Patient Activity After Joint Replacement

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*Royalties Received from DePuy and Stryker
The local college basketball scene might never remind you of 49er hysteria, but this has been a revealing tournament for Cal and Stanford, full of promise for the future. Some would say it’s been 40 years, way back in the Pete Newell-Howie Dallmar era, since both teams could guarantee you a night of great coaching, team basketball and unbridled excitement.

That’s where we are, free of Todd Bozeman. There isn’t a nasty rumor in sight. The Stanford guys are pretty good athletes, for heaven’s sake. The recruiting potential looks wonderful on both sides of the Bay. But we need Mike Montgomery to keep it going. If he leaves, right along with Brevin Knight, the Cardinal could suffer a quick and mighty fall. Next thing you know, they’d be starting five guys named Schmalzreid.
Patient Activity Following TJR

Overview

- Mixed M.D. messages
- Some data
- Capability vs. advisability
- Evolution of technology
- Evolution of philosophy
True or False?

1. On average, patients take about 2 million gait cycles per year
2. Surgeons follow uniform criteria regarding activity following TJR
3. Obesity is a contraindication to TJR
4. Surgeons agree that unlimited walking is OK after TJR
Patient Activity Following TJR

Some JRI Data


ACTIVITY RECOMMENDATIONS FOLLOWING TOTAL HIP AND KNEE ARTHROPLASTY:
A Survey of the American Association for Hip and Knee Surgeons

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Thomas P. Schmalzried, MD*

*Royalties Received from DePuy and Stryker
## Activity Following THR and TKR: Results

- **Low impact generally recommended**
<table>
<thead>
<tr>
<th>Activity</th>
<th>% Unltd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Even</td>
<td>99%</td>
</tr>
<tr>
<td>Swimming</td>
<td>99%</td>
</tr>
<tr>
<td>Golf</td>
<td>99%</td>
</tr>
<tr>
<td>Cycling Even</td>
<td>97%</td>
</tr>
<tr>
<td>Walking Stairs</td>
<td>96%</td>
</tr>
</tbody>
</table>

- **Most activities lacked consensus**
<table>
<thead>
<tr>
<th>Activity</th>
<th>% Unltd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Uneven</td>
<td>86%</td>
</tr>
<tr>
<td>Cycling Incline</td>
<td>75%</td>
</tr>
<tr>
<td>Dbls Tennis</td>
<td>68%</td>
</tr>
<tr>
<td>Climbing</td>
<td>54%</td>
</tr>
<tr>
<td>Skiing Groomed</td>
<td>44%</td>
</tr>
</tbody>
</table>

- **Higher impact generally discouraged**
<table>
<thead>
<tr>
<th>Activity</th>
<th>% Discrgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinting</td>
<td>94%</td>
</tr>
<tr>
<td>Skiing Diff</td>
<td>85%</td>
</tr>
<tr>
<td>Jogging</td>
<td>73%</td>
</tr>
<tr>
<td>Sngls Tennis</td>
<td>55%</td>
</tr>
<tr>
<td>Cycling Off Rd</td>
<td>35%</td>
</tr>
</tbody>
</table>
Activity Following THR and TKR: Other Examples

Surgeons performing a high volume of surgeries were more liberal regarding:

- Higher Volume Primary surgeries
  - Walking Uneven (p=0.0441)
  - Climbing (p=0.0126)
  - Skiing Groomed (p=0.0186)

- Higher Volume Revision surgeries
  - Climbing (p=0.05)
  - Skiing Groomed (p=0.0012)
  - Singles Tennis (p=0.0036)
Activity Following THR and TKR

- The majority of respondents indicated that there was not scientific evidence supporting their recommendations
- “Unlimited golf” – common recommendation
- Why singles but not doubles tennis?
  - Assumes higher aggregate stresses
  - Depends on frequency and intensity

D’ Lima et al. 2008 measured forces from TKR implant (telemetry)

