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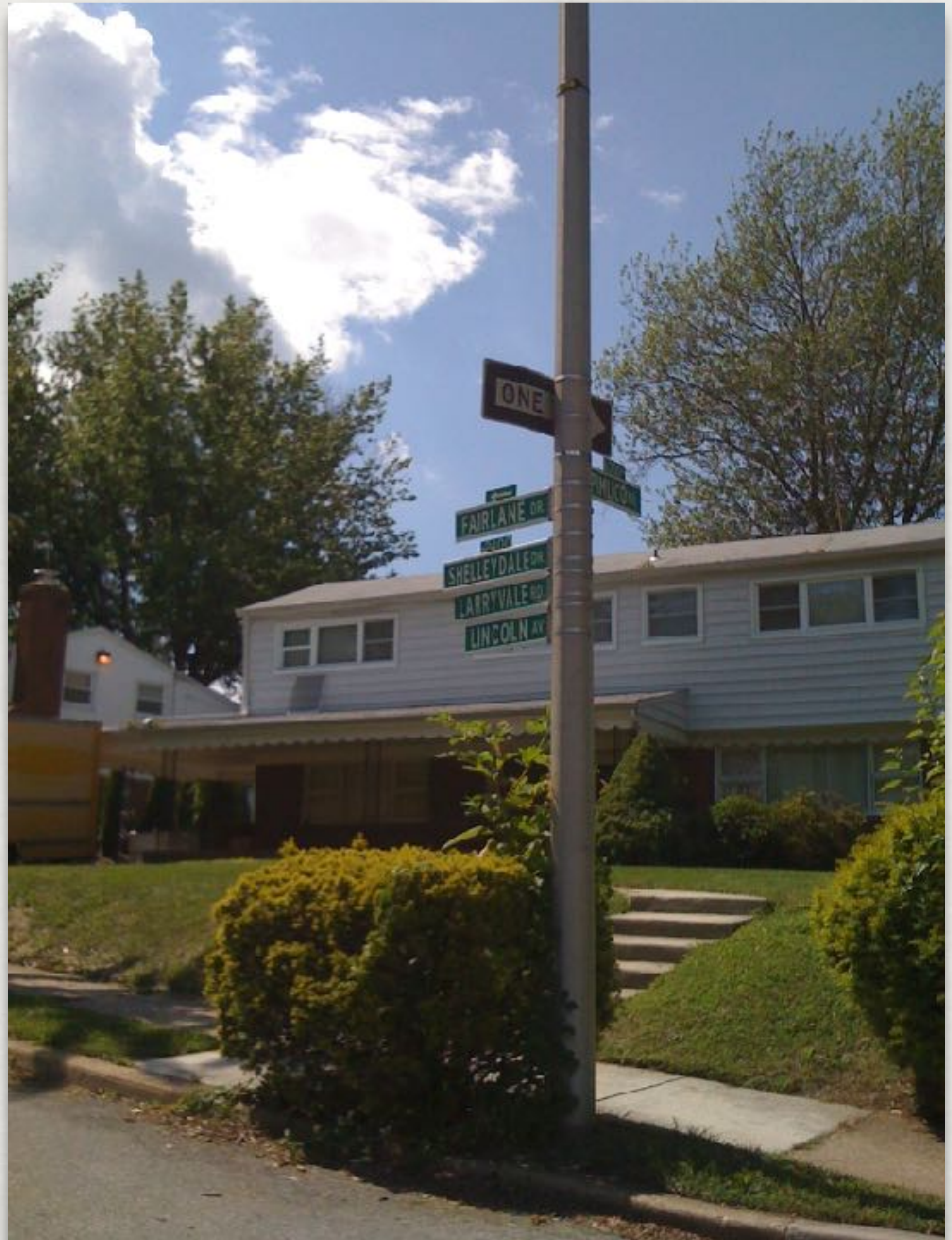
GAIT ANALYSIS

OUTLINE

- Normal Gait
  - Phases of Gait
    - Swing
    - Stance
- Gait Evaluation
- Evidence of Gait Analysis


ONE
FAIRLANE DR.
SHELLEYDALE DR.
LARRYVALE RD
LINCOLN AV

A FEW DEFINITIONS...

- cadence - number of steps per minute
  - average 80 -120
  - linear relationship with stride length
- stride length - distance between two consecutive contacts of the same foot
- step - period from heel contact of one limb to heel contact of the opposite limb
- base of gait - horizontal distance from one heel strike to the next heel strike
  - average 3.5 inches
- angle of gait - bisecting center of the heel and first interspace in the sagittal plane
  - 7 degrees per foot = 12 - 15 degrees total

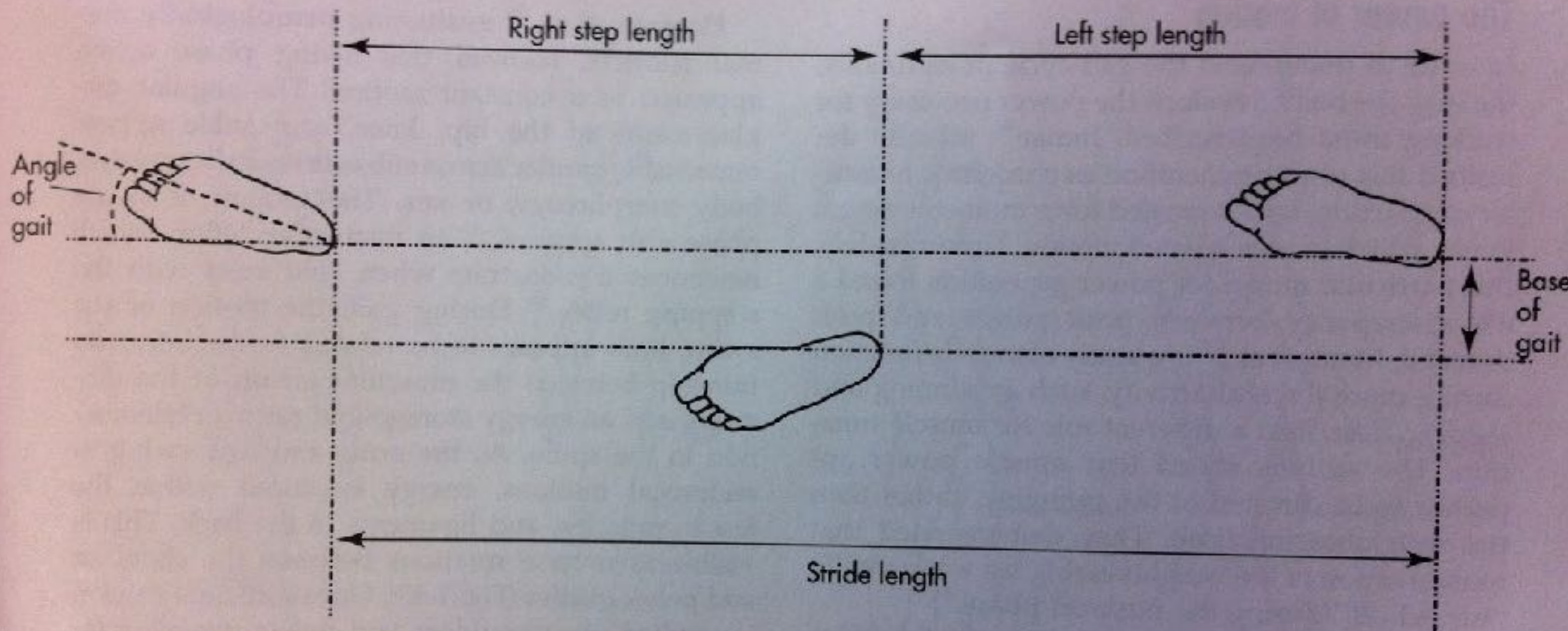


Fig. 1-41. Subdivision of stride length, step length, angle, and base of gait.

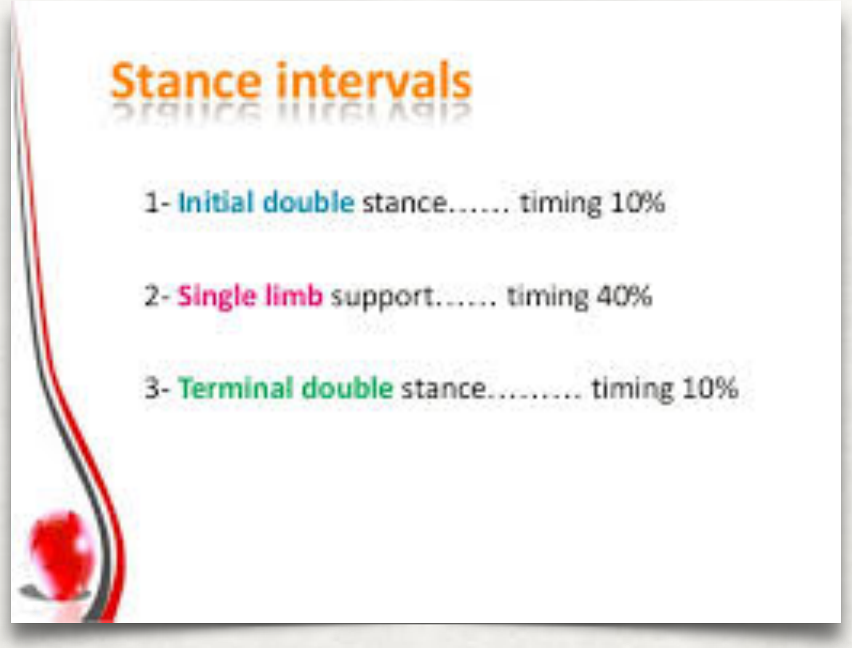
side heel-strike. Therefore, single limb support is identical to the period of swing of the opposite limb and so is responsible for support of the entire body. The duration of single limb stance is often a measure of an individual's capability to stabilize and support the body.

consists of two steps, usually of equal length (Fig. 1-41).

In pathologic gait, it is possible for the step lengths to be unequal. That is, if one foot is moved forward and the other is brought up to it but does not advance in front of it, it is considered a 0 step

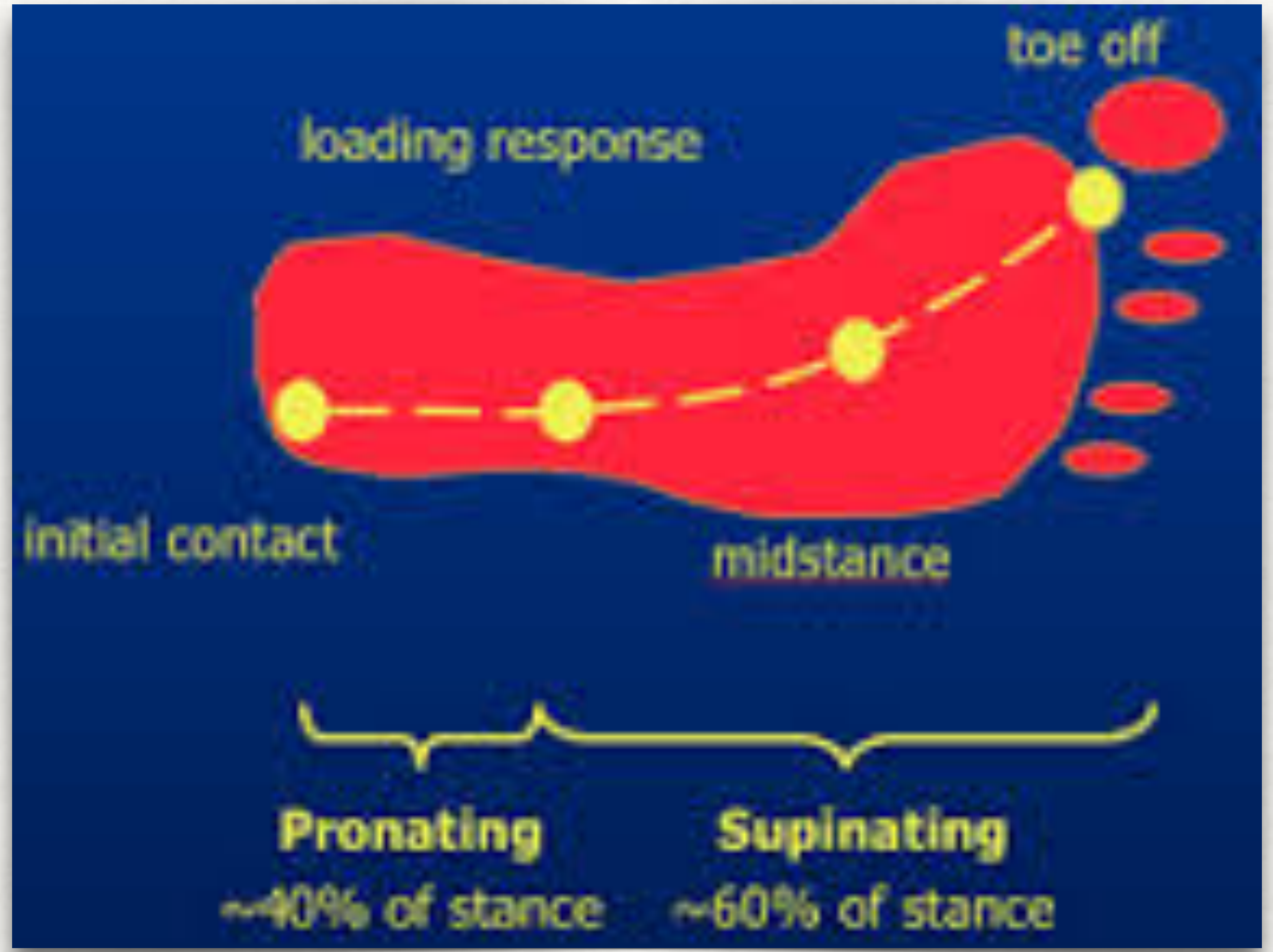
A FEW DEFINITIONS…

- double limb support - both feet are on the floor at the same time
    - initial - heel contact opposite limb
    - terminal - toe off of the other limb
- single limb support - single stance, initiated by opposite foot toe off and terminates with opposite side heel strike



