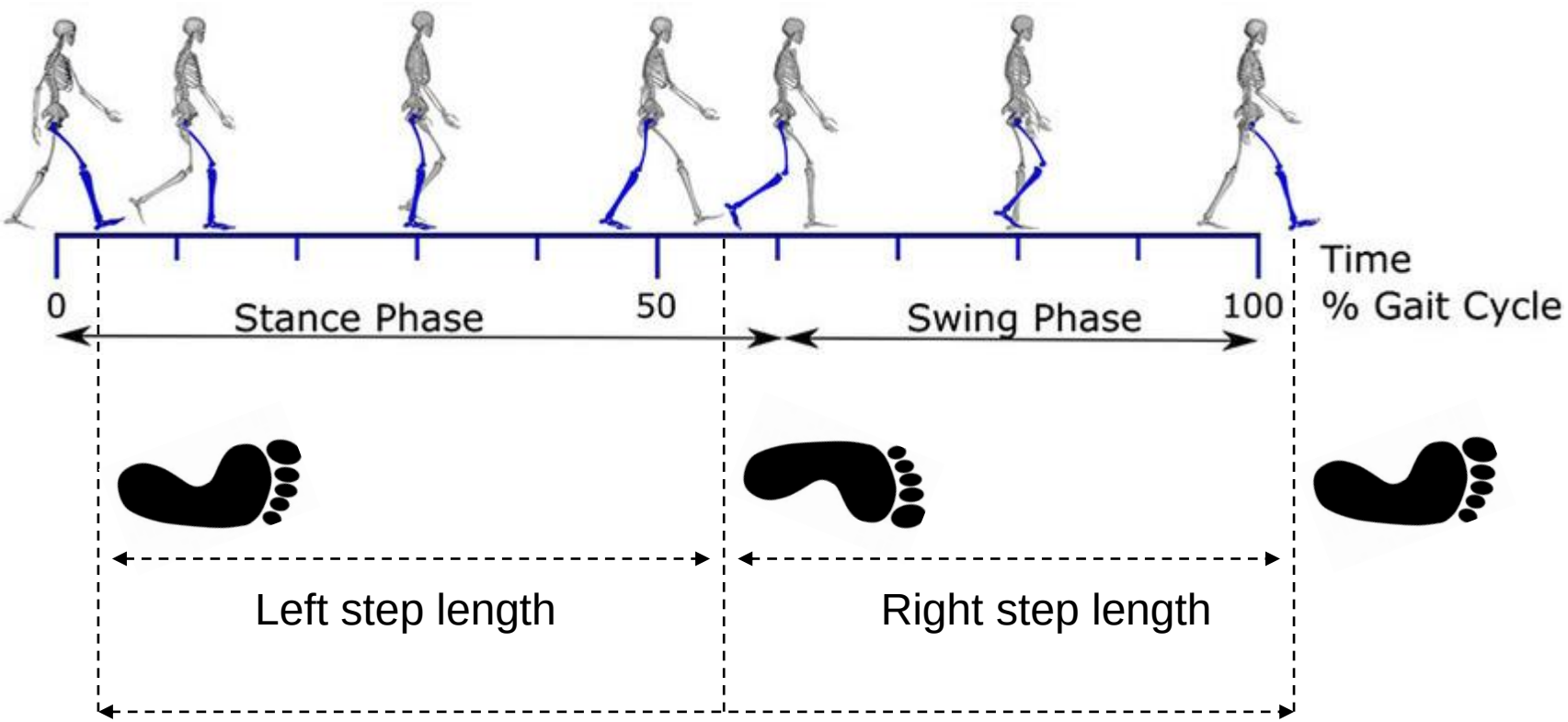
1. A gross review to sense the flow of action

2. An anatomical sequence in order to sort the multiple events happening at the different joints

- Starting at the foot and progressing upward
- Floor contact, ankle/foot, knee, hip, pelvis, and trunk are assessed in this sequence
- The direction and magnitude of motion in each phase of gait

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Following process: Framework of walking cycle



GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Following process: Framework of walking cycle

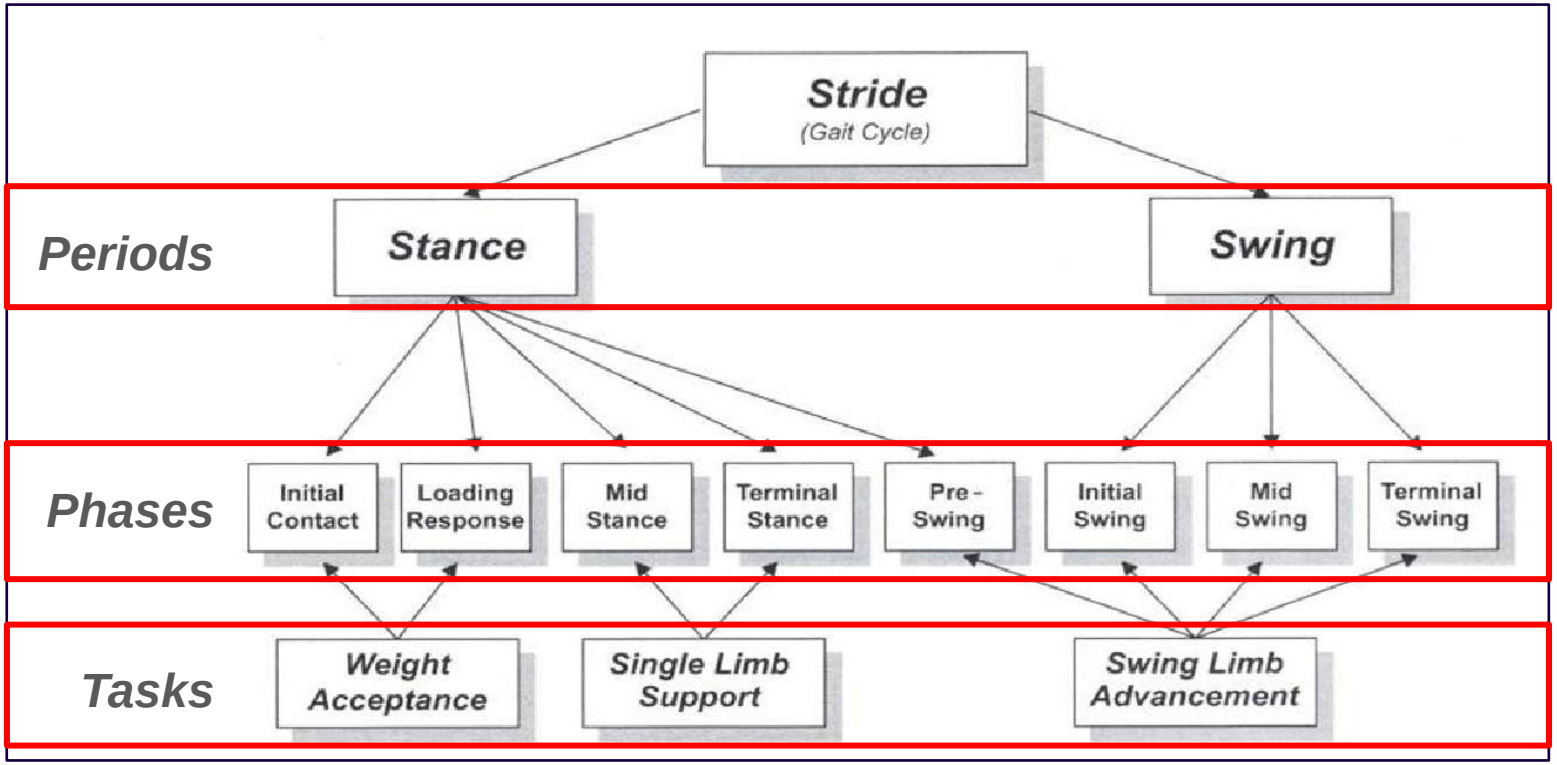


Figure 3. Functional division of Gait Cycle. From Perry J. t al. 2010.

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Following process: walking cycle

Why divide the observation into the milestones of the walking cycle?

- Indentifies the functional significance of the different motions occurring at the individual joints
- Correlating the simultaneous actions of the individual joints into patterns of total limb function
- The relative significance of one joint's motion compared to the others varies among the gait phases
- A posture that is appropriate in one gait phase would signify dysfunction at another point

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

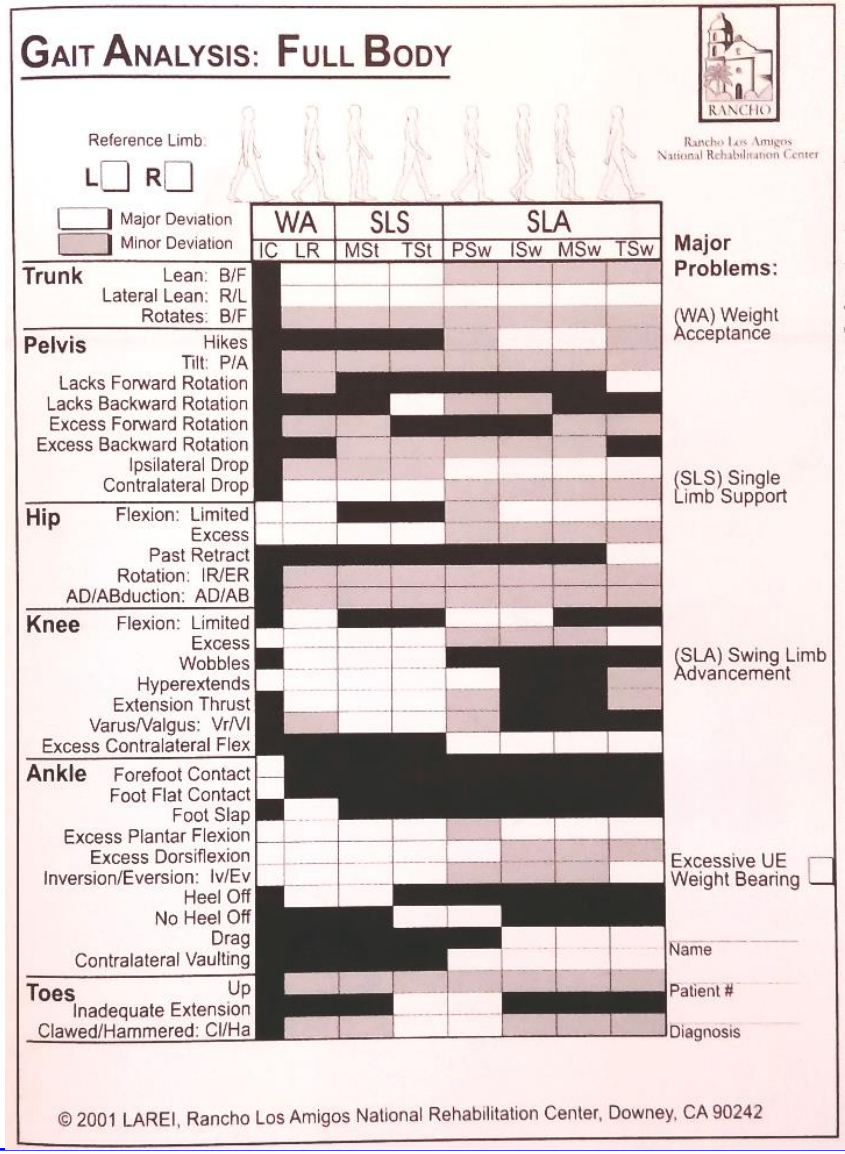
Following process: checklist or form

Rows = represents gait deviations

Columns = represents the gait phases

Gait dysfunction is tabulated by checking the pertinent boxes:

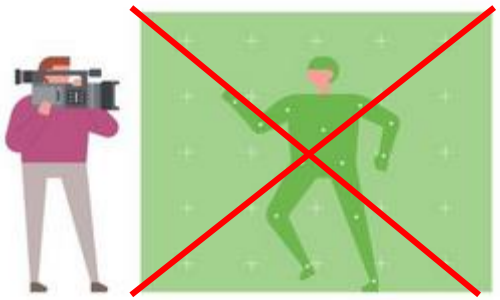
- White boxes represents major gait deviations
- Gray boxes means minor gait deviations
- Black boxes means that is not applicable

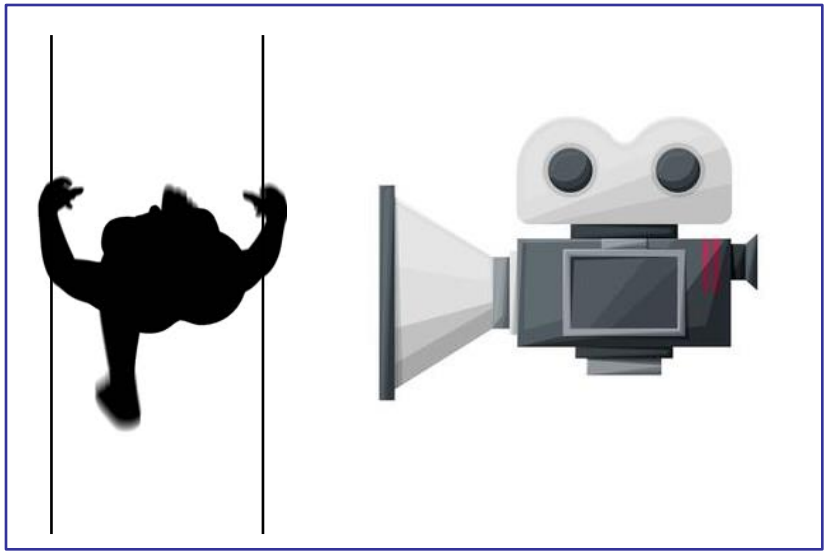


GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Following process: observation and videotaping

- To view gait patterns repeatedly without inducing patient fatigue.
- To increase the precision of the observational assessment.
- The patient does not carry any type of instrumentation.





GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Results from observational gait analysis

STRIDE
(Gait cycle)

Periods

Phases

Tasks

Lower limb function

Deterrents to effective weight acceptance and limb advancement are identified

Weakness

Contracture

Spasticity

Sensory loss

Pain

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Results from observational gait analysis

STRIDE
(Gait cycle)

- Milestone of walking cycle
- Spatiotemporal parameters
- Articular angles of the lower extremities (Kinematics)
- Posture during gait cycle

GAIT ASESSMENT THROUGH CLINICAL OBSERVATION

Medical interview to support the observation assessment

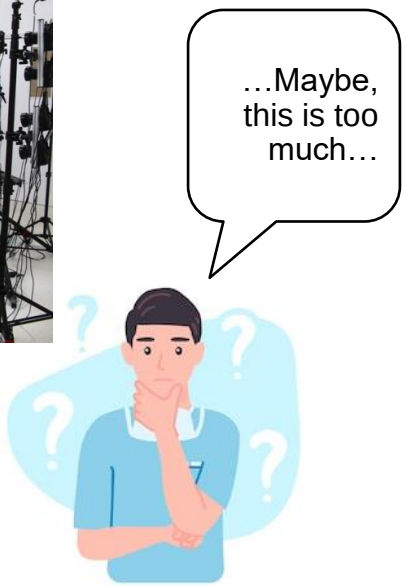
C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

4. Gait evaluation through standardized test and scales

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

General concept

Standardized clinical test and scales



It helps avoid omission

The results is a score

Quick and easy use

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

General concept

Questionnaire-based scales

Observation-based scales

Semi-subjective test

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Questionnaire-based scales

- Set of items listed in a questionnaire.
- Evaluate the patient's capacities when walking or performing a walking-related task.
- They can be self-reported or proxy-reported.

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Questionnaire-based scales: examples

Quality of life

How does impaired gait affect quality of life?

Likert Scale

Parkinson's Disease Questionnaire

	Never	Occasionally	Sometimes	Often	Always or cannot do at all
Had problems walking half a mile?	☐	☐	☐	☐	☐
Had problems walking 100 yards?	☐	☐	☐	☐	☐

Usually Self-reported

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Questionnaire-based scales: examples

Quality of life

How does impaired gait affect quality of life?

Likert Scale

Parkinson's Disease Questionnaire

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Had problems walking half a mile?	☐	☐	☐	☐	☐
Had problems walking 100 yards?	☐	☐	☐	☐	☐

Usually Self-reported

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Questionnaire-based scales: examples

Quality of life

How does impaired gait affect quality of life?

Pediatric Evaluation of Disability Inventory (PEDI)

Walks with walking aid (e.g. cane, crutches, walker) several hours at family or school outing such as zoo, amusement park or fair

- ○ **Unable**: Can't do, doesn't know how or is too young.
- ○ **Hard**: Does with a lot of help, extra time, or effort.
- ◉ **A little hard**: Does with a little help, extra time or effort.
- ○ **Easy**: Does with no help, extra time or effort, or child's skills are past this level.
- ○ I don't know.

Usually Proxy-reported

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Questionnaire-based scales: examples

Locomotion ability

Measure the locomotion ability through a set of items

Functional Mobility Scale

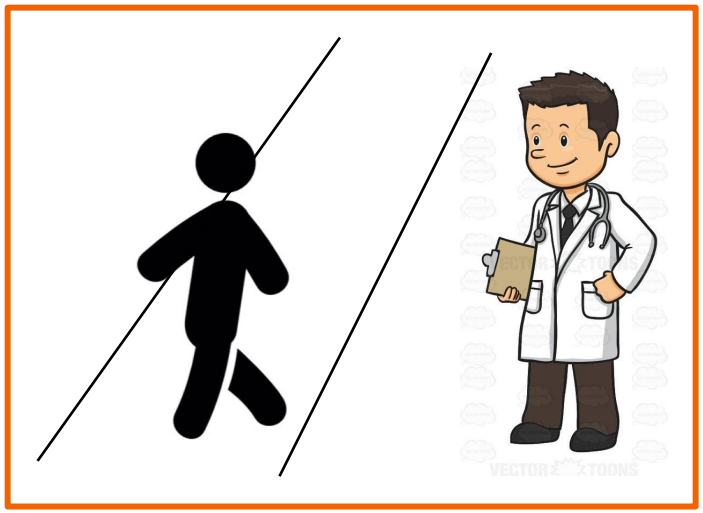
Proxy-reported

1. How does your child move around for short distances in the house? (5m)
2. How does your child move around in and between classes at school? (50m)
3. How does your child move around for long distances such as at the shopping centre? (500m)

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

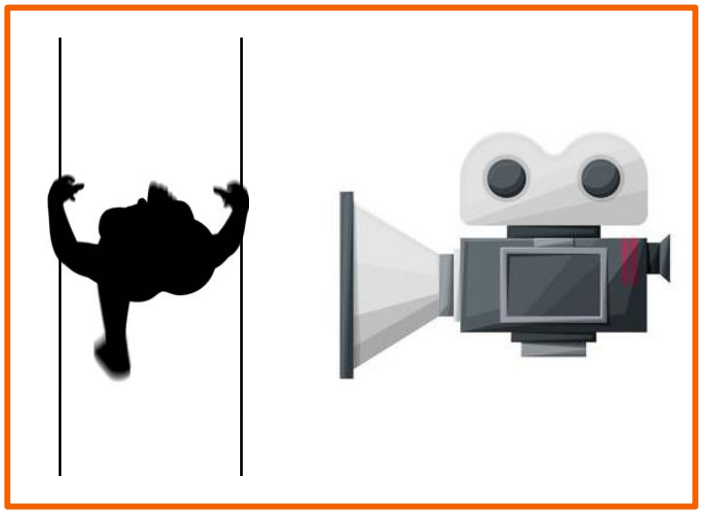
Observation-based scales

Direct observation



TOTAL SCORE

Indirect observation



Observation-based scales: examples

Tinetti Assessment Tool

TASK	DESCRIPTION OF BALANCE	Possible	Score
10. INITIATION OF GAIT (immediately after told to "go)	Any hesitancy or multiple attempts to start	0	
	No hesitancy	1	
11. STEP LENGTH AND HEIGHT	RIGHT swing food does not pass left stance foot with step	0	
	RIGHT foot passes left stance foot	1	
	RIGHT foot does not clear floor completely with step	0	
	RIGHT foot completely clears floor	1	
	LEFT swing foot does not pass right Stance foot with step	0	
	LEFT foot passes right stance foot	1	
	LEFT foot does not clear floor Completely with step	0	
	LEFT foot completely clears floor	1	
12. STEP SYMMETRY	RIGHT AND LEFT step length not equal (estimate)	0	
	RIGHT AND LEFT step appear equal	1	
13. STEP CONTINUITY	Stopping or discontinuity between steps	0	
	Steps appear to continue	1	
14. PATH (estimated in relation to floor tiles, 12-inch diameter. Observe excursion of 1 foot over about 10 feet of the course)	Marked deviation	0	
	Mild/moderate deviation or uses walking aid	1	
	Straight without walking aid	2	
15. TRUNK	Marked sway or uses walking aid	0	
	No sway – but flexion of knees or back, or spreads arms out while walking	1	
	No sway, no flexion, no use of arms, and no use of walking aid	2	
16. WALKING STANCE	Heels apart	0	
	Heels almost touching while walking	1	

