The Effects of Exercise on Emotional Regulation after a Period of Partial Sleep Deprivation: A Pilot Study

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Abstract

Partial sleep deprivation (PSD) is a prevailing issue and has been shown to lead to increased emotional reactivity (ER). Exercise has been found to be beneficial for regulation of ER, however there is minimal research on how it can be used to mitigate the negative effects of PSD. This repeated measures laboratory-based study recruited a sample of 10 runners to investigate whether a session of moderate intensity aerobic exercise after three nights of PSD could regulate ER, measured using heart rate variability (HRV), when compared to a non-exercise control condition. Participants completed a one-week lead-in, the exercise or control condition, a washout-week and the alternate condition. During each condition, they completed four sessions of cognitive and mood tests (baseline, post-PSD, immediate post-exercise/control, 5-hours post-exercise/control). Outcome measures included in this study were performance on the emotional attention interference task and HRV as a measure of ER. Repeated measures Analysis of Variance was used to test our hypotheses. We found statistically significant effects of exercise on HRV, yet exercise did not have a significant effect on performance on the EAIT as a measure of ER. This means that we could not conclusively conclude that exercise mitigated the negative effects of partial sleep deprivation on emotional regulation. Future research should implement a more strenuous PSD protocol, include a larger sample composed of individuals with varying activity levels and be conducted over a longer time period.

Keywords: partial sleep deprivation, emotional regulation, aerobic exercise, heart rate variability

The Effects of Exercise on Emotional Regulation after a Period of Partial Sleep Deprivation: A Pilot Study

Sleep is essential for physical health, cognitive performance and emotional functioning (Almondes et al., 2021; Chattu et al., 2019). Sleep plays a pivotal role in processes such as the consolidation of memory and emotional regulation (ER; Pilcher & Huffcutt, 1996; Tomaso et al., 2021). Despite the knowledge of how important sleep is, sleep deprivation (SD) is a prevailing problem globally (Chattu et al., 2019). Previous literature shows that there are many negative effects of SD such as decreased cognitive performance and increased emotional reactivity (Pilcher & Huffcutt, 1996; Tomaso et al., 2021). Research suggests that exercise is beneficial for ER which could mean that exercise can be used to mitigate the negative effects of SD on ER, and heart rate variability (HRV) could be a useful tool to evaluate these changes in ER (Choi et al., 2017; Goit et al., 2018).

Sleep Deprivation

SD refers to a lack of sleep (Saksvik-Lehouillier et al., 2020; Tomaso et al., 2021). Partial sleep deprivation (PSD) is when an individual sleeps less than their required hours of sleep which is usually 7-9 hours, for a young to middle-aged adult (18-64 years), within a 24 hour period, and total sleep deprivation (TSD) is no sleep for 24 hours (Lo et al., 2012). In a 2020 study, Saksvik-Lehouillier et al. found that PSD experienced by adults throughout a normal week, approximately 1-2 hours per night, increased the risk of day-to-day accidents and significantly impacted emotional functioning. Previous studies show that SD negatively affects motor performance, cognitive functioning and mood, with cognition and mood being the most sensitive to the effects of SD (Guadagni et al., 2014; Pilcher & Huffcutt, 1996). PSD due to work schedules and stress is more common than TSD and multiple nights of PSD have been shown to have stronger negative effects on mood than one night of TSD as multiple

nights of PSD are associated with prolonged impaired ER. (Hairston & Cohen-Zion, 2020; Pilcher & Huffcutt, 1996).

Effects of SD on ER

Although SD affects motor performance, cognition and mood, previous literature shows that mood, specifically ER, is most notably impacted by SD, especially PSD (Saksvik-Lehouillier et al., 2020; Tomaso et al., 2021). ER encompasses actions which moderate our emotional reactions (Palmer & Alfano, 2017; Zhang et al., 2019). SD increases negative emotional reactivity, decreases positive affect and influences individuals' ability to experience and modify emotions (Palmer & Alfano, 2017; Tomaso et al., 202). Many researchers found that SD excites the limbic structures in the brain, increasing emotional arousal, and sensitises the amygdala to negative emotional stimuli and stressful events (Almondes et al., 2021; Gujar et al., 2011). The inability to regulate emotions efficiently can lead to increased feelings of anxiety which further leads to decreased sleep quality (Almondes et al., 2021; Palmer & Alfano, 2017). Thus, it is imperative to investigate interventions which could alleviate the negative effects of PSD on ER.

