Kicking in Soccer

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19.07.-23.07.2010

Kicking: Art and Sports

Sculpture “Soccer Player”
Renée Sintenis - Berlin, Germany
1927

Soccer Subject
University of Duisburg-Essen, Germany
2005
Outline

- Kicking Movement
- Measurement Technology
- Performance Criteria
- Influence of Footwear
- Research Perspectives

Kicking: Complex Motor Movement

6 Phases:
- Approach angle
- Plant foot forces
- Swing limb loading
- Hip flexion and knee extension
- Foot to ball contact
- Follow-through

5 Phases:
- Approach
- Support leg
- Kicking leg
- Foot to ball contact
- Ball flight

Bauer 1990
Barfield 1998
Lees et al. 2010
Kicking Leg – Angular Velocity

Lees 1998

Kicking Leg – Segment Speed

Lees 1998
Key Aspects for Fast and Accurate Kicking

**Velocity:**
- Kicking Type, Technique
- Skill level, Limb Dominance
- Age, Maturity, Gender
- Muscle Strength & Power
- Approach Speed and Angle
- Energy Transfer between Body Segments

**Accuracy:**
- Approach Speed
- Kicking Velocity Reduction
- Foot to Ball Contact Point
- Ball Spin

Foot to ball impact characteristics

Foot to Ball Contact: Impact Phase

Duration: 6 - 16 ms

Open - loop movement

Displacement of the ball

Mixture of impact-like and throwing-like aspects
Impact Phase

Shinkai et al. 2009

Kicking Techniques

- **Instep Kicks:**
  - Full Instep
  - Inner Instep
  - Outer Instep
  
  - Spin

- **Other:**
  - Side Foot
  - Toe Kick
  - Knuckle Kick
  
  - Specific Techniques
Predominant Kicking Techniques – Purposes

<table>
<thead>
<tr>
<th></th>
<th>Full Instep</th>
<th>Inner Instep</th>
<th>Side Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>51</td>
<td>88</td>
<td>330</td>
</tr>
<tr>
<td>Men</td>
<td>42</td>
<td>60</td>
<td>407</td>
</tr>
</tbody>
</table>

Team incidents during a 90 minute soccer game, Althoff et al. 2010

Movement | Measurement Technology | Performance | Footwear | Perspective
---|------------------------|-------------|----------|------------
Full Instep Kick
Giovanni van Bronckhorst (Netherlands) – World Cup 2010: Uruguay vs. Netherlands (2-3)
Inner Instep Kick
Yasuhito Endo (Japan) – World Cup 2010: Denmark vs. Japan (1-3)

Side Foot Kick
Elano (Brazil) – World Cup 2010: Brazil vs. North Korea (2-1)
Kicking Performance

- Levanon & Dapena 1998
- Nunome et al. 2002
- Neilson & Jones 2005
- ...  

Basic Performance Criteria

- Kristensen et al. 2005
- Scurr & Hall 2009
- Sterzing et al. 2009

Velocity

Accuracy

Movement Measurement Technology Performance Footwear Perspective

High Speed Video

provided by Shinkai et al. 2009

Movement Measurement Technology Performance Footwear Perspective
Motion Analysis Systems

Radar Gun

- 20 milliwatt Ka band dual horn microwave
- accuracy: 0.1 km/h
- speed range: 1 to 480 km/h
- acquisition time: 0.01 seconds
- update rate: 100 per second
**Measurement Technology for Kicking Accuracy**

- Plywood wall laminated with carbon paper for impact imprints
  
  Finno et al. 2002

- Circular electronic target (concentric wire frame)
- Ball contact generates electrostatic charges
- Software based determination of ball impact location

  Hennig et al. 2009

- Digital camera recording (25 Hz)

  Scurr & Hall 2009

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**Kicking Accuracy Measurement Technology**

- High speed video capturing of ball impact location (200 Hz)
  
  CMOS Camera HCC-1000, VDS Vosskühler, Germany

- Accuracy determination: distance ball center to bull’s eye
  
  MaxTRAQ 2.06, Innovisions Systems, MI, USA

  Sterzing et al. 2009
Relation of velocity (VEL) and accuracy (ACC)

