RECOVERY FOR PERFORMANCE IN RACKET SPORTS

Alexander Ferrauti
RECOVERY FOR PERFORMANCE IN RACKET SPORTS
Alexander Ferrauti

1 THE FITNESS – FATIGUE RELATION
2 INTERNAL & EXTERNAL LOAD IN RACKET SPORTS
3 OVERVIEW ABOUT RECOVERY INTERVENTIONS
4 SCIENTIFIC EVIDENCE OF RECOVERY EFFECTS
5 FINDINGS
6 MONITORING OF FATIGUE & RECOVERY
7 PRACTICAL RECOMMENDATIONS FOR RACKET SPORTS
1 THE FITNESS - FATIGUE RELATION

The Fitness-Fatigue Model from Banister (1982) and recovery
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The Fitness-Fatigue Model from Banister (1982) and recovery
1 THE FITNESS - FATIGUE RELATION

Quick Recovery

? versus ?

Max Adaptation

The Adaptation Perturbation Theory from Hunt et al. (2008)
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The **racket sports** are defined as sportive modalities in which two or four players use rackets to alternatively hit a ball or shuttlecock with the purpose of placing the missile in a certain position on a defined playing surface that the opponent is unable to successfully return (Lees, 2003).
## Internal Load Match Play

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Tennis (Fernandez-Fernandez et al. 2007; Ferrauti et al. 2001; Ferrauti 1999)</th>
<th>Squash (Girard et al., 2007)</th>
<th>Badminton (Faude, et al. 2007; Manrique &amp; Gonzalez-Badillo 2003)</th>
<th>Table Tennis (Zagatto et al. 2010; Sperlich et al., 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (% HRmax)</td>
<td>161 ± 5 bpm (86 % HRmax)</td>
<td>177 ± 10 bpm (92 ± 3 % HRmax)</td>
<td>174 ± 9 bpm (91 % HRmax)</td>
<td>164 ± 14 bpm (82 ± 7 % HRmax)</td>
</tr>
<tr>
<td>Blood lactate</td>
<td>2.0 ± 0.8 mmol/l</td>
<td>8.3 ± 3.4 mmol/l</td>
<td>3.8 ± 0.9 mmol/l</td>
<td>1.2-1.8 ± 0.7 mmol/l</td>
</tr>
<tr>
<td>VO₂ (% VO₂max)</td>
<td>24.2 ± 2.0 ml/min/kg (55 ± 3.1 % VO₂max)</td>
<td>54.4 ± 4.8 ml/min/kg (86 ± 9 % VO₂max)</td>
<td>39.6 ± 5.7 ml/min/kg (64 % VO₂max)</td>
<td>23.5 ± 7.3 ml/min/kg</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>CHO &gt;60-70 % High Caloric Demands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental &amp; Adrenergic Stress</td>
<td>Adrenaline Release Heat Stress</td>
<td></td>
<td>Adrenaline Release</td>
<td></td>
</tr>
</tbody>
</table>
## External Load Match Play

<table>
<thead>
<tr>
<th>Measurements</th>
<th><strong>Tennis</strong> <em>(Fernandez-Fernandez et al. 2007, 2009)</em></th>
<th><strong>Squash</strong> <em>(Sherman et al., 2004; Vučković et al. 2003; Girard et al. 2007)</em></th>
<th><strong>Badminton</strong> <em>(Abdullahi et al. 2017; Faude et al. 2007; Manrique &amp; Gonzalez-Badillo 2003; Majumdar et al. 1997)</em></th>
<th><strong>Table Tennis</strong> <em>(Zagatto et al. 2010; Sperlich et al. 2011)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Match duration</strong></td>
<td>1.5 to over 4 h</td>
<td>40 min to over 2 h</td>
<td>35 ± 14 min</td>
<td>15 to 35 min</td>
</tr>
<tr>
<td><strong>Effective playing time</strong></td>
<td>21.7 ± 5.0 %</td>
<td>69.7 ± 4.7 %</td>
<td>31.2 ± 2.8 %</td>
<td>44.3 ± 23.7 %</td>
</tr>
<tr>
<td><strong>Distance covered per match</strong></td>
<td>3569 ± 532 m</td>
<td>254 to 1449 m</td>
<td>1763 ± 751 m</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>Rally duration</strong></td>
<td>6.4 ± 4.1 s</td>
<td>18.6 ± 4.6 s</td>
<td>5.5 ± 4.0 s</td>
<td>3.4 ± 1.7 s</td>
</tr>
<tr>
<td><strong>Rest time</strong></td>
<td>14.5 ± 5.2 s</td>
<td>8.0 ± 1.8 s</td>
<td>11.4 ± 6.0 s</td>
<td>8.1 ± 5.1 s</td>
</tr>
<tr>
<td><strong>Work to rest ratio</strong></td>
<td>1 to 0.25</td>
<td>2.4 ± 0.6</td>
<td>0.5 ± 0.34</td>
<td>0.4 ± 0.2</td>
</tr>
<tr>
<td><strong>Shots per rally (both players)</strong></td>
<td>4.2 ± 2.6</td>
<td>n.a.</td>
<td>5.1 ± 3.9</td>
<td>3.9 ± 2.0</td>
</tr>
<tr>
<td><strong>Activities</strong></td>
<td>accelerations, decelerations, sprints, jumps, reactive stretch shortening cycles, eccentric overload, Intensive Hitting - trunk &amp; upper body power actions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recovery demands in Racket Sports:

• Rehydration
• Glycogen restauration
• Muscle performance (after damage, inflammation)
• Mental recovery
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Recovery strategies without likely potential:

- Light emitting diode (LED) therapy (Camargo et al. 2011)
- Low frequency vibration
- Electromyostimulation
- Floating in salty water
- Vacuum therapy ...
**Nutrition and Fluid ingestion with clear potential**

- Short chain CHO during training and match play
- Medium chain CHO between training units and matches
- Post exercise ingestion of flavoured milk is recommended (Gilson et al. 2010)
- 1-2 h post Exercise CHO rich meal with co-ingestion of proteins

  *Protein consumption stimulates muscle protein synthesis, is important for a positive protein balance, decreases CK levels* (Ferguson-Stegall et al. 2011).

- Daily supplementation of tart cherry juice, tomato juice

  *Anti-inflammatory and anti-oxidant effects by blunting the secondary muscle damage response (e.g. IL-6, IL-1, TNF-alpha, CRP)* (Howatson et al. 2010).
OVERVIEW ABOUT RECOVERY INTERVENTIONS

The Fitness-Fatigue Model from Banister (1982) and recovery
Hausswirth & Mujika, 2013

| Energy Metabolism | LA Elimination | | | | | |
| Glycogen Content | | | | | | |

| Muscle Function | Temperature | | | | | |
| DOMS, CK | | | | | | |
| CRP, IL-1, IL-6, TNF α | | | | | | |

| Neuromuscular | Pain Perception | | | | | |
| Contractility | | | | | | |

| Mental Performance | Cognitive Performance | | | | | |
| Wellbeing | | | | | | |

| Performance | Post <30 min | | | | | |
| Post >24 h | | | | | | |
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Cooling and Performance Recovery of Trained Athletes: A Meta-Analytical Review

Wigand Poppendieck, Oliver Faude, Melissa Wegmann, and Tim Meyer

Purpose: Cooling after exercise has been investigated as a method to improve recovery during intensive training or competition periods. As many studies have included untrained subjects, the transfer of those results to trained athletes is questionable. Methods: Therefore, the authors conducted a literature search and located 21 peer-reviewed randomized controlled trials addressing the effects of cooling on performance recovery in trained athletes. Results: For all studies, the effect of cooling on performance was determined and effect sizes (Hedges’ g) were calculated. Regarding performance measurement, the largest average effect size was found for sprint performance (2.6%, g = 0.69), while for endurance parameters (2.6%, g = 0.19), jump (3.0%, g = 0.15), and strength (1.8%, g = 0.10), effect sizes were smaller. The effects were most pronounced when performance was evaluated 96 h after exercise (4.3%, g = 1.03). Regarding the exercise used to induce fatigue, effects after endurance training (2.4%, g = 0.35) were larger than after strength-based exercise (2.4%, g = 0.11). Cold-water immersion (2.9%, g = 0.34) and cryogenic chambers (3.8%, g = 0.25) seem to be more beneficial with respect to performance than cooling packs (−1.4%, g = −0.07). For cold-water application, whole-body immersion (5.1%, g = 0.62) was significantly more effective than immersing only the legs or arms (1.1%, g = 0.10). Conclusions: In summary, the average effects of cooling on recovery of trained athletes were rather small (2.4%, g = 0.28). However, under appropriate conditions (whole-body cooling, recovery from sprint exercise), postexercise cooling seems to have positive effects that are large enough to be relevant for competitive athletes.

