DIGITSOLE®
PRO

Walking analysis manual

English

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Table of contents

Definitions

Colours and Arrows

For better visibility, in general in this new interface, the left side is represented in Orange and the right side in Blue.
The inserts containing the durations of the contact phases are represented in:

- Deviating from the norm
- Close to the norm boundary ends
- Close to the norm

Arrows complete this information by indicating whether they are :

above :

or below :

the norm, respecting the colour code corresponding to their distance from this norm, taken from the literature and adapted to our measurement system.

The parameters

We present two categories of parameters:

Metrics :

Metrics are the parameters we measure directly from the data recorded by the insoles.

Spatio-Temporal Parameters

• **Speed (km/h):** Average speed of the patient.

• **Pace (steps/min):** Number of steps taken per minute, this is the combined total of the two feet.
• **Cycle time (ms):** time between two successive heel landings of the same foot.

• **Cycle length (cm):** The length of time between two successive heel landings of the same foot.

• **Contact time (ms and %):** The length of time the foot is in contact with the ground, standardised to be expressed as a percentage of the cycle time.

• **Foot roll time (ms and %):** Time during which the foot is not in contact with the ground, standardised to be expressed as a percentage of the cycle time.

• **Double contact (%):** Percentage of the cycle during which both feet are in contact with the ground at the same time.

Kinematics

• **Pronation/Supination angles (°, deg):** Defined between the foot and the ground so as to express the inclination in the transverse plane of the foot at the four key moments of the stride sequence: heel landing, toe landing, heel lift-off and toe lift-off.

• **Step progression angle (°, deg):** Defines the relationship between the orientation of the foot and the patient's path of travel.

• **Lateral deviation during the foot roll (cm):** Maximum distance of lateral displacement of the foot during the foot roll.

• **Toe clearance (mm):** Minimum height between the toes and the ground during the foot roll of the foot.

• **Angle of attack of the stride (°, deg):** Defines the distance between the ground and the foot at the moment of heel landing.

Biomarkers:

Biomarkers are parameters that we have calculated using one or more parameters at a given time or for a whole period of the walk.

• **Symmetry (%) :** Expresses the congruence between the values obtained on the left and right foot. Symmetry determines whether one leg is used more than the other when walking.

• **The Digital Gait Line :** Based on the analysis of pronation/supination angles, it represents the trajectory of the centre of support during the contact phase at the foot.

• **Propulsion Ratio :** Calculated as the ratio of the propulsion speed (standardised speed of the foot at lift-off of the toes) to the average stride speed (average speed of the foot during the entire foot roll). **It provides information on the muscles during the foot roll (triceps surae or hip flexors).**

• **Variability :** Available in the detailed overview, this is the standard deviation of the measured parameters to indicate a corridor with the maximum and minimum limits of this standard deviation

Observations

Below each graph, you will find a short text presenting the results in relation to the literature standards, directly informing you if the said parameter is in excess or in default. A recommendation may be made in relation to a condition or other information to look for in that patient.

Comments

At the bottom of each page, an insert is reserved for you to annotate all your comments. You will then be able to find them when you export the analysis in pdf format.

