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The effects of nap duration on sleep inertia and physical performance

Angela Petretta

The Effect of Nap Duration on Sleep Inertia and Physical Performance

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For the Degree of Bachelor of Science

By Angela Rosa Petretta

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Accepted by the faculty of the Department of Kinesiology, James Madison University, in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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PUBLIC PRESENTATION

This work is accepted for presentation, in part of full, at the Kinesiology Departmental Poster Presentations on April 18, 2019.

The Effect of Nap Duration on Sleep Inertia and Physical Performance

Angela Petretta

Undergraduate Honor’s Thesis

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Acknowledgements

I would like to thank Dr. Luden for his constant help and endless support in this process. I would not have been able to complete this project if it weren't for him. Dr. Luden has been a great support system not only in this project but also in my time in undergrad at James Madison University and is a big reason behind my success. I would also like to thank my readers, Dr. Saunders and Dr. Hargens for their help. Another thank you to Dr. Hargens for all his help with the accelerometers. Thank you to everyone in the Human Performance Lab for the support. A final thank you to Luke Pickett, Nick Antonacci, and Grace Gabriele for all their help with data collection and sticking with me throughout the process.

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Abstract

PURPOSE: To assess the effects of 15 and 30-min naps on 3-km time trial performance and peak muscle strength. METHODS: Six recreationally trained college-aged participants visited the lab on 4 separate occasions. During each visit, participants completed a peak strength test, and a 3-km time trial following the nap condition. For the muscle strength test, peak isokinetic leg extension strength was assessed. The 3-km time trial was computer simulated time of completion and average power output was recorded. Nap conditions were: no-nap, 15-minute nap, and 30-minute nap. One-Way (nap condition) and Repeated Measures ANOVA's (time x nap condition) were used to statistically analyze the data, with the level of significance set at $p<0.05$. RESULTS: Neither the 15 or 30-minute nap had an impact on 3-km time trial finishing time or average power output when compared to the no nap condition. Though it did not reach statistical significance, peak strength tended to be impaired by the 30-min nap when compared to the 15-min nap ($p=.075$). CONCLUSION: A 15- or 30-minute nap has no effect on 3-km time trial finishing time, average power output, or peak strength performance, suggesting that napping prior to competition will not improve performance. Data should be gathered on a larger sample size and with naps of longer duration to definitively conclude that napping has no impact on performance.

Chapter 1

Introduction

The most recent survey of U.S. sleep habits by the National Sleep Foundation (2005) indicated that 71% of adults get less than eight hours of nightly sleep, and only 49% of adults report obtaining a “good” night of sleep. Perhaps as a consequence, 55% of adults reported taking at least one nap per week, while 35% reported taking two or more naps a week (~50 min/nap). Napping can attenuate impairments in psychomotor vigilance (i.e. the speed at which a person responds to a visual stimulus) that mount with sleep deprivation and therefore is considered to have recuperative potential (Van Dongen & Dinges, 2005). Sleep has also been identified as an important factor in optimal athletic performance, especially as a recovery modality. Many athletes report acute and chronic problems from sleep loss, therefore, athletes may benefit from sleep supplementation in the form of napping (Bird, 2013). However, little is known about how napping influences physical performance. The only research that we are aware of reported that a 30-minute nap improves reaction time and 20-meter sprint performance, but not grip strength, when compared to no nap (Waterhouse, Atkinson, Edwards, & Reilly, 2007). Importantly, nap length appears to at least partially dictate the specific influence that napping has, at least on psychomotor vigilance, alertness, and cognitive function, with longer naps actually leading to delayed benefits. This is probably related to sleep inertia, a well-documented period of disoriented or impaired behavior, cognitive and sensory-motor performance (Ferrara & Gennaro, 1999; Tassi & Muzet, 2000). Though unknown, it is logical to speculate that duration and consequential sleep inertia may also impact the benefits of a nap on physical performance.

Regarding specific durations, Tietzel and Lack (2001) compared a 10-minute and 30-minute nap to a no nap condition and found that both nap durations had comparable benefits for objective alertness. They also found that there was less sleepiness immediately following the 10-minute nap, suggesting that the 10-minute nap had more immediate benefits when compared to the 30-minute nap (Tietzel & Lack, 2001). Additionally, sleep inertia has been reported to impair self-rated alertness for at least 80 minutes (Achermann, Werth, Dijk, & Borbely, 1995) and maybe as long as two hours after arousal (Jewett, *et al*., 1999). Cognitive performance, which is often related to- and measured along with- alertness, can be defined as the mental processes that occur within our brain from which we can utilize knowledge. Along with the alertness findings detailed above, Achermann et al. (1995) also found that sleep inertia had a negative effect on cognitive performance. Further, Brooks and Lack (2006) tested different nap lengths against a cognitive test battery and found that a 10-minute nap had better cognitive performance scores than a 30-minute nap. They also found that sleep inertia was evident after a 30-minute nap but was not detected in any of the shorter nap times. Like, alertness, sleep inertia's impairments on cognitive performance are seen almost immediately after arousal, and may last for up to two hours (Wertz, Ronda, Czeisler, & Wright, 2006)

The purpose of this project is to test impact of nap duration, and subsequent sleep inertia on both aerobic- and peak muscle strength performance upon arousal from a 15-minute and 30-minute nap. These will also be compared to a no nap condition.

Chapter 2

Methods

Participants

We will be recruiting 8-15 college-aged, recreationally active, men and women for this investigation. Participants will be healthy and have no known sleep disorders. Participants that report napping at least biweekly will be included, so as to increase the likelihood that participants will be able to fall asleep during the experimental trials. Participants must cycle at least once a week for a minimum of 20 minutes, so that they can tolerate the experimental trials. Participants will complete the Pittsburgh Sleep Quality Index before participating in the study. The Pittsburgh Sleep Quality Index is a self-rating questionnaire that results in a score between 0 and 21 that is widely used and an accepted tool to measure sleep quality that has been validated in many populations (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The index will be used to exclude any participants with poor quality of sleep or sleep disorders. A score of 5 or greater is indicative of poor sleep quality and will disqualify a participant from participating.

Preliminary Testing

Participants will be provided with verbal and written information regarding the study and written informed consent will be obtained before any data collection. After height and weight is obtained, an incremental VO_{2max} test will be conducted on an electronically braked cycle ergometer (Velotron; RacerMate Inc., Seattle, Wash., USA) using an automated metabolic system (Moxus, Pittsburgh, Pa., USA) to measure gas exchange. Participants will begin the VO_{2max} test at a self-selected workload determined during a 5-minute warm up, after which power output will increase by 25 Watts every minute until fatigue. Participants will then perform familiarizations trials on the

Velotron and an isokinetic dynamometer single-leg extension (BioDex Medical Systems, Shirley, N.Y., USA). The Karolinska Sleepiness Scale, which will be used to assess perceived alertness will also be explained to the participant, as well as a familiarization trial of the cognitive test. Familiarization trials are used to minimize any error during experimental trials due to learning effects.

