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

TEACH

MODULE BIOMECHANICS OF GAIT

Didactic Unit D: INTRUMENTED ANALYSIS OF GAIT

D.2 NORMAL BIOMECHANICAL ASSESSMENT OF GAIT

Politechnika Śląska

IBV INSTITUTO DE BIOMECÁNICA DE VALENCIA

VNIVERSITAT DE VALÈNCIA

AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE

D.2 How is a normal biomechanical assessment of gait?

Index of the Didactic Unit

D.2 How is a normal biomechanical assessment of gait?

I. Objectives

I. OBJECTIVES

1. To know the relevance of normative gait data in clinical practice.

2. To review the main outcomes that characterize human gait, their definition and clinical relevance.

3. To know the normative values of the biomechanical assessment of human gait in healthy people and the influence on the results of age and sex.

D.2 How is a normal biomechanical assessment of gait?

II. Importance of normative gait data in clinical practice

II. IMPORTANCE OF NORMATIVE GAIT DATA IN CLINICAL PRACTICE

Why we need to know the normal gait pattern?

Compare

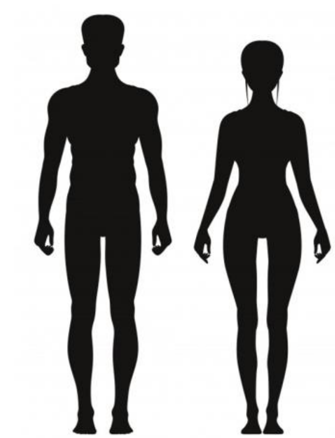
Diagnosis

Treatment

II. IMPORTANCE OF NORMATIVE GAIT DATA IN CLINICAL PRACTICE

How does the gait pattern vary among the healthy population?

Sex influence



Age influence

D.2 How is a normal biomechanical assessment of gait?

III. Spatiotemporal assessment of normal gait

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

- Instrument to measure spatiotemporal parameters

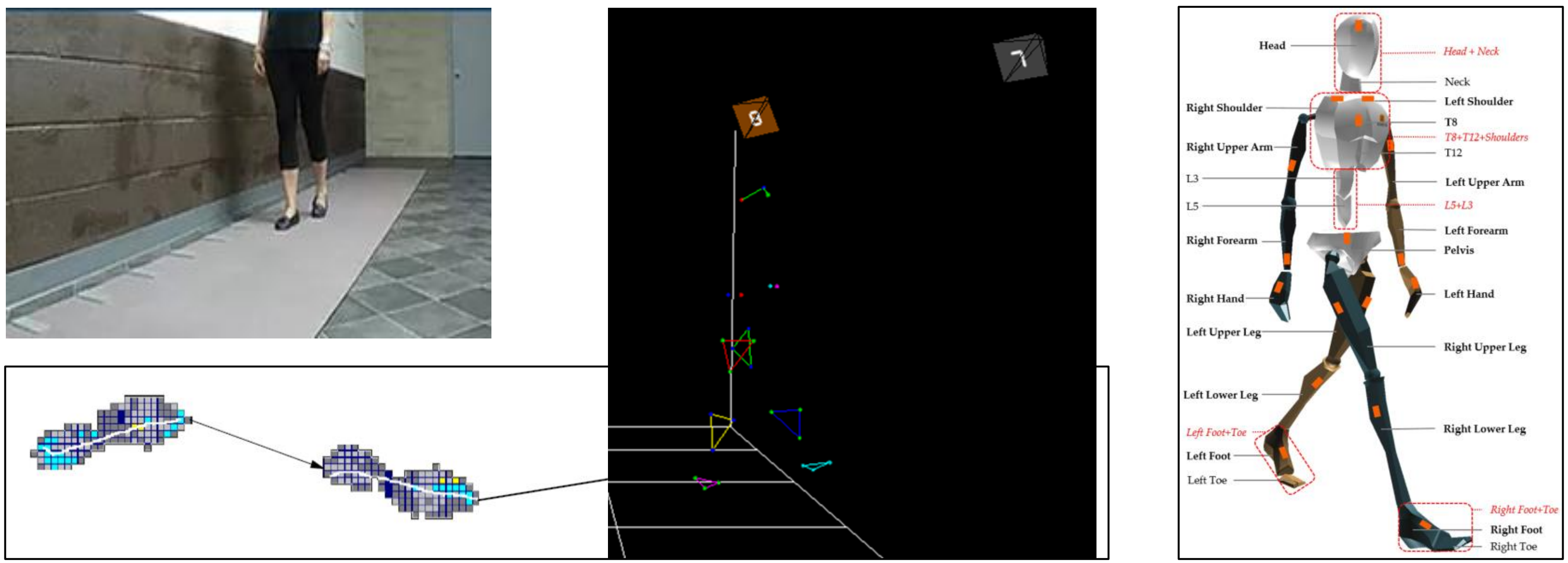


Figure 1 – Biomechanical tools. Left: instrumented walkway from GAITrite. Middle: 3D photogrammetry system from Kinescan/IBV. Right: IMU sensors from Xsens.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatiotemporal parameter

- Gait velocity / gait speed (m/s or km/h): distance traveled by a body in a unit of time.
- Correlated with several health parameters.
- Conditions of measure at preferred, fast and slow gait speed.

	Gai
gait speed [m/s]	

Other authors: 1.20 – 1.53 m/s
(Murray 1970, Chao 1983, Kadaba 1990, Perry 1992)

Figure 2 – Gait velocity results from Pietraszewski B. et al. 2012. Participants were young men with 1795 ± 46 mm body height.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatiotemporal parameter

- Significant interaction effect of *Age x Sex* on gait speed.

	Velocity [m/s]	All mean ± SD All $N = 191$	Males mean ± SD All $N = 99$ Young $N = 31$ Middle $N = 22$ Elderly $N = 46$	Females mean ± SD All $N = 92$ Young $N = 36$ Middle $N = 21$ Elderly $N = 35$
	All	1.35 ± 0.16	1.34 ± 0.18	1.37 ± 0.14
27.21 y.o.	Young	1.36 ± 0.15	1.37 ± 0.17	1.36 ± 0.13
52.74 y.o.	Middle	1.41 ± 0.19	1.41 ± 0.23	1.40 ± 0.14
68.01 y.o.	Elderly	1.32 ± 0.15	1.29 ± 0.14	1.36 ± 0.15

Figure 3 – Gait velocity results from Kobayashi Y. et al. 2016. Participants were young (mean 27.21 years-old), middle (mean 52.74 years-old, and elderly (mean 68.01 years-old). Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatiotemporal parameter

- Significant effect of *Sex* on gait speed of healthy people over 70 years-old.

Gait speed (cm/s)[††]

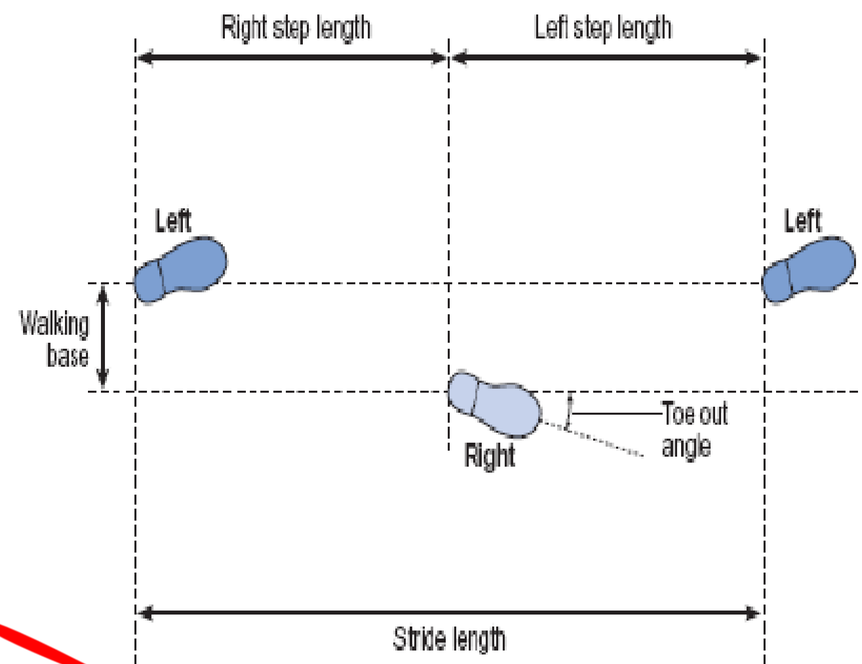
Men (N = 108)				Women (N = 186)			
70–74	75–79	80–84	85+	70–74	75–79	80–84	85+
N = 27	N = 30	N = 37	N = 14	N = 33	N = 77	N = 43	N = 33
117 ± 16	122 ± 15	112 ± 17	101 ± 22	116 ± 20	112 ± 17	101 ± 15	98 ± 20

Figure 4 – Gait velocity results from Hollaman J. et al. 2011. Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatial parameters

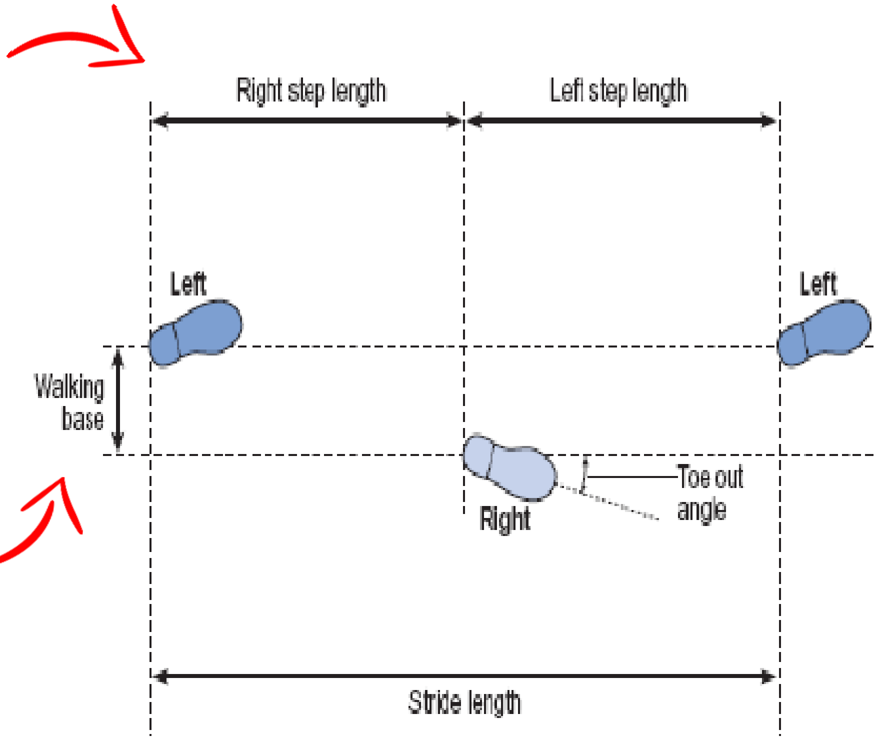
- Stride length (m): Anterior-posterior distance between heels of two consecutive footprints of the same foot (left to left, right to right); two steps (e.g., a right step followed by a left step) comprise one stride or one gait cycle.



III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatial parameters

- Step length (m): Anterior-posterior distance from the heel of one footprint to the heel of the opposite footprint.
- Step width (m): Lateral distance from heel center of one footprint to the line of progression formed by two consecutive footprints of the opposite foot.



III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatial parameters

Gait speed	High	Preferred	Low
stride length [m]	1.73 ± 0.19	1.47 ± 0.13	1.35 ± 0.13
stride width [m]	0.17 ± 0.01	0.17 ± 0.03	0.16 ± 0.02
step length L [m]	0.73 ± 0.05	0.64 ± 0.04	0.60 ± 0.05
step length R [m]	0.69 ± 0.06	0.61 ± 0.06	0.58 ± 0.07

Figure 5 – Spatial parameters results from Pietraszewski B. et al. 2012. Participants were young men with 1795 ± 46 mm body height.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatial parameters

- Sex and age have an effect on step length independently.
- On step width, the interaction of sex x age effect is significant.

Variables	All mean ± SD	Males mean ± SD		Females mean ± SD	
	All $N = 191$	All $N = 99$		All $N = 92$	
		Young $N = 31$		Young $N = 36$	
		Middle $N = 22$		Middle $N = 21$	
		Elderly $N = 46$		Elderly $N = 35$	
Step length [cm]					
All	69.88 ± 6.90	71.23 ± 7.32		68.42 ± 6.10	
Young	71.82 ± 5.88	73.09 ± 6.15	1.46 m	70.72 ± 5.42	1.41 m
Middle	70.46 ± 8.28	72.85 ± 9.46	1.45 m	67.96 ± 5.92	1.35 m
Elderly	67.96 ± 6.36	69.20 ± 6.31	1.38 m	66.33 ± 6.07	1.32 m
Step width [cm]					
All	9.11 ± 2.81	9.63 ± 2.92		8.54 ± 2.57	
Young	8.58 ± 2.83	8.81 ± 3.25		8.38 ± 2.40	
Middle	9.32 ± 2.25	9.73 ± 2.41		8.89 ± 1.99	
Elderly	9.43 ± 3.00	10.14 ± 2.79		8.49 ± 3.01	

Figure 6 – Spatial parameters results from Kobayashi Y. et al. 2016. Participants were young (mean 27.21 years-old), middle (mean 52.74 years-old, and elderly (mean 68.01 years-old). Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Spatial parameters

- Significant effect of *age* on step and stride length of healthy people over 70 years-old. With the length normalized the effect of sex disappear.

Parameter	Men (N = 108)				Women (N = 186)			
	70–74	75–79	80–84	85+	70–74	75–79	80–84	85+
	N = 27	N = 30	N = 37	N = 14	N = 33	N = 77	N = 43	N = 33
Step length (cm)[‡‡]	69 ± 8	68 ± 7	65 ± 8	59 ± 10	61 ± 9	59 ± 7	55 ± 7	54 ± 9
Stride length (cm)[§§]	139 ± 14	137 ± 12	131 ± 17	119 ± 21	123 ± 17	118 ± 15	111 ± 14	109 ± 18
Step width (cm)[¶¶]	9.7 ± 3.0	8.9 ± 5.2	11.2 ± 4.0	9.9 ± 4.8	7.0 ± 3.5	7.7 ± 4.0	7.9 ± 4.1	9.1 ± 2.6
Step width SD (cm)	3.1 ± 2.2	2.9 ± 1.9	3.3 ± 2.3	2.8 ± 1.2	3.4 ± 2.4	3.2 ± 2.5	3.6 ± 3.1	3.0 ± 1.1

Figure 7 – Spatial parameters results from Hollaman J. et al. 2011. Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

- Cadence (steps/min): Number of steps per minute, sometimes referred to as step rate.
- Step time (s): Time elapsed from initial contact of one foot to initial contact of the opposite foot.
- Stride time (s): Time elapsed between the initial contacts of two consecutive footfalls of the same foot.
- Stance time (s): Time elapsed between the initial contact and the last contact of a single footfall.
- Swing time (s): Time elapsed between the last contact of the current footfall to the initial contact of the next footfall of the same foot.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

- Single support time (s): Time elapsed between the last contact of the opposite footfall to the initial contact of the next footfall of the same foot.

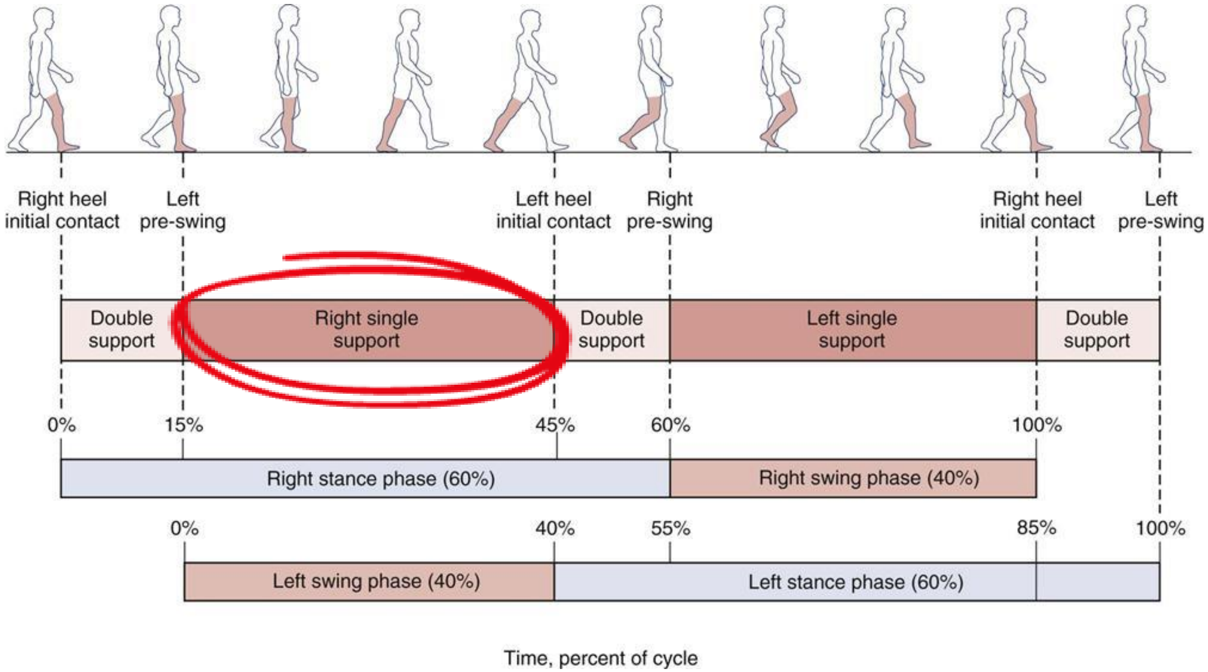


Figure 8. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

- Double support time (s): Sum of the time elapsed during two periods of double support in the gait cycle.

