Biomechanics:
the thinking of the doctor and the engineer together

Kiss Rita

Biomechanics

Herman Ludwig von Helmholz (1821-1894): The application mechanics-science to the study of biological systems - usually living ones.

THEORETICAL RESEARCH:

Application of mechanical laws from the cellular level to model the various physiological functions of the entire organism.

PRACTICAL (CLINICAL) RESEARCH:

Description of the movement of human body parts, the vascular system, the skeletal system and the mechanical functioning of living tissues.

Inter- and multidisciplinary research is the joint thinking of doctors, biologists, engineers, and physicists with the aim of improving the quality of life and living conditions.

Dialogue between doctor and engineer

Preparation

Task of doctors:

definition of research goals

motion selection

→

Task of engineers

method selection

parameter selection

new parameter definiation

validation

influence parameters

→

Task of doctors:

inclusion exclusion criteria

patient and control group

physiological examination

→

Measu-rement

(doctor and engineer together)

→

Data processing

Task of engineers

determination of calculated parameters from measured parameters

statistical analysis

→

Task of doctors

discussion of results

The engineer's task is to develop tools and methods for clarification of diagnosis and effect.

Our important research

A. **DETERMINATION OF THE MECHANICAL PROPERTIES OF BONES, LIGAMENTS AND TENDONS**

- development of clamps
- analysis of the different effects (storage, sterilization) in the case of allografts (grafts from tissue bank)

B. **MOTION ANALYSIS**

- measuring devices: Zebris ultrasound-based, OptiTrack optical-based systems, acustic test
- type of motion: posture (form of spine) position, motion (gait, sport-movement)

C. **EXAMINATION OF BALANCE ABILITY**

- balance while standing (stabilometry)
- balancing after sudden change of direction

NAGYMÁTÉ GERGELY FELVÉTELE

Mechanical properties of human tissues

DETERMINATION OF THE MECHANICAL PROPERTIES OF BONES, LIGAMENTS AND TENDONS

- development of clamps
- analysis of the different effects (storage, sterilization) in the case of allografts (grafts from tissue bank)

Hangody György, Pap Károly, Hangody László, Szebényi Gábor, Faragó Dénes, Göckler Daniella

Effect of clamp

medical thread

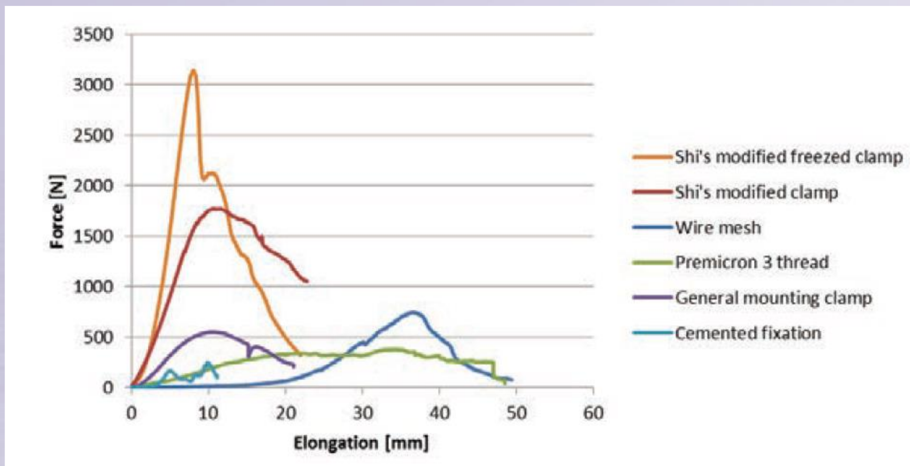
medical cement

wire mesh

Shi's modified clamp

thread

freezed



Method

- Instron 8872 (25kN loading cell), Fasttrack 8800 control unit
- force-elongation diagram
- temperature measurement with thermal camera

Result

- Failure (tear) at Shi's modified clamp with dry ice (frozen)
- Maximum load increased significantly
- No supercooling durint the test

Hangody, Gy; Szebényi, G; Abonyi, B; Kiss, RM; Hangody, L; Pap, K: Does a different dose of gamma irradiation have the same effect on five different types of tendon allografts? — a biomechanical study. *International Orthopaedics*, 41: 357-265. 2017.

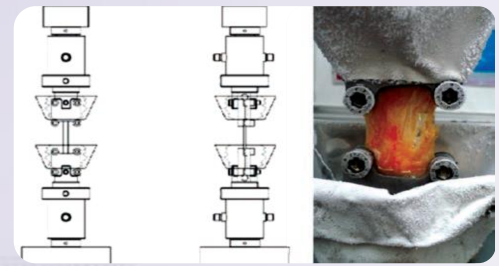
Mechanical properties of tendon – cyclic test

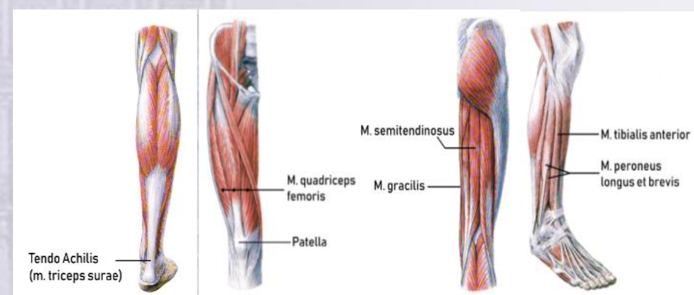
Effect of gamma irradiation (sterilization) on the elastic modulus of tissue bank (allograft) tendons

Sterilization (50-50-50 ín)
no sterilization (A),
21 kGy dose (B bactericidal dose),
42 kGy dose (C virucidal dose)

Method
Instron 8872 (25kN loading cell),
Fasttrack 8800 control unit
Pre-tensioning: 50N, 30 sec
20-250 N 1000 cycle (2Hz) and then
load to failure (20 mm/minutes)

Modified Shiıs clamp with dry ice



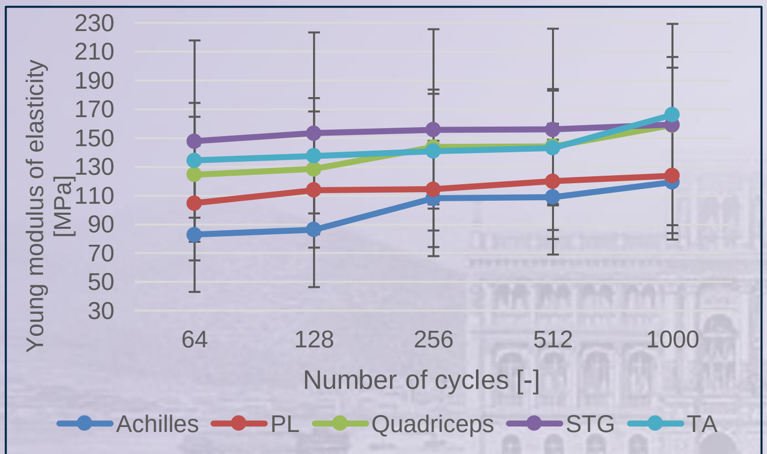


Hangody, Gy; Szebényi, G; Abonyi, B; Kiss, RM; Hangody, L; Pap, K: Does a different dose of gamma irradiation have the same effect on five different types of tendon allografts? — a biomechanical study. *International Orthopaedics*, 41: 357-265. 2017.

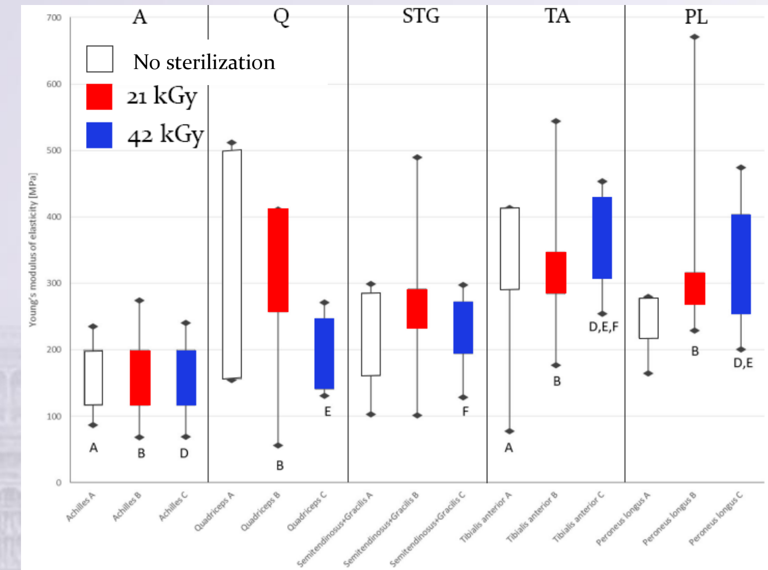
Mechanical properties of tendon – cyclic test

Analysis of Young modulus

- Different tendons react differently
- The quadriceps (the most common in the case of own grafts) is the most sensitive (opposite behavior)



Mean of Young modulus after sterilization with high dose

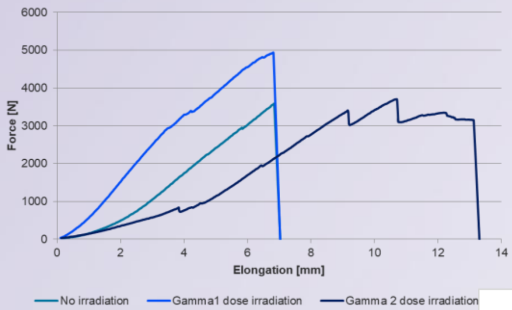


Tibialis anterior és peroneus longus are recommended

Hangody, Gy; Szebényi, G; Abonyi, B; Kiss, RM; Hangody, L; Pap, K: Does a different dose of gamma irradiation have the same effect on five different types of tendon allografts? — a biomechanical study. *International Orthopaedics*, 41: 357-265. 2017.

Mechanical properties of tendon – static test

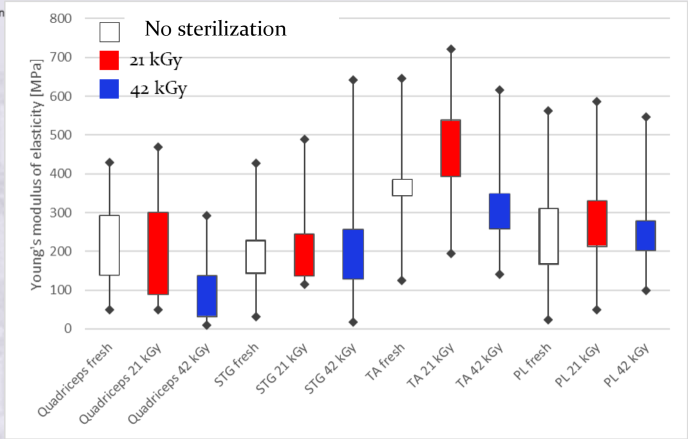
Effect of gamma irradiation (sterilization) on the diagram of load-elongation of tissue bank (allograft) tendons



Sterilization (50-50-50 ín)
no sterilization (A),
21 kGy dose (B bactericidal dose),
42 kGy dose (C virucidal dose)

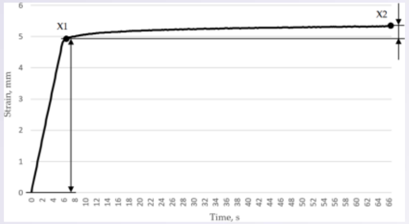
Method
Instron 8872 (25kN loading cell),
Fasttrack 8800 control unit
Pre-tensioning: 50N, 30 sec
load to failure (20 mm/minutes)

Tibialis anterior és peroneus longus are recommended



Hangody, Gy; Szebényi, G; Abonyi, B; Kiss, RM; Hangody, L; Pap, K: Does a different dose of gamma irradiation have the same effect on five different types of tendon allografts? — a biomechanical study. *International Orthopaedics*, 41: 357-265. 2017.

Mechanical properties of tendon – creep test



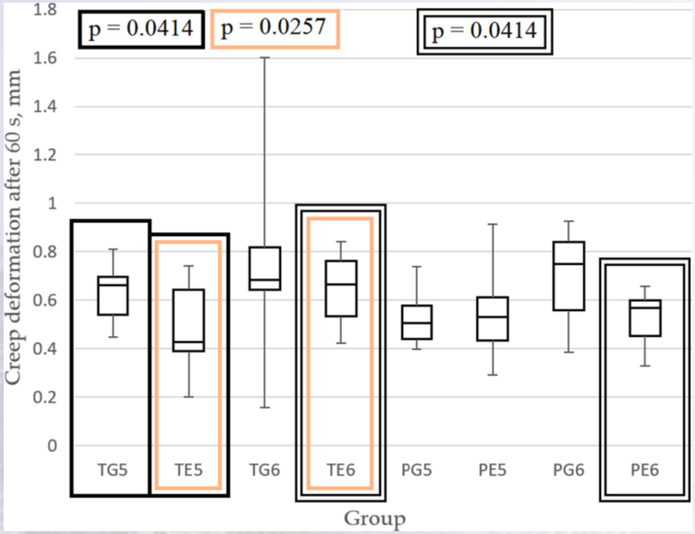
Effect of gamma and electron radiation on creep properties

Sterilization (60 Tibialis anterior és 60 Peroneus longus)
21 kGy gamma-irradiation (G)
21 kGy elektron-irradiation (E)
Storage time: 5 és 6 months

Methods
Instron 8872 (25kN loading cell), Fasttrack 8800 control unit
Loading (static): 250 N 60 s

Analyzing of creep parameters

- In some cases, a large standard deviation
- The method of sterilization and the duration of storage change the creep
- Tendon treated with electron radiation stored for 5 months is best
- Tibialis anterior is more sensitive



Values of creep deformation after 60 s of static load of 250 N. Median, 25 and 75% percentile, minimum and maximum values are illustrated

Gökler, DJ ; Faragó, D; Szebényi, G; Kiss, RM; Pap, K: The effect of sterilization and storage on the viscoelastic properties of human tendon allografts. Journal of Biomechanics, 127: Paper 110697, 8 p. 2021.

B./ Motion analysis

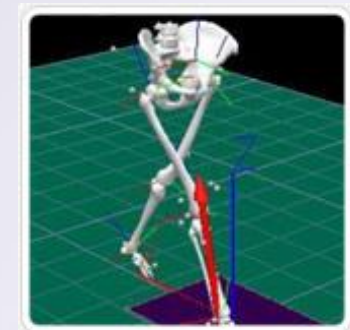
Goals:

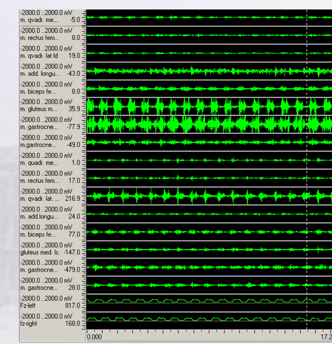
Record and display

- the kinematics of the movement;
- the magnitude and direction of the reaction force;
- the electrical potential change of the muscles.

Calculate

- characteristics of movement (parameters);
- forces generated in joints;
- characteristic of muscle activity.





Knoll Zsolt, Illyés Árpád, Bejek Zoltán, Holnapy Gergely, Takács Mária, Bodzay Tamás, Pethes Ákos, Kocsis László, Zsidai Attila, Paróczai Róbert, Nagymáté Gergely, Petró Bálint, Pálya Zsófia, Rácz Kristóf, Molnár Cecilia

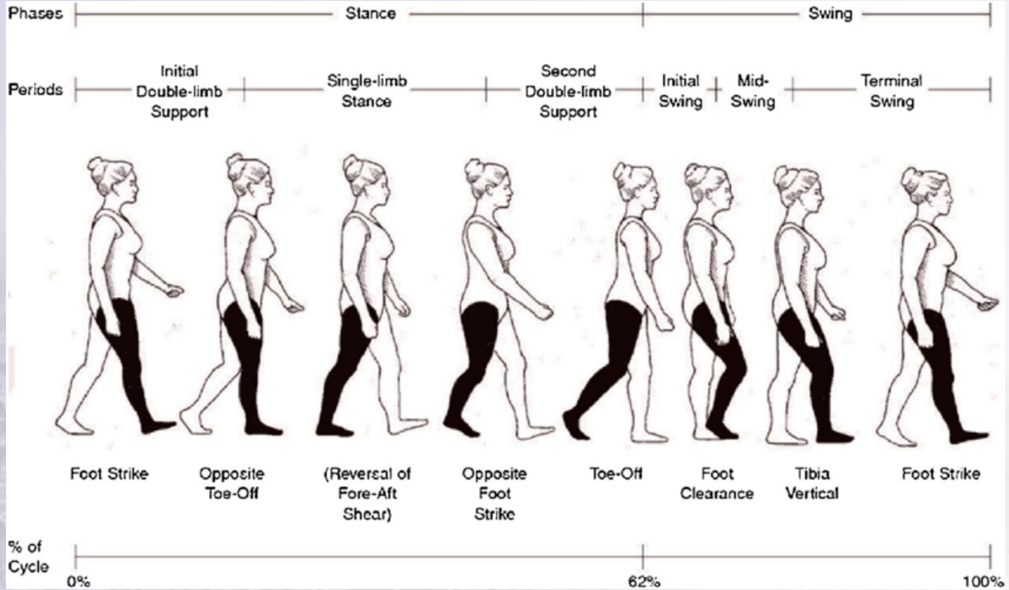
Gait

Leonardo: „perfect movement”

200 bones, 650 muscles, large joints and ligaments are involved;

Characteristic:

- complex,
- cyclic,
- continuous,
- regular,
- stable, balancing.



Gait

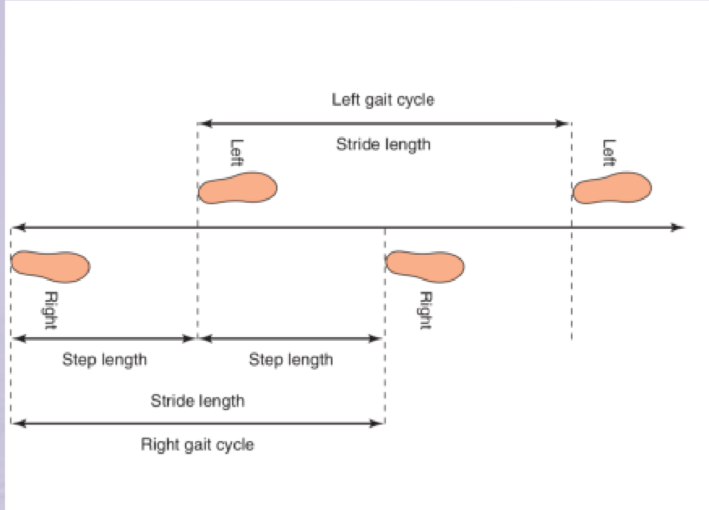
[Takács M]

How can it be characterized and compared numerically?

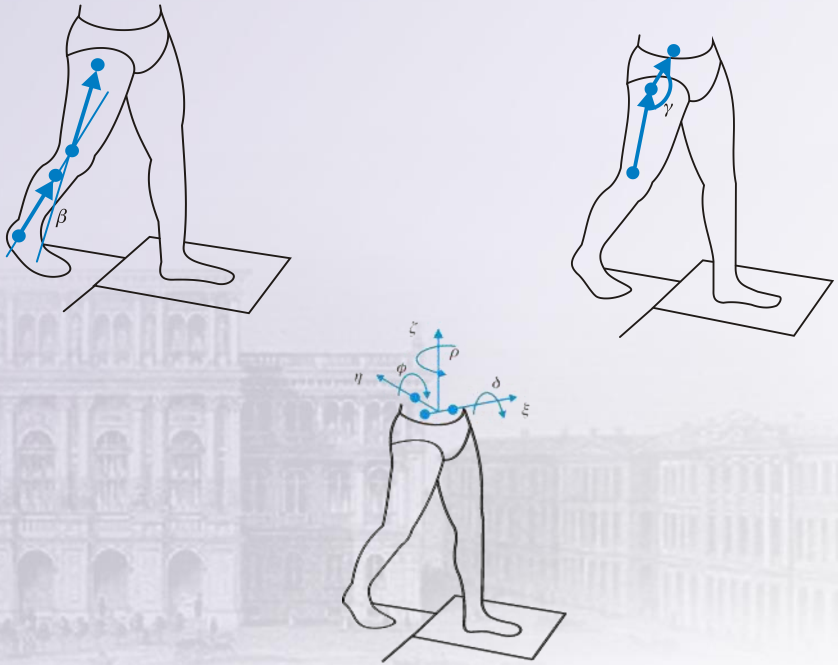
Gait parameters

Time-distance parameters

[Vaughan és mtsai, 1999]



Angle parameters

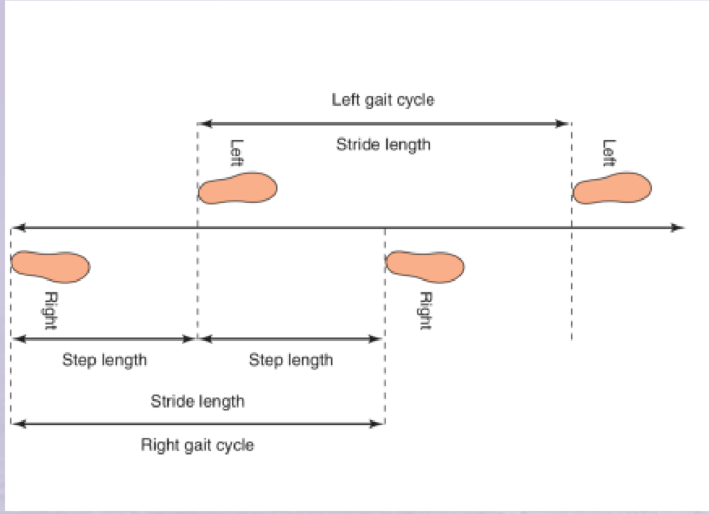


Kiss, RM; Kocsis, L; Knoll, Zs: Joint kinematics and spatial temporal parameters of gait measured by an ultrasound based system *Medical Engineering & Physics,* 26: 611-620, 2004.

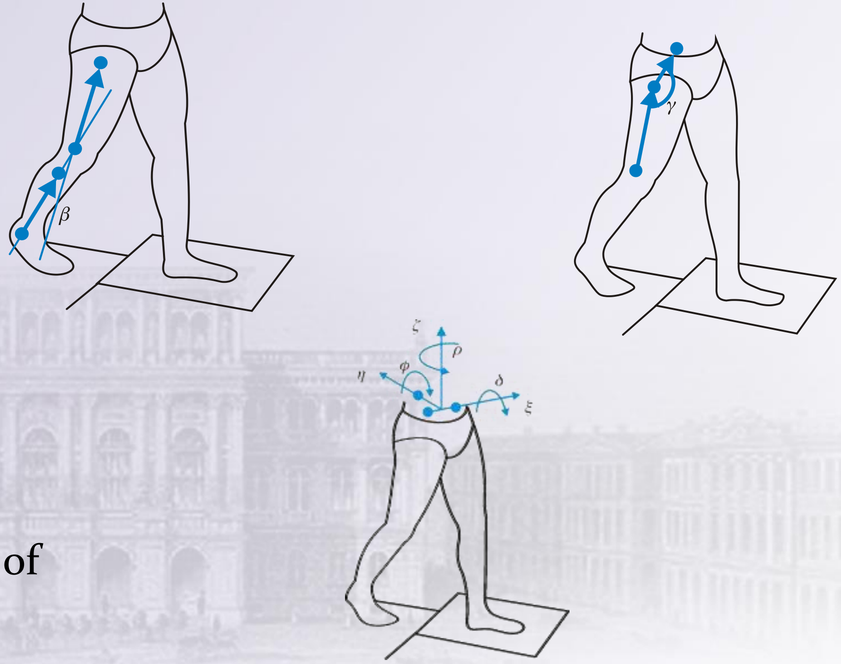
Gait parameters

Time-distance parameters

[Vaughan és mtsai, 1999]



Angle parameters



Determination (measuring) the spatial position of anatomical points

Kiss, RM; Kocsis, L; Knoll, Zs: Joint kinematics and spatial temporal parameters of gait measured by an ultrasound based system *Medical Engineering & Physics*, 26: 611-620, 2004.

Motion analysis

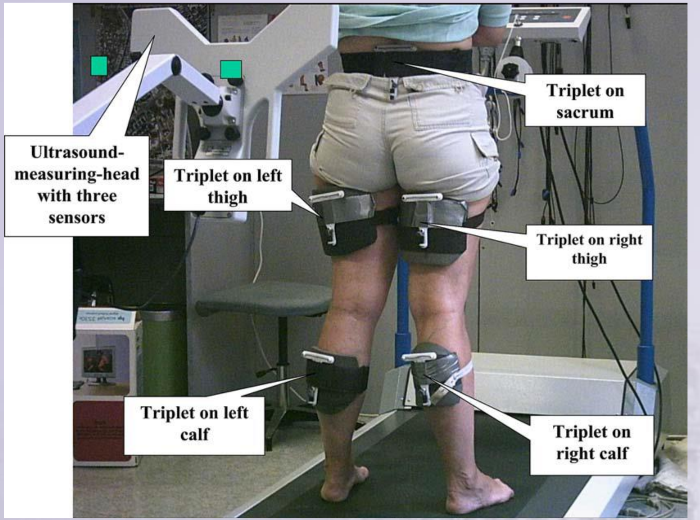
Types

- **Development of measuring method for Zebris ultrasound-based system (walking, sports movements, spine tests)**
- Development of a new measurement method with the OptiTrack optical-based system (verification, reability, walking, sports movements, spine)
- Development of an acoustic gait test method

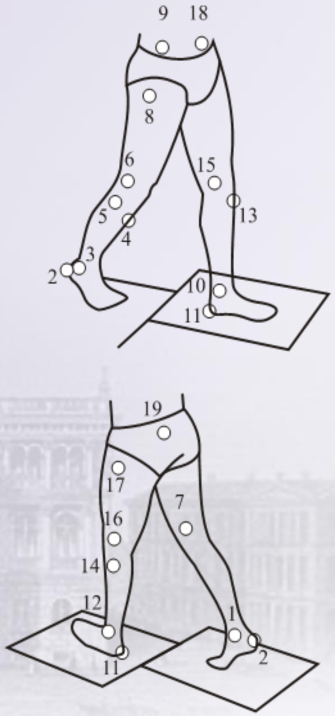
Knoll Zsolt, Illyés Árpád, Bejek Zoltán, Holnapy Gergely, Takács Mária, Bodzay Tamás, Pethes Ákos, Kocsis László, Zsidai Attila, Paróczai Róbert, Nagymáté Gergely, Petró Bálint, Pálya Zsófia, Rácz Kristóf, Molnár Cecília

Ultrasound-based gait analysis

Determination (measuring) the spatial position of anatomical points



Gait analysis with one measuring head (back position) [Kocsis L.]



Our model is composed of 19 anatomical points identified by the position of fundamental points on segments

Kiss, RM; Kocsis, L; Knoll, Zs: Joint kinematics and spatial temporal parameters of gait measured by an ultrasound based system *Medical Engineering & Physics*, 26: 611-620, 2004.

Zebris ultrasound-based gait analysis

We proved with a Zebris ultrasound-based gait analysis:

- for the analysis of the gait pattern, the tests must be performed at the same speed, while for the examination of the regularity of the gait, the tests must be performed at a freely chosen speed;
- different orthopedic lesions, surgeries and types of surgery significantly, but in different ways, affect gait and gait regularity;
- deteriorated joint movements are usually compensated by increased pelvic movement;
- If the joint osteoarthritis is deteriorted, the method of increasing walking speed changes;
- meniscectomy results in early signs of joint osteoarthritis.

Bejek, Z; Paroczai, R; Illyés, Á; Kiss, RM: The influence of walking speed on gait parameters in healthy people and in patients with osteoarthritis. *Knee Surgery Sports Traumatology Arthroscopy*, 14: 612-622. 2006.

Kiss, RM: Effect of walking speed and severity of hip osteoarthritis on gait variability. *Journal of Electromyography and Kinesiology*, 20: 1044-1051. 2010.

Kiss, RM; Illyés Á: Comparison of gait parameters in patients following total hip arthroplasty with a direct-lateral or antero-lateral surgical approach. *Human Movement Science*, 31: 1302-1316. 2012.

Holnapy, G; Illyés, Á; Kiss, RM: Impact of the method of exposure in total hip arthroplasty on the variability of gait in the first 6 months of the postoperative period. *Journal of Electromyography and Kinesiology*, 23: 966-976. 2013.

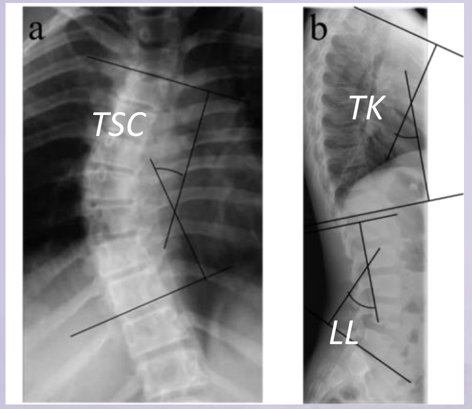
Bejek, Z; Paróczai, R; Szendrői, M; Kiss, RM: Gait analysis following TKA: comparison of conventional technique, computer-assisted navigation and minimally invasive technique combined with computer assisted navigation. *Knee Surgery Sports Traumatology Arthroscopy*, 19: 285-291. 2011.

Kiss, RM; Bejek, Z; Szendrői, M: Variability of gait parameters in patients with total knee arthroplasty. *Knee Surgery Sports Traumatology Arthroscopy*, 20: 1252-1260. 2012.

Magyar, M; Knoll, Zs; Kiss, RM: The influence of medial meniscus injury and meniscectomy on the variability of gait parameters. *Knee Surgery Sports Traumatology Arthroscopy*, 20: 290-297. 2012.

Spine examination

X-ray



Cobb method

TK: thoracic kyphosis

LL: lumbar lordosis

TSC: thoracic scoliosis curvature

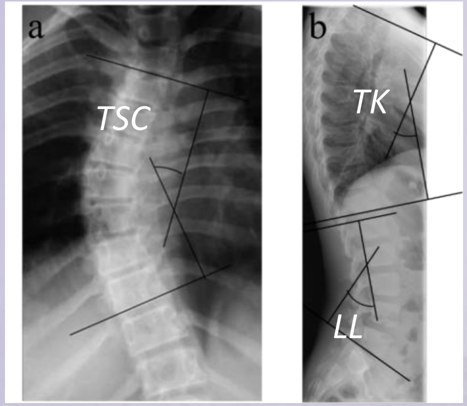
LSC: lumbar scoliosis curvature

Takács Mária, Orlovits Zsanett, Jáger Bence, Tamás Péter

Spine examination

Goal: In addition to reducing X-ray radiation, numerical characterization of the shape of the spine - non-invasive measurements (Zebris spine examination)

X-ray



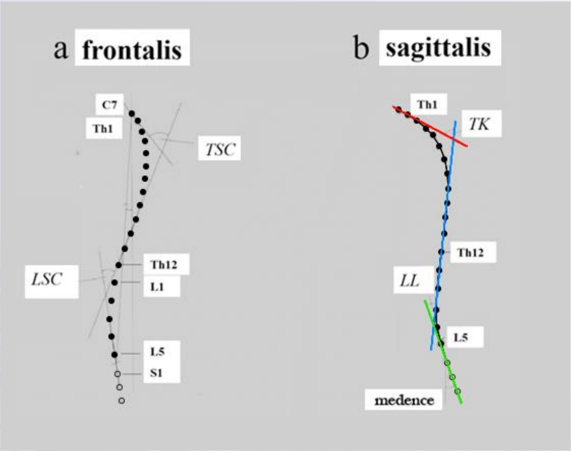
Cobb method

TK: thoracic kyphosis
LL: lumbar lordosis
TSC: thoracic scoliosis curvature
LSC: lumbar scoliosis curvature

Zebris

Determining the spatial position of processus spinous

Spline method on point cloud to fit the spatial curve

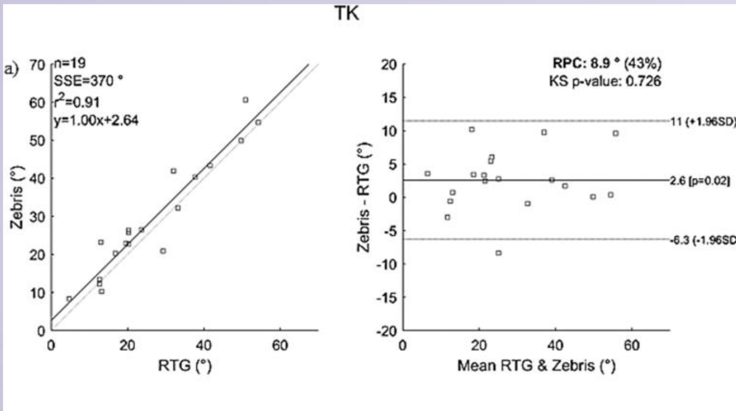


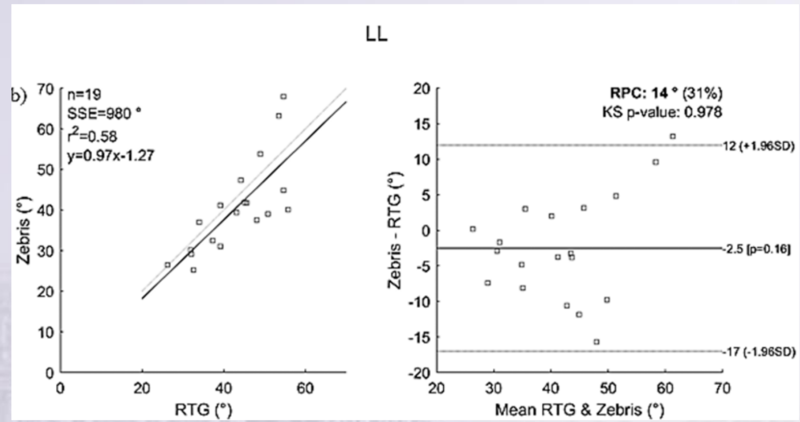
Tangential lines to the vertebrae used in the Cobb method, angles subtended by tangents

Takács Mária, Orlovits Zsanett, Jáger Bence, Tamás Péter

Test-retest reliability

Comparison of angles determined on X-ray using the Cobb method and on ZEBRIS with the Bland-Altman method - 19 children with scoliosis



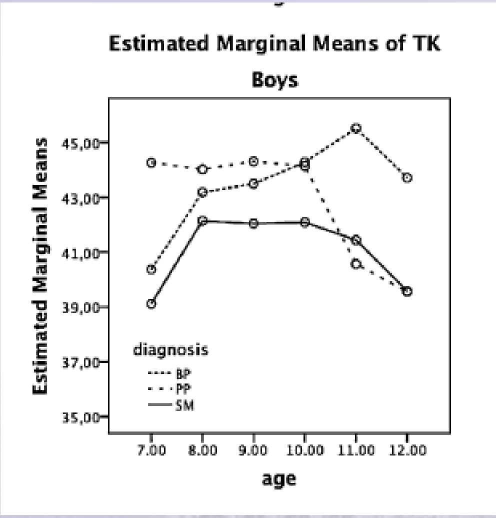


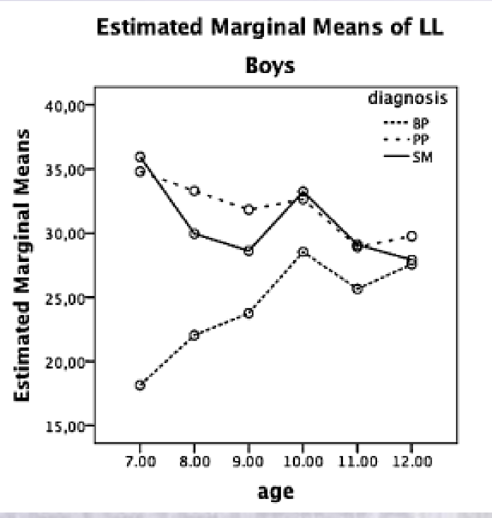
The correlation between the values of the sagittal curvatures (rTK=0.95; rLL=0.76) is excellent and very good, but the differences increase for LL values greater than 50°. The correlation of the frontal thoracolumbar/lumbar curvatures is excellent (rLSC=0.85), but its magnitude is systematically underestimated, mainly due to the rotational and bony deformity of the scoliosis vertebrae.

Takács, M; Orlovits, Zs; Jáger, B; Kiss, RM: Comparison of spinal curvature parameters as determined by the ZEBRIS spine examination method and the Cobb method in children with scoliosis. *PLoS One*, 13: Paper: e0200245, 19p. 2018.

Examples

A sufficiently accurate and precise measurement can be carried out with Zebris spine examination system.





As a result of bad posture the curvatures of the spine and the tendency of changes caused by age change significantly.

Takács, M; Rudner, E; Kovács, A; Orlovits, Z; Kiss, RM: The assessment of the spinal curvatures in the sagittal plane of children using an ultrasound-based motion analysing system. Annals of Biomedical Engineering, 43: 348–62. 2015.

Motion analysis

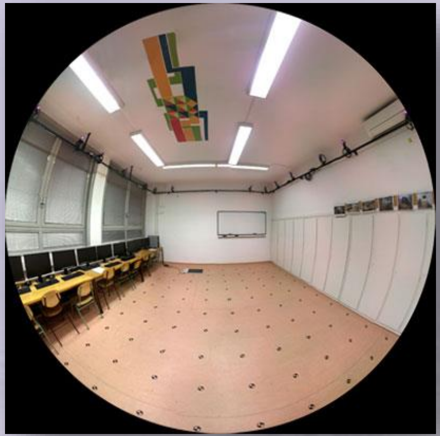
Types

- Development of measuring method for Zebris ultrasound-based system (walking, sports movements, spine tests)
- **Development of a new measurement method with the OptiTrack optical-based system (verification, reability, walking, sports movements, spine)**
- Development of an acoustic gait test method

Knoll Zsolt, Illyés Árpád, Bejek Zoltán, Holnapy Gergely, Takács Mária, Bodzay Tamás, Pethes Ákos, Kocsis László, Zsidai Attila, Paróczai Róbert, Nagymáté Gergely, Petró Bálint, Pálya Zsófia, Rácz Kristóf, Molnár Cecília

OptiTrack optical-based motion capture system

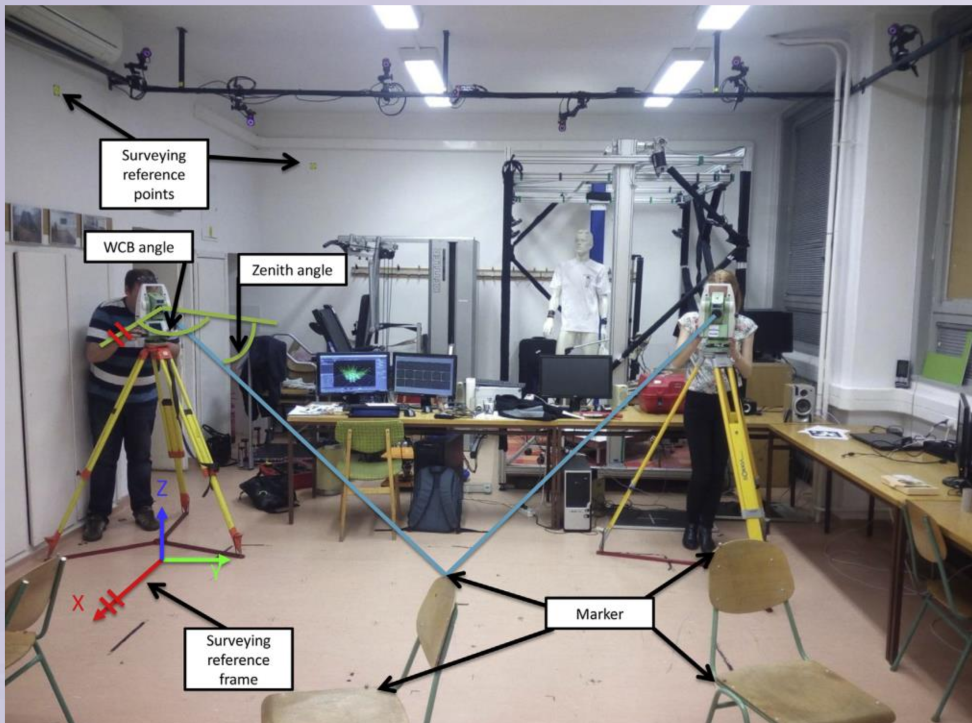
Goals:
- determination of accuracy
- marker group development
- determination of the precision of anatomical point selection

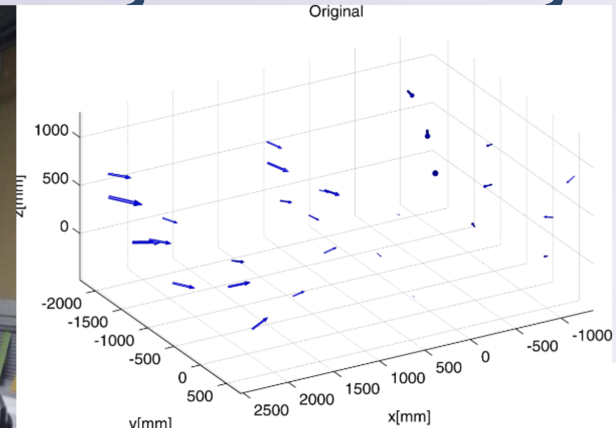


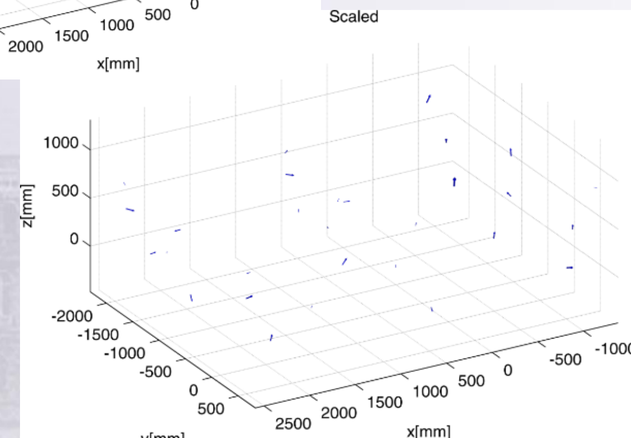

OptiTrack (NaturalPoint, Corvallis, OR, USA):1
8 Flex13 cameras 3 meters above the ground
3 USB hubs
OptiTrack Motive v1.10.3 software
120 Hz sampling frequency

Molnár Cecilia, Nagymáté Gergely, Pálya Zsófia, Petró Bálint, Rácz Kristóf, Tamás Péter, Tuchband Tamás, Rózsa Szabolcs

Test-retest reability– Geodesy







Nagymáté, G; Tuchband, T; Kiss, RM: A novel validation and calibration method for motion capture systems based on micro-triangulation. Journal of Biomechanics, 74: 16-22. 2018.

Precision

Goal: accuracy of anatomical landmark placement methods

Accuracy of anatomical landmark placement methods

$$TDRMSE = \sqrt{\frac{\sum_{i=1}^{n} TDE_i}{n}}$$

$$TDE_i = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2 + (z_i - \bar{z})^2}$$

	TDRMSE (mm)
#1 examiner	6.33±4.13
#2 examiner	5.42±2.30
#2 examiner	6.72±3.80
Interexaminer	8.79±5.14

The actual size and location of the anatomical points significantly determines the precision.

In the case of a series of measurements, the examiner must be the same.

Rácz, K; Nagymáté, G; Kovács, T; Bodzay, T; Kiss, RM: Accuracy of anatomical landmark placement methods for gait analysis. International Journal of Mechanics and Controls, 19: 3-10. 2018.

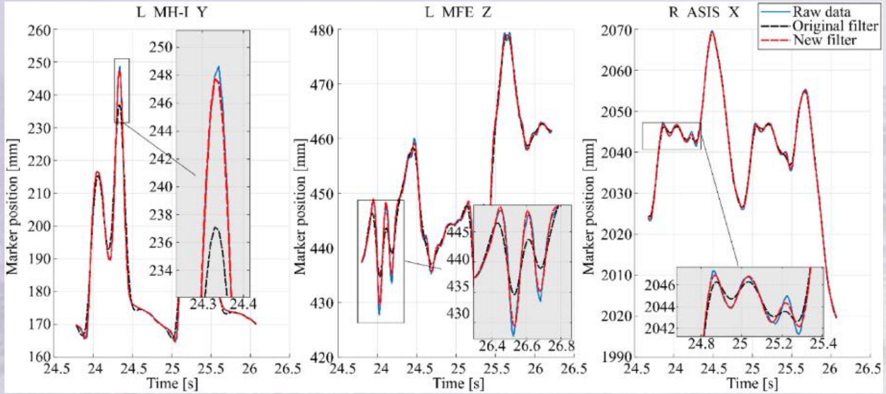
Measurement – marker displacement data filtering

Goal: more precise definition of extreme values

General (Winter et al.,) method independent of the measured value - 2nd order, Butterworth 6Hz lowpass, zero-lagg filtering.

In practice, however, the spectrum of movement of anatomical points depends on the person's step frequency. The method tends to underestimate the local extreme values of the signal.

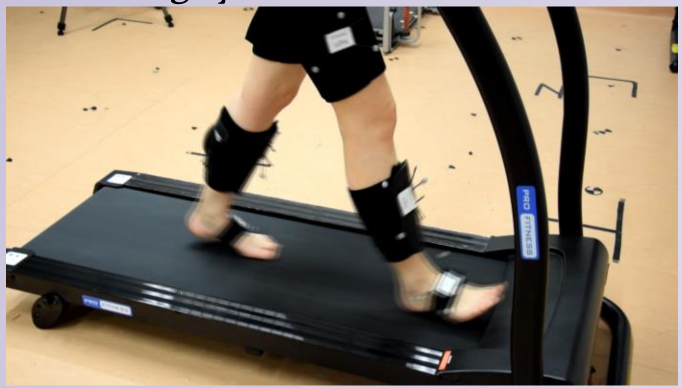
New solution: determination of the cutting frequency as a function of the step frequency



Rácz, K; Kiss, RM: Marker displacement data filtering in gait analysis: A technical note. Biomedical Signal Processing and Control, 70: Paper: 102974, 5p. 2021.

Measurement -examples

Accurate and precise measurements can be performed with the OptiTrack optical-based measuring system.



- application of measurement groups
- calculation of the spatial position of anatomical points from the spatial position of markers with homogeneous transformation
- calculation of gait characteristics from the spatial position of anatomical points (OpenSim))

Measurement -examples

Accurate and precise measurements can be performed with the OptiTrack optical-based measuring system.

Analysis of elderly/ pathological gait

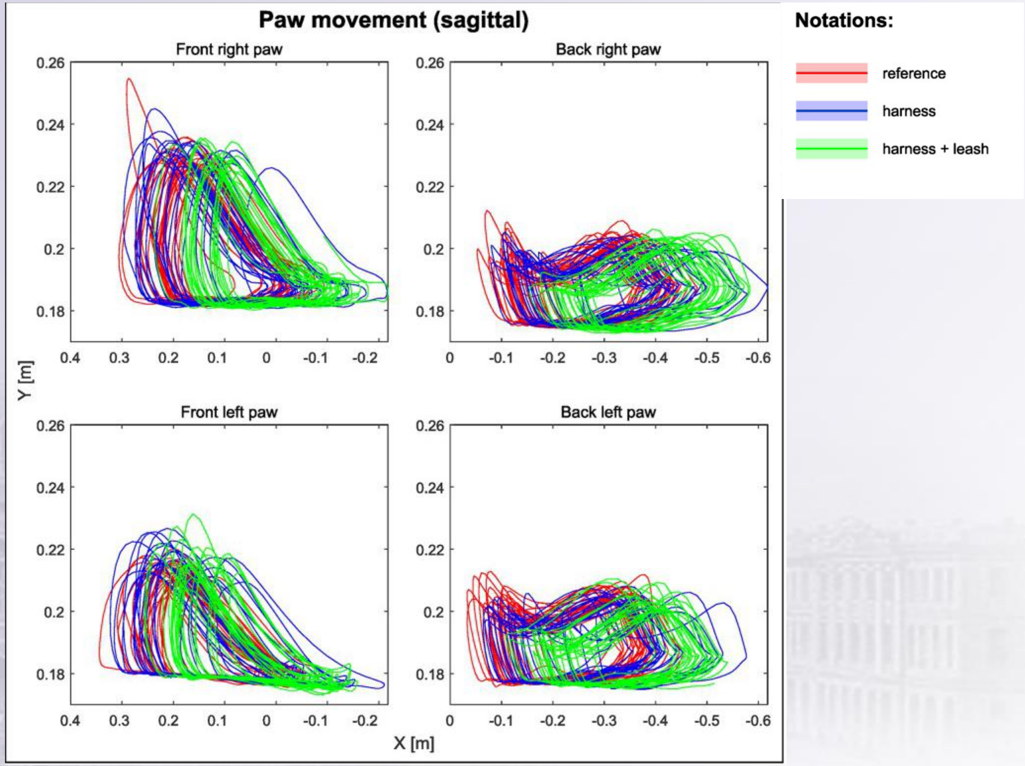
- application of measurement groups
- calculation of the spatial position of anatomical points from the spatial position of markers with homogeneous transformation
- calculation of gait characteristics from the spatial position of anatomical points (OpenSim))

Measurement -examples

Accurate and precise measurements can be performed with the OptiTrack optical-based measuring system.

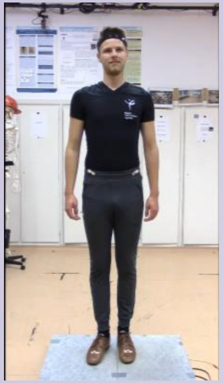
Animals motion analysis

Measurement -examples

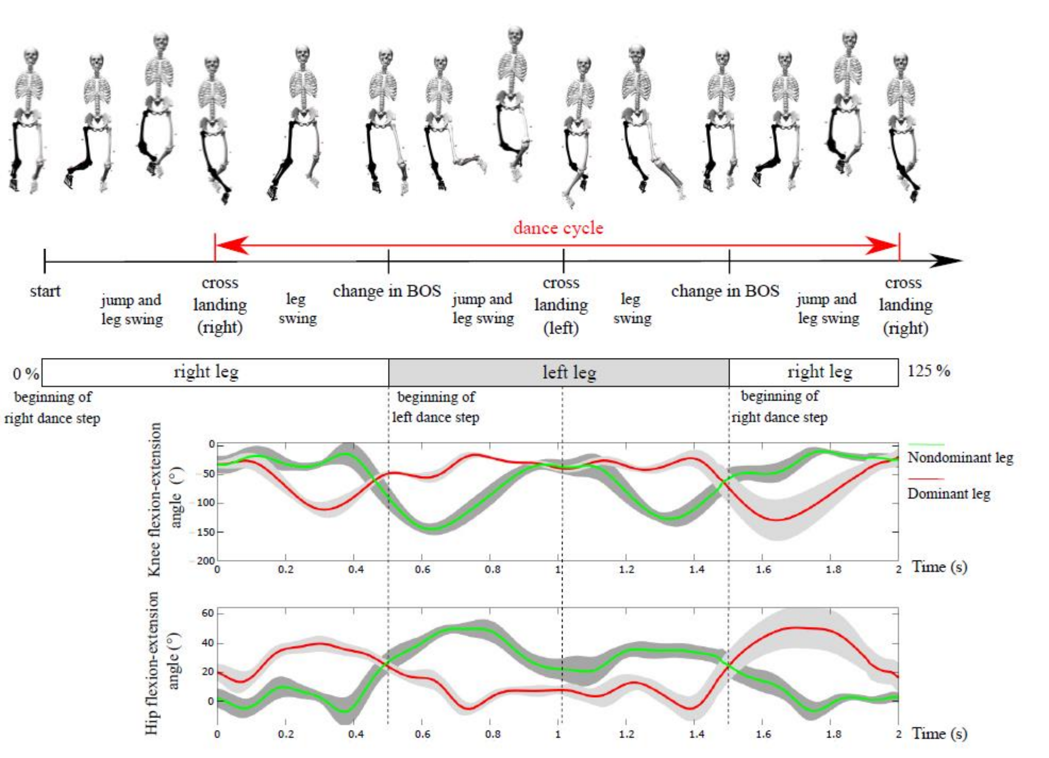


Pálya, Zs; Rácz, K; Nagymáté, G; Kiss, Rita M.: Development of a detailed canine gait analysis method for evaluating harnesses: A pilot study
PLOS ONE 17 : 3 Paper: e0264299 2022

Analysing of the „Kalocsai Mars" Dance



MOLNÁR CECILIA FELVÉTELE



5 female és 6 male
after 1 year of intensive dancing
10 times half a minute of dancing with half-minute breaks

Molnár, C; Pálya, Zs; Kiss, RM: Static Balancing Ability and Lower Body Kinematics Examination of Hungarian Folk Dancers: A Pilot Study Investigating the "Kalocsai Mars" Dance Sequence. Applied Sciences-Basel 11(18): Paper: 8789, 14p. 2021

Acustic gait analysis

Acustic gait analysis

young girl walking in high heels

Acustic gait analysis

young girl walking in high heels

Rácz Kristóf

Acustic gait analysis

young girl walking in high heels

old man shuffling

Acustic gait analysis

Gait and the sound it makes are unique. What information does it contain?

Is it possible to establish such characteristics based on the sound of walking (feasibility)?

Does it make sense with the current walking test methods (right to exist)?

Rácz,K; Kiss, RM: Footstep Sounds as Biometric Authentication Using a Deep Convolutional Neural Network. In: Helmut, J. Holl Book of Abstracts 37th Danubia Adria Symposium on Advances in Experimental Mechanics Linz, Ausztria : Johannes Kepler University 163-164. 2021

Flowchart

Steps

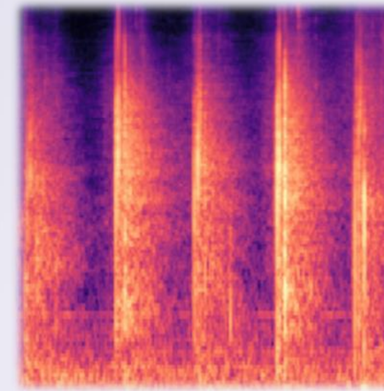
Data collection
Recording footsteps

Filtration
Background noise filtering/minimization

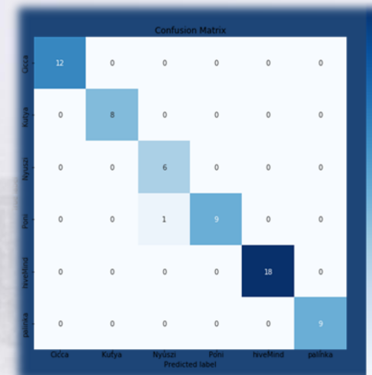
Preparation
Transforming the data into a form that can be used as input to the neural network

Designing the structure of a neural network
Specifying the structure of the neural network, hyperparameter optimization

Teaching and evaluation
Teaching a neural network, evaluating the obtained results



spectogram



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Acustic gait analysis

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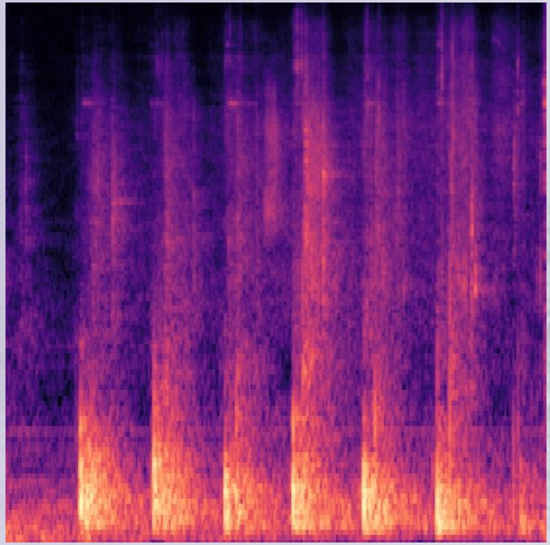
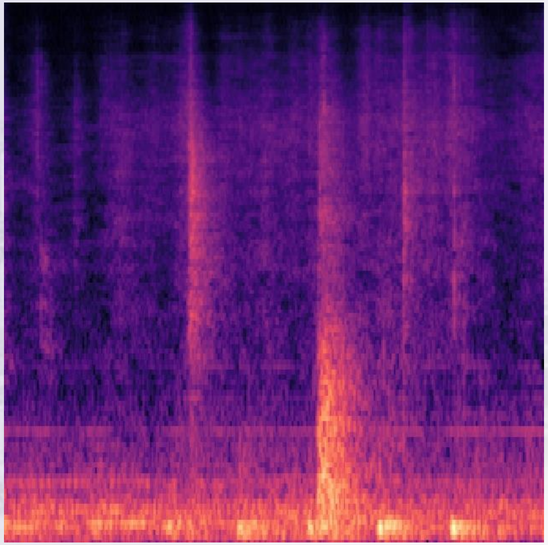
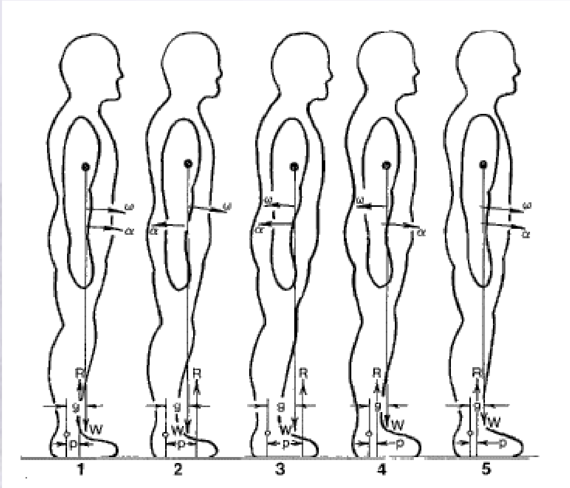




Examination of balance ability

- examination of balancing ability while standing (definition of parameters, filtering of parameters)
- examination of the balancing ability after a sudden perturbation (development of a new method, validation, definition of new parameters, data bank)
- inverted double pendulum model



Stabilometry

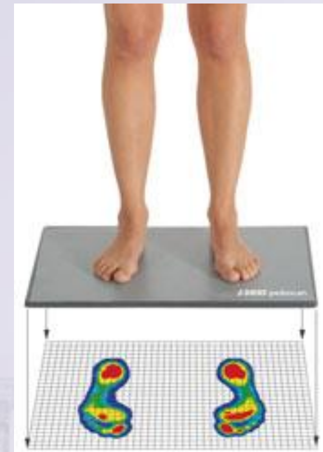
Fast, simple and widespread scientific and diagnostic measurement:

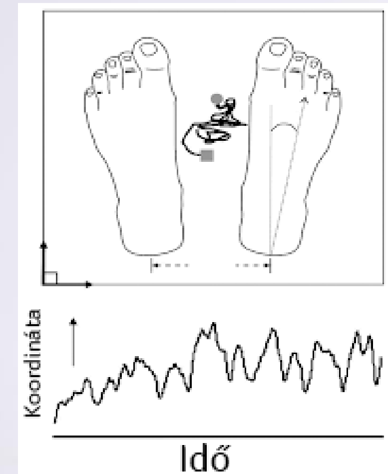
Measurement of the pressure distribution under the sole while standing

- on two legs/one leg with eyes open or closed
- 30s or 60s (rarely 90s or 120s)

The position of the center of pressure and its change can be calculated from the pressure distribution

- distance and time parameters
- frequency parameters

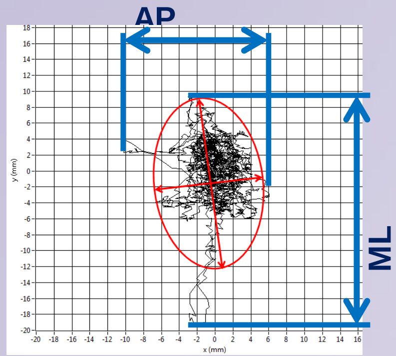


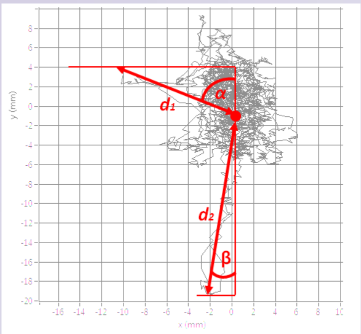


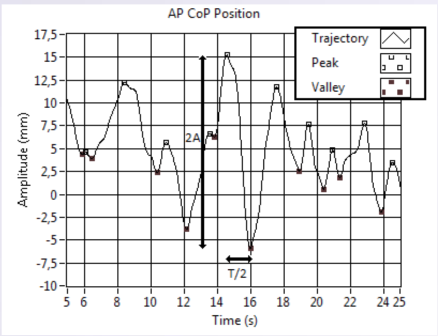
The use of the parameters is not uniform, the independence of the parameters is not known.

Goal: to reduce the number of parameters by statistical analysis based on the data of measurements on two legs with eyes open and closed, and on one leg with eyes open

Time- distance-frequency parameters



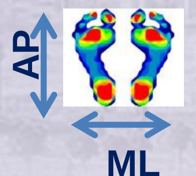




path length
confidence ellipse axis, axis ratio, **area**
Maximum path velocity
AP-ML range ratio

Maximum deviation in anterior (d_1)and posterior (d_2) direction

Larges amplitude in the AP direction (LA)
Frequency power ratios between low-medium and medium-high frequency bands (LMR, MHR)
Mean power frequency(MPF)
Spectral power ratio (SPR)



The reliability of distance- and time-related parameters is good, that of frequency-related parameters is weak (uniqueness?)

Nagymate, G; Orlovits, Z; Kiss, RM: Reliability analysis of a sensitive and independent stabilometry parameter set. PLoS One, 13: Paper: e0195995, 14p. 2018.

Effect of the bad posture

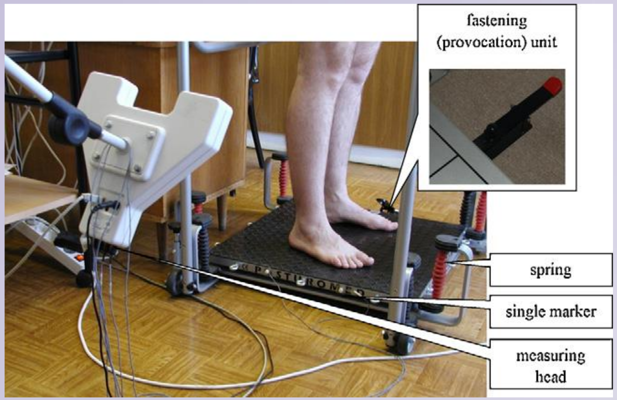
	Children wth correct posture (113 children)	Children with bad posture (22 children)	U-teszt (p)
Path length (mm)	923,13±350,32	975,95±326,67	0,158
LDD (%)	**6,25±5,19**	**8,15±5,9**	**0,021**
AP LA (mm)	31,13±17,24	28,45±12,32	0,633
ML LA (mm)	26,92±14,91	26,64±16,32	0,788
A_{max} *deviation (mm)*	28,86±14,23	27,39±12,97	0,489
P_{max} *deviation (mm)*	28,35±13,09	28,24±14,06	0,763
AP MPF (Hz)	0,15±0,07	0,16±0,07	0,56
ML MPF (Hz)	0,19±0,07	0,19±0,09	0,484
AP MHR	11,72±6,25	10,37±5,52	0,108
ML MHR	**11,53±5,00**	**9,18±4,25**	**0,002**

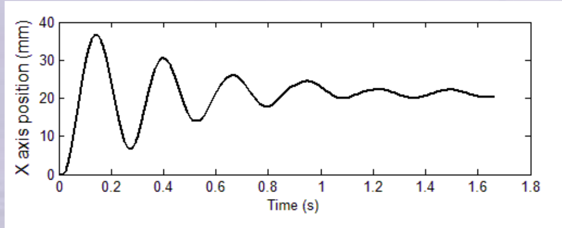
The postural stability of children with bad posture differs from that of children with correct posture, the load distribution between the two sides (LDD) and the medio-lateral frequency power ratios (ML MHR) show a significant difference between the two groups. The central nervous system can properly correct stability by changing posture. The compensatory role of the central nervous system is shown in the frequency-based ML MHR parameter

AP: anteroposterior, *ML*: mediolateralis,
LDD: load distribution between the two sides , *LA*: largest amplitude
A: anterior, P: posterior, *MPF*: Mean power frequency, *MHR*: Frequency power ratios between medium-high frequency bands

Nagymáté, G; Takács, M; Kiss, RM: Does bad posture affect the standing balance? *Cogent Medicine,* 5: Paper: 1503778 , 12p. 2018

Sudden perturbation provocation test





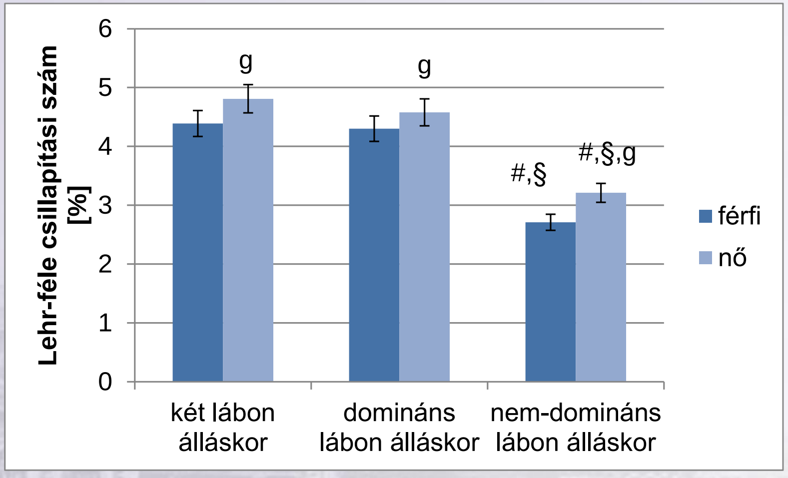
D- Lehr's damping ratio

Kiss, RM: A new parameter for characterizing balancing ability on an unstable oscillatory platform. Medical Engineering & Physics, 33: 1160-1166. 2011.

Gender effect

Women's ability to balance is better. Possible reasons for this:

- the physiological difference between men and women in ensuring balance;
- difference in joint flexibility;
- with increasing age, the somato-sensory, visual and vestibular abilities of men and women change differently [Masui et al., 2005]



Significance # bipedal standing; § standing of dominant leg; g gender effect.

Over 70 years of age, stabilometric tests also show this [Era et al., 1997; Masui et al., 2005]

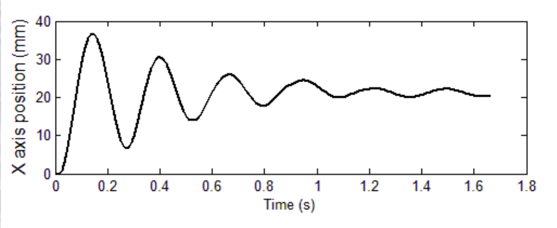
Kiss, RM: A new parameter for characterizing balancing ability on an unstable oscillatory platform. Medical Engineering & Physics, 33: 1160-1166. 2011.

Sudden perturbation provocation test

We have proven the balancing ability

- characterized by the Lehr damping number
- influenced by gender, age, dominance
- it is significantly worsened by changes in the knee joint and hip joint
- it is worsened by early dementia

Measurement of platform's motion



D- Lehr's damping ratio

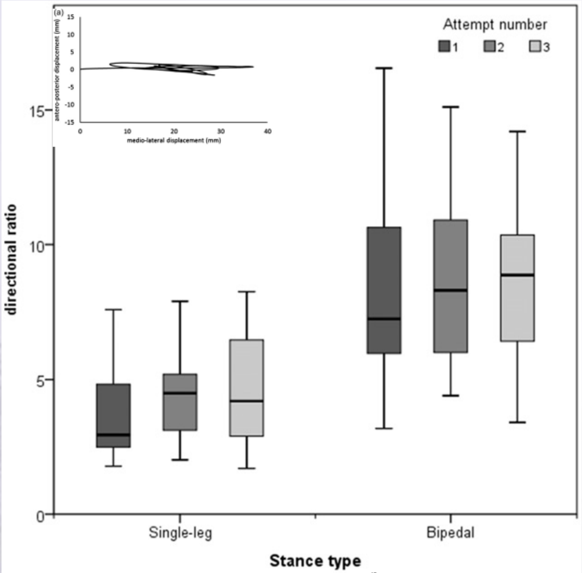
Kiss, RM: A new parameter for characterizing balancing ability on an unstable oscillatory platform. Medical Engineering & Physics, 33: 1160-1166. 2011.
Kiss, RM: Effect of the degree of hip osteoarthritis on equilibrium ability after sudden changes in direction. Journal of Electromyography and Kinesiology. 20: 1052-1057. 2010.
Holnapy, G; Kiss, RM: Impact of the method of exposure in total hip arthroplasty on balancing ability in response to sudden unidirectional perturbation in the first six months of the postoperative period. Journal of Electromyography and Kinesiology, 23: 727-733. 2013.
Kiss, RM: Effect of degree of knee osteoarthritis on balancing capacity after sudden perturbation. Journal of Electromyography and Kinesiology, 22: 575-581. 2012.
Pethes, Á; Bejek, Z; Kiss, RM: The effect of knee arthroplasty on balancing ability in response to sudden unidirectional perturbation in the early postoperative period. Journal of Electromyography and Kinesiology, 25: 508-514. 2015.
Magyar, OM; Knoll, Zs; Kiss, RM: Effect of medial meniscus tear and partial meniscectomy on balancing capacity in response to sudden unidirectional perturbation. Journal of Electromyography and Kinesiology, 22: 440-445. 2012.

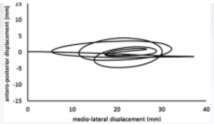
Definition of new parameters

Goal: to define new parameters for describing the movement direction of the platform

Time and distance parameters:

- time to successful balancing (2 mm)
- length of motion trajectory
- Lehr's damping ratio
- ratio of two direction (diraction ratio)

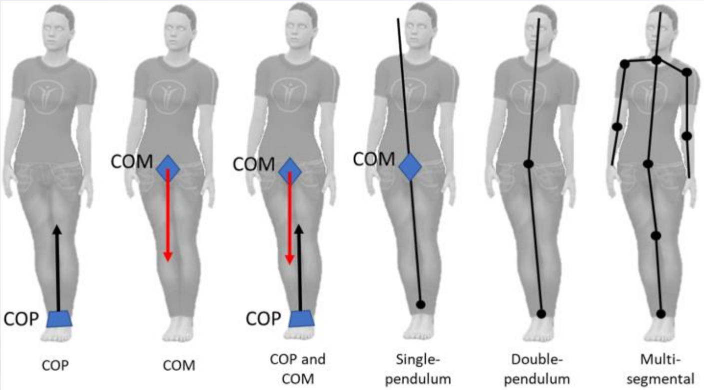




Petró, B; T Nagy, J; Kiss, RM: Effectiveness and recovery action of a perturbation balance test – a comparison of single-leg and bipedal stances. Computer Methods in Biomechanics and Biomedical Engineering, 21: 593-600. 2018.

Inverted double pendulum

Coordination strategies during standing
- Ankle, hip, mixed strategies

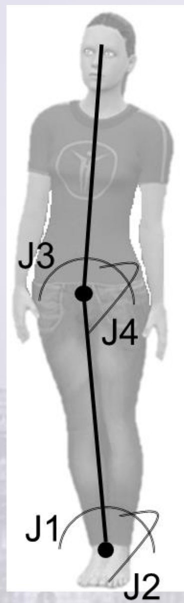


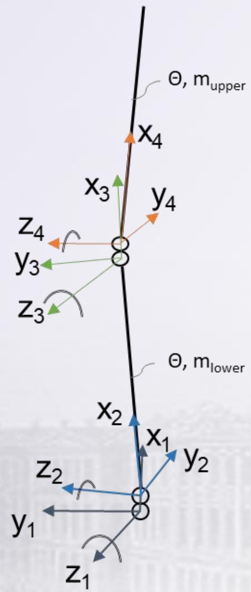
Creation of a spatial biomechanical model corresponding to the strategy to be detected
- based on the Denavit-Hartenberg convention
- two members: lower and upper body

Inverted double pendulum

Coordination strategies during standing
- Ankle, hip, mixed strategies

Creation of a spatial biomechanical model corresponding to the strategy to be detected
- based on the Denavit-Hartenberg convention
- two members: lower and upper body
- two degrees of freedom each: ankle and hip joints
- moments from the equations of motion (Lagrange II.)





Petró, B; Kiss, RM: Validation of the estimated torques of an open-chain kinematic model of the human body. Periodica Polytechnica Mechanical Engineering, 66(2): 175-182. 2022

Model validation by measurement

Inhomogeneous measurement group

- 11 female, 22-56 years; 11 male, 22-61 year

Ankle torque:

- by indirect measurement (from measurement of ground reaction force and ankle position)
- estimation with the model (from ankle, hip and head positions)

Model validation by measurement

Inhomogeneous measurement group

- 11 female, 22-56 years; 11 male, 22-61 year

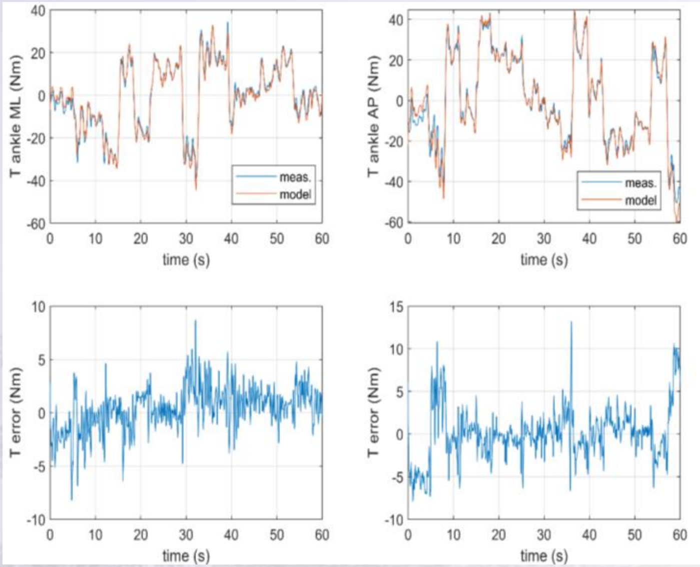
Ankle torque:

- by indirect measurement (from measurement of ground reaction force and ankle position)
- estimation with the model (from ankle, hip and head positions)

A static error in the anterior-posterior direction, it can also be eliminated in the side direction

An outlier error occurs with larger torque changes

- from time delay, unmodeled body parts



Petró, B; Kiss, RM: Validation of the estimated torques of an open-chain kinematic model of the human body. Periodica Polytechnica Mechanical Engineering, 66(2): 175-182. 2022

Summary

A. **DETERMINATION OF THE MECHANICAL PROPERTIES OF BONES, LIGAMENTS AND TENDONS**

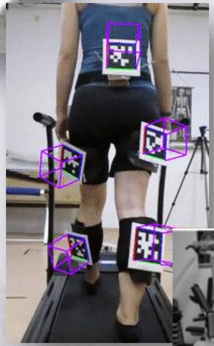
- development of clamps
- analysis of the different effects (storage, sterilization) in the case of allografts (grafts from tissue bank)

B. **MOTION ANALYSIS**

- measuring devices: Zebris ultrasound-based, OptiTrack optical-based systems, acustic test
- type of motion: posture (form of spine) position, motion (gait, sport-movement)

C. **EXAMINATION OF BALANCE ABILITY**

- balance while standing (stabilometry)
- balancing after sudden change of direction



Thank you!