Experimental Design

Participants will arrive at the Human Performance Lab between 13:00 and 16:00 for each of the following three experimental conditions: 30-min nap with arousal during slow-wave sleep (SWS), 30-min nap with arousal during REM, and a no-nap condition. Participants' arousal during SWS or REM will be randomly counterbalanced, and, on those days, participants will be connected to a wearable, real-time, sleep tracker (Dreem Headband; Rythm Corp., San Francisco, CA) and a heart rate monitor (Polar, Bethpage, N.Y.) before given one hour to fall asleep. The onset of sleep will be verified with the Dreem headband. Participants will sleep for approximately 30 min. However, the participant will be allowed to sleep longer than 30 minutes, but no longer than 60 minutes, to allow for the proper sleep stage to be reached. Sleep stage will be determined with the Dreem headband. Immediately upon arousal, the participant will rate their perceived alertness using the Karolinska Sleepiness Scale (KSS), which rates "sleepiness" on a scale of 1 to 9 (Akerstedt, Anund, Axelsson, & Kecklund, 2014). The participant will then complete the Tower of London (TOL) cognitive task on a computer, which will take approximately 5 minutes to complete, so that a relative understanding of their mental state can be obtained. This cognitive task examines pre-planning and execution times and has been validated across different populations to test basic cognitive function (Unterrainer, *et al.*, 2004; Krikorian, Bartok, & Gay, 1994). At the end of the test, the participant will be given a score between 0 and 36.

Participants will then perform a 5-minute warm-up on a bicycle ergometer at a self-selected intensity before performing peak isokinetic dynamometer single-leg extensions at 30 and $120°·s^{−1}$ (BioDex Medical Systems, Shirley, N.Y., USA). The participant will then perform a 10-minute warm up on the Velotron at a self-selected intensity, during which heart rate and rating of perceived exertion (RPE) will be recorded in the final 30 seconds. Immediately following the warm up will be a computer simulated, self-paced, 3-km time trial (TT). Participants will be verbally reminded and encouraged to give maximal effort prior and during the TT. After the participant finishes the TT, they will be asked to rate their perceived alertness again using the KSS.

Dietary and physical activity standardization

Participants will be instructed to abstain from alcohol, tobacco, and caffeine for 24 hours prior to coming into the lab. Participants should report to all sessions in post-absorptive state (≥4 h). Participants should also be properly hydrated, by consuming about half of the recommended water intake based on their weight in kg prior to coming into the lab. Participants will also be instructed to avoid physical activity for 24 hours prior to each session.

Sleep standardization

Participants will need to get at least 6 hours of sleep on the night preceding the test session in the lab, regardless of experimental condition being implemented that session. This will be validated with a wearable sleep tracker (Actigraph wGT3X+; Actigraph Corp., Pensacola, FL) given to the participant the day before coming into the lab.

Statistical analysis

Magnitude-based inferences will be utilized to assess the effects of the sleep conditions on the dependent measures, using methods described by Hopkins and colleagues (Hopkins, 2004, 2007; Hopkins *et al.*, 2009). Published spreadsheets (Hopkins 2004, 2007) will be used to determine the likelihood of the true treatment effect (of the population) reaching the substantial change threshold; these percent likelihoods will be classified as follows: <1% = almost certainly no chance; 1%–5% = very unlikely; 5%–25% = unlikely; 25%–75% = possible; 75%–95% = likely; 95%–99% = very likely; and >99% = almost certain. Clinical inference criteria will be used to classify the effects of all three conditions on 3-km TT performance. Specifically, if the percent chance of the effect reaching the substantial change threshold was <25% and the effect is clear, it will be classified as 'trivial'. If the percent chance of the effect reaching the substantial change threshold for benefit exceeded 25%, but the chance for harm is >0.5%, the effect will be classified as unclear. An exception to the 0.5% chance of harm criterion will be made if the benefit/harm odds ratio is >66, in which case the effect will be interpreted as clear and an inference will be assigned. For all other comparisons, mechanistic criteria will be used such that the chance for harm will be set at >5%. Sleep condition comparisons (The difference between the no-nap, 15-min nap, and 30-min nap) will be assessed using the aforementioned published spreadsheets. To aid interpretation, p values derived from simple contrasts will be presented alongside 'clear' outcomes from the magnitude-based inferences.

Chapter 3

Manuscript

The Effects of Nap Duration on Sleep Inertia and Physical Performance

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Introduction

The most recent survey of U.S. sleep habits by the National Sleep Foundation (2005) indicated that 71% of adults get less than eight hours of nightly sleep, and only 49% of adults report obtaining a "good" night of sleep. Perhaps as a consequence, 55% of adults reported taking at least one nap per week, while 35% reported taking two or more naps a week (~50 min/nap). Napping can attenuate impairments in psychomotor vigilance (i.e. the speed at which a person responds to a visual stimulus) that mount with sleep deprivation and therefore is considered to have recuperative potential (Van Dongen & Dinges, 2005). Sleep has also been identified as an important factor in optimal athletic performance, especially as a recovery modality. Many athletes report acute and chronic problems from sleep loss, therefore, athletes may benefit from sleep supplementation in the form of napping (Bird, 2013). However, little is known about how napping influences physical performance. The only research that we are aware of reported that a 30-minute nap improves reaction time and 20-meter sprint performance, but not grip strength, when compared to no nap (Waterhouse, Atkinson, Edwards, & Reilly, 2007). Importantly, nap length appears to at least partially dictate the specific influence that napping has, at least on psychomotor vigilance, alertness, and cognitive function, with longer naps actually leading to delayed benefits. This is probably related to sleep inertia, a well-documented period of disoriented or impaired behavior, cognitive and sensory-motor performance (Ferrara & Gennaro, 1999; Tassi & Muzet, 2000). Though unknown, it is logical to speculate that duration and consequential sleep inertia may also impact the benefits of a nap on physical performance.

Regarding specific durations, Tietzel and Lack (2001) compared a 10-minute and 30-minute nap to a no nap condition and found that both nap durations had comparable benefits for objective alertness. They also found that there was less sleepiness immediately following the 10-

minute nap, suggesting that the 10-minute nap had more immediate benefits when compared to the 30-minute nap (Tietzel & Lack, 2001). Hayashi, Watanabe, and Hori (1999) compared a 20-minute nap to a no nap condition. A self-evaluation was used pre-task and post-task to measure sleepiness, or subjective alertness, mood and motivation. With these evaluations they found that sleepiness declined, or subjective alertness increased, immediately after napping and stayed this way for up to 3 hours after awakening. Overall, they concluded that the 20-minute nap enhanced the subject's self-confidence, therefore increasing their subjective alertness, and there were no negative effects of napping for 20 minutes (Hayashi, Watanabe, & Hori, 1999). Additionally, sleep inertia has been reported to impair self-rated alertness for at least 80 minutes (Achermann, Werth, Dijk, & Borbely, 1995) and maybe as long as two hours after arousal (Jewett, *et al*., 1999).

Cognitive performance, which is often related to- and measured along with- alertness, can be defined as the mental processes that occur within our brain from which we can utilize knowledge. Along with the alertness findings detailed above, Achermann et al. (1995) also found that sleep inertia had a negative effect on cognitive performance. Further, Brooks and Lack (2006) tested different nap lengths against a cognitive test battery and found that a 10-minute nap had better cognitive performance scores than a 30-minute nap. They also found that sleep inertia was evident after a 30-minute nap but was not detected in any of the shorter nap times (Brooks & Lack, 2006). Doran, Van Dongen, and Dinges (2001) looked at total sleep deprivation and how that compared to psychomotor vigilance performance in those that were given 2 hour nap opportunities every 12 hours within the sleep deprivation. They found that the group that did not have nap opportunities began to decline in testing after about 18 hours. Whereas, the group that was able to nap maintained scores near their baseline throughout the whole testing period (Doran, Van Dongen, & Dinges, 2001). Along with the alertness findings from Hayashi, Watanabe, and Hori

(1999), performance on the cognitive tasks used in their test battery improved after napping, with the exception of the visual detection task which had no statistically significant difference between the 20-minute nap and no nap conditions. They concluded that the 20-minute nap taken during the "post-lunch dip" had positive effects on the maintenance of the subsequent cognitive level (Hayashi, Watanabe, & Hori, 1999). Like, alertness, sleep inertia's impairments on cognitive performance are seen almost immediately after arousal, and may last for up to two hours (Wertz, Ronda, Czeisler, & Wright, 2006)

The purpose of this project is to test impact of nap duration, and subsequent sleep inertia on both aerobic- and peak muscle strength performance upon arousal from a 15-minute and 30-minute nap. These will also be compared to a no nap condition.

Methods

Participants

Seven recreationally trained male and female cyclists were recruited from James Madison University. One subject had to withdraw due to illness, so complete data were gathered on six subjects (3 males; 3 females). Subject demographics are displayed in Table 1.

Table 1. Participant Demographics

Age (y)	Body Mass (kg)	Height (cm)	VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	Peak Power W)
22 ± 1	74 ± 6	179.2 ± 13.3	43.4 ± 12.0	258 ± 74

Experimental Design:

This protocol was designed to examine the effects of nap duration on physical performance assessed via a 3-km time trial and peak muscle strength. Subjects completed a preliminary trial which included a familiarization trial, and three experimental trails. The familiarization and experimental trials each had a cognitive test, an alertness measure, a peak strength measure, and a 3-km time trial. These measures were performed in three different conditions: 15-minute nap (short nap; SN), 30-minute nap (long nap; LN) and no nap (NN). The three experimental trails were separated by approximately 7 days with nap condition determined using a randomly counterbalanced crossover design.

Preliminary Trial

Informed Consent – Before testing was initiated, participants were given consent forms to read and sign that provide a comprehensive description of the study, the risks and benefits associated with the study, and the ways in which confidentiality is maintained.

Body Mass and Height - Participants had their body weight measured to the nearest 0.5 kg, and height measured to the nearest 0.5 cm.

Pittsburgh Sleep Quality Index - Participants completed the Pittsburgh Sleep Quality Index before participating in the study. The Pittsburgh Sleep Quality Index is a self-rating questionnaire that results in a score between 0 and 21. A score greater than 5 is indicative of poor sleep quality and disqualified a participant from participating.

VO_{2max} - During this assessment, participants performed a graded exercise test to determine their cardiovascular fitness (VO_{2max}). Participants rode a cycle ergometer at a self-selected workload estimated as "a comfortable, but not easy pace for a 1-hour ride". Workload was increased by 25 watts every 2 minutes until subjects voluntarily requested to stop due to fatigue or were unable to continue at a cadence >50 rpm. Oxygen uptake was assessed at each stage during this test along with RER and VE. VO_{2max} was assessed directly from data obtained during the test and used as a descriptive characteristic.

Familiarization trials were used to minimize any error during experimental trials due to learning effects. Procedures were the same as the experimental trials detailed below, but with no nap.

Experimental Trials

Participants arrived at the Human Performance Lab between 1-4pm, not having consumed alcohol, tobacco or caffeine for 24 hrs prior to testing. Participants reported to the lab without eating or drinking for at least two hours before their scheduled session.

Nap – When assigned to a napping condition, participants were fitted with EMG electrodes on their forearm and given a compressible stress ball. Participants rested in a quiet, dimly luminated space in Godwin Hall and were instructed to lay down and squeeze the stress ball in time with their breathing. The onset of sleep was marked by a cessation of EMG activity (i.e when the participant stopped squeezing the stress ball). The participant was gently awoken by the researcher when they had slept for 15 minutes or 30 minutes, depending on the randomly selected trail. Participants were given an hour to fall asleep.

Karolinska Sleepiness Scale- Before napping, immediately upon arousal from a nap, and 30 minutes after arousal participants rated their subjective alertness on a scale of 1 to 9 of as described by the Karolinska Sleepiness Scale.

Tower of London Cognitive task - Following the second measure of subjective alertness, participants completed the Tower of London cognitive task on a laptop. This was used to assess the participants' relative mental state by testing pre-planning and execution times. At the end of the test, the participant was given a score between 0 and 36.

Skeletal Muscle Function - 30 minutes after arousal from the nap, or 30 minutes from the time they come into the lab for the no-nap condition, participants performed a 5-minute warm up on a bicycle ergometer at a self-selected pace. Participants then performed peak muscle function testing using a Biodex muscle function device (Biodex Medical Systems Inc., Shirley NY). Muscle function was assessed by having subjects push as hard as possible against a shin pad that is connected to an electronic device that controls speed of movement through the leg-extension. Isokinetic leg dynamometry consisted of four sets of four repetitions of peak strength at 120 deg/sec.

3-km Cycling Time Trial – Following the measure of muscle strength, participants performed a 10-min warm-up at a self-selected pace on a stationary cycle ergometer (Velotron). During the warm-up, heart rate (HR) and rate of perceived exertion (RPE) were assessed. Subjects then performed a 3-km computer-simulated time trial on the cycle ergometer. Performance was assessed via time to complete the time trial, and average power output during the trial.

Submaximal Physiological Markers:

Heart Rate & Rate of Perceived Exertion (HR & RPE)

HR and RPE were measured in the final 30 seconds of the 10-min warm-up preceding the 3-km time trial. HR and RPE was also measured during the max test during the warm-up and each subsequent stage.

Oxygen Consumption, Ventilation, & Respiratory Exchange Ratio (VO_2, VE & RER)

VO_2 and RER was assessed during the max test in the preliminary trial using a Parvo metabolic cart (Sandy, Utah, USA). Breath samples were obtained throughout the VO_{2max} test every 30 seconds.

Sleep Standardization:

Participants were limited to 6 hours of sleep, with onset of sleep between 22:00 and 02:00 on the night preceding the test session in the lab, regardless of experimental condition being implemented that session. This was verified with a wearable sleep tracker (Actigraph wGT3X+; Actigraph Corp., Pensacola, FL). The sleep characteristics are displayed in Table 2. None of the characteristics were different between the nap conditions.

Table 2. Sleep Data

	Sleep onset time	Wake-up time	Duration, hr	% Efficiency
no-nap	0055 h (2330-0115 h)	0618 h (0530-0709 h)	5.3 h (5.0-5.8)	89 (87-98)
15-min	0056 h (2350-0052 h)	0632 h (0602-0655 h)	5.1 h (4.6-5.5)	86 (81-89)
30-min	2325 h (2200-0051 h)	0617 h (0430-0653 h)	5.4 h (5.2-5.5)	86 (75-94)

Dietary and Physical Activity Standardization

Participants were instructed to abstain from alcohol, tobacco, and caffeine for 24 hours prior to coming into the lab. Participants reported to all sessions in post-absorptive state (≥4 h) . Participants were also instructed to avoid physical activity for 24 hours prior to each session.

Statistical Analysis

Average power output (watts) from each 3-km time trial was used as the primary performance measure. Peak torque (N*m) was used as a secondary performance measure. All data was log transformed to diminish the effects of non-uniformity. Data were analyzed with a One-Way ANOVA (3-km TT, peak strength, and ToL) and Repeated Measures ANOVA (time x nap condition; Karolinska sleepiness scale) using SPSS Statistics software. The p-value was set at <0.05. Data are presented as means ± standard deviation unless otherwise stated.

Results

3-km Time Trial

Nap condition had no effect on 3-km TT finishing time or average power output. Individual power output in all nap conditions is displayed in Figure 1. Finishing times (seconds) for the 3-km TT were: no-nap= 353 ± 51; 15-min nap = 362 ± 65; and 30-minute nap= 353 ± 55. Average power output (watts) for the 3km TT: no-nap= 201±87; 15-min= 191 ± 99; and 30-min= 200±101. There were no differences in finishing time between any of the nap conditions.

Skeletal Muscle Function

Nap condition, overall, had no effect on peak strength. Peak strength at $120^{\circ} \cdot s^{-1}$ in all nap conditions is displayed in Figure 2. Peak strength (N*m) by nap condition were: no-nap= 170.6 ± 12.5; 15-min nap = 175.2 ± 20.6; and 30-min nap = 159.9 ± 12.3. There were no differences in peak strength between any of the nap conditions. However, while it did not reach significance, peak strength tended to be impaired by the 30-min nap when compared to the 15-min nap (0.075).

Karolinska Sleepiness Scale

Nap condition did not impact the KSS ratings. Means and standard deviations for each nap and time condition are shown in Table 3. There were no differences in sleepiness ratings between any of the nap conditions.

Tower of London (ToL) Cognitive Test

Mean scores and standard deviations are shown in Table 4. There were no differences in ToL test scores between any of the nap conditions.

Table 3. Mean ratings and standard deviations of Karolinska Sleepiness Scale by nap condition and time. Rated on a scale of 1 to 9.

	Pre-Nap	Post-Nap	Post-30 min
No Nap	5.0 ±1.9	5.0 ± 1.5	5.0 ± 1.5
15-Min Nap	5.5 ± 1.4	6.3 ± 0.5	4.7 ± 0.8
30-Min Nap	5.4 ± 1.0	6.0 ± 1.1	4.4 ± 1.3

Table 4. Tower of London Cognitive Test scores. Scores are out of 36 points.

	No-Nap	15-Min	30-Min
Tower of London	34.8±1.6	34.0±2.8	33.8±3.3

Figure 1. Average power output during 3-km time trial

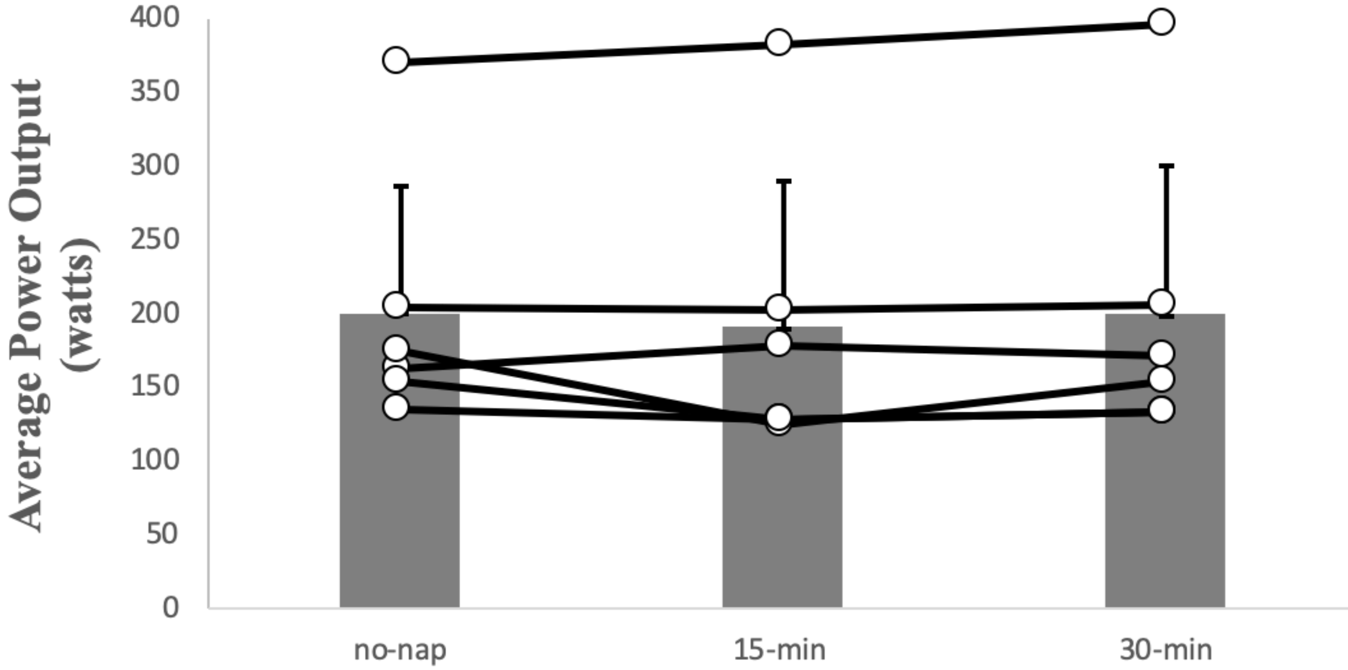
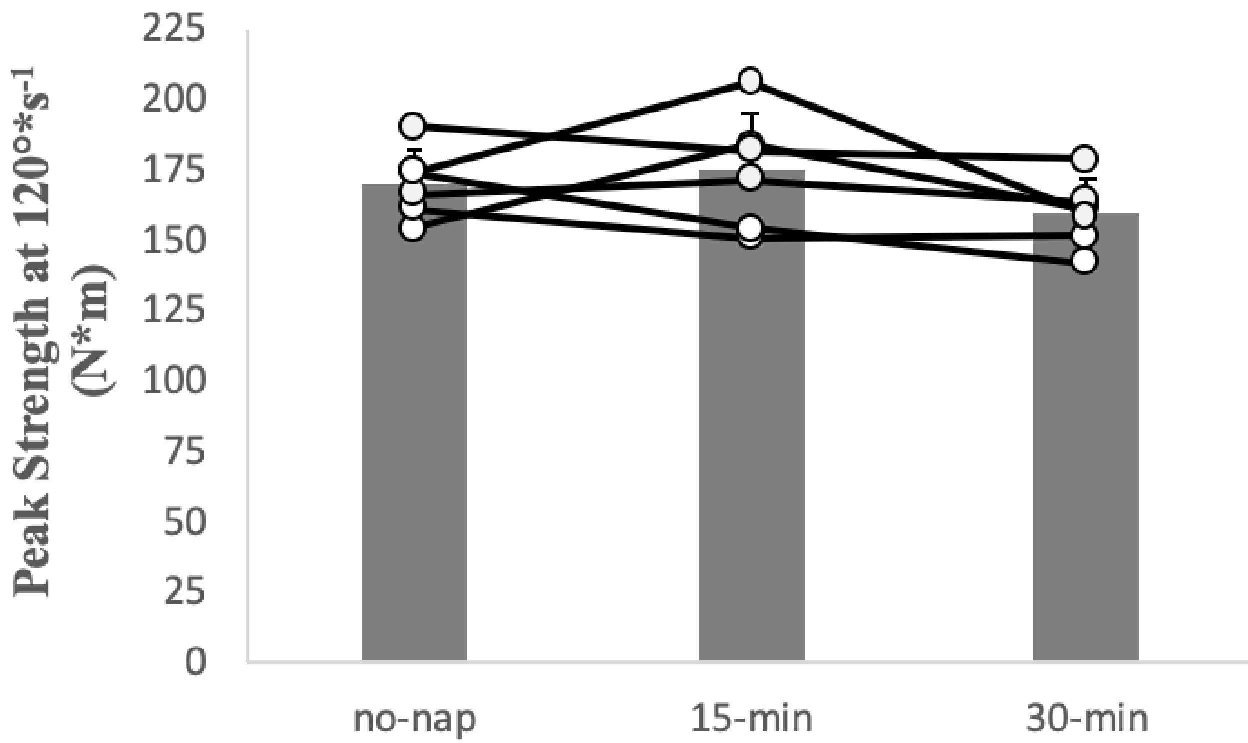


Figure 2. Peak Skeletal Muscle Strength



Discussion

The primary goal of this project was to determine the effects of nap duration on 3-km cycling time trial performance and peak strength. We predicted that the 15-min nap would benefit physical performance while the 30-min nap would be detrimental. Contrary to this hypothesis, our results indicate that there was no clear difference in 3-km time trial between the three conditions. However, although not statistically significant, peak strength tended to be higher following a 15-min nap, compared to the other two conditions. More data need to be gathered to make definitive recommendations to coaches and athletes about napping strategies to enhance performance.

It is difficult to place the current 3-km time trial results in context, as virtually no previous work has been done in the area of napping and aerobic performance. Nonetheless, Waterhouse et. al. (2007) found that 30 minutes of napping led to better 20-meter sprint performances compared to a no-nap condition. Our results contradict these, as we found no clear difference in completion time of a 3-km time trial between not napping and a 30-minute nap. The referenced study, however, did not validate nap time and instead allowed the participants to simply lay in bed for 30-minutes before awaking them for testing (Waterhouse, Atkinson, Edwards, & Reilly, 2007). They also did not verify the sleep restriction the night before, but rather simply prompted their participants to sleep 4 hours less than normal. Thus, the length of time that each participant slept the night before and during the actual nap is unknown, which makes it challenging to know whether or not the discrepant findings can be attributed to the different performance criteria or the sleep methodology.

With regards to muscle strength, the previously referenced work by Waterhouse et. al. (2007), found that grip strength was not affected by napping. Interestingly, in the current study, peak strength was ~10 percent lower following the 30-min nap, compared to the 15-min nap ($p=0.075$). While Waterhouse et. al. (2007) study compared a 30-min nap to no nap, we are not aware of any other study that has compared peak strength following different nap lengths. Somewhat related, an early investigation reported that performance was hindered immediately after sleeping when compared measures taken in the afternoon prior (Jeanneret & Webb, 1963). They also found that there was no relationship between amount of time slept and grip strength, simply that grip strength decreased after arousal from sleep. Altogether, it appears that longer bouts of sleep are more detrimental to strength than shorter sleep durations.

In addition to physical performance measures, we also assessed subjective alertness and objective cognitive performance. Two other studies investigated the relationship between nap duration and alertness. Specifically, one investigated a 10-min nap and 30-min nap, and the other examined a 20-min nap; both found that all nap conditions improved subjective alertness (Tietzel & Lack, 2001; Hayashi, Watanabe, & Hori, 1999). Tietzel & Lack (2001) extended their findings and concluded that while objective alertness increased after both a 10 and 30-min nap, sleepiness, or subjective alertness, was higher after the 10-min nap, indicating that a short nap was more beneficial. Our data indicate that there is no difference in subjective alertness between nap conditions. This contradiction could be attributed to the fact that the 30-min nap may not have been long enough to create enough sleep inertia in our population and therefore, would not influence sleepiness. Similar discrepancies were found in our data and previous data on cognitive performance; Tietzel & Lack (2001) reported that a 10-min nap had immediate benefits to cognitive performance while a 30-min nap was initially detrimental . In addition, Brooks & Lack (2006) found that a 10-min nap led to better performance on a cognitive test battery than a 30-min nap and concluded that sleep inertia was present after a 30-min nap but not after shorter naps. Indeed, sleep inertia has been shown to negatively impact cognitive performance (Achermann, Werth, Dijk, & Borbely, 1995). The current results contradict these earlier findings, as cognitive performance was not influenced by nap conditions. This discrepancy could be due to the use of a simpler cognitive test in the current results which could be less sensitive than the more complex tests used in the previous studies referenced.

One strength of our project was the ability to determine onset of sleep. Previous studies simply prompted participants to lay in bed for 30 minutes and then referenced as a 30-minute nap (Waterhouse, Atkinson, Edwards, & Reilly, 2007), while our study accounts for any sleep latency. However, we were not able to track which sleep stage the participants were in when they were awoken. There are several studies that found stage of sleep upon arousal had effects on cognitive performance (Achermann, Werth, Dijk, & Borbely 1995; Bruck & Pisani, 1999) and grip strength (Tebbs & Foulkes, 1966); all found that when awoken from SWS, performance was negatively affected compared to REM sleep. This could be a confounding variable in how participants responded to the naps.

Altogether, it appears that nap duration has little to no impact on physical performance (strength or 3-km time trial). Naps do not seem to affect short cycling bouts or peak strength. Further research could test the effects of naps of varying durations when testing begins immediately after awaking from a nap, rather than 30-minutes after awakening to prevent any dissipation of inertia. It could also look at longer nap durations, to determine if a nap longer than 30 minutes would evoke more sleep inertia and, therefore, have a greater effect on performance. Future research could also look at trained versus untrained participants to see if sleep inertia would effect neuromuscular, hormonal, and cardiovascular training adaptations compared to those with little to no adaptations.

Manuscript References

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Appendices

James Madison University
Department of Kinesiology
Consent for Investigative Procedure

I, ______________________, hereby agree on _____________ (date) to participate in the research project conducted by Nicholas D. Luden, Ph.D. and Angela Petretta from James Madison University titled: *The Effect of Nap Duration on Sleep Inertia and Physical Performance*

The purpose of this study is to determine how different duration naps (no nap vs. 15 minutes, vs. 30 minutes), impacts cycling performance and muscle strength.

Subject Responsibility

I understand that I will undergo the following testing:

This study consists of 4 separate visits, all of which will involve exercise on a resistance exercise device and exercise on a stationary bike. All testing will occur in Godwin Hall on the campus of James Madison University. You will also be asked about lifestyle behaviors such as smoking and physical activity. The total time commitment is estimated to be less than 8 hours over the course of 6 weeks.

<u>Preliminary Trial (1 trial, 120 min):</u>

Informed Consent – Before testing is initiated, you will be given consent forms to read and sign that provide a comprehensive description of the study, the risks and benefits associated with the study, and the ways in which confidentiality will be maintained (see Informed Consent).

Body Mass and Height - You will have your body weight measured to the nearest 0.5 kg, and height measured to the nearest 0.5 cm.

VO_{2max} - During this assessment, you will perform a graded exercise test to determine your maximal oxygen uptake (VO_{2max}). You will ride a cycle ergometer at a self-selected workload estimated as "a comfortable, but not easy pace for a 1-hour ride". Workload will be increased by 25 W every 2 minutes until you voluntarily request to stop due to fatigue or you are unable to continue at a cadence >50 rpm. Oxygen uptake will be assessed at each stage during this test. VO_{2max} will be assessed directly from data obtained during the test and used as a descriptive characteristic.

Experimental Familiarization - You will be asked to follow the procedures below to acquaint you with the procedures. 15 minutes after you complete the VO_{2max} test (or before if you are ready), you will be asked to complete the same procedures as detailed below.

Experimental Phase

Exercise Trial 1 (3 trials, 120 min each)

You will arrive at the human performance lab between 1-4pm, not having consumed alcohol, tobacco or caffeine in the past 24 hours

Nap- When assigned to a napping condition, you will be fitted with electrodes (forearm), and given a compressible stress ball. You will be in a quiet, lowly lit space in Godwin Hall and will be instructed to lay down and squeeze the stress ball in time with your breathing. The onset of sleep will be marked by a mismatch between EMG activity and respiration (i.e. when you stop squeezing the stress ball). You will be gently awoken by the researcher when they have slept for 15 minutes or 30 minutes, depending on the randomly selected trail. You will be given an hour to fall asleep.

Karolinska Sleepiness Scale- Before napping, immediately upon arousal from a nap, and 30 minutes after arousal you will rate your subjective alertness on a scale of 1 to 9 of as described by the Karolinska Sleepiness Scale.

Tower of London Cognitive task- Following the measure of subjective alertness, you will take approximately 5 minutes to complete the Tower of London cognitive task on a laptop. This will be used to assess your relative mental state by testing pre-planning and execution times. At the end of the test, you will be given a score between 0 and 36.

Skeletal Muscle Function – 30 minutes after arousal from the nap, or 30 minutes from the time you come into the lab for the no-nap condition, you will perform a 5-minute warm up on a bicycle ergometer at a self-selected pace. You will perform peak muscle function testing using a Biodex muscle function device (Biodex Medical Systems Inc., Shirley NY). Muscle function will be assessed by having you push as hard as possible against a shin pad that is connected to an electronic device that controls speed of movement through the leg-extension. Isokinetic leg dynamometry will consist of two warm-up repetitions followed by peak strength at 120 deg/sec.

3-km Cycling Time Trial – Following the measure of muscle strength, you will perform a 10-min warm-up at a self-selected pace on a stationary cycle ergometer (Velotron). During the warm-up, heart rate and rating of perceived exertion will be assessed (see below). You will then perform a 3-km computer-simulated time trial on the cycle ergometer. This will last approximately 4-7 minutes.