Dynamic Parkinson Gait Scale (DYPAGS)	Score
1. Walking 7 m forwards	
Normal	0
Subtle start hesitation (<1 s) *or* slow gait *or* increased double-support time	1
Start hesitation >1 s *or* destination hesitation *or* impaired feet clearance	2
Block *or* accelerated short steps	3
Unable to perform the entire distance *or* near fall	4
Unable to initiate a step forward *or* fall	5
2. Walking 3 m backwards	
Normal	0
Subtle start hesitation (<1 s) *or* slow gait *or* increased double-support time	1
Start hesitation >1 s *or* destination hesitation *or* impaired feet clearance	2
Block *or* accelerated short steps	3
Unable to perform the entire distance *or* near fall	4
Unable to initiate a step backward *or* fall	5
3. Turning 360° on the same place to the right[a]	
Normal	0
Subtle start hesitation (<1 s) *or* ≥8 steps	1
Start hesitation >1 s *or* ≥10 steps	2
≥15 steps *or* block	3
Unable to complete 360° turning *or* near fall	4
Unable to initiate turning *or* fall	5
4. Turning 360° on the same place to the left[a]	
Normal	0
Subtle start hesitation (<1 s) *or* ≥8 steps	1
Start hesitation >1 s *or* ≥10 steps	2
≥15 steps *or* block	3
Unable to complete 360° turning *or* near fall	4
Unable to initiate turning *or* fall	5
5. Stepping over an imaginary obstacle with the right leg[b]	
Step amplitude > 0.5 × patient's height	0
Step amplitude = 0.4 × patient's height − 0.5 × patient's height	1
Step amplitude = 0.3 × patient's height − 0.4 × patient's height	2
Step amplitude = 0.2 × patient's height − 0.3 × patient's height	3
Step amplitude < 0.2 × patient's height	4
Unable to initiate a step forward	5
6. Stepping over an imaginary obstacle with the left leg[b]	
Step amplitude > 0.5 × patient's height	0
Step amplitude = 0.4 × patient's height − 0.5 × patient's height	1
Step amplitude = 0.3 × patient's height − 0.4 × patient's height	2
Step amplitude = 0.2 × patient's height − 0.3 × patient's height	3
Step amplitude < 0.2 × patient's height	4
Unable to initiate a step forward	5
7. Passing through tight quarters	
No hesitation	0
Subtle hesitation (<1 s) *or* shuffling of first step	1
Start hesitation = 1–2 s *or* impaired feet clearance within tight quarters	2
Start hesitation = 2–5 s *or* accelerated short steps within tight quarters	3
Start hesitation = 5–10 s *or* block within tight quarters *or* near fall	4
Start hesitation > 10 s *or* unable to initiate a step forward *or* fall	5
8. Walking while performing a cognitive dual-task (quoting animal names)	
Normal	0
Subtle start hesitation (<1 s) *or* slow gait *or* increased double-support time	1
Start hesitation >1 s *or* destination hesitation *or* impaired feet clearance *or* <6 items quoted	2
Block *or* accelerated short steps	3
Unable to perform the entire distance *or* near fall	4
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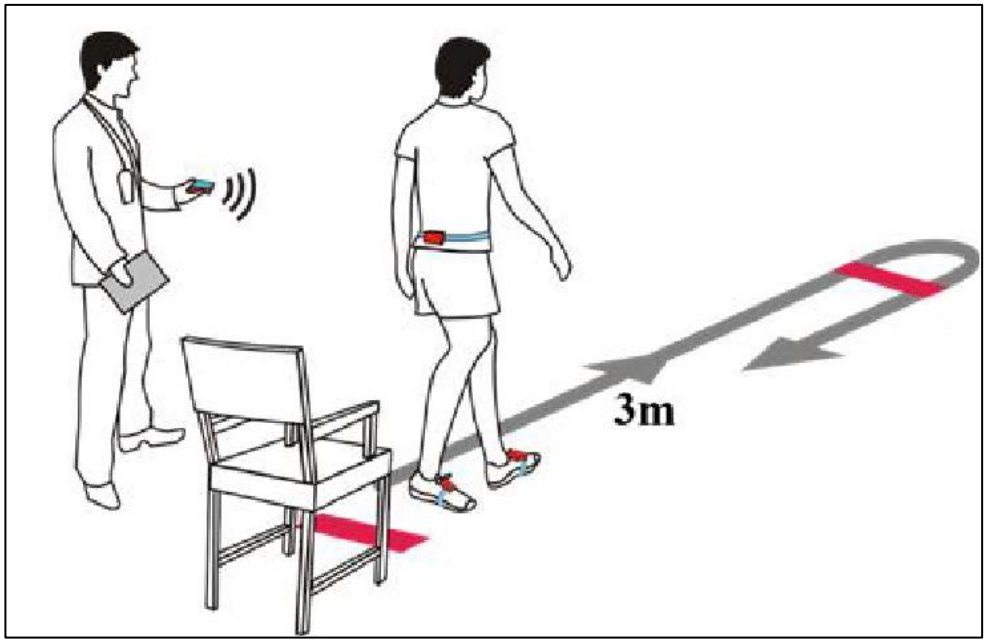
GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Semi-subjective test

- Walks on a pre-determined circuit

- Results is a well-defined magnitude (i.e. TIME)

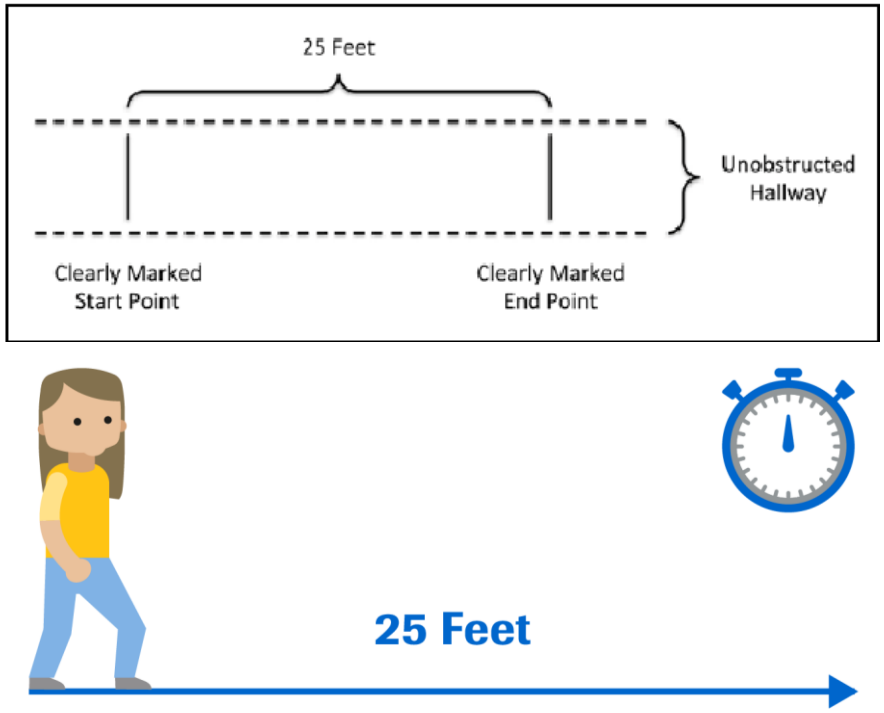


Timed get up and go test setup

GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Semi-subjective test: examples

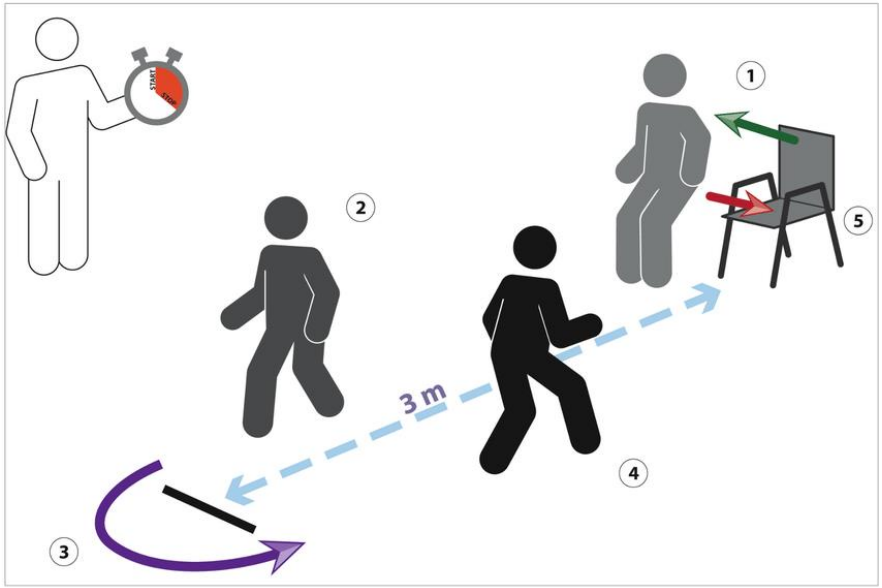
Timed 25-Foot Walk



GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Semi-subjective test: examples

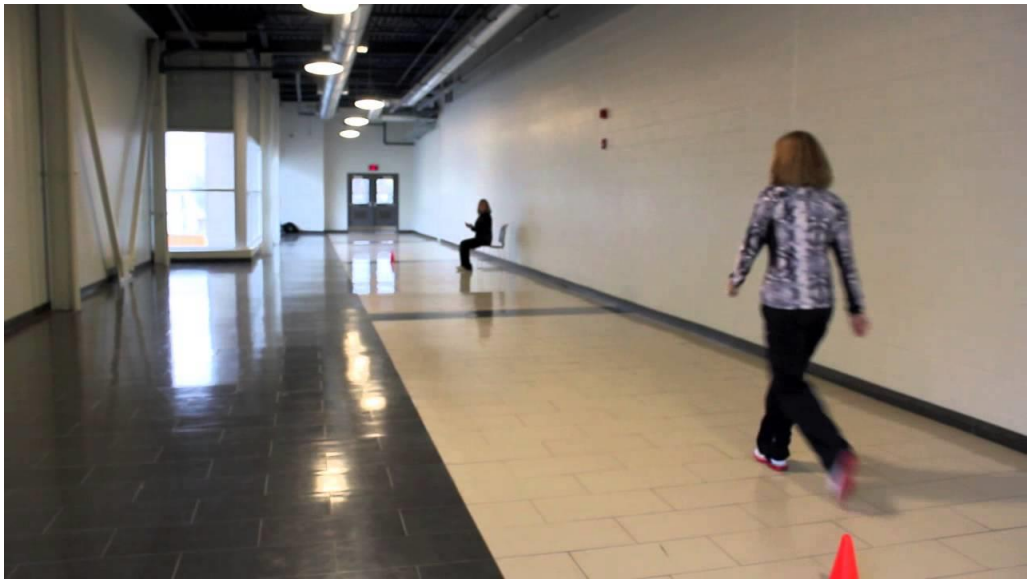
Timed Get up and Go



GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Semi-subjective test: examples

Six-minute walking test



GAIT EVALUATION: STANDARDIZED TEST AND SCALES

Results

- A final score of the patient's performance is obtained
- It facilitates the reporting of gait characteristics
- It allows us to classify the people evaluated into subgroups of patients

C.1 WHAT METHODS MAY I APPLY TO ASSESS GAIT APPROPRIATELY?