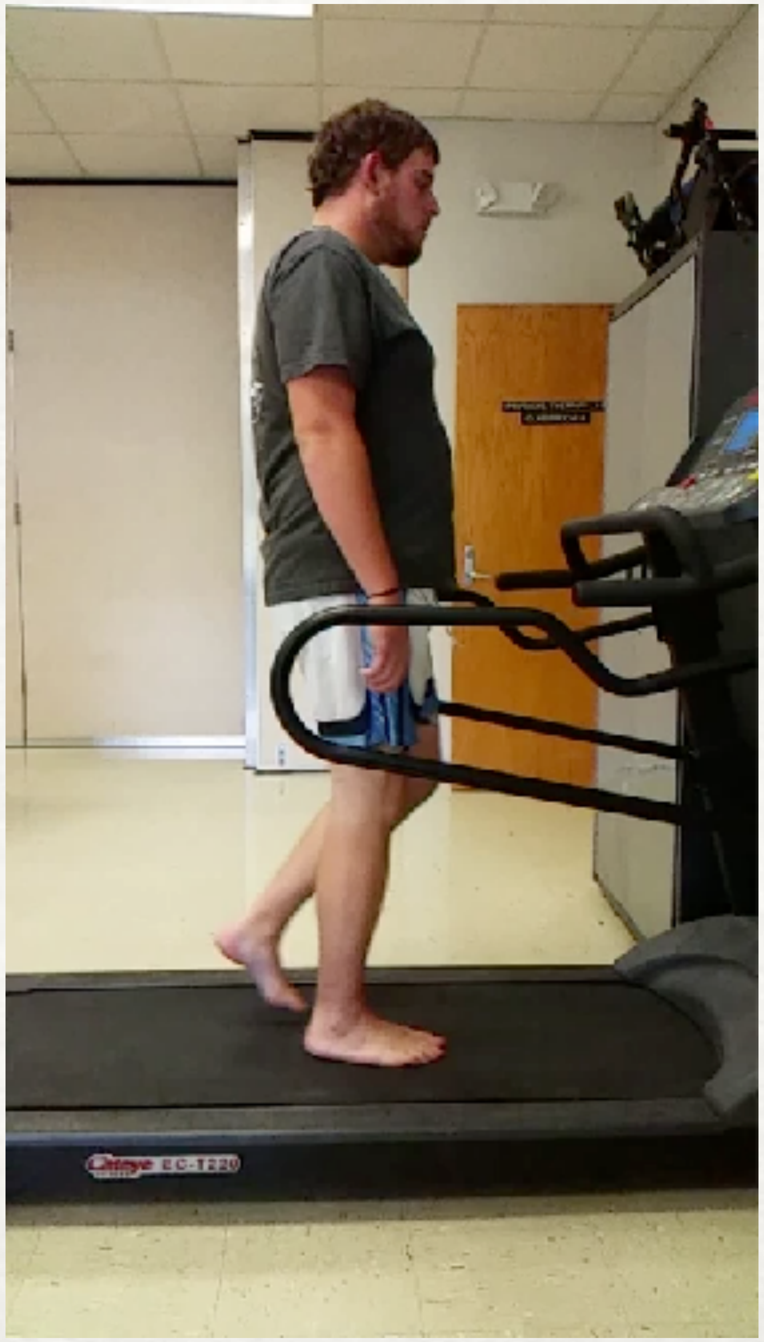
PHASES OF THE GAIT CYCLE

- **Stance (60%)**
  - Contact
  - Midstance
  - Active Propulsion
  - Passive Lift Off
- **Swing (40%)**



OVERVIEW

- It may seem elementary, but our gait prevents us from falling…it essentially is controlling energy transfer



OVERVIEW

- Energy Transfer
  - Vertical displacement of the pelvis during stance allows for the exchange of energy
  - Heel rocker - Ankle rocker - Forefoot Rocker

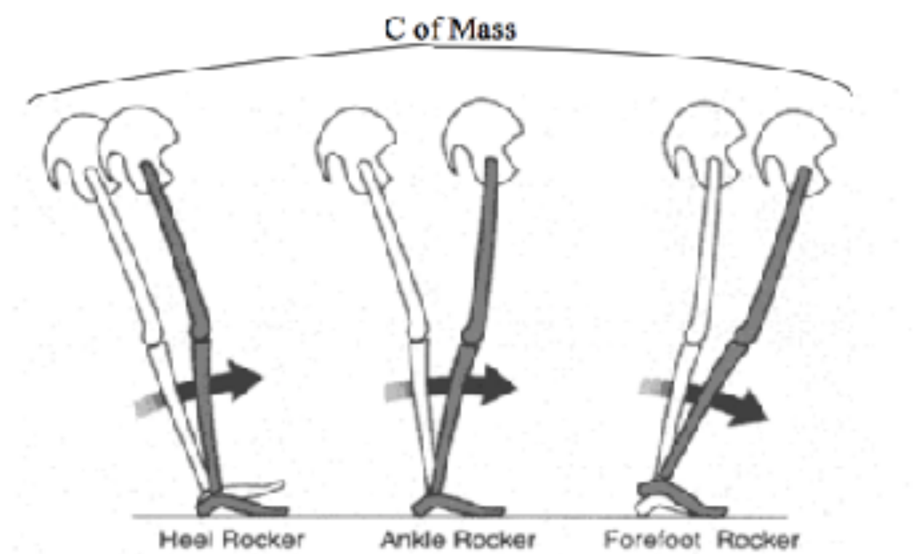


Figure 3.19 Progression (arrow) over the supporting foot is assisted by the actions of three functional rockers: (1) heel rocker, (2) ankle rocker, (3) forefoot rocker.

Diagram from Perry, J., "Normal and Pathological Gait, Disorders of the Foot Churchill and Livingstone, 1985.

HOW MUCH ENERGY?

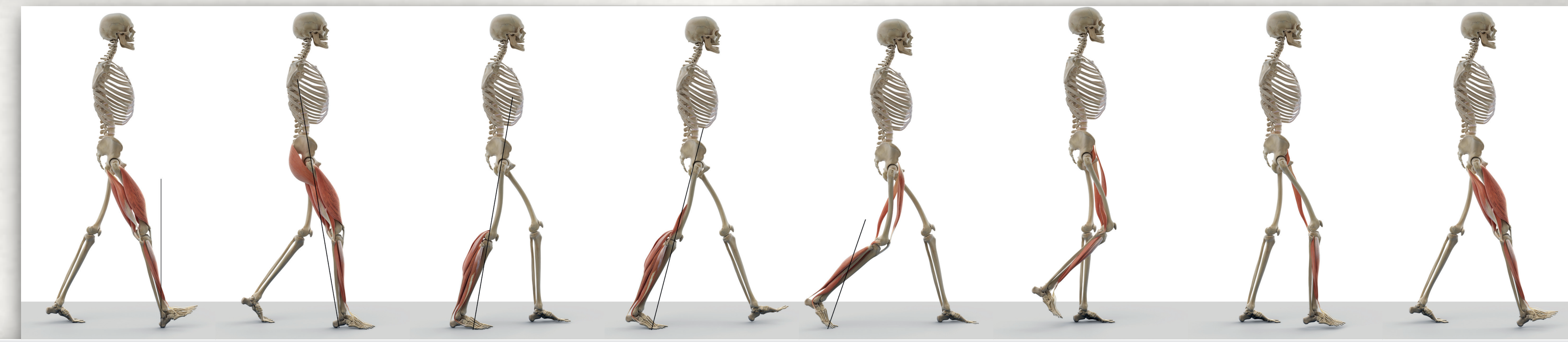
	Peak force (N)
Adductor brevis	303
Adductor longus	400
Adductor magnus	1297
Biceps femoris long head	705
Biceps femoris short head	316
Extensor digitorum longus	345
Extensor hallucis longus	165
Flexor digitorum longus	274
Flexor hallucis longus	437
Gastrocnemius	1914
Gluteus maximus	1852
Gluteus medius	2199
Gluteus minimus	585
Gracilis	137
Iliacus	622
Peroneus brevis	306
Peroneus longus	653
Psoas	480
Rectus femoris	849
Sartorius	114
Semimembranosus	1163
Semitendinosus	301
Soleus	3586
Tensor fascia lataee	155
Tibials anterior	674
Tibialis posterior	906
Vastus intermedius	1024
Vastus lateralis	2255
Vastus medialis	1444

Adapted from data contained in: Arnold, E. M., Ward, S. R., Lieber, R. L., & Delp, S. L. (2010). A model of the lower limb for analysis of human movement. Annals of Biomedical Engineering, 38(2), 269–279.

ITS ALL ABOUT THE MUSCLES

Streifeneder
ortho production

The eight phases of human gait cycle



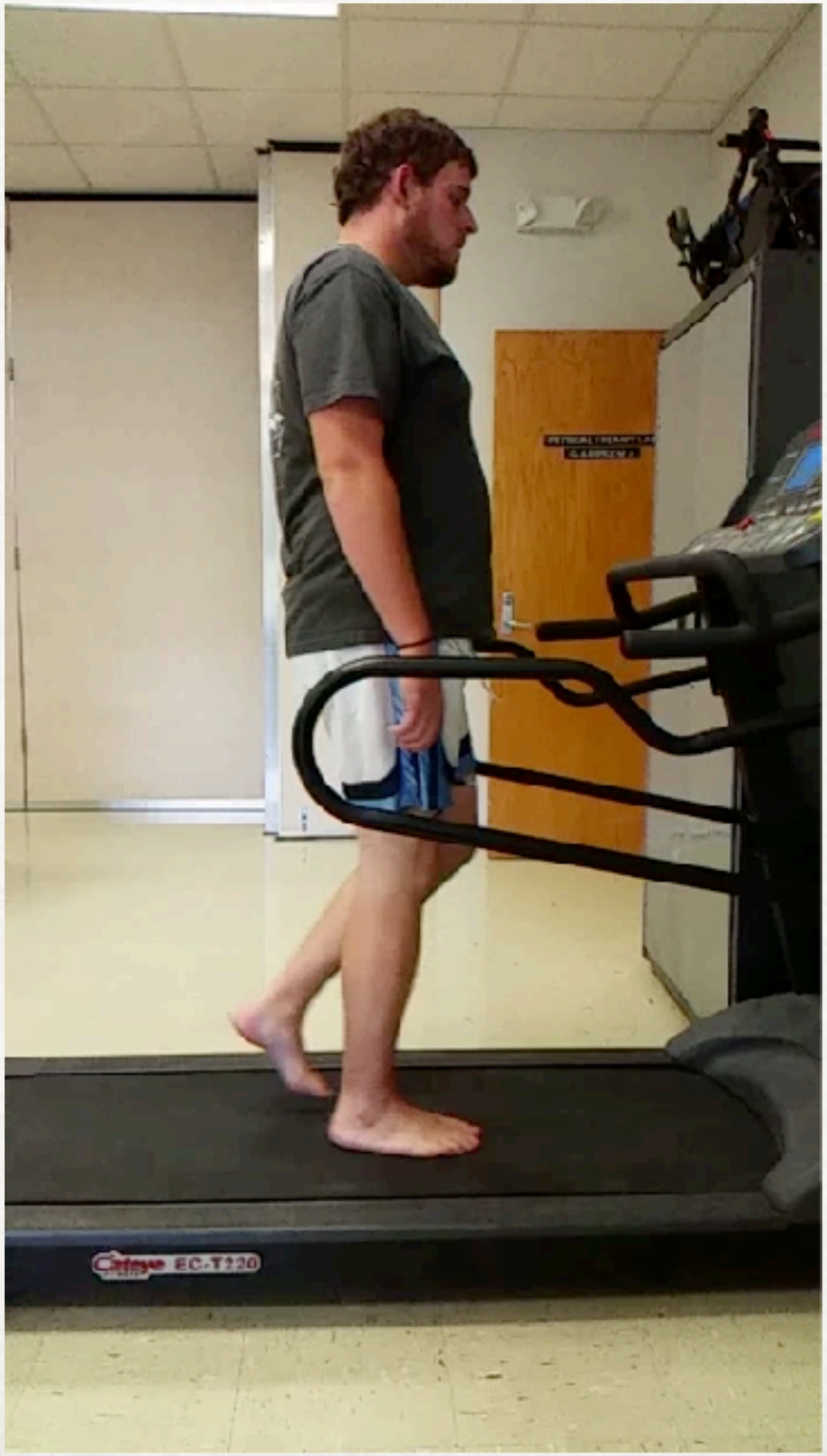
Gait phases	IC Initial Contact	LR Loading Response	MST Mid Stance	TST Terminal Stance	PSW Pre Swing	ISW Initial Swing	MSW Mid Swing	TSW Terminal Swing
Gait cycle	0 %	0 – 12 %	12 – 31 %	31 – 50 %	50 – 62 %	62 – 75 %	75 – 87 %	87 – 100 %
Hip	20° flexion	20° flexion	0° flexion	-20° hyperextension	-10° hyperextension	15° flexion	25° flexion	20° flexion
Knee	0° – 5° flexion	20° flexion	0° – 5° flexion	0° – 5° flexion	40° flexion	60° – 70° flexion	25° flexion	0° – 5° flexion
Ankle joint	0°	5° – 10° plantar flexion	5° dorsal flexion	10° dorsal flexion	15° plantar flexion	5° plantar flexion	0°	0°
Muscle activity	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus Ischiocrurale Muskulatur	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus M. adductor Magnus M. tensor fascia latae M. tibialis posterior M. peroneus longus	M. gastrocnemius M. soleus	M. soleus M. gastrocnemius M. flexor digitorum longus M. flexor hallucis longus M. tibialis posterior M. peroneus longus M. peroneus brevis	M. soleus M. gastrocnemius M. rectus femoris M. adductor longus	M. extensor hallucis longus M. flexor hallucis longus M. sartorius M. iliacus M. tibialis anterior	M. semimembranosus M. semitendinosus M. biceps femoris M. tibialis anterior	M. quadriceps femoris M. semitendinosus M. semimembranosus M. biceps femoris M. tibialis anterior
Functions	• heel contact to the ground	• shock absorption in knee and ankle joint • load transmission and stability in the hip • forward motion by heel rocker	• controlled forward motion of the tibia • shifting of the gravity centre to the front by ankle rocker	• controlled dorsal extension at the ankle joint with lifting the heel from the ground	• passive knee joint flexion of 40° • plantar flexion of the ankle joint	• min. 55° knee flexion for sufficient ground clearance	• increasing hip flexion to 25° • dorsal extension of the ankle joint to neutral-zero-position	• knee joint extension to neutral-flexion • preparation for stance phase