Interpretations

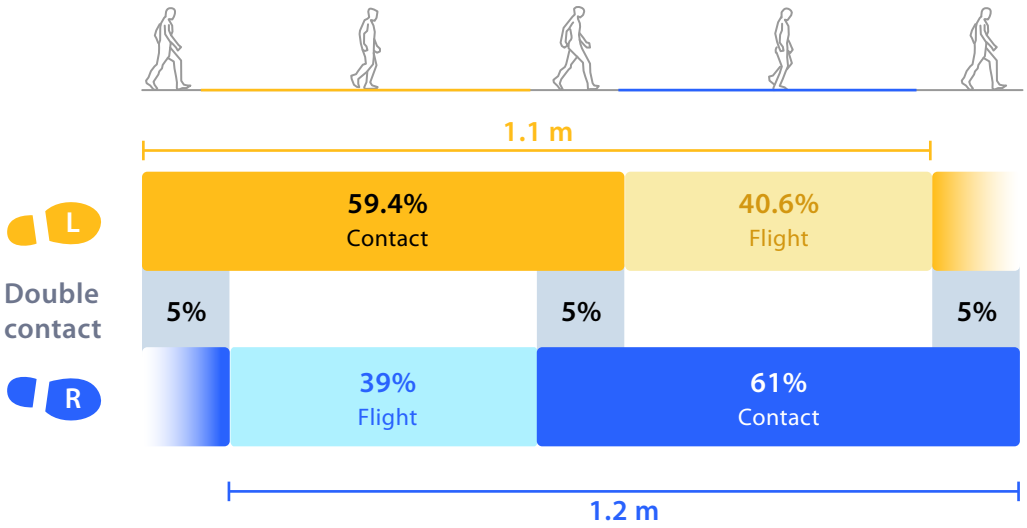
At the bottom of each page, you will find an insert reserved for interpretations which will inform you on a possible limp, on the propulsion and the walking sequence of the patient.

Presentation of results

Abstract

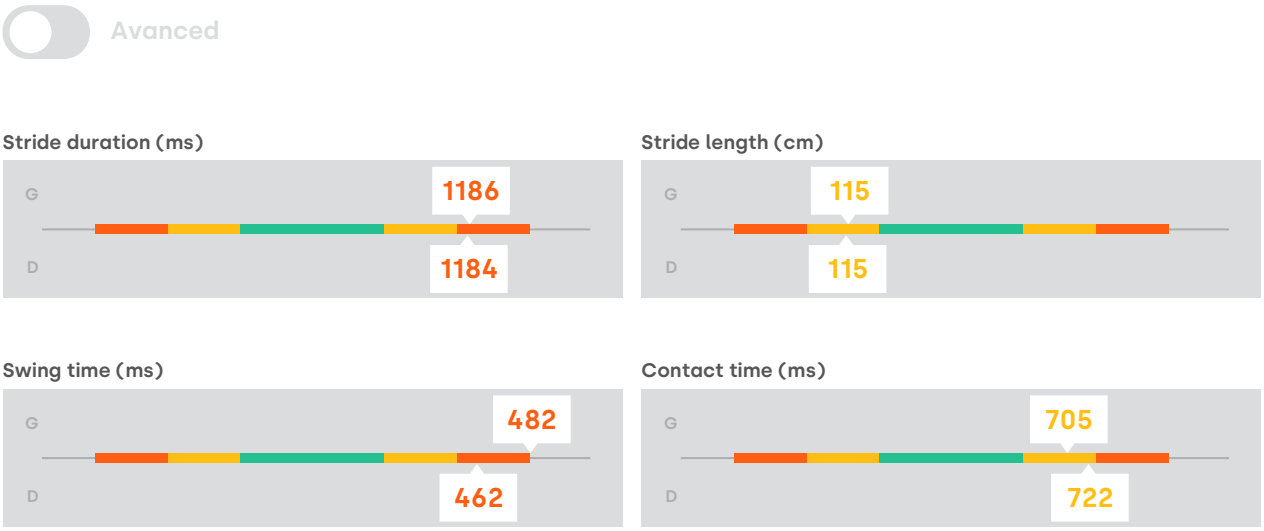
Gives the general values of the recording, which are independent of laterality. Symmetry close to 100% indicates good congruence between left and right steps. On the other hand, less symmetry may indicate different behaviours of the lower limbs and therefore either an abnormality in one foot only or both feet are affected in different ways.
Speed is a good indicator of walking quality and range. Walking too fast or too slow may be the first sign of a locomotion problem.
Pace is strongly correlated with speed and will therefore also be a qualitative indicator of walking

Walking phases



This figure shows the percentage durations of the different running phases: contact, foot roll and double contact, and the length of the cycle. As in the rest of this document, the left foot is represented in orange and the right foot in blue, the contact times are in a darker colour while the foot rolls are in a lighter colour.
Double contact is located between the two feet, in grey. Finally, the cycle lengths are at the top for the left side (orange) and at the bottom for the right side (blue).