Sterzing et al. 2009

Simultaneous quantification of VEL and ACC of full instep, inner instep and side foot kicks

- Speed - accuracy trade-off
- Variability of VEL and ACC

6 Kicking Conditions

2 Performance Tasks

Maximization ACC (Max ACC)  Maximization VEL (Max VEL)

3 Kicking Techniques

- Full Instep
- Inner Instep
- Side Foot

I  II
III  IV
V  VI
Methods

- 19 soccer players (4th - 6th league)
- Kicking of stationary ball – 6 m target distance
- 6 repetitive trials per kicking condition (total: 36 kicks)

- Mean and standard deviation (SD)
- Coefficient of variability (CoV)
  across subjects
- Repeated measures ANOVA
- Post-hoc test (Bonferroni)

- Coefficient of variability (CoV_{6 \text{ repetitive kicks}}) within subjects

Experimental Set-up

- Radar gun for VEL measurements  
  Stalker Pro, Applied Concepts, TX, USA
- High speed video capturing of ball impact location (200 Hz)  
  CMOS Camera HCC-1000, VDS Vosskühler, Germany
- ACC determination: distance ball center to bull's eye  
  MaxTRAG 2.06, Innovisions Systems, MI, USA
Performance Task

**Kicking Velocity (p<0.001)**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Task</th>
<th>Mean</th>
<th>SD</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Instep</td>
<td>Max VEL</td>
<td>103.16</td>
<td>6.51</td>
<td>0.063</td>
</tr>
<tr>
<td>Full Instep</td>
<td>Max ACC</td>
<td>87.76</td>
<td>11.17</td>
<td>0.127</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max VEL</td>
<td>100.75</td>
<td>6.90</td>
<td>0.068</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max ACC</td>
<td>82.99</td>
<td>14.45</td>
<td>0.174</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max VEL</td>
<td>89.79</td>
<td>5.65</td>
<td>0.063</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max ACC</td>
<td>77.38</td>
<td>11.27</td>
<td>0.146</td>
</tr>
</tbody>
</table>

- Reduction of VEL to 82-86%, independent of kicking technique

**Kicking Accuracy (p<0.001)**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Task</th>
<th>Mean</th>
<th>SD</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Instep</td>
<td>Max VEL</td>
<td>59.51</td>
<td>14.04</td>
<td>0.236</td>
</tr>
<tr>
<td>Full Instep</td>
<td>Max ACC</td>
<td>45.93</td>
<td>9.90</td>
<td>0.216</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max VEL</td>
<td>50.85</td>
<td>12.29</td>
<td>0.242</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max ACC</td>
<td>39.65</td>
<td>11.02</td>
<td>0.278</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max VEL</td>
<td>40.53</td>
<td>14.38</td>
<td>0.355</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max ACC</td>
<td>28.83</td>
<td>7.90</td>
<td>0.274</td>
</tr>
</tbody>
</table>

- Decrease of ACC by 29-41%, dependent on kicking technique
Within Subject Variability – \( (\text{CoV}_6 \text{ repetitive kicks}) \)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Task</th>
<th>VEL( \text{CoV}_6 )</th>
<th>ACC( \text{CoV}_6 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Instep</td>
<td>Max KV</td>
<td>0.034</td>
<td>0.633</td>
</tr>
<tr>
<td>Full Instep</td>
<td>Max KA</td>
<td>0.044</td>
<td>0.550</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max KV</td>
<td>0.032</td>
<td>0.477</td>
</tr>
<tr>
<td>Inner Instep</td>
<td>Max KA</td>
<td>0.052</td>
<td>0.613</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max KV</td>
<td>0.029</td>
<td>0.573</td>
</tr>
<tr>
<td>Side Foot</td>
<td>Max KA</td>
<td>0.047</td>
<td>0.572</td>
</tr>
</tbody>
</table>

Reduction of velocity did not lead to more constant accuracy.

Findings

• VEL differences between techniques confirmed
• ACC differences between techniques fundamentally quantified
• VEL and ACC relation appeared stable for the two performance tasks

• Variability of VEL extremely low within subjects
  ➡️ Motor Input
• Variability of ACC considerably high especially within subjects
  ➡️ Motor Output
Discussion of Speed – Accuracy Trade-off

Tennis Serve

- Slice
- Straight
- Kick

Ball Velocity [km/h]

- p < 0.01
- p = n. s.

