"It's not what it looks like Laura, I just couldn't sleep."

Prof. Jason Ellis
“Next to the air we breathe, food and sleep are the most crucial physical essentials for maintaining a sound and healthful state of living.”
(Pickett & Morris, 1975)
What Is Sleep?

A physical state of:

Postural recumbency
Quiescence
Closed eyes

However, two separate states of sleep have been identified

REM-Rapid Eye Movement

Non-REM-(4 distinct sleep stages)

Each sleep phase is characterised by changes in brain-wave activity and neuro-transmitter frequency.
What Is Sleep 2?

Non-REM accounts for 75% of a typical night's sleep, sub-divided into four stages

Stage 1  
Decreased EEG + increased theta activity

Stage 2  
Brief EEG bursts + -EMG + -EOG

Stages 3 & 4  
Mixed frequency EEG

(Slow Wave Sleep: SWS)
What Is Sleep 3?

Stage 1
Stage 2
Stage 3 & 4
REM (90 minute)
Muscle tension nonexistent
Body Paralysis
Eye movements and Respiratory System Active
Dream Activity
Sleep
Influence of Chronotype

- Evening types more likely to have variable sleep schedules
- Evening types more likely to eat late
- Evening types more prone to weight gain
- Evening types more likely to report insomnia
- Evening types more likely to get depression
- Evening types more likely to get sleep apnoea
The Relationship between Chronotype and Amylase (Enzyme)

n = 1,138

Gardani, Biello, and Ellis (2010)
Normal Sleep in Athletes

- Athletes require 9-10 hours per night (Bompa, 2009; Calder 2003)
- 80-90% of 24h sleep should be at night
- Napping is encouraged in this population (Kentta & Hassmen, 2002)

Unlikely to reflect individual sleep need
Unlikely to reflect variability in different sports
Excess time in bed is likely to lead to fragmented sleep
Excess napping (1h per 24h) is likely to disrupt the sleep homeostat
# Normal Sleep in Athletes

Sleep in athletes: Most research to date is self-report

Leeder et al (2012) – 46 Athletes vs. 20 Controls
  Canoeing
  Diving
  Rowing
  Speed Skating

**Actigraphy**

Lower Sleep Efficiency – 80.6% vs. 88.7% (Clinical Threshold)
Higher Sleep Fragmentation – 36 vs. 29.8 (%epochs of >0 during sleep)
Higher Time in Bed – 8h 36minutes vs. 8h 07minutes
Higher Sleep Onset Latency – 18.2minutes vs. 5minutes
Lower Total Sleep Time – 6h 55minutes vs. 7h 11minutes
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Is this a Sleep Extension issue?
Sleep problems in athletes: Hanton et al (2005)

Venter et al (2010) – 890 Elite South African team sport players
Field Hockey
Rugby
Netball
Soccer

Self-report

Irregular sleep pattern – 33%
Sleep Onset Latency – 41%
Early Morning Awakenings – 60%
Napping – 68%

Noise and light in the sleep environment affected sleep quality
Nutrition and Performance

Good Sleep

Nutrition & Supplementation

Performance & Recovery
Nutrition & Recovery

• Carbohydrate and Fatty Acids – oxidized by skeletal-muscle tissue during exercise
• Mediated by exercise intensity, duration, and prior exercise status
• Endogenous Carbohydrate stored as muscle and liver glycogen
• Glycogen levels can decline between 30-70% depending on type of exercise
• Following exercise 24h to restore back to pre-exercise levels (individual differences in glycogen repletion rates)

• Repletion synthesis occurs in two phases:
  • Insulin-independent phase (II)(30-60 minutes)
  • Insulin-dependent (ID)phase – slower up to 48h

• Supplementation during ID phase with Carbohydrate promotes repletion with more frequent supplementation conferring more benefits for endurance recovery