Advanced mode

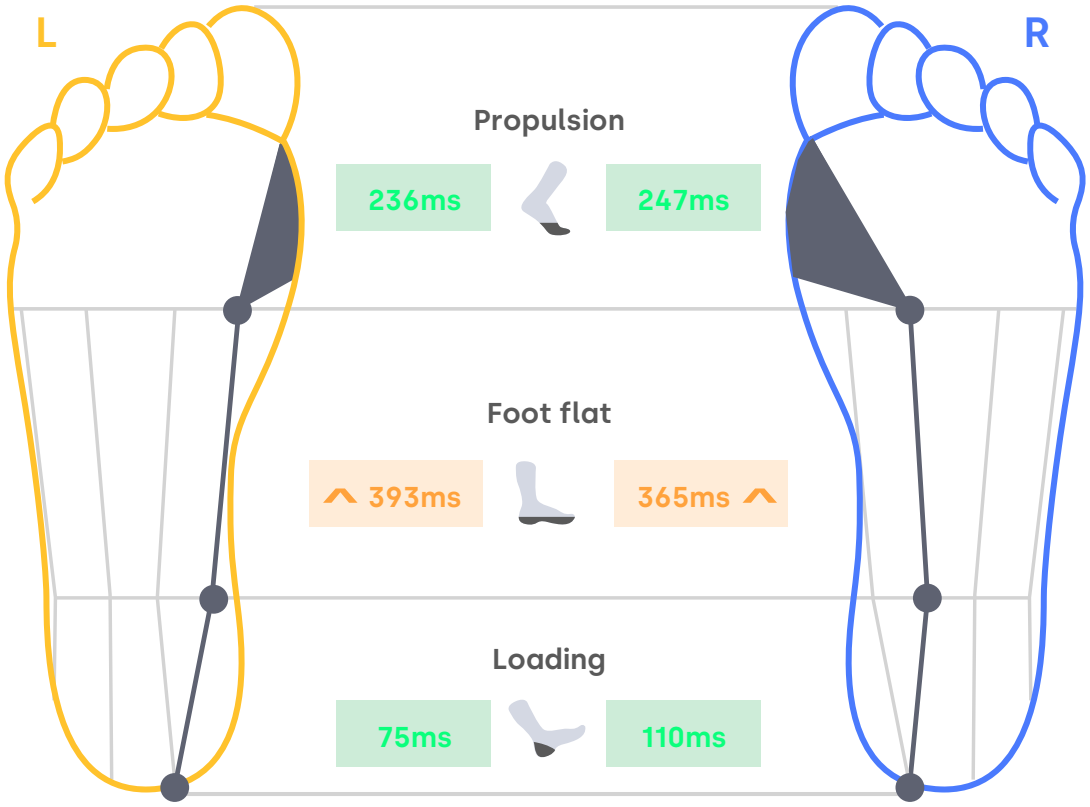


By activating the advanced mode, you will be able to access the graphical representation of the averages of the above parameters in relation to the literature standard, which is also available at the end of this document.

You will therefore be able to assess the situation of these parameters and determine whether they are in excess or in deficit, while considering the distance from this norm.
This information will complement the observations you will be able to make when comparing the two graphs.

The colour code used is as follows: green includes the average measurement plus or minus one standard deviation. Orange includes data from the norm that is between one and two standard deviations away from the mean.
Finally, red corresponds to values above the mean plus or minus two standard deviations.

