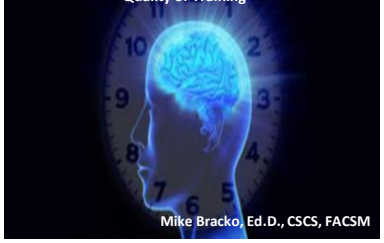
Circadian Rhythms: How Time of Day Affects Quality of Training



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Outline

1. What are Circadian Rhythms?
2. What Controls Circadian Rhythms?
3. What Disrupts Circadian Rhythms?
4. Circadian Rhythm Research
   - Aerobic Performance
   - Anaerobic/Strength/Plyometric Performance
   - Sports Performance
   - Psycho-Social
6. What Time are our Clients Training?
7. Responders and Non-Responders
8. Exercise Motivation

What are Circadian Rhythms?

Circadian rhythms are physical, mental, and behavioral changes that follow a 24-hour cycle, responding primarily to light and darkness.
(http://www.nigms.nih.gov/Education/Pages/Factsheet_CircadianRhythms.aspx)

Regulate periods of sleepiness and wakefulness through day/night.

Circadian rhythm dips and rises at different times of the day.

What are Circadian Rhythms?

- Circadian rhythms are a 24-hour internal clock running in the brain.
- The "rhythms" cycle between sleepiness and alertness.
- Also known as . . . "Sleep / Wake Cycle."
- We have dips in energy between 2:00am and 4:00am (when we're fast asleep) and in early afternoon (1:00pm to 3:00pm).
- This is when we crave a nap.
- Dips in energy can be different if you're naturally a "Lark" or "Owl."
- This is Chronotype.

Chronotype

Chronotype . . . what time of day our physical functions (hormone level, body temperature, cognitive faculties, eating and sleeping) reach a high level.

Chronotype . . . determines if we are a "morning person," "afternoon person," or a "night person."

Chronotype . . . Can also determine when is the best time to do certain kinds of work, ie: answer e-mails, talk on the phone, and exercise.

What Controls Circadian Rhythms?

- Part of the hypothalamus controls circadian rhythms.
- Circadian pacemaker is the suprachiasmatic nucleus (SCN) (Teo, Newton, and McGuigan, 2011).
- The SCN receives input from the sun through the retina (Hastings and Herzog, 2004).

The SCN coordinates daily biological rhythms (ie. hormone secretion, temperature fluctuation, neural activation) in line with the solar time and sleep-wake cycle (Teo, Newton, and McGuigan, 2011).

What Controls Circadian Rhythms?

- Light and darkness also impact the rhythms.
- At night, eyes send a signal to the SCN - time to feel tired.
- The brain sends a signal to the body to release melatonin.
- And …we get tired.
- Circadian rhythms coincide with the cycle of daytime and nighttime.
- This makes it hard for shift workers to sleep during the day and stay awake at night.

What Disrupts Circadian Rhythms?

Don't use computer, cell phone/hand held device/tablet 1.5 hours before bed.

Limit TV before bed.

LED light "tells" brain to be awake . . . prevents sleepiness.

Suppresses melatonin.

Light on computer screens designed to look like the sun.

9 – 11pm . . . we shouldn't be "looking at the sun."

Programs like f.lux adjust the screen display so it doesn't stimulate.

Use if you're reading on a device.

What Disrupts Circadian Rhythms?

Cell phone addiction . . . "Dopamine Loop."

Dopamine a neurotransmitter released in association with pleasure.

Dopamine can interfere with the natural sleepiness at night.

Risk of addiction to phones and tablets for social media and work.

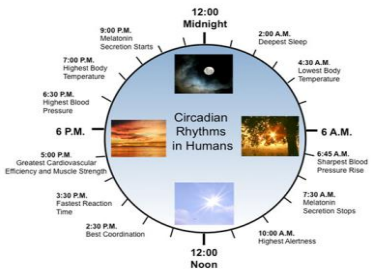
Dopamine has been linked to "seeking behavior."

What Disrupts Circadian Rhythms?