- Need more quantitative information
  - Stresses (adjust for patient variables)
  - Number of loading cycles from that activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>BODY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIKING</td>
<td>1.3</td>
</tr>
<tr>
<td>TREADMILL</td>
<td>2.05</td>
</tr>
<tr>
<td>WALKING GROUND</td>
<td>2.6</td>
</tr>
<tr>
<td>TENNIS (Serve)</td>
<td>3.1</td>
</tr>
<tr>
<td>TENNIS (Forehand)</td>
<td>3.6</td>
</tr>
<tr>
<td>TENNIS (Backhand)</td>
<td>3.8</td>
</tr>
<tr>
<td>JOGGING</td>
<td>4.3</td>
</tr>
<tr>
<td>GOLF</td>
<td>4.5</td>
</tr>
<tr>
<td>Forward Knee</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Conclusions

- Walking on even surfaces, swimming, golf, cycling on even surfaces, and stairs were generally recommended.
- Higher impact activities more variable.
- Higher volume surgeons tend to be more liberal.
- Little scientific support for current recommendations.
- More quantitative data needed:
  - Stress levels
  - Cycles
- Philosophical debate remains: Survivorship v. quality of life.
Multi-Center Wear Study

“Gamma-in-air” Poly

Minimum 2 Years

(N=1,024)
## Adjusted Linear Penetration Rates

<table>
<thead>
<tr>
<th>Effect (mm/yr)</th>
<th>% Change</th>
<th>P&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.152 mm/yr</td>
<td></td>
</tr>
<tr>
<td>1. Surgeon high</td>
<td>+0.114</td>
<td>75</td>
</tr>
<tr>
<td>2. Male gender</td>
<td>+0.056</td>
<td>37</td>
</tr>
<tr>
<td>3. Hylamer</td>
<td>+0.051</td>
<td>34</td>
</tr>
<tr>
<td>4. age &lt; 60</td>
<td>+0.050</td>
<td>33</td>
</tr>
<tr>
<td>5. 32 mm head</td>
<td>+0.025</td>
<td>16</td>
</tr>
<tr>
<td>6. non-DePuy femur</td>
<td>+0.017</td>
<td>11</td>
</tr>
<tr>
<td>7. Cementless femur</td>
<td>+0.003</td>
<td>2</td>
</tr>
<tr>
<td>8. Revision surg.</td>
<td>+0.001</td>
<td>-</td>
</tr>
<tr>
<td>9. &gt; 3 years f.u.</td>
<td>-0.036</td>
<td>24</td>
</tr>
<tr>
<td>10. Ceramic head</td>
<td>-0.045</td>
<td>30</td>
</tr>
<tr>
<td>11. Surgeon low</td>
<td>-0.072</td>
<td>47</td>
</tr>
</tbody>
</table>
Multi-Center Wear Study

(N=1,024)
Variability in Linear Penetration Rates

Wear as a Function of Time

• Ten factors
• Explain only 21% of the variability in wear rates
• Surgeon / center = strongest effect
  • patient selection
  • surgical technique
  • post-operative activity recommendations
  • hospital differences in shelf-life of polymers
• Impact of Patient Activity on Wear?
Patient activity is highly variable

45-fold range in steps per day

Age is not the salient criteria for prosthesis selection

Some older patients are very active!

Limitations of categorical variables

Quantitative Assessment of Walking Activity…
Schmalzried et al., JBJS (Am.), 1998
The 2000 John Charnley Award:

Wear is a Function of Use, Not Time!

Thomas P. Schmalzried, M.D., Eric F. Shepherd, M.D.,
Frederick J. Dorey, Ph.D., Walter O. Jackson, M.D.
Mylene dela Rosa, B.S., Fa’vae Fa’vae,
Harry A. McKellop, Ph.D., Christian D. McClung, M.Phil.
John Martell, M.D., John R. Moreland, M.D., Harlan C. Amstutz, M.D.
Wear is a Function of Use!

- Tires
- Shoes
- Hips & Knees
Wear is a Function of Use!

Step Activity Monitor (SAM)

- 2-D accelerometer
- Micro-processor
- Infra-red dock download
- More accurate than pedometer 0.5% vs. up to 6% error
- Records in real time - assess walking speed and patterns of activity

Shepherd et al., JOR 1999
Wear is a Function of Use!

Radiographic Assessments

- Digitized AP radiographs of the hips and pelvis
  - initial film at least 18 months post-op.
  - follow-up film at least 3 years later (max. 6.2; avg. 4.5)
- 2-D linear penetration measured using the edge detection-based computer algorithm of Martell and Berdia (JBJS, 1997)
- Biomechanical parameters measured using published methods (Massin et al. 1989)
- Single observer (EFS)

Cup inclination = 43°
Wear angle = -3.2°
Magnitude = 2.7mm
Wear is a Function of Use!