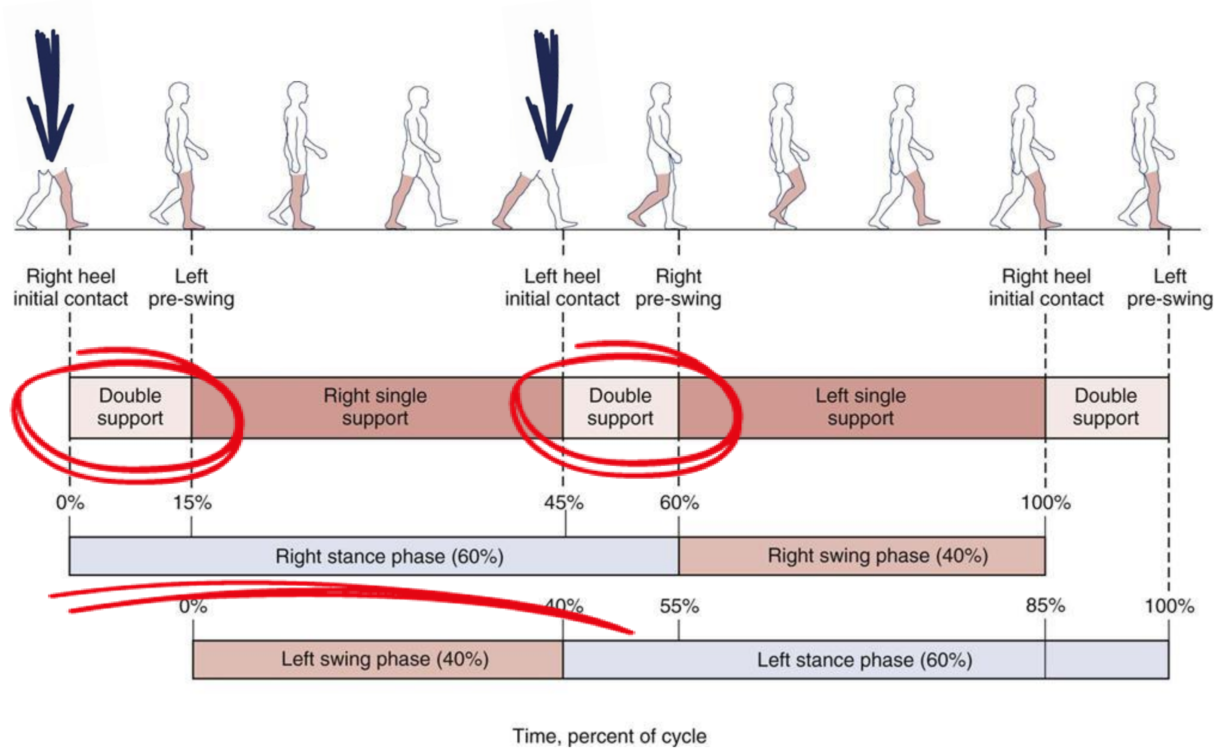


Figure 8. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

Other authors: 102 – 117 steps / min
(Murray 1970, Chao 1983, Kadaba 1990, Perry 1992)

Gait spee			
cadence [steps/min]			
stride time (cycle time) [s]	0.94 ± 0.06	1.09 ± 0.8	1.18 ± 0.08
stance duration R [s]	0.61 ± 0.04	0.71 ± 0.06	0.79 ± 0.07
swing duration R [s]	0.33 ± 0.02	0.36 ± 0.03	0.39 ± 0.02
double stance duration R [s]	0.14 ± 0.02	0.18 ± 0.02	0.20 ± 0.03
stance duration L [s]	0.60 ± 0.05	0.72 ± 0.06	0.78 ± 0.07
swing duration L [s]	0.34 ± 0.02	0.37 ± 0.03	0.39 ± 0.02
double stance duration L [s]	0.13 ± 0.02	0.18 ± 0.03	0.20 ± 0.02

Figure 9– Temporal parameters results from Pietraszewski B. et al. 2012. Participants were young men with 1795 ± 46 mm body height.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

- Interaction effect of age and sex on stance and swing duration.

Variables	All mean ± SD All $N = 191$	Males mean ± SD All $N = 99$ Young $N = 31$ Middle $N = 22$ Elderly $N = 46$		Females mean ± SD All $N = 92$ Young $N = 36$ Middle $N = 21$ Elderly $N = 35$	
Stance time [s]					
All	0.59 ± 0.05	0.61 ± 0.05		0.57 ± 0.05	
Young	0.60 ± 0.05	0.61 ± 0.05	**1,03**	0.59 ± 0.04	**1,00**
Middle	0.57 ± 0.05	0.59 ± 0.05	**0,99**	0.55 ± 0.03	**0,94**
Elderly	0.58 ± 0.05	0.61 ± 0.04	**1,03**	0.55 ± 0.04	**0,94**
Swing time [s]					
All	0.41 ± 0.03	0.42 ± 0.03		0.40 ± 0.03	
Young	0.42 ± 0.03	0.42 ± 0.03		0.41 ± 0.03	
Middle	0.40 ± 0.04	0.40 ± 0.05		0.39 ± 0.02	
Elderly	0.41 ± 0.03	0.42 ± 0.03		0.39 ± 0.03	

Figure 10 – Spatial parameters results from Kobayashi Y. et al. 2016. Participants were young (mean 27.21 years-old), middle (mean 52.74 years-old, and elderly (mean 68.01 years-old). Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporal parameters

Parameter	Men (*N* = 108)				Women (*N* = 186)			
	70–74	75–79	80–84	85+	70–74	75–79	80–84	85+
	N = 27	*N* = 30	*N* = 37	*N* = 14	*N* = 33	*N* = 77	*N* = 43	*N* = 33
Rhythm								
Cadence (steps/min)*	102 ± 8	106 ± 10	103 ± 8	102 ± 11	113 ± 20	114 ± 13	110 ± 9	108 ± 10
Step time (s)†	0.59 ± 0.05	0.56 ± 0.05	0.59 ± 0.04	0.59 ± 0.08	0.53 ± 0.06	0.53 ± 0.06	0.55 ± 0.05	0.56 ± 0.05
Stride time (s)‡	1.18 ± 0.08	1.13 ± 0.09	1.16 ± 0.08	1.19 ± 0.14	1.06 ± 0.13	1.06 ± 0.12	1.10 ± 0.09	1.12 ± 0.11
Swing time (s)§	0.43 ± 0.03	0.41 ± 0.03	0.42 ± 0.04	0.42 ± 0.05	0.39 ± 0.05	0.38 ± 0.05	0.39 ± 0.04	0.40 ± 0.04
Stance time (s)¶	0.75 ± 0.07	0.72 ± 0.06	0.74 ± 0.06	0.78 ± 0.11	0.68 ± 0.10	0.67 ± 0.08	0.71 ± 0.07	0.72 ± 0.09
Single support time (s)#	0.44 ± 0.03	0.42 ± 0.03	0.42 ± 0.04	0.42 ± 0.04	0.39 ± 0.06	0.38 ± 0.06	0.39 ± 0.04	0.40 ± 0.04

Figure 11 – Spatial parameters results from Hollaman J. et al. 2011. Walk was registered at self-selected speed.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporophasic parameters

- Stance time (%GC): Stance time normalized to stride time.
- Swing time (%GC): Swing time normalized to stride time.

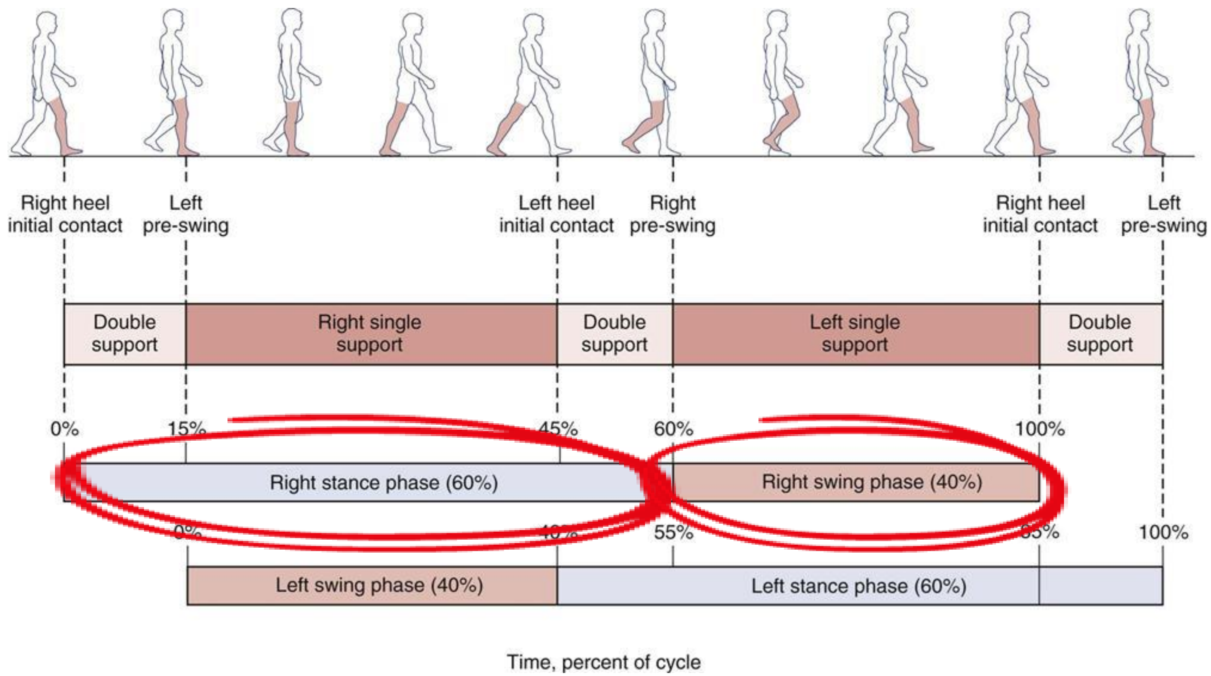


Figure 7. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporophasic parameters

- Single support time (%GC): Single support time normalized to stride time.
- Double support time (%GC): Double support time normalized to stride time.

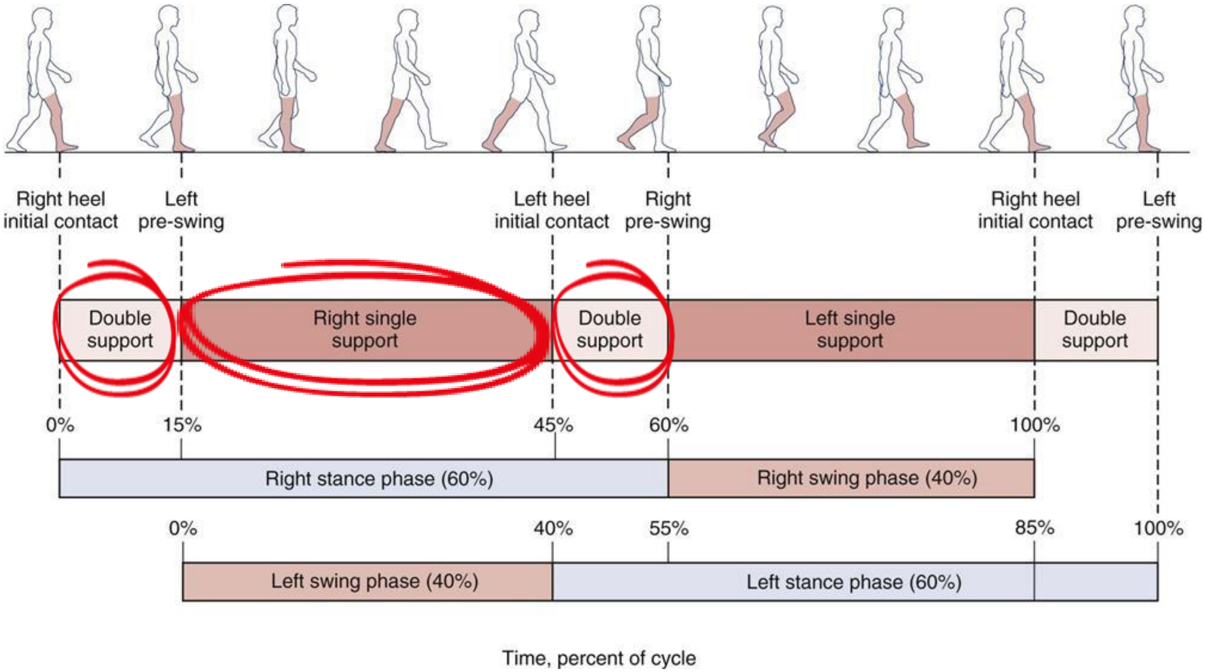


Figure 7. Gait cycle and temporal segmentation (%). Image from www.musculoskeletalkey.com

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporophasic parameters

- Stance duration decreases and the relative swing duration increases as the speed increases.

Gait speed	High	Preferred	Low
relative stance duration R [%]	64.6 ± 1.3	65.1 ± 3.6	66.9 ± 1.4
relative swing duration R [%]	35.4 ± 1.3	33.3 ± 1.9	33.1 ± 1.4
relative dbl stance durat. R [%]	14.4 ± 1.5	16.4 ± 1.4	16.9 ± 1.7
relative stance duration L [%]	64.9 ± 0.9	62.2 ± 1.4	66.6 ± 1.6
relative swing duration L [%]	36.0 ± 0.9	33.8 ± 1.4	33.3 ± 1.6
relative dbl stance durat. L [%]	14.4 ± 1.0	16.7 ± 2.0	16.6 ± 1.3

Figure 12 – Temporophasic parameters results from Pietraszewski B. et al. 2012. Participants were young men (mean 22 ± 1 years-old) with 1795 ± 46 mm body height.

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporophasic parameters

Variables	All mean ± SD	Males mean ± SD	Females mean ± SD
	All $N = 191$	All $N = 99$	All $N = 92$
		Young $N = 31$	Young $N = 36$
		Middle $N = 22$	Middle $N = 21$
		Elderly $N = 46$	Elderly $N = 35$
Stance time [s]			
All	0.59 ± 0.05		
Young	0.60 ± 0.05		
Middle	0.57 ± 0.05		
Elderly	0.58 ± 0.05		
Swing time [s]			
All	0.41 ± 0.03		
Young	0.42 ± 0.03		
Middle	0.40 ± 0.04		
Elderly	0.41 ± 0.03		

Stance time (% gait cycle)	
59.22	59
59.59	58.51
59.22	58.51
Swing time (% gait cycle)	
40.77	41
40.40	41.48
40.77	41.48

Figure 13 – Temporophasic parameters pa ... et al. 2016. Participants were young (mean 27.21 ... s-old, and elderly (mean 68.01 years-old). Walk w...

III. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

Temporophasic parameters

- In subjects older than 70 years the double support time differed between genders.
- Also, age affect double support time.

Parameter	Men (N = 108)				Women (N = 186)			
	70–74	75–79	80–84	85+	70–74	75–79	80–84	85+
	N = 27	N = 30	N = 37	N = 14	N = 33	N = 77	N = 43	N = 33
Swing (%GC)	36.6 ± 1.5	36.7 ± 1.5	36.6 ± 2.8	35.1 ± 2.69	36.6 ± 2.6	36.1 ± 3.0	35.5 ± 2.5	35.7 ± 2.6
Stance (%GC)	63.2 ± 2.1	64.0 ± 2.5	63.8 ± 2.7	64.9 ± 2.7	63.3 ± 3.1	63.9 ± 3.0	64.5 ± 2.6	64.5 ± 2.5
Single support (%GC)	37.1 ± 1.8	37.0 ± 1.7	36.5 ± 2.2	35.2 ± 2.1	37.0 ± 3.20	35.8 ± 4.8	35.6 ± 2.4	35.7 ± 2.8
Double support (%GC)	26.3 ± 3.0	26.5 ± 2.3	27.4 ± 4.7	30.3 ± 3.5	27.14 ± 4.0	28.4 ± 6.4	29.0 ± 4.6	28.7 ± 4.8

Figure 14 – Temporophasic parameters results from Hollaman J. et al. 2011. Walk was registered at self-selected speed.

D.2 How is a normal biomechanical assessment of gait?

IV. Kinematic assessment of normal gait

II. SPATIOTEMPORAL ASSESSMENT OF NORMAL GAIT

- Instrument to measure kinematics parameters

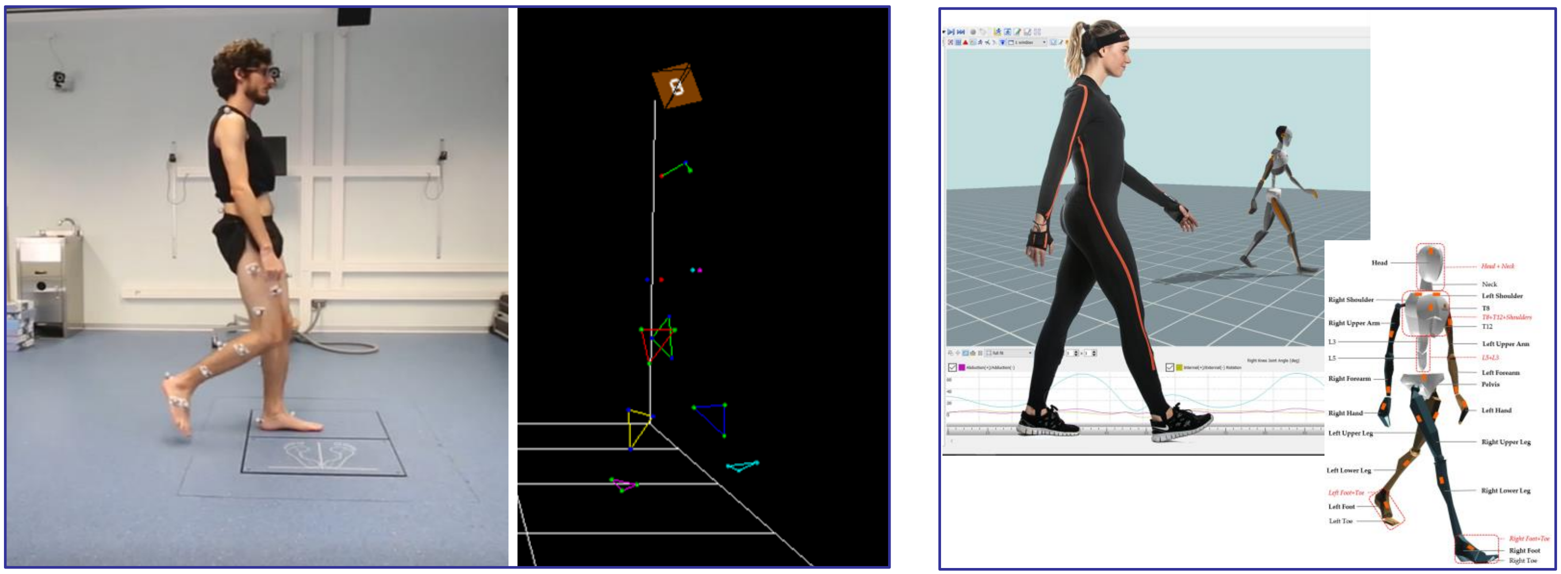


Figure 1 – Biomechanical tools. Left: 3D photogrammetry system from Kinescan/IBV. Right: IMU sensors from Xsens (Motion Capture System).