5. Gait assessment through objective instruments

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

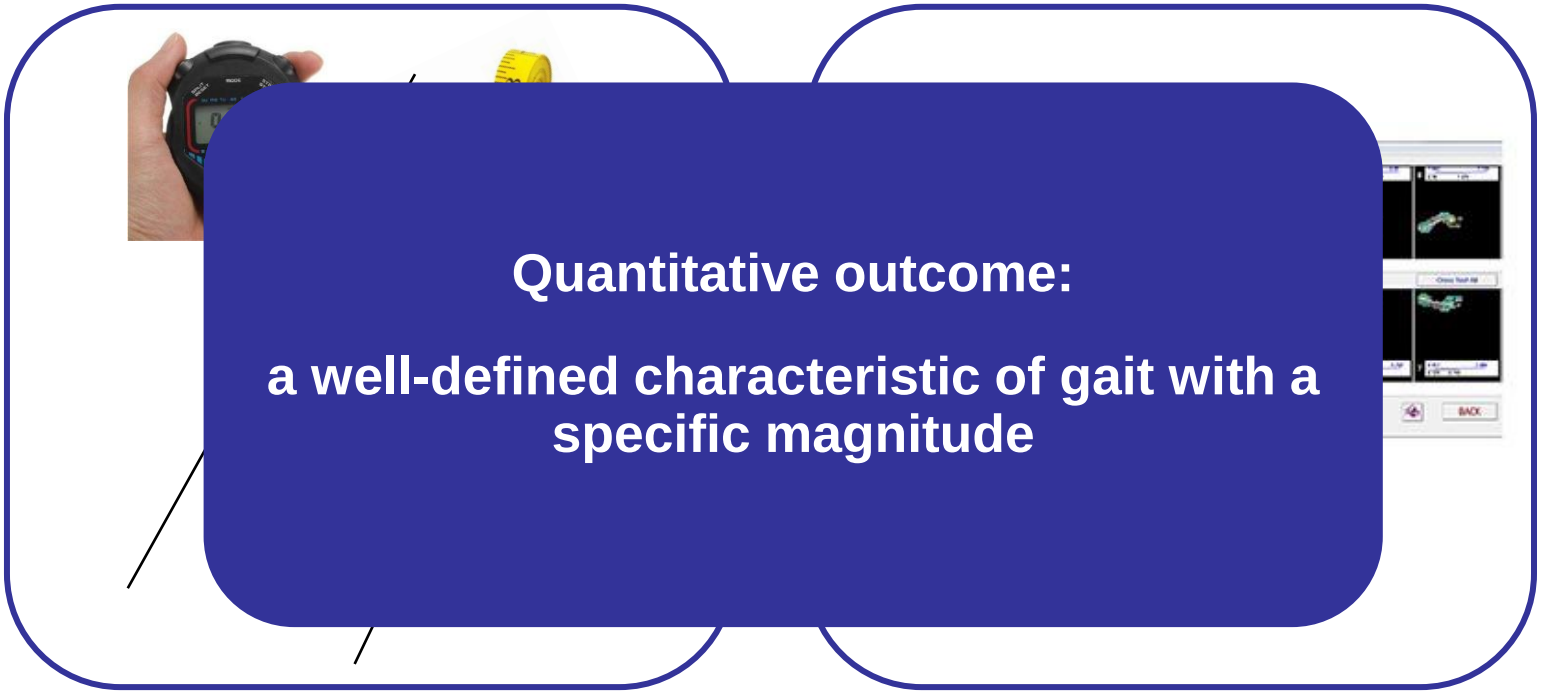
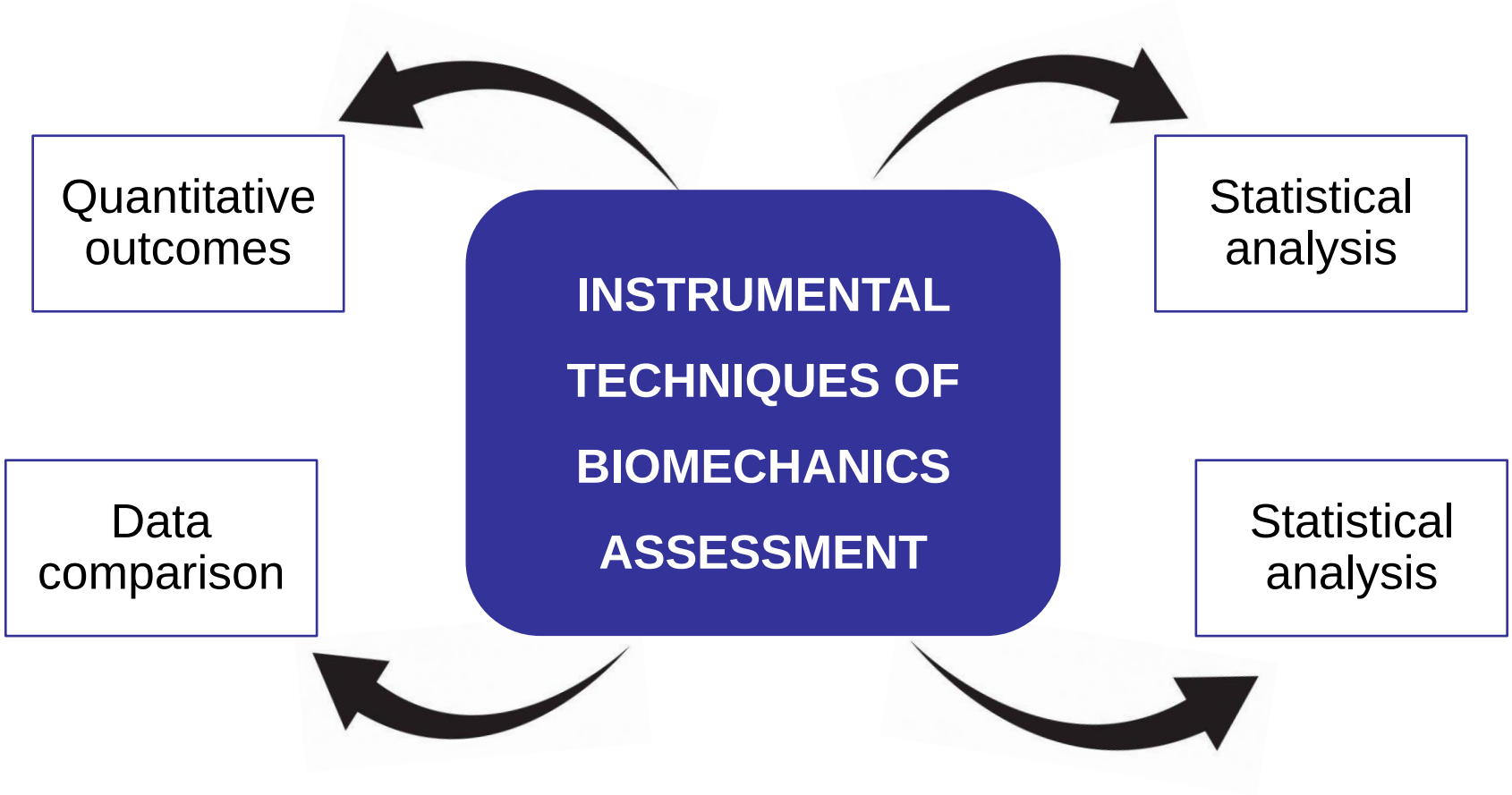


Figure 4. Left: setup for gait assessment with chronometer and metric tape. Right: GAITrite system. Image from accesshealth.com