Adjust for Activity

- This cohort close to 2 million cpy average
- Adjust annual wear rates for comparisons
- SAM about 50% higher than pedometer

<table>
<thead>
<tr>
<th></th>
<th>mm/yr</th>
<th>Ped.</th>
<th>SAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (24)</td>
<td>0.11</td>
<td>0.088</td>
<td>0.056</td>
</tr>
<tr>
<td>Males (11)</td>
<td>0.16</td>
<td>0.133</td>
<td>0.084</td>
</tr>
<tr>
<td>Females (13)</td>
<td>0.07</td>
<td>0.053</td>
<td>0.035</td>
</tr>
</tbody>
</table>
Wear is a Function of Use!

Regression Analyses

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male Gender</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Height</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Medial COR</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Femoral Off-set</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Liner Thickness</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Hylamer</td>
<td></td>
<td>0.043</td>
</tr>
<tr>
<td>Steps/min. (speed)</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Steps/year</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Joint Use</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Time In Situ</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Wear is a Function of Use!

Important Covariates

- **The Patient**
  Gender, height, weight and use
  Male gender - strongest independent effect on wear
  Behavior? Anatomy? Physiology?

- **The Surgeon**
  Technique - lower wear associated with medial COR and higher off-set

- **The Implants**
  Higher average wear with Hylamer
  Less effect than gender and off-set

10 Million-Plus Cycles Per Year ???
Activity Patterns and Polyethylene Wear

Not Just Total Cycles!

Patient A

3,504 cycles/day at 14.7 cycles/min;
80 starts/stops; 4.9% time spend walking fast..
Polyethylene wear rate: 55 mm³/year

Patient B

3,846 cycles/day at 17.8 cycles/min;
91 starts/stops; 9.4% time spend walking fast.
Polyethylene wear rate: 140 mm³/year
Activity Patterns and Polyethylene Wear

Average Walking Activity

- 5.6 hours/day
- 5,200 cycles/day
- 1.9 million cycles/year
- No male / female difference
Activity Patterns and Polyethylene Wear

Walking Speed

- 20 cycles/min (avg.)
- Males: 13.2% faster (p=0.1)

• Males spent 22% less time walking very slow (p=0.03) and 34% more time walking fast (p=0.1)

AVG. SPEED

Cycles / Minute

Males (14) Females (17)

Range Average
**Activity Patterns and Polyethylene Wear**

**Average Activity Patterns**

- **Starts-Stops:** 64 times/day
- **81 cycles** between stops
- **Active interval:** 5.3 minutes

**Males**
- 4% more starts/stops
- 19% shorter active interval 
  ($p=0.07$)

**Graph**:
- Starts / Stop * 10
- Active Interval (min)

**Comparison**:
- Males (14)
- Females (17)
- Males (14)
- Females (17)
Activity Patterns and Polyethylene Wear

Regression Analysis

Volumetric Wear Rate

Walking Speed: $R=0.4$ (p=0.02)
5-9 cycles/min.: $R=-0.5$ (p=0.004)
30-49 cycles/min.: $R=0.4$ (p=0.02)
Activity Patterns and Polyethylene Wear

Conclusion

- SAM allows assessment of patterns and intensity of joint use.
- How you walk matters!
- Similar to a set of automobile tires, wear is function of the amount and type of use.

“Your mileage depends on how you drive”
The 2012 Frank Stinchfield Award

Decreasing Patient Activity with Aging: Implications for Cross-Linked Polyethylene Wear

Andrew K. Battenberg, BS+
Jeffrey S. Hopkins, MD *
Andrew D. Kupiec*
Thomas P. Schmalzried, MD †*

+UCLA David Geffen School of Medicine, Los Angeles, CA
*Joint Replacement Institute at St. Vincent Medical Center, Los Angeles, CA
† Harbor-UCLA Medical Center, Torrance, CA
Wear is a Function of Use
Schmalzried et al. CORR 2000
John Charnley Award

This raises questions:
1. How does activity change over time?
2. What is the effect on polyethylene wear?
3. Is cross-linked polyethylene sufficient to last a lifetime?