In order to do this, ER needs to be measured somehow. There are various ways in which ER can be measured such as the use of psychological assessments in the form of questionnaires such as the Positive and Negative Affect Schedule (PANAS), The International Affective Picture System (IAPS) and the Emotional Regulation Questionnaire (ERQ) (Chuah, et al., 2010; Pilcher et al., 2015; Zhang et al., 2019). These tests provide indirect measures of ER by measuring cognitive performance in emotionally stressful settings (Zhang et al., 2022). However, these assessments can produce highly subjective results; to combat this, HRV has become popular as an objective measure of ER (Choi et al., 2017; Quintana et al., 2012).

HRV and ER

HRV refers to fluctuations of time between heart beats (Kemp & Quintana, 2013; Shaffer & Ginsberg, 2017). HRV is regulated by the two branches of the autonomic nervous system (ANS): the parasympathetic (PNS) and sympathetic nervous systems (SNS), which innervate the heart at the sinoatrial node (Ernst, 2017). As PNS drive increases, HRV increases, whereas greater SNS activity decreases HRV (Kemp et al., 2010; Thayer et al., 2012). Thus, HRV can be used to evaluate ANS functioning (McCraty & Shaffer, 2015). The ANS also plays a key role in regulating emotions to meet certain demands and greater ANS flexibility allows for a greater ability to shift emotions (Appelhans & Luecken, 2006). HRV can be used to evaluate changes in ER (Appelhans & Luecken, 2006). In a 2012 study, Quintana et al. used HRV to assess emotion recognition on the 'Reading the Mind in the Eyes Test' and found that HRV and emotion recognition are positively associated with each other. This evidence indicates that ER can affect HRV, however the inverse is also true. A meta-analysis found that 'resonance breathing' (taking a breath every 10 seconds) resulted in high heart rate (HR) oscillations, increasing HRV and enhancing ER (Mather & Thayer, 2018).

It is well established that increased HRV is associated with improved ER (Appelhans & Luecken, 2006; Mather & Thayer, 2018). As mentioned earlier, it is also evident that SD decreases ER. It can therefore be presumed that sleep duration should also lead to a decreased HRV, and various studies support this (Arslan et al., 2019; Dettoni et al., 2012; Haiblum-Itskovitch et al., 2018).

Effects of PSD on HRV and ER

There is evidence that PSD causes changes in autonomic cardiovascular functioning, with a shift towards SNS activity and thus decreased HRV (Arslan et al., 2019). Dettoni et al. (2012) showed that five nights of PSD caused a significant increase in SNS activity. Hairston and Cohen-Zion (2020) replicated this finding with a sample of 31 young adults when sleep

was restricted to 5 hours for three consecutive nights. Conversely, Bourdillon et al. (2021) found that PSD caused a marked decrease in PNS activity but no significant increase in SNS activity. These findings show that changes in HRV caused by SD may be associated with decreased ER. Scholars have begun to identify exercise as a potential solution for the negative effects of PSD.

Beneficial Effects of Exercise

HRV is a suitable way to assess ANS activity during and after exercise (Goldberger et al., 2006; Stanley et al., 2013). During exercise, SNS drive is dominant, increasing HR (Imai et al., 1994). Following exercise, the PNS drive increases, recovering the ANS and HR (Imai et al., 1994; Michael et al., 2017). The time taken for PNS reactivation varies and various factors should be considered. For instance, Michael et al. (2017) found that workouts with greater intensity lead to slower HRV recovery and no effect was found with regard to duration or modality. Additionally, exercise improves HRV in both healthy and pathological individuals (Goit et al., 2018; Murad et al., 2012; Stein et al., 1999). Overall, current literature suggests that exercise improves HRV.

