BIOMECHANICS IN TABLE TENNIS

Presented by
Ivan Malagoli Lanzoni, PhD
BIOMECHANICS IN TABLE TENNIS

1. General definitions
2. Revision of the TT literature: methods
3. TT Examples
4. TT Examples: News
5. Conclusions
BIOMECHANICS IN TABLE TENNIS

1 + 1 = 3!
1: Definitions
Biomechanics of Sport and Exercise  
(Peter M. McGinnis, 2004)

**BIOMECHANICS**

- **BIO-**: indicates that biomechanics has something to do with living or biological systems
- **MECHANICS**: indicates that biomechanics has something to do with the analysis of forces and their effects

**Kinematics** is a branch of classical mechanics (with statics and dynamics) that describes the motion of points, bodies, and systems of bodies not considering the forces that caused the motion. It is often referred to as the "geometry of motion"

**Biomechanics is the study of forces and their effects on living systems**

**Exercise and Sport Biomechanics aims:**

- **Performance Improvement:**
  Technique, Equipment, and Training
- **Injury Prevention and Rehabilitation:**
  Technique, Equipment, and Training to reduce Injuries
2: Revision of the literature
BIOMECHANICS IN TABLE TENNIS
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• From 49 (2018) to 57 studies (today) about TT Kinematics (articles, chapters, etc.)
• First Authors: Sklorz (1979), Muster (1986), Hudetz (1988), etc.
• Laboratory set-up (nothing during a «real competition»)
• Different aims, variables, and methods
Literature revision: methods

SHOTS

- Top spin: 55%
- Drive: 17%
- Service: 10%
- Smash: 5%
- Top spin-Smash: 5%
- Others: 8%
Literature revision: methods

SHOTS: forehand or backhand

- Forehand: 68%
- Backhand: 9%
- Forehand and backhand: 23%
Literature revision: methods

SUBJECTS

- Male experts: 73%
- Female experts: 4%
- Experts vs Beginners: 14%
- Male and Female (expert beginners): 4%
- Male and Female: 5%
Literature revision: methods

PROTOCOLS

- Upper body: 63%
- Total body: 26%
- Arm: 7%
- Lower body: 4%
Literature revision: methods

TARGET
(at the other side of the table)

Target 37%

No Target 63%
Literature revision: methods

Robots: 47%

No Robots: 53%
Literature revision: methods

RACKET
(information about the Racket)

- Racket: 69%
- No Racket: 31%
Literature revision: methods

BALL
(information about the Ball)

Ball
39%

No Ball
61%
Literature revision: methods

IMPACT
(between Ball and Racket)

Impact 80%

No Impact 20%
Literature revision: methods

INSTRUMENTS

- Cameras 71%
- EMG 11%
- Camera+ForcePL 7%
- InsolePlantarPR 2%
- Cameras+InsolePlantarPR 5%
- Cameras+1ForcePL 2%
- Cameras+EMG 2%
- Cameras+ 2%
- EMG 11%
Literature revision: methods

**Hz (Stereophotogrammetry Cameras)**

- 200 Hz: 32%
- 500 Hz: 11%
- 250 Hz: 16%
- 100 Hz: 11%
- 120 Hz: 8%
- 60 Hz: 2%
- 50 Hz: 8%
- 125 Hz: 3%
- 150 Hz: 3%
- 1000 Hz: 3%
- 1000 Hz: 3%
- 125 Hz: 3%
- 150 Hz: 3%
- 180 Hz: 3%
- 100 Hz: 11%
- 500 Hz: 11%
- 50 Hz: 8%
- 120 Hz: 8%
- 60 Hz: 2%
3: TT Examples
TT Examples

Injury prevention:
• Insole Plantar Pressure Measurement
• Electromyography
AIM OF THE STUDY:
was to examine the ground reaction forces, knee and ankle moments, and in-shoe plantar pressure distribution during topspin forehand with three typical table tennis specific footwork.

Authors assumed that the three footwork would exhibit distinct plantar pressure, ground reaction forces and joint moments. It might contribute to the development of table tennis shoes and trainings which help prevent injuries.
• **Materials and Methods:**
  - **Subjects:** 15 male players
  - **Materials:** targets, no racket, no ball, no table, no impact
  - **Protocol:** lower body
  - **Instruments:** 8 Oxford Metrics Ltd Cameras 200 Hz + Insole Plantar pressure measurement system 100Hz, Force plate Amti 1000 Hz
  - **Other aspects:** comparison of the 3 steps (one-, side- and cross-step)

• **Results and Conclusions:**
  As compared to one-step, significant higher maximum ground reaction forces, maximum joint angles and moments, and peak plantar pressure were found during forehand topspin in the side- and cross-steps.

  The high plantar loading in the forefoot and medial midfoot regions observed in side- and cross-step suggests that footwear and foot orthoses design should consider the stronger emphasis on those areas.
AIM OF THE STUDY:
was to compare the muscle activity of eight lower limb muscles across typical TT strokes.