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Planes of movement

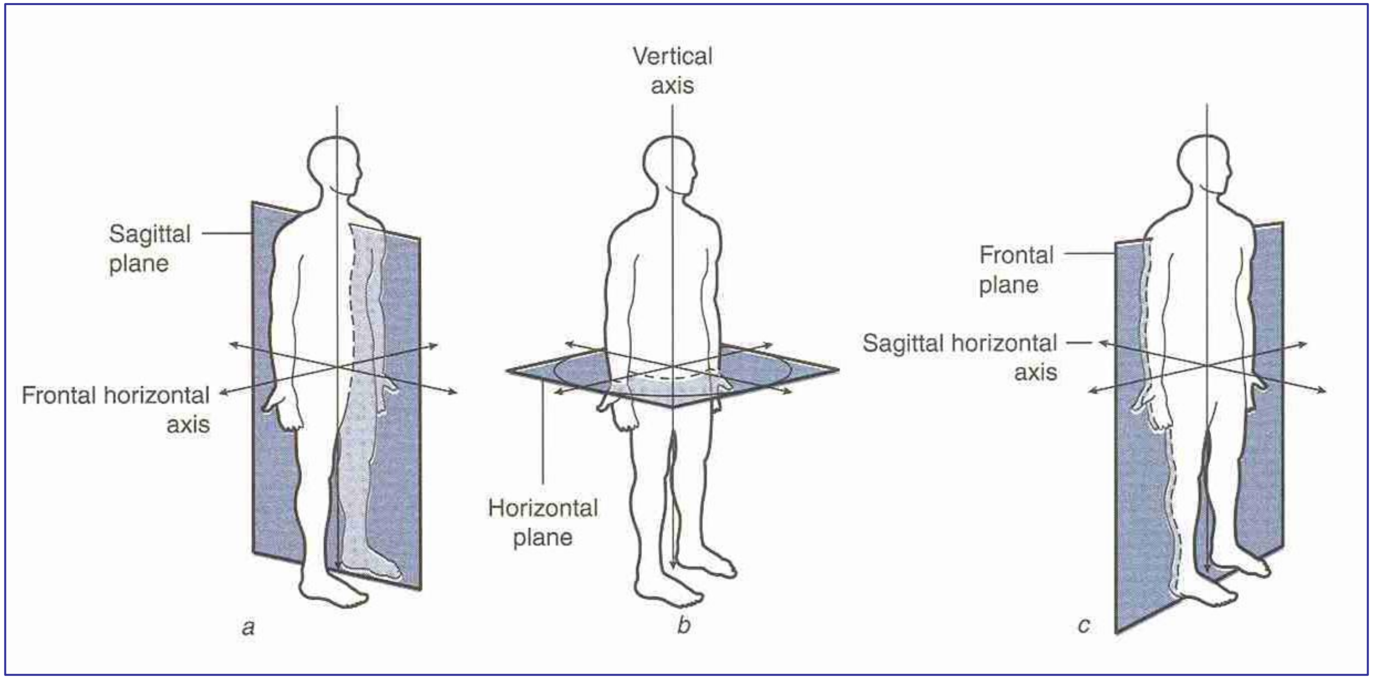


Figure 2 – Planes of movement. Gait kinematics is described in (a) sagittal plane, (b) horizontal o transversal plane, and (c) frontal plane.

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Curves of movement

FRONTAL	SAGITTAL	TRANSVERSE
-	Plantar flexion-dorsiflexion	Foot rotation
-	Knee flexion-extension	-
Hip abduction-adduction	Hip flexion-extension	Hip rotation
Pelvic obliquity	Pelvic tilt	Pelvic rotation

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Outcomes from joint movement

- Range of motion
- Maximum flexion/extension
- Angular velocity
- Angular acceleration
- Jerk

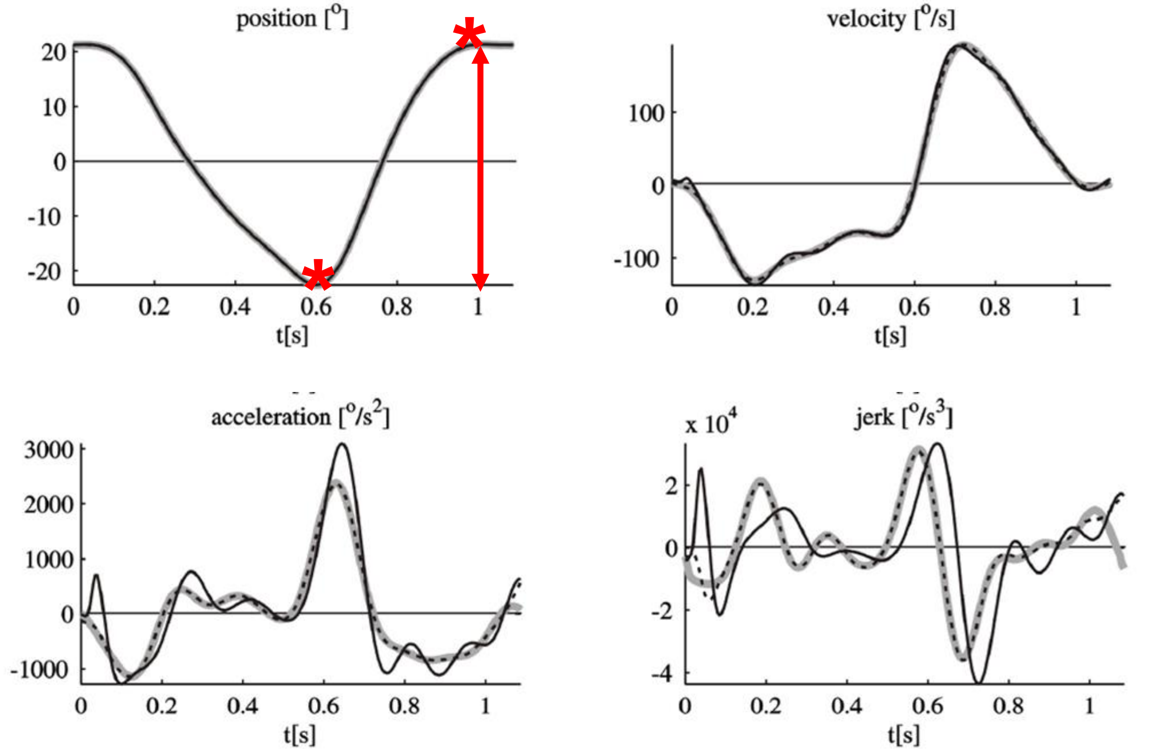


Figure 3 – Estimates of angular position, velocity, acceleration and jerk of the hip from De Groote, F. et al. 2008

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Reminder: Periods and phases of gait cycle

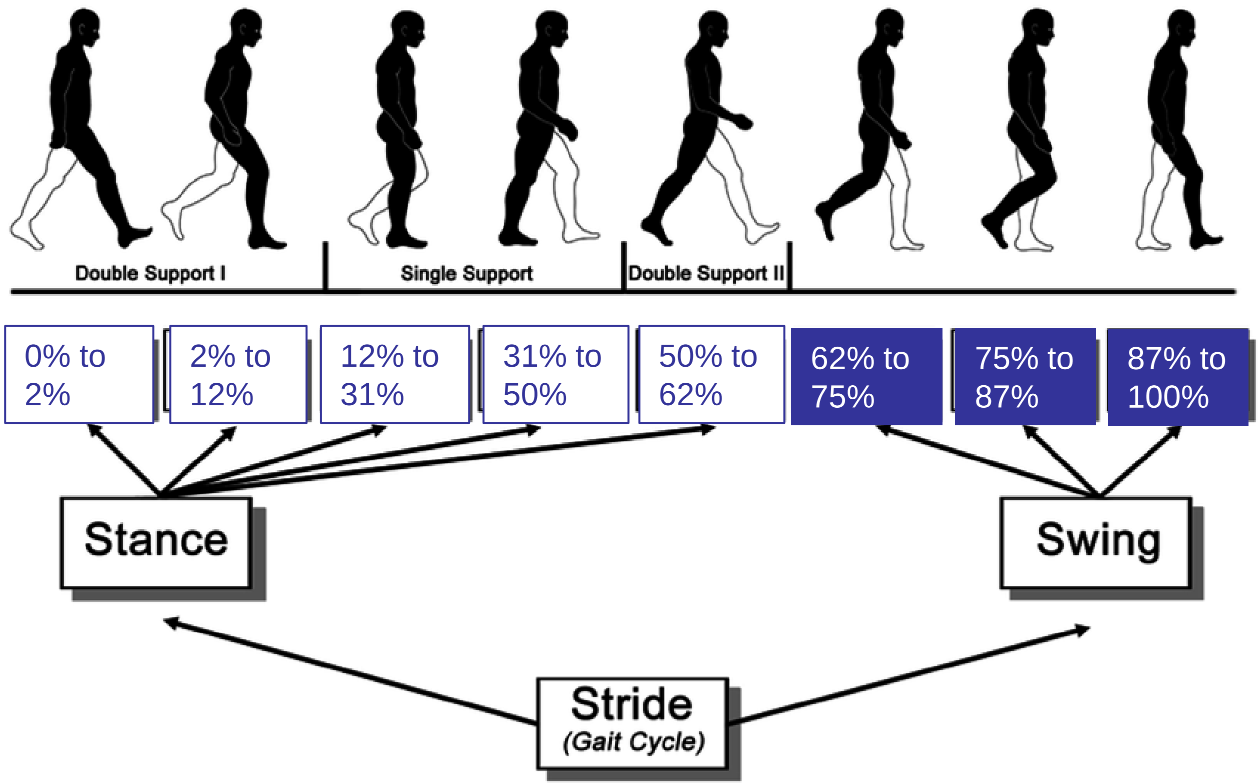


Figure 5 – Period and phases of gait cycle. In each sub-phase the percentage of gait in which it takes place is shown. (Perry J and Burnfield J. 2010)

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the ankle

- Sagittal plane.
- Initial contact: neutral position.
- Load response: 1º plantar-flexion.
- Terminal stance: 1 dorsal-flexion.
- Preswing: 2º plantar-flexion.
- Mid/termina swing: 2º dorsal-flexion.

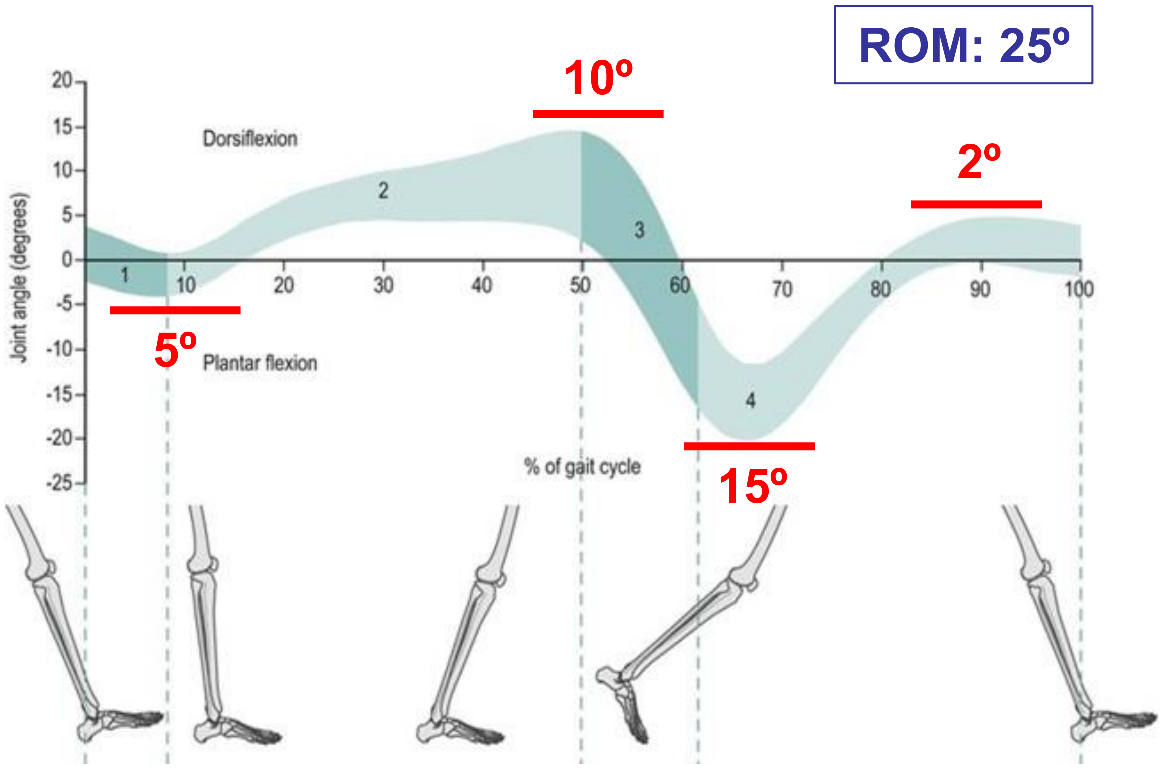


Figure 6 – Ankle movement in sagittal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the foot

- Subtalar, midtarsal, and metatarsal joint have measurables arcs of motion during walking.
- Subtalar joint allows inversion and eversion.
- Initial contact: neutral position.
- Midstance: maximum eversion.
- Swing phase: neutral position.

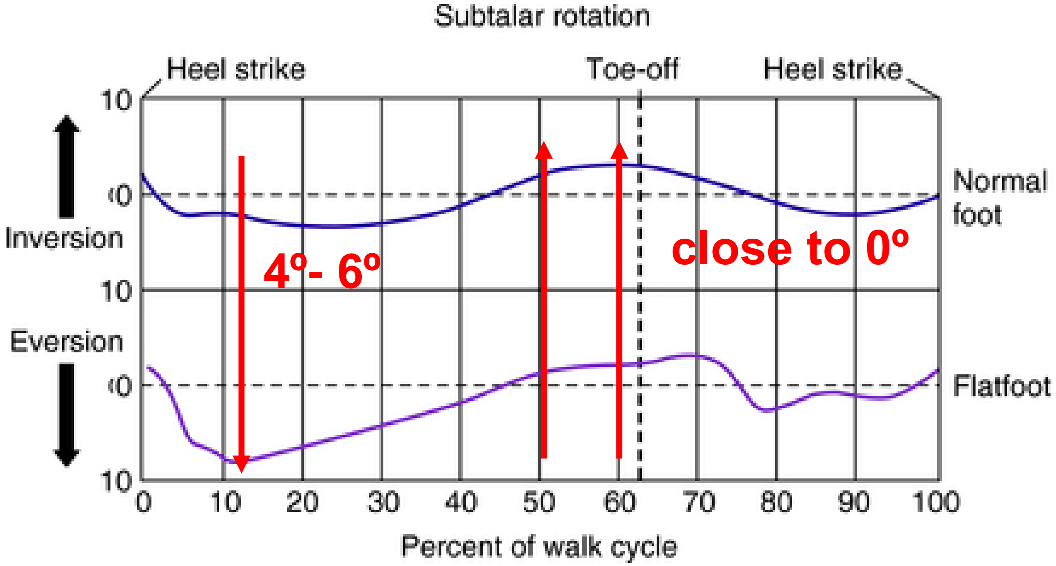


Figure 7 – Subtalar movement through gait cycle. Image from https://musculoskeletalkey.com

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the knee

- Sagittal plane: flexion and extension of the knee.
- Initial contact: slight flexion.
- Between loading response and midstance: first flexion peak.
- Terminal stance: first extension peak.
- Initial swing: second flexion peak.
- Terminal swing: second extension peak.

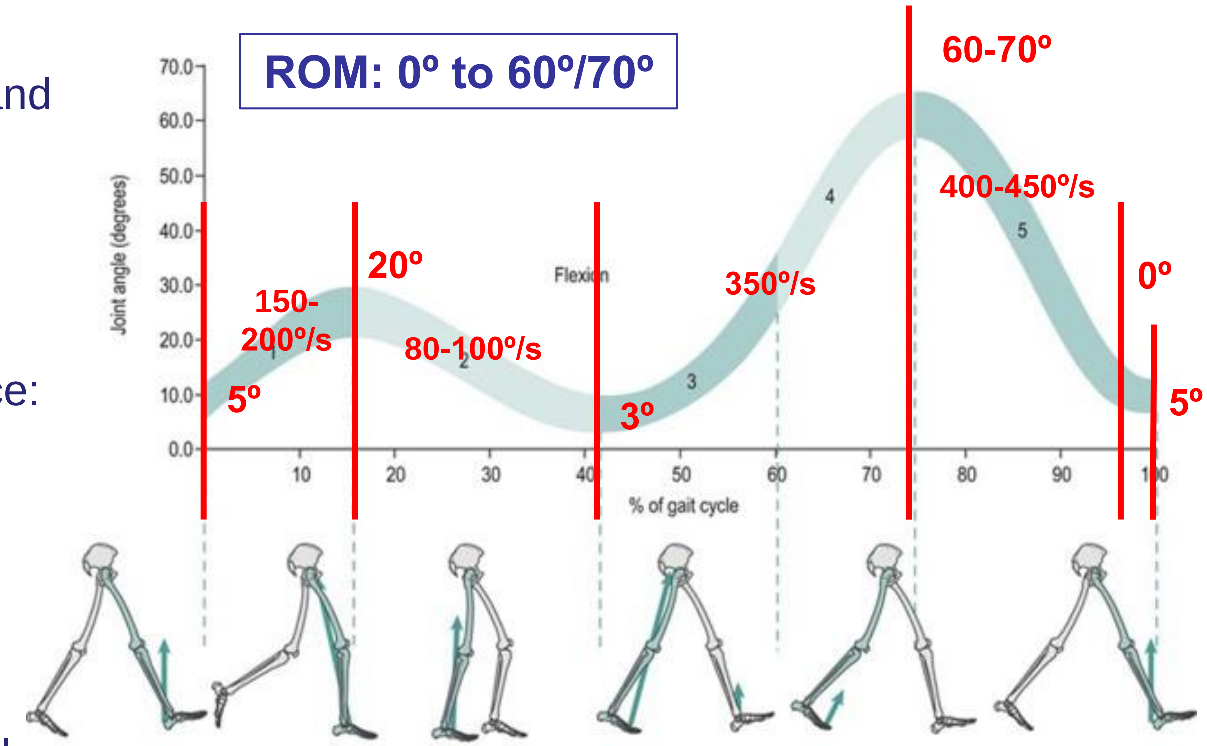


Figure 8 – Knee movement on sagittal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Absolute and relative analysis of the hip and pelvis

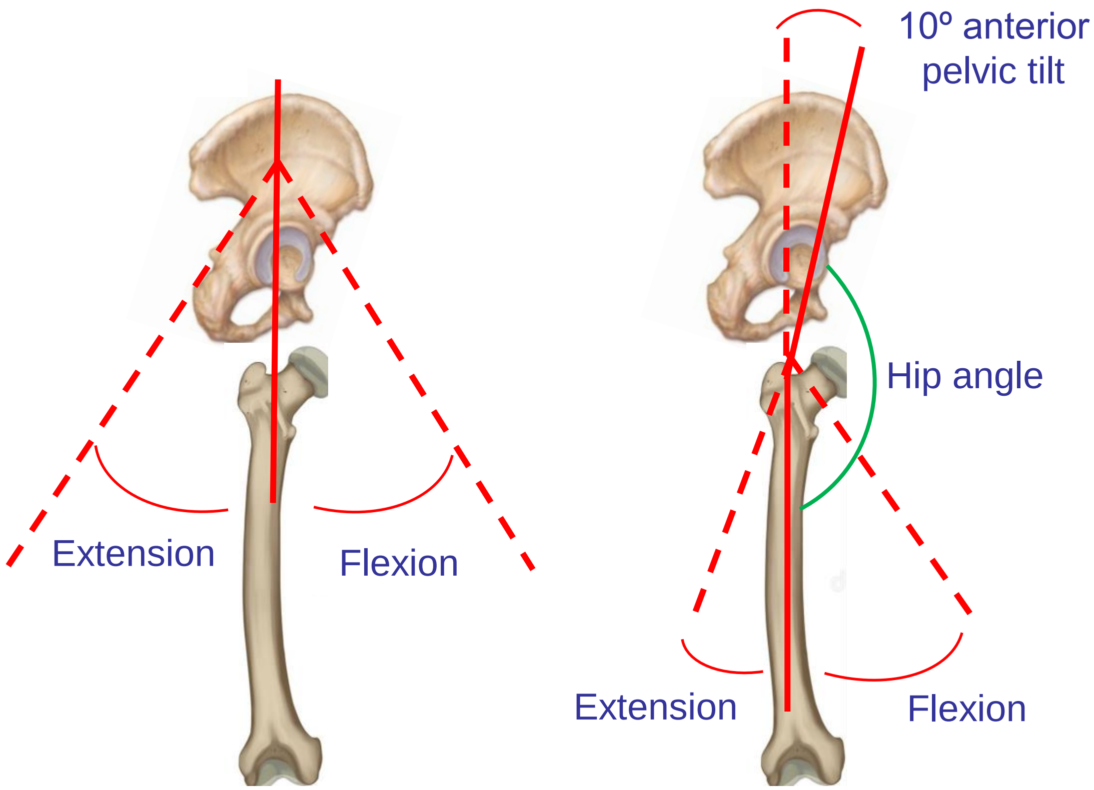


Figure 9 – Absolute (left) and relative (right) movement of the thigh.