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS



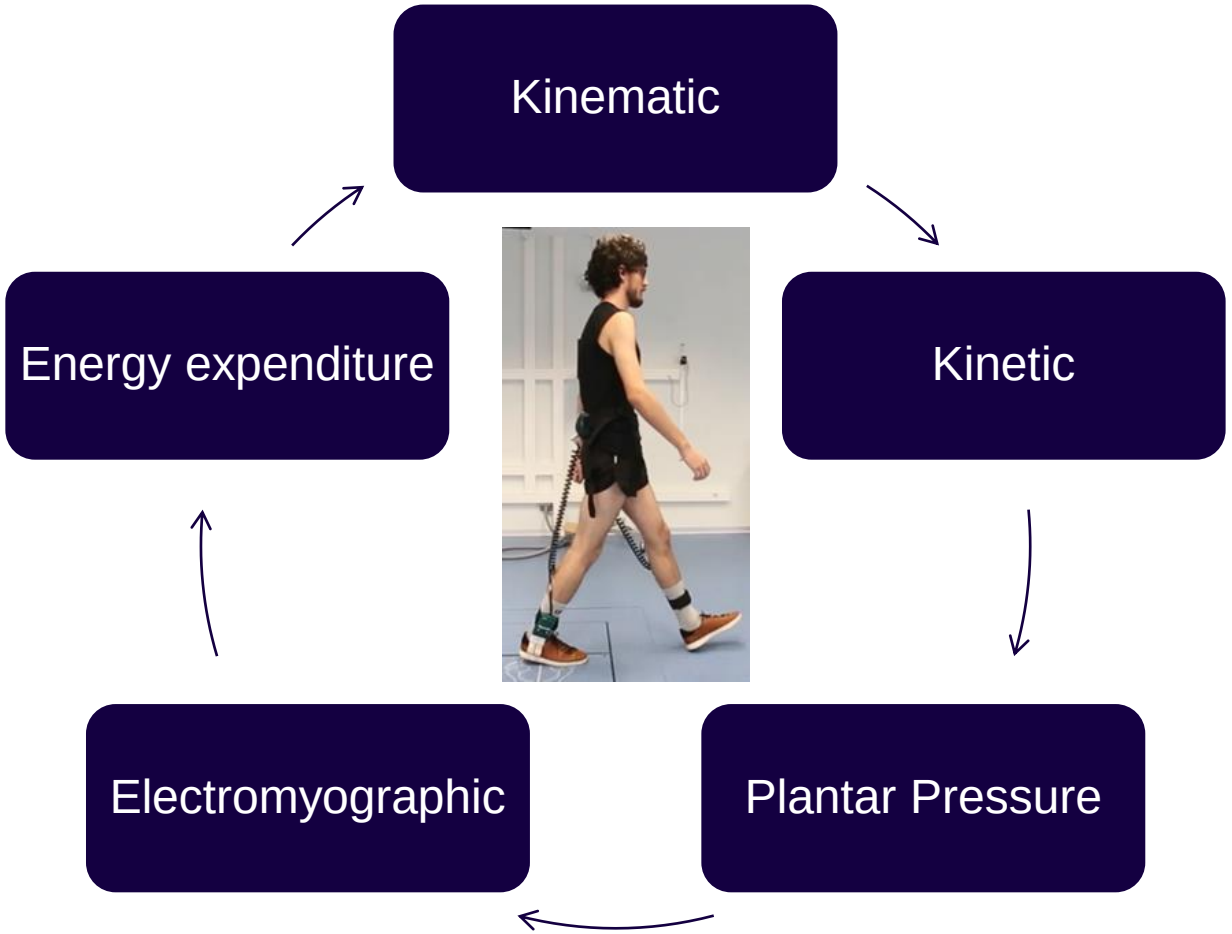
GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Image processing

Floor sensor

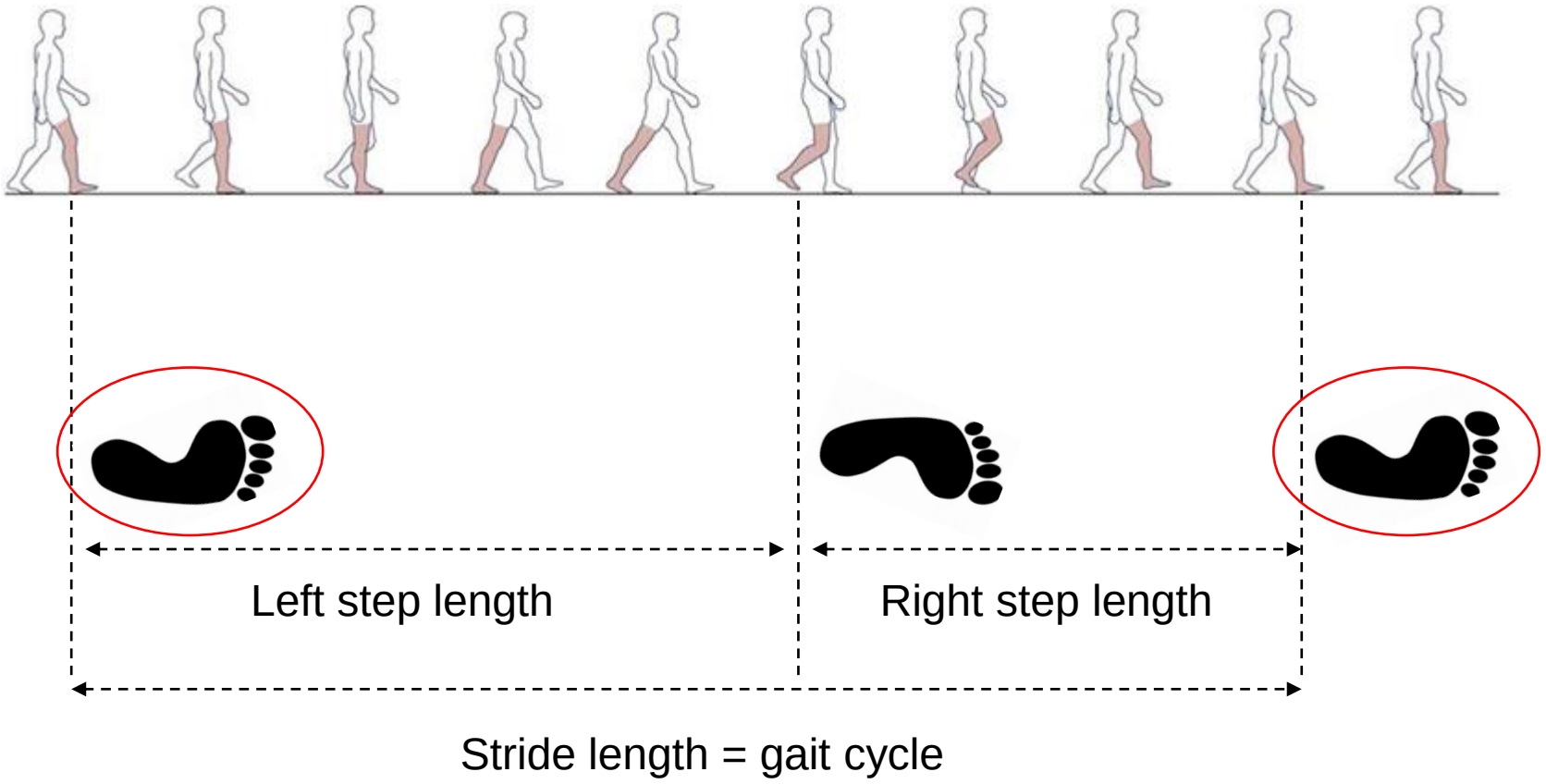
Sensor located on body

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS



GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Spatiotemporal outcomes



GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Spatiotemporal outcomes

Velocity	• Rate of change of the object's position with respect to a frame of reference and time
Step length	• Distance between the ipsilateral foot strike and the following controlatal foot strike
Cadence	• Number of steps per minute
Stride length	• Distance between two consecutive ipsilateral foot strike
Step width	• Distance between of the two feet, perpendicular to the plane of walking

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Spatiotemporal outcomes

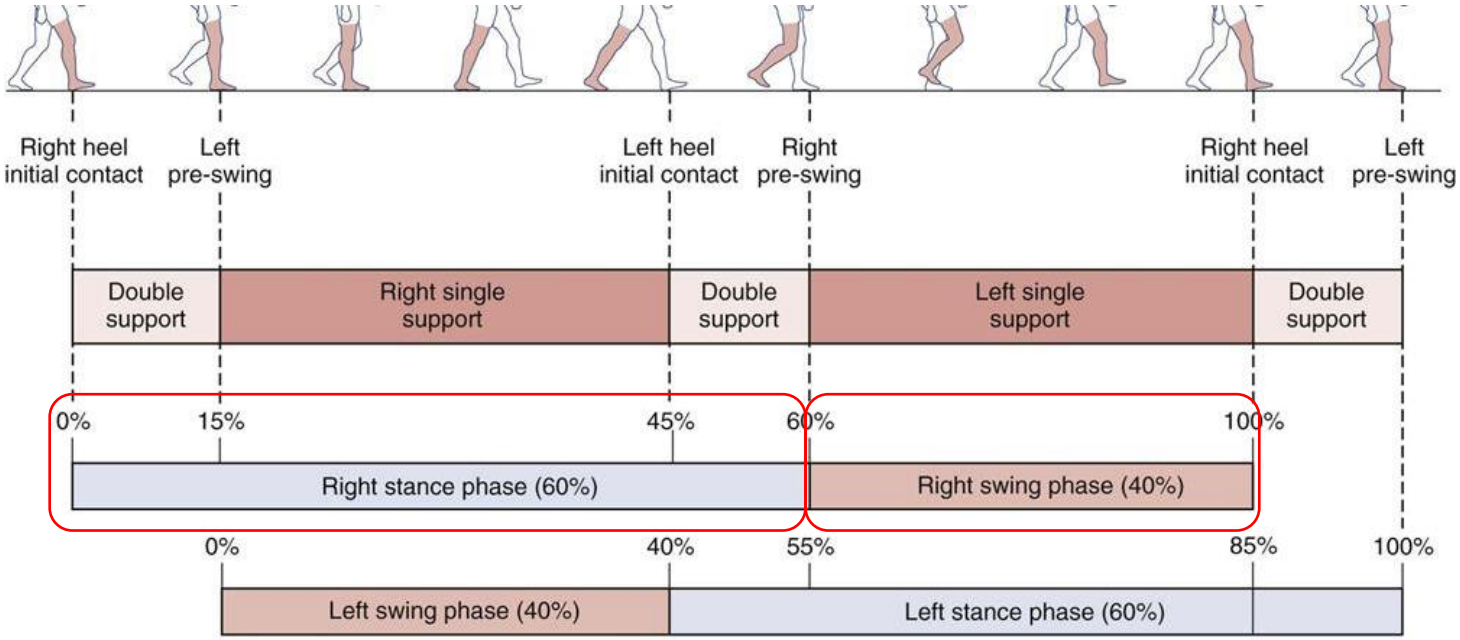


Figure 5. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Spatiotemporal outcomes