The association between HRV and ER is well established and suggests that enhancing HRV, through exercise, enhances ER. Thus, exercise could potentially be used to mitigate the effects of PSD on ER. Other methods of SD symptom alleviation have been established such as caffeine, however such stimulants have disadvantages, including dependence and withdrawal effects (Behling & Winters, 2021; Cook et al., 2011). Scholars have begun investigating whether exercise is able to alleviate the effects of PSD. Cincin et al. (2015) investigated autonomic regulatory function in relation to acute SD. After PSD due to shift work, participants performed a treadmill exercise test after which they recovered for 5-minutes (Cincin et al., 2015). It was found that parasympathetic activation (measured by heart rate recovery) was blunted with the SD group (Cincin et al., 2015). Similarly, a randomised

cross-over study by Rae et al. (2017) investigated whether sleep affected recovery from high-intensity interval training (HIIT) in a group of cyclists, using a blood pressure proxy to assess ANS functioning. The SD group, sleeping half of their usual sleep duration, experienced greater SNS activation in recovery (Rae et al., 2017). Neither study found PNS reactivation following exercise, which allows insight into the role exercise plays in alleviating symptoms of SD. Additionally, this delayed increase in PNS drive can be hypothesised as a dysfunction of the ANS, therefore leading to reduced ER. A limitation of both studies is that neither used HRV as a measure to study the relationship between the ANS activity and exercise.

Although findings show that the effects of PSD on ER are more severe than that of TSD, most research investigates the effects of TSD on ER rather than PSD on ER. Current literature on the specific consequences of PSD on HRV and ER is very limited. No study has, to our knowledge, investigated whether the ER impairments (through HRV or self-reported measures) as a result of SD can be ameliorated through exercise.

Rationale, Aims and Hypotheses

Sleep deprivation (SD) is an eminent problem in today's society (Chattu et al., 2019; Tomaso et al., 2021). PSD is more likely to occur than TSD as TSD is primarily seen in shift workers, yet PSD is commonly caused by factors which affect all individuals such as stress and academic demands (Hairston & Cohen-Zion, 2020; Pilcher & Huffcutt, 1996). It is well-known that SD significantly increases emotional reactivity and decreases cognitive performance which is likely to have a negative impact on overall health, productivity and general well-being (Schwarz et al., 2018; Tomaso et al., 2021). Thus, it is imperative to explore strategies which may help individuals to reduce the negative effects associated with SD. According to previous literature, one such strategy may be exercise (Goit et al., 2018; Michael et al., 2017; Shi et al., 2018).

Previous literature shows that HRV is strongly associated with ER (Appelhans & Luecken, 2006; Mather & Thayer, 2018; Quintana et al., 2012). Studies also show that exercise improves HRV, which could in turn improve ER (Goit et al., 2018; Murad et al., 2012). However, no study has investigated whether the ER impairments as a result of SD can be ameliorated through exercise. Although findings show that the effects of PSD on ER are more severe than that of TSD, most research investigates the effects of TSD on ER. Due to this lack of research, there is a need to investigate how exercise affects deficiencies in ER after PSD.

This study aimed to determine whether a session of moderate intensity aerobic exercise ameliorates the negative effects of PSD on ER among healthy adults.

Manipulation check

Manipulation checks were conducted to establish whether the PSD protocol is successful. Our hypothesis was as follows:

After three nights of PSD, participants will show decreased HRV and performance on the Emotion-Attentional Interference Task (EAIT) as measures of ER in comparison to baseline.

Main hypothesis

Following a session of moderate intensity aerobic exercise after a period of PSD, participants will show increased HRV and performance on the EAIT as measures of ER in comparison to their control condition (i.e. when they did not perform a session of moderate intensity aerobic exercise after a night of PSD).

Methods

Research design

This study was a part of a larger study examining the effects of exercise on decreased cognitive performance and mood deficits after three nights of PSD. This study investigated the effects of exercise on ER deficits resulting from three nights of PSD.

This study was laboratory-based and followed a repeated measures design aimed at examining whether a session of moderate intensity aerobic exercise reduced the effects of PSD on ER. Following three nights of PSD the participants were exposed to an *Exercise* intervention and a *Control* condition with intermittent cognitive, mood and ER testing.

The independent variable is moderate intensity aerobic exercise and the dependent variable is ER.

Participants

Non-probability convenience sampling was used to recruit participants. Announcements were sent out for this study on various platforms, including: the Department of Psychology's Student Research Participation Programme (SRPP) at the University of Cape Town (UCT; see Appendix A); the Department of Student Affairs (DSA); running clubs; social media platforms (see Appendix B); and word of mouth.

The proposed sample size was computed by G*Power (v3.1) to be N=12 (f =0.38, power = 0.80, $\alpha = 0.05$). This effect size was averaged based on the effect sizes found by Tomaso et al. (2021) (f =0.16) and Wehrens et al. (2012) (f =0.59). This study aimed to recruit N=17 participants to account for attrition and/or missing data.