PRO.vision TWIN, 2D and 3D – innovative systems for video-based gait analysis
For further information see: www.streifeneder.com/op

VISUAL CUES FOR THE GAIT EXAM

- Evaluate head position
- Shoulder position
- Hip Position
- Knee alignment
- Ankle alignment
- Angle of gait and foot position
- Foot characteristics
- Limb Length Discrepancy

LET'S BREAK THIS DOWN

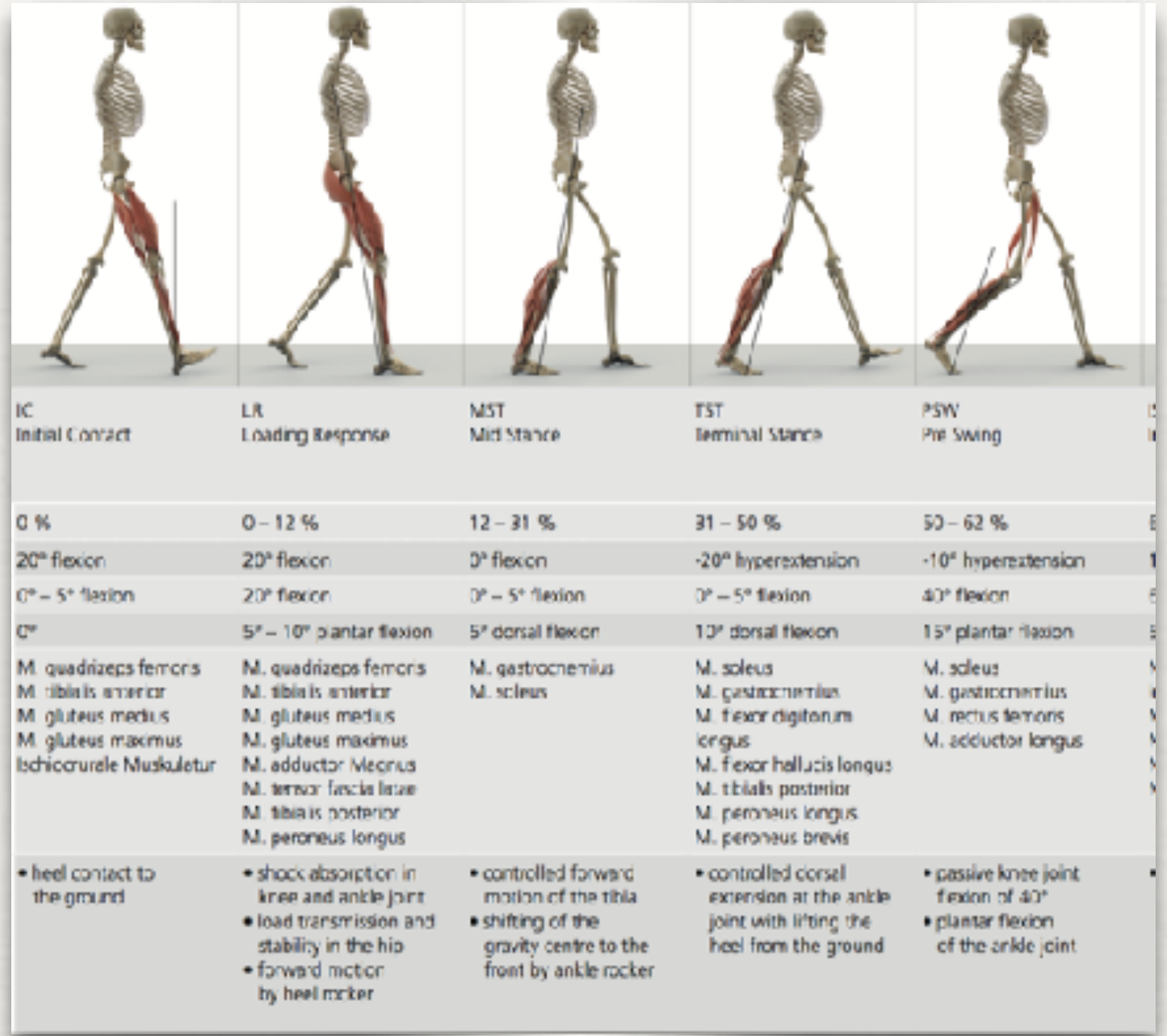


PHASES OF GAIT - PART 1

- Stance phase
  - Period of time that the foot is on the ground;
  - 60% of the gait cycle is spent in the stance phase
  - Single support of the leg during stance
  - WE WILL WATCH THE RIGHT LEG

STANCE PHASE (60%)

- Four components
  - Initial contact
  - Midstance
  - Terminal stance
  - Pre-swing/Passive heel lift

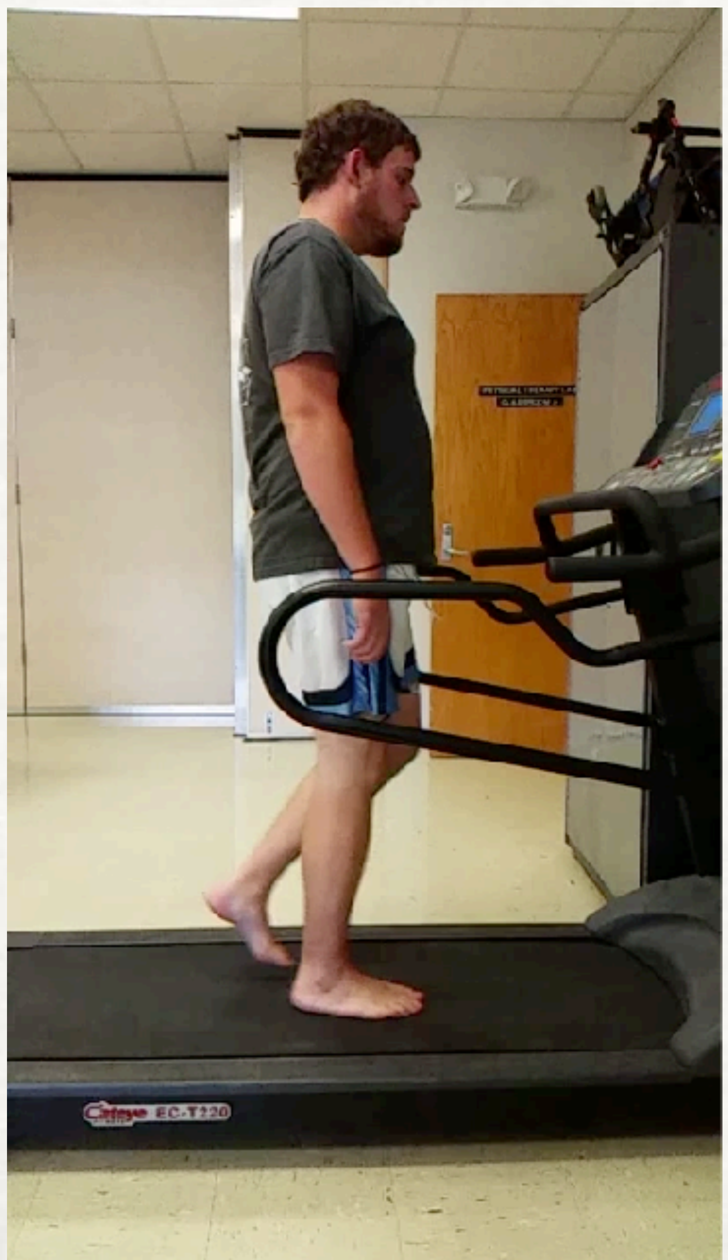


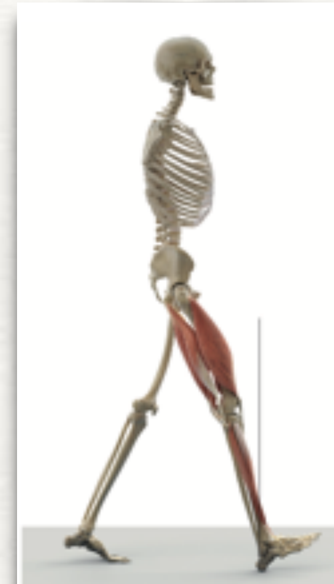
IC Initial Contact	LR Loading Response	MST Mid Stance	TST Terminal Stance	PSW Pre Swing
0 %	0 – 12 %	12 – 31 %	31 – 50 %	50 – 62 %
20° flexion	20° flexion	0° flexion	-20° hyperextension	-10° hyperextension
0° – 5° flexion	20° flexion	0° – 5° flexion	0° – 5° flexion	40° flexion
0°	5° – 10° plantar flexion	5° dorsal flexion	10° dorsal flexion	15° plantar flexion
M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus Ischiocrurale Muskulatur	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus M. adductor Megnus M. tensor fascia latae M. tibialis posterior M. peroneus longus	M. gastrocnemius M. soleus	M. soleus M. gastrocnemius M. flexor digitorum longus M. flexor hallucis longus M. tibialis posterior M. peroneus longus M. peroneus brevis	M. soleus M. gastrocnemius M. rectus femoris M. adductor longus
• heel contact to the ground	• shock absorption in knee and ankle joint • load transmission and stability in the hip • forward motion by heel rocker	• controlled forward motion of the tibia • shifting of the gravity centre to the front by ankle rocker	• controlled dorsal extension at the ankle joint with lifting the heel from the ground	• passive knee joint flexion of 40° • plantar flexion of the ankle joint

Gait phases	IC Initial Contact	LR Loading Response	MST Mid Stance	TST Terminal Stance	PSW Pre Swing	I I
Gait cycle	0 %	0 – 12 %	12 – 31 %	31 – 50 %	50 – 62 %	6
Hip	20° flexion	20° flexion	0° flexion	-20° hyperextension	-10° hyperextension	1
Knee	0° – 5° flexion	20° flexion	0° – 5° flexion	0° – 5° flexion	40° flexion	6
Ankle joint	0°	5° – 10° plantar flexion	5° dorsal flexion	10° dorsal flexion	15° plantar flexion	5
Muscle activity	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus Ischiocrurale Muskulatur	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus M. adductor Magnus M. tensor fascia latae M. tibialis posterior M. peroneus longus	M. gastrocnemius M. soleus	M. soleus M. gastrocnemius M. flexor digitorum longus M. flexor hallucis longus M. tibialis posterior M. peroneus longus M. peroneus brevis	M. soleus M. gastrocnemius M. rectus femoris M. adductor longus	N I N N N N
Functions	• heel contact to the ground	• shock absorption in knee and ankle joint • load transmission and stability in the hip • forward motion by heel rocker	• controlled forward motion of the tibia • shifting of the gravity centre to the front by ankle rocker	• controlled dorsal extension at the ankle joint with lifting the heel from the ground	• passive knee joint flexion of 40° • plantar flexion of the ankle joint	•