- Relative movement versus absolute movement.
- Optical kinematic analysis systems allow to record the absolute position of the thigh and pelvis.
- Systems based on electro-goniometers measure relative positions.

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the hip and thigh

- Sagittal plane: flexion-extension.
- Difference values from hip and thing motion.

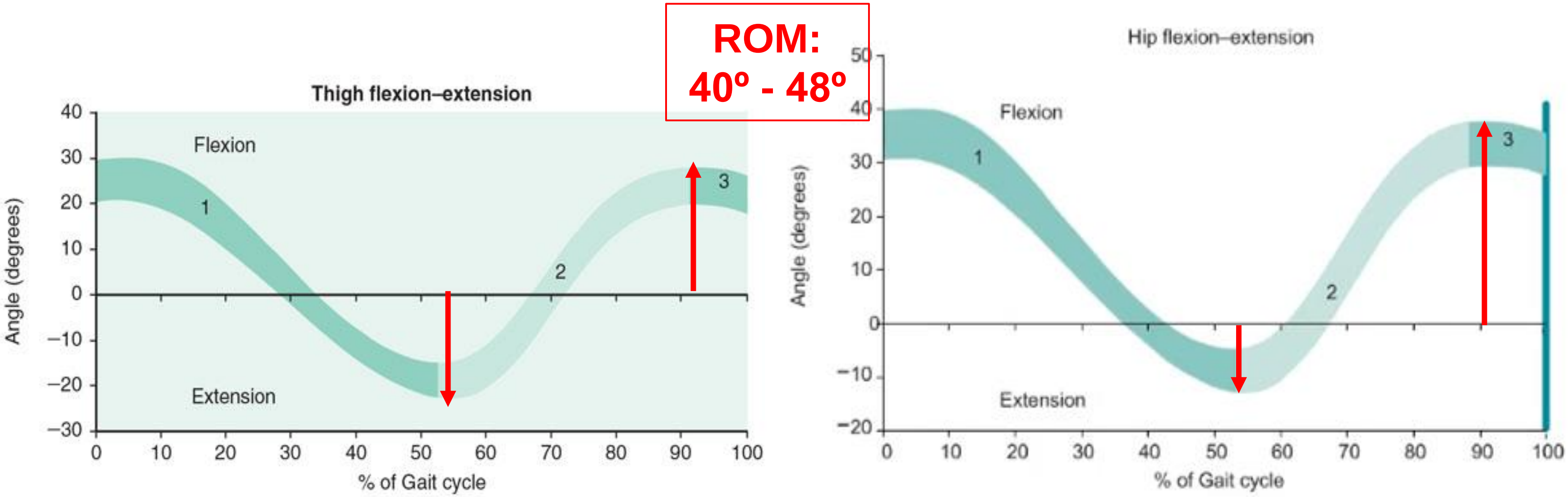


Figure 10 – Thigh (left) and hip (right) movement on sagittal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the hip and thigh

- Sagittal plane: flexion-extension.
- Difference values from hip and thing motion.
- Pre-swing: maximum extension (10º hip, 20º thigh).
- Terminal swing: maximum flexion (30º hip, 25º thigh).

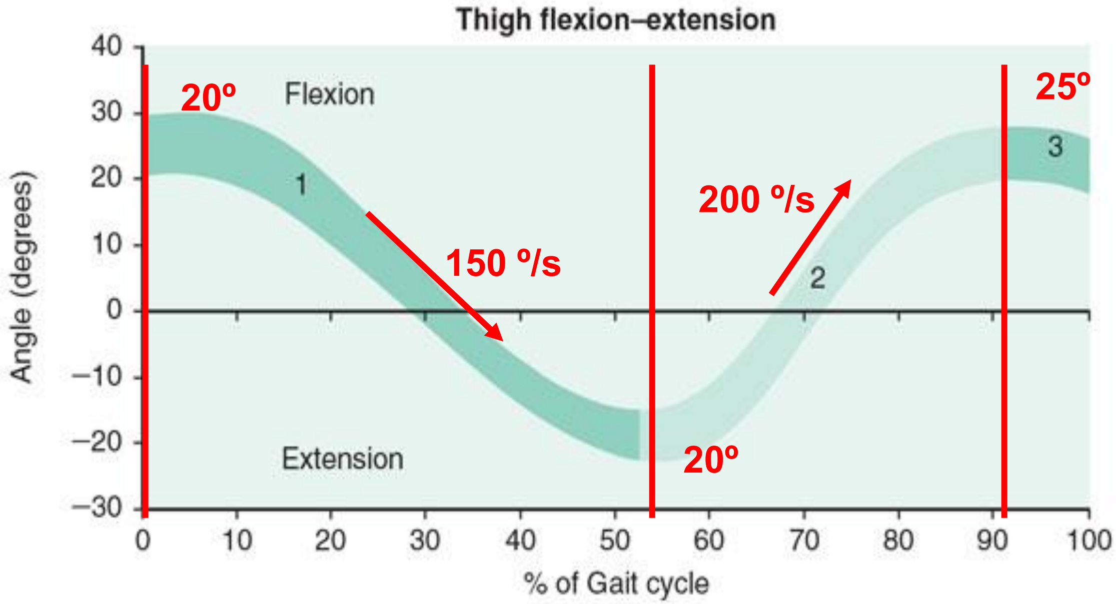


Figure 11 – Thigh movement on sagittal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the hip and thigh

- Frontal plane: adduction and abduction.
- Initial contact: neutral position.
- Loading response: maximum adduction.
- Pre-swing: neutral position.
- Initial swing: maximum abduction.
- Mid and terminal swing: neutral position.

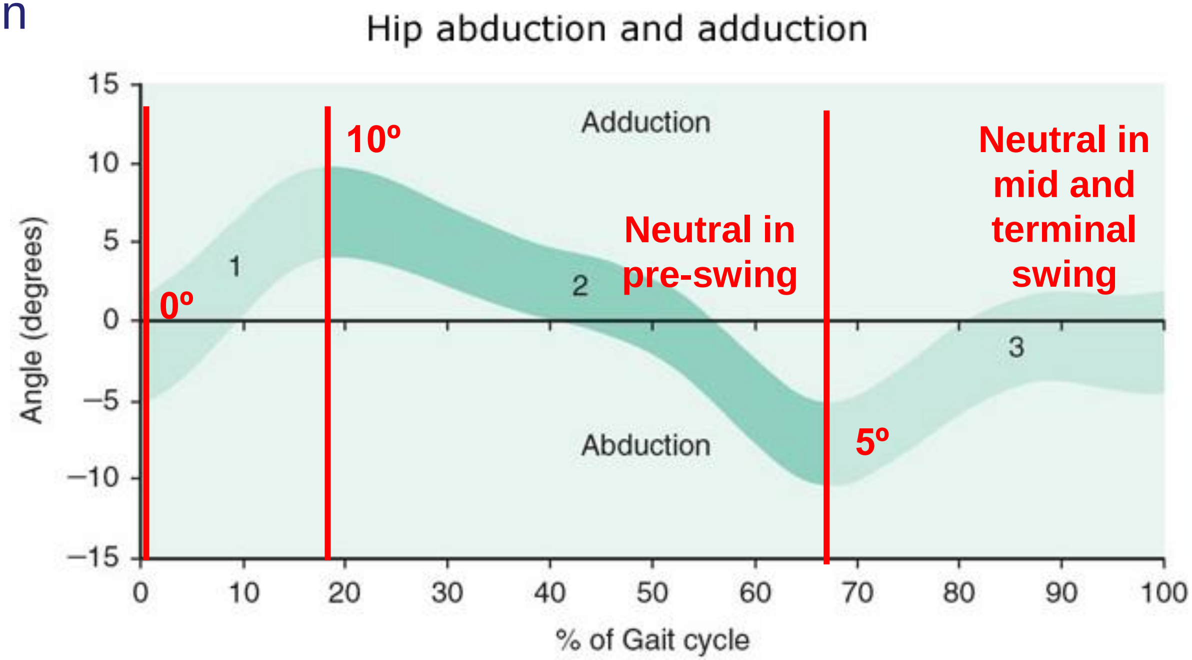


Figure 11 – Hip movement on frontal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the hip and thigh

- Transverse plane: internal and external rotation.
- Loading response: maximum internal rotation of the thigh.
- Initial swing: maximum external rotation of the thigh.
- Total ROM of thigh: 8º.
- Total ROM with pelvic motion added: 15º.

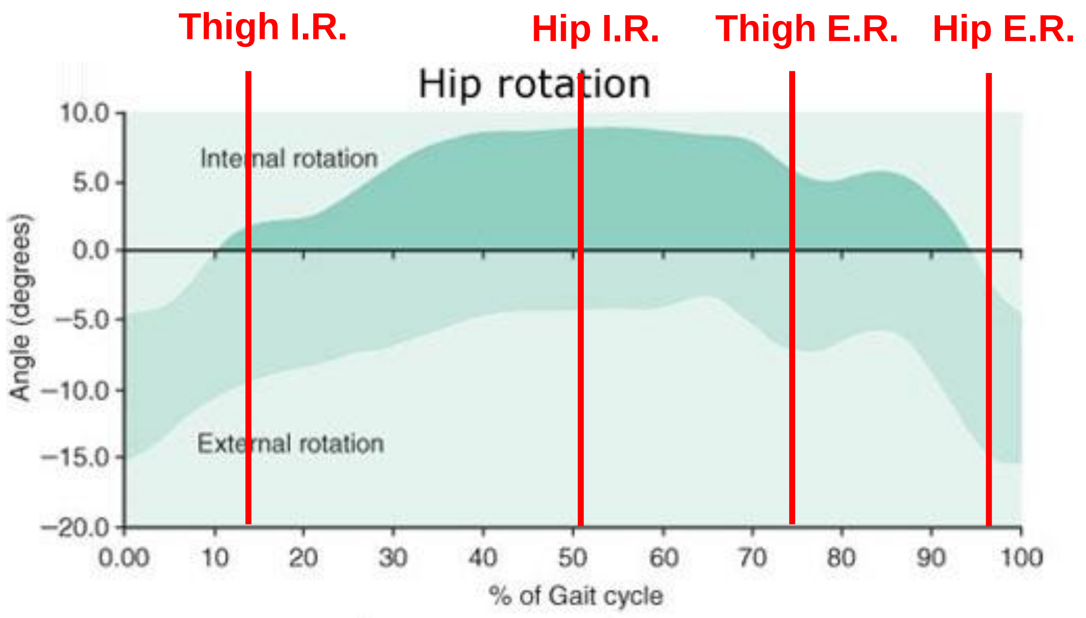


Figure 12 – Hip movement on transverse plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the pelvis

- The pelvis moves asynchronously in all 3 direction during each stride.
- All the movements are small, representing a continuum of postural change.

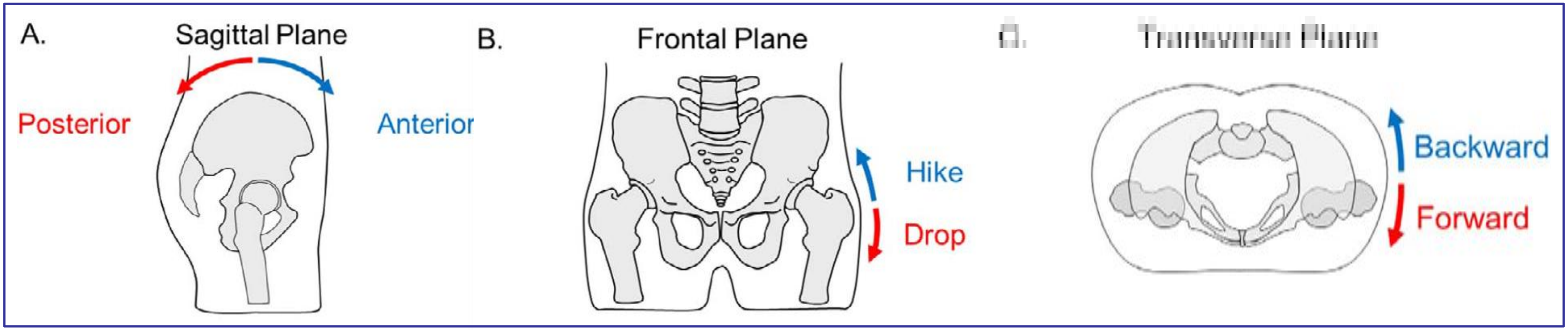


Figure 13 – Pelvic motion in the three planes of the space. Image from Lewis C. et al. 2017

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the pelvis

- Sagittal plane: anterior and posterior tilt.
- Gait add 4º to the anatomical tilt of the pelvis.
- Posterior tilt: single limb support at mid stance and during initial swing.
- Anterior tilt: terminal stance and terminal swing.
- ROM: 3º to 5º.

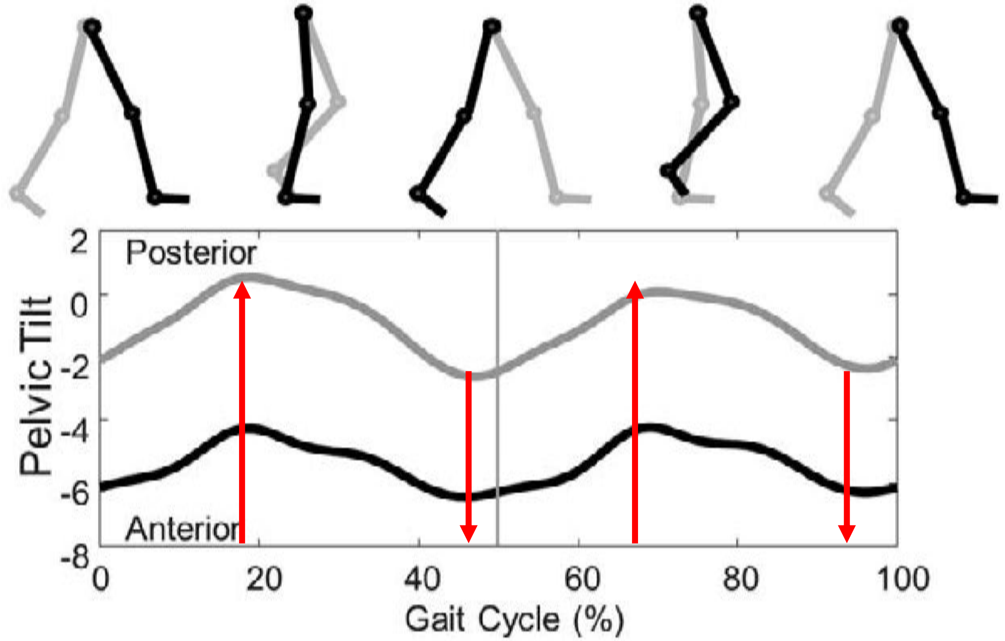


Figure 14 – Pelvic motion in the sagittal plane during gait cycle. Black line is referring to female performance and gray to male. Image from Lewis C. et al. 2017.

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the pelvis

- Frontal plane: drop (down) and hike (up) of the pelvis.
- Weight acceptance: ipsilateral pelvis up.
- Pre-swing: ipsilateral pelvis drops 4º.
- ROM: 6º to 10º.

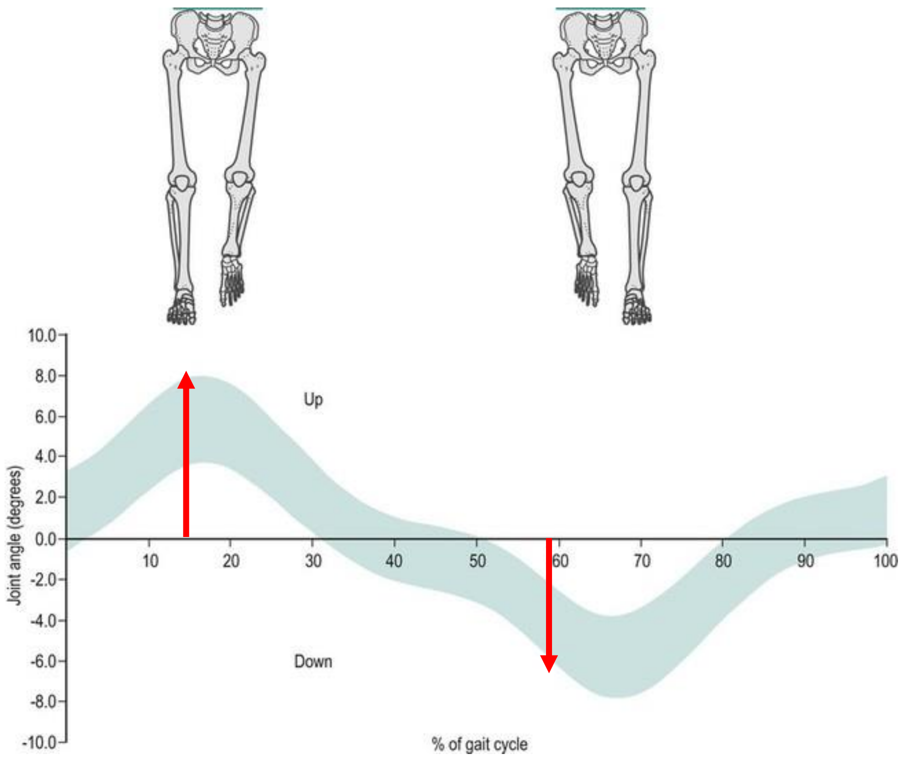


Figure 15 – Pelvis movement on frontal plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Kinematic of the pelvis

- Transverse plane: forward and backward rotation of the pelvis.
- Terminal swing + Initial contact of the next cycle: maximum forward rotation.
- Terminal stance: maximum backward rotation.
- ROM: 10º.