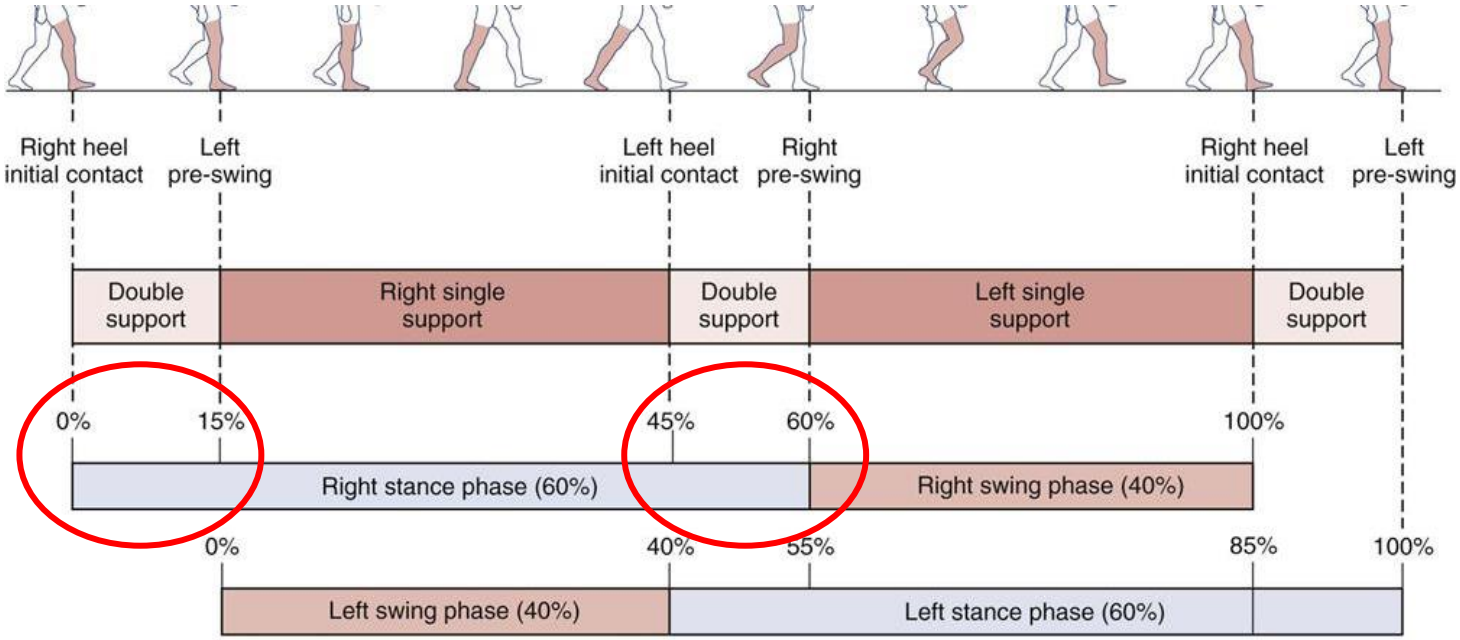


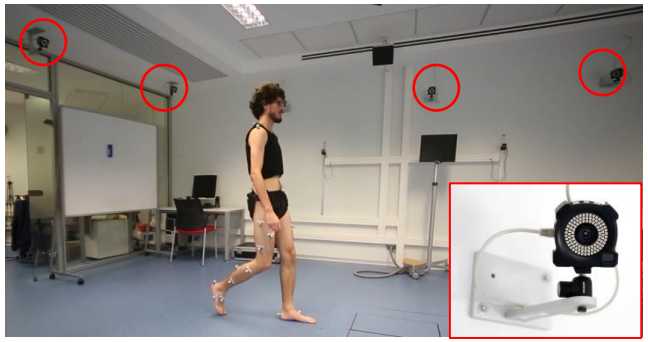
Figure 5. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

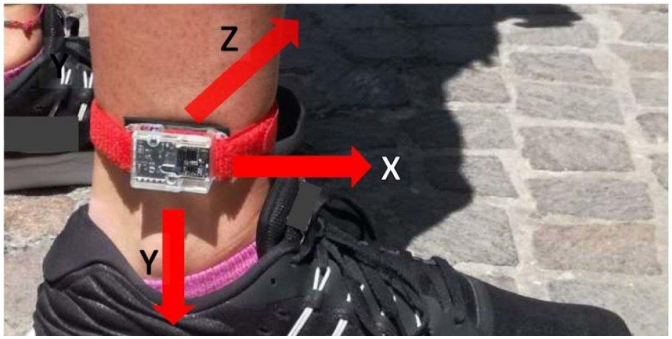
Spatiotemporal outcomes

Instrumented walkway

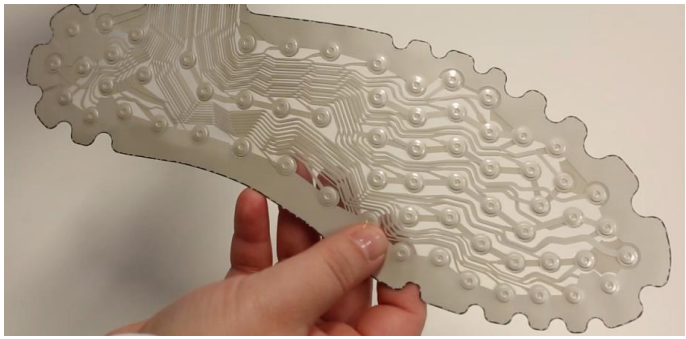
Optoelectronics cameras



Accelerometers



Footswitches



GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Spatiotemporal outcomes

Instrumented walkway

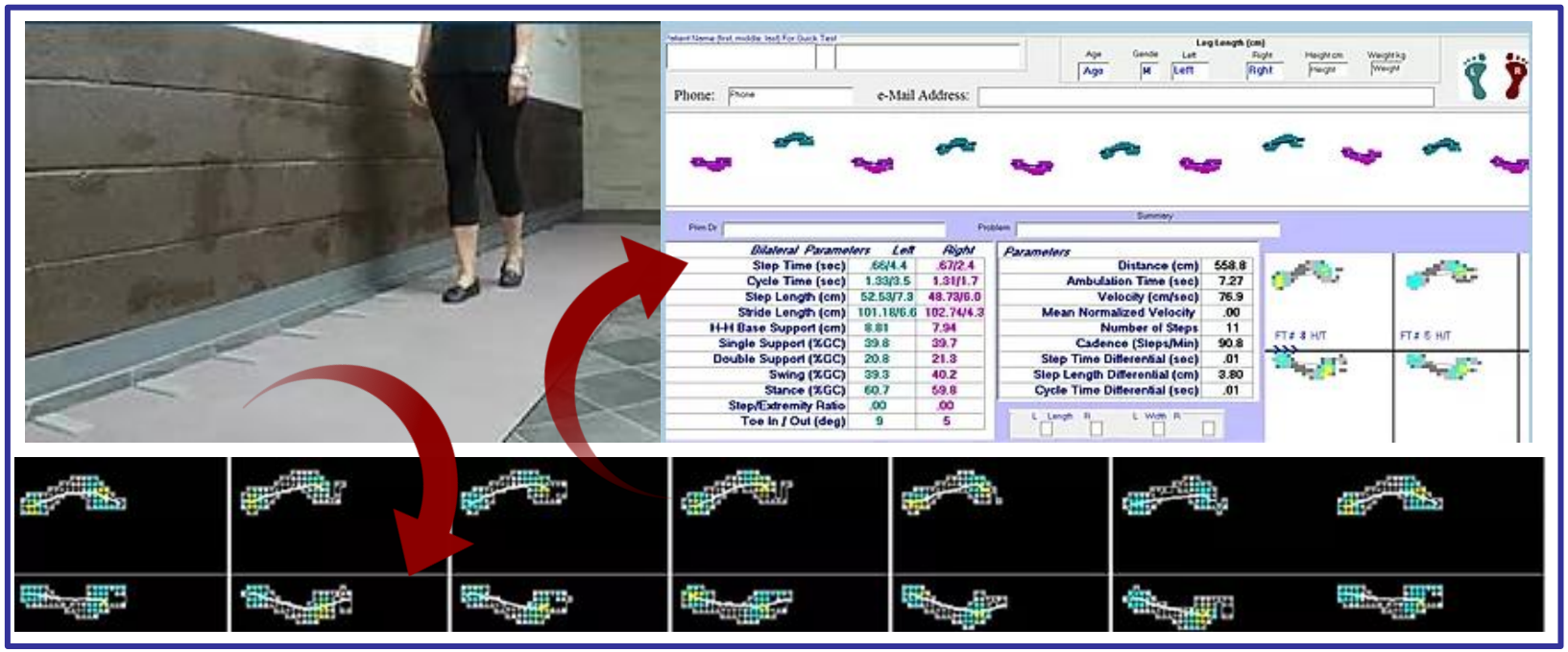
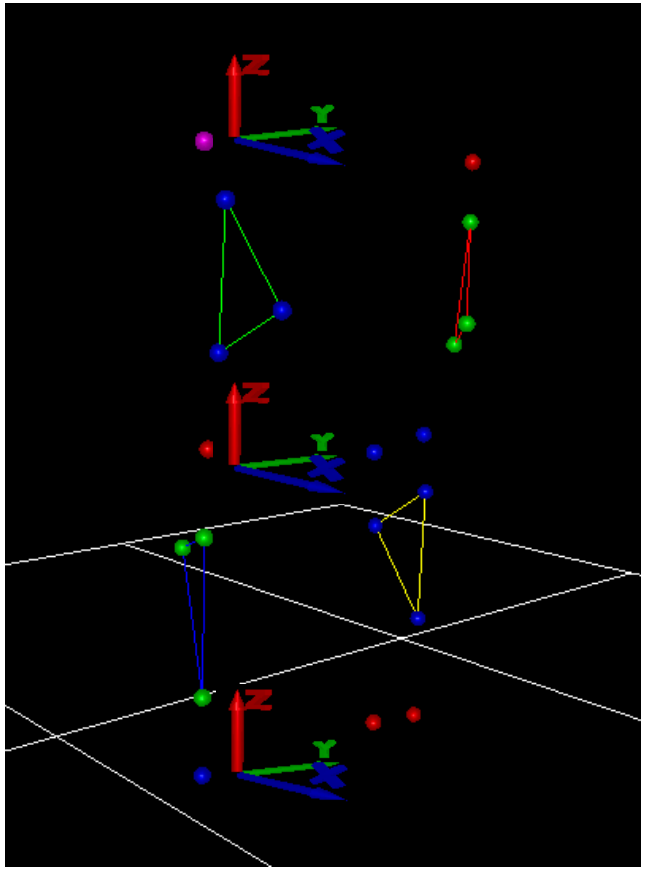