Authors assumed that as decisive strokes, the topspin and smash would be associated with the higher level of muscle activity and activity level of each muscle depend on the characteristics of the shot.
**Materials and Methods:**

- **Subjects:** 14 male expert players
- **Materials:** robot, no targets, no racket, no ball, no table, no impact
- **Protocol:** lower body (soleus, gastrocnemius medialis and lat., Gmax, Biceps femoris, rectus femoris, vasto medialis and lat.) on the leg corresponding to the side of the racket
- **Instruments:** EMG system, no cameras
- **Other aspects:** comparison of different shots

**Results and Conclusions:**

Authors found that both hip extensors and plantar flexors were strongly activated during decisive strokes. Forehand smash and top exhibited higher levels of activity than other shots. Each shots involves muscles differently (VL, VM and RF: during forehand topspin; GL, GM, and Sol during smash).

It is important for trainers and/or conditioning coaches (DIFFERENT GENDERS).
TT Examples

Performance Analysis
(Technique and Training):
1. Forehand (phases)
2. Forehand (pelvis)
3. Forehand (two different shots)
AIM OF THE STUDY:
was to propose an analysis for identifying the phases of a forehand table tennis stroke, which is based only on the velocity of racket centre motion.

An experimental investigation, including a number of players of two different levels, was conducted as an example implementation of this investigation.
Materials and Methods:

- **Subjects:** ten experts vs ten novices
- **Materials:** robot, ball, impact, targets, racket, no table
- **Protocol:** racket markerization
- **Instruments:** 8 cameras 100Hz (Motion Analysis Eagle System)
- **Other aspects:** comparison between experts and novices

TT Examples (Zhang et al., 2016)
Results and Conclusions:
This method applies a novel way to identify phases using max and min speed rather than maximum displacement as commonly used by researchers and others. It confirms that there is an opportunity to improve novices’ performance through coaching to move them towards the characteristics of experts.
AIM OF THE STUDY:
was to determine the hip joint kinetics during the TT topspin forehand, and to investigate the relationship between the relevant kinematic variables examined and the racket horizontal and vertical velocities at impact.
Materials and Methods:

- **Subjects:** eighteen male advanced players
- **Materials:** robot, ball, impact, no targets, racket, no table
- **Protocol:** total body (48 retro-reflective markers)
- **Instruments:** 8 cameras 250 Hz (Vicon Motion Systems) + 1 camera (for the ball rates of spin)
- **Other aspects:** cross-court topspin

• **Results and Conclusions:**
  The peak pelvis axial rotation velocity and the work done by the playing side hip pelvis axial rotation torque were positively related to the racket horizontal velocity at impact. The results suggest that the playing side hip pelvis axial rotation torque is important for acquiring a high racket horizontal velocity at impact.
AIM OF THE STUDY:
was to compare the biomechanical characteristics of TT topspin shot when played cross-court (CC) or long-line (LL) in competitive TT players.

From a practical perspective, this study would provide TT coaches with useful information to guide the selection of training exercises with the goal of producing specific torsional and rotational movements of the pelvis and shoulders.
**Materials and Methods:**

- **Subjects:** seven male advanced players
- **Materials:** robot, targets, racket, table, impact, no ball
- **Protocol:** total body
- **Instruments:** 8 cameras 500 Hz (BTS)
- **Other aspects:** cross-court vs long-line execution

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**TT Examples** (Malagoli Lanzoni et al., 2018)
Results and Conclusions:

Significant differences were detected for lower and upper body angles (max, min, and MMV).

Coaches should consider that the two top spin executions require specific joint angles and torsions, and specific position with respect to the table.

Results seem to indicate that the position of the feet with respect to the table may have a primary impact on the kinematics of both executions.

A practical suggestion would be to continue to plan training sessions including the two types of shot, and to keep the position of the feet fixed to possibly achieve a more pronounced torsional-rotational movement of the pelvis and shoulders.

* Indicates a significant difference (p<0.05)
TT Examples

Performance Analysis:
• Different equipment
AIM OF THE STUDY:
Investigate the effect of using the new plastic ball (PB) with respect to the celluloid one (CB): comparing upper and lower body kinematics of Forehand top spin
Materials and Methods:

- **Subjects**: ten male advanced players
- **Materials**: robot, targets, table, impact, racket, no ball
- **Protocol**: total body
- **Instruments**: 10 cameras 500Hz (BTS)
- **Other aspects**: cross-court topspin with CB and PB

**TT Examples** (Malagoli et al., 2017)
Results

Upper limb

- Girdle Protraction [Deg]
- Shoulder Flexion [Deg]
- Elbow Flexion [Deg]

IMP

Lower limb

- Hip Flexion [Deg]
- Knee Flexion [Deg]
- Ankle Plantarflexion [Deg]