Searching for new information … each Tweet, "Like," message, or notification increases desire to keep going—creating the dopamine loop.

"We eventually associate texts, Twitter, Facebook, Instagram, etc with the promise of instant gratification,"
Kathy Gill, expert human-computer interactions, University of Washington.

Dopamine can increase desire to keep "searching" for Facebook posts, Twitter, Instagram, etc.



Naps

Small "hump" in sleepiness in mid-afternoon … normal and actually programmed into the circadian schedule.

A planned nap is a powerful alertness strategy that can significantly increase performance and alertness.

General guidance:

a. **20 - 40 minutes in length (helps to avoid deep sleep)**
c. **Avoid a long nap too close to bedtime**
c. **Sleeping too long can cause sleep inertia**
c. **Allow 10-15 minutes "wake-up" after nap … if slept too long.**
d. **Consider sleep aids: eye mask, ear plugs**

Naps

Rosekind, M, et al., 1994. Crew Factors in Flight Operations IX: Effects of Planned Cockpit rest on Crew Performance and Alertness in Long Haul Operations (NASA Technical Memorandum 108839). Moffett Field, California: NASA Ames Research Center.

Pilots flying 9 hour legs between the US and Japan.

Monitored the pilots' brainwaves and eye movements and they completed performance tests.

Pilots fell asleep in about 6 minutes and slept for about 26 minutes.

26-minute naps enhanced
- **objective performance 34%**
- **physiological alertness 54%**
- **effects lasting around 3 to 4 hrs**

A Nap Improves Sports Performance

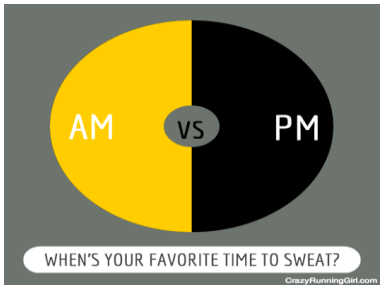
Waterhouse, et al., 2007

- A nap has been found to improve performance, alertness, and accuracy on a reaction time test.
- 10 men napped or sat quietly for 30 mins after a night of 4 hours sleep.

30 min nap:

Improved:
- Alertness
- Short-term memory
- Accuracy at 8-choice reaction time test
- Grip strength

Decreased
- Sleepiness
- Resting heart rate
- 2-m sprint decreased 0.041 seconds
- 20-m sprint decreased 0.093 seconds



Best Circadian Time for Training

Generally, peak performances occur in the late afternoon/early evening, at the peak of core body temperature.

Increase in core body temperature:
- **increases energy metabolism**
- **improve muscle compliance**
- **facilitates actin-myosin cross bridging**

Active warm-ups, in morning or cold environments to increase body temperature prior to competitions or training.

Sports performance: is there evidence that the body clock plays a role?

Reilly T., Waterhouse J. (2009) European Journal of Applied Physiology 106, 321-332

Identified three determinants in the contribution towards a circadian rhythms in sports performance.

1. **External environmental influences that are usually uncontrollable.**
   - **ambient temperature**
   - **humidity**
2. **Internal (physiological) come from within the individual.**
   - **biological rhythm**
   - **ability to adapt to changes in those rhythms**
3. **Lifestyle (psycho-biological) affecting timing preference in activities.**
   - **sleeping patterns**
   - **ability to cope with sleep inertia and sleep loss**

Circadian Rhythms in Exercise Performance: Implications for Hormonal and Muscular Adaptation

Teo, Newton, & McGuigan, 2011, *Journal of Sports Science and Medicine*, **10, 600-606,**
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3761506/

Aerobic Results

All these following studies demonstrated increased performance and higher V02max in the later part of the day.

Increase in performance also highly correlated to body temperature, which was higher later in the day.

Circadian Rhythms in Exercise Performance: Implications for Hormonal and Muscular Adaptation

Aerobic

Swimming

Arnett (2002) - 6 male, 4 female competitive swimmers (15 yrs), protocol unknown.

