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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

MODULE BIOMECHANICS OF GAIT

Didactic Unit D: INSTRUMENTED ANALYSIS OF GAIT

D.4 USEFULNESS OF BIOMECHANICAL INSTRUMENTED ANALYSIS OF GAIT

Politechnika Śląska

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D.4 In which cases and how can a biomechanical instrumented analysis be useful?

INDEX

D.4 In which cases and how can a biomechanical instrumented analysis be useful?

I. OBJECTIVES

I. OBJECTIVES

1) To study the clinical application of instrumented biomechanical gait analysis and the different research designs in which it is used.
2) To analyze the application of the instrumented biomechanical gait analysis in the sports field and the information it provides to athletes and coaches.
3) To study the practical application in the area of ergonomics and exemplify how the instrumented biomechanical gait analysis can improve jobs conditions.
4) To study how the instrumented biomechanical gait analysis is applied in legal medicine where a dysfunction must be characterized to determine a degree of incapacity for work or financial compensation.

D.4 In which cases and how can a biomechanical instrumented analysis be useful?

II. CONTENTS

II.1 Clinical application of biomechanical instrumented gait analysis.

II.1 CLINICAL APPLICATION

What is the use of instrumented gait analysis in medical practice?

- To characterize the population
- To support the medical diagnosis
- To assess the effectiveness of medical and physical rehabilitation treatments

II.1 CLINICAL APPLICATION

Instrumented gait analysis to characterize the population

How different is the gait of people with a disease compared to people with similar characteristics but healthy?

How does gait evolve throughout of a pathology?

What normality values should we achieve when applying a gait treatment?

II.1 CLINICAL APPLICATION

Instrumented gait analysis to characterize the population

Example

Diabetes Mellitus

Foot and Ankle Surgery 26 (2020) 163–168

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Gait changes in persons with diabetes: Early risk marker for diabetic foot ulcer

Saraswathy Gnanasundaram[a,*], Priyadharshini Ramalingam[a], Bhabendra Nath Das[b], Vijay Viswanathan[c]

Peripheral neuropathy | **Vasculopathy** | **Foot deformities** → **Foot ulcer**

II.1 CLINICAL APPLICATION

Instrumented gait analysis to characterize the population

Example

What is the dynamic plantar pressure profile of persons with diabetes without neuropathy and the diabetic neuropathy, compared with the healthy control ?

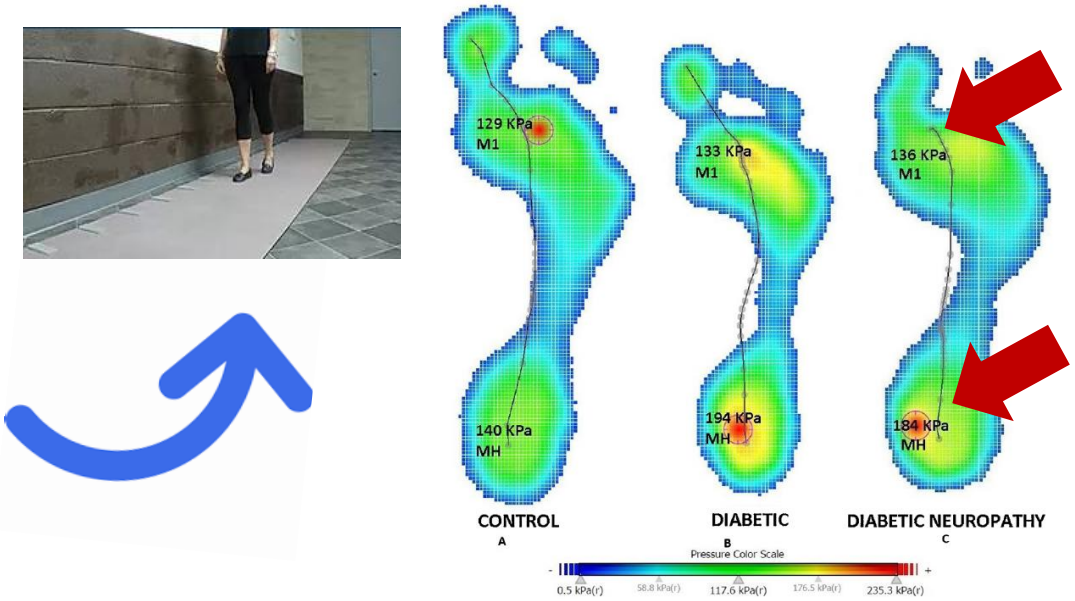


Figure 1 - instrumented walkway example (GAITrite) and surface area results of the foot contact during walking (Gnanasundaram et al. 2020)

II.1 CLINICAL APPLICATION

Instrumented gait analysis in medical diagnosis and decision-making

How should I intervene in my patient?