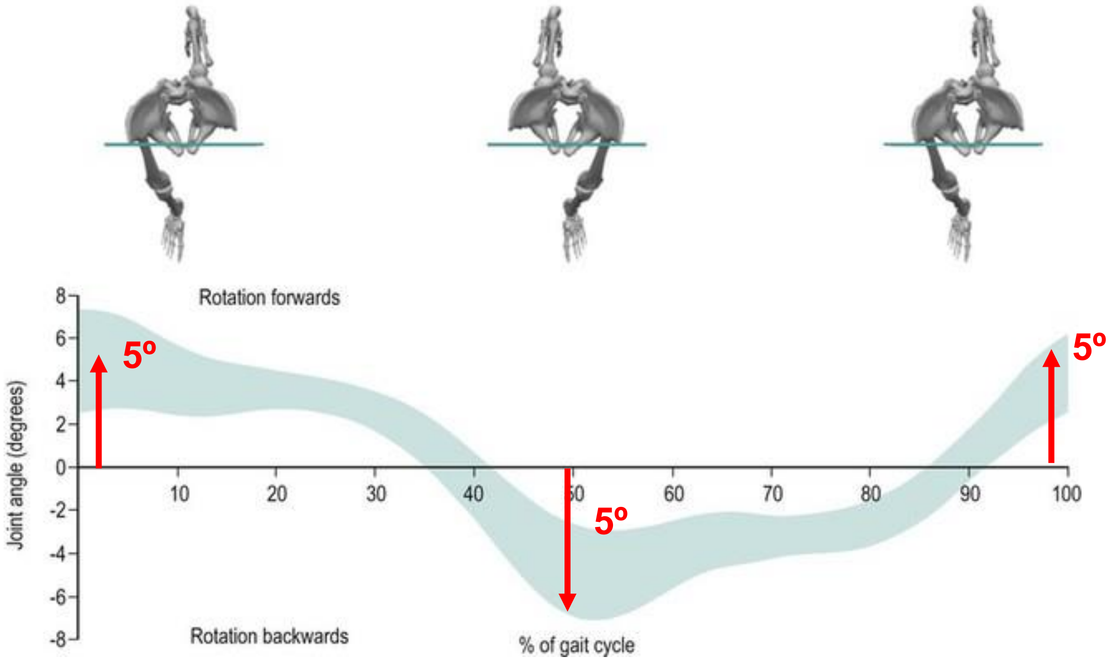


Figure 16 – Pelvis movement on transverse plane through gait cycle. Image from Richards J. 2015

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Age and sex differences on gait normal pattern

PLOS ONE

RESEARCH ARTICLE

Whole body kinematic sex differences persist across non-dimensional gait speeds

Dustin A. Bruening[1]*, Andrew R. Baird[2], Kelsey J. Weaver[1], Austin T. Rasmussen[1]

1 Exercise Sciences Department, Brigham Young University, Provo, Utah, United States of America,
2 Mechanical Engineering Department, Brigham Young University, Provo, Utah, United States of America

$$F = \frac{v}{\sqrt{gl}}$$

Where F = the non-dimensional speed or Froude speed, v = speed, g = gravity, and l = leg length.

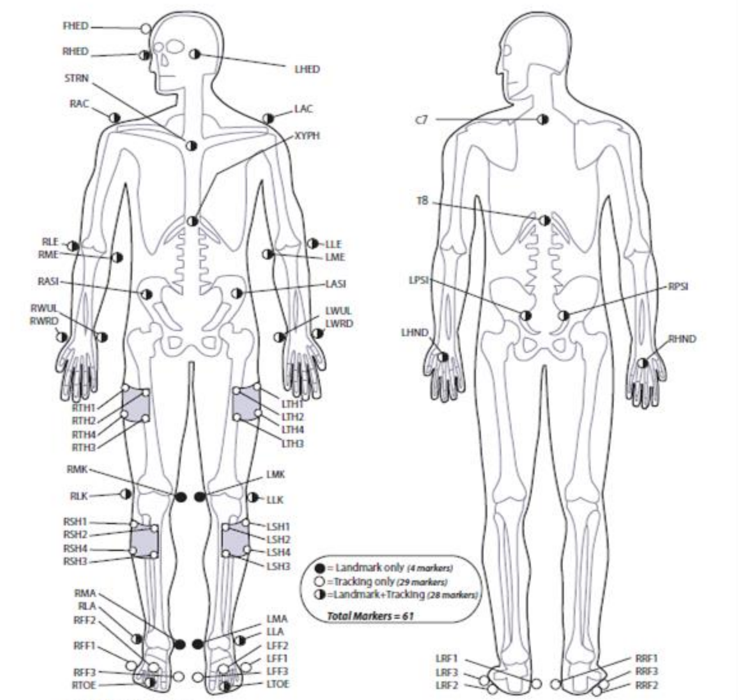


Figure A1: Marker set.

Figure 17 – Market set from the study of Bruening D. et al. 2020

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Age and sex differences on gait normal pattern

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RESEARCH ARTICLE

Whole body kinematic sex differences persist across non-dimensional gait speeds

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Other authors: females walk with more knee extension and have greater peak hip adduction and internal rotation than males.

- Sex differences on ankle (plantar-dorsal flexion) and pelvis (rotation and obliquity) ROM.

	ANOVA main effects *p*-values	
	Sex	Interaction
Range of motion		
Ankle (Sagittal)	<0.001*	0.008*
Midtarsal (Sagittal)	0.734	0.333
Pelvis (Frontal)	<0.001*	0.092
Pelvis (Transverse)	<0.001*	0.006*

		Walk		
Froude speed (ND)		**0.32**	**0.48**	**0.64**
Speed (m/s)	M	1.0 ± 0.02	1.5 ± 0.03	1.9 ± 0.04
	F	0.9 ± 0.02	1.4 ± 0.03	1.8 ± 0.04
Ankle-Sagittal (°)	M	21.1 ± 3.6	26.0 ± 3.8	31.0 ± 4.6
	F	25.0 ± 6.4	29.1 ± 4.9	32.8 ± 4.7
Midtarsal-Sagittal (°)	M	10.9 ± 2.7	12.9 ± 4.2	13.5 ± 3.7
	F	11.8 ± 2.3	12.3 ± 2.8	14.0 ± 4.1
Pelvis-Frontal (°)	M	6.0 ± 1.8	7.6 ± 2.3	9.4 ± 2.5
	F	9.3 ± 3.1	12.6 ± 3.4	14.8 ± 3.8
Pelvis-Transverse (°)	M	10.0 ± 3.2	11.4 ± 3.5	14.9 ± 4.5

Figure 18 – Kinematics results (right) and statistics analysis (left) from comparison female and male participants and across of three non-dimensional gait velocity. Results from Bruening D. et al. 2020.

IV. KINEMATIC ASSESSMENT OF NORMAL GAIT

Age and sex differences on gait normal pattern

GAIT PARAMETERS OF HEALTHY, ELDERLY PEOPLE

Róbert Paróczai[1], Zoltán Bejek[2], Árpád Illyés[2], László Kocsis[1], Rita M. Kiss[3]

- Elderly present a reduction of movement at ankle and knee, but an increase of rotation and obliquity of the pelvis.

Parameter		Unit	Elderly		Young	
			Female	Male	Female	Male
Hip flexion						
Range	Dominant side	degree	52.34±3.56	59.20±3.5	61.64±4.56	64.02±3.56
	Nondominant side	degree	50.12±4.78	54.30±3.3	59.2±3.45	62.76±3.56
Maximum	Dominant side	degree	64.23±6.78	69.30±9.1	66.76±4.56	68.62±5.63
	Nondominant side	degree	60.12±4.57	63.67±8.5	64.32±3.12	67.54±5.23
Minimum	Dominant side	degree	11.89±3.78	9.91± 5.78	5.12±1.34	4.60±1.44
	Nondominant side	degree	10.00±5.08	9.63±3.89	5.32±2.1	4.79±1.45
Pelvic rotation						
Range		degree	8.29±2.96	7.42±1.69	4.46±2.34	6.57±2.01
Maximum		degree	2.91±2.6	6.37±1.30	2.12±1.23	5.34±1.34
Minimum		degree	-5.38±0.35	-1.26±1.15	-2.34±1.23	-1.23±2.23
Pelvic obliquity						
Range		degree	2.65±0.38	3.12±1.87	1.42±0.33	1.75±0.44
Maximum		degree	5.64±1.58	3.97±1.55	4.56±2.34	3.12±1.23
Minimum		degree	2.99±1.19	0.85±0.85	3.14±1.03	1.37±0.76
Knee flexion						
Range	Dominant side	degree	43.08±2.57	41.15±2.9	54.23±3.67	56.86±2.89
	Nondominant side	degree	39.67±1.79	40.45±3.1	50.79±2.99	52.97±3.12
First peak	Dominant side	degree	16.21±2.4	19.77±2.94	21.56±2.67	23.34±2.45
	Nondominant side	degree	27.45±1.08	17.83±2.36	19.89±1.99	22.39±3.47
Second peak	Dominant side	degree	56.89±0.31	50.67±2.58	59.99±3.12	61.99±3.44
	Nondominant side	degree	48.5 ±0.35	49.44±3.78	56.78±3.21	59.34±3.22
Minimum	Dominant side	degree	17.22±2.1	10.08±2.08	5.89±3.12	5.13±0.23
	Nondominant side	degree	15.41±2.22	9.80±2.88	5.99±3.33	5.74±2.12

Figure 19 – Kinematics performance from female and male participants at different ages (elderly and young) during gait cycle. Results from Paróczai R. et al. 2006.

D.2 How is a normal biomechanical assessment of gait?

V. Kinetic assessment of normal gait

V. KINETIC ASSESSMENT OF NORMAL GAIT

- Instrument to measure kinetic parameters

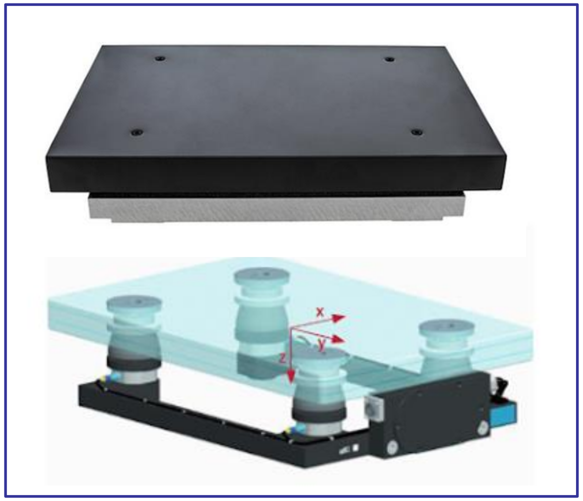


Figure 1 – Strain gauge (up) and piezoelectric sensors (down) force platforms for ground reaction forces measure.

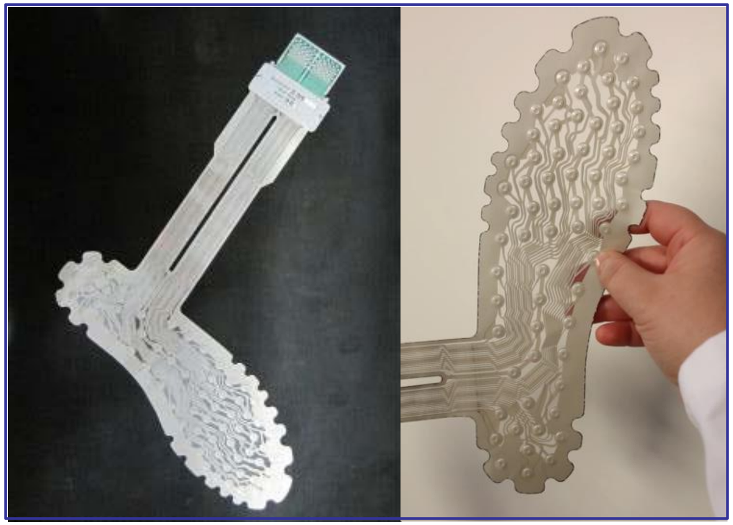


Figure 2 – Instrumented insole from Biofoot/IBV system for plantar pressure measure.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Ground reaction force

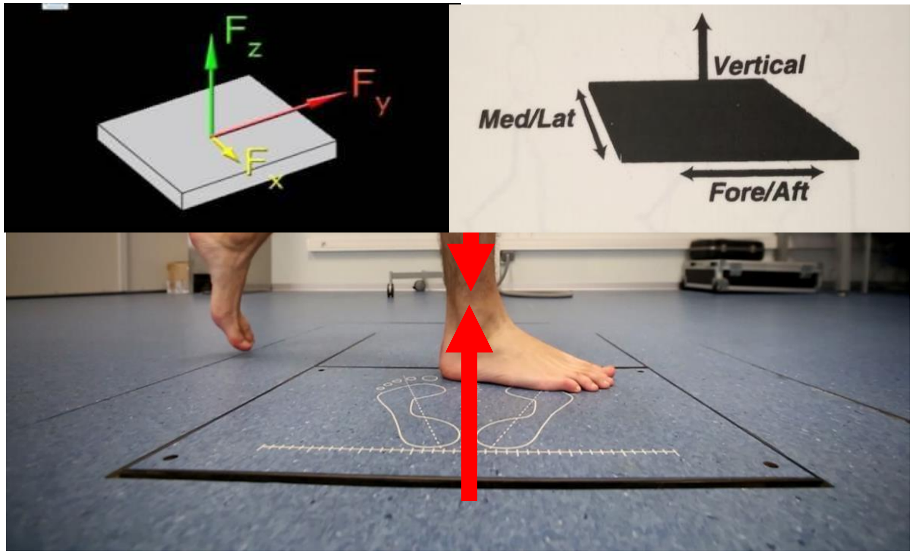
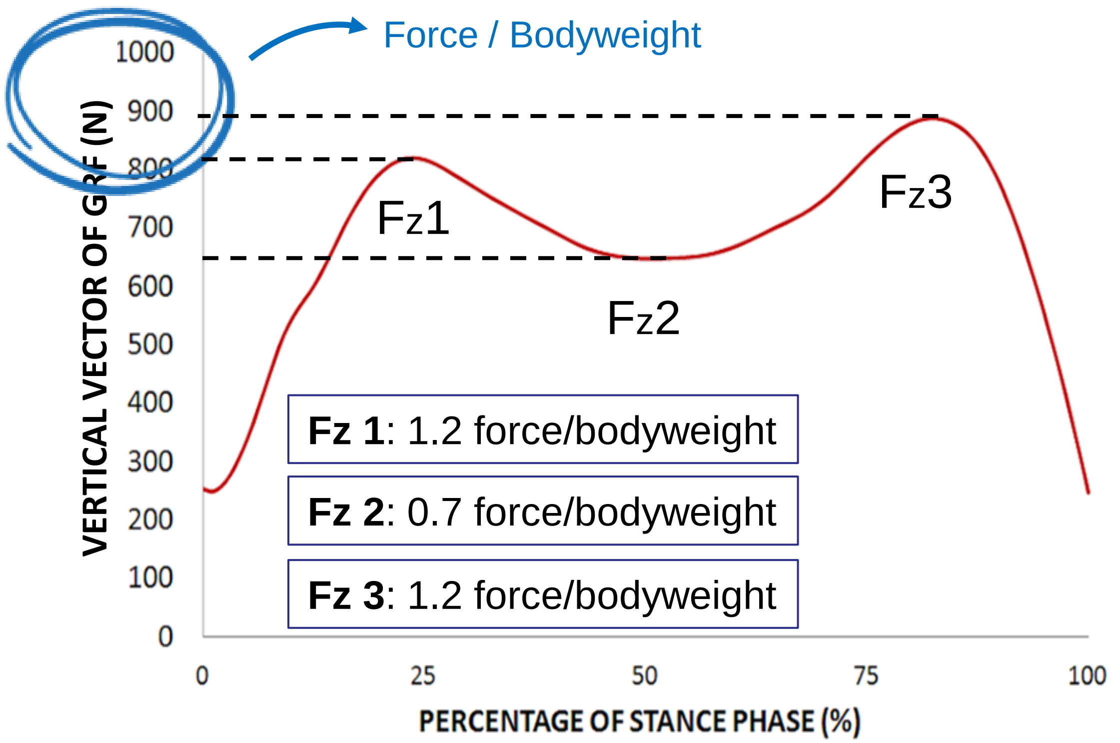


Figure 3 – Ground reaction force (GRF) produced when the body hitting the ground during stance phase of walking cycle.