Digital Gait Line



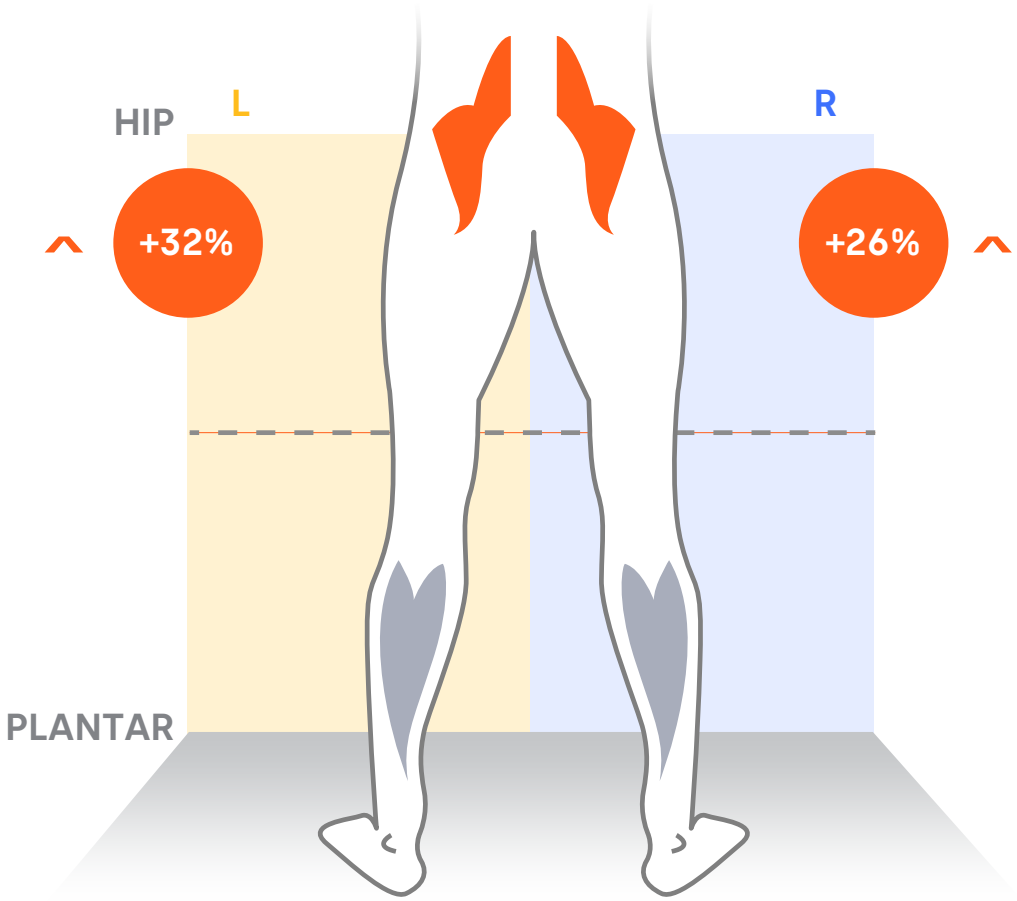
This diagram represents the displacement of the centre of support (black line) at the foot during the contact phase. We can assess the pronation and supination of the foot through the displacement of the centre of support, for each key moment of the stride sequence (heel and toe landing, heel and toe lift-off).

This information is supplemented by the duration of each phase (between key moments), expressed in milliseconds (as above) when the cursor is in the "Absolute" position and in percentages of the contact time when it is in "Relative".

Finally, thanks to this presentation, it is easy to compare the sequence of the two feet and to appreciate their symmetry.

It will then be possible to identify the spatial and temporal location of the disorder in order to adapt your treatment.

