Using Kinematic Data as a Surrogate for Impact Forces: Science and Practical Implementation

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The views expressed in this presentation are our own and are not intended to reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

AGENDA

• Background
• Methods
• Results
• Conclusion
• Application: The Injury Mitigation Model
Musculoskeletal Injuries account for approximately 50% of Disease non-battle injuries (DNBI)\(^1\).

DNBI accounted for more evacuations from recent theaters of operations than any other injury\(^2\).

Musculoskeletal Injuries cost the US military >$500,000,000/yr\(^3\).

\(\frac{4}{5}\) of all medical encounters\(^4,5\).

25 million lost duty days\(^4,5\).

### Background & Current State of the Literature

#### Identification

- Multiple Common Factors in those who sustain injury
  - Modifiable
  - Non-Modifiable
- Key: Modifiable Risk Factors
  - Movement Profile
  - Impact Forces

### To mitigate..

- STEP 1: Identify those who are prone to injury
- STEP 2: Intervene early to decrease the risk of injury
Purpose of this Study

- Movement analysis continues to advance quickly
  - Now easily used in the field
  - Relatively inexpensive
  - Equipment required is often just the cell phone
- Impact forces often require laboratory equipment
- If both are important and modifiable:
  Does the movement profile also give us information about the impact profile?

Methods

- Cross-sectional analysis of baseline data collected on US Service Academy cadets from 2005-09
- Cadets/Midshipmen performed the Landing Error Scoring System (LESS) graded jump landing
- Vertical Ground Reaction Force profiling was performed during the jump landing task

STATISTICAL ANALYSIS

- vGRF was normalized to the person's bodyweight
- Multi-variable linear regression, ANOVA, and ANCOVA analyses
  - Various analyses conducted to control for known, "unmodifiable" variables:
    - Sex
    - BMI
  - LESS scores analyzed both as a continuous and categorical variable
- Alpha set to 0.05 a priori
RESULTS

• N=5579
  – 3413 males (61.18%)
  – 2166 females (38.82%)
• Multi-variable linear regression & ANCOVA:
  – LESS score is a significant predictor of vGRF
  – (p < .001)

Each error on the LESS

Bodyweight force experienced

11%

RESULTS

• ANOVA:
  – LESS Trichotomized: Good, Fair, & Poor
  – 3x3 factorial ANOVA also took BMI into account
  – Significant among group difference in vGRF
  – (p < .001)

RESULTS

1.1 1.2 1.3 1.4 1.5 1.6 1.7

vGRF (in BWs) by Movement Category

NORMAL OVERWEIGHT OBES

POOR FAIR GOOD

# of faults on the LESS = vGRF when jumping

Controlling for sex and BMI

IMPORTANTLY:
A field-based movement quality assessment can be used to screen for an important impact risk factor
  – Screening now requires <3 minutes per person
  – Fully automated
  – Corrective exercises automatically generated

A rapid, pragmatic movement screen can give information about important kinetic variables without expensive or bulky equipment

Summary of Results
So what: Research → Practice

• Using the screen as part of an Injury Mitigation Model

How it is Applied at UNC: The “Injury Mitigation Model”

1. Identify Risk Level of Athletes
   - Injury history
   - Movement quality profile

   Movement Quality Score Range = 0 - 36
   LESS Total Possible = 17
   2 Leg Squat Total Possible = 7
   1 Leg Squat Total Possible = 12

<table>
<thead>
<tr>
<th>Construct</th>
<th>Classification</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Quality</td>
<td>Excellent</td>
<td>≥90% Total Assessment Score</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>75-89% Total Score</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>&lt;75% Total Score</td>
</tr>
<tr>
<td>Injury History</td>
<td>None</td>
<td>NO days lost to injury in past year</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>≤7 Days lost to injury in past year</td>
</tr>
<tr>
<td></td>
<td>Significant</td>
<td>≥7 Days lost to injury or prior major surgery in past year</td>
</tr>
</tbody>
</table>

Consider Movement Quality & Injury History

- Low Risk
- Medium Risk
- High Risk
2. Implement injury prevention programming model

<table>
<thead>
<tr>
<th>Programming Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Risk</strong></td>
</tr>
<tr>
<td>• Team Warm-Up</td>
</tr>
<tr>
<td>• Strength &amp; Conditioning Programming</td>
</tr>
<tr>
<td>• Team/Position Programming</td>
</tr>
<tr>
<td><strong>Medium Risk</strong></td>
</tr>
<tr>
<td>• Personalized Self-Care Corrective Ex.</td>
</tr>
<tr>
<td>• Team Warm-Up</td>
</tr>
<tr>
<td>• Strength &amp; Conditioning Programming</td>
</tr>
<tr>
<td>• Team/Position Programming</td>
</tr>
<tr>
<td><strong>High Risk</strong></td>
</tr>
<tr>
<td>• Personalized Self-Care Corrective Ex.</td>
</tr>
<tr>
<td>• Hands-On Corrective Ex.</td>
</tr>
<tr>
<td>• Team Warm-Up</td>
</tr>
<tr>
<td>• Strength &amp; Conditioning Programming</td>
</tr>
<tr>
<td>• Team/Position Programming</td>
</tr>
</tbody>
</table>