I need an analysis of his gait!

Diagnosis

Additional information

Medical treatment

II.1 CLINICAL APPLICATION

Instrumented gait analysis in medical diagnosis and decision-making

Example

74 *Acta Orthopaedica* 2007; 78 (1): 74–80

Preoperative gait analysis has a substantial effect on orthopedic decision making in children with cerebral palsy

Comparison between clinical evaluation and gait analysis in 60 patients

Bjørn Lofterød[1], Terje Terjesen[2], Ingrid Skaaret[1], Ann-Britt Huse[1] and Reidun Jahnsen[1]

60 children between 4 and 18 years-old with cerebral palsy

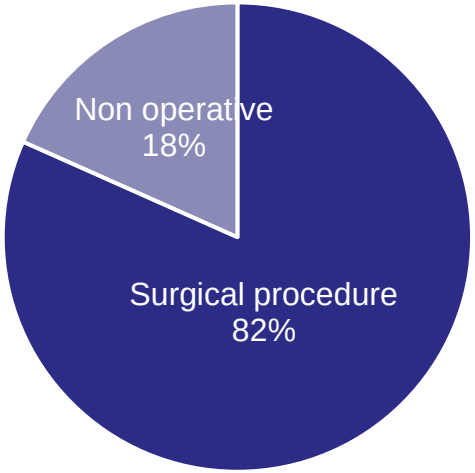
They had a specific surgical plan outlined → 3-dimensional kinematics and kinetics analysis → How did the surgical plan change after the gait analysis?

II.1 CLINICAL APPLICATION

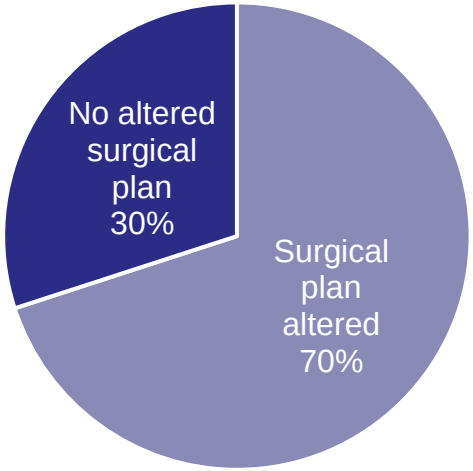
Instrumented gait analysis in medical diagnosis and decision-making

Example

Changes after gait analysis



Participants n = 60



Surgical procedure	Number recommended	
	before gait analysis	after gait analysis
Psoas	25	39
Adductors	32	14
Hamstrings	46	38
Rectus femoris	36	53
Gastrocnemius	61	46
Foot and ankle	14	12
Femoral osteotomy	32	16
Tibial osteotomy	7	3
Total	253	221

13%

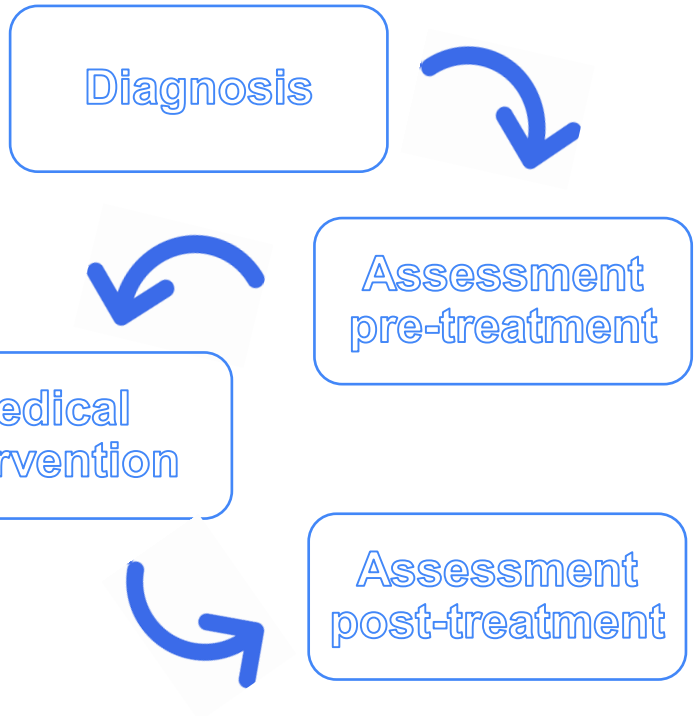
Figure 2 – Results from Lofterød et al. 2015

