Biomechanics of Karate: Measuring Impact Force in Shotokan Karate Strikes

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OVERVIEW

- Purpose
- Shotokan Technique
- Hypotheses
- Apparatus
- Experiment Protocol
- Data
- Results
- Future Plans and Studies
PURPOSE

- Studying Martial Arts from an Engineering Perspective
- Quantifying Strength of Various Techniques
- Finding Scientific Proof behind the Traditional Arts and their Applications
- Assisting Proper Teaching of Shotokan Karate Strikes
REVERSE PUNCH

- One of the Most Basic and Common Strikes
- Delivered in 3 Orientations:
  - Horizontal – Kihon (Basics)
  - Vertical (Jab) – Kumite (Sparring)
  - 45 Deg – Bunkai (Real Life Application)
REVERSE PUNCH
REVERSE PUNCH
HYPOTHESES

- Strike Effectiveness will be influenced by:
  - Experience
  - Angle of Delivery
    - Horizontal – Strongest
    - Vertical – Fastest
    - 45 Deg – Most Practical
  - Gender
  - Size
APPARATUS DESIGN

Criteria:

- Deliver Direct Linear Impact to a Force Sensor
- Produce No Moment if Hit Off-centered
- Be Adjustable According to Different Heights
- Be Robust and Stable
- Can Be Built Within Our Time Limit and Available Materials
DATA COLLECTION

- 2000lb Load Cell
  - Located Directly Behind the Target
- Motion Capture System
  - 3 High Speed Cameras to Record the Motion
  - 6 Reflective Markers on Joints of Interest on the Subjects
APPARATUS DESIGN

Diagram: Components of an apparatus design including a Load Cell, Punching Pad, and Force Plate.
EXPERIMENTS

- Set Up
  - Calibrating the Cameras
  - Pilot Testing
EXPERIMENTS

- **Subjects:**
  - Beginner (1F, 2M)
  - Intermediate (3F, 3M)
  - Advanced (3F, 3M)
  - Read & Sign the Consent Form
  - Warm up
  - Free Trials
  - Wear 6 Reflective Markers

- **Testing Protocol**
  - 3 Sets (Horiz, 45 Deg, Vert)
  - 5 Punches Each
DATA PROCESSING

- SIMI
  - Recording the Force Data
  - Processing Video Files and Tracking Markers
- C++
  - Finding Peak Forces and Time of Impact
  - Adjusting the Off Set of the Force
  - Importing Data and Creating Excel Files
- Excel
  - Processing Numeric Results
  - Normalizing and Finding Correlations among Different Variables
RESULTS

- Processed Data

[Diagram: Force vs. Time - 45 Deg]
RESULTS

Overall Average Force

Categories

Force (lbs)

Horizontal
45 Deg
Vertical
RESULTS

• Comparing Force Based on Gender and Experience
## RESULTS

<table>
<thead>
<tr>
<th>Pearson Correlation Coefficient</th>
<th>Max F (lbs)</th>
<th>Average F (lbs)</th>
<th>Force STD</th>
<th>Max Impulse (lb.s)</th>
<th>Ave. Impulse (lb.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength (lbs)</td>
<td>0.863</td>
<td>0.902</td>
<td>0.320</td>
<td>0.678</td>
<td>0.819</td>
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<tr>
<td>Weight (lbs)</td>
<td>0.741</td>
<td>0.686</td>
<td>0.523</td>
<td>0.705</td>
<td>0.607</td>
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<tr>
<td>Height (in)</td>
<td>0.587</td>
<td>0.628</td>
<td>0.168</td>
<td>0.191</td>
<td>0.509</td>
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<tr>
<td>BMI</td>
<td>0.436</td>
<td>0.318</td>
<td>0.562</td>
<td>0.392</td>
<td>0.332</td>
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<tr>
<td>Experience (Months)</td>
<td>-0.107</td>
<td>-0.054</td>
<td>-0.173</td>
<td>-0.082</td>
<td>-0.023</td>
</tr>
</tbody>
</table>
RESULTS

- Impulse = \int F \cdot dt
- Ave. Impulse vs. Ave. Force
  - Pearson Correlation Coefficient = 0.8685

\[ Y = 0.0208 \times + 0.955 \]

\[ R^2 = 0.7543 \]
CHALLENGES

- Not Having Enough Support to Keep the Apparatus in Place
  - Having Off-set Force Data
- Verifying if the Strike is Delivered Correctly
- Having to Recalibrate the Cameras
- Exporting Force Data from SIMI
FUTURE STUDIES

- Processing the Motion Capture Video Files
- Testing Larger Group of Subjects
- Using Random Combinations
- Experiment Different Padding or Gloves
- Modifying Apparatus Design
- Securing the Apparatus to the Wall
- Possibly Studying Other Strikes, i.e. Kicks
- ...