A screening questionnaire was used to identify potential participants who met the criteria for participation in the study (see Appendix D). Of the 31 people who filled out the questionnaire, 23 (74%) were eligible to participate. Our final sample consisted of 10 participants. All participants were between the ages of 18-45 years old as sleep patterns of

this age group differ from that of older adults and adolescents. Participants habitually slept between 7-9 hours nightly as this is the recommended hours of sleep for this age range. They were regular runners or took part in sports that required running, for a minimum of 60-minutes, twice a week, for 6-months prior to screening to ensure that they could comfortably complete the aerobic exercise protocol. Participants had not been injured or ill in the two weeks prior to screening as this may have affected their ability to complete the exercise protocol. Participants were not definitely morning or evening types as this would have influenced their performance on cognitive tasks at baseline and after PSD. None of the participants presented with a sleeping disorder. No participants had been diagnosed with PTSD, nor experienced moderate-to-severe symptoms of depression and/or anxiety as these are associated with sleep disturbances. Participants did not consume excessive amounts of alcohol or drugs as this is associated with abnormal circadian patterns. Participants did not have any neurological conditions which may have affected cognitive performance and were not on any medication that interferes with sleep. No participants had taken any psychoactive medications in the past month as they interfere with natural sleep cycles. Eligible participants did not consume more than 4 units of caffeine daily as they may have experienced caffeine withdrawal on PSD days. All participants were proficient in English as some of the tests for the larger study are only available in English. No participants were colour-blind as they would have been unable to complete a cognitive task which forms part of the larger study.

Materials and apparatus

Psychometric Properties and Additional Information of Measures and Apparatus can be found in Appendix C.

Diagnostic and Screening Instruments

See Appendix D for the full online screening questionnaire.

To determine participants' eligibility to participate in the study, their socio-demographic information, medical history and exercise history was collected using a *socio-demographic, medical history and training history questionnaire*.

The *Horne-Ostberg morning-evening personality questionnaire* (MEQ-HO) was used to evaluate whether participants fell within extreme chronotypes (Horne & Östberg, 1976). Total scores were interpreted as follows 16-30: definitely evening type, 31-41: moderately evening type, 42-58: neither type, 59-69: moderately morning type, 70-86: definitely morning type (Horne & Östberg, 1976).

The *Insomnia Severity Index* (ISI) is a 7-item self-report instrument used to evaluate various dimensions of insomnia to determine the severity, nature and impact of insomnia (Morin et al., 2011). Scores were interpreted as follows; 0-7=absence of insomnia, 8-14 = subthreshold insomnia, 15-21 = moderate insomnia and 22-28 = severe insomnia (Morin et al., 2011).

The *Patient Health Questionnaire-8* (PHQ-8) is an 8-item questionnaire used to evaluate the presence of major depressive disorder or associated symptoms (Peters, et al., 2021). Scores indicate severity of depressive symptoms as follows; absence (0-4); mild (5-9); moderate (10-14); moderately severe (15-19); and severe (20-24) (Kroenke, et al., 2009).

The *Generalized Anxiety Disorder scale-7* (GAD-7) is a self-report scale of seven items used to evaluate symptoms of generalised anxiety disorder (Peters, et al., 2021). Tallied scores can be interpreted as follows; 0–4=minimal anxiety; 5–9= mild anxiety; 10–14=moderate anxiety; and 15–21= severe anxiety (Spitzer et al., 2006).

The *Primary Care Post Traumatic Stress Disorder Screen for DSM5* (PC-PTSD-5) is a 4-item measure consisting of binary choice items and is used to screen for PTSD (Bovin, et al., 2021). Scores ≥3 indicate possible PTSD (Bovin, et al., 2021).

The *Alcohol Use Disorders Identification Test-Consumption* (AUDIT-C) is a 3-item scale which utilises a 5-point Likert scale and is used to assess alcohol misuse (Bovin, et al., 2021). The cut-off for this sample was ≥7 for men and ≥5 for women (Eyawo, et al., 2018).

The *Drug Abuse Screening Test* (DAST-10) is a 10-item self-report questionnaire used to assess the misuse of drugs. Scores >3 indicate drug misuse (Evren, et al., 2013).

Experimental Measures

Physiological measures. To confirm participants met physical activity and habitual sleep eligibility criteria, *wrist-worn accelerometers* (Actiwatch Spectrum Pro, Philips Respironics, Koninklijke Philips N.V, Amsterdam, Netherlands) were used during the lead-in week. These devices were also used to ensure that each participant was prescribed a personalised timing and duration of sleep which could be verified on PSD and control nights. Lastly, the devices were used to prescribe the exercise intervention. Philips Actiware software was used to process the data (Philips Actiware, Philips Respironics, Koninklijke Philips N.V, Amsterdam, Netherlands).

HR and HRV were recorded. To minimise circadian variation in HR, baseline measurements were collected 15 minutes after habitual waking time. During 10 minutes of rested seating, HR and HRV readings were taken with a wearable electrocardiograph (ECG) recorder (Polar H10 heart rate sensor with HRV Elite, Finland). Participants' HR was also recorded for a 10 minute period while they completed the EAIT. HR recorded during this task was used to assess HRV of participants. HRV comprises two major interacting components, the low-frequency (LF) and the high-frequency (HF) components (Appelhans & Luecken, 2006; Cygankiewicz & Zareba, 2013). The LF component primarily reflects SNS activity, however it is affected by PNS activity as well, and the HF component mainly reflects PNS activity (Appelhans & Luecken, 2006; Forte et al., 2019). Since both SNS and PNS activity affect HRV antagonistically, the LF/HF ratio was used to assess changes in HRV as it

represents the shifts towards either SNS or PNS dominance over cardiac functioning (Appelhans & Luecken, 2006).

A ramp incremental running protocol on the treadmill was utilised to determine participants' maximum HR (HR_{max}). This test was used to determine the intensity of the running protocol that was used after the period of PSD. The purpose of this test was to ensure that the protocol made participants workout at an intensity that was suitable for them. A Polar H10 heart rate sensor and Elite HRV were used to record HR at 5 second intervals during the test to collect HR_{max} , and Borg's 20-point scale was used to collect a rating of perceived exertion (RPE) every 60 seconds (see Appendix E) (Borg, 1998).

Self-report Diary. In order to collect information about the participant's subjective daily habitual sleep, dietary and exercise procedures an adjusted version of the *Consensus Sleep Diary* (M-CSD) was used (see Appendix F) (Maich et al., 2018).

Emotional Regulation Measure. The *Emotional-Attention Interference task* (EAIT) (adapted from the work of Erthal et al. (2005) and Luo et al. (2010)) was used to measure emotional regulation. Accuracy and reaction time was used to assess performance on this task as an indirect measure of emotional regulation (Zhang, et al., 2022).

Procedure

A screening phase, lead-in and washout week, PSD phase 1, and PSD phase 2 were included in the procedure. The full procedure took place over 21 days at the participant's home and at the Sports Science Institute of South Africa (SSISA).

Screening Phase

Interested participants gave informed consent (see Appendix G) and completed an online screening questionnaire on Google Forms (see Appendix C). An email was sent to eligible participants to see if they were still interested in participating while ineligible participants were sent an email thanking them for their interest and appropriate referrals were

provided if they were identified as having PTSD, or moderate-to-severe symptoms of anxiety or depression.(see Appendix H).

Consent and Familiarisation

Selected participants were invited to the SSISA sleep lab where the study took place. At this session participants received a booklet with a full overview of the study (see Appendix I). Researchers went through this booklet with them to ensure that they understood the procedure and reiterated that their participation was voluntary. Participants then signed informed consent forms (see Appendix J). Some of the computer-based measures were completed by the participants for familiarisation (only the tests with no practice effects). Next, their weight and height was measured. The ramp incremental running protocol was then performed (to measure HR_{max}) and they also received their actiwatch and self-report diary.

Lead-in and Washout Week

Before PSD phase 1, participants underwent a lead-in week in which they tracked their usual sleeping, dietary, and exercise habits to ensure that they did not violate inclusion criteria. Participants were asked to try their best not to alter their usual routines. They were informed that their wrist accelerometer will be used to track these activities.

The washout week followed the same protocol as the lead-in week and was used to ensure consistency in the participant's routine.

PSD Phase 1 and 2

Session 2 took place at the participant's house. 15 minutes after their habitual wake-up time, participants were fitted with HR equipment. Participants then completed a sleepiness and mood questionnaire, thereafter they remained seated for 10 minutes while their HR was recorded. Thereafter, a cognitive test battery was completed which took approximately 90 minutes to complete. HR was recorded while they completed the EAIT.

After session 2, the PSD protocol took place over three days. Participants were given sleep- and wake-up times which were calculated based on lead-in week data. Night 1 and 2 took place at the participant's home and they slept 70% and 60% of their usual sleep duration, respectively. Night 3 was 50% of their usual sleep duration and took place at SSISA where they arrived 2 hours before their scheduled bedtime. During this period, participants were allowed to consume caffeine, until 15:00, and were allowed to exercise, except for the 24 hours before session 3.

Session 3 took place in the sleep lab, 15 minutes after wake-up, and was a repeat of session 2. Participants would either perform a 40 minute treadmill run (exercise condition) or go on with their day as usual (control condition). Sessions 5 and 6 took place 5 hours and 10 hours after session 3, respectively. These follow the same procedure as session 3. After session 6, participants completed a washout week.

Following the washout week, PSD phase 2 began (sessions 7-11). This phase followed the same protocol as phase 1, except participants received the alternate condition in session 9. Participants were then thanked, debriefed (see Appendix K) and compensated for their participation (R1500; R750 for each phase; see Appendix L).

The larger study, which includes these procedures, was approved by the Human Research Ethic Committee (HREC) of UCT's Department of Psychology and Faculty of Health Sciences (Appendix M).

Data Analysis

R Studios was used to clean, describe, and analyse the data. Descriptive statistics were produced with appropriate figures to describe the sample, then data analysis was conducted. Paired samples Wilcoxon tests and repeated measures Analysis of variance tests (RM-ANOVAs) were used to test the various hypotheses (statistical significance set at $\alpha = .05$).

Fast Fourier Kubios HRV Premium software (v3.5.0, Kubios Oy) was used to analyse the HRV data. This software transforms R-R intervals to calculate power spectral densities within the VLF (0-0.04Hz), LF (0.04-0.15Hz), and HF (0.15-0.4Hz) bands of the cardiac spectrogram, which are estimates of ANS functioning, were used for HRV analysis along with the LF/HF ratio and the time domain measure SDNN. The LF Band has been associated with greater sympathetic activation, while the HF Band has been associated with vagal dominance (Shaffer & Ginsberg, 2017).

Manipulation check

A series paired sample Wilcoxon tests were conducted to determine whether HRV and performance on EAIT decreased as measures of ER. This nonparametric hypothesis test was used due to small sample size (Cleophas & Zwinderman, 2016).

HRV. We hypothesised that PSD would result in decreased HRV, based on the very low frequency (VLF; ms^2), low frequency (LF; ms^2), high frequency (HF, ms^2), LF/HF ratio, PNS Index, SNS Index, and standard deviation of normal-to-normal beats (SDNN; ms) metrics. Extreme outliers for each HRV metric and missing values in the dataset were removed. Table 1 shows the expected direction of change for each metric from baseline to after three nights of PSD across conditions.

EAIT. The expected direction for reaction time and accuracy at each testing session, across both conditions, is presented in Table 2. One participants' results were removed from the dataset as they did not complete the EAIT for both conditions. It was hypothesised that accuracy would decrease after three nights of PSD when compared to baseline.

Testing Hypotheses

HRV. We expected HRV to increase after exercise, at follow-up session 1 (FU-1) and remain stable at follow-up session 2 (FU-2). Repeated measures ANOVAs (RM-ANOVAs; 2x3) were performed to analyse the effects of condition and time of testing session on HRV.

Table 1

The Expected Deviations of HRV Metrics at Different Timepoints and Conditions

Metric	Exercise				Control			
	BL	PSD	FU-1	FU-2	BL	PSD	FU-1	FU-2
VLF	0	0 - n	PSD + n	PSD + n	0	0 - n	PSD - n	PSD - n
LF	0	0 + n	PSD - n	PSD - n	0	0 + n	PSD + n	PSD + n
HF	0	0 - n	PSD + n	PSD + n	0	0 - n	PSD - n	PSD - n
LF/HF	0	0 + n	PSD - n	PSD - n	0	0 + n	PSD + n	PSD + n
PNS Index	0	0 - n	PSD + n	PSD + n	0	0 - n	PSD - n	PSD - n
SNS Index	0	0 + n	PSD - n	PSD - n	0	0 + n	PSD + n	PSD + n
SDNN	0	0 - n	PSD + n	PSD + n	0	0 - n	PSD - n	PSD - n