Propulsion ratio

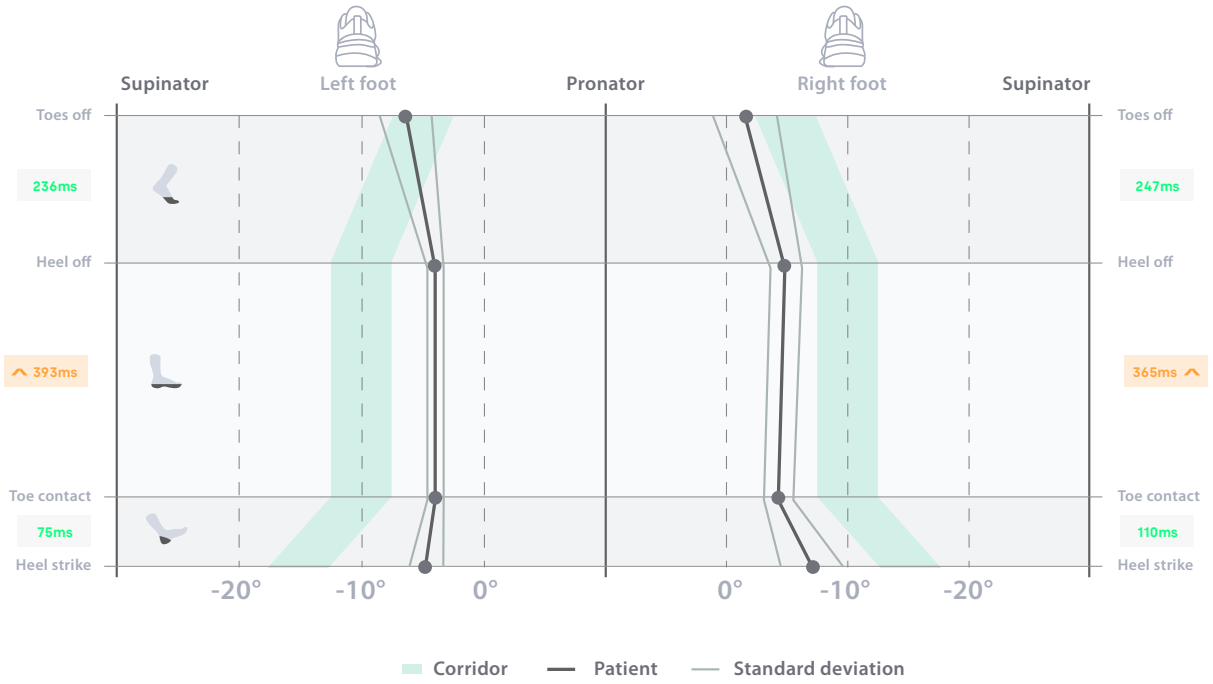


The propulsion ratio is the ratio of the propulsion speed (foot speed at lift-off of the toes) to the average stride speed (average foot speed during foot roll).

Through this ratio, we can determine whether the speed of foot movement is created more by the plantar flexors or the hip flexors, we can then highlight the muscle group and the deviation from perfect balance.

In this example, it is the hip flexor muscles that are mainly used, so that the feet accelerate during the foot roll phase in a quasi-symmetrical way since there is a difference of 6 percentage points between the left and right foot.

Pronation and supination angles



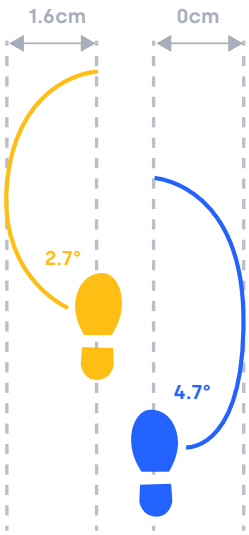
During the contact phase, we measure pronation/supination angles at the four key moments of the step sequence, heel landing, toe landing, heel lift-off, and toe lift-off. This angle corresponds to the lateral inclination of the foot in relation to the ground.

We propose a corridor of normality (green) based on the literature and adapted to Podosmart with health professionals, representing the sequence of a healthy subject, to compare the mean value (black line) and the variability (grey lines) of your patient.

The more pronate a patient is, the closer the mean value will be to the centre of the graph and conversely, the more supine the patient is, the closer to the lateral edges of the graph.
In this example, we can see that the angle is overpronated during the entire sequence on the right, on the left it is also overpronated but at the end of the propulsion and until the toes lift off it becomes "normal".