II.1 CLINICAL APPLICATION

Instrumented gait analysis to assess the effectiveness of treatments

How effective is my medical treatment?

Is treatment A more effective than treatment B?



II.1 CLINICAL APPLICATION

Instrumented gait analysis to assess the effectiveness of treatments

Example

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Biomechanical analysis on total knee replacement patients during gait: Medial pivot or posterior stabilized design?

Francesco Esposito[a,b,*], Marco Freddolini[e], Massimiliano Marcucci[a,c,d], Leonardo Latella[a,c], Andrea Corvi[a,b]

II.1 CLINICAL APPLICATION

Instrumented gait analysis to assess the effectiveness of treatments

Example

Both prothesis reduced walking speed, reduced stride length and increased stance time respect to control group.

Reduction of knee flexion and flexor moment in patients with Medial Pivot mechanism.

Prolonged muscular activity of rectus femoris was observed in Medial Pivot patients compared to Posterior Stabilized.

Medial Pivot prothesis, causes a less rigid knee pattern than Posterior Stabilized prothesis, and seems to better reproduce the physiological condylar movement as gait parameters

D.4 In which cases and how can a biomechanical instrumented analysis be useful?

II. CONTENTS

II.2 Usefulness of biomechanical instrumented gait analysis in sports science

II.2 USEFULNESS IN SPORTS SCIENCE

What is the use of instrumented gait analysis in sports science?

- Analysis of the sporting gesture
- Injury prevention
- Effectiveness of physical activity and sports

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis in sports gesture

Figure 3 – Racewalking event. Image from The New York Times.

Long-distance discipline within the sport of athletics

One leg must be in contact with the ground

the knee must be fully extended from first contact with the ground until the "vertical upright position".

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis in sports gesture

Example

sensors

MDPI

Article

Automatic Detection of Faults in Race Walking: A Comparative Analysis of Machine-Learning Algorithms Fed with Inertial Sensor Data

Juri Taborri [1,*], Eduardo Palermo [2] and Stefano Rossi [1]

Define the best-performing classifiers for the automatic and objective detection of illegal steps from the instrumented gait analysis with inertial sensors.

Figure 4 – Placement of IMUs (orange probes) on an athlete during the experimental procedure. Image from Taborri et al. 2018.

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis in sports gesture

Example

Control through observation

Loss of contact

Knee-bent

Legal gait

Loss contact

Knee-bent

Linear acceleration

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis to study injury conditions

Example

Effects of Hiking Downhill Using Trekking Poles while Carrying External Loads

MICHAEL BOHNE[1] and JULIANNE ABENDROTH-SMITH[2]

[1]Western Illinois University, Macomb, IL; and [2]Willamette University, Salem, OR

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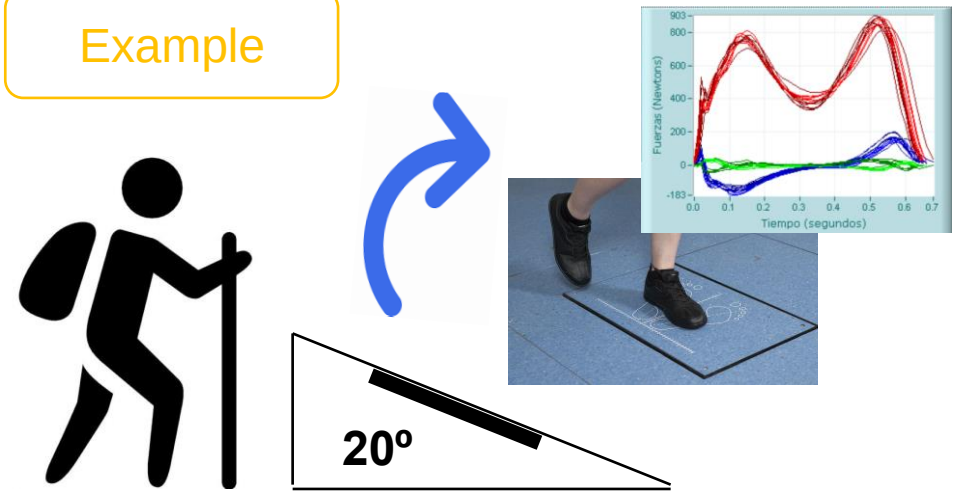
II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis to study injury conditions