STANCE PHASE

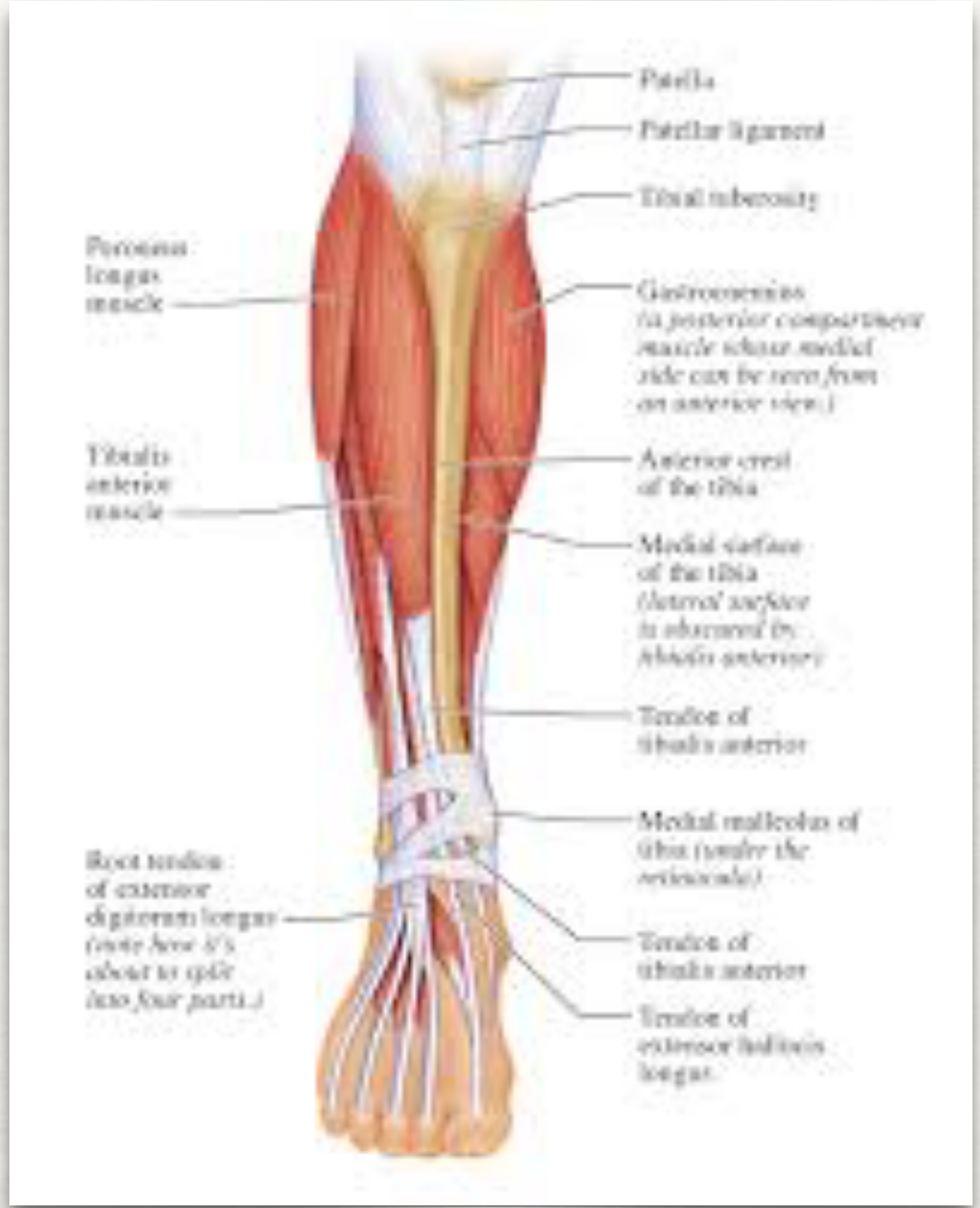
- **Initial contact**
- Video





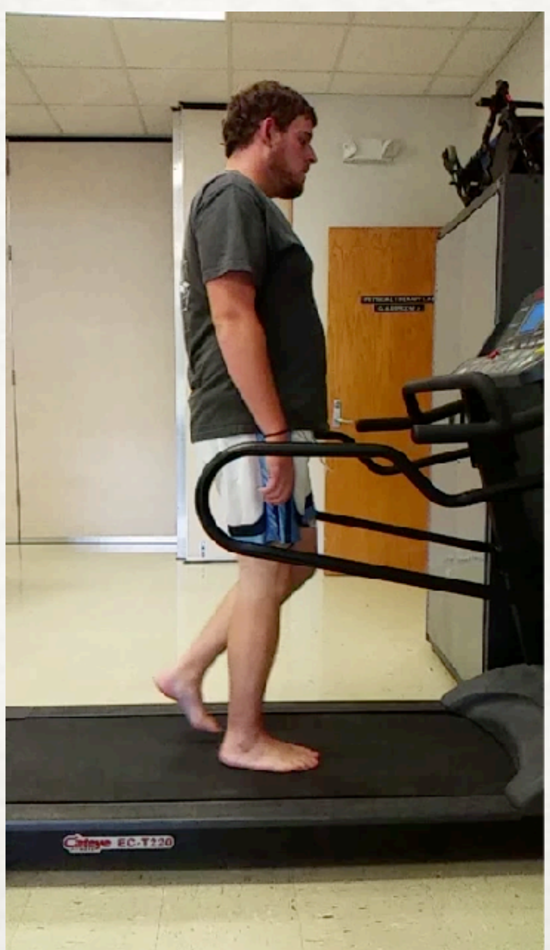
Gait phases	IC Initial Contact
Gait cycle	0 %
Hip	20° flexion
Knee	0° – 5° flexion
Ankle joint	0°
Muscle activity	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus Ischiocrurale Muskulatur
Functions	• heel contact to the ground

TIBIALIS ANTERIOR M.

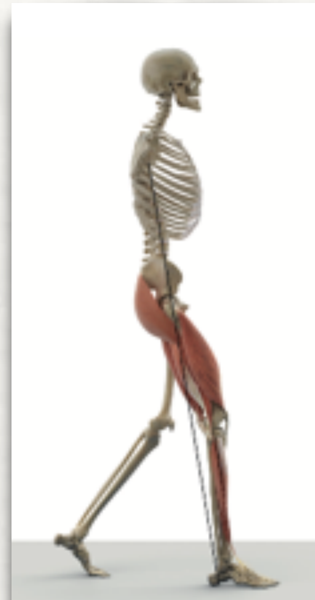


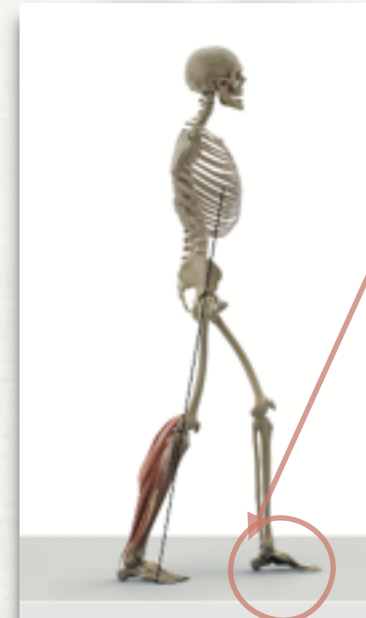
STANCE PHASE

- **Midstance**
- Energy transfer
- Look at hip position



Improper foot position





LR Loading Response	Gait phases	MST Mid Stance
0 – 12 %	Gait cycle	12 – 31 %
20° flexion	Hip	0° flexion
20° flexion	Knee	0° – 5° flexion
5° – 10° plantar flexion	Ankle joint	5° dorsal flexion
M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus M. adductor Magnus M. tensor fascia latae M. tibialis posterior M. peroneus longus	Muscle activity	M. gastrocnemius M. soleus
• shock absorption in knee and ankle joint • load transmission and stability in the hip • forward motion by heel rocker	Functions	• controlled forward motion of the tibia • shifting of the gravity centre to the front by ankle rocker

Late mid stance

OVERVIEW

- Energy Transfer
  - Vertical displacement of the pelvis during stance allows for the exchange from kinetic energy to potential energy
  - Potential energy (stored) for heel lift

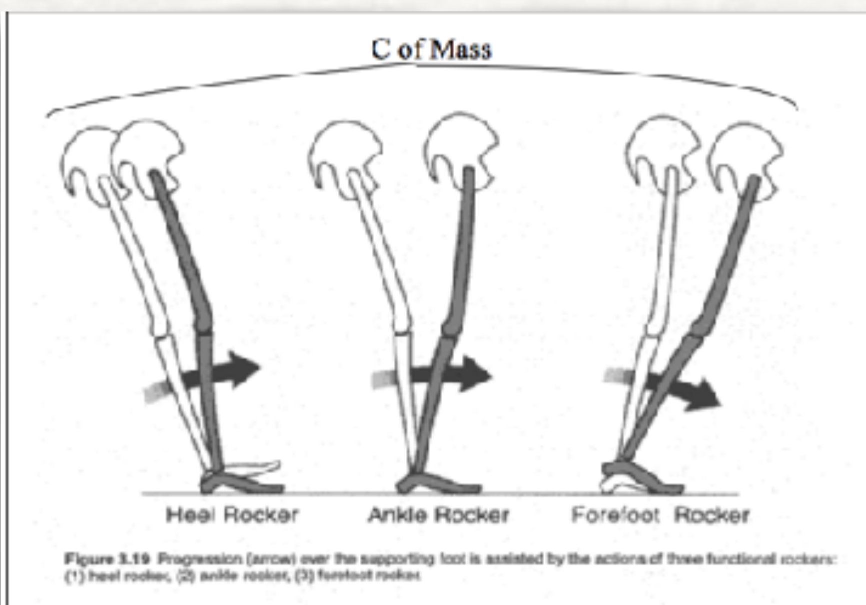
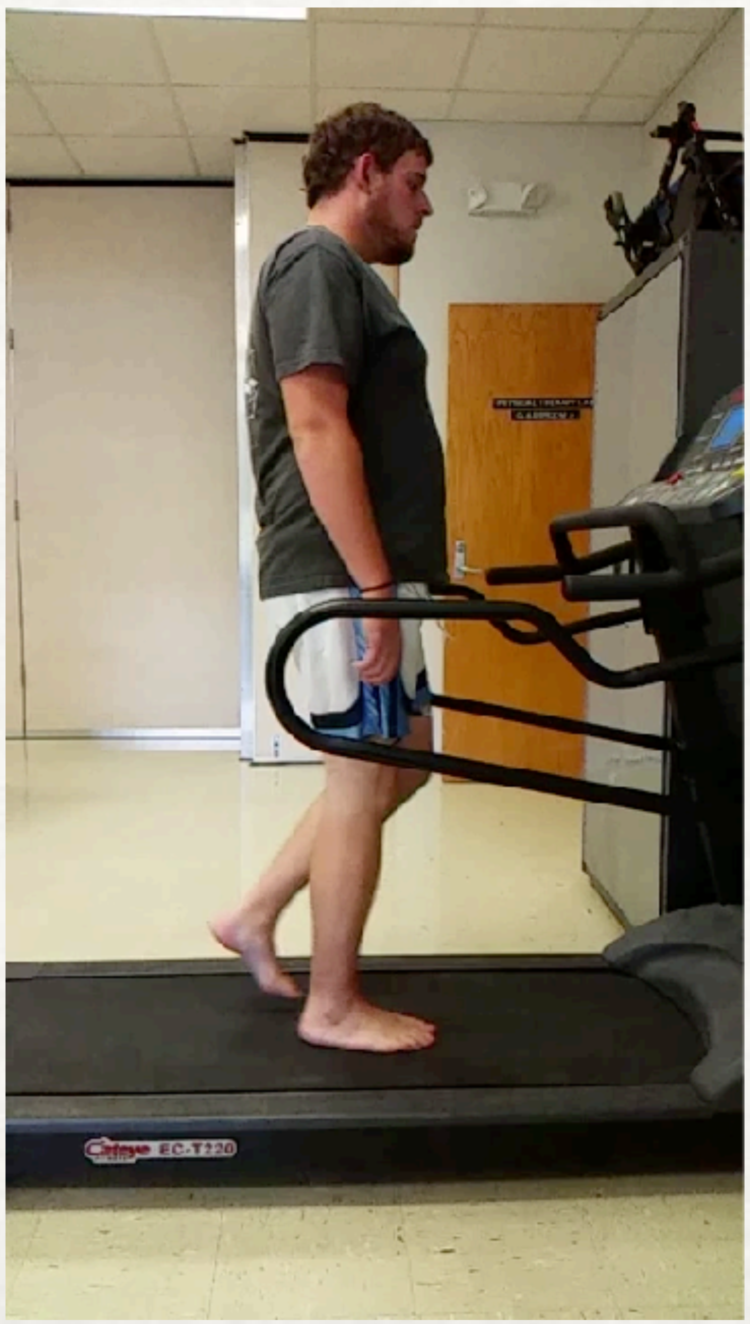
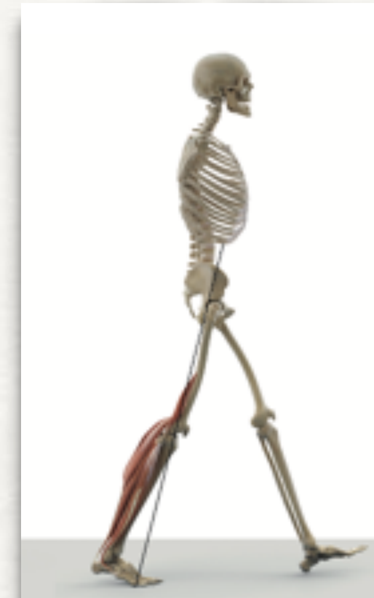


Diagram from Perry, J., "Normal and Pathological Gait, Disorders of the Foot Churchill and Livingstone, 1985.

STANCE PHASE

- **Terminal stance**





Gait phases	TST Terminal Stance
Gait cycle	31 – 50 %
Hip	-20° hyperextension
Knee	0° – 5° flexion
Ankle joint	10° dorsal flexion
Muscle activity	M. soleus M. gastrocnemius M. flexor digitorum longus M. flexor hallucis longus M. tibialis posterior M. peroneus longus M. peroneus brevis
Functions	• controlled dorsal extension at the ankle joint with lifting the heel from the ground

GASTROCSOLEUS M.

DONEC QUIS NUNC

WHAT DOES THIS NEWTON STUFF MEAN?

- 1 Newton = 0.22489 lbs
- So if the soleal muscles has 3500 N of force then that equates to 786 lbs of force.
- That equates to about three-fourths as heavy as a Grand Piano.

HOW MUCH ENERGY?