- Vertical force component of the GRF
- Anterior-posterior component of the GRF
- Medio-lateral component of the GRF
- Centre of pressure during walking

V. KINETIC ASSESSMENT OF NORMAL GAIT

Vertical force component of GRF



Fz 1: Peak force in maximal weight acceptance

Fz 2: Peak force in mid stance

Fz 3: Peak force in push-off

Figure 4 –Force in the vertical direction during normal walking and outcomes obtained from force magnitude.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Vertical force component of GRF

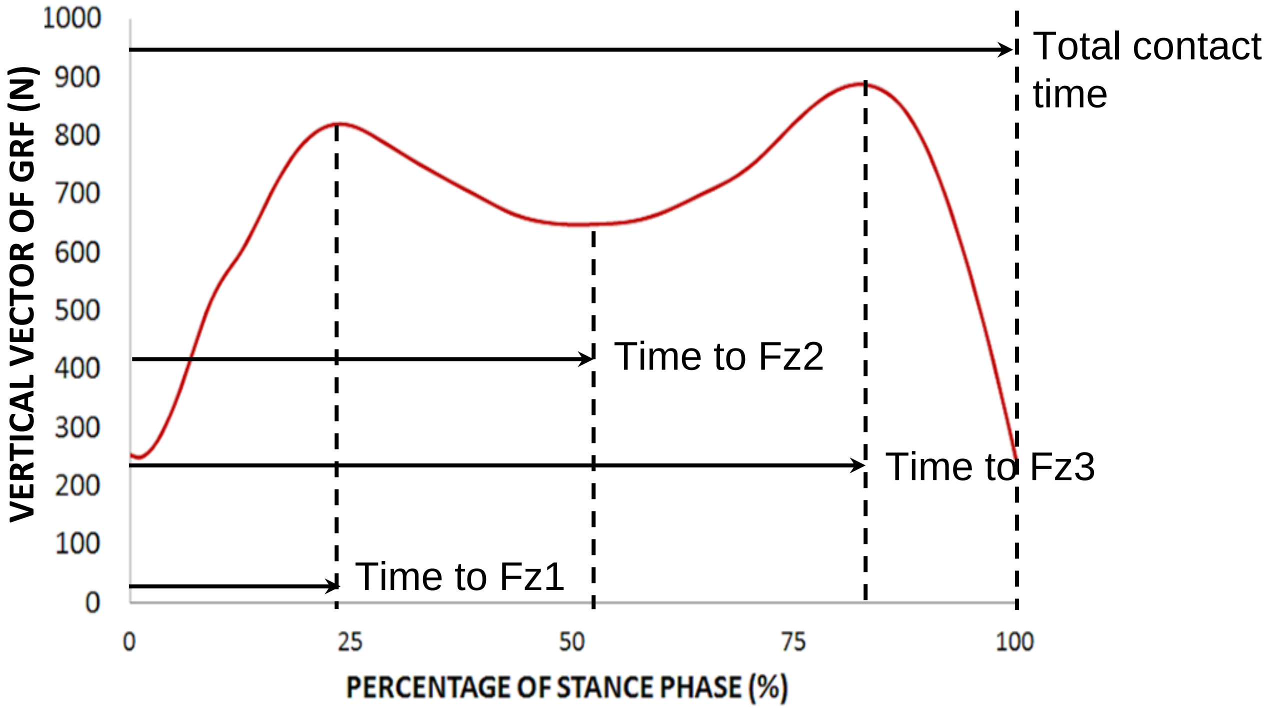
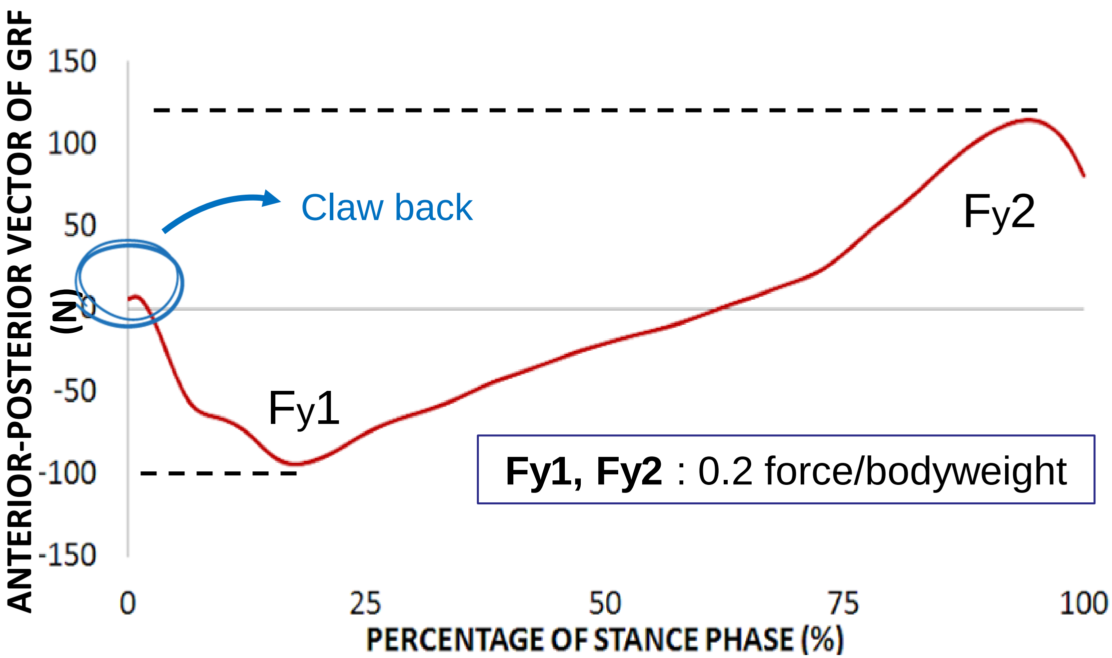


Figure 5 –Force in the vertical direction during normal walking and outcomes obtained from time.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Anterior-posterior force component of GRF



Fy 1: Maximum posterior force. Correspond to the breaking.

Fy 2: Maximum anterior force. Correspond to the heel-off.

Figure 6 –Force in the anterior-posterior direction during normal walking and outcomes obtained from force magnitude.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Anterior-posterior force component of GRF

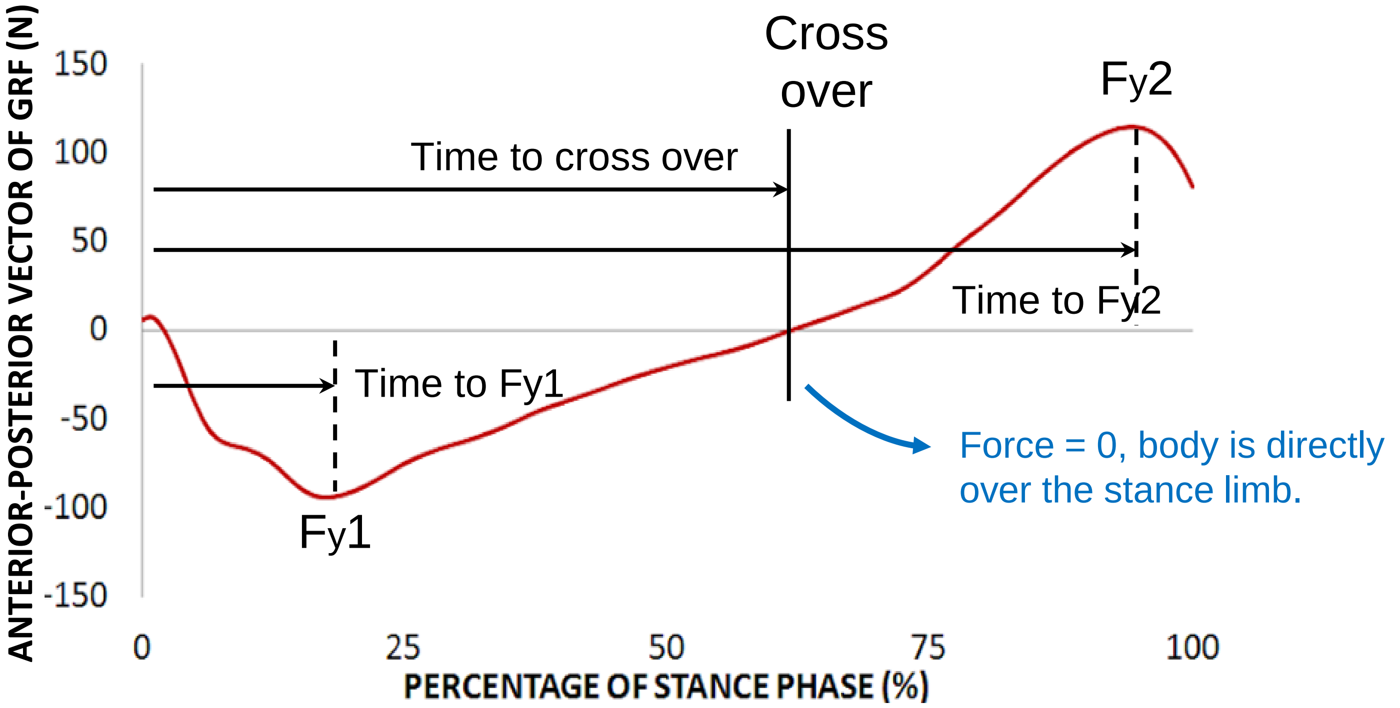


Figure 7 –Force in the anterior-posterior direction during normal walking and outcomes obtained from force time.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Anterior-posterior force component of GRF

The impulse of a force or just **impulse (I)** is a vector magnitude that relates the force with the time that its action lasts.

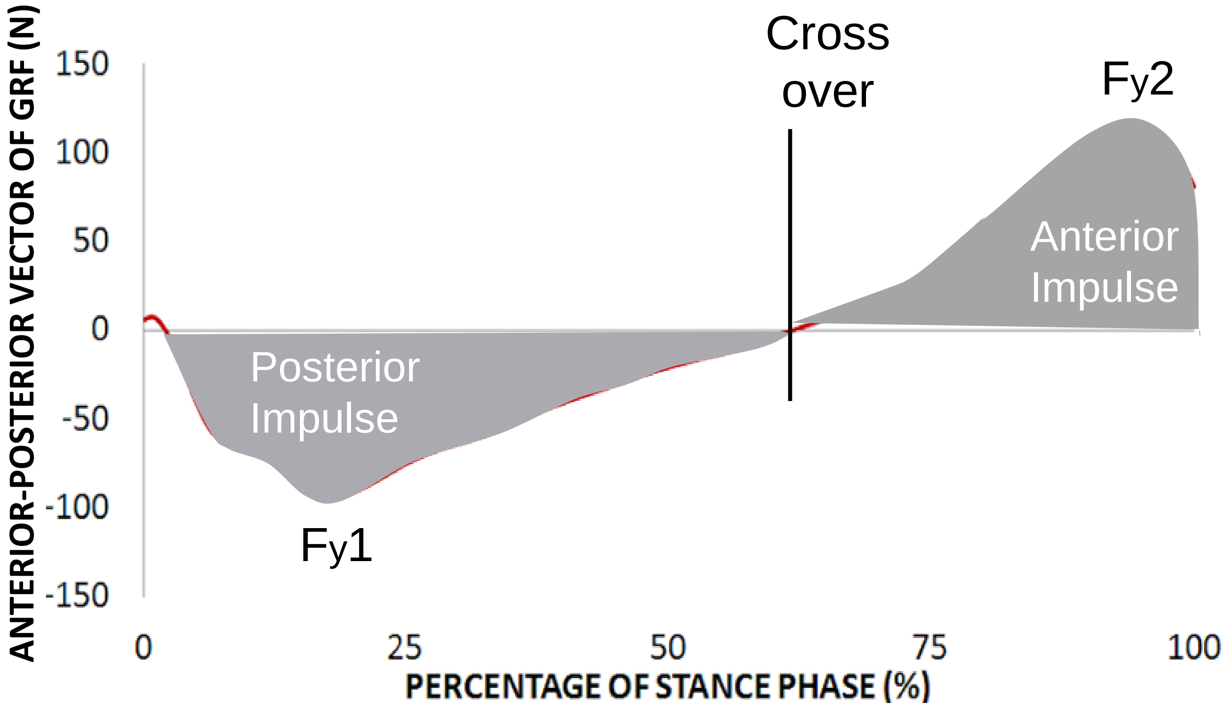
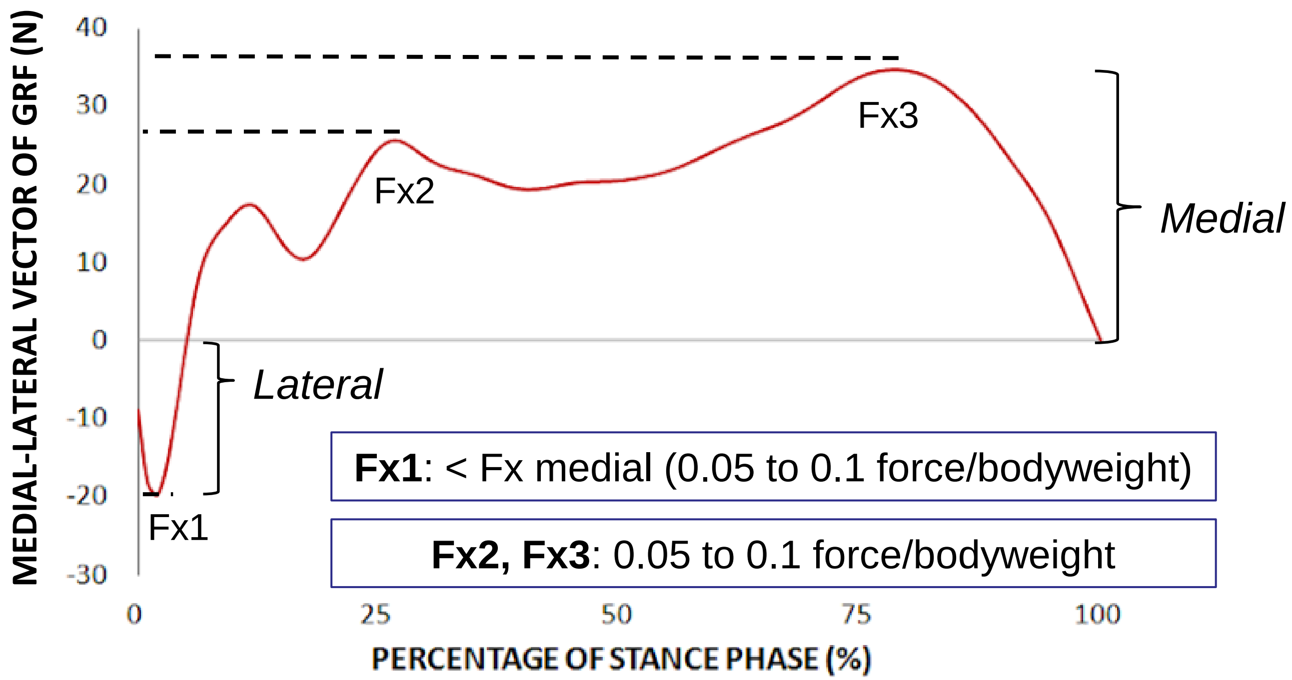


Figure 8 –Force in the anterior-posterior direction during normal walking and outcomes obtained from curve area.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Medio-lateral force component of GRF



Fx 1: Maximum lateral force

Fx 2: Maximum loading medial force

Fx 3: Maximum propulsion medial force

Figure 9 –Force in the medio-lateral direction during normal walking and outcomes obtained from force magnitude.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Centre of pressure movement

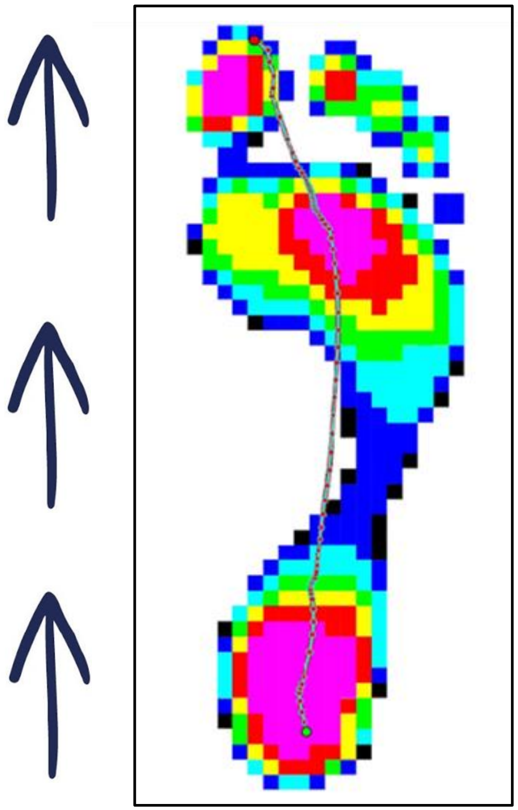


Figure 10 – Typical centre of pressure distribution. From Buldt A.K. et al. 2018.

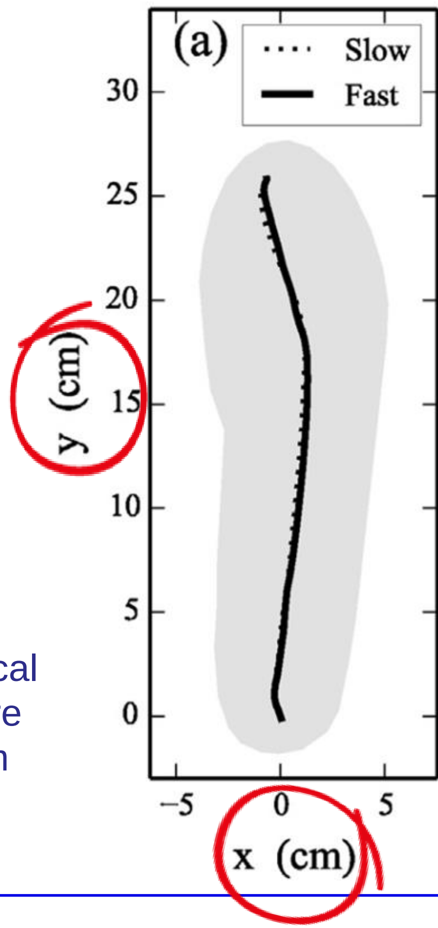


Figure 11 – Centre of pressure movement during gait at slow (dashed line) and fast velocity (solid line). From Todd C. Pataky et al. 2014.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Centre of pressure movement

What outcomes can we analyze of the excursion of the center of pressure?

Centre of pressure excursion index

Excursion of the COP from a constructed line connecting the first and the last points of the COP curve measured at the distal third of the foot and normalized to foot width.

Velocity of the centre of pressure

Resultant displacement of the COP divided by the elapsed time between measurements.

Parts from stance phase
Portions of the foot (rear, mid, forefoot)
In X or Y axis.