Keywords: cryotherapy, cold-water immersion, regeneration
Jump Performance

Figure 5 — Effects of cooling after exercise on recovery of jump performance. For each study, the number of subjects (n) and the timing of the posttest (multiple timings possible) are given, as well as the type of exercise to induce fatigue and the cooling method. CWI indicates cold-water immersion.
Sprint Performance

Figure 4 — Effects of cooling after exercise on recovery of sprint performance. For each study, the number of subjects (n) and the timing of the posttest (multiple timings possible) are given, as well as the type of exercise to induce fatigue and the cooling method. CWI indicates cold-water immersion.
**Sprint Performance**

Amico et al., 2017 (n = 18), post 0h, mixed
Amico et al., 2017 (n = 18), post 24h, mixed
Pearcey et al., 2015 (n = 8), post 24h, strength
Rey et al., 2017 (n = 9, post 24, mixed)

**p-Value = 0.13**  
Sprint post 24h (n = 53)
Amico et al., 2017 (n = 18), post 48h, mixed
Pearcey et al., 2015 (n = 8, post 48h, strength)

**p-Value = 0.20**  
Sprint post 48h (n = 25)
Amico et al., 2017 (n = 18), post 72h, mixed
Pearcey et al., 2015 (n = 8, post 72h, strength)

**p-Value = 0.20**  
Sprint post 72h (n = 25)
Amico et al., 2017 (n = 18), post 96h, mixed

**p-Value = 0.12**  
Total Sprint (n = 123)

**Döweling et al. (in preparation)**
SPECIAL INSIGHT INTO PHYSIOLOGY OF TENNIS

SCIENTIFIC EVIDENCE OF RECOVERY EFFECTS

Pain Perception

Döweling et al. (in preparation)
An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review With Meta-Analysis

Olivier Dupuy, Wafa Douzi, Dimitri Theuot, Laurent Bosquet and Benoit Dugué

Laboratoire MOVE (EA6314), Faculty of Sport Sciences, University of Poitiers, Poitiers, France

Introduction: The aim of the present work was to perform a meta-analysis evaluating the impact of recovery techniques on delayed onset muscle soreness (DOMS), perceived fatigue, muscle damage, and inflammatory markers after physical exercise.

Method: Three databases including PubMed, Embase, and Web-of-Science were searched using the following terms: (“recovery” or “active recovery” or “cooling” or “massage” or “compression garment” or “electrostimulation” or “stretching” or “immersion” or “cryotherapy”) and (“DOMS” or “perceived fatigue” or “CK” or “CRP” or “IL-6”) and (“after exercise” or “post-exercise”) for randomized controlled trials, crossover trials, and repeated-measures studies. Overall, 99 studies were included.

Results: Active recovery, massage, compression garments, immersion, contrast water therapy, and cryotherapy induced a small to large decrease ($-2.26 < g < -0.40$) in the magnitude of DOMS, while there was no change for the other methods. Massage was found to be the most powerful technique for recovering from DOMS and fatigue. In terms of muscle damage and inflammatory markers, we observed an overall moderate decrease in creatine kinase [SMD (95% CI) = $-0.37$ ($-0.58$ to $-0.16$), $I^2 = 40.15\%$] and overall small decreases in interleukin-6 [SMD (95% CI) = $-0.36$ ($-0.60$ to $-0.12$), $I^2 = 0\%$] and C-reactive protein [SMD (95% CI) = $-0.38$ ($-0.59$ to $-0.14$), $I^2 = 39\%$]. The most powerful techniques for reducing inflammation were massage and cold exposure.