As on the Digital Gait Line, on each side of the graph we find the duration of each phase of the sequence: loading, unipodal, and propulsion. As this representation is dynamic, the spaces corresponding to these durations and the juxtaposition of the curves of the angles during the sequence make it possible to appreciate their symmetry.

Step Progression Angle and Lateral Deviation at the Foot Roll



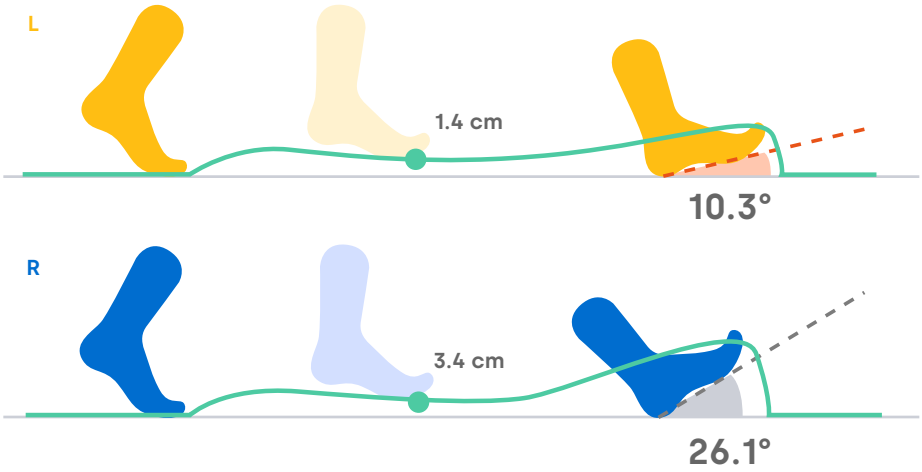
The Step Progression Angle (SPA) is expressed in degrees and corresponds to the orientation of the foot in relation to the patient's gait trajectory.

To be precise, it is a question of opening or closing the feet.
A healthy person is supposed to walk with a slight opening of the feet towards the outside.

The Foot Roll Lateral Deviation (FRLD) is also represented on this graph. This is the maximum lateral distance the foot travels during the foot roll, relative to the line joining two consecutive landings of the same foot. For a healthy subject, this value is close to zero.

It will then tend to be high for subjects with a neurological/spastic type of limp.

Clearance and angle of attack



Clearance is the minimum height between the toes and the ground during the foot roll phase of the step. It is a question here of having information on the free passage of the step, indeed, with a height that is too low, the foot roll of the foot could meet an obstacle and cause a loss of balance at the very least and a fall in the worst case.

Finally, the Angle of Attack is also represented on this graph, this is the angle between the foot and the ground at heel landing. A healthy person does not place the foot flat or walk with the toes

Detailed view

It groups all the measured parameters, for which you will find the values of Symmetry and Variability, in the following order :

Walking phases :

	Symmetry	Variation	
		MIN	MAX
∨ Walking profile			
Contact time	97.6%	686 ms L	723 ms L
		708 ms R	736 ms R
Flight time	95.8%	467 ms L	497 ms L
		450 ms R	473 ms R
Taligrade	68.3%	686 ms L	723 ms L
		708 ms R	736 ms R
Plantigrade	92.7%	467 ms L	497 ms L
		450 ms R	473 ms R
Digitigrade	95.4%	467 ms L	497 ms L
		450 ms R	473 ms R

Foot roll phase :

	Symmetry	Variation	
		MIN	MAX
∨ Oscillating phase			
Average stride speed	98.6%	1.4 m/s L	1.6 m/s L
		1.4 m/s R	1.6 m/s R
Propulsion speed	94.1%	0.9 m/s L	1.1 m/s L
		1 m/s R	1.2 m/s R
Walking speed	99.2%	3.1 m/s L	3.9 m/s L
		3.3 m/s R	3.8 m/s R
Stride length	99.7%	1 m/s L	1.3 m/s L
		1.1 m/s R	1.2 m/s R
Cadence	99.5%	49.5 pas/min L	51.5 pas/min L
		49.7 pas/min R	51.9 pas/min R