Figure 6. *GAITRite* PLATINUM PLUS CLASSIC system from www.gaitrite.com

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Kinematics outcomes

Joint angles



GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Kinematics outcomes

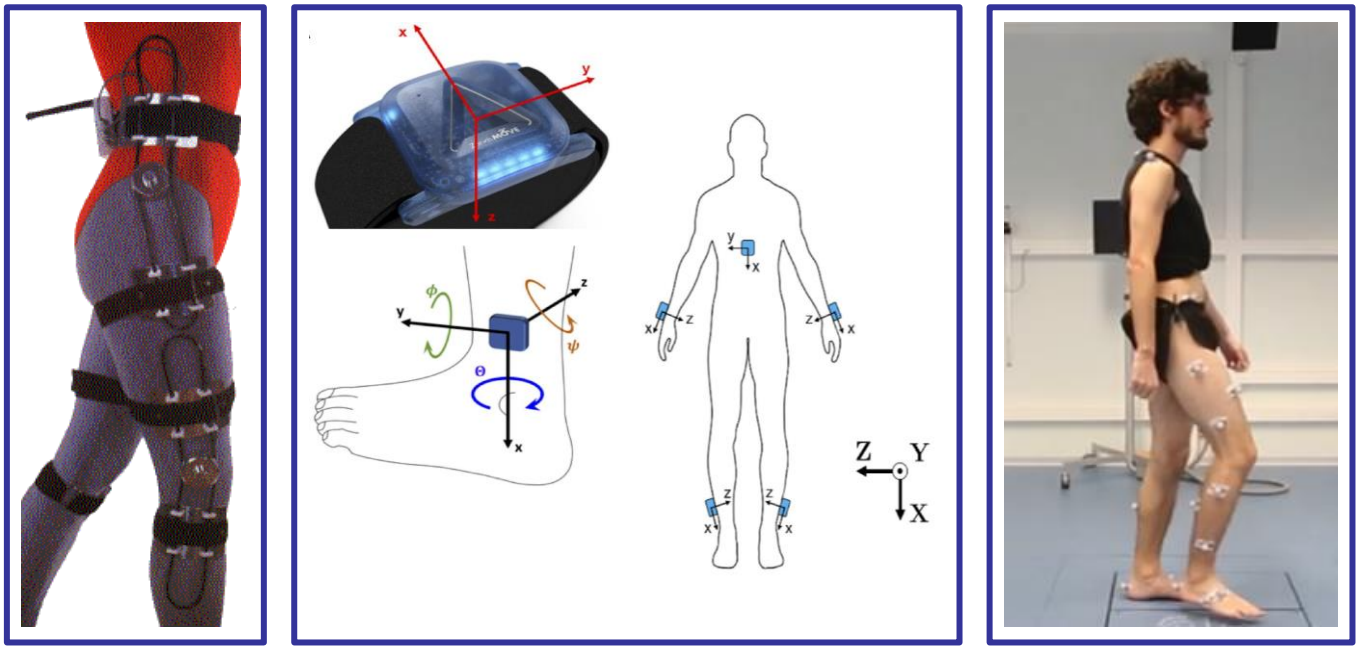
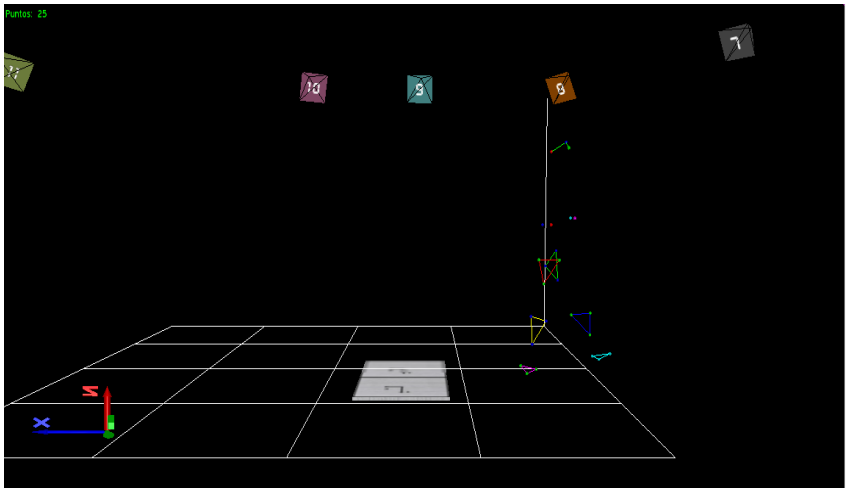


Figure 7. (*Left)* Electrogoniometer from www.mie-uk.com, *(Middle)* Inertial sensor from Rengglie et al. 2020 *(Right)* Biomechanical model for photogrammetry measurement.

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Kinematics outcomes

Photogrammetry system

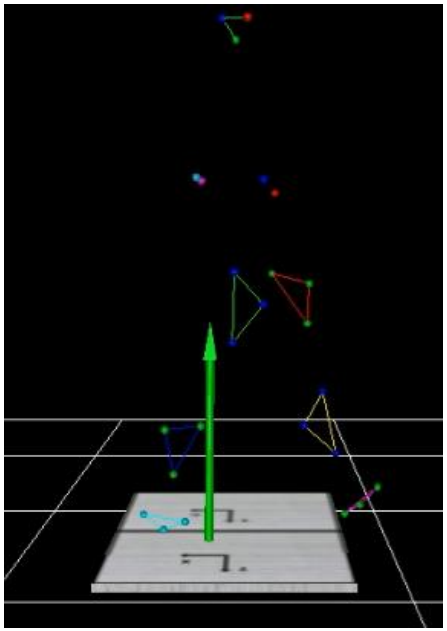


Active versus Passive landmarks

Figure 8. Photogrammetry system from Faculty of Medicine at University of Valencia

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Kinetics outcomes



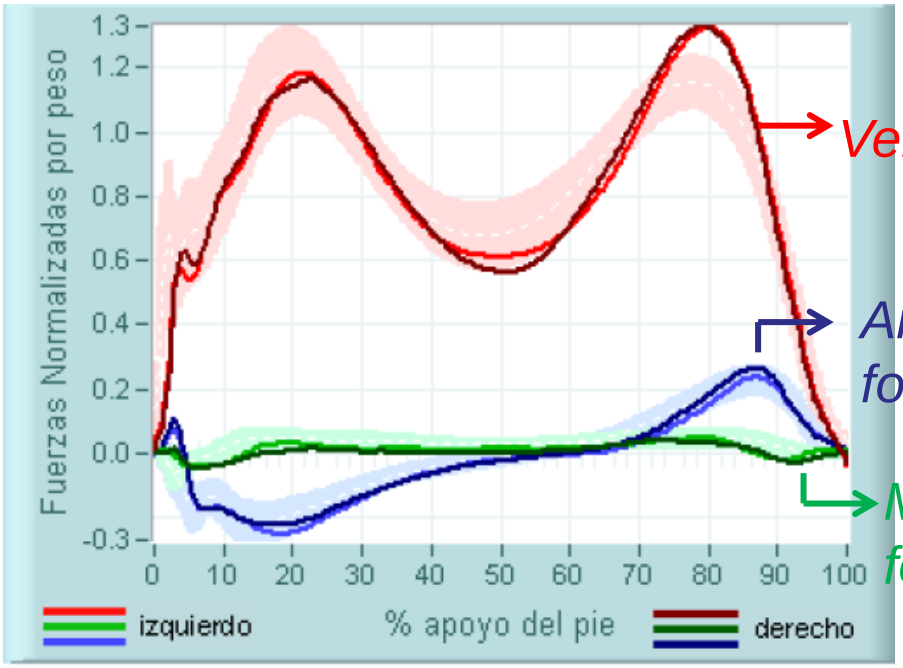


Figure 9. Ground reaction force and its three components in X, Y and Z axes.

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Kinetics outcomes

Dynamometric platform

Figure 10. Dynamometric platform system from Faculty of Medicine at University of Valencia

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Electromyographic outcomes

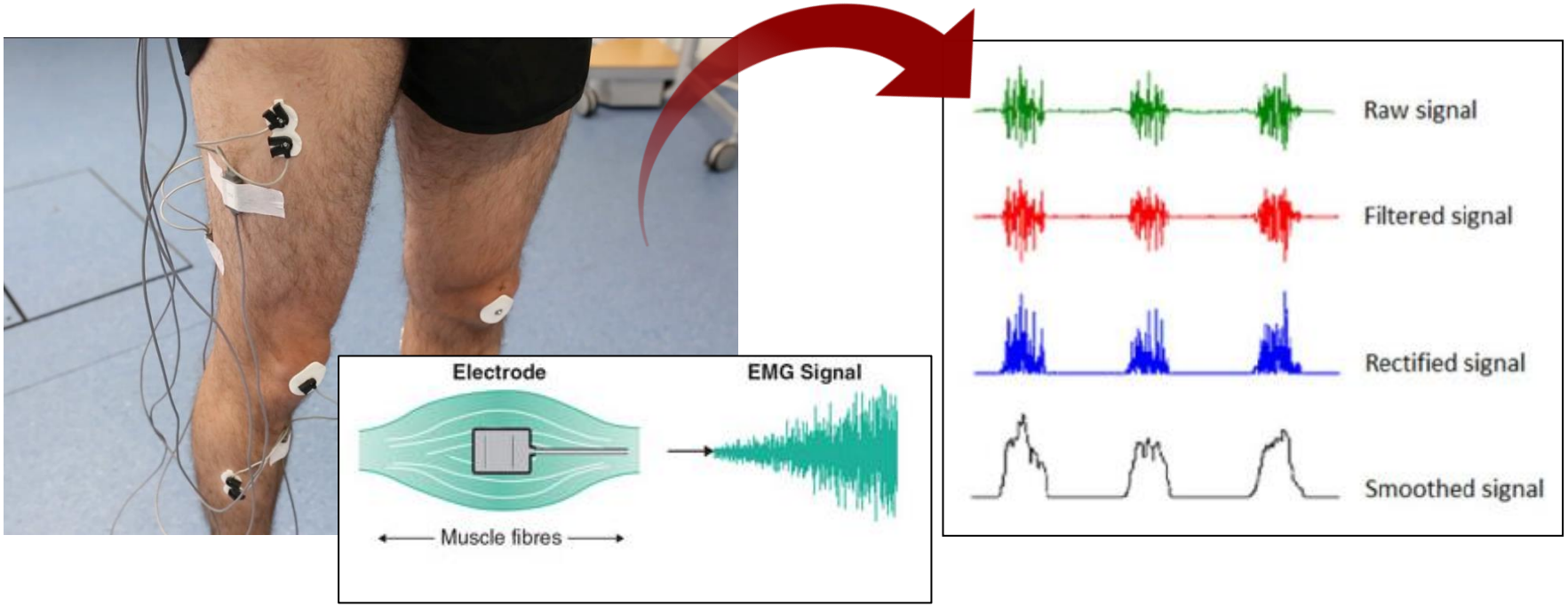
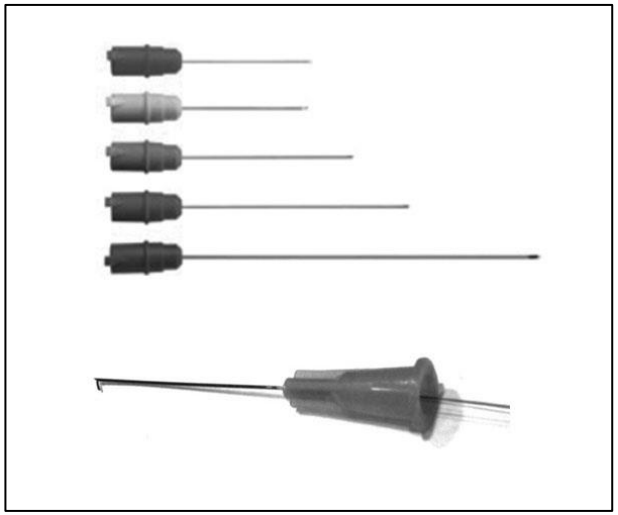