V. KINETIC ASSESSMENT OF NORMAL GAIT

Centre of pressure movement

Centre of pressure excursion index

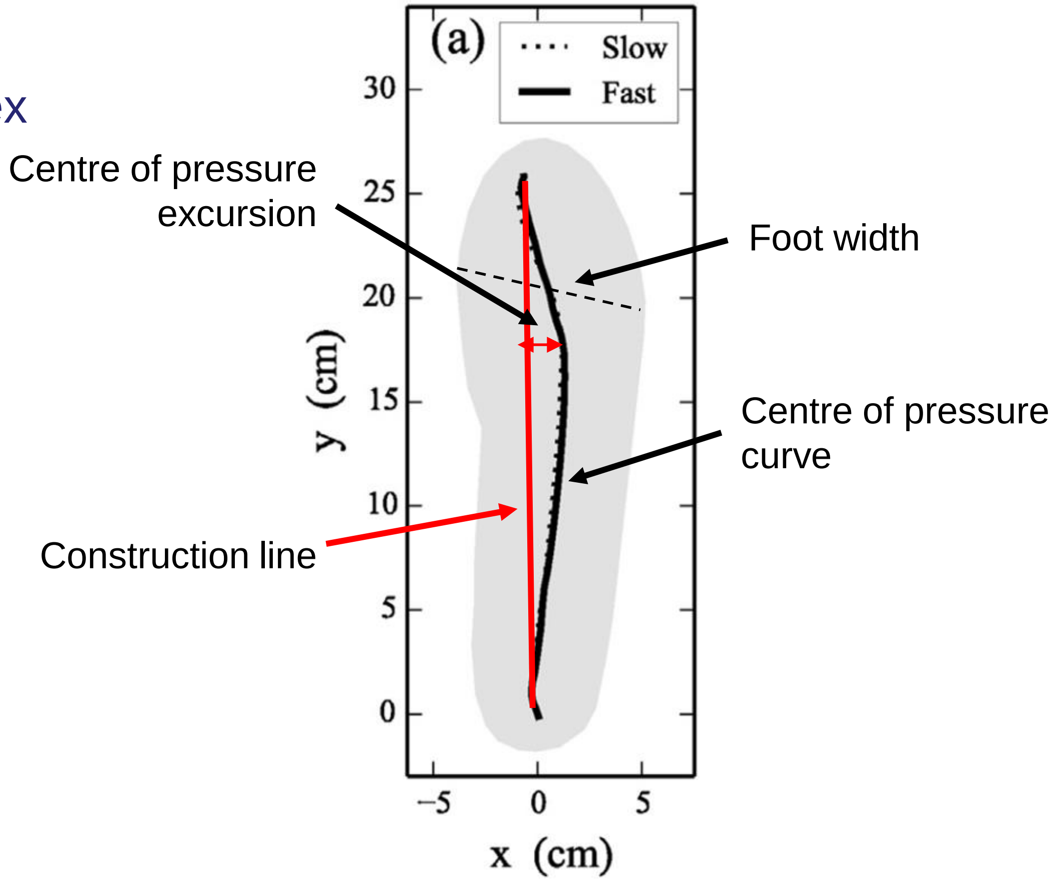
$$CPEI = \frac{Center\ of\ pressure\ excursion}{Foot\ Width}\ x\ 100\ \%$$

Values from 92 healthy subject (aged 18 to 45) with different foot posture walking at comfortable speed:

CPEI in normal: 20.4 (6.5)

CPEI in feet *planus*: 18.4 (4.5)

CPEI in feet *cavus*: 20.2 (5.8)



V. KINETIC ASSESSMENT OF NORMAL GAIT

Centre of pressure movement

Centre of pressure velocity

Bo Li et al.	AP velocity (m/s)	ML velocity (m/s)
Initial contact	0.426 (0.157)	0.106 (0.057)
forefoot contact	0.723 (0.405)	0.090 (0.058)
foot flat phase	0.292 (0.087)	0.028 (0.010)
Forefoot push-off	0.277 (0.050)	0.117 (0.029)

Buldt et al.	AP velocity (m/s)
Loading response	0.405 (0.084)
Midstance	0.435 (0.061)
Terminal stance	0.177 (0.069)
Pre-swing	0.453 (0.098)

Fuchioka et al.	AP velocity (cm/s)	Mean value in m/s
Rear foot	26.9 ± 8.8	0.26
Mid foot	83.0 ± 33.1	0.83
Forefoot	20.9 ± 5.3	0.20

Figure 12 – Centre of pressure velocity (m/s) mean value (SD) from healthy subjects with normal foot posture of Bo Li et al. 2020, Buldt et al. 2018, and Fuchioka et al. 2015 studies in the antero-posterior and medio-lateral axis.

D.2 How is a normal biomechanical assessment of gait?

VI. Plantar pressure assessment during normal gait

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

- Unit to inform pressure: KPa
- 10 kPa = 10 kN/m²

For normal subjects, typical peak pressure beneath the foot are 80-100 kPa in standing and 200-250 kPa in walking.

The area around the second and third metatarsal heads experiences the highest maximum pressure for the foot during walking in healthy adults.

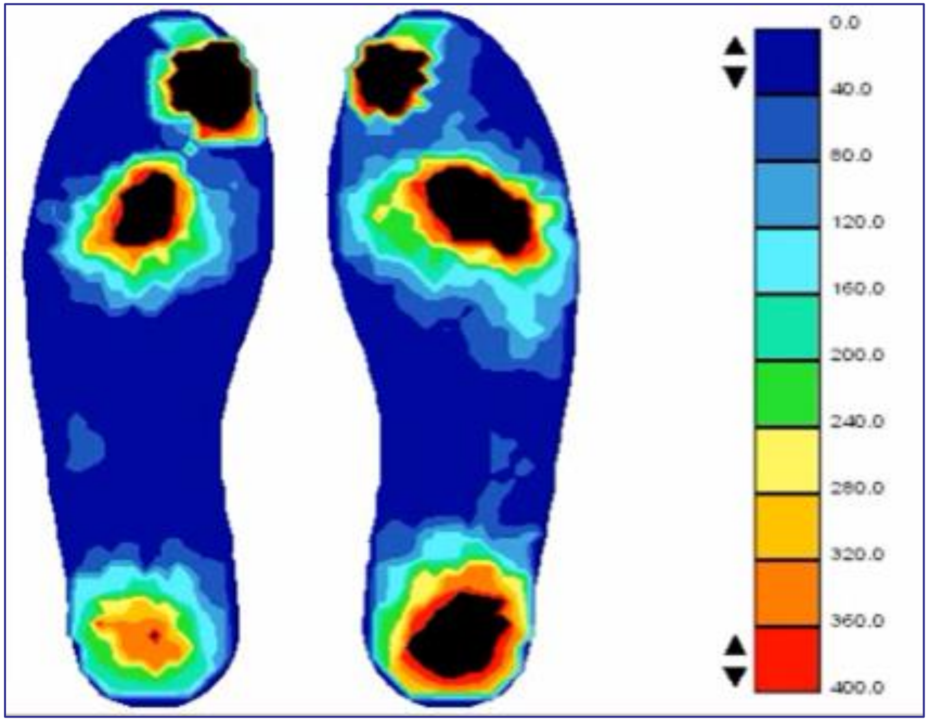


Figure 13 – Colour scale map from a plantar pressure assessment with Biofoot/IBV equipment.

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

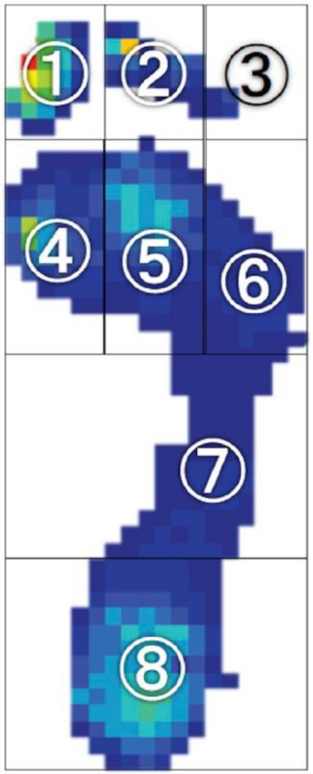


Figure 14 – Example of the analysis by regions of the foot. (1) the great toe; (2) the second and third toes; (3) the fourth and fifth toes; (4) the medial forefoot; (5) the central forefoot; (6) the lateral forefoot; (7) the midfoot; and (8) the hindfoot. Image from Tsujinaka S. et al. 2019.

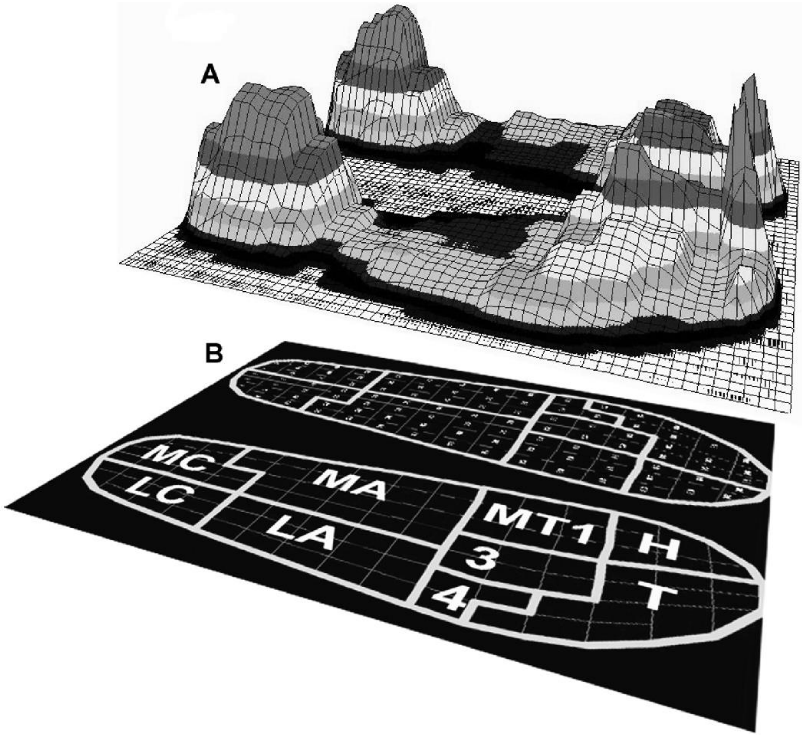
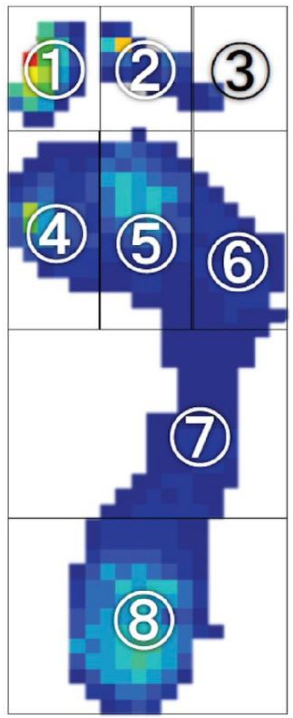


Figure 15 – Example of the analysis by regions of the foot. MC = medial calcaneus, LC = lateral calcaneus, MA = medial arch, LA = lateral arch, MT1 = first metatarse, 3 = second and third metatarse, 4 = fourth and fifth metatarse, H = hallux, and T = toes. Image from Hessert M. et al. 2005.

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

- Measurement equipment: insoles with pressure sensors.
- Participants walked a distance of 4 to 5.5 m during 5 seconds of recording (50 Hz).
- Normal walking speed.



Peak pressure (kPa) (*n* = 24. Age mean 52.4 ± 11.8)	
1. Great toe	311.7 (236.3)
2. 2º and 3º toes	186.9 (91.0)
3. 4º and 5º toes	141.6 (94.4)
4. Medial forefoot	304.5 (227.0)
5. Central forefoot	590.9 (357.1)
6. Lateral forefoot	215.0 (161.6)
7. Midfoot	128.5 (69.1)
8. Hindfoot	296.1 (155.1)

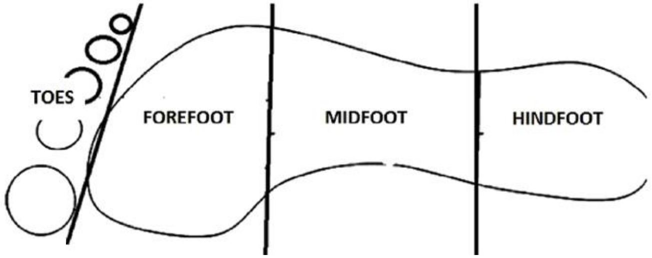
Figure 16 – Plantar pressure peak from normal walking subjects of Tsujinaka et al. 2019 study.

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

- Measurement equipment: instrumented platform.

- Data were collected barefoot in mid-gait at self-selected gait speed.



Gender comparison of pedobarographic data (MaxF, PP, CA) of adolescents according to age.

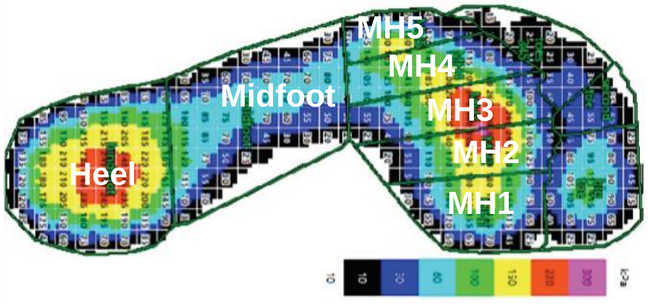
Age (Year)		11		12		13		14	
		F (n = 64)	M (n = 41)	F (n = 62)	M (n = 99)	F (n = 25)	M (n = 78)	F (n = 60)	M (n = 95)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Peak pressure (kPal)	Total	316.68 ± 94.66*	282.87 ± 66.36	333.70 ± 92.05	311.51 ± 67.96	305.80 ± 56.60	318.1 ± 72.2	374.08 ± 113.93*	338.61 ± 85.85
	Hindfoot	262.38 ± 93.90	241.34 ± 65.90	261.77 ± 91.37	260.90 ± 68.87	229.90 ± 42.84	261.05 ± 73.12*	271.71 ± 61.12	265.61 ± 78.40
	Midfoot	106.79 ± 27.01	100.37 ± 26.53	100.27 ± 29.54	103.35 ± 31.27	106.90 ± 36.73	113.84 ± 31.23	118 ± 32.76	108.52 ± 36.49
	Forefoot	253.39 ± 77.91*	221.52 ± 60.53	251.08 ± 73.36	244.04 ± 64.23	246.60 ± 55.63	255.12 ± 67.30	305.66 ± 82.14	281.35 ± 79.59
	Toes	201.05 ± 86.77	198.72 ± 69.96	253.79 ± 104.93*	216.00 ± 81.12	264.40 ± 65.02*	227.21 ± 83.4	299.75 ± 140.60*	238.75 ± 103.32

Figure 17 – Peak plantar pressure (SD) from Demirbüken I. et al. 2019.

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

- Measurement equipment: instrumented platform.
- Plantar pressures were recorded during barefoot walking at naturally chosen gait speed.



		Mean pressure									
		Toe 1	Toe 2	Toes 345	MH1	MH2	MH3	MH4	MH5	Midfoot	Heel
Males 60–69	Mean	109.45	62.56	44.70	111.48	145.94	142.21	118.31	90.45	49.56	160.06
	SD	46.71	23.38	22.81	33.19	28.62	35.13	31.22	35.61	20.99	23.84
Males 70–79	Mean	68.71	39.71	29.74	103.26	133.04	130.65	127.42	116.83	70.39	157.93
	SD	28.47	13.69	15.45	33.71	34.78	19.31	36.44	35.84	13.27	18.49
Females 60 69	Mean	81.38	53.55	42.27	101.88	160.71	156.10	122.08	99.23	66.03	147.71
	SD	23.44	24.66	20.75	34.81	43.88	30.32	34.30	46.74	26.03	22.87
Females 70–79	Mean	71.01	41.39	33.37	125.62	136.96	137.90	106.79	90.95	54.03	130.37
	SD	36.44	19.25	15.40	50.52	39.22	35.93	28.90	47.09	22.81	17.64

Figure 18 – Mean plantar pressure (SD) from Gimunova M. et al. 2018. n = 61 healthy elderly (21 men, 40 women).

VI. PLANTAR PRESSURE DURING NORMAL GAIT

Plantar pressure

- Measurement equipment: instrumented platform.
- Walking at comfortable speed.
- Healthy groups: children, adolescents, adults and older adults.

	Aged 3-9		Aged 10-19		Aged 20-59		Aged 60+	
	Male	Female	Male	Female	Male	Female	Male	Female
Maximum mean pressure (kPa)								
Rearfoot	67.0 (34.3)	76.1 (31.0)	99.2 (25.5)	102.1 (28.2)	105.6 (24.2)	99.5 (26.8)*	106.3 (37.4)	99.1 (32.1)
Midfoot	11.4 (8.8)	13.1 (12.0)	20.7 (14.6)	16.2 (12.6)*	26.2 (17.3)	22.0 (15.6)*	23.3 (22.0)	24.8 (17.9)
Forefoot	79.1 (35.3)	84.0 (30.0)	147.7 (51.0)	147.9 (40.5)	181.7 (55.8)	180.3 (45.7)	207.4 (73.9)	201.5 (74.0)
Whole foot	94.5 (4.9)	99.3 (31.9)	154.8 (49.1)	154.1 (38.1)	182.8 (55.2)	181.5 (44.7)	210.1 (73.0)	203.8 (72.5)
Peak pressure (kPa)								
Rearfoot	249.3 (129.3)	269.6 (120.1)	365.4 (129.2)	341.0 (92.3)	375.0 (122.6)	345.7 (113.5)*	356.7 (148.3)	319.9 (113.7)*
Midfoot	49.3 (26.9)	49.1 (34.0)	71.3 (41.1)	57.1 (35.5)*	80.6 (44.3)	74.4 (46.7)	75.9 (63.3)	84.7 (52.7)
Forefoot	230.0 (80.0)	245.1 (87.0)	433.4 (161.4)	431.0 (116.2)	523.9 (164.8)	527.7 (148.3)	576.1 (200.0)	570.3 (190.1)
Whole foot	290.9 (124.0)	310.8(120.3)	475.8 (163.9)	456.1 (111.9)	540.7 (168.0)	541.7 (147.0)	591.8 (203.5)	580.2 (186.4)

Figure 19 – Maximum mean pressure and Peak plantar pressure (SD) from McKay M. et al. 2017. n = 1000 healthy individuals aged 3-101 years. (21 men, 40 women).

D.2 How is a normal biomechanical assessment of gait?

VII. Electromyographic assessment of normal gait

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Instrument to measure muscular activity

Figure 1 – Surface electromyography system and instrumentation of the lower limb. To determine the instrumentation protocol, the SENIAM guide should be used, which standardizes the location of electrodes in the different body segments. (www.seniam.org).

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic outcomes

AMPLITUDE

- Root mean square
- Rectification
- Envelope

ACTIVATION TIMING

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Amplitude: Root Mean Square (RMS)

1) Each data point in the signal is squared
2) The average value over a specified window length is determined
3) The square root of this value is then calculated

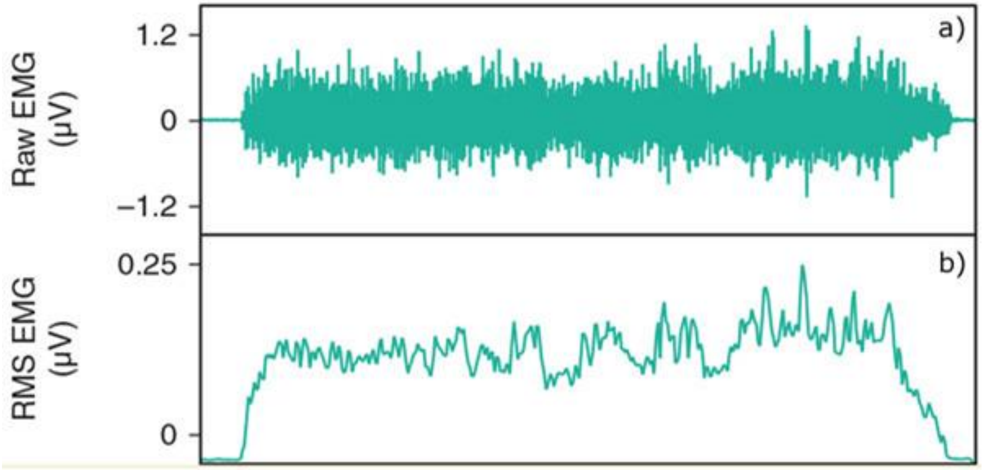


Figure 2 – a) Raw EMG Signal. b) Root Mean Square (RMS) Calculated with a Moving Window of Length of 0.25 ms. Image from Richars J. 2018.

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Amplitude and Normalization

- Method 1: Maximal voluntary contraction.
- Method 2: Maximum observed EMG signal during the activity.

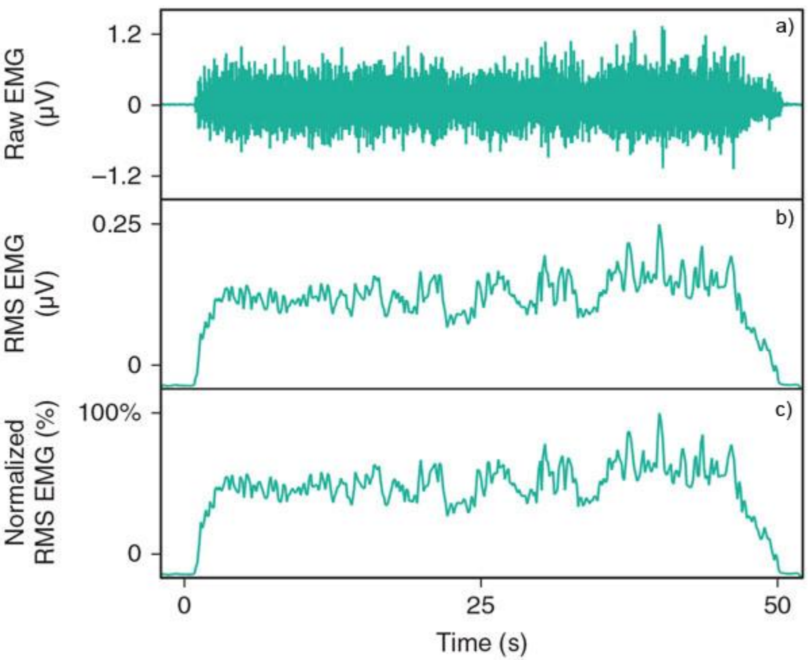


Figure 3 – a) Raw EMG Signal. b) Root Mean Square (RMS) Calculated with a Moving Window of Length of 0.25 ms. c) Normalized RMS of the EMG Signal. Image from Richars J. 2018.

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

EMG activation timing

The activation timing is performed by identifying the time instant when the EMG amplitude increases above (start) or decreases below (end) a predetermined baseline level.

The rectified EMG or RMS EMG are used for activation timing calculation.

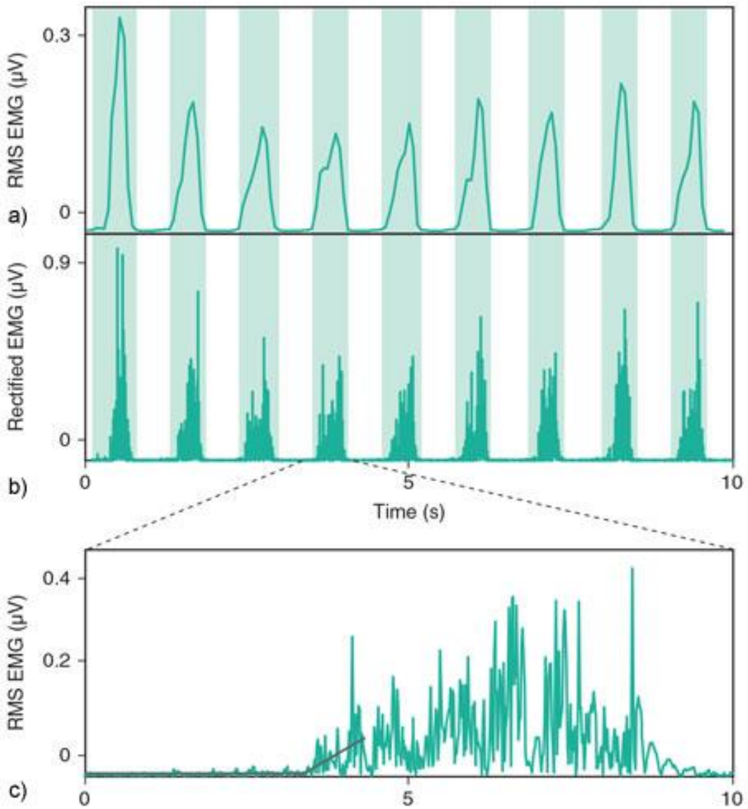


Figure 4 – a), b) Activation timings from EMG RMS and rectified EMG signal from the gastrocnemius muscle during walking. c) EMG RMS and superimposed regression lines. Image from Richars J. 2018.

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern during gait

Muscles in the stance limb act to support the body (postural control) and propel it forward (progression)

Muscle activity in the beginning and end of the swing phase

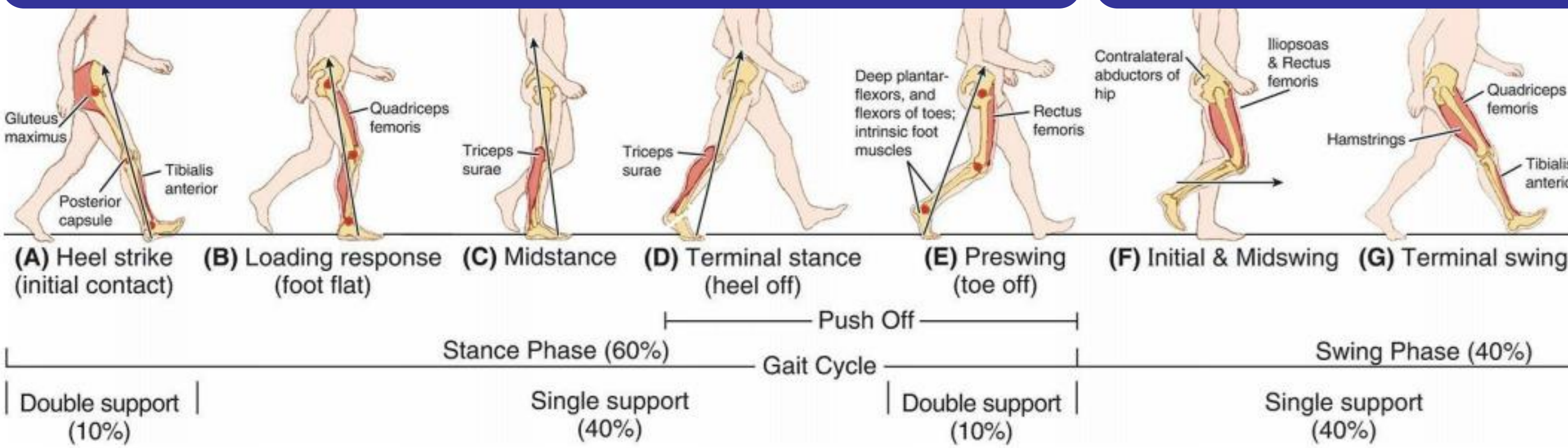


Figure 5 – EMG pattern associated with the adult gait cycle. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern – Stance phase

Activation of gluteus maximus

Eccentric activation of tibials anterior

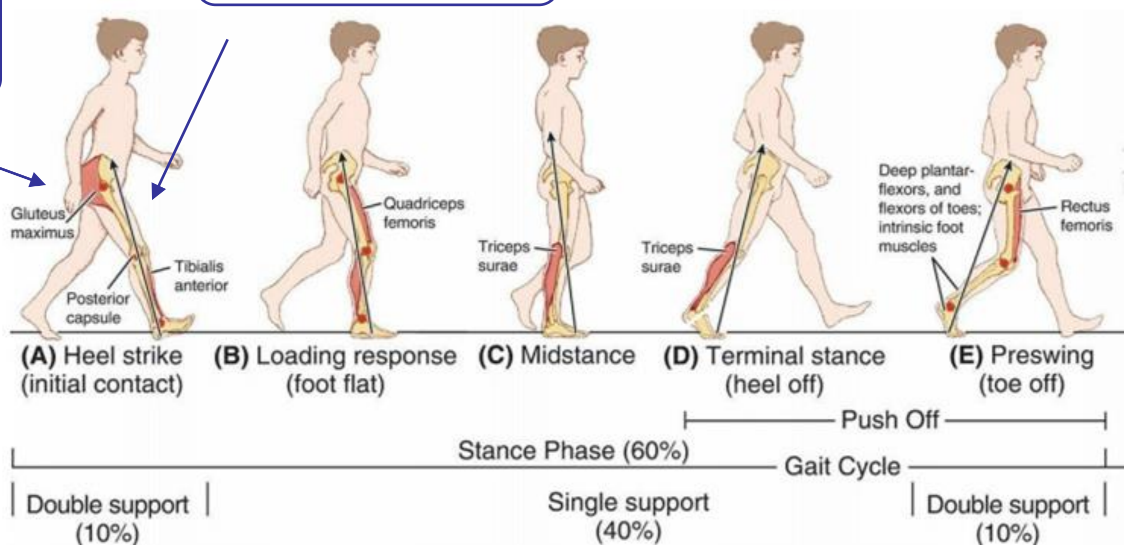


Figure 6 – EMG pattern associated with the adult gait cycle in the stance phase. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern – Stance phase

Activation of extensor muscles

Eccentric activation of quadriceps

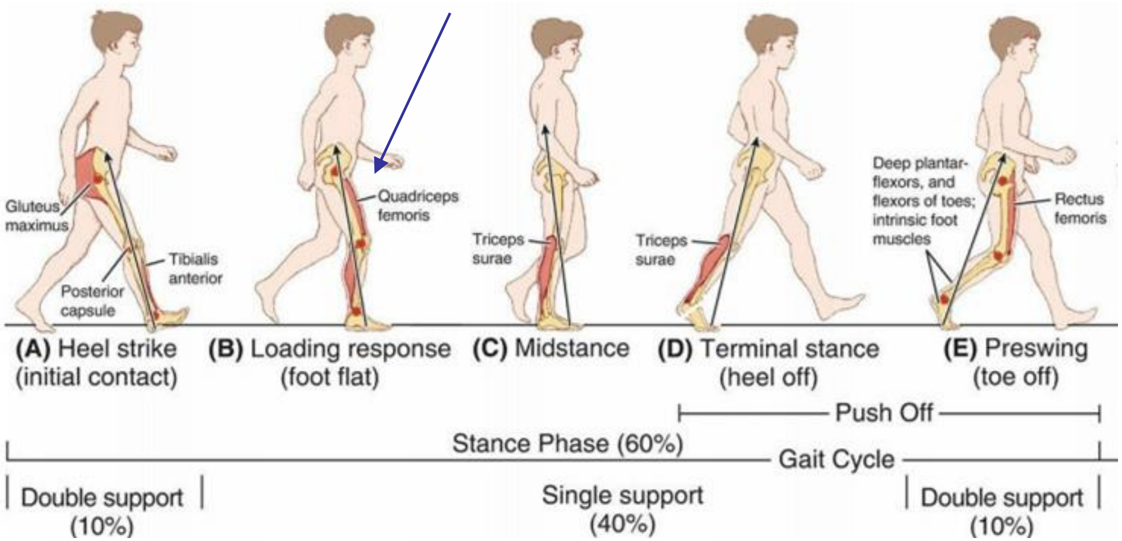


Figure 6 – EMG pattern associated with the adult gait cycle in the stance phase. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern – Stance phase

Activation of triceps surae only

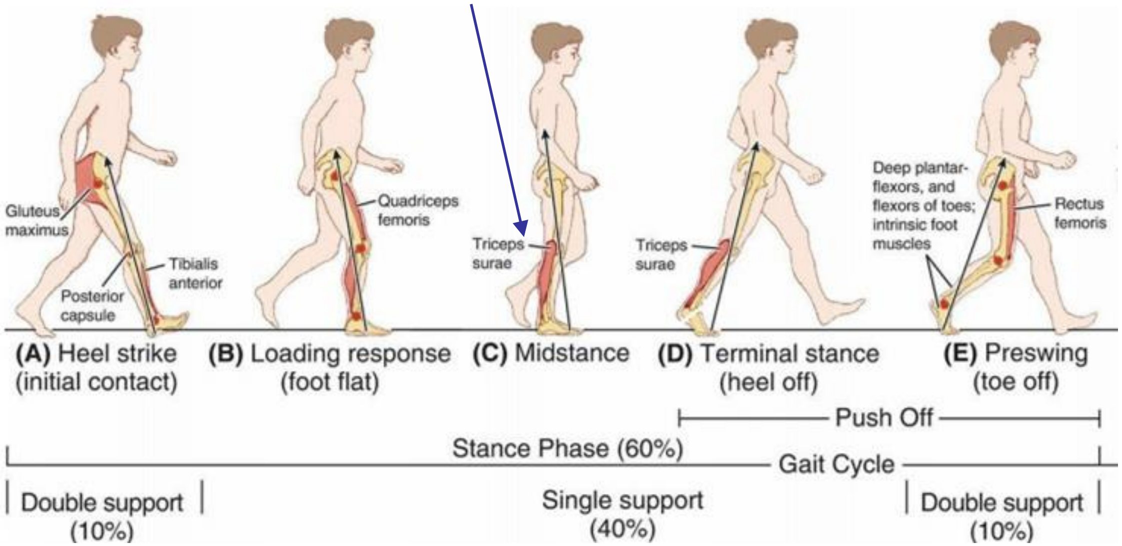


Figure 6 – EMG pattern associated with the adult gait cycle in the stance phase. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern – Stance phase

1º concentric contraction of the plantar-flexors + Assistance of the hip flexors during pre-swing

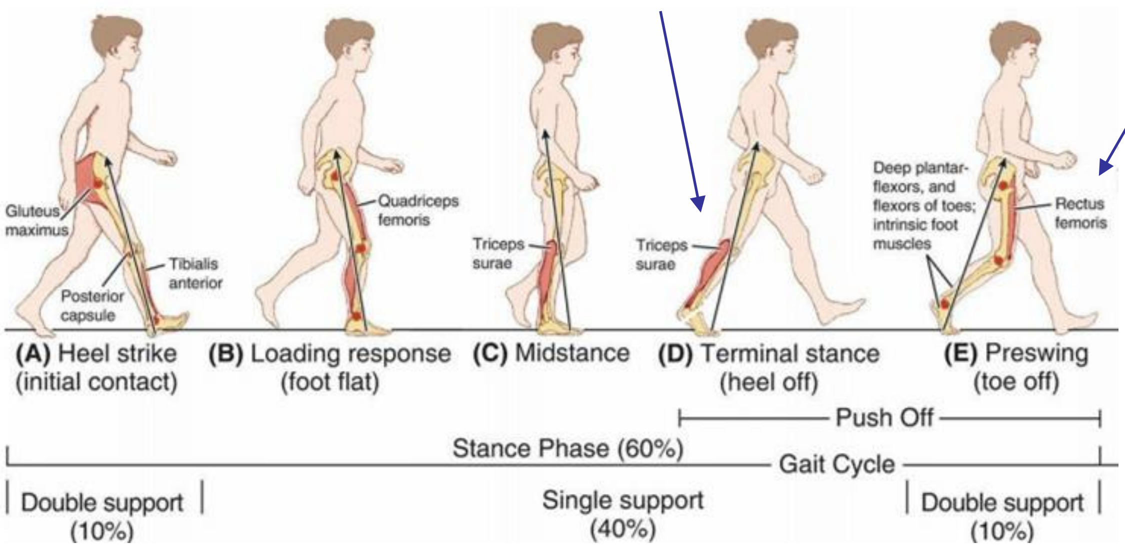


Figure 6 – EMG pattern associated with the adult gait cycle in the stance phase. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Electromyographic pattern – Swing phase

Hip flexors activity

Biceps femoris assist

Hamstring active

Quadriceps muscles accomplished flexion hip

Activation pretibial muscles for ankle dorsiflexion

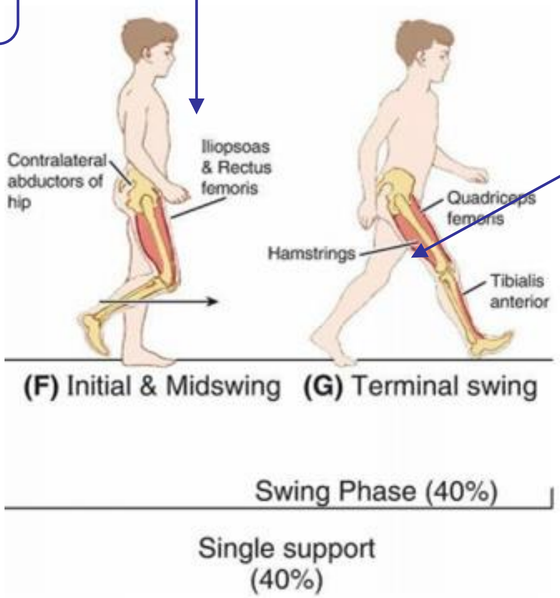


Figure 7 – EMG pattern associated with the adult gait cycle in the swing phase. Image from Shumway-Cook A. and Woollacott M. 2017

VII. ELECTROMYOGRAPHIC ASSESSMENT OF NORMAL GAIT

Age and sex differences

Authors	Age differences	Sex differences	Muscles
Bailey C. et al. 2019	yes	yes	EMG cycle-to-cycle variability, rectus femoris, gastrocnemius lateralis
Bailey C. et al. 2018	yes	yes	EMG within-cycle coefficient of variation, rectus femoris, gastrocnemius lateralis
Kwee-Meier S. et al. 2018	yes	-	Gastrocnemius medialis, m. soleus
Ribeiro N. et al. 2016	yes	-	Internal oblique, rectus femoris
Di Nardo F. et al. 2015	-	yes	tibialis anterior, gastrocnemius lateralis, vastus lateralis
Chung M. et al. 2010	yes	yes	tibialis anterior, rectus femoris

Figure 8 – Results from several studies on electromyography activity during gait between age and sex groups.

D.2 How is a normal biomechanical assessment of gait?

VIII. Key ideas

VIII. KEY IDEAS

1. In healthy subjects' walking, the parameters extracted from the biomechanical assessment may be influenced by the anthropometric characteristics of the assessed person. Walking speed and stride length will be influenced by the size of the subject and the length of the lower limbs. On ground reaction forces values, the subject's weight will influence the findings. This is why, is a better option to present the normality values normalized by the anthropometric characteristic of the subject.

2. Just as the anthropometric data influence the gait results of healthy subjects, age and gender also influence these outcomes. In summary, gender differences begin to stand out after adolescence and age causes us to walk slower, with less lower limb kinematics and exerting greater pressure under the foot.

VIII. KEY IDEAS

3. In gait evaluation of healthy subjects with biomechanical instruments, it is not represented by a single normality value, but by a range of data, where the performance of the subjects is normal. In any case, the conditions of the assessment that aims to characterize normal gait pattern can be diverse, due to we do not always walk in fixed conditions. For this reason, studies on this matter not only analyze walking at a comfortable speed, but also at slow and fast speeds.

D.2 How is a normal biomechanical assessment of gait?

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