Sleep standardization:

Participants will be limited to 6 hours of sleep, with onset of sleep between 22:00 and 02:00 on the night preceding the test session in the lab, regardless of experimental condition being implemented that session. This will be validated with a wearable sleep tracker (Actigraph wGT3X+; Actigraph Corp., Pensacola, FL) given to the participant the day before coming into the lab. The Sleep Cycle smartphone application (Northcube AB, Göteborg, Sweden) and a subjective feedback from the subject will be used for "quick sleep checks".

Dietary and physical activity standardization

You will abstain from alcohol and tobacco for 24 hours prior to coming into the lab. You should also abstain from caffeine for 12 hours before coming into the lab (no caffeine the day of your scheduled session). You should report to all sessions in post-absorptive state (≥4 h) but you should also be properly hydrated. You will also be instructed to avoid exercise for 24 hours prior to each session as well as avoiding unaccustomed exercise a few days prior to your session.

Risks

Skeletal Muscle Function:

The risks of BioDex muscle function testing and resistance exercise include soreness from exertion 24-48 hours post and potential lightheadedness or loss of consciousness if correct form is not utilized. You will be instructed in correct form and breathing techniques prior to testing. Expected soreness will be comparable to that typically experienced following unaccustomed physical activity (i.e. following a pick-up basketball game, long runs, resistance training, etc.)

Cardiovascular Testing (3-km Time Trial and VO_{2max} test):

According to the American College of Sports Medicine's Guidelines for Exercise Testing and Prescription, the risk associated with heavy exercise for individuals categorized as "low risk" is very minimal, and physician supervision is not necessary. Any subjects who do not meet the ACSM criteria for "low risk" will not be allowed to participate in the study. In the unlikely event of cardiac or other complications during exercise, an emergency plan is in place. This includes immediate access to a phone to call emergency personnel. In addition, at least one of the listed investigators will be present during the exercise sessions, and all are CPR certified.

Benefits

Provided that you comply with testing protocols, you will be provided with information regarding their cardiovascular and strength fitness testing. As a whole, the present study may provide useful information for athletes who are particularly susceptible to sleep deprivation.

Confidentiality:

The results of this research will be presented at conferences and published in exercise science journals. The results of this project will be coded in such a way that your identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. However, you can ask that your data be removed from the study at any point prior to presentation and publication. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Final aggregate results will be made available to you upon request.

Participation & Withdrawal:

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind. Again, your data will not be identifiable without the coding document that will be locked away in a filing cabinet.

Questions:

You may have questions or concerns during the time of your participation in this study, or after its completion. If you have any questions about the study, contact Nicholas D. Luden, Ph.D. at ludennd@jmu.edu or by phone at 540-568-4068.

Giving of Consent:

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

______________________________	______________________________
Name of Participant (Printed)	Name of Researcher(s) (Printed)
______________________________	______________________________
Name of Participant (Signed)	Name of Researcher(s) (Signed)
______________________________	______________________________
Date	Date

For questions about your rights as a research subject, you may contact the chair of JMU's Institutional Review Board (IRB). Dr. Taimi Castle, (540) 568-5929, castletl@jmu.edu.

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire
Assess your health status by marking all *true* statements

History
You have had:
______ a heart attack
______ heart surgery
______ cardiac catheterization
______ coronary angioplasty (PTCA)
______ pacemaker/implantable cardiac
______ defibrillator/rhythm disturbance
______ heart valve disease
______ heart failure
______ heart transplantation
______ congenital heart disease

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility

Symptoms
______ You experience chest discomfort with exertion
______ You experience unreasonable breathlessness
______ You experience dizziness, fainting, or blackouts
______ You take heart medications

Other Health Issues
______ You have diabetes
______ You have asthma or other lung disease
______ You have burning or cramping sensation in your lower legs when walking short distances
______ You have musculoskeletal problems that limit your physical activity
______ You have concerns about the safety of exercise
______ You take prescription medication(s)

Cardiovascular risk factors
______ You are a man older than 45 years
______ You smoke, or quit smoking within the previous 6 months
______ Your blood pressure is > 140/90 mmHg
______ You do not know your blood pressure
______ You take blood pressure medication
______ Your blood cholesterol level is > 200 mg/dl
______ You do not know your cholesterol level
______ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)
______ You are physically inactive (i.e. you get < 30 minutes of physical activity on at least 3 days of the week)
______ You are > 20 pounds overweight

If you marked two or more of the statements in this section, you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a ***professionally qualified exercise staff*** to guide

---

______ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise

Subject Prescreening Information

Age:_____years

Height________________ Weight________________

Typical Exercise Habits over the Past 3-6 Months:

Average number of days of cycling per week_______________

Average number of hours of cycling per week______________

Briefly describe your cycling habits over the past 3-6 months:

Average number of days of non-cycling exercise per week ___________

Average number of hours of non-cycling exercise per week __________

Briefly describe your non-cycling exercise habits over the past 3-6 months:

Average number of days of resistance exercise/weight lifting per week _____________

Average number of days of resistance exercise/weight lifting per week _____________

Briefly describe your resistance training habits over the past 3-6 months:

Do you have a muscle or joint injury/condition that precludes the completion of the cycling or muscle function protocol? If yes, please explain.

Subject's Initials________________ID#__________________Date________________Time______AM/PM

PITTSBURGH SLEEP QUALITY INDEX

INSTRUCTIONS:
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

   BED TIME ___________

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

   NUMBER OF MINUTES ___________

3. During the past month, what time have you usually gotten up in the morning?

   GETTING UP TIME ___________

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

   HOURS OF SLEEP PER NIGHT ___________

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .

a) Cannot get to sleep within 30 minutes

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

b) Wake up in the middle of the night or early morning

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

c) Have to get up to use the bathroom

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

d) Cannot breathe comfortably

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

e) Cough or snore loudly

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

f) Feel too cold

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

g) Feel too hot

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

h) Had bad dreams

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

i) Have pain

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

j) Other reason(s), please describe____

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

6. During the past month, how would you rate your sleep quality overall?

Very good ____________

Fairly good ____________

Fairly bad ____________

Very bad ____________

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all	___________
Only a very slight problem	___________
Somewhat of a problem	___________
A very big problem	___________

10. Do you have a bed partner or room mate?

No bed partner or room mate	___________
Partner/room mate in other room	___________
Partner in same room, but not same bed	___________
Partner in same bed	___________

If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .

a) Loud snoring

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

b) Long pauses between breaths while asleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

c) Legs twitching or jerking while you sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

d) Episodes of disorientation or confusion during sleep

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

e) Other restlessness while you sleep; please describe____________________________________

____

Not during the past month_____	Less than once a week_____	Once or twice a week_____	Three or more times a week_____

Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ: Psychiatry Research, 28:193-213, 1989.