Ankle sequence :

	Symmetry	Variation	
		MIN	MAX
∨ Stance phase			
Heel strike	2.2 °	-5.9 ° L	-3.5 ° L
		-9.5 ° R	-4.3 ° R
Toe contact	0.3 °	-4.6 ° L	-3.4 ° L
		-5.6 ° R	-3 ° R
Heel off	0.9 °	-4.6 ° L	-3.3 ° L
		-6.2 ° R	-3.6 ° R
Toes off	4.9 °	-8.7 ° L	-4.3 ° L
		-4.2 ° R	1.1 ° R

High variance in the parameters may be a sign of difficulty in reproducing the same steps consecutively, and therefore of a neuromuscular control deficit. Conversely, too little variability could be linked to a certain limitation in the execution of lower limb movements.

Tips

• If you have a case where the pace is too high and the speed is slow, this patient may be looking for balance. You can objectify this phenomenon by observing that the sum of the two double legs will be greater than 25%.

• Asymmetry of contact time :
If the cycle times are equivalent and the percentage of contact time is not symmetrical, this means that the patient is spending more time on one limb, which is described as "stronger". This may be due either to pain on the other side, or to a lack of sensitivity or "confidence", which will prevent one from putting his weight on that leg for long.

• The Step Progression Angle :
It completes the information given by the pronation-supination angles and the gait line to better understand the plantar sequence and thus explain certain situations such as excessive pronation or supination during the loading and propulsion phases.
It is also of great importance in the analysis of propulsion, because during this phase, the leverage on the foot is the most pronounced and an angle that is too open could eventually modify or explain a change in the skeletal architecture of the foot due to the high forces to which the forefoot is subjected.An abnormality measured on this angle can thus highlight architectural modifications of the foot, secondary to an inadequate contraction of certain muscles causing an inversion, an eversion (combined with the angles of pronation and supination) or an inadequate rotation of the hip, knee, femur or tibia (to be checked with the alignment of the patella and a static analysis).
- Inward: look for a possible varus adductus foot, or internal rotation of the hip, tibia or femur (checking the orientation of the patella and hip)
- Outward: monitor pronation in propulsion, check for a possible valgus adductus foot, or external rotation of the hip, tibia or femur (checking patella orientation and hip rotation)

• The Lateral Deviation of the Foot Roll :
It is often a sign of a deficit in knee flexion, to clear the way for the footfall, or to prevent the minimum toe height (clearance) being too low. It can potentially be due to spasticity of the rectus femoris, or a dorsal flexion deficit of the ankle. This could itself be due to an inappropriate contraction of the plantar flexors, which can be found, for example, in certain pathologies such as multiple sclerosis or post-stroke during hemiparesis. It is therefore interesting from this point of view to relate it to clearance and step progression angle (which are likely to be disturbed in the presence of this gait anomaly).

• The Clearance :
The minimum toe height is normally reached at peak foot speed during the foot roll. This parameter tells us about the patient's ability to lift the foot sufficiently so that it does not hit the ground or any obstacle during its trajectory, which could lead to a loss of balance and potentially a fall. Moreover, several authors in the clinical literature have identified it as an important parameter to take into account when assessing the risk of falling.
- If there is an excess or lack of minimum toe height, look for a possible problem with proprioception or motor control of the knee flexors

- **Angle of Attack :**

Three possible situations are considered:
- The angle is > 0: The patient makes contact with their heel first
- The angle = 0: the patient places the foot flat
- Angle < 0: the patient makes contact with the forefoot first