• Similar story for Muscle Protein Synthesis to facilitate muscle-damage repair (achieve a positive muscle/protein balance) for reconditioning
• Caffeine or Guarana = 2-6mg/kg optimal for cognitive performance (alertness, vigilance, STMemory), ameliorating impact of sleep deprivation in terms of skill execution, sustained performance sport, recovery (combined with carbohydrate)

• Vitamin D = 25-hydroxy-vitamin D is optimal level for physical performance (Cannell et al, 2009) and most athletes are deficient and this changes over seasons and declines with age (Bannert et al, 1991)

• Glycerol = 1-1.5g/kg glycerol with 25-35ml fluid provides 600-1000ml (2011 World Anti-Doping Agency ruling against supplemented diuretics)
Are Tart Cherries Double Agents?

- Good Sleep
- Performance & Recovery
- Tart Cherry Juice
Recuperative Benefits

Numerous Phytochemicals (flavonoids & anthocyanins)

1. ‘free radical’ scavengers that reduced oxidative stress
2. Anti-inflammatory properties

- Isometric Strength recovery
- Reduced inflammation
- Increased Total Antioxidant Capacity
- Peroxidation
- Reduced Reports of Pain
Increasing Melatonin through Supplementation

Terminal antioxidant

Adapted from Peuhkuri, Sihvola & Korpela (2012)
**Food Melatonin Levels**

<table>
<thead>
<tr>
<th>Food</th>
<th>Melatonin Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tart Cherries</td>
<td>1,350 ng/100g</td>
</tr>
<tr>
<td>Walnuts</td>
<td>90-450 ng/100g</td>
</tr>
<tr>
<td>Corn</td>
<td>187 ng/100g</td>
</tr>
<tr>
<td>Rice</td>
<td>149 ng/100g</td>
</tr>
<tr>
<td>Ginger Root</td>
<td>142 ng/100g</td>
</tr>
<tr>
<td>Barley Grains</td>
<td>87 ng/100g</td>
</tr>
<tr>
<td>Oats</td>
<td>79 ng/100g</td>
</tr>
<tr>
<td>Almonds</td>
<td>39 ng/100g</td>
</tr>
<tr>
<td>Banana</td>
<td>18-31 ng/100g</td>
</tr>
<tr>
<td>Strawberry</td>
<td>20 ng/100g</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>13-29 ng/100g</td>
</tr>
<tr>
<td>Green Tea</td>
<td>9 ng/100ml</td>
</tr>
<tr>
<td>Black Olives</td>
<td>9 ng/100g</td>
</tr>
</tbody>
</table>
Study Overview

Supplementation

2 x servings of 30ml concentrate (42.6 μg /30ml day melatonin or 90-100 cherries) or placebo diluted in 200ml of water

30 minutes post wake and 30 minutes before evening meal for seven days
Study Overview

Main Findings

- Significant reduction in duration of daytime naps (-22%)
- Increased Time In Bed (+24 minutes from 490 to 514 minutes)
- Increased Total Sleep Time (+34 minutes from 385 to 419)
- Increased Sleep Efficiency (from 76.8 to 82.3%)
Study Overview

Main Findings

- Significant reduction in duration of daytime naps (-22%)
- Increased Time In Bed (+24 minutes from 490 to 514 minutes)
- Increased Total Sleep Time (+34 minutes from 385 to 419)
- Increased Sleep Efficiency (from 76.8 to 82.3%)

6-sulfatoxymelatonin levels (aMT6s)
Additional Benefits on Mood
Anticipation causes sleep onset problems

Spielman et al (1987)
Protocol to Disrupt Sleep Latency

Schematic of Stress Assessment Day Tasks From Normal Waking Time (mins)

-14 to 0
Pre-assessment

Screening / Adaptation Night
Anticipation Night
Recovery Night

1
2

3
Assessment Battery

Overnight Polysomnography

Group 1 – Controls (N = 11)
Group 2 – Anticipation (N = 22)
Protocol to Disrupt Sleep Latency

### Schematic of Stress Assessment Day Tasks From Normal Waking Time (mins)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>CAR / Cortisol Sampling</td>
</tr>
<tr>
<td>+30</td>
<td>Meal</td>
</tr>
<tr>
<td>+60</td>
<td>Mood</td>
</tr>
<tr>
<td>+90</td>
<td>Multi-tasking Framework</td>
</tr>
<tr>
<td>+120</td>
<td>Altered Emotional Stroop</td>
</tr>
<tr>
<td>+150</td>
<td>Iowa Gambling Task</td>
</tr>
<tr>
<td>+180</td>
<td>Pre-assessment</td>
</tr>
<tr>
<td>+210</td>
<td>Screening / Adaptation Night</td>
</tr>
<tr>
<td>+240</td>
<td>Anticipation Night</td>
</tr>
<tr>
<td>+300</td>
<td>Recovery Night</td>
</tr>
<tr>
<td>+330</td>
<td>Assessment Battery</td>
</tr>
<tr>
<td>+360</td>
<td>Overnight Polysomnography</td>
</tr>
</tbody>
</table>

**Group 1 – Controls (N = 11)**

**Group 2a – Anticipation alone (N = 11) + Incentive**

**Group 2b – Anticipation and Demand (N = 11) + Incentive**
The Impact of Anticipated Demand on Sleep

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>Anticipation</th>
<th>Anticipation and Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>23.46 (3.21)</td>
<td>24.66 (4.54)</td>
<td>22.19 (1.88)</td>
</tr>
<tr>
<td>PSQI Scores</td>
<td>3.56 (1.34)</td>
<td>3.45 (2.11)</td>
<td>3.27 (1.74)</td>
</tr>
<tr>
<td>Time in Bed</td>
<td>521.94 (25.39)</td>
<td>539.55 (44.52)</td>
<td>532.27 (42.8)</td>
</tr>
<tr>
<td>Sleep Latency</td>
<td>14.72 (9.31)</td>
<td>10.68 (5.25)</td>
<td>12.36 (6.45)</td>
</tr>
<tr>
<td>Number of Awakenings</td>
<td>1.22 (1.22)</td>
<td>1 (.89)</td>
<td>1.18 (1.15)</td>
</tr>
<tr>
<td>Wake After Sleep Onset</td>
<td>8.83 (14.21)</td>
<td>3.36 (5.84)</td>
<td>5.82 (6.66)</td>
</tr>
<tr>
<td>Total Sleep Time</td>
<td>441.22 (38.06)</td>
<td>470.27 (40.04)</td>
<td>455.82 (60.45)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Controls Mean</th>
<th>Controls SD</th>
<th>Anticipation Mean</th>
<th>Anticipation SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sleep time (mins)</td>
<td>452.8</td>
<td>41.21</td>
<td>434.78</td>
<td>23.44</td>
<td>-1.74</td>
<td>n.s.</td>
</tr>
<tr>
<td>Sleep efficiency (%)</td>
<td>95.96</td>
<td>1.89</td>
<td>94.71</td>
<td>2.19</td>
<td>-1.94</td>
<td>n.s.</td>
</tr>
<tr>
<td>WASO</td>
<td>8.68</td>
<td>4.31</td>
<td>12.08</td>
<td>7.27</td>
<td>1.84</td>
<td>n.s.</td>
</tr>
<tr>
<td>SOL</td>
<td>10.25</td>
<td>7.21</td>
<td>22.79</td>
<td>9.47</td>
<td>2.77</td>
<td>p&lt;.01</td>
</tr>
<tr>
<td>NWAK</td>
<td>12.09</td>
<td>4.95</td>
<td>13.78</td>
<td>5.78</td>
<td>1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time in REM (%)</td>
<td>24.07</td>
<td>6.15</td>
<td>22.59</td>
<td>4.17</td>
<td>-0.87</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time in N1 (%)</td>
<td>3.3</td>
<td>1.85</td>
<td>3.38</td>
<td>1.41</td>
<td>0.15</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time in N2 (%)</td>
<td>51.06</td>
<td>8.33</td>
<td>54.45</td>
<td>5.76</td>
<td>1.46</td>
<td>n.s.</td>
</tr>
<tr>
<td>Time in N3 (%)</td>
<td>21.58</td>
<td>5.86</td>
<td>19.58</td>
<td>5.12</td>
<td>-1.14</td>
<td>n.s.</td>
</tr>
<tr>
<td>Latency to REM (mins)</td>
<td>99.75</td>
<td>36.67</td>
<td>85.8</td>
<td>39.92</td>
<td>1.15</td>
<td>n.s.</td>
</tr>
</tbody>
</table>
The Impact of Anticipated Next Day Demand on the CAR