Muscle	Peak force (N)
Adductor brevis	303
Adductor longus	400
Adductor magnus	1297
Biceps femoris long head	705
Biceps femoris short head	316
Extensor digitorum longus	345
Extensor hallucis longus	165
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Rectus femoris	849
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Soleus	3586
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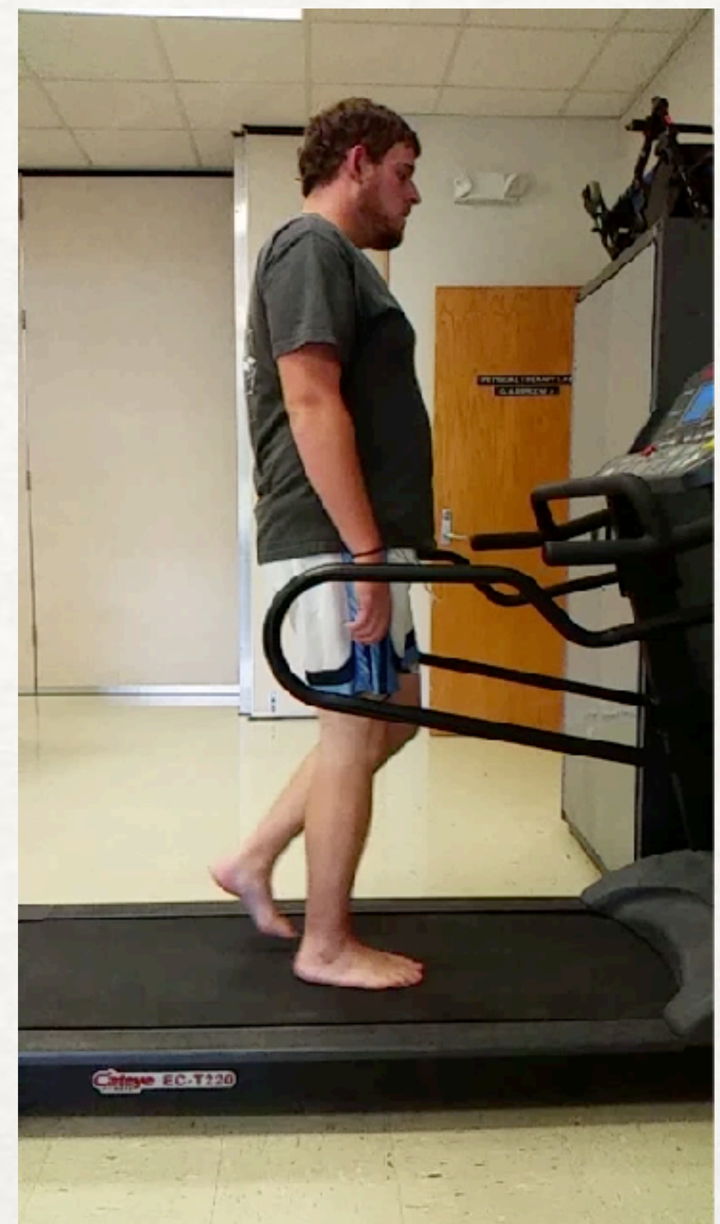
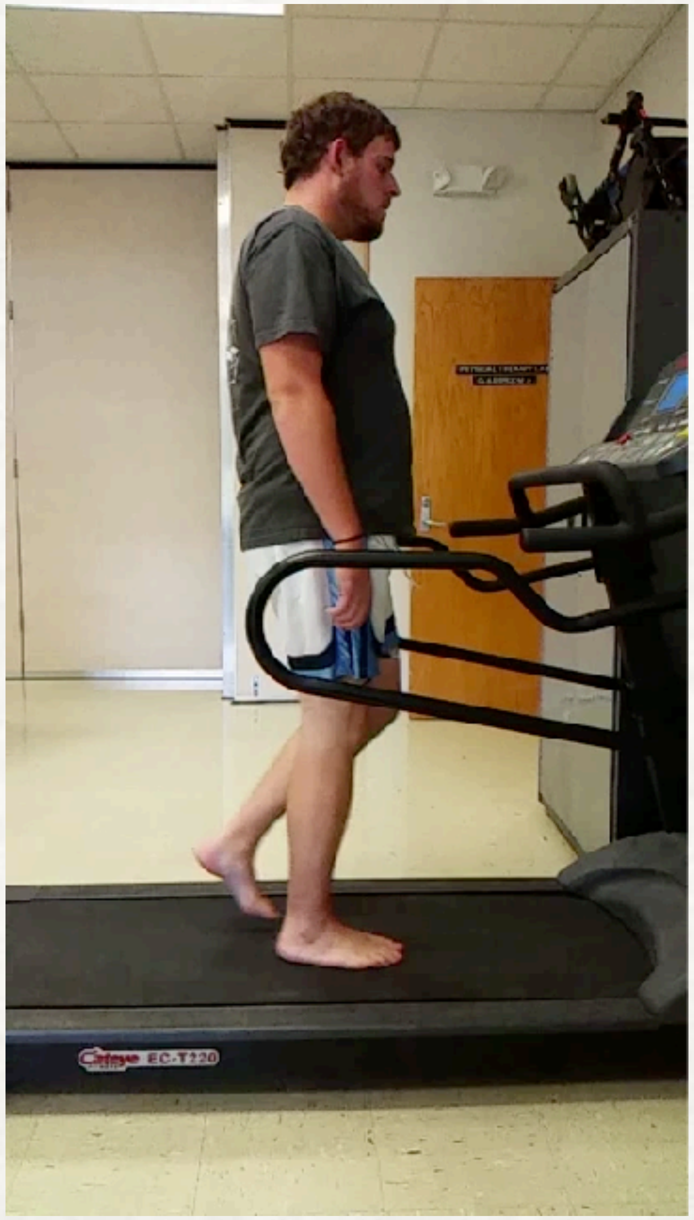
PHASES OF GAIT - PART 2

- **Swing phase**
  - Period of time the foot is off the ground moving forward
  - 40% time of the gait cycle
  - Has three phases
    - Initial(toe off)
    - Midswing(swing)
    - Terminal



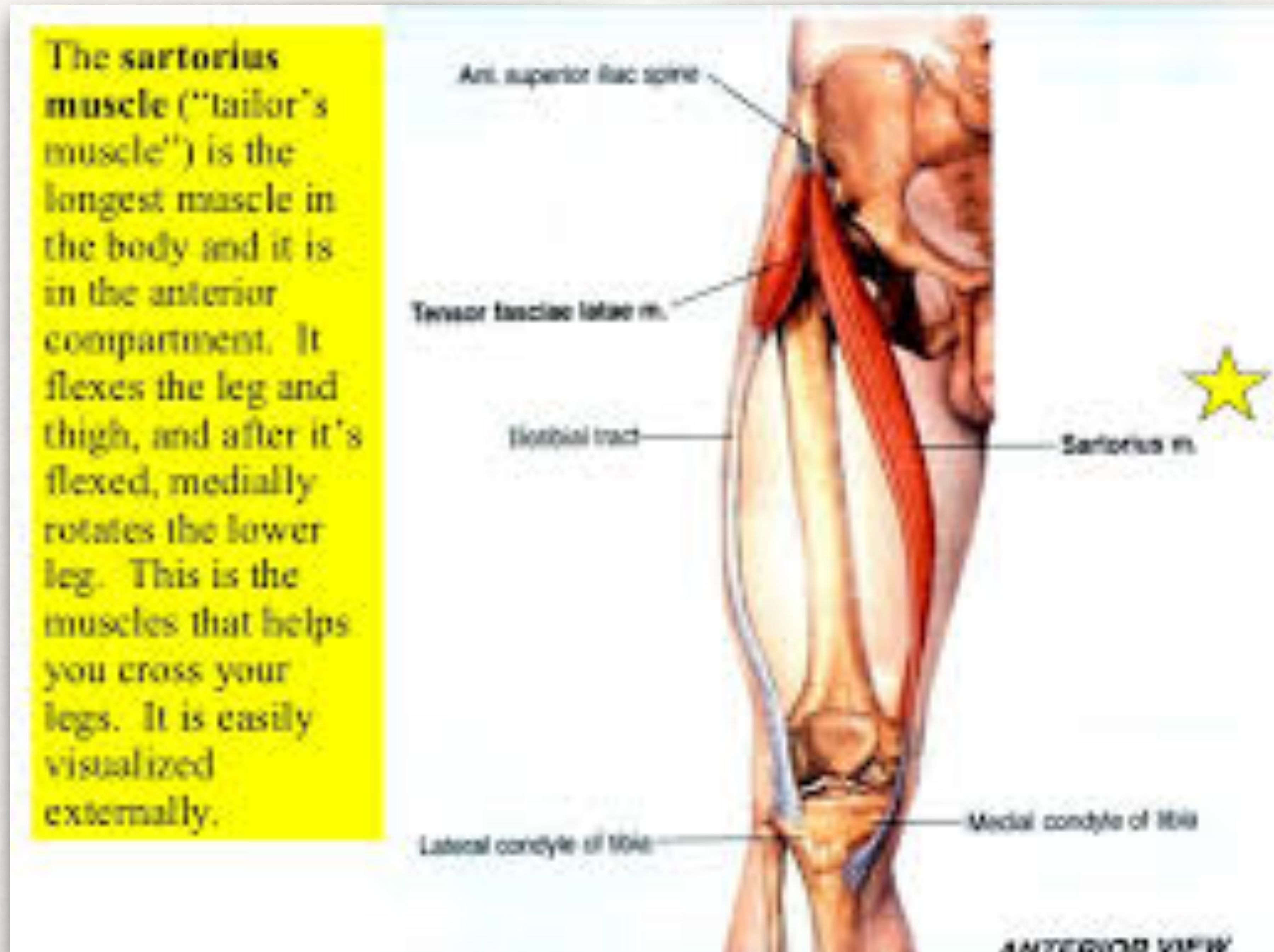
SWING PHASE

- **Initial Swing**



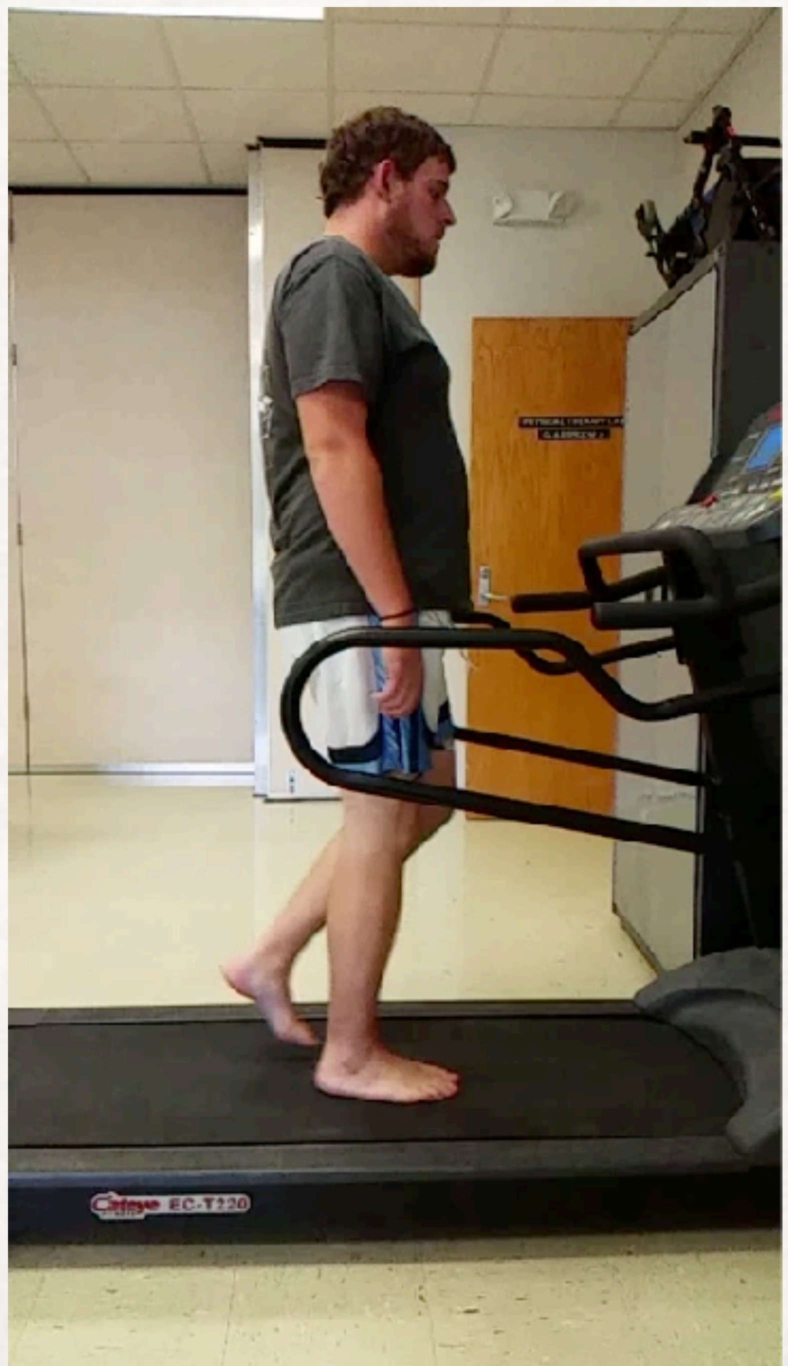
Gait phases	ISW Initial Swing
Gait cycle	62 – 75 %
Hip	15° flexion
Knee	60° – 70° flexion
Ankle joint	5° plantar flexion
Muscle activity	M. extensor hallucis longus M. flexor hallucis longus M. sartorius M. iliacus M. tibialis anterior
Functions	• min. 55° knee flexion for sufficient ground clearance

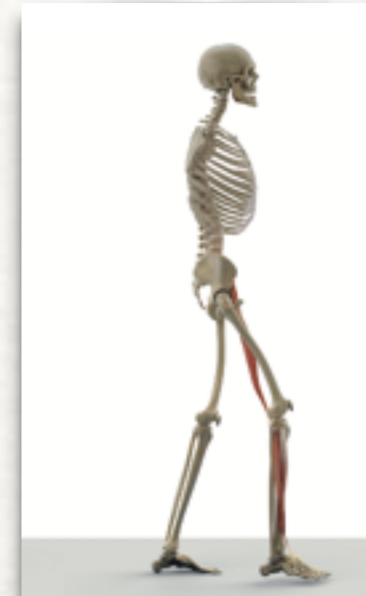
SARTORIUS M.


