Technology and Sports Biomechanics
Trends in Research and Applications

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About Republic Polytechnic

- Established in 2002
- 7 schools & 3 centers
- Over 14,000 students
- About 1,000 staff
- Leverage Problem-Based Learning and Authentic Learning Modalities

Background

- Sport Biomechanics
- Human Movement
- Sports and Exercise Science

I AM STILL LEARNING

Overview

1. Sports Biomechanics and its Function in Sports
2. Technology Trends for Research and Applications in Biomechanics
3. Integrated Technology Solutions and Biomechanics
    a. Wearable Technology
    b. Adaptive Technology
    c. AI and Machine Learning

Biomechanics and Its Function is Sports

Biomechanics and its Function in Sports

- The study of the structure and function of biological systems by means of the methods of mechanics and mathematics

(Hatze, 1974)

- Stems from two main disciplines:-
  - Physics
  - Biology

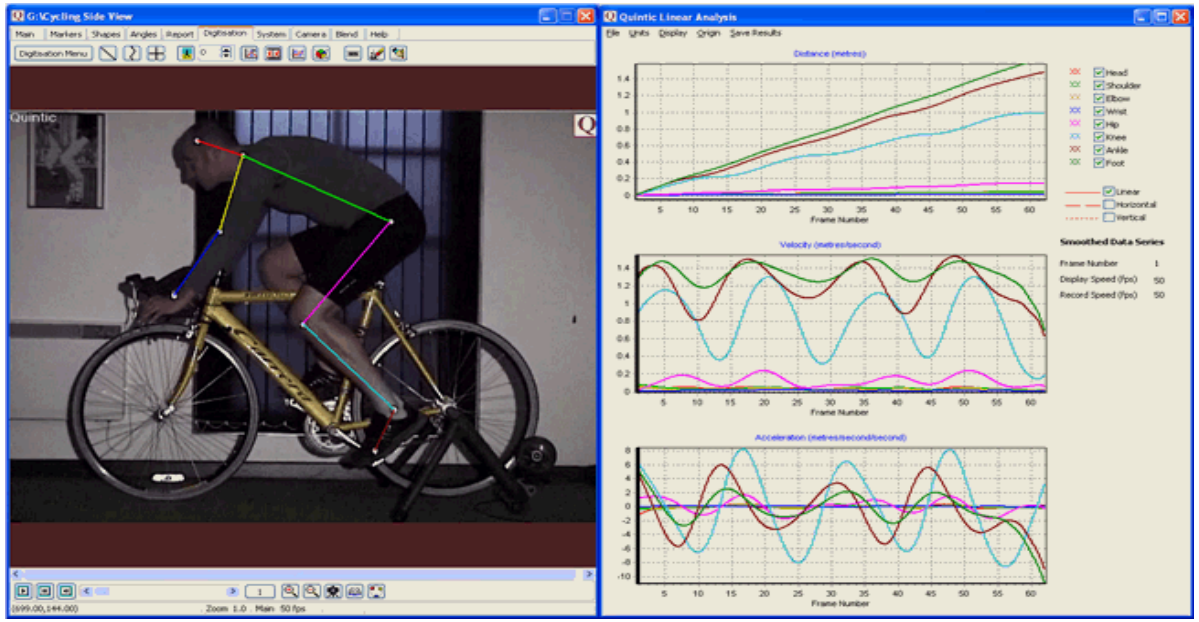
- Study and analyse human movement and sports performance

(Bartlett, 2007)

Biomechanics and its Function in Sports

"Since both the human body and the implement are employed in physical activities, they have to follow the conventional laws of classic physics.

Therefore, it is important to understand the basic concepts of mechanics and how they are applied to human movement in order to coach effectively thereby enhancing performance." (Rasch & Burke, 1978).



Biomechanics and its Function in Sports

- Eliminates guessing what good technique is
- Understand the effect of training
- Match athlete with sport
- Assess efficacy of sports equipment
- Prevent injury
- Explain the cause and effects using concepts of mechanics and mathematics

Biomechanics and its Function in Sports

Force causes motion

https://giphy.com/explore/free-kick

Force terminates motion

https://gfycat.com/discover/goalkeeper-training-gifs

https://giphy.com/explore/goalkeeper-save

Force changes direction of motion

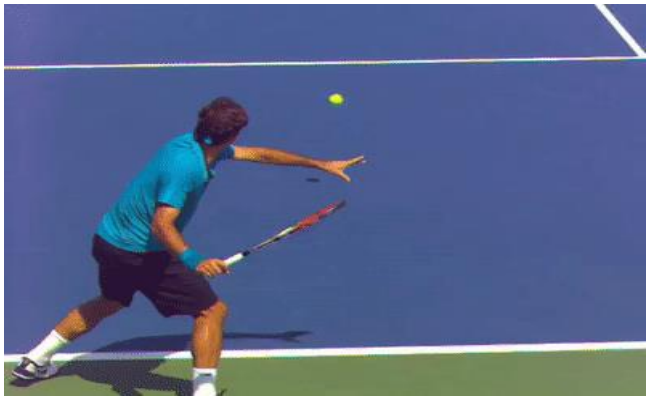
Biomechanics and its Function in Sports

- The rate of change of momentum of a body is proportional to the force causing it and the change takes place in the direction in which the force acts.

$$\mathbf{F} = m\frac{\mathbf{v_f} - \mathbf{v_i}}{t} = m\mathbf{a},$$

where **F** = force acting on a body (vector), m = mass of a body,

$\mathbf{v_f}$ = final velocity, $\mathbf{v_i}$ = initial velocity, **t** = time duration between $\mathbf{v_f}$ and $\mathbf{v_i}$, **a** = acceleration



https://gfycat.com/gifs/search/roger+federer+forehand

F [N] = m [kg] • a [m/s^2]

Unit of force

[N] = [kg] • [m/s^2]

Biomechanics and its Function in Sports

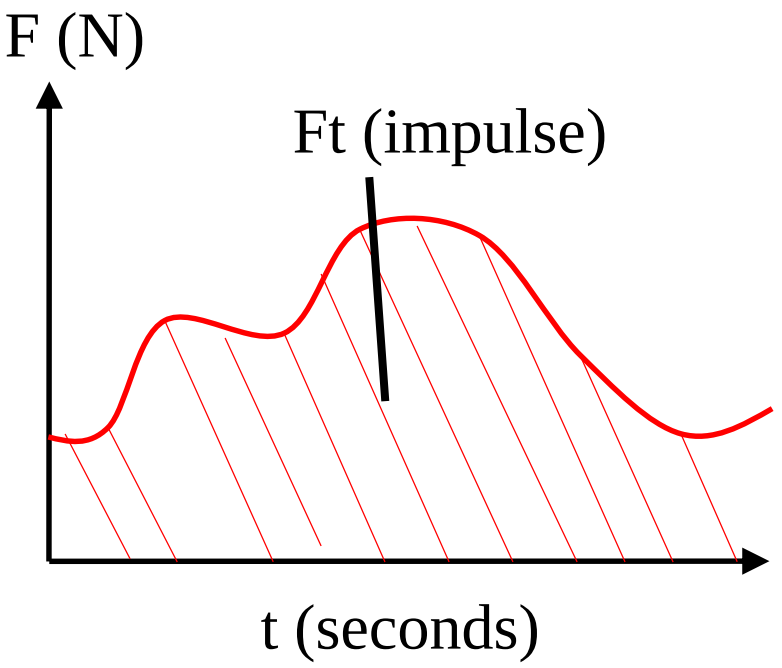
When a force is applied on a system for certain duration (impulse), the impulse is equal to the change of momentum that it produces.

$$\mathbf{F} = m\mathbf{a}$$

$$\rightarrow \mathbf{F} = m\,\frac{\mathbf{v_f} - \mathbf{v_i}}{t}$$

$$\rightarrow \boxed{\mathbf{Ft} = m\mathbf{v_f} - m\mathbf{v_i}\ [\mathrm{Ns}]}$$

where F = force, m = mass, a = acceleration, v_f = final velocity, v_i = initial velocity, t = time between v_f and v_i



Biomechanics and its Function in Sports

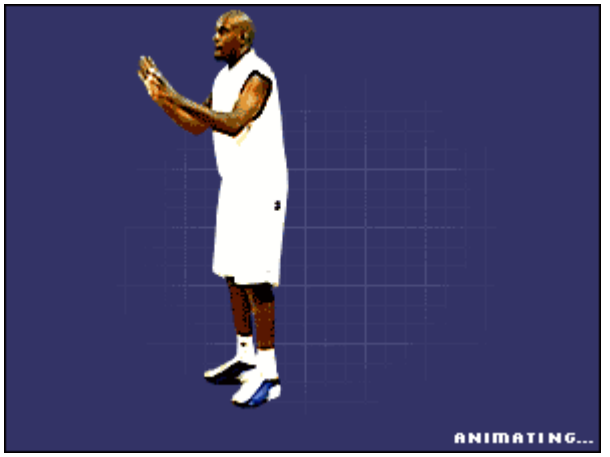
Enhance Performance

https://bonnewshaiti.com/how-captchas-could-show-if-an-algorithms-getting-closer-to-agi/

Time in contact with the ball longer (follow-through)

Time in contact with the ball longer dissipates force experience by joints ((bending of arms)

Injury Prevention

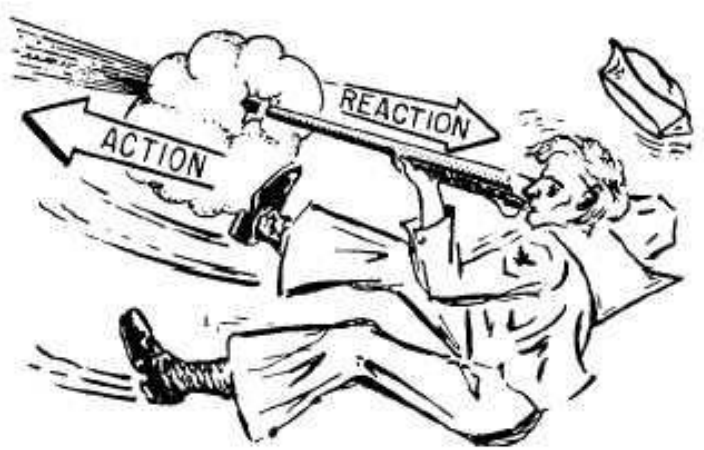


http://myhobyisbasket.blogspot.com/2010/11/animation-drills-skills-basket-ball.html

Linear impulse – Momentum Relationship

Biomechanics and its Function in Sports

https://giphy.com/explore/newtons-3rd-law



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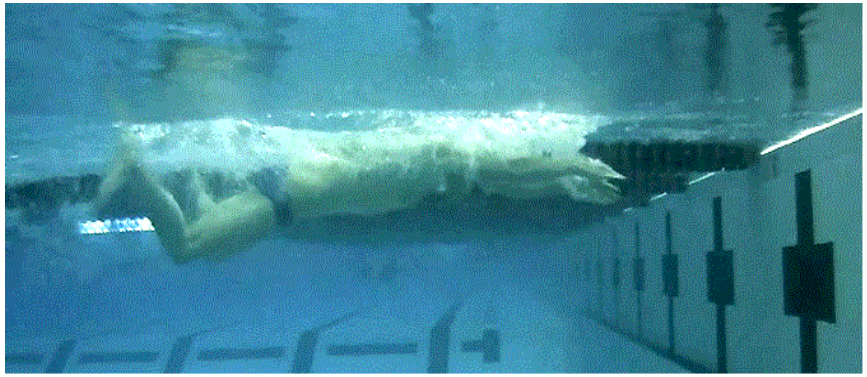
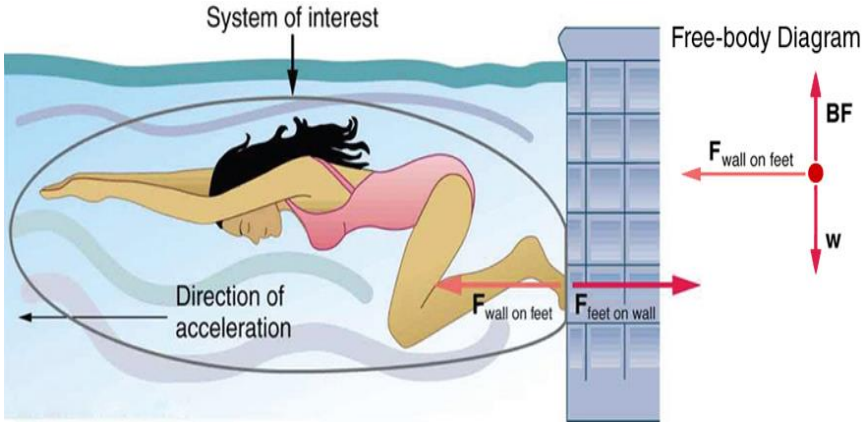
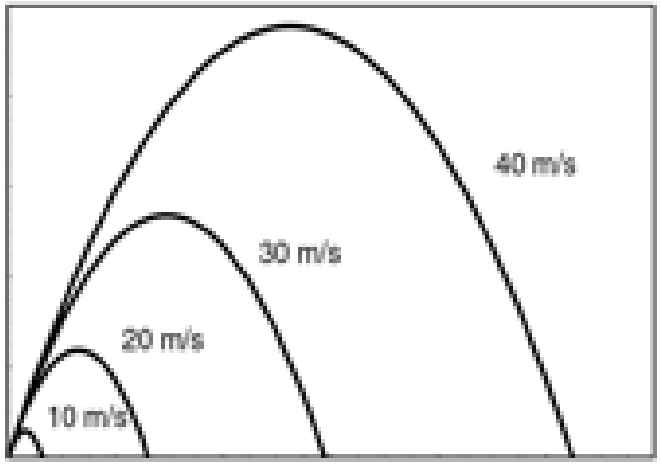


https://coachsci.sdsu.edu/swim/champion/BS-BF%20Turn.htm

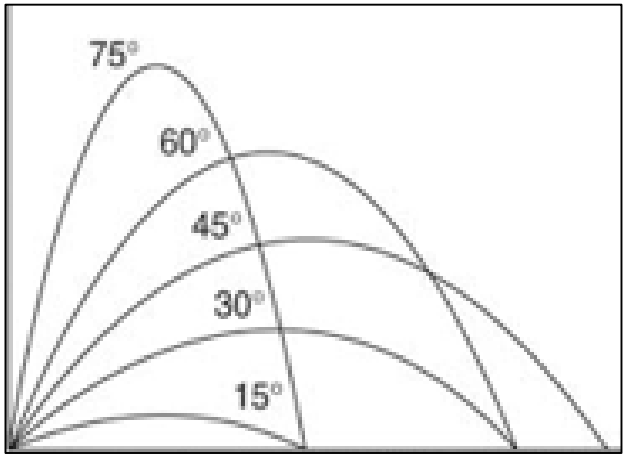


https://nigerianscholars.com/tutorials/force-newtons-laws-motion/newtons-third-law-of-motion-symmetry-in-forces/

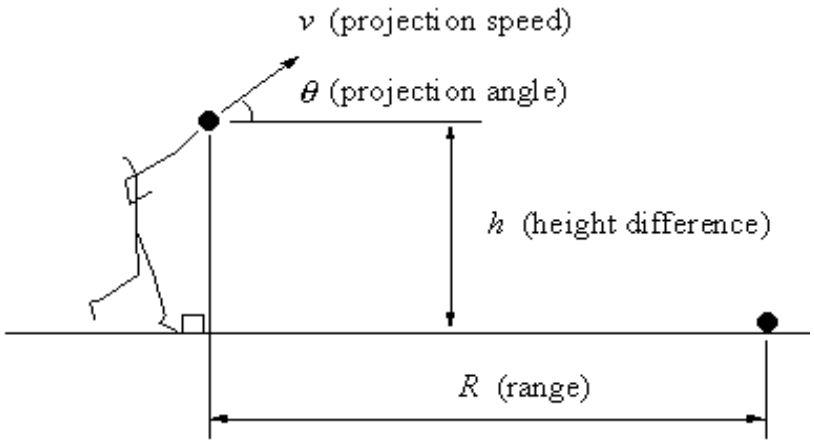
Biomechanics and its Function in Sports



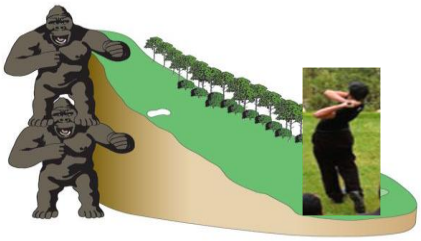
Release Velocity

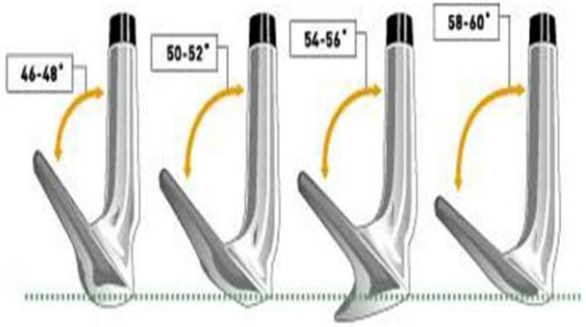


Release Angle



Release Height

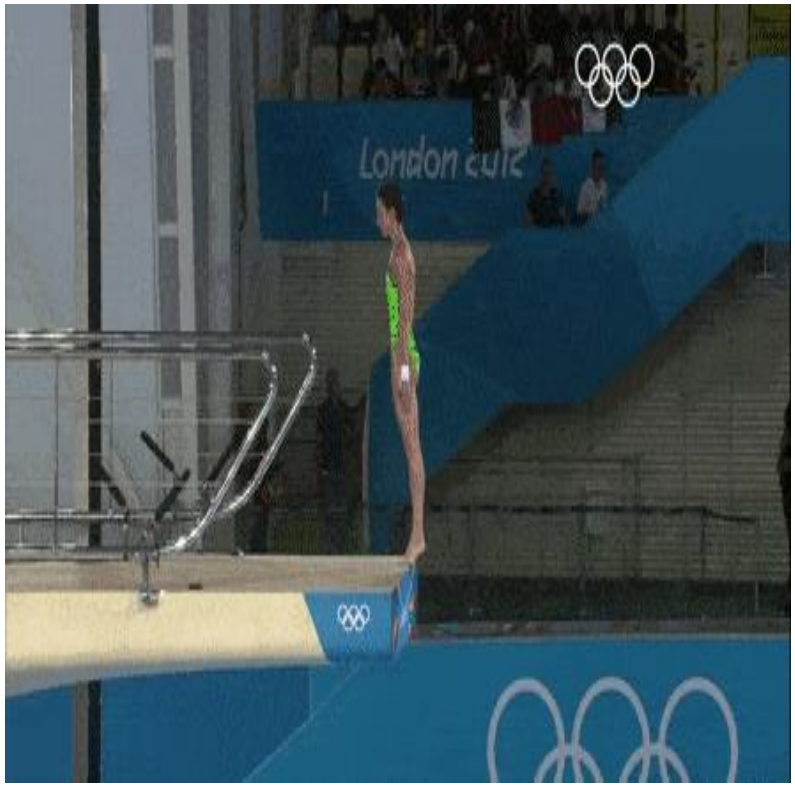




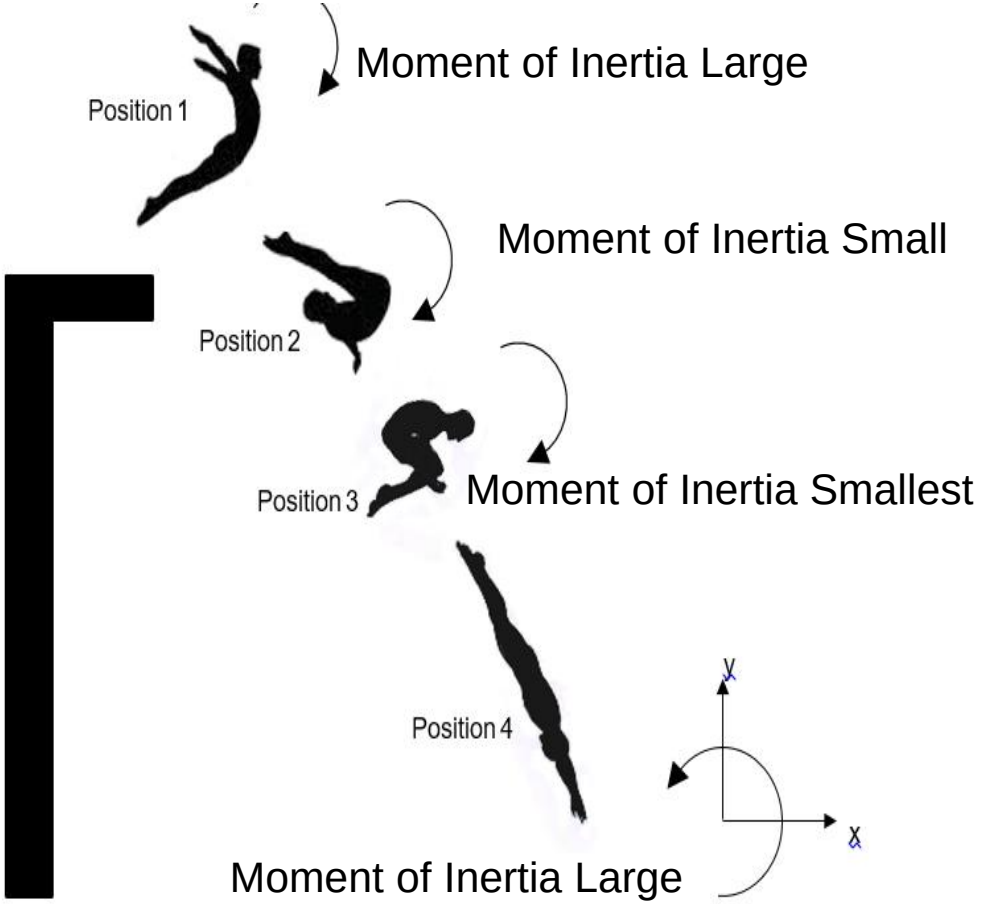
Biomechanics and its Function in Sports

No External Forces to cause a change is direction to twist and turn in the air

Moment of Inertia small = rotation faster



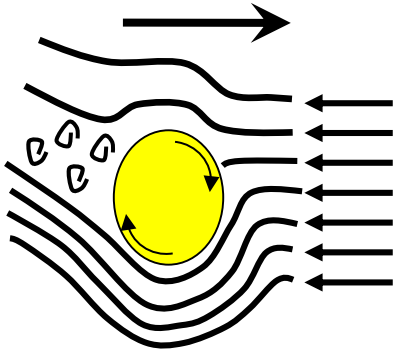
https://giphy.com/explore/olympic-diving



Biomechanics and its Function in Sports

https://gfycat.com/gifs/tag/tiro

https://sports.orange.fr/videos/insolite/-la-splendide-amortie-revers-de-roger-federer-CNT0000018w8NV.html



https://phys.org/news/2021-06-sticky-baseballs-physics-latest-scandal.html

Magnus effect

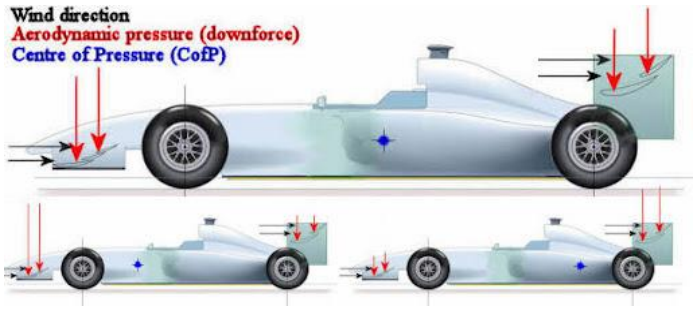
https://tenor.com/view/benditlikebeckham-juicyjuicymangoes-gif-20064021

Biomechanics and its Function in Sports

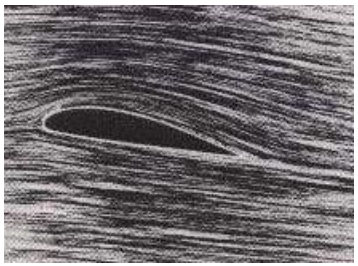
- Fluid Mechanics
- Athletes such as speed skaters, cyclists, swimmers, runners wear a tight uniform/suit to reduce the drag forces.
- The wing in the racing car, large lift forces in the vertically down direction act on the wings, so that the racing car avoid flipping over in fast speed.

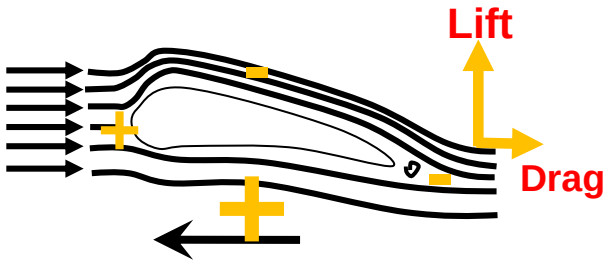
https://www.reuters.com/article/idCNChina-1961820080810

https://www.nydailynews.com/new-york/city-cheers-homegrown-olympic-medalist-article-1.1134162



The motion of wing



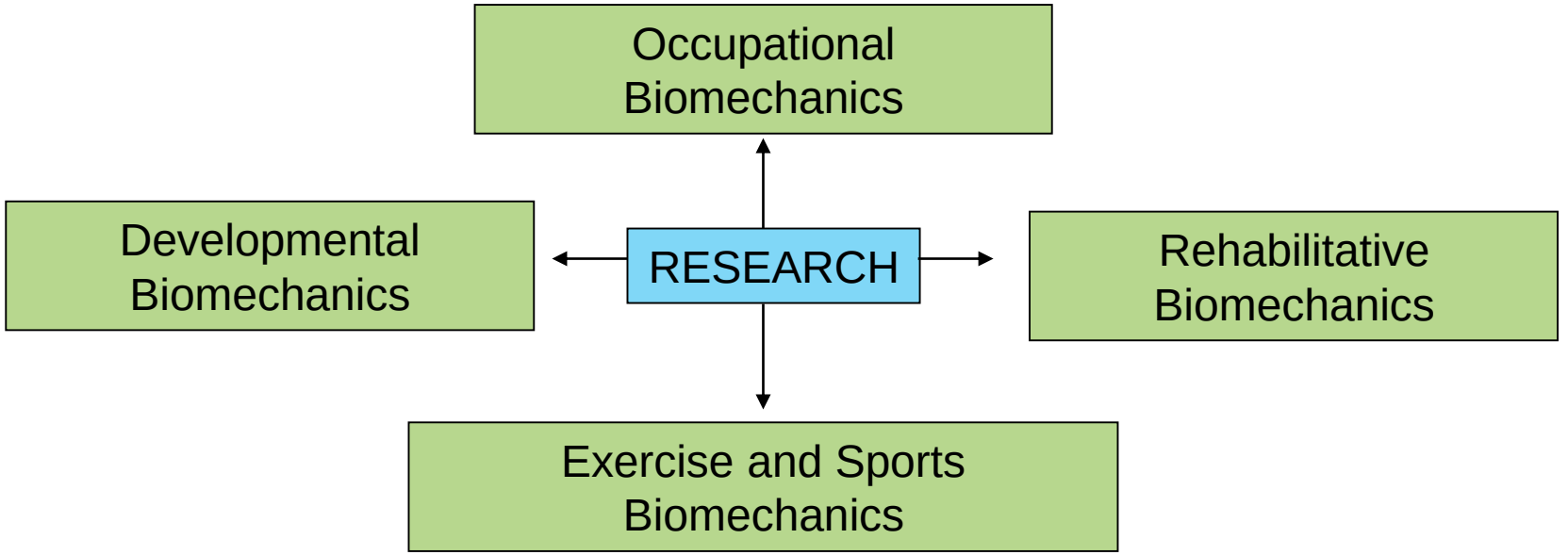


Let's Recap …

- Eliminates guessing what good technique is
- Understand the effect of training
- Match athlete with sport
- Assess efficacy of sports equipment
- Prevent injury
- Explains cause and effects

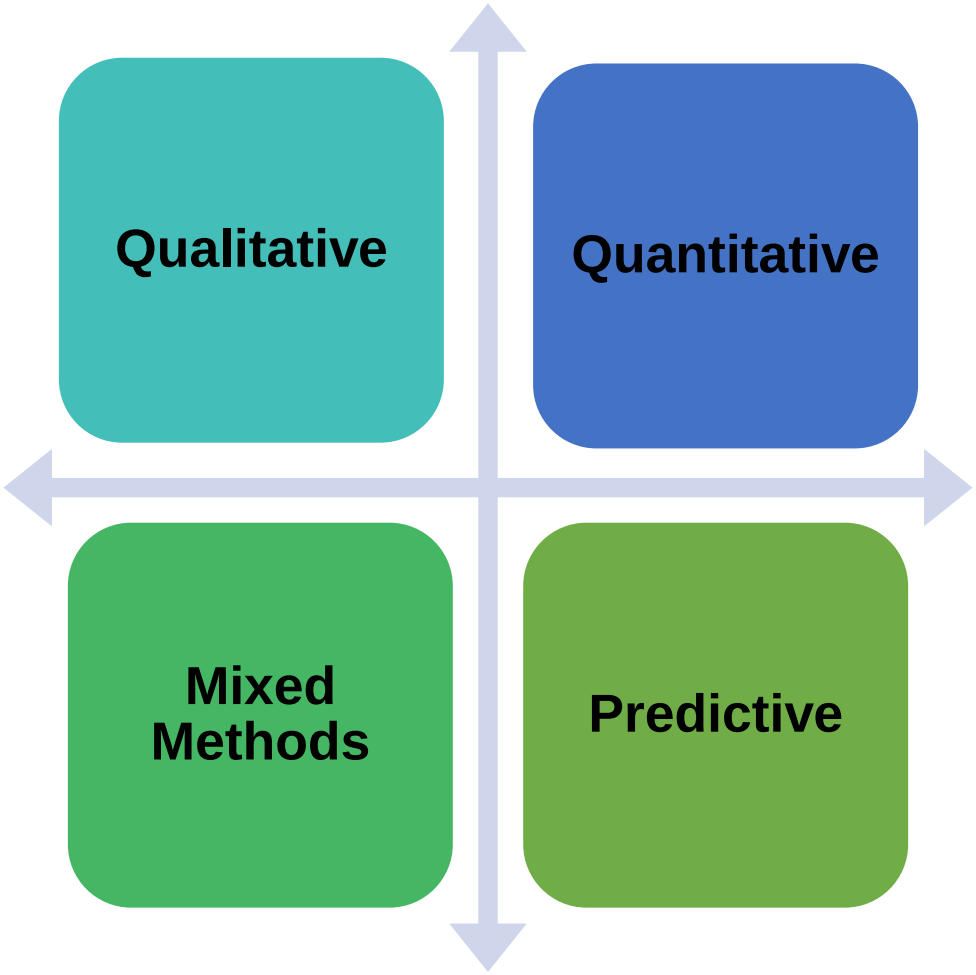
Technology Trends for Research and Applications in Biomechanics

Areas of Biomechanics Research

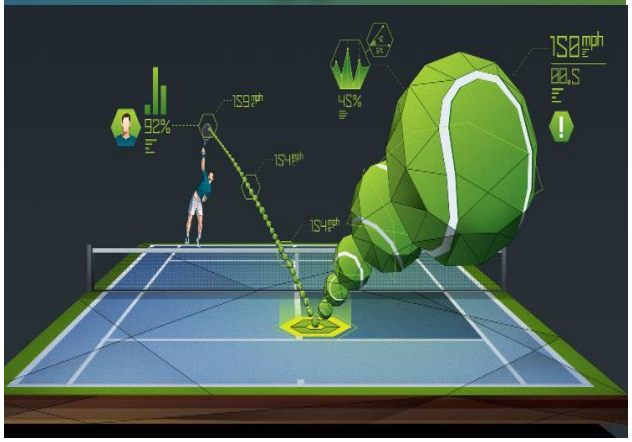


- Understanding human movement
- Improve technique
- Reduce risk of injury
- Enhance performance
- Cause and effect

Areas of Biomechanics Research

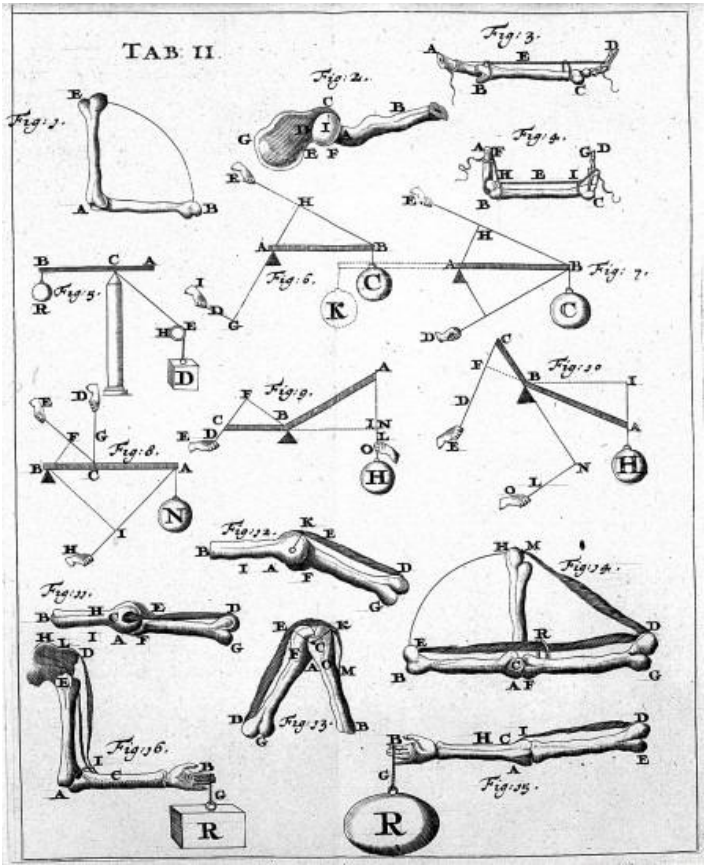


Areas of Biomechanics Research



Bridging the GAP

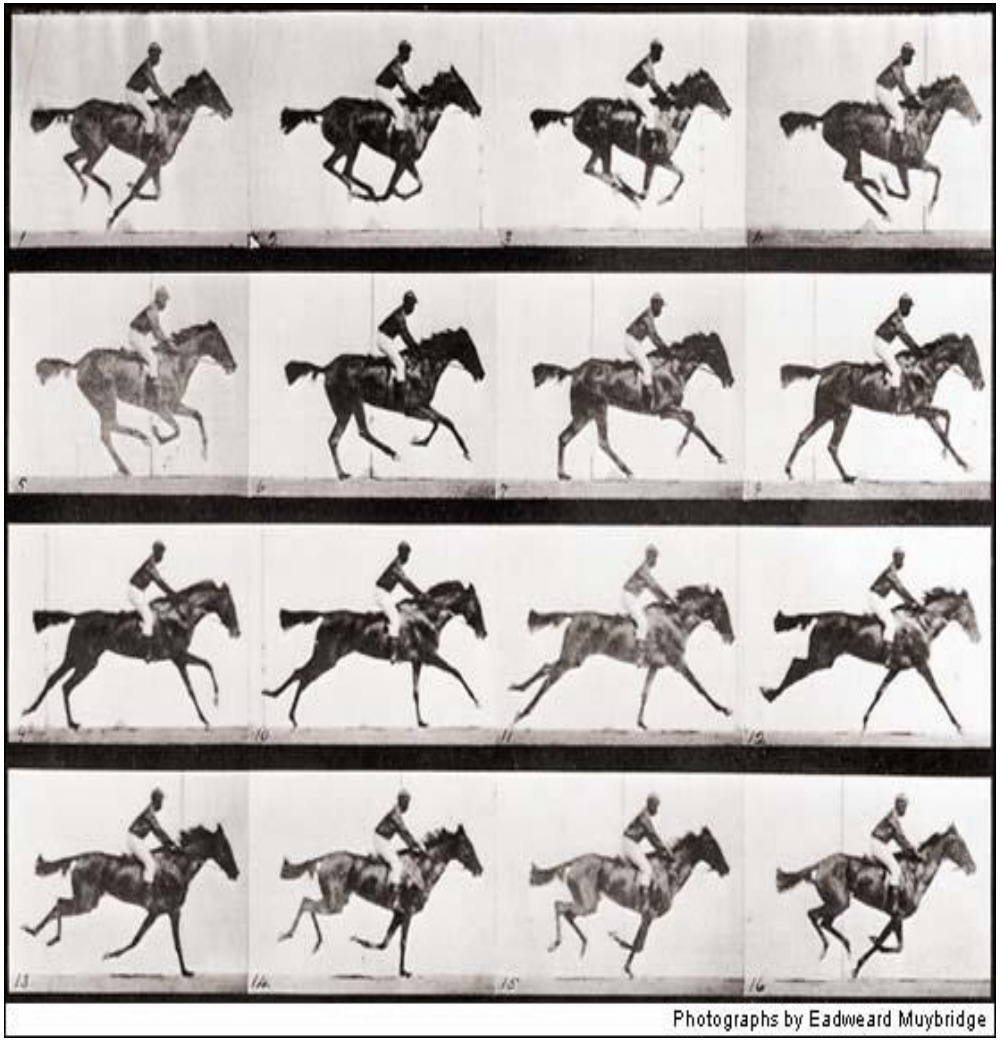
Technology in Research and Applications



Giovanni Alfonso Borelli

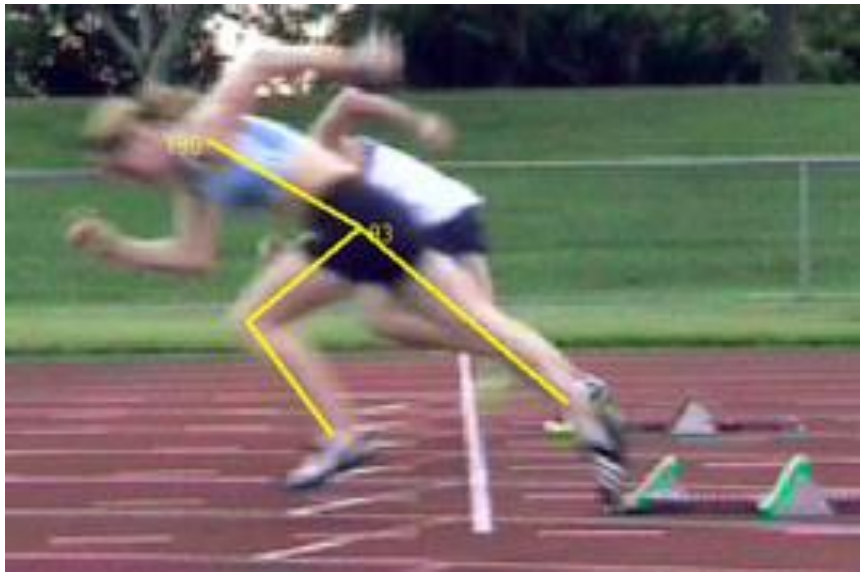
"De Motu Animalium"

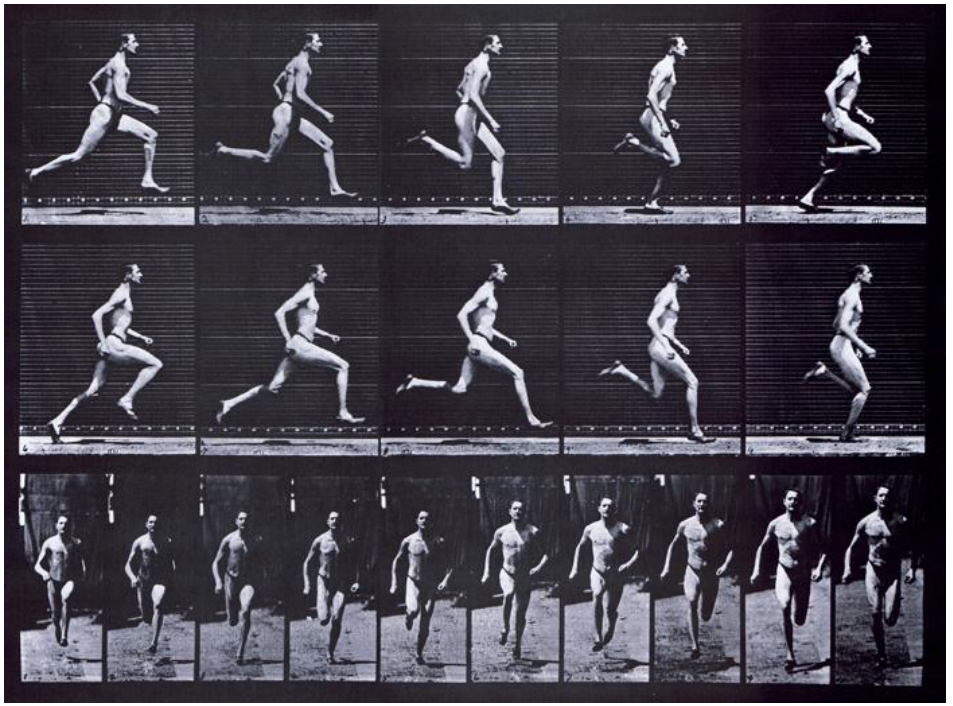
(28 January 1608 – 31 December 1679)



Technology in Research and Applications

Sports Biomechanics is the study and analysis of human patterns in sport

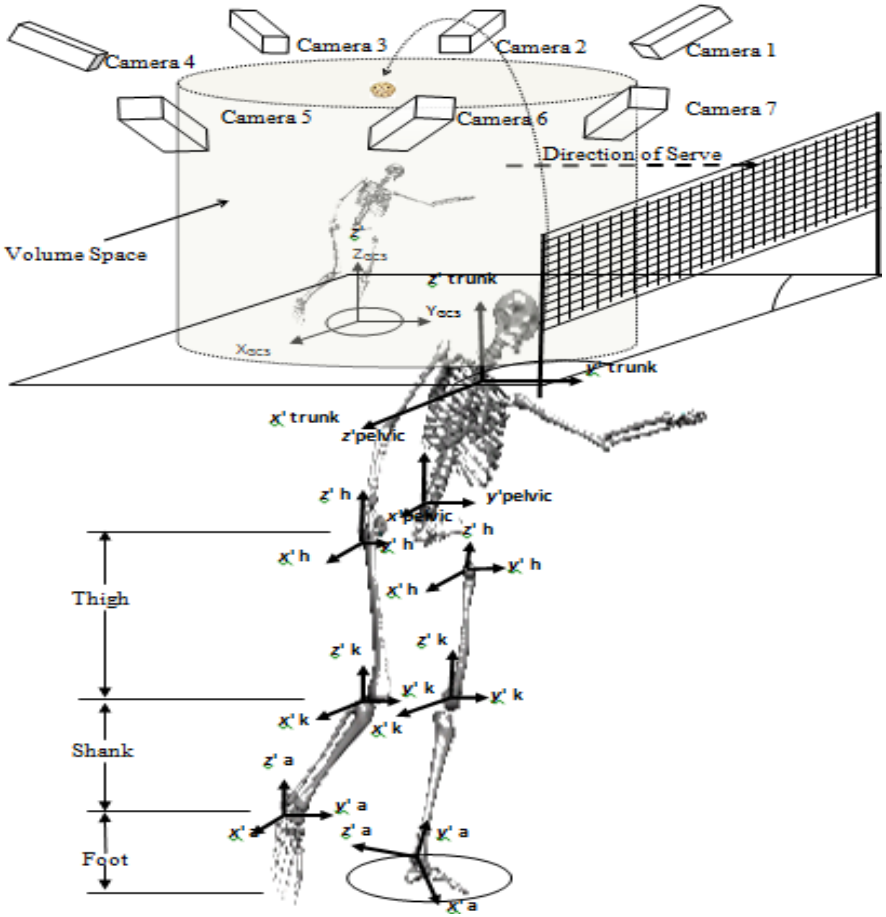




High-Speed Video Camera Technology

Technology in Research and Applications

High-Speed Optical Motion Capture Technology



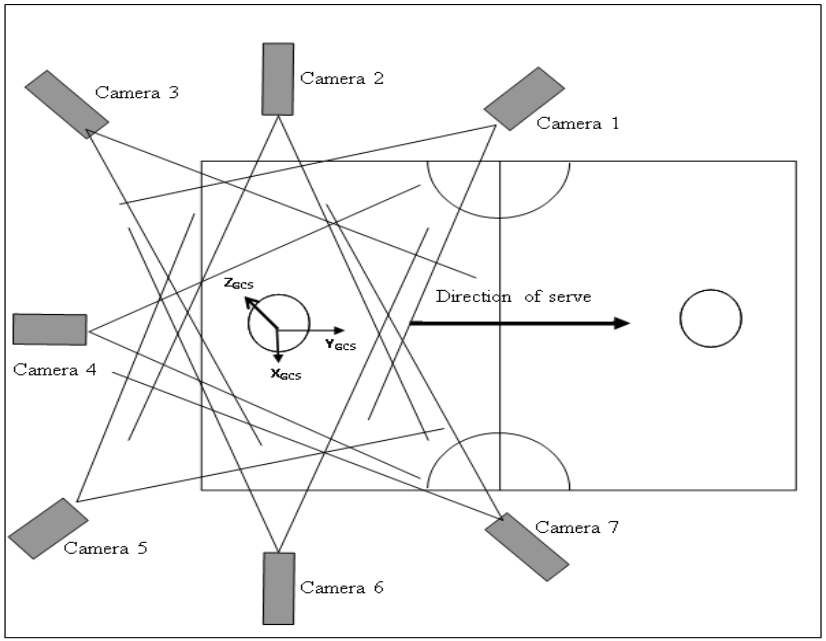
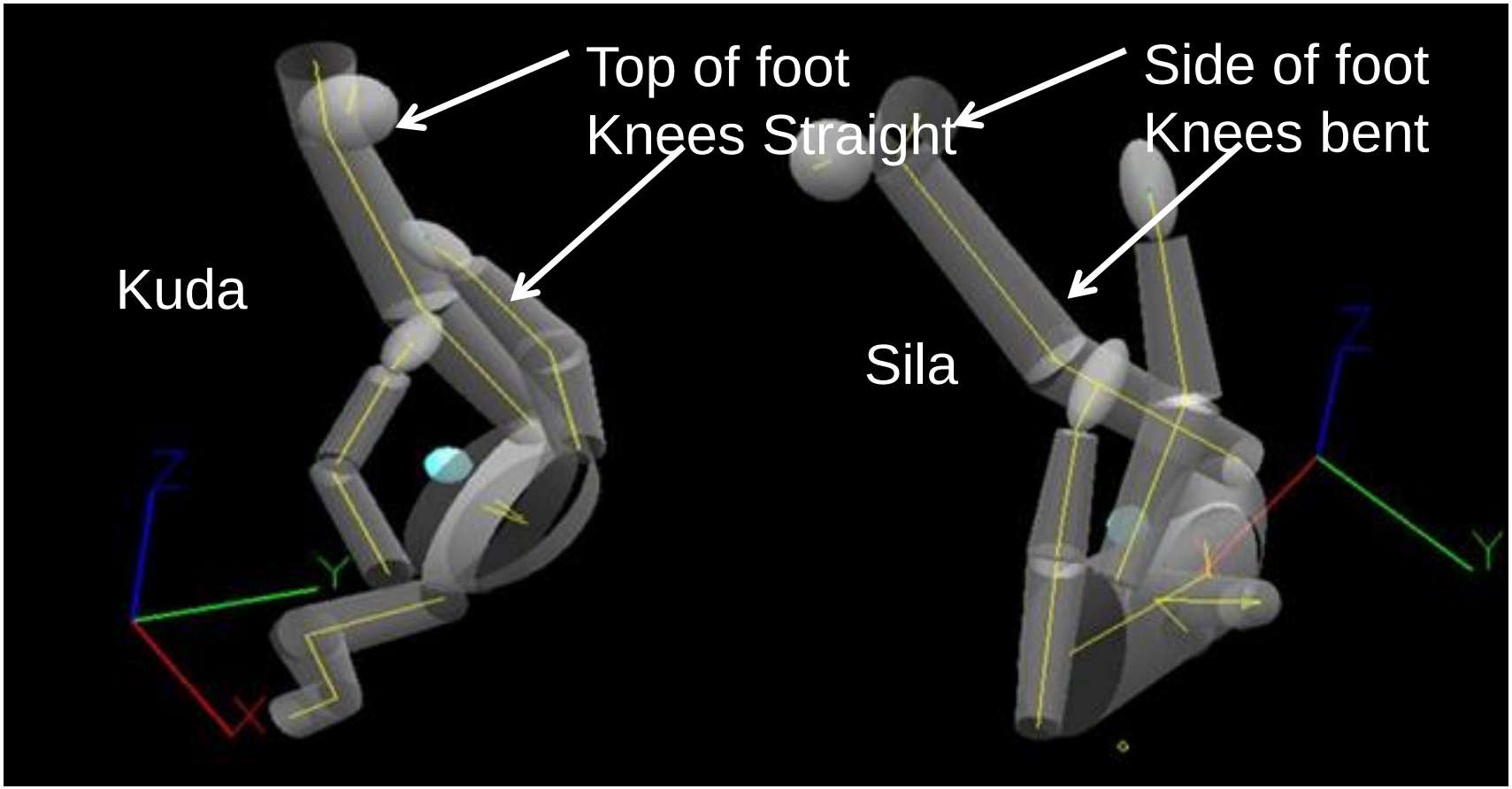


Figure 3.2 Seven camera placements for three-dimensional analysis of the *kuda* and *sila* serve kicking techniques. The serving circle (marked 'H') is within the calibrated three-dimensional volume space. The X_{GCS}-, Y_{GCS}- and Z_{GCS}-axes refers to the Global Cartesian Coordinate System (GCS) comprising of orthogonal planes with the Y-axis is the direction of the serve.

Sujae & Koh, 2008

Technology in Research and Applications

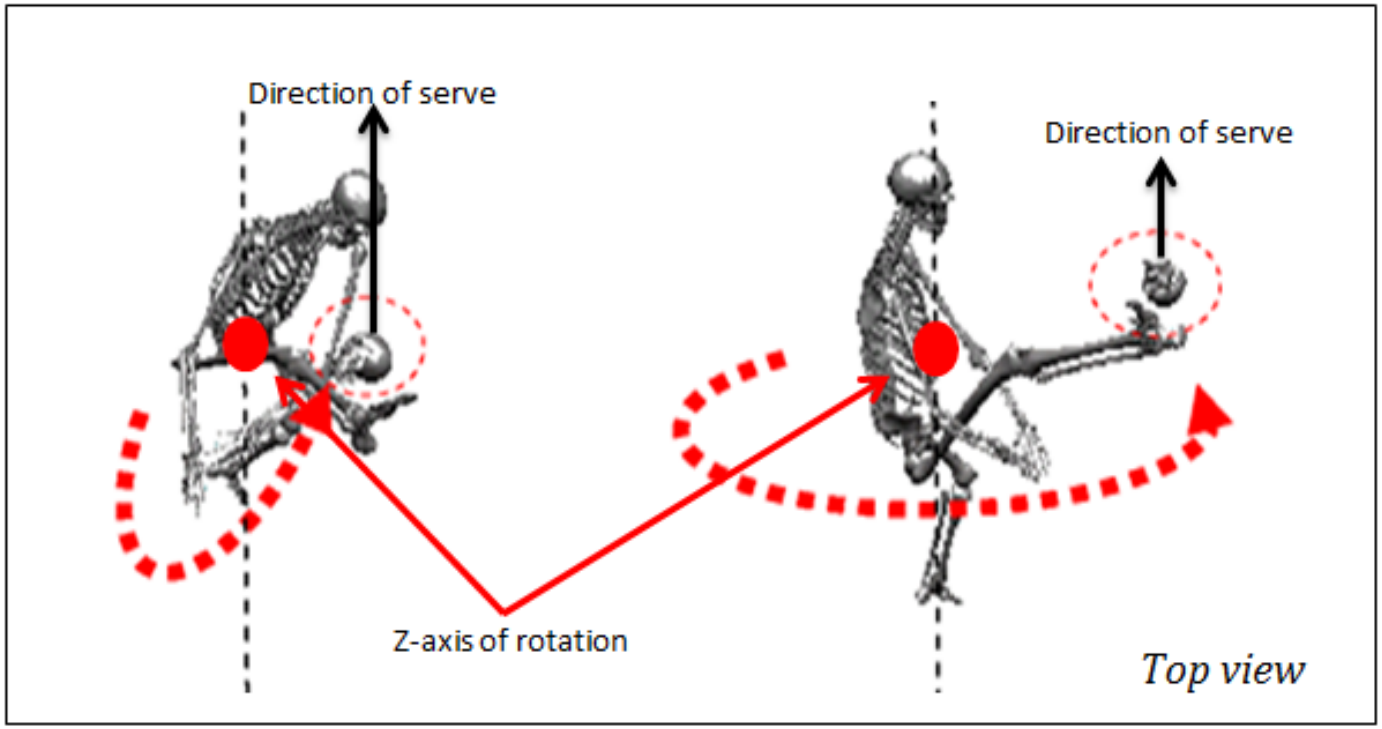
Identifying Technique Difference



Sujae and Koh, 2008

Technology in Research and Applications

Coaching Implications

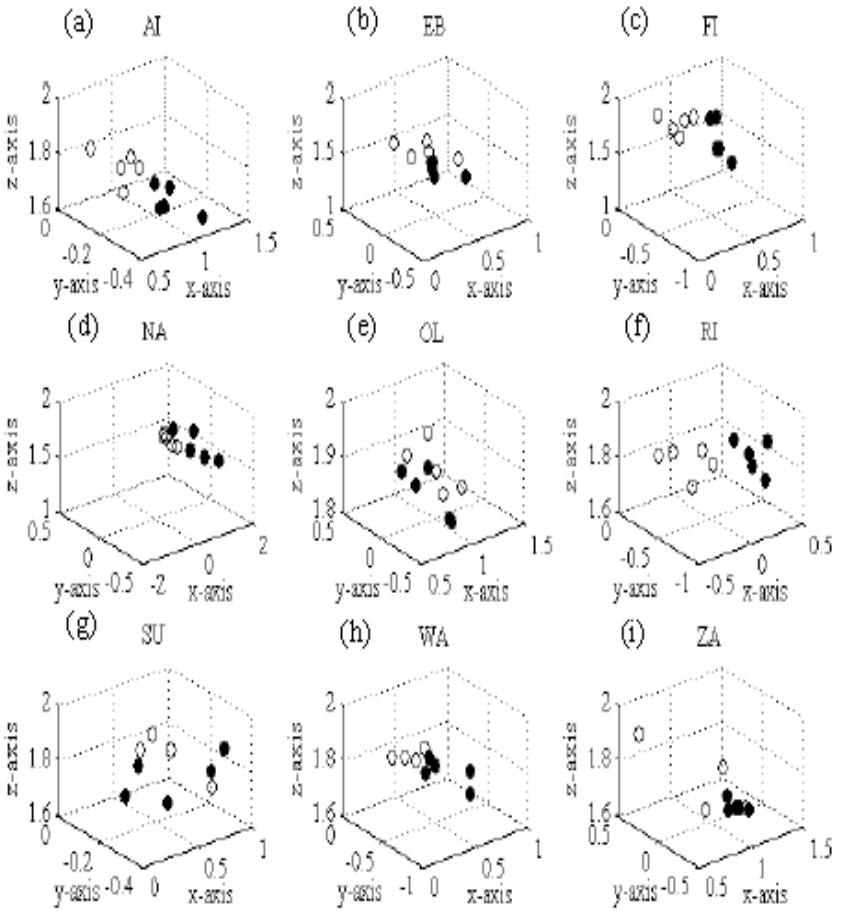


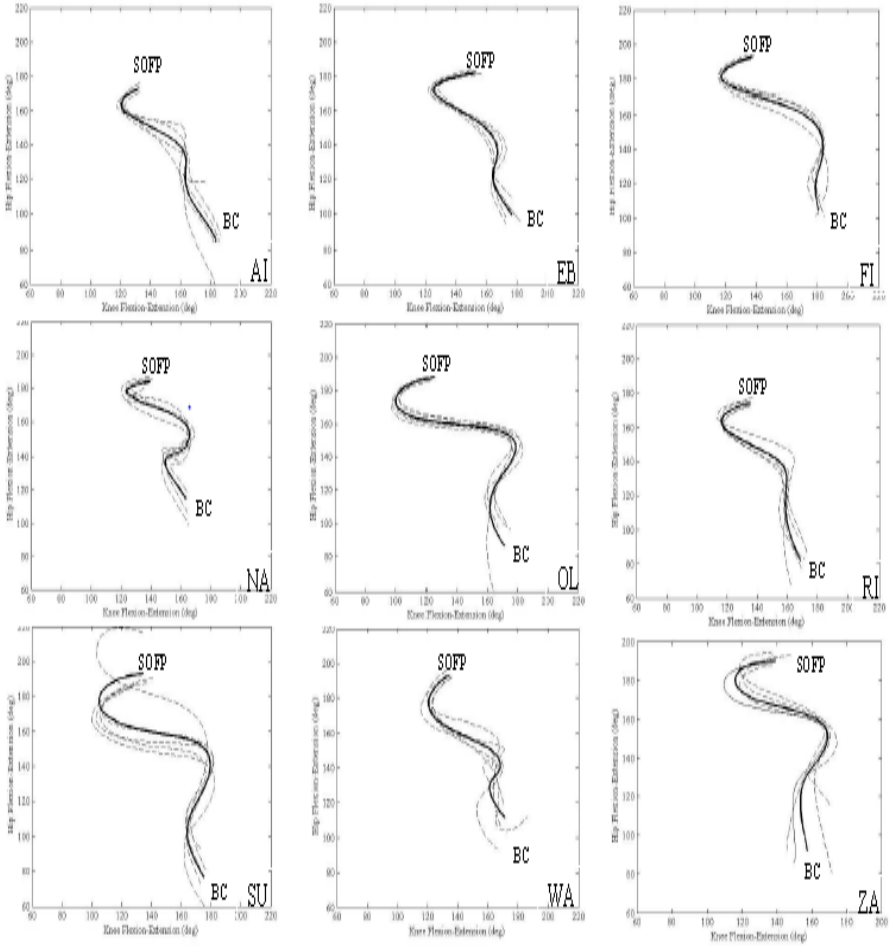
- Kicking with knees fully extended at point of impact (Single rigid kicking segment at impact) generates optimal impact speeds
- Training must include presence of perturbation

Sujae, Kim & Koh, 2010

Technology in Research and Applications

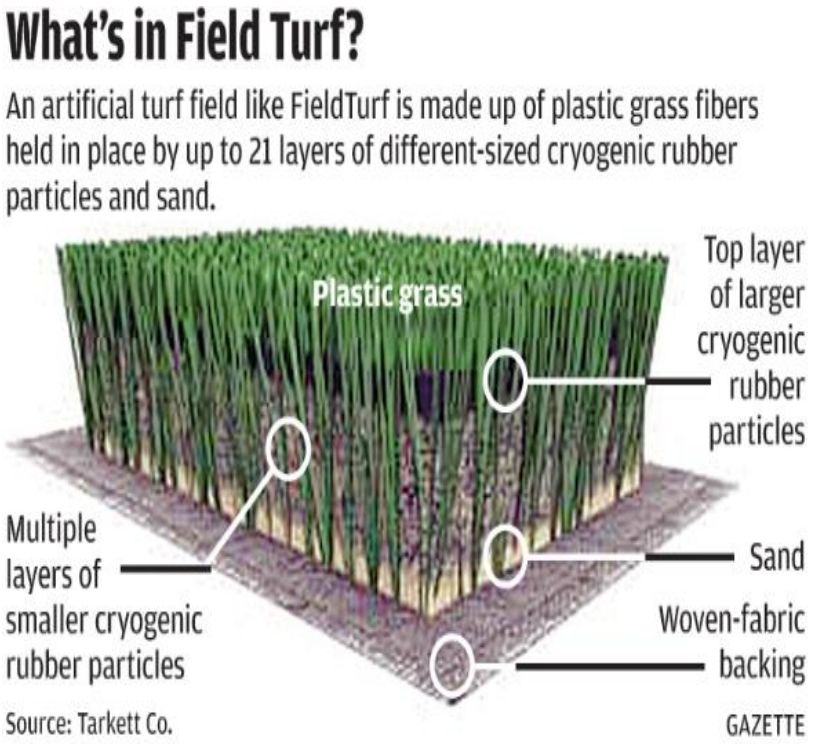
Identifying Variability in Joint Coordination





(Sujae, Koh & Hamill, 2012)

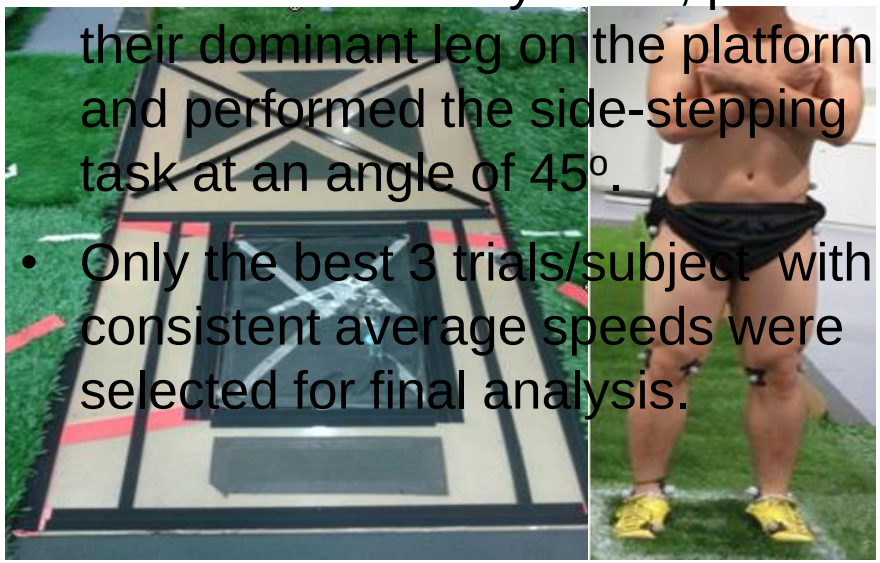
Technology in Research and Applications



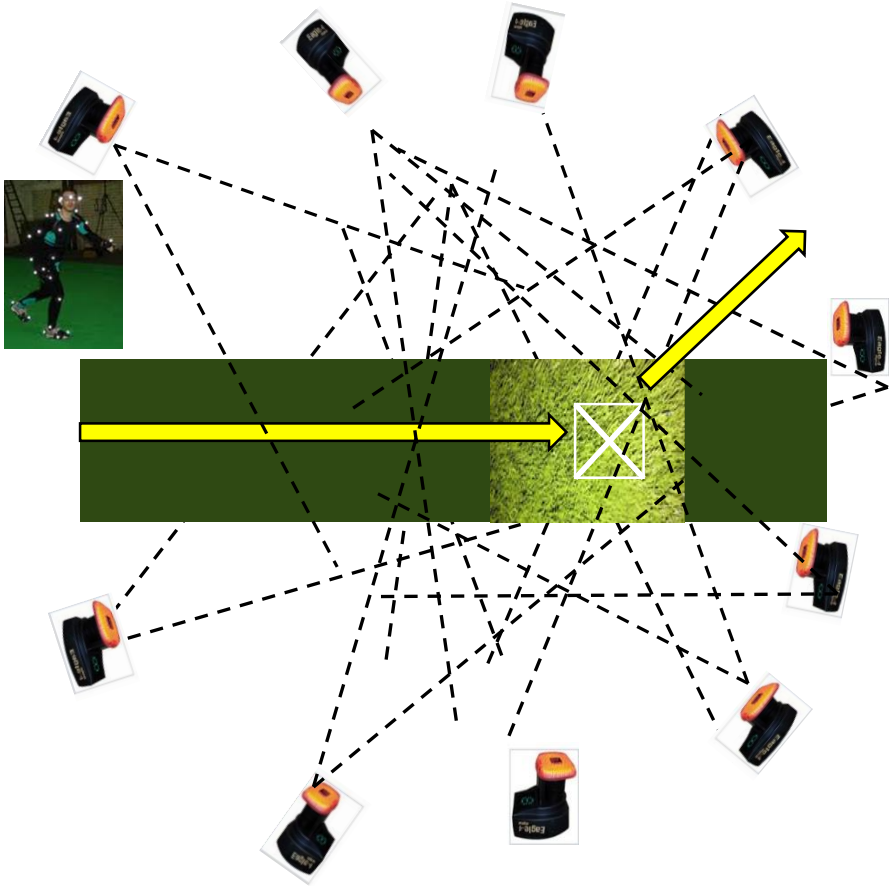
- Improved playability
- Grass turf characteristics
  - moisture
  - hardness
  - grass cover
  - root density
  - naps in the turf type
  - distribution and compaction of infill
- Sand and rubber infills
- A cushioning effect
- Associated with reductions in hardness of playing surface.

Technology in Research and Applications

- Wore the same FIFA approved turf shoes.
- Randamized 10 trials of side-step cutting on infill depths of 2cm (Condition A) and 4cm (Condition B)
- Ran as fast as they could, plant their dominant leg on the platform and performed the side-stepping task at an angle of 45^{o}.
- Only the best 3 trials/subject with consistent average speeds were selected for final analysis.



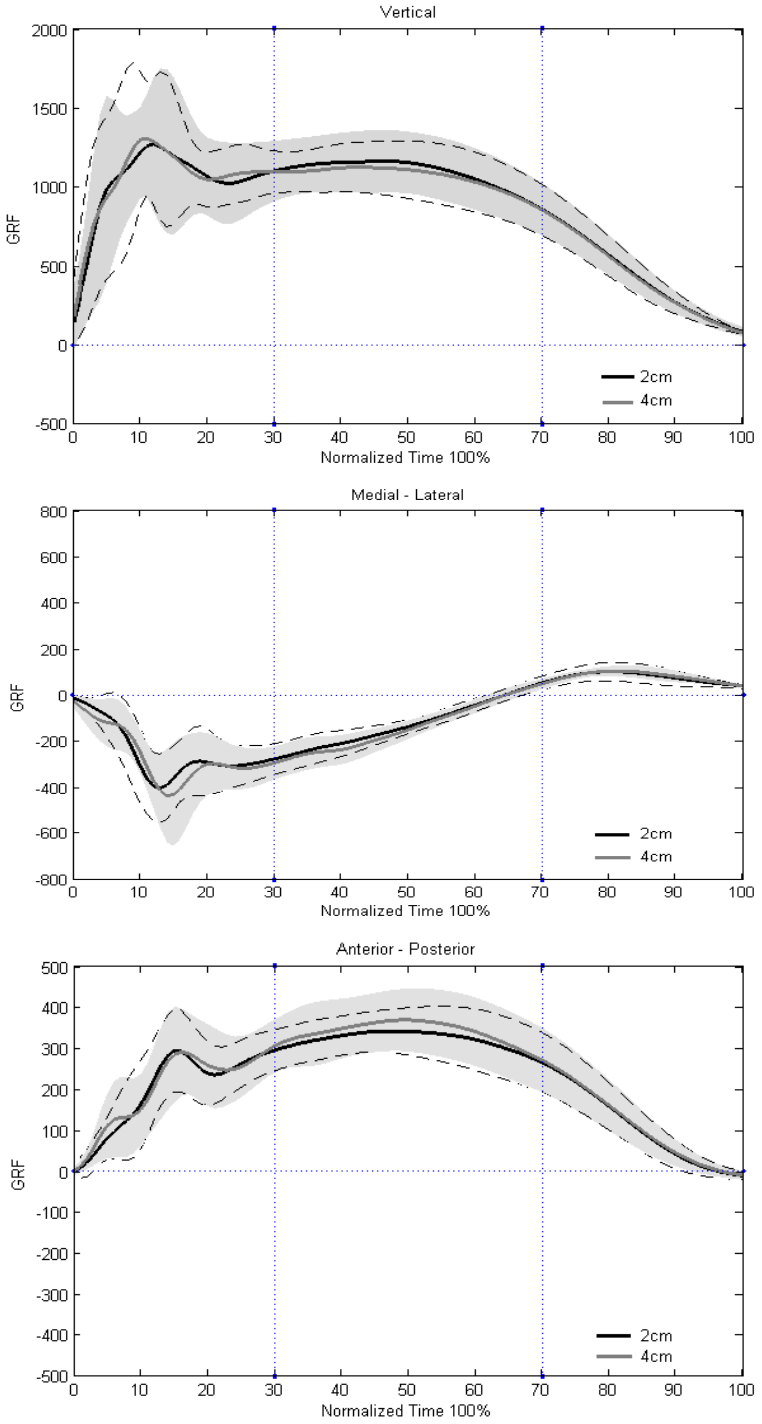
High-Speed Optical Motion Capture + Force Platform Technology



Technology in Research and Applications

- Greater infill depths increase surface hardness (less ‘cushiong effect’).
- Elicited greater joint loadings at the ankle, not knee joint.
- Players adopting a change in technique when performing the side-step manoeuvre on different infill depths.
- Lower extremity adaptations - associated with the ankle rather than the knee; hinting that the body posture adopted a change in technique
- It is possible that performing side-step on artificial grass turf with thicker infill depths may increase the risk of ligament injuries.

(Sujae, Jabbar, Ong & Hamill, 2019)



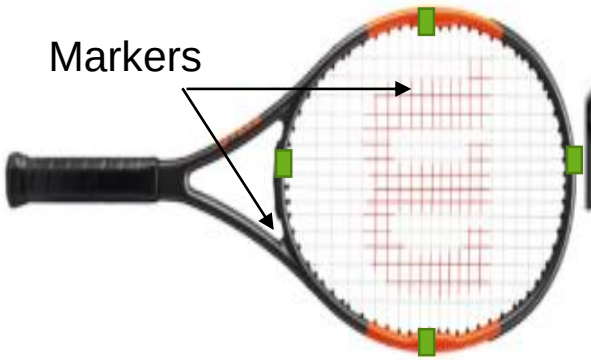
Technology in Research and Applications

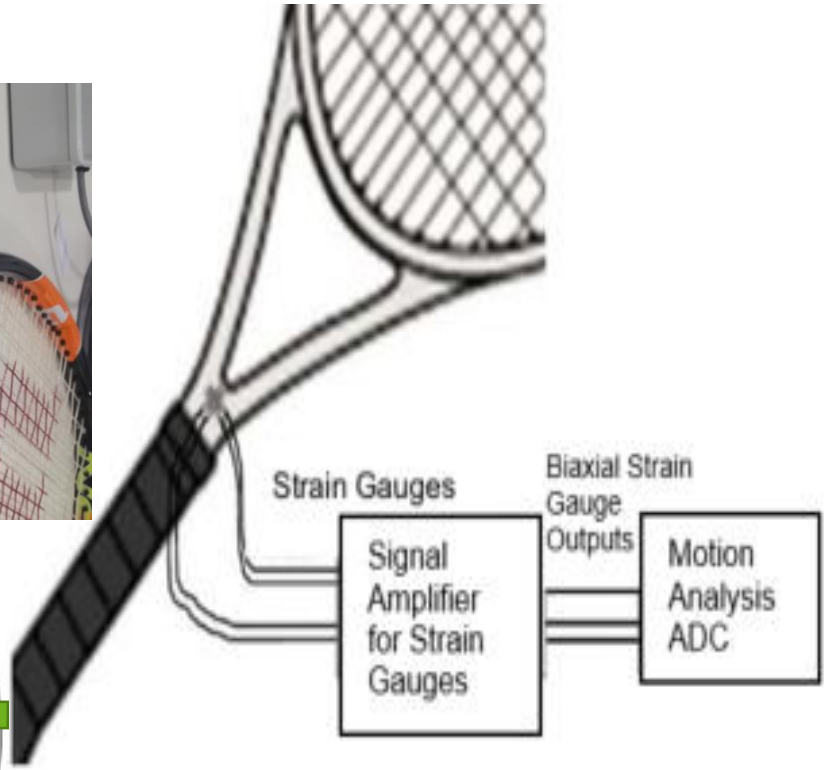
High-Speed Optical Motion Capture + Strain Gauges (Load Cells) Technology

- One factor that could influence impact force may be string tension
- String tension changes after hitting the ball continuously with the same racket
- Several studies (under simulated laboratory conditions) have suggested how string tension affects rebound speeds (Brody & Knudson, 2000; Cross & Bower, 2001), but not impact force *per se*
- Existing means = high-speed camera using inverse dynamics
- Such means are not accessible for coaches/practitioners

Technological Trends in Research and Applications

- Fabrication of Tennis Racket with Strain Gauges

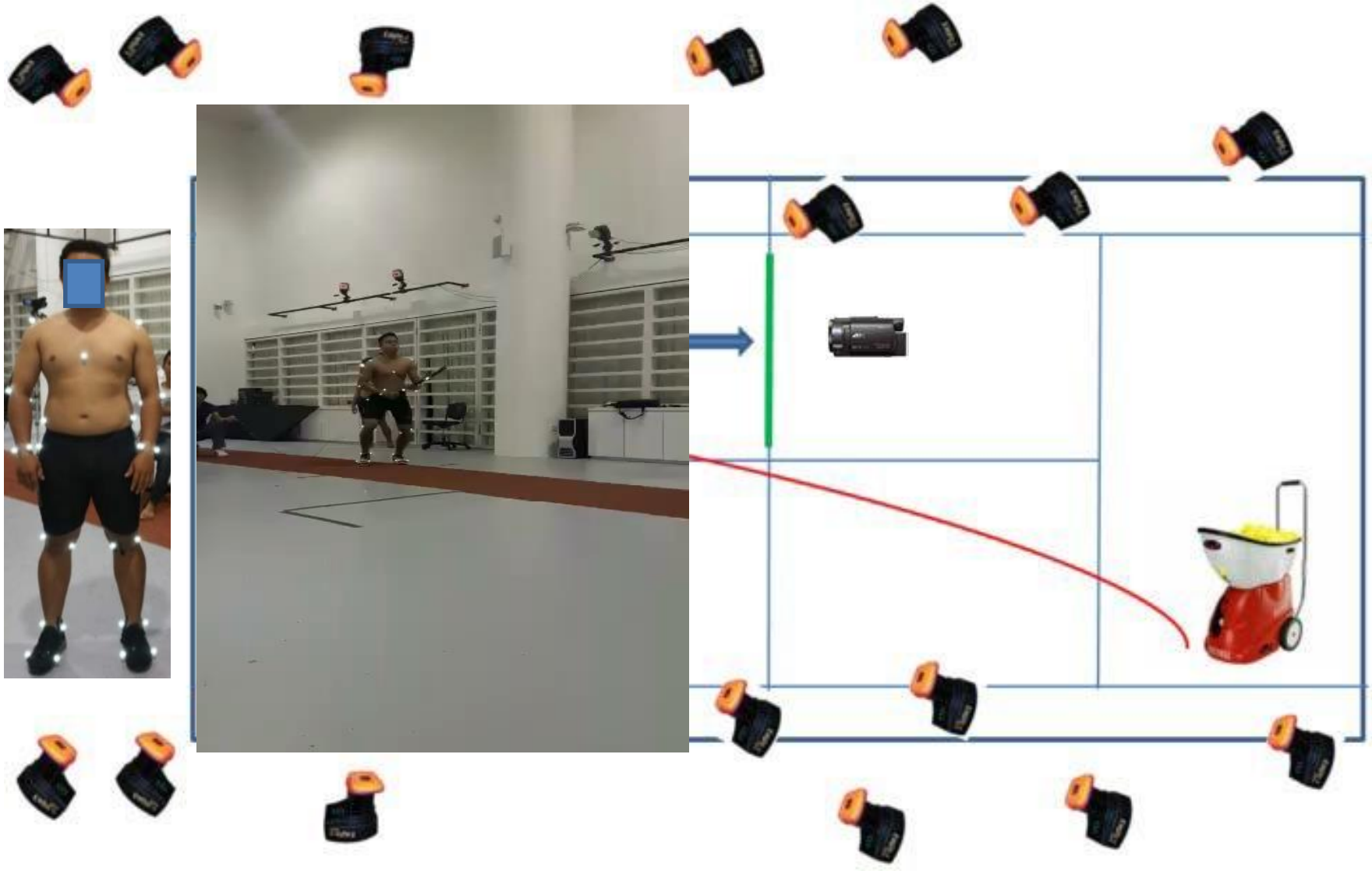




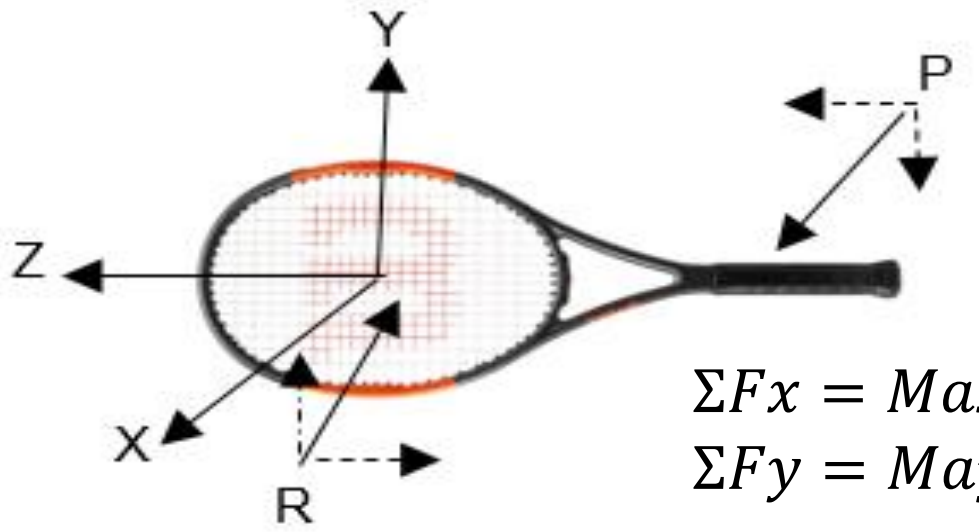
Technology in Research and Applications

- Calibration of Strain Gauges

Technology in Research and Applications



Technology in Research and Applications



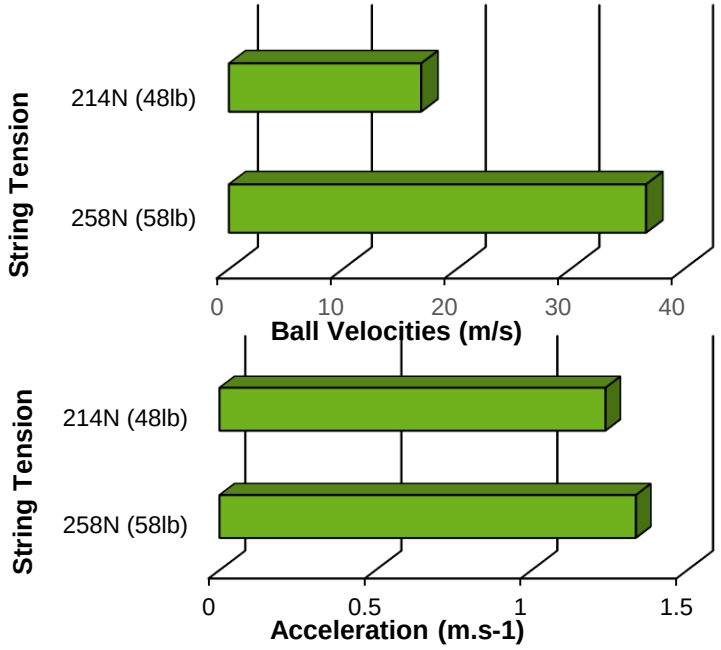
$$\Sigma Fx = Max = Rx + Px \quad (1)$$

$$\Sigma Fy = May = Ry + Py + Mg \quad (2)$$

- M = mass of racket, a_x and a_y = acceleration, R_x and R_y = impact force, P_x and P_y = force measured from strain gauge, Mg is acceleration due to gravity
- Velocity and acceleration of the racket, expressed as x, y and z were determined based on the local coordinate system of the marker position

Technological Trends in Research and Applications

	String Tension		
	214N (48lbs)	258N (58lbs)	Method
Resultant Force (N)	264N	392	Kinematic data + Strain Gauge data



- Larger peak resultant impact force for the 258N string tension than for 214N string tension
- Higher string tension, the lesser the string deforms at impact and the impact duration may be shorter
- The higher string tension racket gives more control at impact (Bower & Cross, 2005).

Bakhtiar, Sujae, Wan Zakariah, Kudo, Ong and Hamill, 2018

Technology in Research and Applications

- Universitas Negeri Padang, Sumatra Barat, Indonesia
- Semi-Professional Tennis Players
- Biomechanics Team from Republic Polytechnic

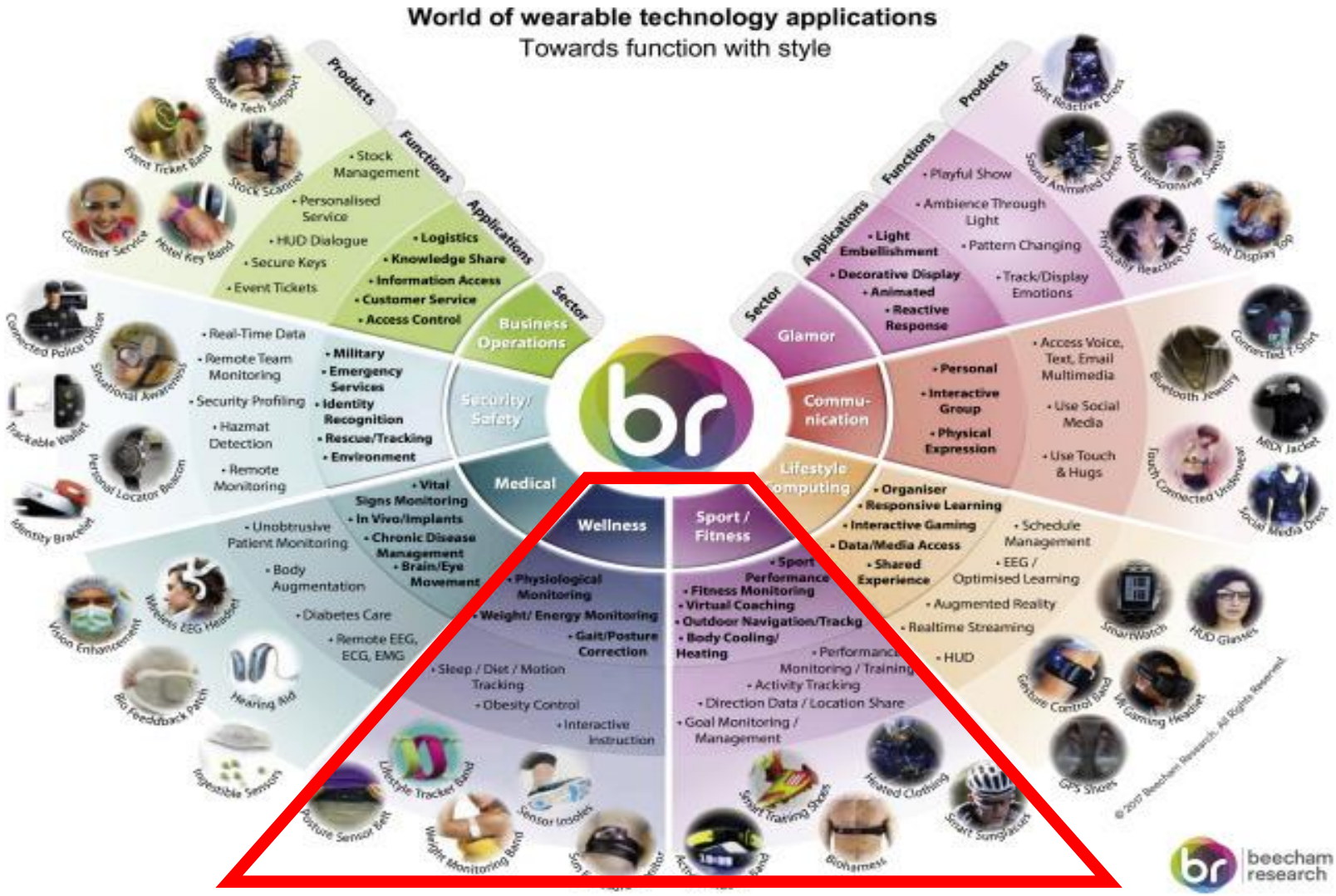
Let's Recap …

- Technology have been used for research and application in biomechanics
- Type of technology used depends on research modalities
- Data measurement and analysis enhanced by using technology
- Provide a more comprehensive feedback for coaching implications

Importance of Technology

Integrated Technology Solutions and Biomechanics

Wearable Technology



Wearable Technology and Biomechanics

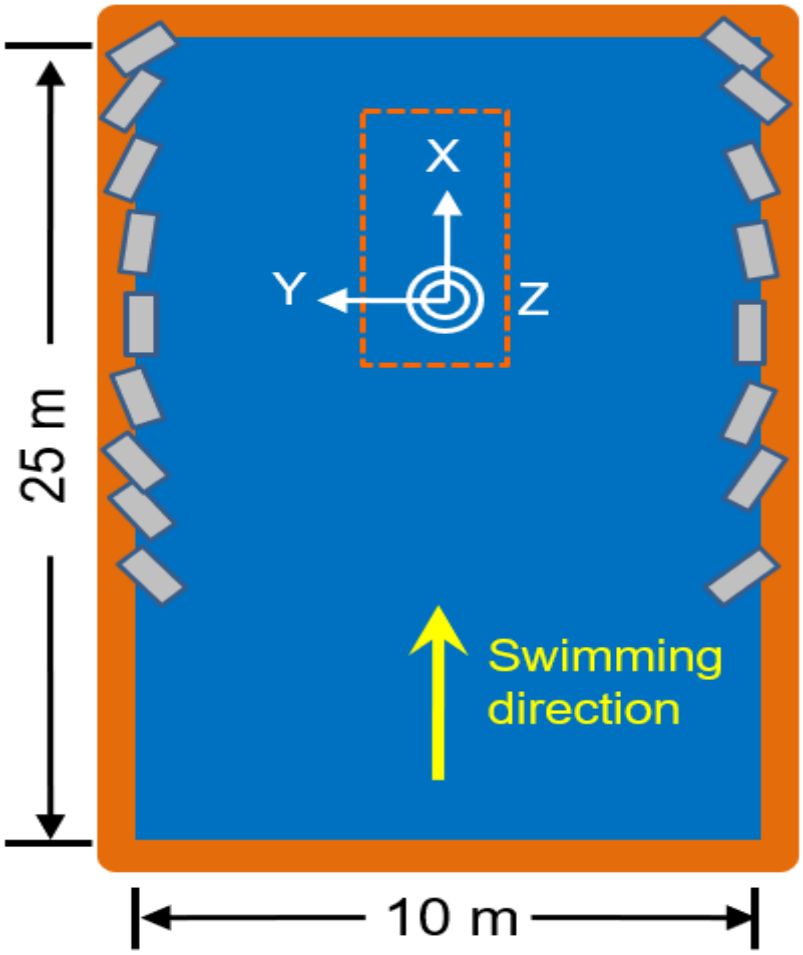
Changing Times in Sports Biomechanics: Baseball Pitching Injuries and Emerging Wearable Technology

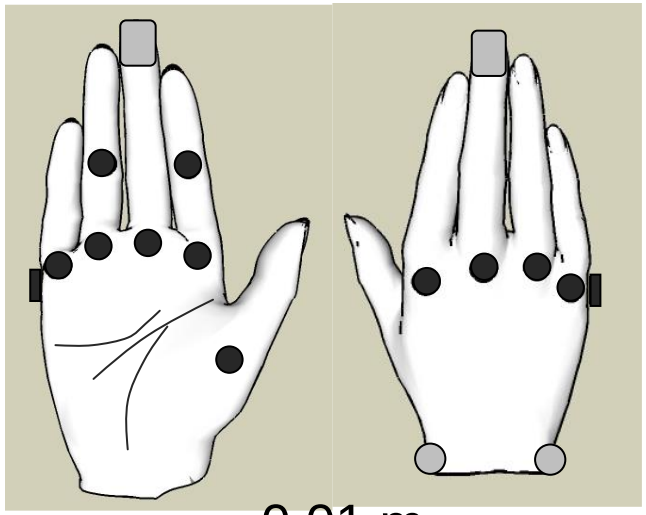
Glenn S. Fleisig, Ph.D.

Research has shown relations between amount of baseball pitching and overuse injuries, as well as between poor mechanics and high loads on the elbow and shoulder. However, overuse injuries continue to be a problem from youth to professional sports. Emerging wearable technology may enable players, parents, coaches, leagues, and clinicians to monitor biomechanics during competition and training, reducing the risk of serious injury.

Wearable Technology and Biomechanics

High-Speed Motion Camera Technology + Pressure Sensors



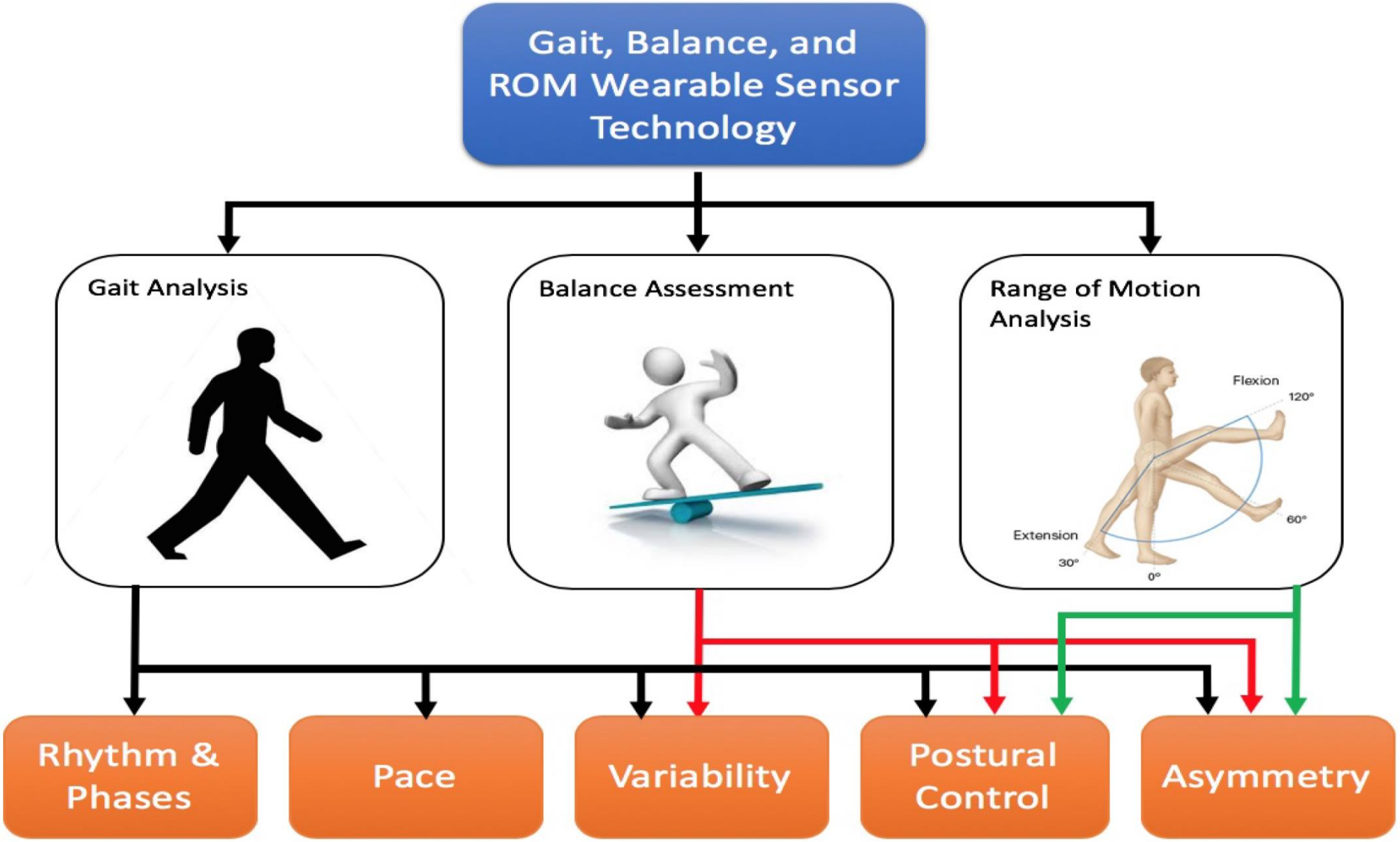


0.01 m

Data logger and pressure sensors (MMT, Japan)

(Kudo, Yanai, Wilson, Takagi & Vennell, 2008)

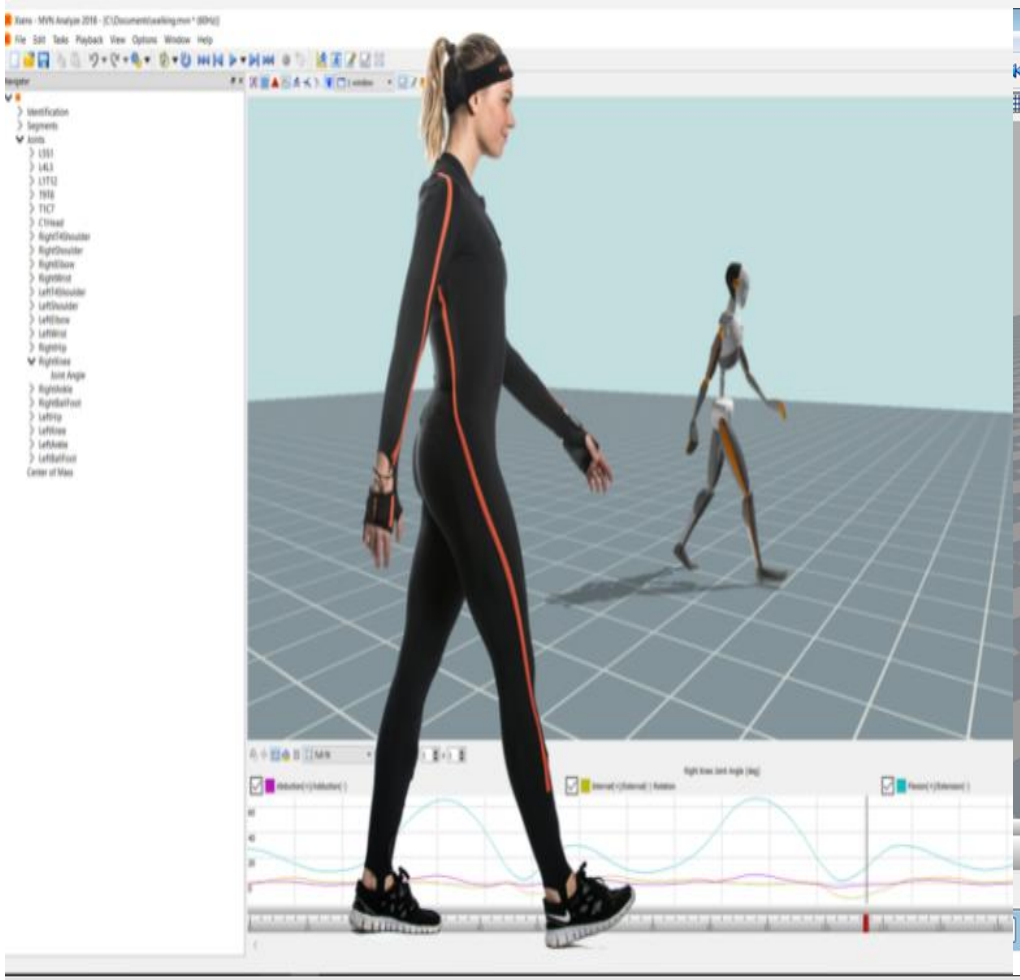
Wearable Technology and Biomechanics

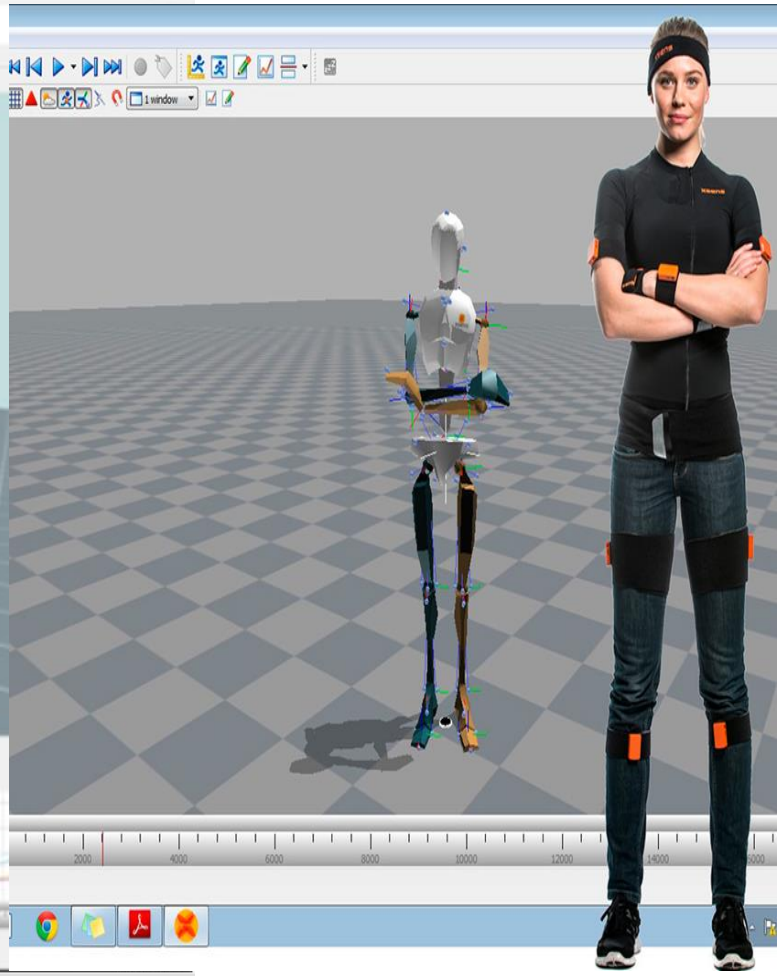


Wearable Technology and Biomechanics

https://www.indiamart.com/proddetail/3d-motion-capture-analysis-system-20811430962.html

https://www.sportsbe.es/en/technology/





Motion capture and analysis based on inertial technology

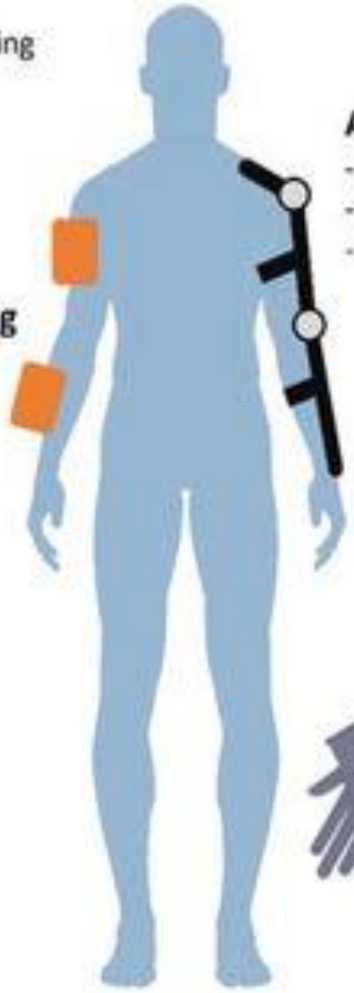
Wearable Technology and Biomechanics

Wireless Surface EMG

https://www.sportsbe.es/en/technology/

Wearable Technology and Biomechanics

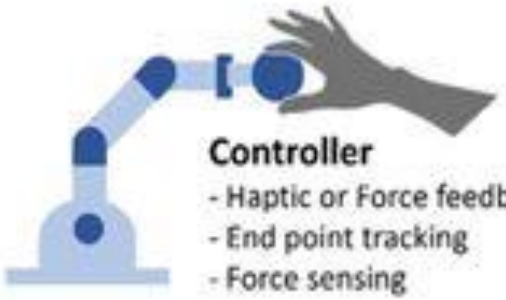
Camera
- Color-based tracking using image processing
- Optical marker tracking
- Depth sensing for body tracking
- Depth sensing for hand tracking
- Image marker tracking



Arm Exoskeleton
- Sensor for torque, force, joint rotation
- Potentiometer, optical encoder
- IMU (inertia measurement unit) for joints

Body motion tracking
- Multiple IMU tracking

Hand exoskeleton
- Hall effect sensors with pneumatic actuators
- Fusion with data glove



Controller
- Haptic or Force feedback included
- End point tracking
- Force sensing

Data glove
- Bending or optical flex sensor for fingers
- IMU for hand movement
- Accelerometer and gyroscope sensor
- Electromagnetic tracker for global position/rotation

Other sensors in devices
- IMU in hand-held controller
- Force or optical fiber curvature sensing for machine handle
- EMG (electromyography) for muscle activity

Neurorehabilitation

(Kim, Cho, Ku, Kim, Lee, Hwang & Paik, 2020)

Adaptive Technology

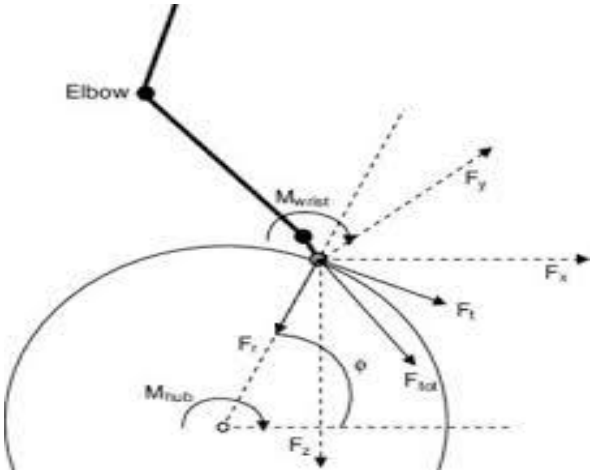
ASSISTIVE TECHNOLOGY

Any item, system, or product used to improve the functional capabilities of people with disabilities. Assistive technology can be bought off-the-shelf, modified, or custom-made.

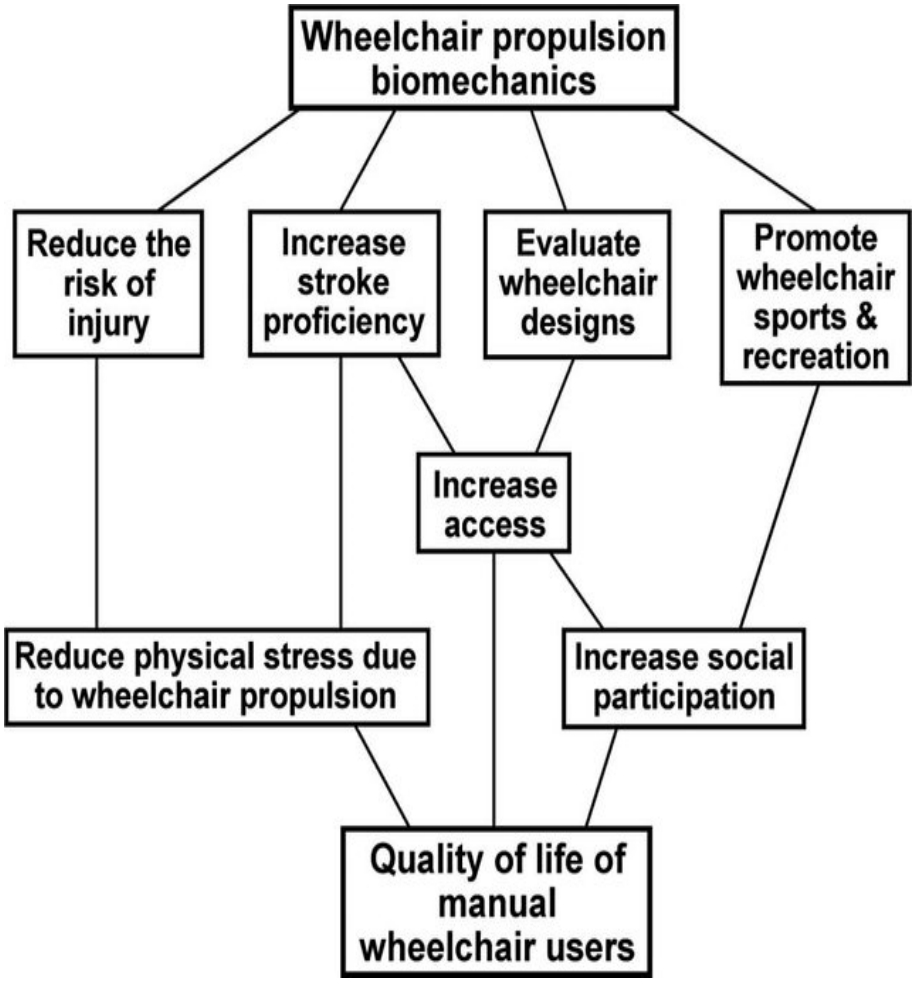
ADAPTIVE EQUIPMENT

Adaptive equipment is a subcategory of assistive technology; it refers to something specifically designed for people with disabilities.

Adaptive Technology and Biomechanics



(Vanlandewijck , Theisen &. Daly, 2001)

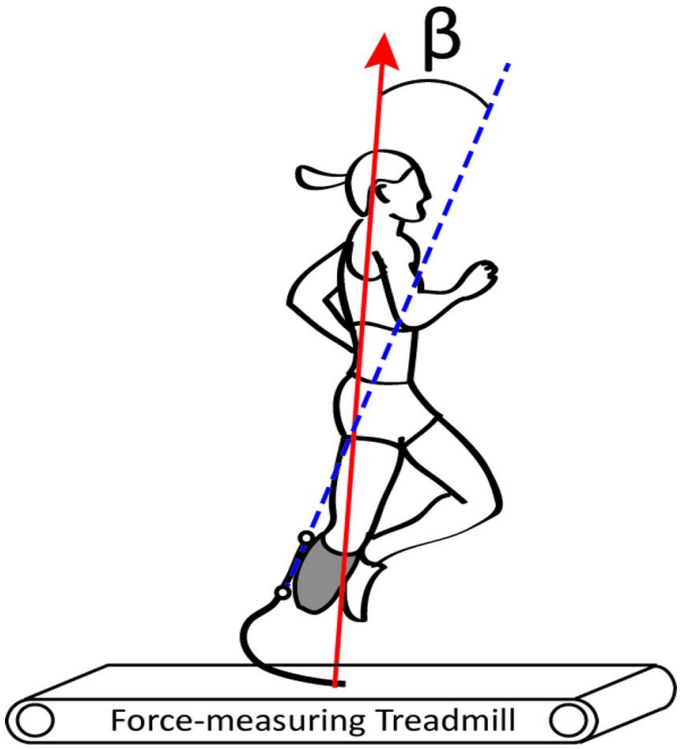


(Chow & Levy, 2010)

Wheel Chair

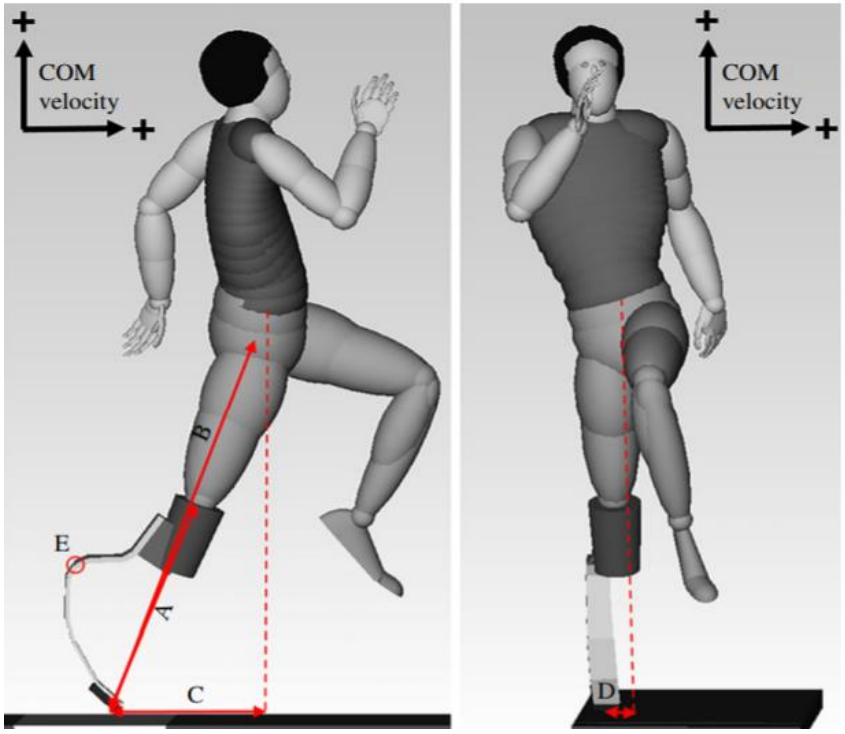
Adaptive Technology and Biomechanics

Running Gait



(Beck, Taboga &. Grabowski, 2016)

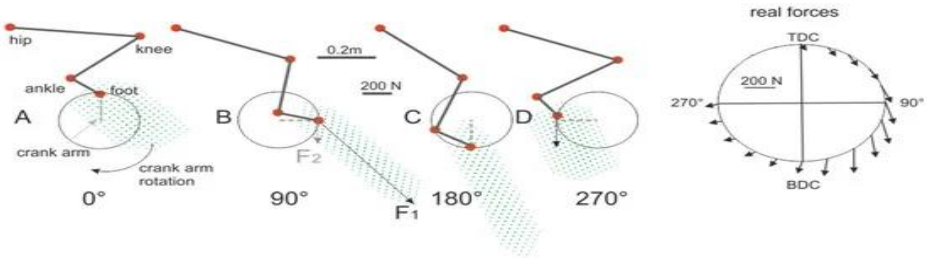
Long Jump



(Funken, Willwacher, Heinrich, Mu¨ller, Hobara, Grabowski & Potthast, 2019)

Prosthetics

Adaptive Technology and Biomechanics



(Turpin & Watier, 2020)

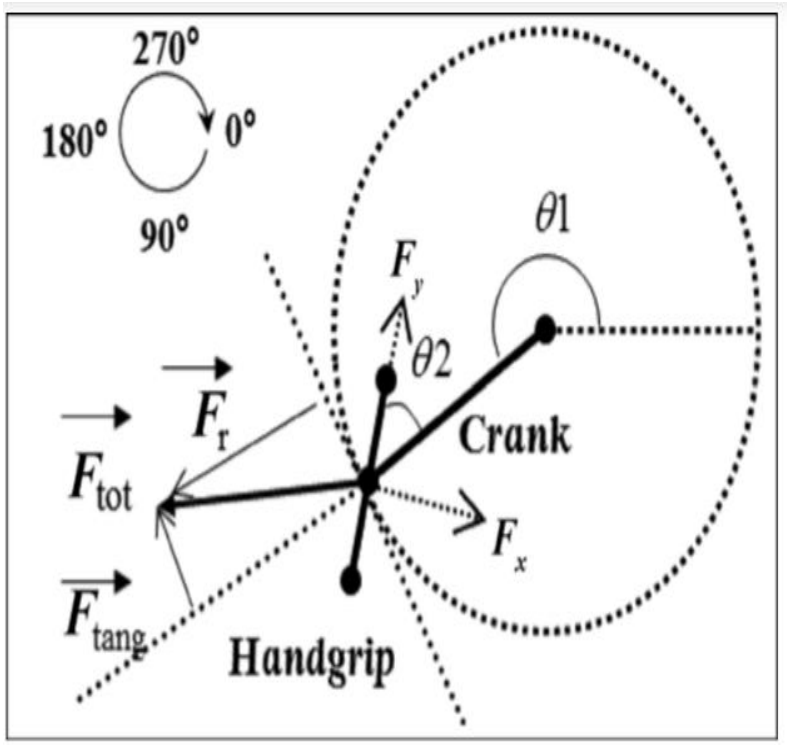


Figure 4.
Schematic representation of force using two-dimensional dynamometric pedal (on right side). Total force (F_{tot}), radial force (F_r), and tangential force (F_{tang}) were calculated from handgrip orientations ($\theta 2$) and crank angle ($\theta 1$) in global reference system.

(Faupin, Gorce & Meyer, 2011)

Cycling

Adaptive Technology and Biomechanics

Rehabilitation Robots & Intelligent Rehabilitation Systems

Applied Research

- Assistive robot of daily activities for the disabilities
- Bionic mechanism & lightweight drive system
- Training Robot for patients with nerve injuries

Biomechanics of Human Motion & Intelligent Motion Perception

Applied Basic Research

- Human-machine modeling technology
- Physical method of multimodal neuro networks of motion feedback
- Nonlinear coupled Motion control of biomechanics of human motion

Neurophysiologic Rehabilitation & Electrophysiological Technology

Basic Research

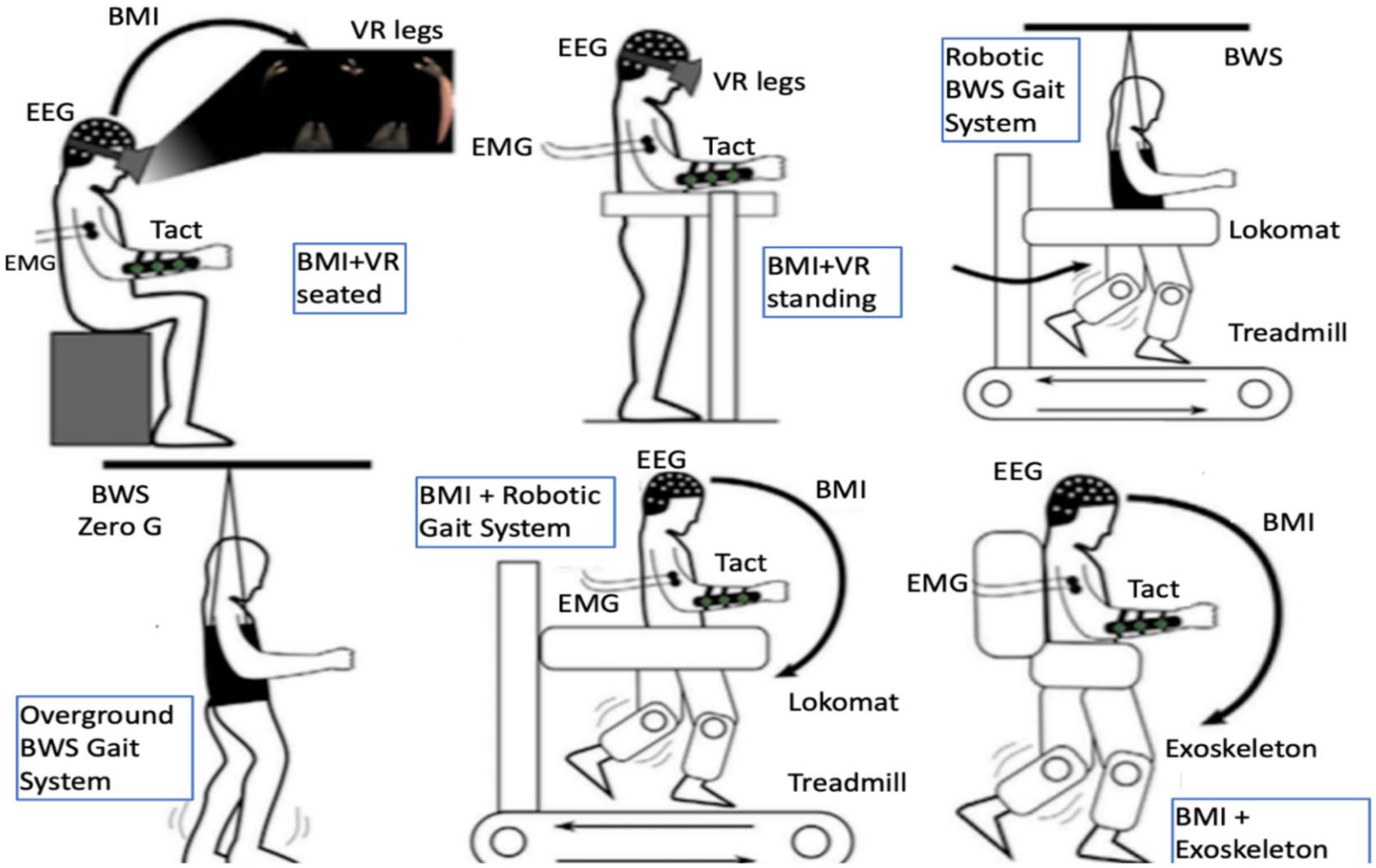
- Implanted microelectrodes treatment for central nerve injuries
- Mechanisms of neuro rehabilitation
- Detecting technology of neuroelectrophysiological signal

Rehabilitation

https://en.usst.edu.cn/Research/Institute_and_Center/Shanghai_Engineering_Research_Center__of_Assistiv1.htm

Adaptive Technology and Biomechanics

Rehabilitation



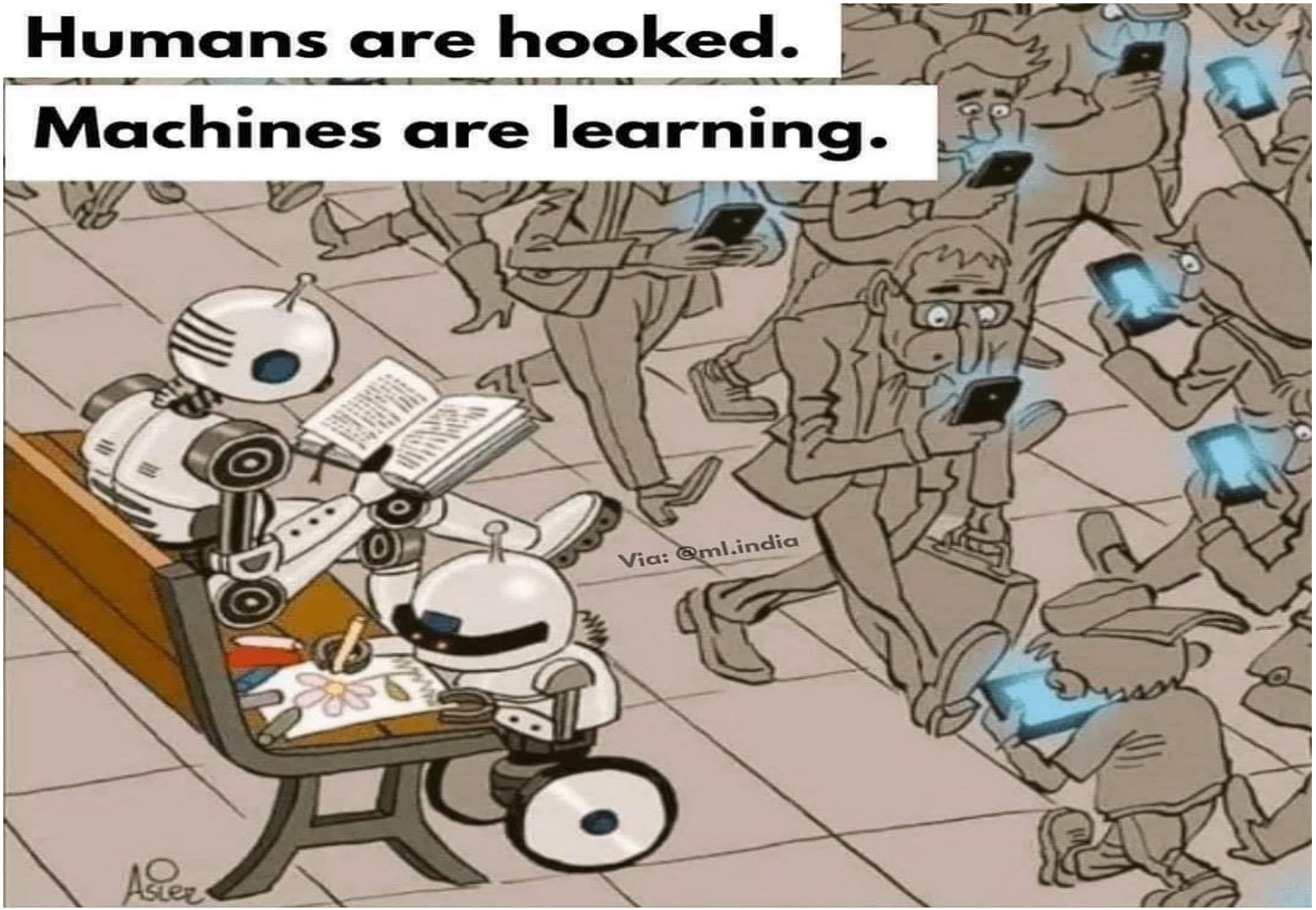
(Nizamis, Athanasiou, Almpani, Dimitrousis & Astaras, 2021; Donati et al. 2016)

AI, ML and Biomechanics

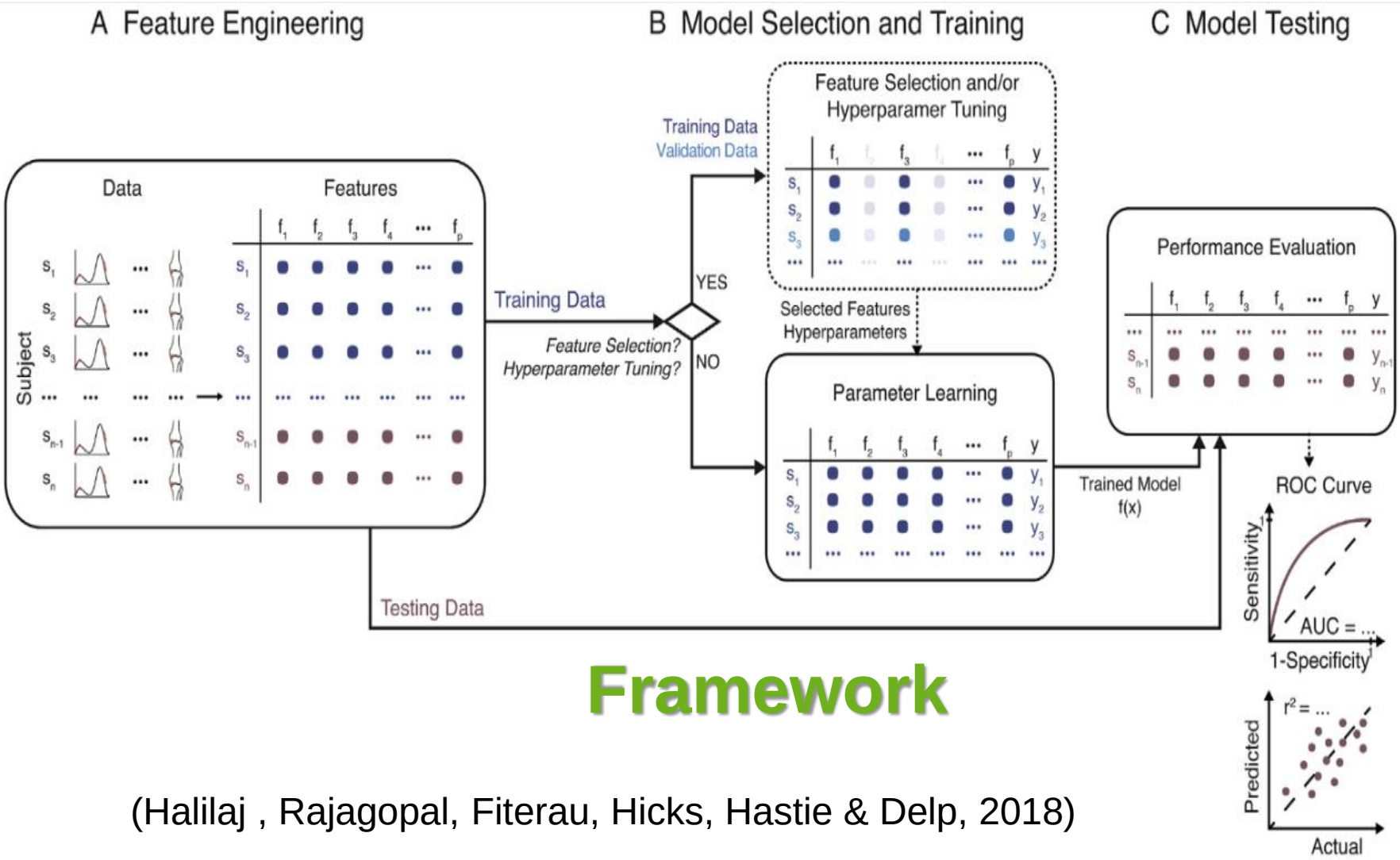
Artificial Intelligence in Sports Biomechanics:
New Dawn or False Hope?
Roger Bartlett

Automatic marker-tracking systems allow more, and more accurate, human movement data to be collected. This could lead to the use of fuzzy Expert Systems for diagnosis of faults in sports techniques, a substantial development of the rudimental.

AI, ML and Biomechanics



AI, ML and Biomechanics

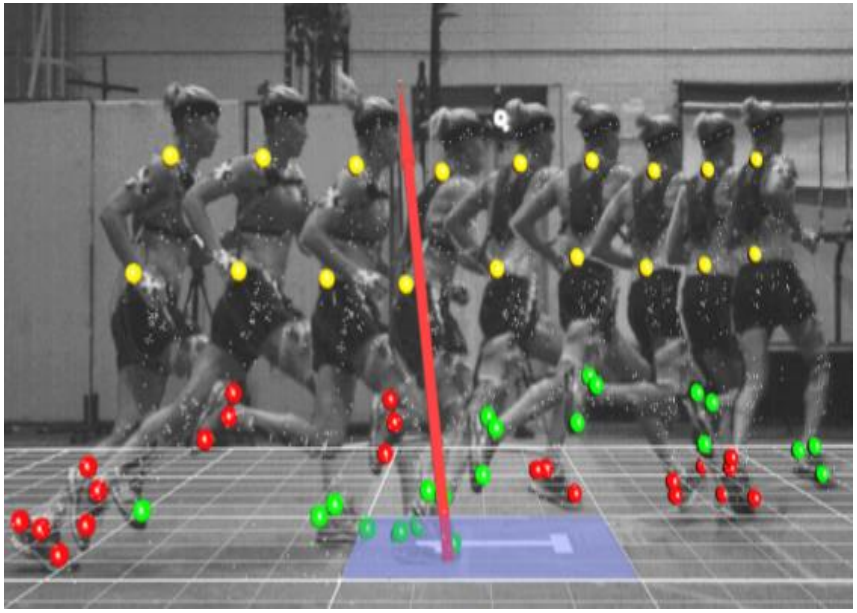


Framework

(Halilaj , Rajagopal, Fiterau, Hicks, Hastie & Delp, 2018)

Predicting athlete ground reaction forces and moments from motion capture

- 11 PLS Method and achieved average correlation coefficients of 0.9804 for GRFs and 0.9143 for GRMs
- The feasibility of predicting accurate GRF/Ms from raw motion capture trajectories in real-time



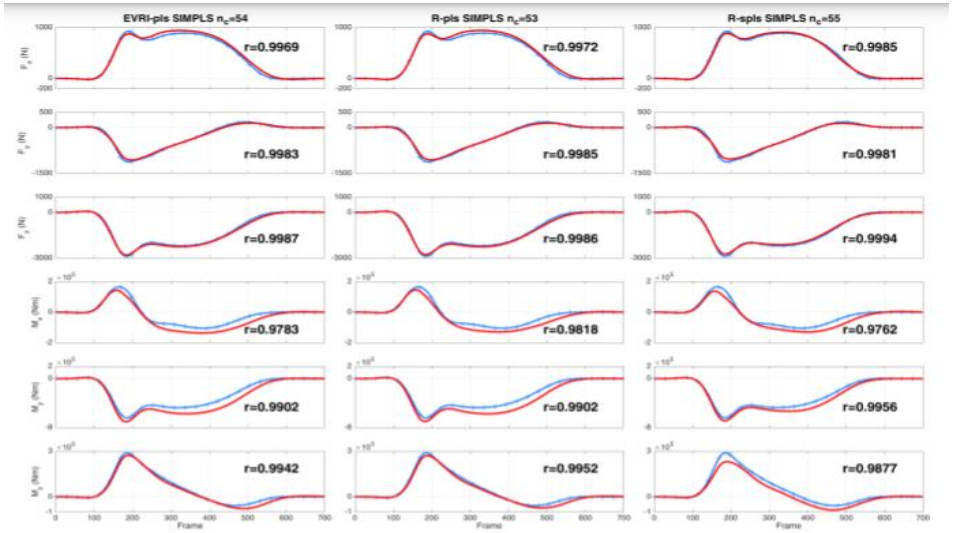
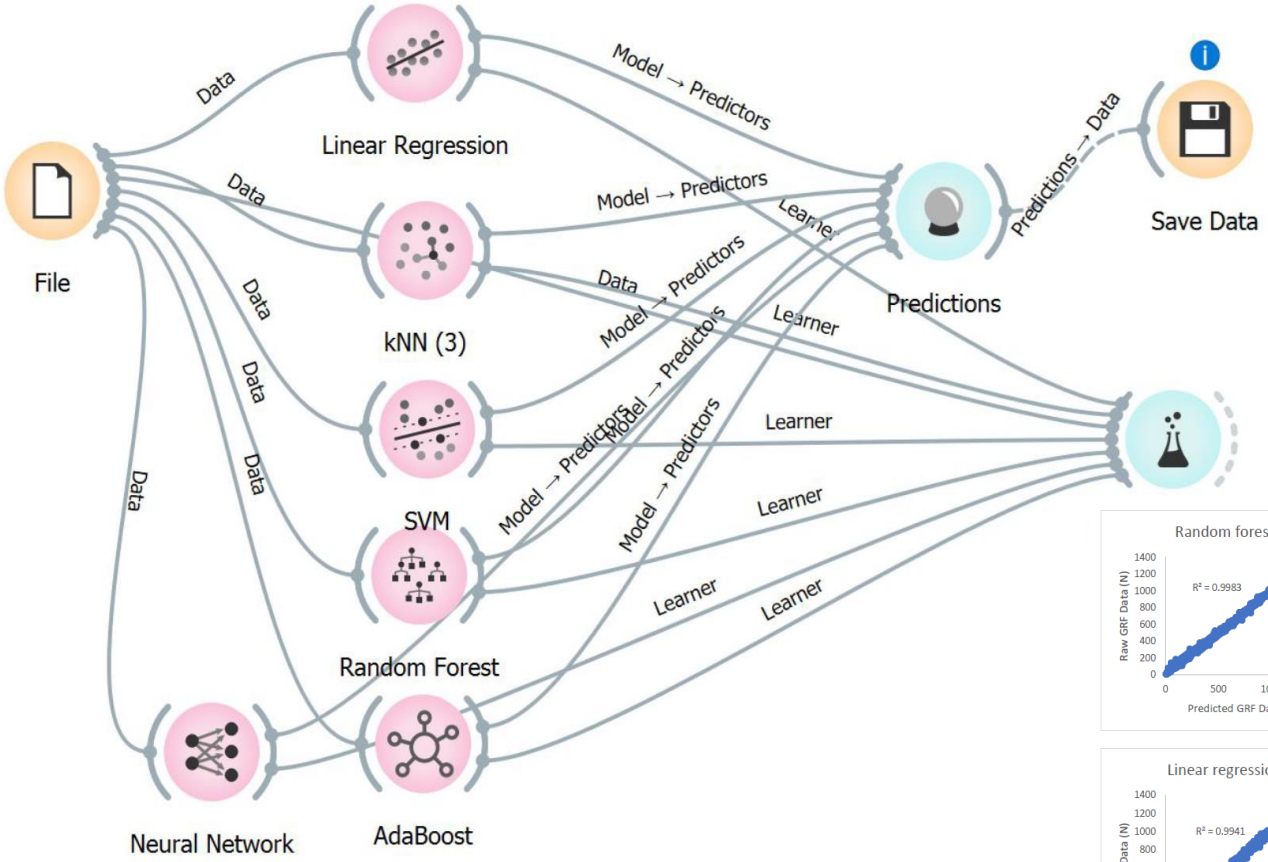


Fig. 10 Ground truth GRF/Ms (blue ticks) and predicted (red), plotted as F_x, F_y, F_z, M_x, M_y and M_z versus force plate frame for the same sample using each of the strongest PLS methods by package: EVRI-pls SIMPLS, R-pls SIMPLS and R-spls SIMPLS. The sample was selected for having the highest $r(F_{measure})$ with R-spls SIMPLS.

(Johnson, Mian, Donnelly, Lloyd & Alderson 2018)

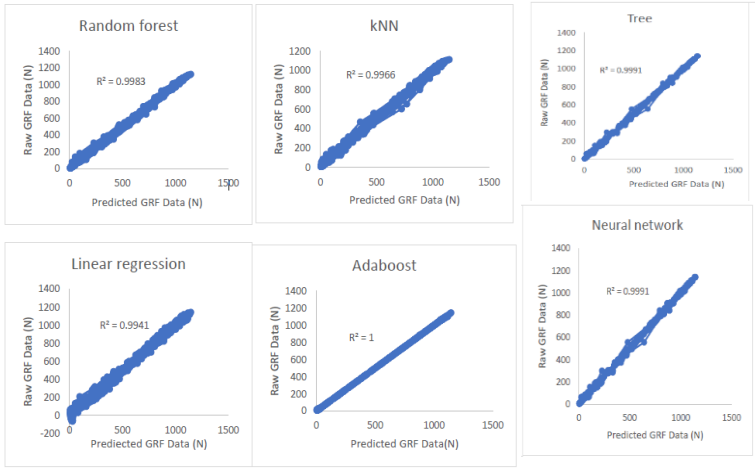
AI, ML and Biomechanics

Estimating Vertical Ground Reaction Forces (GRF) with Kinematic Data Using Machine Leaning Approach



- The kinematic data
- of the pelvis, lower limbs
- vGRF

80 – 90% Accuracy



(Sujae & Alex, 2020)

Let's Sum Up …

Thanks to the advancement of technology:-

- Biomechanics has evolved from a qualitative/ descriptive to a highly quantitative model of research.
- This development to a more quantitative approach and analysis has resulted in many ways to increase the ability to measure and evaluate movement
- The data collection and analysis techniques have led to a more detailed characterization of movement patterns.

The Labs and The Toys

Thank you

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