* $t = -2.09$, $p < .05$
The CAR Following a Demanding Day

Cortisol levels (nmol/l)

Time point

M3 Control
M3 Demand
M3 Anticipation

Wake Wake + 15 mins Wake + 30 mins Wake + 45 mins Wake + 60 mins

$F = 2.96, \ p = .06$
Dealing with Sleep Onset Latency

High vs. Low-Glycemic-Index Carbohydrate Meal (Jasmine vs. Mahatma Rice)

<table>
<thead>
<tr>
<th>Effect of the glycemic index (GI) and timing of meals on sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep variable</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>SOL (min)</td>
</tr>
<tr>
<td>ROL (min)</td>
</tr>
<tr>
<td>SE (%)</td>
</tr>
<tr>
<td>Arousal index (no./h)</td>
</tr>
<tr>
<td>REM</td>
</tr>
<tr>
<td>NREM</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Sleep stage 1 (%)</td>
</tr>
<tr>
<td>Sleep stage 2 (%)</td>
</tr>
<tr>
<td>Sleep stage 3 (%)</td>
</tr>
<tr>
<td>Sleep stage 4 (%)</td>
</tr>
<tr>
<td>NREM sleep (%)</td>
</tr>
<tr>
<td>REM sleep (%)</td>
</tr>
<tr>
<td>Total sleep time (min)</td>
</tr>
<tr>
<td>Total wake time (min)</td>
</tr>
</tbody>
</table>

$^a n = 12$. SOL, sleep onset latency; ROL, rapid eye movement latency; REM, rapid eye movement; SE, sleep efficiency (the ratio of total sleep time in bed); NREM, non–rapid eye movement. Sleep stages and proportion of NREM and REM sleep are presented as a percentage of total sleep time.

$^2$ Comparison of high-GI meal given 4 h and 1 h before bedtime.

$^3$ Comparison between high-GI meal ingested 4 h before bedtime with low-GI meal ingested 4 h before bedtime.

$^4 x ± SD$ (all such values).

Afaghi, O’Conner, Chow (2007)
Dealing with Sleep Onset Latency

High vs. Low-Glycemic-Index Carbohydrate Meal (Jasmine vs. Mahatma Rice)