Conclusion: Massage seems to be the most effective method for reducing DOMS and perceived fatigue. Perceived fatigue can be effectively managed using compression techniques, such as compression garments, massage, or water immersion.
SCIENTIFIC EVIDENCE OF RECOVERY EFFECTS

**Creatine Kinase**

- Active Recovery
- Stretching
- Massage
- Massage + Stretching
- Electrostimulation
- Compression Garment
- Immersion
- Contrast Water Therapy
- Cryotherapy
- Hyperbaric Therapy

**IL 6**

- Active Recovery
- Stretching
- Massage
- Massage + Stretching
- Electrostimulation
- Compression Garment
- Immersion
- Contrast Water Therapy
- Cryotherapy
- Hyperbaric Therapy

**CRP**

- Active Recovery
- Stretching
- Massage
- Massage + Stretching
- Electrostimulation
- Compression Garment
- Immersion
- Contrast Water Therapy
- Cryotherapy
- Hyperbaric Therapy

*Dupuys et al. 2018*
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Recovery Management in Sports

Prof. Dr. Michael Kellmann, Sport Psychology
Prof. Dr. Alexander Ferrauti, Training and Exercise Science

Prof. Dr. Tim Meyer, Sports Medicine and Training Science

Prof. Dr. Mark Pfeiffer, Training Science
**REGman – EXPERIMENTAL STUDIES**

**RUHR-UNIVERSITÄT BOCHUM**

6th World Congress of Racket Sport Science

Prof. Dr. Alexander Ferrauti
REGman - Open 2015
Ein Herren-Einzel-Turnier unter sportwissenschaftlichen Fragestellungen im Rahmen des BiSp-Projekts „Regenerationsmanagement im Sport“

- 1000 € Antrittsgeld und 3000 € Preisgeld! (zur Verfügung gestellt von der ITF)
- individuelle Leistungsdagnostik für jeden Teilnehmer!
- zwölf garantierte Tennismatchs - aufgeteilt auf zwei Turnierblöcke!

<table>
<thead>
<tr>
<th>Wann:</th>
<th>Block 1: 20.05. - 29.05.2015</th>
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<td>Block 2: 12.08. - 21.08.2015</td>
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<tr>
<td>Meldeschluss</td>
<td>01.05.2015</td>
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<tr>
<td>Wo:</td>
<td>Fakultät für Sportwissenschaft</td>
</tr>
<tr>
<td></td>
<td>Sportanlagen Halte Markstraße</td>
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</tbody>
</table>

Anmeldung: Thimo Wiewelhove
            thimo.wiewelhove@rub.de
            0234 3225969

Fakultät für Sportwissenschaft | 44604 Bochum | Gesundheitscampus Nord 10
REGman Open
REGman Open
REGman Open
REGman Open
REGman – EXPERIMENTAL STUDIES

REGman Open

??

6th World Congress of Racket Sport Science

Prof. Dr. Alexander Ferrauti
REGman Open

Countermovement Jump

- Kontrolle
- Intervention

```
  Pre  Post₁ Post₂ Post₃
  30   32   34   36
```

```
  cm
  32   34   36   38   40   42   44   46   48   50
```

REGman – EXPERIMENTAL STUDIES

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REGman – EXPERIMENTAL STUDIES

REGman Open

![Graph showing CK levels over time with Kontrolle and Intervention groups.](image)

U/l

0  200  400  600  800  1,000  1,200  1,400  1,600  1,800

1  2  3  4  5

Kontrolle

Intervention
### REGman Open

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Intervention</th>
<th>Control</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bewegungsanalyse</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laufdistanz (Netto-Spielzeit) [m]</td>
<td>2526 ± 1061</td>
<td>2558 ± 1068</td>
<td>0.92</td>
<td>0.03</td>
</tr>
<tr>
<td>Anzahl der Sprints [n]</td>
<td>98 ± 51</td>
<td>119 ± 68</td>
<td>0.27</td>
<td>0.49</td>
</tr>
<tr>
<td>Im Sprint zurückgelegte Distanz [m]</td>
<td>273 ± 139</td>
<td>321 ± 158</td>
<td>0.24</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Spielanalyse</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gewonnene Punkte [n]</td>
<td>99 ± 26</td>
<td>96 ± 19</td>
<td>0.73</td>
<td>0.13</td>
</tr>
<tr>
<td>Asse und Servicewinner [n]</td>
<td>4.1 ± 4.1</td>
<td>3.3 ± 2.3</td>
<td>0.52</td>
<td>0.24</td>
</tr>
<tr>
<td>Doppelfehler [n]</td>
<td>4.9 ± 3.6</td>
<td>4.1 ± 3.7</td>
<td>0.30</td>
<td>0.22</td>
</tr>
<tr>
<td>Fehler [n]</td>
<td>63 ± 13</td>
<td>63 ± 19</td>
<td>0.96</td>
<td>0.00</td>
</tr>
<tr>
<td>Gewinnschläge [n]</td>
<td>27 ± 13</td>
<td>25 ± 13</td>
<td>0.54</td>
<td>0.15</td>
</tr>
</tbody>
</table>
OVERVIEW ABOUT RECOVERY INTERVENTIONS