KAROLINSKA SLEEPINESS SCALE

Please, indicate your sleepiness during the 5 minutes before this rating through circling the appropriate description

1=extremely alert
2=very alert
3=alert
4=rather alert
5=neither alert nor sleepy
6=some signs of sleepiness
7=sleepy, but no effort to keep awake
8=sleepy, some effort to keep awake
9=very sleepy, great effort to keep awake, fighting sleep

If used electronically, please make sure that the wording of the scale is presented at each rating for easy reference

References

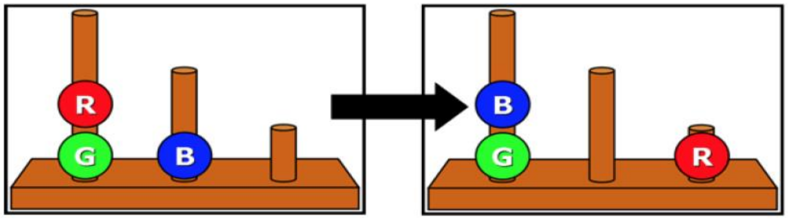
Original study: Åkerstedt, T. and Gillberg, M. Subjective and objective sleepiness in the active individual. *International Journal of Neuroscience*, 1990, 52: 29-37.

Recent review: Akerstedt, T., Anund, A., Axelsson, J. and Kecklund, G. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. *Journal of Sleep Research*, 2014, 23: 240-52.

Tower of London Cognitive Task

Welcome to the Tower of London Task!

You will see 3 posts of different lengths and 3 colored balls on the screen. The balls can be arranged to make different patterns, just like the ones you see here:



The pattern on the left is the starting pattern. The pattern on the right is the goal pattern. Your job is to change the starting pattern to the new one by shifting the balls around on the posts.

Continue

However, there are some rules you need to follow to complete the task:

- You can only move one ball at a time.
- You are not allowed to pick up more than one ball at any time.
- You cannot place balls anywhere else other than the three pegs.
- You can only place 3 balls on the left peg, 2 on the middle peg, and 1 on the right peg.
- Finally, you need to make the new pattern in a special number of moves.

The allowed number of moves for each pattern will be displayed in the upper right corner of the screen. To pick up one of the balls, click on it with your mouse. Move the ball to a peg with at least one free spot on it and release it.

If you make a mistake, you can press the 'Reset' button to put the balls back to the starting pattern and try again. You have 3 attempts to solve each problem in the number of prescribed moves.

If you feel that you cannot solve one of the problems, you can press the 'Next' button to move on to the next pattern.

Continue to a practice problem.

NapPer VO_{2max} Test

Date: Subject Code:

Age: Body Weight (kg):

Height (cm):

Seat Height: Handlebar Height:
Seat Fore/Aft: Handlebar Fore/Aft:

Heart Rate Monitor?

Nosepiece?

Subject will determine starting workload (what can they maintain for 60 minutes?);
Increase workload 25 W every 1 min

Time (min)	Watts	HR (bpm)	RPE
5-min warm-up	Self-Selected		
0-1			
1-2			
2-3			
3-4			
4-5			
5-6			
6-7			
7-8			
8-9			
9-10			
10-11			
11-12			
12-13			
13-14			
14-15			

Max Heart Rate:

VO_{2max} (mL/kg/min):

NapPer Study
Familiarization Trial

Subject Number: __________ Date: _____________

Subject has given written informed consent and completed questionnaires check: _____________
Consent form has been signed by investigator check: ____________
Subject does not have more than 1 ACSM risk factor check: ____________
Subject meets all entry criteria on questionnaires check: ____________
Subject falls within acceptable Pittsburg Sleep Index range (0-5) check: ____________

- Body weight: ________kg (nearest 0.1 kg in cycling gear)
- Height: _________ cm (nearest 0.5 cm without any footwear)

$VO_{2\,max}$ Test: see VO_{2max} data sheet for protocol and stage data

VO_{2max}: _______ml/kg/min
Power at last complete stage: _______ (watts)

Baseline Tower of London task

Time started: _______________

Time finished: ______________

Score:_____________

Prior to Exercise

Explain protocol in detail to ensure that the subject understands what is expected

- 5-minute self-selected warm-up on Velotron, 4 sets of 3 reps building up to peak, peak will be recorded

BioDex

Peak torque ___________

NapPer Study
Familiarization Trial

Subject number: __________ Date:______________

Prior to Exercise

Explain the protocol in detail to ensure that the subject understands what is expected

- 10-minute self-selected warm-up, 3 km computer-simulated time trial on Velotron

Put subjects' pedals on Velotron (provided if not already done)

Put a Polar HR monitor on subject

Velotron set-up

Seat height: __________________

Seat fore/aft: __________________

Handlebar height: ______________

Handlebar fore/aft:_______________

Time Trial

Self-Selected warm-up

Time	**HR**	**RPE**
Minute 10	__________	___________

Time Trial

Time _________________

Average Power Output _______________

NapPer Study
Exercise Trial

Subject number: __________ Date:______________

Trial 1 2 3

Prior to Nap

Subject's body weight: ____________________

Collect Actigraph (check): ______________________

Check Sleep app; hours slept: ___________________

Put a Polar HR monitor on subject

Get first KSS rating:

Time: ______________ Rating: _______________

Nap

Condition (circle): no-nap 15-minutes 30-minutes

Connect EMG

Time participant got in bed: _________________

Time fell asleep: _________________

Time awaken: ________________

Second KSS rating

Time: ______________ Rating: _______________

Disconnect EMG and return to lab

Tower of London Cognitive Task

Time started: ______________

Time finished: ____________

Score: ___________

NapPer Study
Exercise Trial

Subject number: __________ Date:______________

30 minutes after arising

Third KSS rating

Time: _______________ Rating: _______________

Prior to BioDex test

5- minute warm-up on Monarch, explain protocol
- 4 sets of 4 reps with reps building up to peak force

BioDex

Peak torque ___________

Prior to Time Trial

Check placement of HR monitor

Explain the protocol in detail to ensure that the subject understands what is expected

- 10-minute self-selected warm-up, 3 km computer-simulated time trial on Velotron

Connect watch

Time Trial

Warm-up consistent across trials (mark down resistance), resistance can only be changed on the minutes, and last 3 need to be fixed to get steady state HR and RPE.

Self-Selected warm-up

Time	**HR**	**RPE**
Minute 10	__________	___________

Blind time on the computer screen!

Remind participants that this is to be treated as a championship race! It should be finished as fast as possible, this is the most important data of the study!!

Time Trial

Time ________________

Average Power Output ______________

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