<table>
<thead>
<tr>
<th>Sleep variable</th>
<th>1 h</th>
<th>4 h</th>
<th>Low-GI meal, 4 h</th>
<th>p²</th>
<th>p³</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOL (min)</td>
<td>14.6 ± 9.9*</td>
<td>9.0 ± 6.2</td>
<td>17.5 ± 6.2</td>
<td>0.01</td>
<td>0.009</td>
</tr>
<tr>
<td>ROL (min)</td>
<td>84.1 ± 39.8</td>
<td>97.0 ± 33.2</td>
<td>82.6 ± 35.7</td>
<td>0.32</td>
<td>0.16</td>
</tr>
<tr>
<td>SE (%)</td>
<td>92.0 ± 2.2</td>
<td>92.4 ± 2.7</td>
<td>90.7 ± 2.7</td>
<td>0.63</td>
<td>0.06</td>
</tr>
<tr>
<td>Arousal index (no./h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REM</td>
<td>15.4 ± 10.4</td>
<td>15.4 ± 7.8</td>
<td>14.5 ± 7.1</td>
<td>0.99</td>
<td>0.70</td>
</tr>
<tr>
<td>NREM</td>
<td>12.1 ± 5.3</td>
<td>10.7 ± 4.5</td>
<td>10.6 ± 5.8</td>
<td>0.15</td>
<td>0.93</td>
</tr>
<tr>
<td>Total</td>
<td>12.6 ± 5.1</td>
<td>11.5 ± 4.2</td>
<td>11.4 ± 5.3</td>
<td>0.32</td>
<td>0.95</td>
</tr>
<tr>
<td>Sleep stage 1 (%)</td>
<td>5.7 ± 2.0</td>
<td>6.3 ± 2.8</td>
<td>17.5 ± 6.2</td>
<td>0.37</td>
<td>0.08</td>
</tr>
<tr>
<td>Sleep stage 2 (%)</td>
<td>56.2 ± 5.4</td>
<td>54.5 ± 4.8</td>
<td>82.6 ± 35.7</td>
<td>0.18</td>
<td>0.43</td>
</tr>
<tr>
<td>Sleep stage 3 (%)</td>
<td>5.3 ± 2.0</td>
<td>4.7 ± 2.2</td>
<td>90.7 ± 2.7</td>
<td>0.37</td>
<td>0.17</td>
</tr>
<tr>
<td>Sleep stage 4 (%)</td>
<td>14.7 ± 5.3</td>
<td>14.9 ± 7.2</td>
<td>17.5 ± 6.2</td>
<td>0.82</td>
<td>0.64</td>
</tr>
<tr>
<td>NREM sleep (%)</td>
<td>81.9 ± 4.3</td>
<td>80.6 ± 4.5</td>
<td>82.6 ± 35.7</td>
<td>0.15</td>
<td>0.77</td>
</tr>
<tr>
<td>REM sleep (%)</td>
<td>18.0 ± 4.3</td>
<td>19.4 ± 4.5</td>
<td>90.7 ± 2.7</td>
<td>0.14</td>
<td>0.75</td>
</tr>
<tr>
<td>Total sleep time (min)</td>
<td>478 ± 68.7</td>
<td>472.0 ± 66.4</td>
<td>464.1 ± 70.1</td>
<td>0.78</td>
<td>0.74</td>
</tr>
<tr>
<td>Total wake time (min)</td>
<td>26.0 ± 9.0</td>
<td>27.6 ± 7.5</td>
<td>29.3 ± 12.7</td>
<td>0.66</td>
<td>0.59</td>
</tr>
</tbody>
</table>

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⁴ x ± SD (all such values).

Afaghi, O’Conner, Chow (2007)
Conclusions

Sleep in Athletes –
  - More objective studies needed on sleep need in athletes
  - More education about the relationship between sleep, nutrition, and performance / recovery needed
  - Environmental factors appear to be neglected

Timing is everything –
  - Supplementation through food for performance too close to bedtime has the potential to disrupt sleep
  - Performance supplements that increase fluid retention or dehydrate have the potential to disrupt sleep
  - The use of some sleep aids may hinder both performance and recovery
Collaborators from around the World

Dr. Michael Perlis (U Penn)
Professor Celyne Bastien (U Laval)
Dr. Wendy Troxel (RAND Corporation)
Professor Dieter Riemann (U Freiberg)
Dr. Sean Drummond (UCSD)
Professor Colin Espie (Oxford U)
Dr. Maria Gardani (U Glasgow)
Dr. Amy Thomson (U Glasgow)
Dr. Alice Gregory (U London)
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Dr. Malcolm von Schantz (U Surrey)
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Dr. Mark Wetherell
Dr. Samantha Man
Dr. Naomi Hynde
Dr. Greg Elder
Rachel Sharman
Zoe Gotts
Umair Akram
Alejandro Sanchez

And the people who fund this programme of work