Figure 11. Electromyographic instrumentation of lower limb and EMG signal from Richards J. 2018

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Electromyographic outcomes

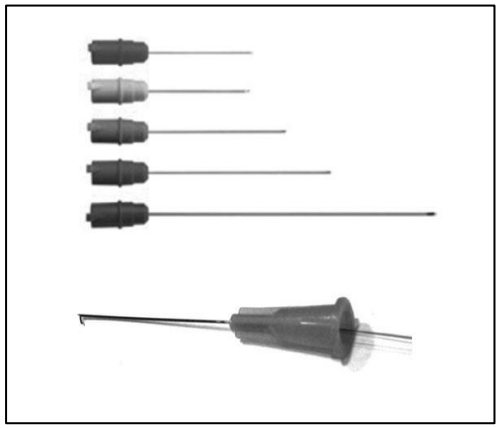
Cutaneous electrodes are used for surface muscles



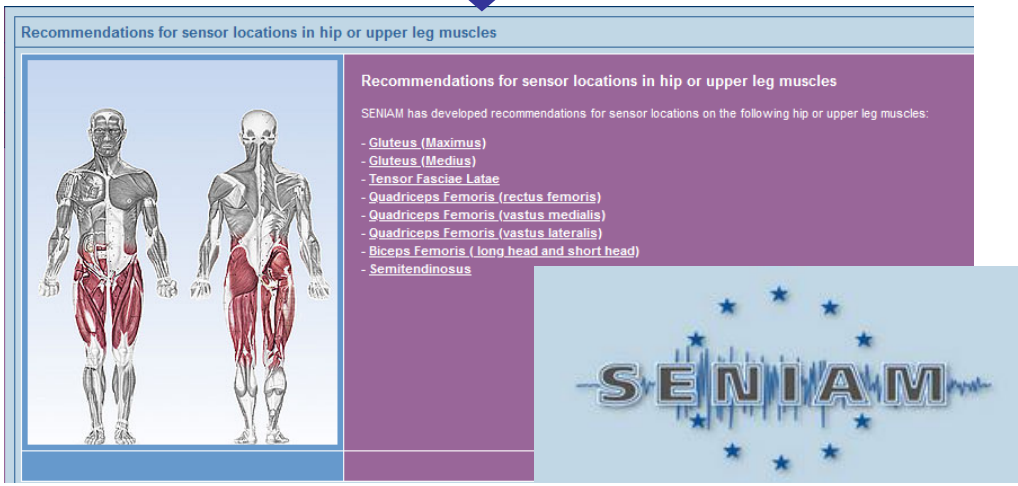
Fine-wires electrodes are required to record the electrical activity of the deep muscles

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Electromyographic outcomes



The quality of the signal is highly influenced by the electrode location



GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Plantar pressure outcomes

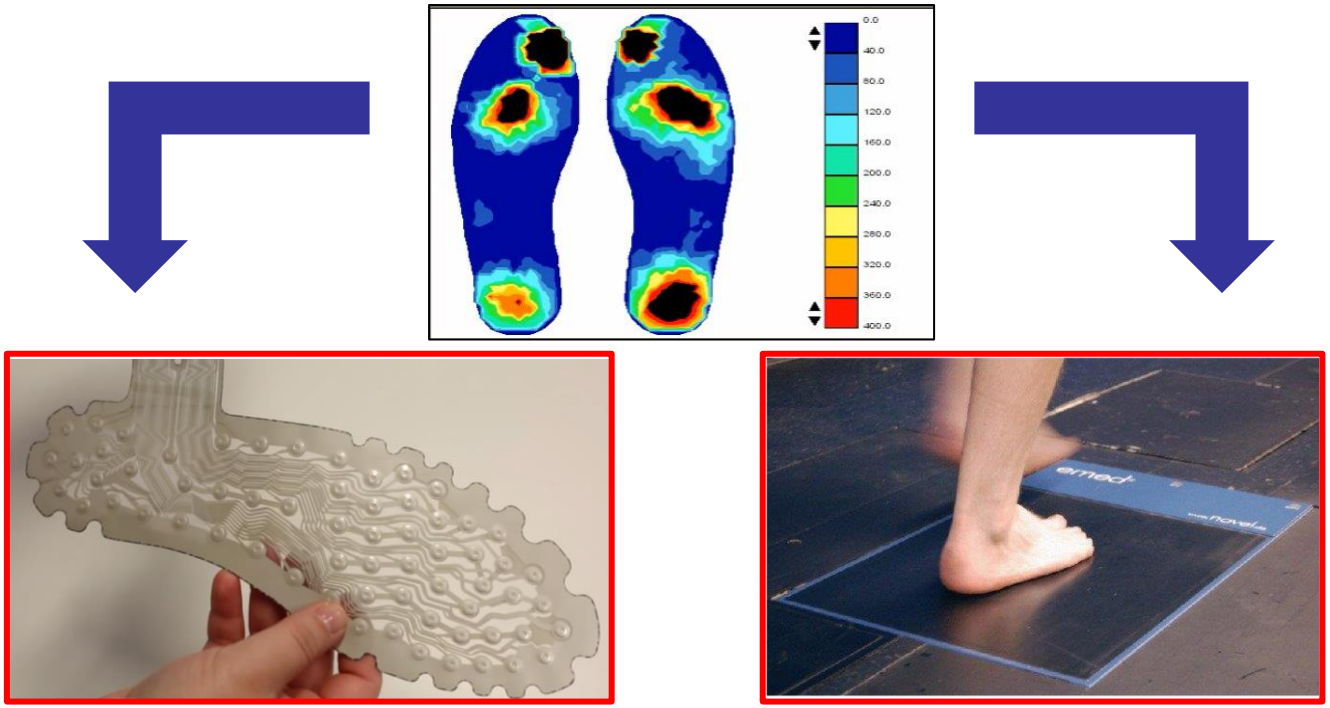


Figure 12. (*Left*) Intrumented insole with pressure sensor. (*Right*) Pressure platform from Zebris Medical GmbH.

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Plantar pressure outcomes

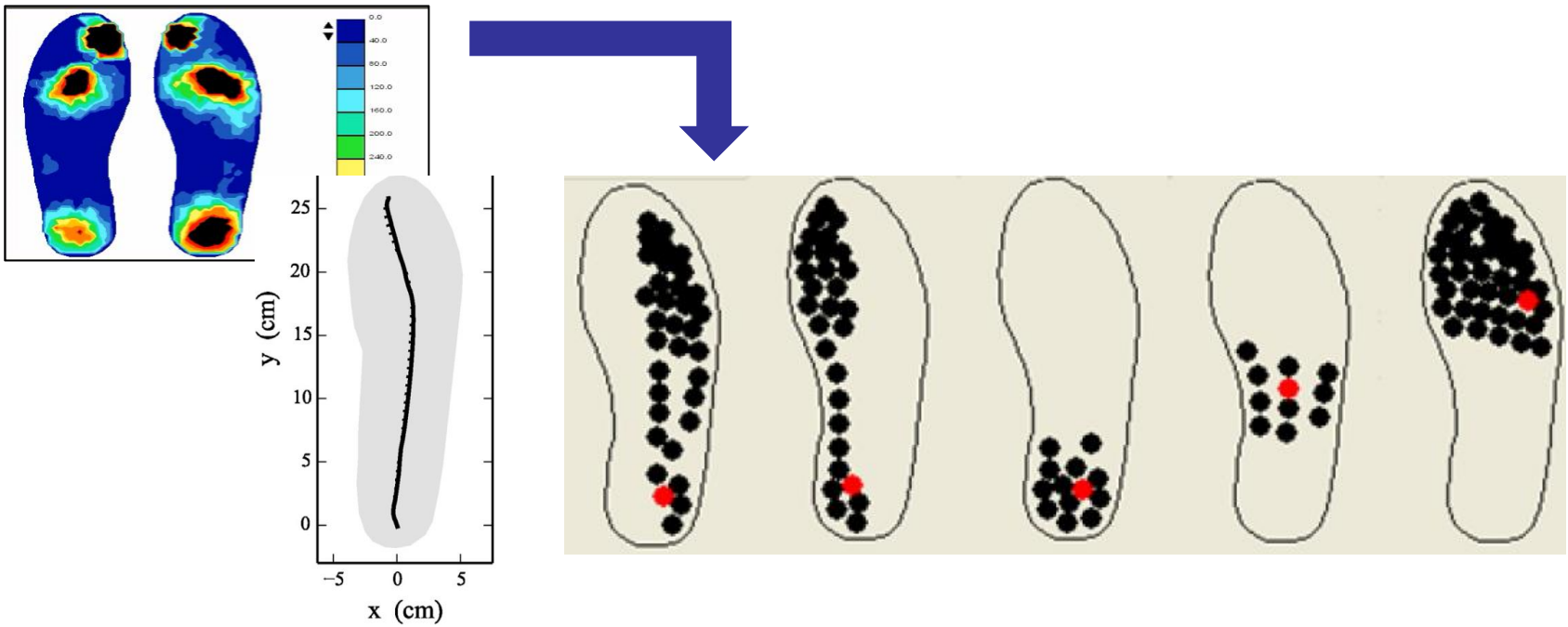


Figure 13. Results from plantar pressure analysis. Image from (Left) Todd C. Pataky et al. 2014 (Right) Biofoot/IBV system.

GAIT ASSESSMENT THROUGH OBJECTIVE INSTRUMENTS

Energy expenditure outcomes

Figure 14. Tools for energy expenditure measurement. From left to right: Global position system, accelerometer, pedometers, heart rate monitor and oxygen consumption monitors.

Erasmus+

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VNIVERSITAT DE VALÈNCIA

AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE