The significance of technology for human performance in sports

Objectives

Brainstorm on technology and sports performance
Think about:
Technology to measure performance
Technology to illustrate/document performance
Technology to support performance
Technology to counteract performance
Technology to analyse performance
Contents

1. Course setup - Brainstorm
2. Measurement as fundamental constituent of performance
3. Visualisation/documentation of performance
4. Using technology to improve performance
5. Where technology becomes hindrance
6. Technology to analyse and improve performance

The course:
Applied Technology in Sports

Learning goals:
- To give the student a broad understanding of how and in which ways technology have contributed to performance in sports (+)
- When the students have completed the course the students shall be able to analyze and give suggestions to how technology can be applied in sports at present and in the future

Course format: Introductory lecture
Mini project
Presentation of mini project outcome
The course: Applied Technology in Sports

Analysis of sport performance is a multidisciplinary research area involving e.g.:
- Human physiology
  - Musculo-skeletal anatomy/physiology
  - Exercise physiology
  - Motor control
- Physics / mechanics
  - General mechanics
  - Materials
- Mathematics
  - Numerical techniques
    - Musculo-skeletal modeling
    - Optimization
- Computer science
  - Simulation
  - Visualization
- Mechanical engineering
  - Equipment design
- Sports medicine
  - Musculo-skeletal injury mechanisms
  - Injury prevention

Historical perspective

'One on one' comparisons
Group/team matches
War 'games', hunting, ...
Cricket (pre 1600, England)
About being 'a good sport!'
Other gentlemen 'sports'
**Cricket vs Baseball**

- **Cricket**: Ball bounces when delivered  
  Ball delivered from 20yds  
  Bowler delivers 6 deliveries then new bowler  
  Innings consists of 10 outs  
  Normally 2 innings each per game

- **Baseball**: Ball reaches batsman on full  
  Ball delivered from 20yds 6"  
  Pitcher pitches until he is pulled by coach  
  Innings consists of 3 outs  
  9 innings each per game

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**Technology is needed for results**

- Tape measure
- Stop watch
- Photographic techniques (up to 3000 Hz)
- Timing gates/contact mechanisms (video up to 2000 Hz)
Applied Technology in Sports

Has analysis of human movement and technology given significant improvement in sport performance?

Example speed skating

Speed skating – classical push off technique

Fig. 2. Knee angle $\theta$ during the speed skating stroke. Note that the skate loses contact with the ice well before full extension (the continuing extension to 180° takes place after the skate is lifted from the ice).

From: Ingen-Schenau (1989)
Theoretical background -
Action of bi-articular muscles

'belt like' action

'jumping jack'

Ingen-Schenau (1989)

Theoretical background -
Action of bi-articular muscles

'power transportation'
- proximal to distal

- mechanical power generated by proximal mono-articular muscles is transported to distal joints via bi-articular muscles

Ingen-Schenau (1989)
Introduction of the clap-skate

Alles over de klapschaats

Other examples

Other examples of disciplines analysis and technology have contributed significantly

Bicycling
- Reducing drag
- Frame technology
- Bicycle weight reduction

Running
- Injury prevention based on basic biomechanical understanding of running
- Design of running shoes
- Tuned tracks

Understanding running economy
Cycling
- optimization/minimization of drag force

- Wind tunnel experiments

Cycling
- optimization of maximal crank power output

Empirical determination of maximal muscle torque vs crank angle profile
Taking the force-velocity relation into consideration and the inertia of the legs they developed an equation for the maximum applied torque as a function of crank angle and angular velocity
An optimization algorithm determined the theoretical crank angular velocity profile maximizing the power output per pedaling cycle
The velocity variation was constrained so a chaining shape could actually reproduce the velocity profile
Basic running mechanics

(From: Biomechanics in Sport
Editor Vladimir Zatsiorsky
Blackwell Science 2000)
Understanding running economy

Twenty eight Danish male elite runners
Personal record >33min on 10km.

Determination of running economy (RE):

\[ RE = \frac{VO_2}{BM \times Vel} \text{ ml kg km}^{-1} \text{ km h}^{-1} \]

Hypothesis:
Runners with good running economy activate their muscles earlier before ground contact

Measurement of oxygen consumption
(Medgraphics CPX On-line)

from: Voigt at al. 1997, ISB Tokyo

Table 1.