Footwear Measurement Technology Movement Performance Perspective

Sterzing & Rodewald 2010

Does footwear influence kicking velocity?

Copa Mundial
PR Mania
Tiempo Premier
AZT 90 II
Mercurial Vapor

Ball Accuracy [cm]

- p < 0.05
- p = n. s.

Footwear Movement Measurement Technology Performance Perspective
Requirements of Soccer Footwear

Questionnaire
n = 249

Sterzing et al. 2007

The Influence of Soccer Shoes on Kicking Velocity in Full-Instep Kicks

Thosten Sterzing1 and Ewald M. Henning2

1Department of Human Locomotion, Institute of Sports Science, Chemnitz University of Technology, Chemnitz; and 2Biomechanics Laboratory, Sports and Movement Sciences, University of Duisburg-Essen, Essen, Germany

STERZING, T., and E.M. HENNIG. The influence of soccer shoes on kicking velocity in full-instep kicks. Exerc. Sport Sci. Rev., Vol. 36, No. 2, pp. 91–97, 2008. Soccer shoes enhance the traction required by the stance leg but decrease the quality of the ball contact during full-instep kicking. Shoe features that influence ball velocity include traction, foot protection, foot rigidity, and toe box height. Upper material and general comfort potentially affect ball velocity. In contrast, shoe weight and outsole stiffness do not influence ball velocity. Key Words: full-instep kicking, ball velocity, shoe features, stance leg, kicking leg.
Systematic Evaluation of Isolated Shoe Features

General Testing Procedures

Biomechanics Laboratory
University of Duisburg-Essen

Radar Gun
Stalker Pro
General Testing Procedures ctd.

**Force Plate – Kistler**

**Photo Cell Arrangement**

Swing Phase Time: foot strike (GRFs) to initial ball movement (photo cell)

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**Laboratory environment**

Experimental set-up: 1) radar gun, 2) goal with target area, 3) photo cell arrangement, 4) force plate next to 5) ball, 6) three-step approach
Neutral Shoe Method at Contra Lateral Foot

- Kicking Foot
- Support Foot

General Testing Procedures ctd.

- About 20 experienced soccer players
- Familiarization with laboratory testing environment
  - Warm-up
  - Practice trials
- 6 maximum full instep kicks per shoe condition – stationary ball
  - 3-step approach
  - Standardized resting intervals
  - Randomization of shoe conditions between subjects
- Ranking of ball velocity
  - Rating of study specific items
Support Foot Traction
Diego Forlan (Uruguay) – World Cup 2010: Uruguay vs. Netherlands (2-3)

Support Foot Traction
Yasuhito Endo (Japan) – World Cup 2010: Denmark vs. Japan (1-3)
Plantar Pressures – Support Foot
Sterzing & Hennig 2005

Plant Foot Forces
Barfield 1995
**Resultant Shear Force max.**

- **ZFG**: 1200 N
- **HFG**: 1300 N
- **FFG**: 1400 N
- **FSG**: 1000 N

\[ p < 0.01 \]

**Swing Phase Time**

- **ZFG**: 120 ms
- **HFG**: 115 ms
- **FFG**: 110 ms
- **FSG**: 135 ms

\[ p < 0.01 \]

**Ball Velocity**

- **ZFG**: 90 km/h
- **HFG**: 105 km/h
- **FFG**: 110 km/h
- **FSG**: 100 km/h

\[ p < 0.01 \]

**Perception Ball Velocity**

- **ZFG**: 3.5 ms
- **HFG**: 4.5 ms
- **FFG**: 3 ms
- **FSG**: 2 ms

\[ p < 0.01 \]

Functional traction necessary for fast kicking.
Shod vs. Barefoot Kicking

Regular Soccer
Beach Soccer

Ball Condition

outdoor – regular
• circumference: 68.6 cm
• weight: 436.6 g

indoor – regular
• circumference: 71.9 cm
• weight: 422.9 g

Reduction of Skin Pain
### Kicking Velocity

**own shoe**

OSH  | NNN  | AAA  | SOC  | BAR  
---|---|---|---|---
80  | 82.5 | 85 | 87.5 | 90 |
90  | 92.5 | 95 | 97.5 | 100 |

Mean (SEM) $p = 0.05$

### Perception Variables

**own shoe**

OSH  | NNN  | AAA  | SOC  | BAR  
---|---|---|---|---
better | worse |
OSH  | NNN  | AAA  | SOC  | BAR  
1  | 2  | 3  | 4  | 5 |