This parameter informs us about the way the patient starts his or her step, which will condition the whole process that will follow.
This information is important for determining a dorsiflexion defect of the foot, which may potentially be related to weakness of the dorsal flexors, inappropriate muscular activity of the plantar flexors (spasticity, muscle retraction) or limitation of the knee or ankle joint amplitudes compelling an abnormal approach either with the foot flat or with the forefoot.
It is, therefore, relevant to look for, during the clinical assessment:
- Possible locking of the knee in flexion (> 30°)
- Spasticity or retraction of the plantar flexors
- A true equinus (knee and hip in extension, and ankle in equinus) in the unipodal phase
- An apparent equinus (ankle at 90°, knee and hip flexed)
- A jumping step (foot in equinus, knee and hip flexed)
- A squatting walk (ankle in hyper-dorsiflexion, knee and hip in hyperflexion)

- **The Risk of Falling :**

Difficult to assess objectively, many tests and scales are dedicated to it, including information on the patient's life, social and health situation (pathologies and medication intake, psychotropic drugs for example), fall history and clinical assessments (Timed Up & Go test, One leg stance, Romberg test, etc.).
In the literature, several behaviours and in particular certain parameters in relation to the norm have been identified as being characteristic of a population at risk of falling.

The parameters include:
- Cycle length: decrease, but increase in variability
- Duration of the use of both legs: increase in duration and variability
- Propulsion ratio: decrease (increased use of hip flexors at the expense of plantar flexors to advance the foot)
- Pace: increase
- Speed: decrease
- Contact time: increase in duration and variability
- Duration of loading and propulsion: increase (linked to the increase in the duration of the use of both legs).
- Cycle time: increase.

Walk analysis

Parameters	*Definitions*	*Accuracy*
Stride length	Distance travelled by the foot in a gait cycle.	+/- 5cm
Pace	Number of steps taken per minute.	+/- 5pas/min
Cycle time	Time between two successive contacts of the same foot.	+/- 100ms
Contact time	The duration between heel strike and toe lift for each foot during the stride cycle is used to determine gait stance time, which is the length of the period of the gait cycle when the limb is in contact with the ground.	+/- 50ms
Swing time	The duration between foot lift and heel strike for each foot during the stride cycle is used to determine the swing time, which is the length of the section of the gait cycle when the limb is not in contact with the ground.	+/- 50ms
Double contact	This is the percentage of the gait cycle during which both limbs make contact with the ground.	+/- 50ms
Speed	The speed at which the body moves in a straight line while walking.	+/- 0.2km/h
Pronation and supination angles	The average angle of inclination between the foot and the earth's surface. Supination is a negative angle, while pronation is a positive angle.	+/- 7°
Duration of the support phase	The stance phase's first sub-component. When the heel strikes the ground and absorbs the impact, the support phase begins. It comes to an end when the toes touch the ground.	+/- 50ms
Duration of the flat foot phase	The support phase's second sub-component. The flat foot phase begins when the full foot is in contact with the ground and ends when the heel is removed.	+/- 50ms
Duration of propulsion phase	The stance phase's third sub-component. The time between the heel and toe lifting events is referred to as propulsion.	+/- 50ms
Symmetry	The ratio of the exposure time of the right foot (respectively, the left foot) and the sum of the exposure times of the right and left feet.	+/- 0.5%
Gait line	The gait line is estimated using the pronation/supination angles at four important events (heel strike, toe strike, heel lift, and toe lift) to determine the trajectory of the center of pressure during the unrolling of the foot.	+/- 0.5
Propulsion ratio	The ratio of the speed at which the foot is removed from the ground to the average speed during the swing.	NA
Stepping	During initial contact, the angle of flexion/extension of the foot on the earth's surface.	+/- 5°
Circumduction	Perpendicular to the progression line, the distance between the centre of each foot's heels.	+/- 1cm
Clearance	Minimum toe height at swing.	+/- 2cm
Step progression angle	During the flat foot phase, the angle between the walking path and the foot's orientation.	+/- 0.5°

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Help and assistance

Help

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Do you have a question or a suggestion? Do not hesitate to contact us.

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