<table>
<thead>
<tr>
<th></th>
<th>B group</th>
<th>G group</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean (SD)</td>
<td>mean (SD)</td>
<td></td>
</tr>
<tr>
<td>height (m)</td>
<td>1.81 (0.03)</td>
<td>1.81 (0.03)</td>
</tr>
<tr>
<td>body weight (kg)</td>
<td>69.21 (4.39)</td>
<td>70.57 (3.68)</td>
</tr>
<tr>
<td>age (years)</td>
<td>25.70 (3.50)</td>
<td>27.70 (4.30)</td>
</tr>
<tr>
<td>(VO_2) max (l min(^{-1}))</td>
<td>4.82 (0.29)</td>
<td>4.60 (0.32)</td>
</tr>
<tr>
<td>stride length (m)</td>
<td>3.54 (0.13)</td>
<td>3.64 (0.38)</td>
</tr>
<tr>
<td>stride frequency (Hz)</td>
<td>1.51 (0.09)</td>
<td>1.47 (0.09)</td>
</tr>
<tr>
<td>record velocity, 10km (km h(^{-1}))</td>
<td>19.22 (0.84)</td>
<td>19.14 (0.90)</td>
</tr>
</tbody>
</table>

from: Voigt at al. 1997, ISB Tokyo
Understanding running economy

• Group averages of EMGs (light colors)
• Velocities of origin-to-insertion length-changes (dark colors)
• 8 lower extremity muscles of the right leg
• Blue = Ggroup (N=6)
• Red = Bgroup (N=6).
• average velocity corresponding personal record at 10km (about 19.18 km hr⁻¹).
• The signals are both amplitude and time-normalized.

- no significant differences between groups!
Understanding running economy

“........The good running economy cannot be explained by differences in muscle fibre type as they are the same in Kenyan and Caucasian runners. The same is true when comparing untrained adolescent Kenyan boys with their Caucasian counterparts. A difference exists in BMI and body shape, and the Kenyans’ long, slender legs could be advantageous when running as the energy cost when running is a function of leg mass. .......”


Running shoe design

Performance
• Mechanics

Injury prevention
• Mechanics
• Foot climate

• Fashion
• The looks

From:
Biomechanics of Distance Running. Ed. P. Cavanagh
Human Kinetics 1990
The effect of material characteristics of shoe soles on muscle activation and energy aspects of running
(Nigg et al. J. Biomechanics 36(2003), 569-575)

- 20 runners
- two different shoe sole materials
- treadmill running
- EMG measurement
- Oxygen consumption

Running shoe mechanics – and performance

Fig. 1. Force-deformation diagrams for the two kinds of the tested shoes as determined through MTS testing at 0.9 Hz. Each curve is the average of three test results under the same conditions.

Running shoe mechanics – and performance

Fig. 4. Individual normalized differences in oxygen consumption between the elastic and the viscous shoe condition. Positive values indicate that VO$_2$(elastic) > VO$_2$(viscous). Negative values indicate that VO$_2$(elastic) < VO$_2$(viscous). The differences were determined based on four oxygen measurements during four different trials per shoe condition (a total of 16 measurements per shoe and 32 measurements per difference). The shaded bars indicate the five subjects that had the same positive difference between the elastic and the viscous shoe condition for both days.
Optimization of running shoes - for prevention of injuries

Table 8.3: Common injury sites in running.

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Subjects</th>
<th>No. of Injuries</th>
<th>Type of Data</th>
<th>Site of Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>James et al. (1978)</td>
<td>Runners</td>
<td>180</td>
<td>Clinic</td>
<td>Knee pain 29.0</td>
</tr>
<tr>
<td>Clement et al. (1988)</td>
<td>Runners</td>
<td>150</td>
<td>Clinic</td>
<td>Shin spirt tibial-stress 13.0</td>
</tr>
<tr>
<td>Dallas et al. (1997)</td>
<td>Runners</td>
<td>860</td>
<td>Clinic</td>
<td>Syndroms 13.2</td>
</tr>
<tr>
<td>Bennell and Crossley (1996)</td>
<td>Runners</td>
<td>39</td>
<td>Interview</td>
<td>Archilis tendinitis 6.0</td>
</tr>
<tr>
<td>Bennell and Crossley (1996)</td>
<td>Sprinters</td>
<td>19</td>
<td>Interview</td>
<td>Plantar Fascitis 4.7</td>
</tr>
</tbody>
</table>

Rear foot motion - over pronation

Fig. 8.3: Leg, heel, and rear foot angle curves during rear foot pronation for an example runner.

(From: Biomechanics in Sport, Editor Vladimir Zatsiorsky, Blackwell Science 2000)
Running shoe technology

For sprint running as well as distance running the concept of energy return has proven to be far more difficult than expected.

Reebok1
Reebok2
Reebok3
(Shorten 1992; Stefanyshyn, 2004)

Solution

Applied Technology in Sports
- societies and www resources

International Sport Engineering Association (ISEA)
Homepage: http://www.sportsengineering.co.uk
Journal: Sports engineering

International Society of Biomechanics (ISB)
Homepage: http://www.isbweb.org/
Journals: Journal of Biomechanics, Journal of Applied Biomechanics, Clinical Biomechanics
Conference every fourth year
World council of Biomechanics
Biannual conference
http://www.wcb2010.org
International Society of Biomechanics in Sport (ISSB)
Homepage: http://www.twu.edu/biom/isbs/
Journal: Sports Biomechanics

Applied Technology in Sports
- Other areas of interest (not a complete list):

Athletics
Technique
High jumping - Fosbury flop
Long jumping - coordination of second last step
Shot put - linear vs. rotating
Equipment
Running tracks - surface structure and compliance/stiffness
Pole-vaulting - the pole
Javelin - design of the javelin

Trampoline, diving
Technique
Airborne movement (combinations of somersaults and twists)

Ball games
Technique
Throwing - e.g. baseball pitching
Batting - e.g. baseball and cricket
Golf - the swing
Equipment
The aerodynamics of the football
Functional design of soccer shoes
Functional design of rackets (tennis, badminton)
Functional design of golf clubs

Swimming
Technique
Freestyle and breast stroke - hydrodynamics
Equipment
Swim suits - drag
Skiing
Equipment
Discipline specific ski design
Etc. etc.
Applied Technology in Sports

University of Loughborough
- Sport Technology Institute
- http://www.lboro.ac.uk/departments/mm/research/sports-engineering/

Apparel:
- Computer Modeling of Functional Fabrics
- Intermittent pneumatic compression systems
- Ball Sports (Generic):
  - Automated Measurement of Ball Launch Conditions
  - Laser Measurement of Sports Ball Spin
  - Aerodynamics of Sports Balls
- Cricket:
  - Virtual Reality for Automated Training
  - The Effect of Weight Distribution on Cricket Bat Properties
- Equestrian:
  - Development of Horse Hooves
- Fitness:
  - Implementation of new technologies in treadmill design
  - Increased energy expenditure with reduced perceived exertion
  - Innovative developments in resistance training equipment
- Golf:
  - Assessment of Human Perception of Golf Equipment
  - Customization of sports grips using rapid manufacturing methodologies
  - Measurement and Analysis of the role of the grip in a golf shot
  - Robotic Simulation of Golf Swings
- Perception:
  - Player perception of Soccer Balls
  - Assessment of Human Perception of Sports Equipment
- Rugby:
  - Advanced modeling of Ovoid Balls
- Soccer:
  - Soccer ball surface interactions
  - Player perception of Soccer Balls
  - Advanced modeling of Soccer Balls
  - Sports Pitch:
  - Design of Synthetic Hockey Pitches
  - Non-Metric Shockpad for Outdoor Artificial Sports Surfaces
- Swimming:
  - Swimming Goggle Design
  - Human Factors in Tennis Ball Design
- Tennis:
  - Customization of sports grips using rapid manufacturing methodologies
  - Human Arm Modeling of Tennis Strokes
  - Tennis Ball Degradation
  - Computer Simulation of the Backhand Tennis Stroke

Footwear:
- Advanced Modeling of Athletic Footwear
- Boundary Conditions for Athletic Footwear Testing

Sports Pitches:
- Design of Synthetic Hockey Pitches

And the trampoline ...