TECHNOLOGY AND SPORTS OF THE HANDICAPPED
Objectives

Review the history of handicapped sport and the paralympic movement

Know about the development of disability disciplines and classes

Know about fundamentals of technology in handicapped sport

Compare handicapped sports technology and general sports technology

Get an overview of biomechanical analyses in amputee walking and running
Contents

1. Origins of sport of the handicapped

2. Origins and history of the paralympic games

3. Fundamentals of classification system for paralympics

4. Examples of technology in paralympic/handicapped sport

5. Analysis of amputee walking and running
Origins of handicapped sport

• Importance of physical activity acknowledged in middle ages

• 1880 (England) - Drawing of open races

• 1888 (Germany) - foundation of the German Sport Club for the Deaf

• 20th century: time after the wars; Importance of activity during rehabilitation
Dr. Ludwig Guttmann

- 1944 (England) - established the National Spinal Injuries Centre; Stoke Mandeville Hospital, Aylesbury
- Scope: Integration of the wounded into normal life
- International professional/clinical interest in his work
- 1948 (England) - 'Stoke Mandeville Games': 16 paralysed archers (same day as opening of the London Olympic Games!)
Dr. Ludwig Guttmann ...

- 1952 (England) - SMG attract international competitors
- Idea: peaceful international sporting event: Hope & integration

→ 1960 (Italy) - 1st "Paralympic Games", Rome (same venue as OG)
Regional & national

• 1950 (Austria) - Salzburg: School for Persons with Amputations - special skiing instructions manual

• 2007 (Sierra Leone) - First all african amputee soccer championships
Organized handicapped sport

• 1952 (England) - Guttmann: foundation of ISMGF → ISMWSF

• 1964 (–“–) - International Veterans Federation founds ISOD (Int’l Sports Org. for the Disabled)

• 1968 (–“–) - Int’l CP Society founds CP-ISRA (CP-Int’l Sport & Recr. Ass.)

• 1964 (Japan) - 'Paralympic Games' (name only locally used; same venue; para - alongside)
Further development

• 1960 (Italy) - Rome: 400/23 athletes/countries represented

• 1988 (Korea) - Seoul: 3013/61 athletes/countries; hence always the same venue as the OG; ‘Paralympic Games’ as the official name by ICC (Int’l Coordinating C’ttee Sport for the Disabled in the World)

• 1989 (-“-”) - Foundation of the IPC (Int’l Paralympic C’ttee)
Winter & Summer Games

• 1974: Idea of paralympic wintergames discussed by ISOD

• 1974 - 75: SHIF (Swedish Sport Org. For the Disabled) warrants to add the 1st Winter Olympic Games for the Disabled to the Örnsköldsvik Games (Sweden), 1976
Technology

Are the 'paralympics' a showcase for technology in sport?
More technology?
Classification

Initially purely based on medical diagnosis:
L2 spinal cord injury vs. Double above knee amputee (T54)

Focus on sport, rather then diagnosis - GOAL:

The purpose of a Paralympic Sport classification system is to minimize the impact of impairment on the outcome of competition, so that the athletes who succeed in competition are those with best, anthropometry, physiology and psychology and who have enhanced them to best effect (training hard, quality coaching).

(IPC, 2009)

→ Evidence based classification ...
Technology interaction

Ambulation in lower extremity amputees

Amputation effects?

Reduced muscle mass, passive joints, ideal elastic deformation of springlike mechanisms, coupling/connection problem

- Unilateral vs. Bilateral amputees
- Transtibial vs. Transfemoral amputees

Mechanical analysis required
Modeling & Simulation

- Represent human anatomy as simplified mechanical model – e.g. rigid body model
- Derive dynamic equations of motion – Newton-Euler, Lagrangian method, etc.
- Measure kinematic data and GRF
- Inverse Solution → Forces & Torques
- Solve differential equations of motion by specifying input forces & torques plus initial conditions
Free-body diagram of two-segment foot

\[ F = \sum M a + \sum I \alpha \]

- \( F \) – net force;
- \( M \) – segment mass;
- \( a \) – acc.;
- \( \alpha \) – ang. Acc;
- \( I \) – moment of inertia
Example of Full Body Model

- Fifteen segment 3D model
- Rigid Body assumption
- Fixed joint axes
- Ideal joints
- Fixed inertia properties
- No muscles

Study I

Powers et al. (1998) - Knee kinetics in TTA

- 10 amputees vs. 10 healthy
- Walking
- Seattle light foot
- 1 month accommodation
- 3D motion capture
- 1 force plate
- EMG (fine wire, VL, BF, SM)
Results

Walking speed: 1.21 - 1.42 m/s
Cadence similar
Heel only contact: 20.6 - 12.1%
Knee Moment & Power

Normals:
external flexion moment

\[ P = M \times \omega \]

Demo!
EMG results

Higher & longer activation of all muscle groups investigated
Discussion

Stiff knee strategy

Reduced mechanical demand at knee joint

Increased muscle effort of knee flexors and extensors

Explanantion for increased energy demand in amputee walking (135%)
Study II

Czernieckie et al. (1991)
- 5 amputees vs. 5 healthy
- Slow running (2.8 m/s)
- SACH, Flex, Seattle feet
- experienced
- 2D motion capture
- 1 force plate
Results

SACH foot

Hip: greater extension moment → greater power fluctuation

Knee: reduced moment → less absorption

Ankle: power generator → balanced
Total work

Comparably small differences between prosthesis types

Work: Integral of power over stance phase
Summary

Overall less work done on prosthetic side

Seattle light and Flex feet improve energy generation (99.7, 127.6, 141.1 J)

Passive use of amputated side?

With suitable prosthesis design a more normal situation can be achieved.

Limitations: contact mechanism neglected, fixed joint axis assumption
Study III

Kersting et al. (2010) - Case study
- 1 left sided TTA (female)
- $M = 63 \text{ kg}$
- Running (sub-/maximal)
- Carbon blade leg
- experienced
- 3D motion capture
- 2 force plates
Results: GRF right

- Medial-Lateral Force
- Anterior-Posterior Force
- Vertical Force
- Impulse
GRF left

- Medial-Lateral Force
- Anterior-Posterior Force
- Vertical Force
- Impulse
Moments & Power right

Hip Moments right

Hip Power right

Knee Moments right

Knee Power right

Ankle Moments right

Ankle Power right
Moments & Power left

- Hip Moments left
- Hip Power left
- Knee Moments left
- Knee Power left
- Ankle Moments left
- Ankle Power left
Frontal Plane

A

B

C

D
Summary

Stiff knee strategy partially confirmed

→ Maybe result of spring blade inclusion

→ Problem velocity adaptation

→ Knee muscles on amputee side reflect passive ‘knee action’

Highly asymmetric hip joint loading

→ Injuries at the hip (trunk?)

→ Mass distribution

→ Room for improvement, further research
Study IV and V

The Pistorius story

two independent tests ...

Next meeting / date?
Conclusion

Paralympics are a consequence of ‘human nature’

Point of discussion: Paralympics as a showcase of sport technology?

Interaction of assistive devices and human body is not well researched

Therefore, a great scope may lie in further work in this area
Tasks for next seminar

Literature review: Following the instructions
Individual presentation of 10 min

Group work on:
- IPC classification system - does the evidence based approach work?
- Paralympics as technical showcase Yes/No?
- The case Oscar Pistorius - should handicapped and healthy athletes compete together?