The **sartorius muscle** ("tailor's muscle") is the longest muscle in the body and it is in the anterior compartment. It flexes the leg and thigh, and after it's flexed, medially rotates the lower leg. This is the muscles that helps you cross your legs. It is easily visualized externally.
Ant. superior iliac spine
Tensor fasciae latae m.
Iliotibial tract
Sartorius m.
Medial condyle of tibia
Lateral condyle of tibia
ANTERIOR VIEW

SWING PHASE

- **Mid Swing**



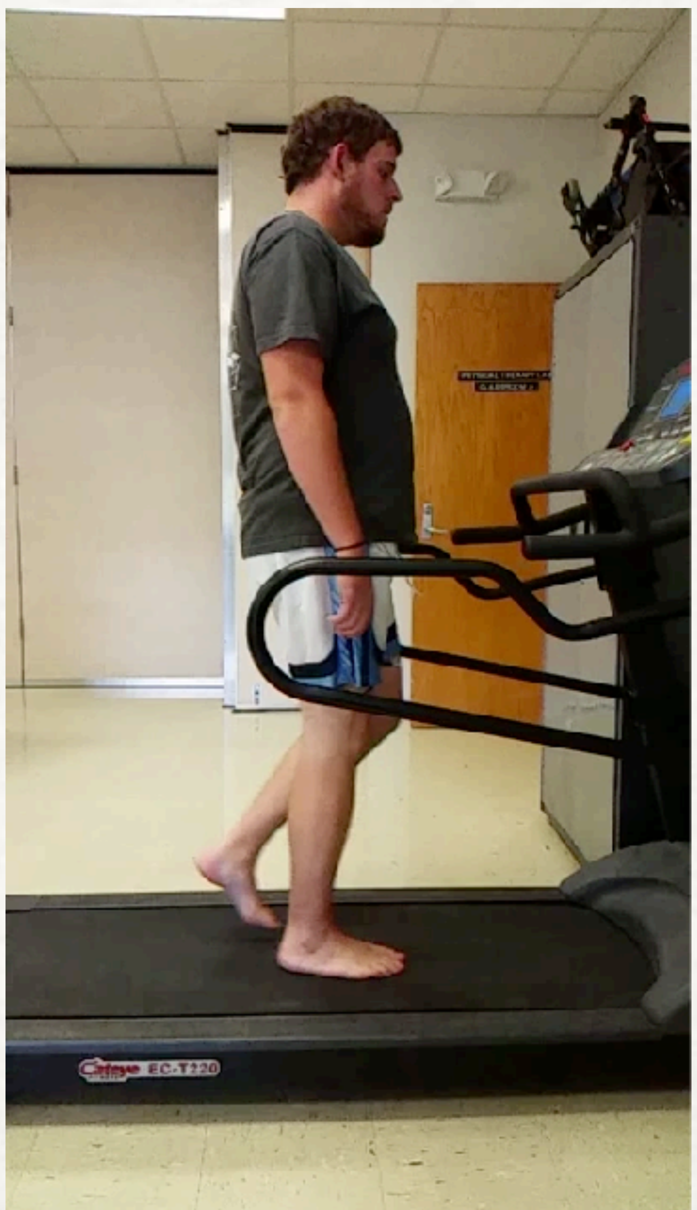


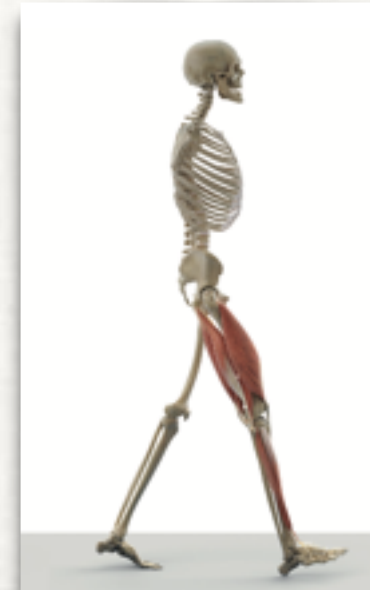
Gait phases	MSW Mid Swing
Gait cycle	75 – 87 %
Hip	25° flexion
Knee	25° flexion
Ankle joint	0°
Muscle activity	M. semimembranosus M. semitendinosus M. biceps femoris M. tibialis anterior
Functions	• increasing hip flexion to 25° • dorsal extension of the ankle joint to neutral-zero-position

HAMSTRINGS M.

SWING PHASE

- **Terminal Swing**

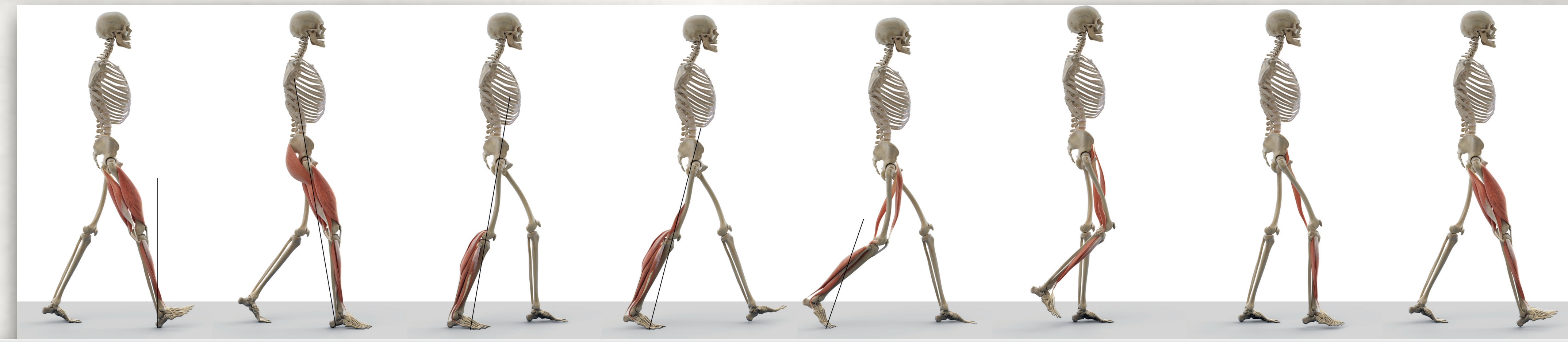




Gait phases	TSW Terminal Swing
Gait cycle	87 – 100 %
Hip	20° flexion
Knee	0° – 5° flexion
Ankle joint	0°
Muscle activity	M. quadriceps femoris M. semitendinosus M. semimembranosus M. biceps femoris M. tibialis anterior
Functions	• knee joint extension to neutral-flexion • preparation for stance phase

Streifeneder ortho production

The eight phases of human gait cycle



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Hip	20° flexion	20° flexion	0° flexion	-20° hyperextension	-10° hyperextension	15° flexion	25° flexion	20° flexion
Knee	0° – 5° flexion	20° flexion	0° – 5° flexion	0° – 5° flexion	40° flexion	60° – 70° flexion	25° flexion	0° – 5° flexion
Ankle joint	0°	5° – 10° plantar flexion	5° dorsal flexion	10° dorsal flexion	15° plantar flexion	5° plantar flexion	0°	0°
Muscle activity	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus Ischiocrurale Muskulatur	M. quadrizeps femoris M. tibialis anterior M. gluteus medius M. gluteus maximus M. adductor Magnus M. tensor fascia latae M. tibialis posterior M. peroneus longus	M. gastrocnemius M. soleus	M. soleus M. gastrocnemius M. flexor digitorum longus M. flexor hallucis longus M. tibialis posterior M. peroneus longus M. peroneus brevis	M. soleus M. gastrocnemius M. rectus femoris M. adductor longus	M. extensor hallucis longus M. flexor hallucis longus M. sartorius M. iliacus M. tibialis anterior	M. semimembranosus M. semitendinosus M. biceps femoris M. tibialis anterior	M. quadriceps femoris M. semitendinosus M. semimembranosus M. biceps femoris M. tibialis anterior
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ABNORMAL GAIT EXAMPLES

- Parkinsonian
- Neuropathic/Steppage
- Ankle fusion
- Pediatric flatfoot

PARKINSONIAN GAIT

- Parkinsonian gait

NEUROPATHIC GAIT

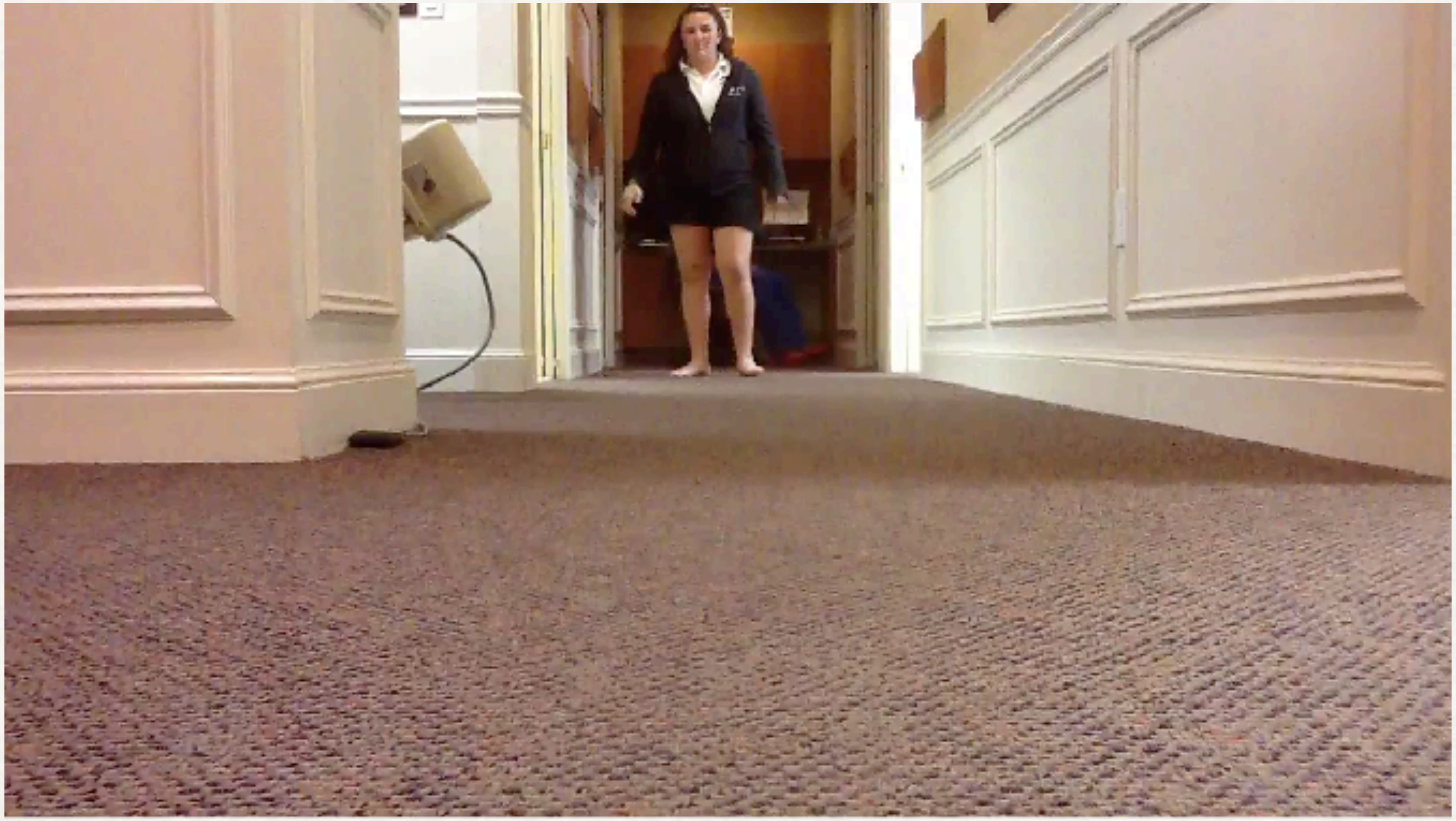
- Neuropathic or steppage gait

ANKLE FUSION

- Ankle fusion gait

PEDIATRIC FLATFOOT

- Pediatric Flatfoot gait



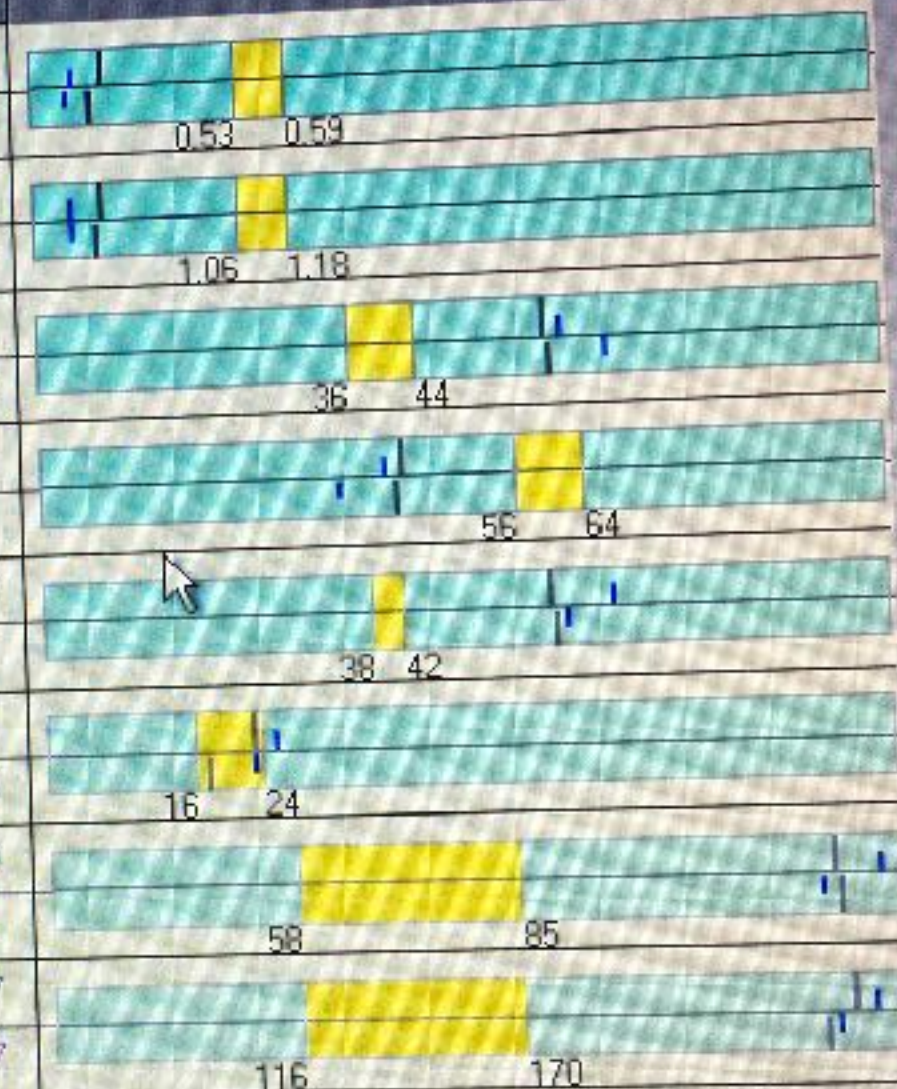
GAIT EVALUATION

- John -
- Collegiate basketball player
- Injury - knee dislocation with multiple soft tissue injuries requiring complex reconstruction and extensive rehab
- GaitRite System -