Arnett (2001) – same as above, 91.44-m freestyle stroke, morning and afternoon testing.

Martin & Thompson (2000) - 7 male collegiate swimmers (22 yrs), sub-max swimming w/controlled stroke rate, morning and afternoon testing.

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Aerobic

Cycling

Atkinson et al. (2005) - 8 male cyclists (24.9 yrs), 16.1-km time trial with & w/out warm-up at 07:30 and 5:30.

Edwards et al. (2005) – 8 male cyclists, 2 exercise sessions of sub-max cycle ergometry (60% VO2peak for 30 min) at 07:00 and 12:00 the day before a 16.1-km time trial at 07:00 h

Reilly and Garrett (1998) - 7 males cyclists (19-24 years), cycle ergometer test at 70% VO2max performed at 08:30 and 5:30

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Anaerobic Strength Power

Swimming

Kline et al. (2007) – 25 experienced swimmers, 6 max effort 200-m swim trials, morning, afternoon, evening.

Martin et al. (2007) - Each group 8 swimmers (15.2 & 15.4 yrs), 150-m race-pace swim & 100-m time trial, morning and afternoon.

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Anaerobic Strength Power

All the following studies found superior performances in later part of the day.

Anaerobic fitness, strength, power and performance shown to be significantly higher later in the day.

Performance was correlated to the increase in body temperature.

These studies show an increase in neural drive and better coordination between agonist-antagonist contractions.

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Anaerobic Strength Power

Cycling/Wingate

Souissi et al. (2007) - Wingate test 06:00 & 18:00.

Bessot et al. (2007) - submax exercise on cycle ergometer at power output 50% of their Wingate max at 06:00 and 18:00.

Bessot et al. (2006) - 3 tests at 06:00 and 3 at 18:00 at a free pedal rate & two imposed pedal rates.

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Anaerobic Strength Power

Cycling/Wingate

Giacomoni et al. (2006) - ten 6-s max sprints inter-spaced by 30-sec 08:00-10:00am & 5:00-7:00pm.

Moussay et al. (2003) - submax exercise cycle ergometer for 15 min at 50% of their Wingate max, 2 tests performed at 06:00am and 6:00pm.

Souissi et al. (2002) - Wingate & peak knee extension torque at six angular velocities were recorded between 7:00 & 8:00am & and between 5:00 & 6:00pm.

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Anaerobic Strength Power

Resistance/Plyometrics

Taylor et al. (2011) - 8 men, 29.8 yrs, tested 4 times: 1) control warm-up 8:00am, 2) control warm-up 4:00pm, 3) extended warm-up 8:00am, & 4) extended warm-up 4:00pm, 6 loaded counter-movement jumps.

Teo et al. (2011) – 20 men, 28.3 yrs, circadian rhythm of cortisol (C) and testosterone (T) on countermovement jumps, squat jumps, isometric midthigh pulls, & 1-rep max squat, 8:00am, 12:00, 4:00, and 8:00pm.

Pereira et al. (2011) – 30 men, 22 yrs, 2 max voluntary knee extensions to measure explosive force, 7:30-09:30am, 1:30-3:30pm & 7:30-9:30pm.

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Anaerobic Strength Power

Resistance/Plyometrics

Sedliak et al. (2008) – 32 men, measured at 7:00 - 8:00am, 12:00 - 1:00pm, 5:00 - 6:00pm & 8:30 - 9:30pm, over 2 days, power during loaded squat jumps, torque & EMG during maximal & submaximal voluntary isometric knee extension contractions.

Sedliak et al. (2008) – 27 men, max strength & EMG of knee extensors in men, randomized into 7:00-9:00am & 5:00-7:00pm groups.

Bird and Tarpenning (2004) – 13 men, 21.8 yrs, 8-station heavy-resistance exercise protocol 6:00am & 6:00pm, performance, testosterone & cortisol.

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Agility/ Coordination

Soccer

Reilly et al. (2007) - 8 men, 19 yrs, grip strength, reaction time, "game-performance" flexibility, ball juggling and dribbling tasks, and wall-volley test were compared at 8:00am, 12:00pm, 4:00pm, & 8:00pm.