Example



With poles

Without poles

No pack

Pack 15% BW

Pack 30% BW

With poles: reduction of the moments at each of the joints

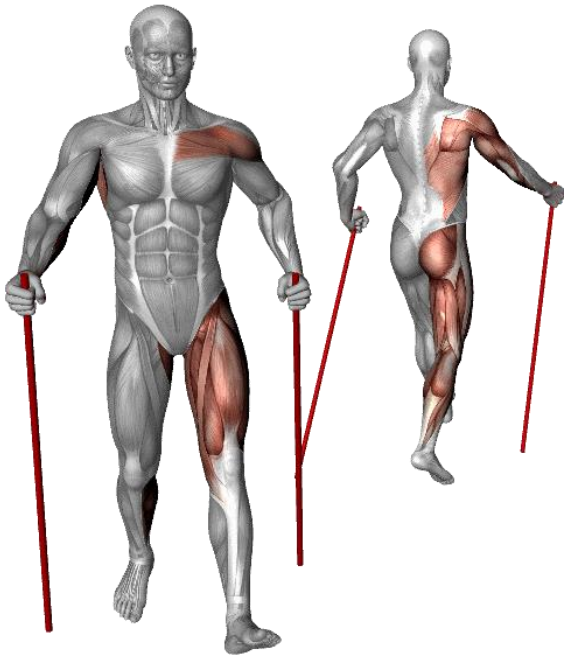
With poles: reduction of the power absorption for the ankle and knee

Packs only resulted in a larger power generation at the hip.

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis to assess effectiveness of physical activity and sports

Example



Original Article

Does Nordic walking improves the postural control and gait parameters of women between the age 65 and 74: a randomized trial

Piotr Kocur, PhD[1)*], Marzena Wiernicka, PhD[1)], Maciej Wilski, PhD[2)], Ewa Kaminska, PhD[1)], Lech Furmaniuk, PhD[1)], Marta Flis Maslowska, PhD[1)], Jacek Lewandowski[3)]

- Active movement of arms
- More muscle involve

→ What is the effect on the asymmetry in upper and lower limb movements of Parkinson's disease?

Figure 5 – Animation of muscle involve in the development of Nordic Walking (Image from http://b.nw.free.fr)

II.2 USEFULNESS IN SPORTS SCIENCE

Gait analysis to assess effectiveness of physical activity and sports

Example

14 participants

11 weeks / two weekly sessions of NW

3D motion analysis system

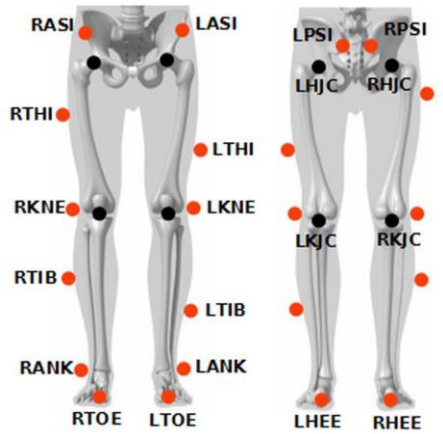


Figure 6 – Plug-in-Gait Full-Body with thirty-five landmarkers. (Image from Baudet et al. 2014)

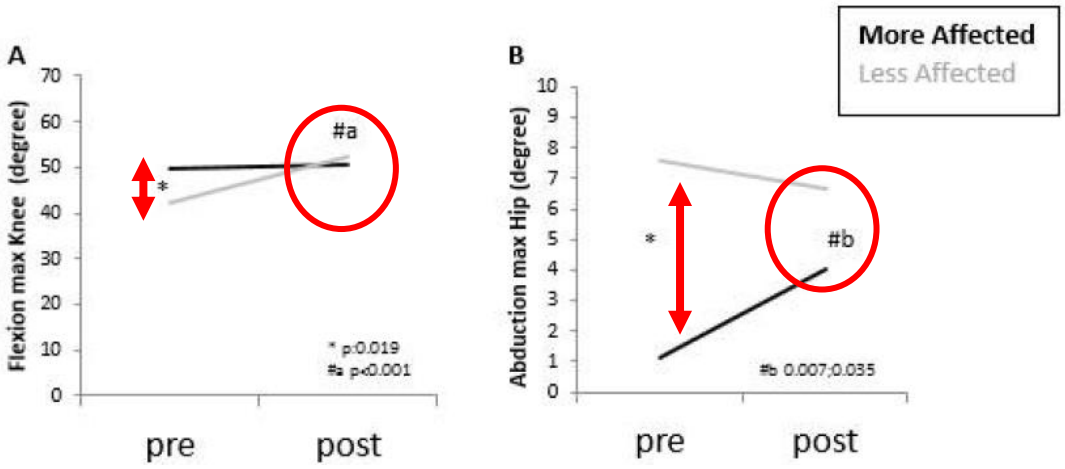


Figure 7 – Results from Kocur et al. 2019

D.4 In which cases and how can a biomechanical instrumented analysis be useful?

II. CONTENTS

II.3 Ergonomics implications of biomechanical instrumented gait analysis

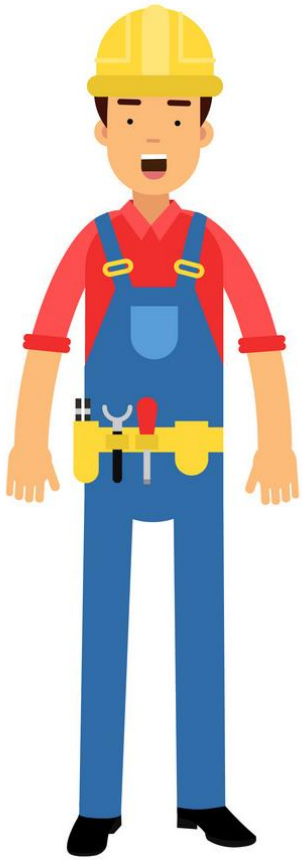
II.3 ERGONOMICS IMPLICATIONS

Ergonomics

Is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Physical requirements and risks measured through biomechanical tools.

Walking and standing is an essential part of many jobs.



II.3 ERGONOMICS IMPLICATIONS

Example

Ergonomics, Vol. 48, No. 4, 15 March 2005, 380–398

Taylor & Francis
Taylor & Francis Group

Modulation of mechanical and muscular load by footwear during catering

U. G. KERSTING*†, L. JANSHEN‡, H. BÖHM§, G. M. MOREY-KLAPSING¶ and G.-P. BRÜGGEMANN¶

To investigate the biomechanical load on the lower extremity and the low back during catering service when wearing different types of footwear.

- 70% of job induced days off work to relate to traumas of the ankle joint or overloading of the leg, knee and lower back.
- Increased incidence in service areas outdoors

II.3 ERGONOMICS IMPLICATIONS

Example

16 experienced waiters

Three types of ground

Paved | Gravel | PVC

Three types of footwear

Casual | Neutral | Functional

Figure 7 – Instrumentation from Kersting U. et al. 2015

Surface EMG: tibialis anterior, gastrocnemius medialis, peroneus longus

Accelerometer fixed at the anterior tibial aspect of each leg

Custom-made in-shoe goniometer

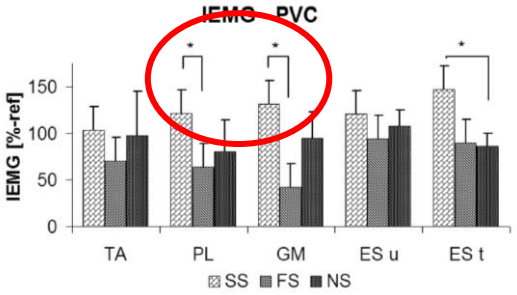
Plantar pressure in-shoe (99 sensors per insole and 50 Hz)

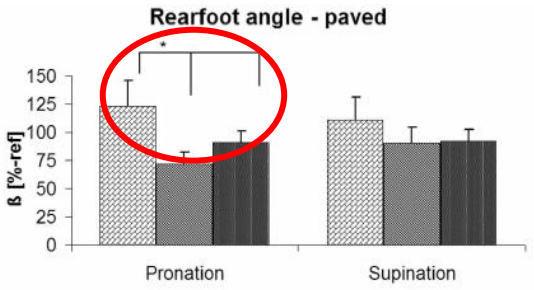
II.3 ERGONOMICS IMPLICATIONS

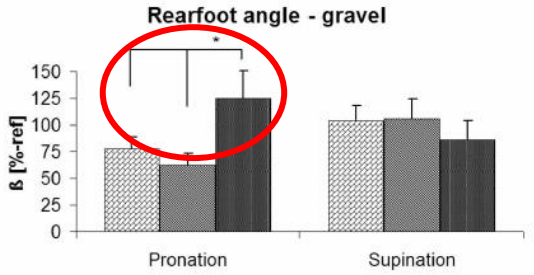
Example

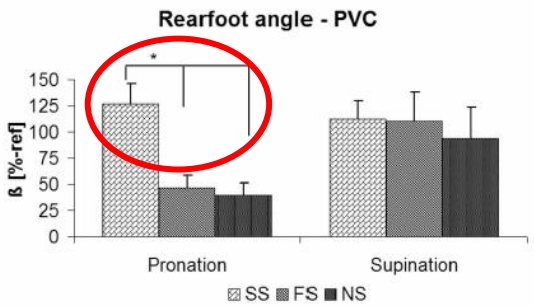
Shoes and Surface have an effect on gait

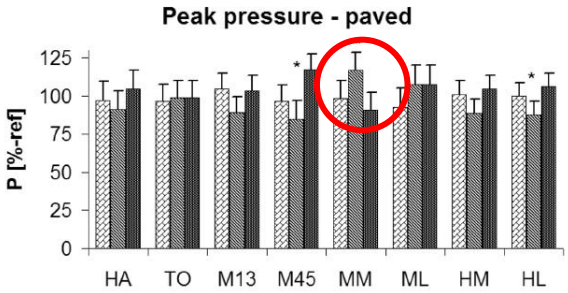
Differences between footwear increase in critical situations

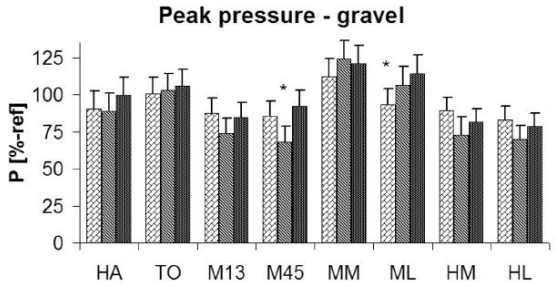


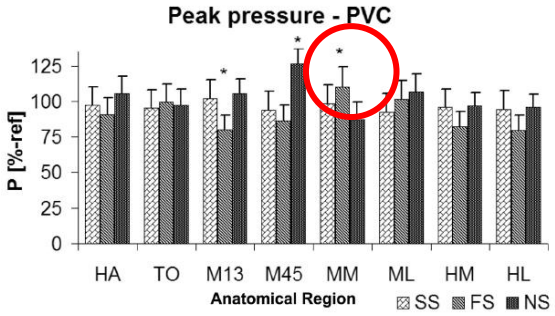












D.4 In which cases and how can a biomechanical instrumented analysis be useful?

II. CONTENTS

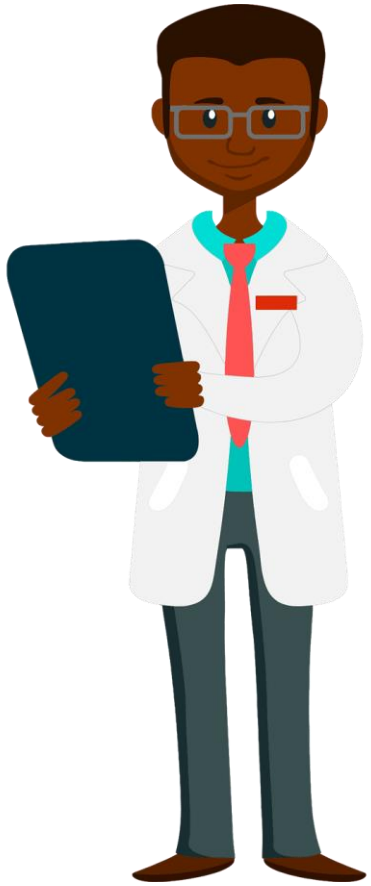
II.4 biomechanical instrumented gait analysis to assist legal medicine

II.4 ASSISTANCE IN LEGAL MEDICINE

Malingering

Is falsification or profound exaggeration of illness (physical or mental) to gain external benefits such as avoiding work or responsibility, seeking drugs, avoiding trial (law), seeking attention, avoiding military services, leave from school, paid leave from a job, among others.

Is not a psychiatric disorder!



II.4 ASSISTANCE IN LEGAL MEDICINE

Modes of Malingering

- Caused disease
- Alleged disease
- Immitted disease
- Exaggerated disease
- Imputed disease
- Disguised disease

II.4 ASSISTANCE IN LEGAL MEDICINE

Example 1

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

ELSEVIER

GAIT & POSTURE

Short communication

Interpreting sources of variation in clinical gait analysis: A case study

Stephanie L. King[a], Gabor J. Barton[a,*], Lakshminarayan R. Ranganath[b]

Discuss sources of gait deviations during a gait analysis to identify in an objective way the malingering from a patient.

- Gait deviation due to experimental error
- A genuine gait deviation is a trusted abnormality
- Intentional or non-habitual gait deviations are simulating by the patient