Progress/OutCome for: D. John

BACK

Parameters	L/R	5/15/2018 3:46:24 PM	5/15/2018 3:48:11 PM		
Step Time (sec)	L	.375(.0)	.341(.0)	-0.034	
	R	.363(1.7)	.334(.0)	-0.029	
Cycle Time (sec)	L	.742(.0)	.675(.0)	-0.067	
	R	.733(.0)	.675(.0)	-0.058	
Swing Time (sec)	L	.433(.0) /58.4	.408(.0) /60.4	-0.025	
/ %GC	R	.433(.0) /59.1	.442(.0) /65.5		0.009
Stance (sec)	L	.309(.0) /41.6	.267(.0) /39.6	-0.042	
/ %GC	R	.300(.0) /40.9	.233(.0) /34.5	-0.067	
Single Support (sec)	L	.433(.0) /58.4	.442(.0) /65.5		0.009
/ %GC	R	.433(.0) /59.1	.408(.0) /60.4	-0.025	
Double Support (sec)	L	.175(.0) /23.6	.175(.0) /25.9	0.000	
/ %GC	R	.133(.0) /18.1	.158(.0) /23.4		0.025
Step Length (cm)	L	119.168(.0)	124.293(4.6)		5.125
	R	120.083(3.7)	118.100(.0)	-1.983	
Stride Length (cm)	L	242.369(.0)	246.646(.0)		4.277
	R	236.160(.0)	238.337(.0)		2.177
Base of Support (cm)	L	5.34(.0)	9.54(.0)		4.200
	R	7.85(.0)	4.66(.0)	-3.190	
Toe In / Out (deg)	L	2(.0)	2(.0)	0.000	
	R	3(.0)	3(.0)	0.000	



D. John

Walk 5/15/2018 3:40:18 PM

Test

nder	Age	Left - Leg	Right
M	21	88	87.75

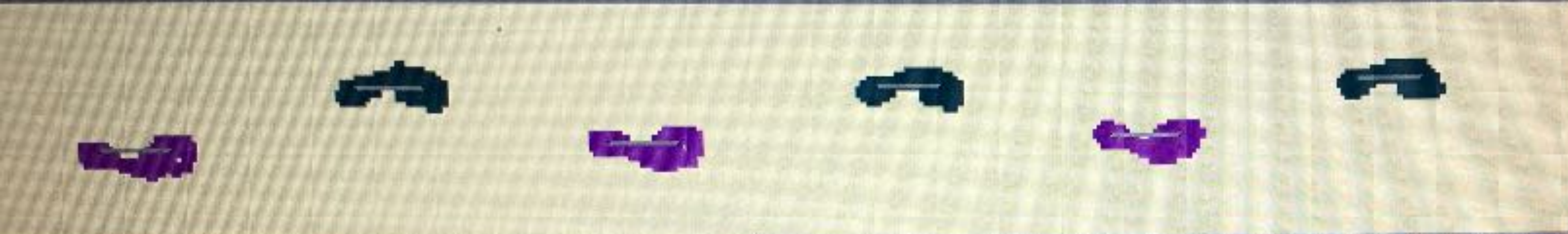
Patient Name (first, middle, last) For Quick Test: John | D

Shoe/Foot Size: Shoe | Length: 0 | Width: 0

l Toe Gap 2 (toe in/out)

Level of Assistance

FAP 99



Bilateral Parameters	Left	Right
Step Time (sec)	.56/4.3	.53
Cycle Time (sec)	1.10/2.6	1.10/2.6
Step Length (cm)	66.72/4.0	63.12/1.1
Stride Length (cm)	130.88/2.6	130.30/2.2
H-H Base Support (cm)	13.84	13.29
Single Support (%GC)	35.3	39.5
Double Support (%GC)	25.2	26.0
Swing (%GC)	39.5	35.3
Stance (%GC)	60.5	64.7
Step/Extremity Ratio	.76	.72
Toe In / Out (deg)	1	2

Parameters	
Distance (cm)	326.4
Ambulation Time (sec)	2.74
Velocity (cm/sec)	119.1
Mean Normalized Velocity	1.36
Number of Steps	5
Cadence (Steps/Min)	109.5
Step Time Differential (sec)	.04
Step Length Differential (cm)	3.60
Cycle Time Differential (sec)	.00

Length L	Length R	Width L	Width R
25.90	27.10	6.80	7.90

Scan Rate = 120 Hz @8.3333

Detail | Exit

Replay | Temporal

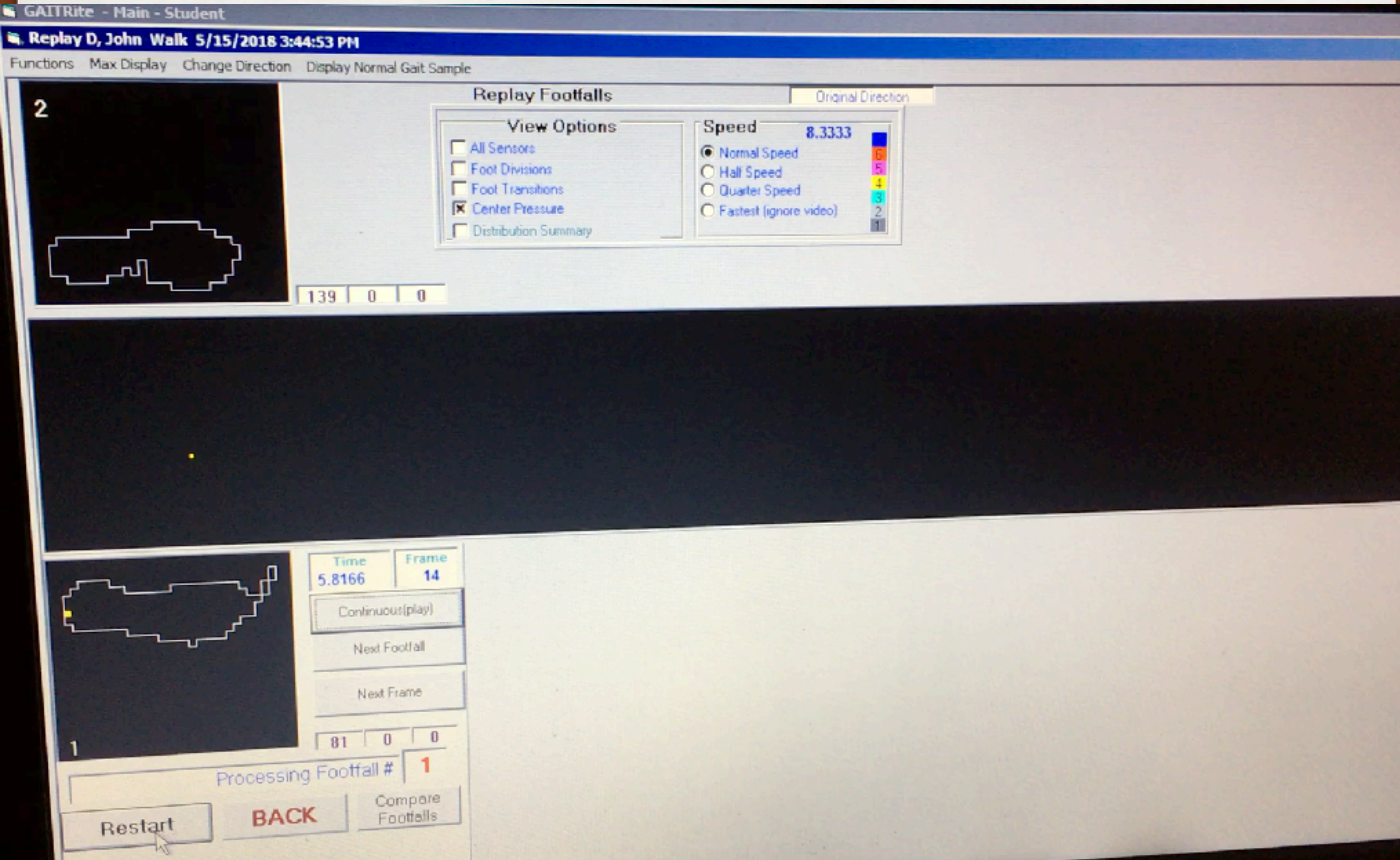
"Replay walk showing sensor pressure with video"

Save | Memo

Primary Dr.

Problem

Sample Normal Values


GAITRite - Main - Student
Replay D, John Walk 5/15/2018 3:44:53 PM
Functions
Max Display
Change Direction
Display Normal Gait Sample
Replay Footfalls
Original Direction
View Options
All Sensors
Foot Divisions
Foot Transitions
Center Pressure
Distribution Summary
Speed
8.3333
Normal Speed
Half Speed
Quarter Speed
Fastest (ignore video)
2
139
0
0
1
Time
5.8166
Frame
14
Continuous(play)
Next Footfall
Next Frame
81
0
0
Processing Footfall #
1
Restart
BACK
Compare Footfalls

INTERPRETATION

- Left side is pathologic side
  - Spends more time in swing phase
  - Less time in stance phase
  - Pressure points help show where his foot is at in mid stance
    - There is not really high pressure during his gait cycle; the highest pressure is to the left fore foot - WHY?
    - Hint- think about his anterior muscle group
  - These few points can help guide rehab, bracing, custom orthotics
  - It tells me as a clinician that he is at increased risk for stress fractures

HOW RELIABLE IS THIS?

WHITE PAPERS

- Journal of Phys Therapy
- 1985
- Krebs et al.

Reliability of Observational Kinematic Gait Analysis

DAVID E. KREBS,
JOAN E. EDELSTEIN,
and SIDNEY FISHMAN

Gait analysis, like all clinical assessments, is subject to measurement error. Specification of the extent of measurement error is imperative before drawing conclusions from any test. The purpose of this study was to determine the within-rater and between-rater reliability of observational gait analysis in a pediatric sample wearing knee-ankle-foot orthoses. Three expert observers, using a 3-point scale, rated videotaped gait kinematics of 15 children who had lower limb disability and who wore braces. The rating sessions were then repeated, with one month between sessions. Total agreement (identical ratings), both between-raters and within-raters, occurred in two-thirds of the observations, and an additional 29% of the observations differed by one point. Between-rater intraclass correlation coefficient type 2,1 was .73; within-rater Pearson product-moment correlation averaged .60. Observational kinematic gait analysis appears to be a convenient, but only moderately reliable, technique.

Key Words: *Clinical trials, Gait, Orthotic devices, Physical therapy.*

Clinicians frequently assess the effect of therapeutic interventions by observing the ambulatory status of disabled persons. Kinematics (joint motions) are perhaps most frequently analyzed.[1] Although sophisticated, instrumented gait-analysis techniques are widely used in research, their complexity, cost, and inconvenience have inhibited widespread clinical application. Careful observation by trained practitioners remains the most convenient type of kinematic analysis. The observer must, however, differentiate among rapidly changing movements to identify departures from symmetry and other distortions of "normal" gait patterns.[1]

The clinical suitability of observational kinematic gait analysis is supported by Carroll and his staff who observed videotapes of 15 myelodysplastic children, walking with and without braces, to determine the relative merits of various orthotic options.[2] Two clinicians rated gait independently and then conferred. The scoring system was not explicated; although the reported intent was to minimize bias, persuasive conference, in fact, may promote bias. Reliability of the rating system was not reported.