One athlete with PB

IMP
Results

### Table: Kinematics Variables

<table>
<thead>
<tr>
<th></th>
<th>Celluloid Ball</th>
<th>Plastic Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAX</td>
<td>IMP</td>
</tr>
<tr>
<td><strong>Girdle joint Protraction [Deg]</strong></td>
<td>-23.4 ± 2.2</td>
<td>-36.1 ± 5.7</td>
</tr>
<tr>
<td><strong>Shoulder Internal rotation [Deg]</strong></td>
<td>47.8 ± 10.6</td>
<td>-24.5 ± 14.7</td>
</tr>
<tr>
<td><strong>Shoulder Flexion [Deg]</strong></td>
<td>111.2 ± 11.8</td>
<td>46.8 ± 16.8</td>
</tr>
<tr>
<td><strong>Elbow Flexion [Deg]</strong></td>
<td>99.4 ± 6.1</td>
<td>84.2 ± 8.5</td>
</tr>
<tr>
<td><strong>Shoulders-table [Deg]</strong></td>
<td>82.6 ± 6.3</td>
<td>30.9 ± 6.3</td>
</tr>
<tr>
<td><strong>Pelvis-table [Deg]</strong></td>
<td>52.5 ± 3.3</td>
<td>10.0 ± 2.9</td>
</tr>
<tr>
<td><strong>Feet-table (mean value) [Deg]</strong></td>
<td>9.7 ± 2.4</td>
<td>8.7 ± 2.2</td>
</tr>
<tr>
<td><strong>Racket-table X [Deg]</strong></td>
<td>-151.7 ± 12.8</td>
<td>-157.7 ± 10.0</td>
</tr>
<tr>
<td><strong>Racket-table Y [Deg]</strong></td>
<td>31.0 ± 2.0</td>
<td>29.8 ± 2.4</td>
</tr>
<tr>
<td><strong>Racket-table Z [Deg]</strong></td>
<td>152.7 ± 6.6</td>
<td>150.3 ± 7.5</td>
</tr>
<tr>
<td><strong>Knee Flexion [Deg]</strong></td>
<td>58.0 ± 3.2</td>
<td>34.1 ± 2.1</td>
</tr>
<tr>
<td><strong>Hip Flexion [Deg]</strong></td>
<td>73.5 ± 6.8</td>
<td>36.2 ± 4.0</td>
</tr>
</tbody>
</table>

* = p ≤ 0.05

No differences in kinematics variables of upper and lower limbs
Conclusions

**Total** body kinematics

• **No differences:**
  • Upper limb joints kinematics
  • Lower limb joints kinematics
  • Athlete-table orientation
  • Racket-table orientation

Elite athletes do not modify the technical motor task execution (despite their concern regarding the different characteristics of the ball)
4: News
Mechanical character of lower limb for table tennis cross step maneuver

Shirui Shao¹, Changxiao Yu¹, Yang Song¹, Julien S Baker², Ukadike C Ugbolue², Ivan Malagoli Lanzoni³ and Yaodong Gu¹

11 professional and 11 novice athletes
Insole plantar pressure measurement system

RESULTS (professional athletes):
- Smaller forefoot plantarflexion and abduction
- Larger hallux dorsiflexion at the end
- Larger forefoot dorsiflexion and abduction
- Smaller forefoot eversion and rearfoot inversion
- Smaller joints range of motion (hindfoot/tibia)
- Higher footwork agility and greater foot motor technique
6 male and 6 female advanced tt players
Top spin forehand and backhand, receiving a backspin ball

**MAIN RESULTS (sig. differences):**
- Angular parameters and maximum hand acceleration
- Large muscle groups and large joints (hip, trunk, shoulder)
- Maximal acceleration difference reached almost: 50 m/s² (forehand) and 20 m/s² (backhand)

**CONCLUSIONS:**
- Anthropological differences and limitations
- Women can use both sides to perform a top spin attack
- Men should seek opportunities to use the top spin forehand
Review

Biomechanics of Table Tennis: A Systematic Scoping Review of Playing Levels and Maneuvers

Duo Wai-Chi Wong 1,*, Winson Chiu-Chun Lee 2 and Wing-Kai Lam 3,4,5,*

1 Department of Biomedical Engineering, Faculty of Engineering, The Hong Kong Polytechnic University, Hong Kong 999077, China; duo.wong@polyu.edu.hk
2 School of Mechanical, Materials, Mechatronic & Biomedical Engineering, University of Wollongong, Wollongong, NSW 2522, Australia; winson_lee@uow.edu.au
3 Guangdong Provincial Engineering Technology Research Center for Sports Assistive Devices, Guangzhou Sport University, Guangzhou 510000, China
4 Department of Kinesiology, Shenyang Sport University, Shenyang 110102, China
5 Li Ning Sports Science Research Center, Li Ning (China) Sports Goods Company, Beijing 101111, China

* Correspondence: gilbertlam@li-ning.com.cn; Tel.: +86-010-80801108

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5: Conclusions
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• Limited number of studies about TT Kinematic: 57

• Laboratory set-up (no «real competition»)

• Methodological TT aspects: shots, subjects, protocols, targets, robot, racket, ball, impact racket-ball, instruments, etc.

• Kinematics is a very «powerful tool»

• The study “does not seem compatible with interests of both researchers' biomechanical conceptual challenges and coaches' practical applications to training.....” (Blind reviewer)

• The manuscript “is limited to a biomechanical laboratory exercise to spatially and temporally describe the participants' movement....” (Blind reviewer)

• Cooperation between Coaches and Researchers
THANK YOU FOR YOUR ATTENTION!

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