Mean (SEM) $p < 0.01$

Perception Ball Velocity

Perception Pain
Impact Phase: High Speed Video (1 kHz)

Reduction of „passive, forced plantarflexion“ for barefoot kicks

„Passive, forced plantarflexion“ for shod kicks

Movement Measurment Technology Performance Footwear Perspective

Soccer shoe

Shoe

Shoe model

Shoe material

Shoe weight

Dorsal foot protection

Rigidity lower limb

Shoe box height

Shoe width

Swing phase

Swing phase

Ball

Ball velocity

Mechanism

Influence

Potential influence

No influence

Sterzing & Hennig 2008

Footwear Measurement Technology Movement Performance Perspective
Summary – Kicking Velocity

- Functional, rather than maximal, traction at the support foot is needed.
- Soccer shoes at the kicking foot actually reduce ball velocity.
- Some shoe features influence kicking velocity, others do not.
- Both feet need to be considered for adequate footwear design.

Kicking Foot — Support Foot

Kicking Accuracy & Soccer Footwear
Kicking Accuracy
Chu-Young Park (South Korea) – World Cup 2010: Uruguay vs. South Korea (2-1)

Kicking Accuracy – Benefit Hypotheses

- **Shape:**
  Homogenous pressure distribution between ball and shoe

- **Friction:**
  High friction between ball and shoe

- **Spin:**
  Spin production allows stable flight path

- **Ball Sensing:**
  Better ball sensing

- **Shoe Weight:**
  Larger moment of inertia results in more stable swing leg path

- **Support foot stability:**
  Enhancement of kicking foot movement control

Hennig & Sterzing 2010
Set-up

- Circular electronic target (concentric wire frame)
- Ball contact generates electrostatic charges
- Software based determination of ball impact location

Footwear Conditions

Footwear Measurement Technology Movement Performance Perspective
Discussion: Barefoot vs. Shod Kicks

- Bony structures of the foot may create pressure peaks not allowing a homogenous pressure distribution between ball and foot.
- Shoe upper material may provide an interface providing more homogenous pressure distribution between foot and ball.

Polyurethane soft foam
10 Shore A, 6 mm

Dr. Scholl Silicone Gel Pads

Follow-up Study: Foot Padding

Instep Kicks

Side Foot Kicks
Implementation of Knowledge into Products

provided by Nike Inc., USA

Nike Laser Elite Series
T90 Laser

Soccer shoe specifically designed to enhance accuracy by even pressure

- shape correcting foam inside the shoe
- flat shot shield on top at ball contact area for a full instep kick

Research Perspective

Siphiwe Tshabalala (South Africa) – World Cup 2010: South Africa vs. Mexico (1-1)
Research Perspective
Maicon (Brazil) – World Cup 2010 Brazil vs. North Korea (2-1)

Research Perspective
Luis Fabiano (Brazil) – World Cup 2010: Brazil vs. Ivory Coast (3-1)
Research Perspective
Andrés Iniesta (Spain) – World Cup 2010: Netherlands vs. Spain (0-1)

Status Quo: Review Articles 2007 - 2010

The Influence of Soccer Shoes on Kicking Velocity in Full-Instep Kicks

The biomechanics of kicking in soccer: A review

A. LEID1, T. ASAD2, T. R. ANDERSEN3, B. SUNNAGE4, & T. STERNING2

1Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK; 2Centre of Health and Sports Sciences, University of Tromsø, Tromsø, Norway; 3Department of Sports Science, University of Tromsø, Norway; 4Ecole Supérieure des Sports, Alès, France; 5Institute for Sports Medicine, University of Tromsø, Norway.
Future Directions

- Kicking analysis of non-stationary balls (rolling, bouncing balls)
- Gender
- Ball construction
- Determination of performance influencing variables

Thank you very much for your attention!