Patient with severe osteoarthritis

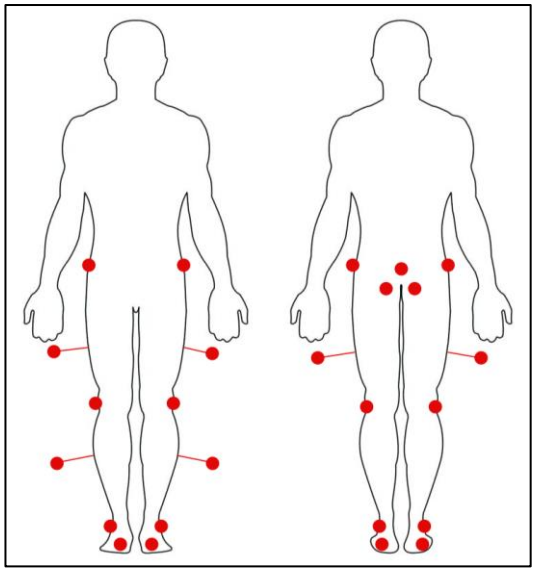


Figure - Helen Hayes marker set configuration

II.4 ASSISTANCE IN LEGAL MEDICINE

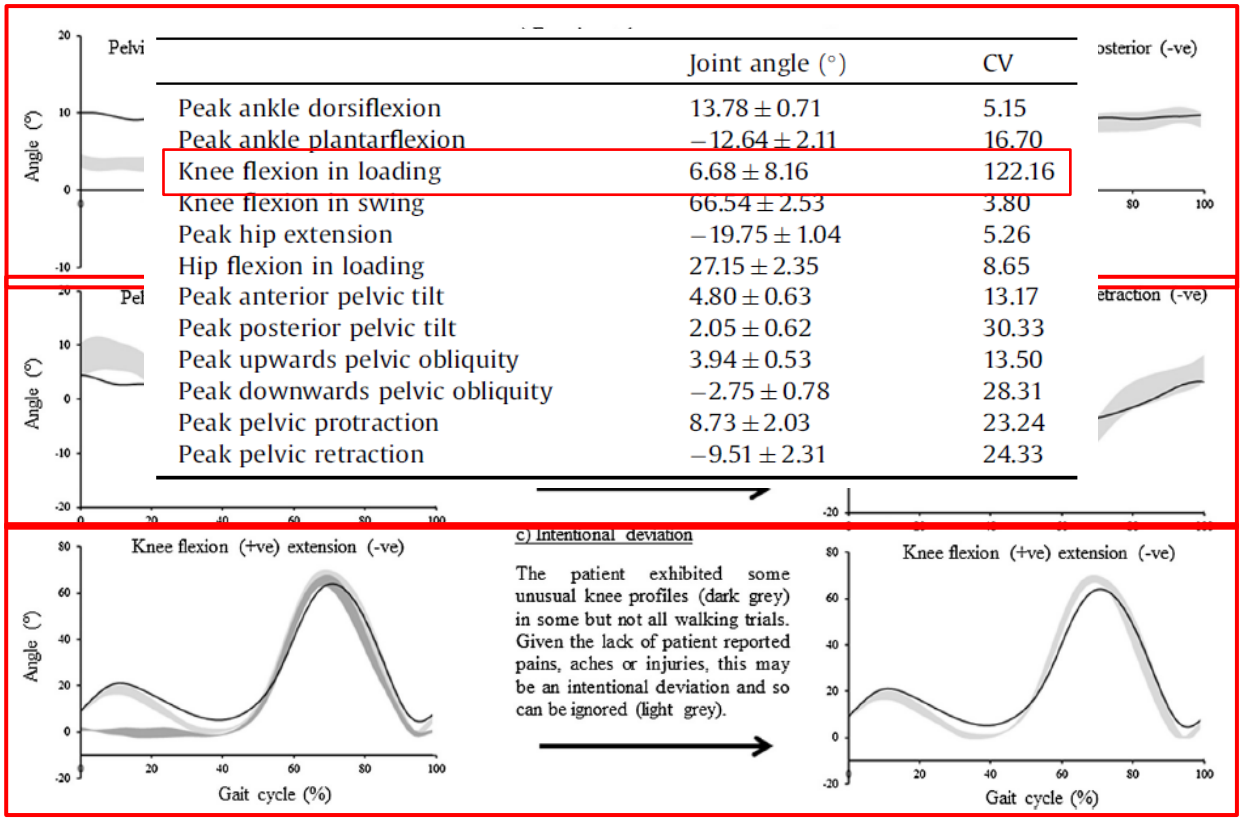
Example 1

$$CV = \frac{\sigma}{\mu}$$

CV ⟶ coefficient of variation

σ ⟶ standard deviation

μ ⟶ mean



	Joint angle (°)	CV
Peak ankle dorsiflexion	13.78 ± 0.71	5.15
Peak ankle plantarflexion	−12.64 ± 2.11	16.70
Knee flexion in loading	6.68 ± 8.16	122.16
Knee flexion in swing	66.54 ± 2.53	3.80
Peak hip extension	−19.75 ± 1.04	5.26
Hip flexion in loading	27.15 ± 2.35	8.65
Peak anterior pelvic tilt	4.80 ± 0.63	13.17
Peak posterior pelvic tilt	2.05 ± 0.62	30.33
Peak upwards pelvic obliquity	3.94 ± 0.53	13.50
Peak downwards pelvic obliquity	−2.75 ± 0.78	28.31
Peak pelvic protraction	8.73 ± 2.03	23.24
Peak pelvic retraction	−9.51 ± 2.31	24.33

Figure – Results from King S. et al. 2017

Instrumented Analysis of Gait - Clinical Application

III. KEY IDEAS

III. KEY IDEAS

1) The instrumented biomechanical assessment of gait is useful in medicine as it allows characterizing the population, supporting medical diagnosis and decision-making, and evaluating the effectiveness of medical and rehabilitative gait treatments.
2) In the sports field, the instrumented biomechanical gait evaluation allows us to analyze the sporting gesture, the performance conditions that can cause injury, and the impact of the sporting activity itself on the population. This information is useful in sports such as race-walking, hiking or Nordic walking.
3) In the area of ergonomics, the instrumented biomechanical gait assessment allows to analyze the impact of working conditions on the lower extremities and lumbar spine, being able to clearly identify changes in the worker's apparel or in the elements surrounding the job as the type of ground or the most demanding actions.
4) Within legal medicine, instrumented biomechanical gait evaluation allows the identification of abnormal and inconsistent movement patterns, related to simulation, which are usually characterized by a great variability of the repetitions recorded.

Instrumented Analysis of Gait - Clinical Application

IV. REFERENCES

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