Tennis

Atkinson and Speirs (1998) – 6 players, 15 "first" (emphasis-speed) serves and 15 "second" (emphasis-accuracy) serves at 9:00am, 2:00pm and 6:00pm.

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Agility/ Coordination

Soccer

Tennis

Results

Soccer skills showed increased ability to dribble and more accurate shots later in the day.

Consistent finding in tennis, increase in serve velocity and handgrip on the racquet.

Serve accuracy was not consistent with time-of-day variation.

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Psycho-social

Time of day Preference

Brown et al. (2008) - evaluated AM PM effects on rowing performance of experienced, university rowing team.

Daily 5:00-7:00am & 4:30-6:00pm training.

2000-m ergometer rowing sprint & standing broad jump measured early morning & late afternoon.

"Larks" did better in AM, "Owls" did better in PM.

Hill et al. (1998) – 32 college students, either "Larks" or "Owls," maximal cycle ergometer tests in the AM and PM, diurnal variations responses to exercise are same for "Larks" and evening "Owls."

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Psycho-social

Results

Studies are limited …

- Results demonstrate better performance during an individual's preferred chronotype

- Morning chronotypes perform better earlier and evening chronotypes perform better later.

Best Circadian Time for Performance

Smith et al., (2013) evaluating 40 years of Monday Night Football.

Hypothesized - west coast teams should have an advantage over east coast teams.

MNF games begin at 9 p.m. E.S.T.

West coast teams:

- won more often
- won by more points
- west coast teams beat the point spread twice as often.

Selecting the west coast team . . . predicted the winner against the point spread 67.9% of the time.

Greater circadian disadvantage during evening games for the NBA, NHL and NFL teams travelling westward.

J Sleep Res. 2018 Feb;27(1):86-89. doi: 10.1111/jsr.12565. Epub 2017 Jun 1.
Roy D¹, Forest G¹.

Effects of a circadian disadvantage (i.e. playing in a different time zone) on the winning percentages in 3 leagues.

Reviewed 5 years of games in NBA, NHL, NFL and noted the winning percentage of the visiting team depending on the direction of travel (west, east, and same time zone) and game time.

Clear disadvantage for the teams travelling west.

East coast team plays in west at 7:30pm Pacific or Mountain = 10:30 or 11:30pm eastern.

Significant difference in the teams' winning percentages depending on the travelling direction in the NBA and NHL, and a trend in the NFL.

These results also highlight the importance of circadian rhythms in sport performance and athletic competitions.

What Time are our Clients Training?

The HERITAGE Study
Responders and Non-Responders

- Bouchard, et al., (1999) … differences in improvement of V02max to an identical training program.
- 481 sedentary adult Caucasians from 98 two-generation families, rode bikes for 20 weeks.
- tested V02max on cycle ergometer twice before, and twice after, training program.
- training at HR of 55% of V02max for 30 minutes/day for 14 weeks.
- increased training HR to 75% of V02max for 50 minutes/day for 6 weeks.
- 3 days/week through entire study.

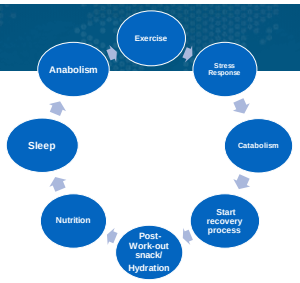
The HERITAGE Study
Responders and Non-Responders

Results

- Average change in V02max was 400 ml/min
- Some subjects increased V02max more than 1000 ml/min.
- But … many subjects did not improve V02max, or had little improvement.

- Roth (*Genetics Primer for Ex Sci & Health, 2007*) - there is no normal response to exercise.
- Expect clients who don't respond to cardio or respond very little.
- Other clients will have dramatic response.

Who has had a non-responder?



What are the variables we can control or change to enhance our clients work-out, enhance the benefit he/she gets, and make exercise enjoyable?

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