THR Patient in Paris Marathon
14 Charnley Class A Patients
- Age at Surgery: Mean 55 years (range, 26-78)
- BMI: Mean 30 (range, 21.5-38.5)

Marathon™ PE
- 5 Mrad cross-linked, remelted
- 28 or 32mm bearings

Activity Data at two time points
- Early: Mean 1.5 yrs (range, 0.5-3.5 yrs)
- Late: Min. 10 yrs; mean 11.1 yrs (range, 10.0-12.3 yrs)

Wear Measurements during two time periods
- Early: From 1-5 yrs
- Late: From 5-13 yrs
Decreasing Activity and Wear with Patient Aging

- **StepWatch™ Activity Monitor (SAM)**
  - Microprocessor
  - Minute-by-minute activity measurements
  - Activity (cycles/day)
  - Gait Speed (cycles/min)
  - Number of Starts and Stops

![Activity Monitors](image)

**Activity:** 3372 cycles/day  
**Gait Speed:** 14.5 cycles/min

**Activity:** 8058 cycles/day  
**Gait Speed:** 22.2 cycles/min
Decreasing Activity and Wear with Patient Aging

Gait Speed Decreases with Aging

- Early mean gait speed: 15.4 cycles/min (range, 6.9 – 32.2 cycles/min)
- Late mean gait speed: 14.0 cycles/min (range, 7.1 – 22.2 cycles/min)
- 8.8% decrease over 9.6 years (p=0.19)
Decreasing Activity and Wear with Patient Aging

Ambulation Decreases with Aging

- Early mean activity: 2.04 million cycles/yr
- Late mean activity: 1.71 million cycles/yr
- 16% decrease ($p = 0.006$)
- Max total cycles: 37 million
Decreasing Activity and Wear with Patient Aging

**Gait Speed**

Patients <65 yrs had a greater decrease in Gait Speed (9.7% vs 5.5 %) while patients ≥65 yrs had a significantly slower Gait Speed.

**Activity**

Patients ≥65 yrs were sig. less active and had a greater decrease in gait cycles (28% vs 14%).
Decreasing Activity and Wear with Patient Aging

Wear Decreases with Patient Aging

- Linear wear rate decreased 42%
- Volumetric wear rate decreased 40%
- Adjusted volumetric wear rate decreased 11%

Linear wear decreased 42% (0.043 to 0.025 mm/yr; p=0.18)

Volumetric wear decreased 40% (15 to 9 mm³/yr; p=0.28)

Adjusted vol wear decreased 11% (6.5 to 5.8 mm³/yr; p=0.38)
Predicting Wear

- The First Five Years
  Mean volumetric wear rate = 15mm³/yr
- 40% mean decrease in wear from First 5 to 5-13 years
- Approximately a 3% compounded decrease in wear per year
- Life Expectancy for 50 yr old = 31.0 yrs
- Total volumetric wear over 31yrs = 305mm³
- Low risk of osteolysis during lifetime
Patient Activity Following TJR

Evolution of Technology

- Better materials
- Better designs
- Better fixation
- Better bearings
- (Better surgery)
- Increased durability
Patient Activity Following TJR

Evolution of Philosophy?

- Millennium patients
- Less accepting of disability
- Lifestyle v. longevity
- Capability v. advisability?

White men with Bilateral Total Knees can jump!
Thank You

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The Piedmont Foundation
Harbor-UCLA Department of Orthopaedics

South Santa Monica Bay, Palos Verdes & Catalina Island
Patient Activity Following TJR

Historical Perspective

- Hippocrates, “Do no harm”
- Conservative approach to activity recommendations
- Desire to maximize longevity of the arthroplasty
- Limited data to predict outcomes
- Operation was reserved for the older and sedentary
- Activity restrictions
Patient Activity Following TJR

Audience Response

How long does a total joint replacement last?

1. 10 years?
2. 15 years?
3. 20 years?
4. >20 years?
5. Not possible to predict
Patient Activity Following TJR

Audience Response

True or False?

1. You cannot run after joint replacement
2. It is not possible to play tennis after joint replacement
3. It is not possible to play basketball after joint replacement
4. A joint replacement can be “re-done” several times
5. Most joint replacements “out live” the patient