PEAK Program

3. Daily Readiness Monitoring

<table>
<thead>
<tr>
<th></th>
<th>Ready</th>
<th>Sleep</th>
<th>Fatigue</th>
<th>Stress</th>
<th>Soreness</th>
</tr>
</thead>
<tbody>
<tr>
<td>This technology could be scaled but feasibility of use is questionable particularly in larger units</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

4. Daily Load Monitoring

Record the following information:
- RPE within 30 minutes of training/game
- How was training today?
- Focus on feeling of exertion (not pain or shortness of breath)
- Total minutes of exercise

<table>
<thead>
<tr>
<th>RPE</th>
<th>Minutes of Exercise</th>
<th>Training Load (AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very, very easy</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat hard</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Very hard</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Maximal</td>
<td>7</td>
</tr>
</tbody>
</table>

RPE  x  Minutes of Exercise  =  Training Load (AU)
5. Communicate with Coaches

Alternative Dashboard for Coaches

Dynamic Load – Response Model for Athlete Management
Dynamic Load – Response Model for Athlete Management

<table>
<thead>
<tr>
<th>Load</th>
<th>Modifiers</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Duration</td>
<td>• Movement Quality Steering, alignment, tire pressure</td>
<td>• Readiness</td>
</tr>
<tr>
<td>• Frequency</td>
<td>• Sleep Duration &amp; Quality Fuel &amp; oil</td>
<td>• Fatigue</td>
</tr>
<tr>
<td>• Intensity</td>
<td>• Nutrition &amp; Hydration Fuel &amp; oil</td>
<td>• Soreness</td>
</tr>
<tr>
<td></td>
<td>• Tissue Capacity (prior injury Natory) Material strength</td>
<td>• Stress / Mood</td>
</tr>
<tr>
<td>Mileage amount and type</td>
<td></td>
<td>• Performance</td>
</tr>
</tbody>
</table>

Modifiers:
- Readiness
- Fatigue
- Soreness
- Stress / Mood
- Performance
- Movement Quality

Subjective Objective:
- Coach Controls
- Sports Medicine / S&C Optimizes
- Sport Science Monitors & Educates
  - Coach / Athlete
  - Sports Medicine / S&C
  - Modify programming

Coach Controls

Sports Medicine / S&C Optimizes

Sport Science Monitors & Educates
  - Coach / Athlete
  - Sports Medicine / S&C
  - Modify programming
Conclusion: How Movement Quality Fits Into the Larger Picture

- Movement Quality:
  - Gives us information on Kinetic Load using field expedient equipment
  - Helps us identify those at greater risk for injury
  - Guides early and ongoing intervention
  - Enhances the holistic view of the load our Soldiers experience by informing the team

Thank you

For what you do
For your time
For allowing me to speak

Questions?/Discussion
## 2. Daily Readiness & Load Monitoring

<table>
<thead>
<tr>
<th>Daily Construct</th>
<th>Qualification</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Behaviors &amp; Readiness</td>
<td>Fully Ready / Recovered</td>
<td>&gt;90% Recovery / Readiness Scores</td>
</tr>
<tr>
<td></td>
<td>Moderately Ready / Recovered</td>
<td>&gt;75% Recovery / Readiness Scores</td>
</tr>
<tr>
<td></td>
<td>Not Ready / Recovered</td>
<td>&lt;75% Recovery / Readiness Scores</td>
</tr>
<tr>
<td>Training Load Exposure</td>
<td>Positive Load Exposure / Response</td>
<td>0.8 – 1.45 Acute-to-Chronic Workload Ratio</td>
</tr>
<tr>
<td></td>
<td>Sub-Optimal Load Exposure / Response</td>
<td>&lt;0.8 or 1.46 – 1.52 Acute-to-Chronic Workload Ratio</td>
</tr>
<tr>
<td></td>
<td>Overload Exposure / Response</td>
<td>&gt;1.53 Acute-to-Chronic Workload Ratio</td>
</tr>
<tr>
<td></td>
<td>Undershoot Exposure / Response</td>
<td>&lt;0.8 Acute-to-Chronic Workload Ratio</td>
</tr>
</tbody>
</table>