Gait assessment, like all clinical measurements, is subject to observer error. Measurement error may result from poor rater training, personal bias, the limited capacity of human visual perception, and other sources.[3]

LITERATURE REVIEW

No standardized, observational gait-analysis (OGA) system is in universal use, and no agreement exists regarding the optimal characteristics of normal gait. Urging simplification and standardization of kinematic analysis, Stanic and associates decried the lack of an internationally accepted set of definitions of the normal range of gait characteristics.[4]

Data Collection

The method of grading influences the usefulness of the gait-analysis record. One approach, formulated by New York University Post-Graduate Medical School, Prosthetics and Orthotics, requires the rater to judge the presence and severity of deviations from normal gait with the aid of a check list of common problems.[5,6] Brunnstrom also advocated a check list of stance and swing phase deviations at the ankle, knee, and hip for observational analysis of hemiplegic gait.[7]

In the attempt to achieve greater precision in observation, deviations may be arrayed on a chart that indicates the segments of swing and stance phase when a given fault might occur.[8–10] Most forms require a present or absent notation of whichever faults are seen. An alternative is the assignment of points to describe deviation severity; the sum is intended to produce a quantitative evaluation score.[11]

Data Reduction and Analysis

Observational gait records are ordinarily subjected only to visual inspection before the formation of a clinical judgment by the reviewer(s). Alternative ways of dealing with the data collected from observations may include addition of points assigned various deviations[11] or the use of computerized analysis to interpret gait factors to indicate the degree of likelihood that a particular diagnosis is true.[12]

DeBruin et al reported a study in which six orthopedic residents viewed videotapes of cerebral palsied children whose deviations scored as none, mild, or severe.[13] Although no

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This work was supported by grant MCJ-363-082-26-0 to New York University Child Prosthetic-Orthotic Studies from the Bureau of Community Health Services, Public Health Service, Department of Health and Human Services, Rockville, MD.

This article was submitted July 3, 1984; was with the authors for revision four weeks; and was accepted January 28, 1985.

WHITE PAPERS

- Journal of Phys Therapy
- 1991
- Eastlack et al.

Research Report

Interrater Reliability of Videotaped Observational Gait-Analysis Assessments

Martha E Eastlack
Julianne Arvidson
Lynn Snyder-Mackler
Jerome V Danoff
Charles L McGarvey

The purpose of this study was to determine the interrater reliability of videotaped observational gait-analysis (VOGA) assessments. Fifty-four licensed physical therapists with varying amounts of clinical experience served as raters. Three patients with rheumatoid arthritis who demonstrated an abnormal gait pattern served as subjects for the videotape. The raters analyzed each patient's most severely involved knee during the four subphases of stance for the kinematic variables of knee flexion and genu valgum. Raters were asked to determine whether these variables were inadequate, normal, or excessive. The temporospatial variables analyzed throughout the entire gait cycle were cadence, step length, stride length, stance time, and step width. Generalized kappa coefficients ranged from .11 to .52. Intraclass correlation coefficients (2,1) and (3,1) were slightly higher. Our results indicate that physical therapists' VOGA assessments are only slightly to moderately reliable and that improved interrater reliability of the assessments of physical therapists utilizing this technique is needed. Our data suggest that there is a need for greater standardization of gait-analysis training. [Eastlack ME, Arvidson J, Snyder-Mackler L, et al. Interrater reliability of videotaped observational gait-analysis assessments. Phys Ther. 1991;71:465–472.]

Key Words: *Education: physical therapist, clinical education; Gait; Kinesiology/biomechanics, gait analysis.*

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CL McGarvey, MS, PT, is Chief of Physical Therapy, Department of Rehabilitation Medicine, Warren G Magnusen Clinical Center.

Ms Eastlack and Ms Arvidson were students in the Master of Science in Physical Therapy Program, Sargent College of Allied Health Professions, Boston University, when this study was conducted in partial fulfillment of the requirements of their Master of Science in Physical Therapy degrees.

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The opinions presented in this article reflect the views of the authors and not necessarily those of the National Institutes of Health or the US Public Health Service.

The design of this study was approved by the National Institutes of Health Human Subjects Review Board.

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Gait assessment has become an increasingly important part of physical therapy patient evaluations. Gait assessment is used to determine whether the patient's gait differs from "normal," to quantify the degree of abnormality, and to identify the causes of the abnormal gait patterns, and it is used as a reassessment tool to evaluate the efficacy of treatment.[1,2] Although some instrumented gait-analysis systems have been shown to give reliable and valid measurements, they are costly and may be impractical for most clinicians to use as an everyday assessment tool.[1–6]

We believe that some form of observational gait analysis (OGA) is the most widely used method of gait analysis. Observational gait anal-

WHITE PAPER

- Sensors
- 2014
- Muran de-la-Herran et al.

Sensors **2014**, *14*, 3362-3394; doi:10.3390/s140203362

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Review

Gait Analysis Methods: An Overview of Wearable and Non-Wearable Systems, Highlighting Clinical Applications

Alvaro Muro-de-la-Herran, Begonya Garcia-Zapirain * and Amaia Mendez-Zorrilla

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Abstract: This article presents a review of the methods used in recognition and analysis of the human gait from three different approaches: image processing, floor sensors and sensors placed on the body. Progress in new technologies has led the development of a series of devices and techniques which allow for objective evaluation, making measurements more efficient and effective and providing specialists with reliable information. Firstly, an introduction of the key gait parameters and semi-subjective methods is presented. Secondly, technologies and studies on the different objective methods are reviewed. Finally, based on the latest research, the characteristics of each method are discussed. 40% of the reviewed articles published in late 2012 and 2013 were related to non-wearable systems, 37.5% presented inertial sensor-based systems, and the remaining 22.5% corresponded to other wearable systems. An increasing number of research works demonstrate that various parameters such as precision, conformability, usability or transportability have indicated that the portable systems based on body sensors are promising methods for gait analysis.

Keywords: gait analysis; wearable sensors; clinical application; sensor technology; gait disorder

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WHITE PAPER

- Transactions on information
    - technology in biomedicine
- 2008
- Bamberg et al.

IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE, VOL. 12, NO. 4, JULY 2008 413

Gait Analysis Using a Shoe-Integrated Wireless Sensor System

Stacy J. Morris Bamberg, *Member, IEEE*, Ari Y. Benbasat, *Member, IEEE*, Donna Moxley Scarborough, David E. Krebs, and Joseph A. Paradiso, *Senior Member, IEEE*

***Abstract*—We describe a wireless wearable system that was developed to provide quantitative gait analysis outside the confines of the traditional motion laboratory. The sensor suite includes three orthogonal accelerometers, three orthogonal gyroscopes, four force sensors, two bidirectional bend sensors, two dynamic pressure sensors, as well as electric field height sensors. The "GaitShoe" was built to be worn in any shoe, without interfering with gait and was designed to collect data unobtrusively, in any environment, and over long periods. The calibrated sensor outputs were analyzed and validated with results obtained simultaneously from the Massachusetts General Hospital, Biomotion Laboratory. The GaitShoe proved highly capable of detecting heel-strike and toe-off, as well as estimating foot orientation and position, *inter alia*.**

***Index Terms*—Biomedical measurements, body sensor networks, legged locomotion, multisensor systems, telemetry.**

I. Introduction

CLINICAL gait analysis is the investigation of the pattern of walking. At present, gait analysis is primarily carried out in one of two ways: in a motion laboratory, with full analysis of the motion of body segments using highly accurate computer-based force and optical tracking sensors, or in an office with the clinician making visual observations. The first method is expensive, requires the maintenance of a dedicated motion laboratory, and uses cumbersome equipment attached to the patient, but produces well-quantified and accurate results for short-distance ambulation. The second method is inexpensive and does not require special equipment, but requires additional time from the clinician, and the results are qualitative, unreliable, and difficult to compare across multiple visits.

There is a need for an alternative analysis method that is capable of providing quantitative and repeatable results over extended time periods. A system that can quantitatively analyze gait for patients offers clinicians and patients new opportunities for diagnosis and treatment of chronic walking problems. There has been considerable previous work in both research and commercial spheres focused on the development of more mobile methods of analyzing gait. The advantage of directly measuring the pressure distribution beneath the foot drove many early shoe-based systems. The shrinking size of data storage has further encouraged the development of untethered systems.

In 1990, Wertsch *et al.* [1] developed a tethered system for measuring the pressure distribution beneath the foot, using seven force-sensitive resistors (FSRs), and used this device to quantify the differences between shuffling and walking [2], and identified the need to collect data over a long time period in populations with large step-to-step variations in gait [3]. In 1994, Hausdorff *et al.* [4], [5] developed a system capable of detecting several of the temporal gait parameters with two FSRs positioned under the heel and in the general area under the toes and metatarsals, connected to a circuit board and battery pack worn on the ankle, which has been used to evaluate the likelihood of falling in the elderly [6] and to find patterns in gait [7].

More recent research has been driven by subspecialty interests in gait analysis. For diabetics, Morley *et al.* [8] and Maluf *et al.* [9] developed an insole-based system to quantify the conditions inside the shoe, to predict the progression of skin breakdown and ulceration in diabetic patients with peripheral neuropathy. Pappas *et al.* [10], [11] used a pattern recognition algorithm to define the transitions during the gait cycle using their device consisting of three FSRs located on an insole (one under the heel, and two at the first and fourth metatarsal heads), and a gyroscope. The system was tested on two subjects with incomplete spinal injury and was used to trigger functional electrical stimulation (FES), with demonstrated benefit for both subjects.

Vildjiounaite *et al.* [12] developed a real-time system, using accelerometers and magnetic sensors. The magnetic sensor data were used to determine foot orientation and identify steps; the averaged peak forward acceleration was used with a lookup table to estimate the step length. For level walking, location was estimated with an error of 5%.

Other research devices include instrumented walkways [13], "piezodyanomometric" platforms [14], or instrumented floors [15], [16]. Such systems can only provide information while the subject walks on the platform. In addition, research platforms have been developed to recognize gait without instrumenting the subject, primarily by videotape analysis [17]–[21], and also through the use of radar [21], [22].

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CURRENT EVIDENCE ON GAIT ANALYSIS

- What is the role of gait analysis in our professions?
- How can a university system benefit from a gait analysis lab?

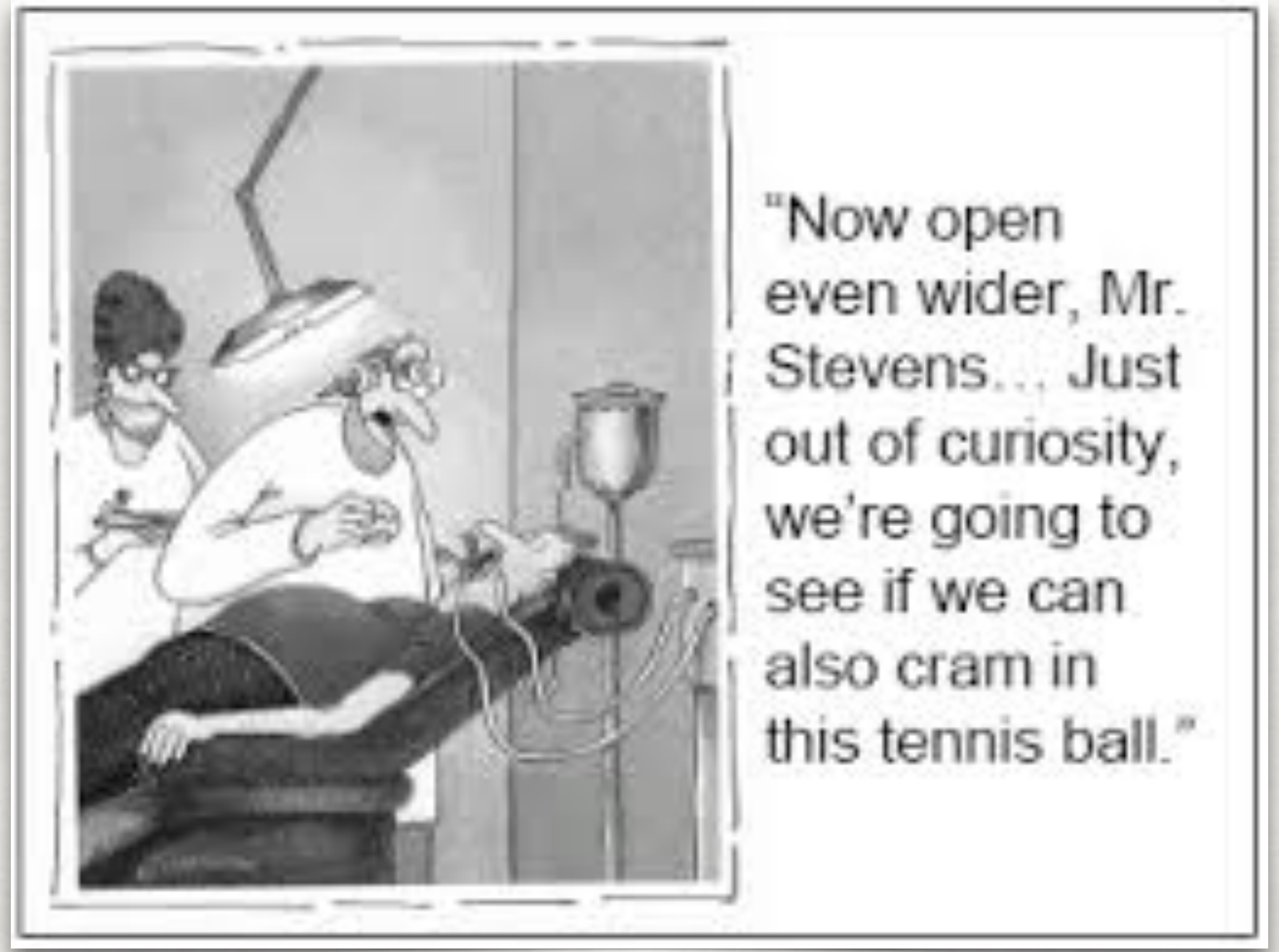
GAIT ANALYSIS

- What's needed for effective analysis
  - HIPAA
  - Training
  - High quality video instruments;$$$
  - Visualization - hips, knees, ankles, feet, upper body, arm swing
  - Platform length (12-15 feet)

PERHAPS...

- Apple© has already set up the sensors in our devices that are monitoring our gait characteristics, more than just our steps??
- iPhone X? For a mere $999....

THANK YOU


"Now open even wider, Mr. Stevens… Just out of curiosity, we're going to see if we can also cram in this tennis ball."

THANK YOU

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