The Fitness-Fatigue Model from Banister (1982) and recovery
The Adaptation Perturbation Theory from Hunt et al. (2008)
Active Recovery After High-Intensity Interval-Training Does Not Attenuate Training Adaptation

Thimo Wiewelhove¹*, Christoph Schneider¹, Alina Schmidt¹, Alexander Döweling¹, Tim Meyer², Michael Kellmann¹,³, Mark Pfeiffer⁴ and Alexander Ferrauti¹

¹ Faculty of Sport Science, Ruhr-University Bochum, Bochum, Germany, ² Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany, ³ School of Human Movement Studies and School of Psychology, The University of Queensland, Brisbane, QLD, Australia, ⁴ Institute of Sports Science, Johannes Gutenberg University, Mainz, Germany
Quick Recovery

Small positive effects on endurance with Active Recovery
(Wiewelhove et al. 2018)

Max Adaptation

Small positive effects on strength without CWI
(Skorski, in preparation)
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Monitoring of Training & Competition Load

Blanch & Gabbett 2015; Gabbett 2016
Multivariate Monitoring of Recovery Markers

**Psychological Ratings:**
- POMS: Profile of Mood States
- EBF-Sport
- TQR: Total Quality Recovery
- DALDA: Daily Analysis of Life Demands for Athletes
- **DOMS:** Delayed Onset Muscle Soreness
- Sleep Duration & Quality
- Cognitive Performance Tests

**Performance Tests:**
- SJ, DJ, RJ, CMJ
- Sprints, RSA
- Power Tests (Wingate, NMT Tests)
- MVIC, 1RM

**Blood, Urine, Salvia**
- Metabolic Markers: Urea, Glutamin, Insulin, IGF-1, Testosteron, Cortisol, T/C, ACTH, ACTH/C, GH
- Immunological Markers: CRP, IL-1, IL-6, TNF-alpha
- Muscle related Markers: CK
- Gene Expression: miRNA

**Cardiac Regulation:**
- HRV, HR-rest, HR-max, HR-submax

**Neuromuscular Function:**
- TMG
Psychological Ratings = Nº1 for Juniors
SPECIAL INSIGHT INTO PHYSIOLOGY OF TENNIS

RESEARCH ARTICLE

Blood-Borne Markers of Fatigue in Competitive Athletes – Results from Simulated Training Camps

Anne Hecksteden¹*, Sabrina Skorski¹, Sascha Schwindling¹, Daniel Hammes¹, Mark Pfeiffer², Michael Kellmann³, Alexander Ferrauti³, Tim Meyer¹

¹ Institute of Sports and Preventive Medicine, Saarland University, Saarbruecken, Germany, ² Institute of Sports Science, Johannes-Gutenberg University, Mainz, Germany, ³ Faculty of Sports Science, Ruhr-University of Bochum, Bochum, Germany, ⁴ Schools of Human Movement Studies and Psychology, The University of Queensland, Queensland, Australia

PLOS ONE | DOI:10.1371/journal.pone.0148810  February 18, 2016
Individualization of Blood-Borne Marker Ranges

Hecksteden et al. 2016
HR submax a potential HR marker in racket sports

Heart Rate Monitoring in Team Sports – A Conceptual Framework for Contextualizing Heart Rate Measures for Training and Recovery Prescription

Christoph Schneider1*, Florian Hanakam1, Thimo Viewelhove3, Alexander Döweling1, Michael Kellmann1,2, Tim Meyer1, Mark Pfeiffer1 and Alexander Ferrauti2

1 Faculty of Sport Science, Ruhr-Universität Bochum, Germany
2 School of Human Movement and Nutrition Sciences, The University of Queensland, Australia
3 Institute of Sports and Preventive Medicine, Saarland University, Germany
4 Institute of Sports Science, Johannes Gutenberg-Universität Mainz, Germany
HR submax a potential HR marker in racket sports
HR submax a potential HR marker in racket sports
Multivariate Decision Making
Multivariate Decision Making

Source: Testgruppe TraiWi

Alexander Ferrauti

Diagramm bearbeiten und ergänzen

- Training Load Schwimmtraining
- Training Load Radtraining
- Training Load Lauftraining
- Training Load Athletiktraining
- S. Muskuläre Beanspruchung
- Bewertung des Schlafs
- Körpergewicht (in kg)
- Herzfrequenzvariabilität
Intelligent Online-Tools

MONITORING OF FATIGUE & RECOVERY

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Regenerationsmanagement im Spitzensport

REGman – Ergebnisse und Handlungsempfehlungen
General advices

1. The efficiency of most recovery interventions in racket sports is lower than expected.
2. Recovery routines should be individualized according to players preferences, surrounding conditions and availability of methods.
3. Long term adaptation is not strongly affected by recovery.
4. A daily monitoring of training load and markers of fatigue is recommended for the fine tuning of training prescription.
General advices
1. The efficiency of most recovery interventions in racket sports is lower than expected.
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Overnight performance recovery
- **High evidence:** CHO plus protein consumption, hydration, sleep
- **Moderate evidence:** CWI, massage, roller massage
- **Low evidence:** active recovery, compression garments, others
General advices
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Short-term recovery (between tournament matches or training units)
- CHO, hydration, roller massage, massage, active recovery, Power naps, relaxation strategies
General advices
1. The efficiency of most recovery interventions in racket sports is lower than expected.
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Short-term recovery (between tournament matches or training units)
CHO, hydration, roller massage, massage, active recovery, Power naps, relaxation strategies

Future challenges for research
Recovery of the upper extremities, recovery between points and during change of ends
Selection of References


Call for papers
German Journal of Exercise and Sport Research
Racket and Batting Sports. A multidisciplinary perspective on globally popular lifetime sports.

This thematic issue will contain – but is explicitly not limited to – outstanding contributions to the 6th World Congress of Racket Sport Science, held in Bangkok in 2018. The issue will include original papers and reviews on performance and health related aspects in Badminton, Baseball, Cricket, Golf, Softball, Squash, Table Tennis and Tennis, as well as new racket and batting sport games. Its goal is to combine research perspectives from science and medicine (e.g. physiology and sports medicine, training and exercise science, biomechanics) with those from the humanities (e.g. sport philosophy, sport history, physical education) and from various social and behavioural academic disciplines (e.g. sport sociology, sport psychology, sport management). Six senior action editors
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RECOVERY FOR PERFORMANCE IN RACKET SPORTS
Alexander Ferrauti
Active Recovery

- Running, biking or swimming (15-30 min, 30-60 % VO\textsubscript{2}max immediately after match)
- Blood lactate ↓ and pH (Fairchild et al. 2003) ↑
- Glycogen synthesis (Fairchild et al. 2003) ↓
- Sprint and Jumping performance (Andersson et al. 2008) ↔
- Muscle soreness, CK (Andersson et al. 2008) ↔
- Inflammatory response and oxidative stress markers (Andersson et al. 2010) ↔
Cold Water Immersion

- Not deeper than hip
- Cold water 10-15°C, 10-20 min
- Immediately after Exercise
- Venous blood return $\uparrow$
  
  *Water temperature and hydrostatic pressure*
- Inflammation from muscle damage $\downarrow$

(Nédélec et al. 2012)
OVERVIEW RECOVERY INTERVENTIONS

Foam-Rolling

Biomechanical effects
- Mechanical pressure on tissues
  - ↓ Tissue adhesion
  - ↑ Muscle compliance
  - ↑ Range of joint motion
  - ↓ Passive stiffness
  - ↓ Active stiffness

Physiological effects
- Changes in tissue or organ
  - ↑ Muscle blood flow
  - ↑ Skin blood circulation
  - ↑ Parasympathetic activ.
  - ↑ Relaxation hormones
  - ↓ Stress hormones

Neurological effects
- Reflex stimulation
  - ↓ Neuromus. Excitability
  - ↓ Pain
  - ↓ Muscle tension/spasm

Psychological effects
- Increased relationship between body and mind
  - ↑ Relaxation
  - ↓ Anxiety

(Weerapong et al. 2015)
German Volleyball Team (n=8)

**Mess**
- p < 0.01**
**Int**
- p = 0.07
**Mess x Int**
- p = 0.10

**CMJ**

-4.4 cm
-3.2 cm