Note. BL = Baseline, FU-1 = Follow-up testing session 1, FU-2 = follow-up testing session 2, PSD = Partial Sleep Deprivation

Table 2

Expected Deviations of EAIT Metrics at Different Timepoints and Conditions

Metric	Exercise				Condition			
	BL	PSD	FU-1	FU-2	BL	PSD	FU-1	FU-2
Accuracy (%)	0	0-n	PSD+n	PSD+n	0	0-n	PSD-n	PSD-n
Reaction Time (ms)	0	0+n	PSD-n	PSD-n	0	0+n	PSD+n	PSD+n

Note. BL = Baseline, FU-1 = Follow-up testing session 1, FU-2 = follow-up testing session 2, PSD = Partial Sleep Deprivation

EAIT. After exercise we expected accuracy to increase and reaction time to decrease from after PSD to FU and remain stable from FU-1 to follow-up session 2 FU-2. In the control condition, we expected accuracy to decrease and reaction time to increase throughout the day. A 2x3 RM-ANOVA was performed to analyse whether the effects of condition (exercise vs control) and the timing of the testing session (PSD vs FU-1 vs FU-2) on accuracy of the EAIT as a measure of ER were significant.

Results

A sample of ten participants completed the study (age 23.40 ± 5.85 years, bedtime 22:05:54, wake-up time 06:38:53, See Table 3). *Microsoft Excel* was used to prepare the data for exploration, description, and analysis which was done in *R Studios*.

2.1 Manipulation Checks

2.1.1 HRV

VLF (ms2). The VLF band, which is the slow recovery component of HRV, was expected to decrease during resting state after PSD. However, an increase in VLF, during resting state and during the EAIT, was found in both the exercise and control conditions. These increases were significant for resting state, $r = 0.40$, $p = .96$, and during the EAIT, $r = 0.23$, $p = .84$ (Table 4 & Table 5).

LF (ms^2). The median of the LF component of HRV increased as expected after PSD, while participants were performing the EAIT and while at rest. This increase was significant at resting state, $r = 0.57$, $p = .01$, indicating greater sympathetic activation while at rest following PSD, but not significant during the EAIT, , $r = 0.04$, $p = .45$ (Table 4 & Table 5).

HF *(ms^2)*. The difference in medians of the HF component of HRV in the control and exercise conditions significantly changed in the opposite direction of what was expected

during the EAIT, $r = 0.51$, $p = .01$, and while at rest, $r = 0.63$, $p < .001$. This suggests that the participants' HRV increased following PSD (Table 4 & Table 5).

Table 3

Sociodemographic Characteristics of Participants

Sample Characteristic	*n*	*%*	*M*	*SD*
Age			23.4	5.85
Gender				
Female	2	20%		
Male	8	80%		
Type of exercise				
Running	7	70%		
Other	3	30%		
Bedtime			10:06 p.m.	0.04
Wake-up time			6:39 a.m.	0.05
Sleep Duration			8h	0.65
Language				
Afrikaans	2	20%		
English	8	80%		
Education				
Matric	2	20%		
Tertiary	8	80%		

Table 4

Median and Interquartile Range of HRV metrics at resting state for each condition between baseline and PSD

Metric	BL		PSD		*p*-value
	Mdn	*median (IQR)*	*Mdn*	*median (IQR)*	
VLF	164.93	186.11	277.28	312.88	.96
LF	1 402.01	1 181.27	2 358.03	1 788.82	.01
HF	853.29	923.69	1 552.12	2 079.90	.00
LF/HF	1.68	1.76	1.65	0.87	.43
SDNN	60.19	30.93	71.36	29.63	.03

Note. BL = Baseline, FU-1 = Follow-up testing session 1, FU-2 = follow-up testing session 2, PSD = Partial Sleep Deprivation

Table 5

Median and Interquartile Range of HRV metrics during the EAIT for each condition between baseline and PSD

Metric	BL		PSD		*p*-value
	Mdn	*median (IQR)*	*Mdn*	*median (IQR)*	
VLF	302.78	358.90	423.65	395.69	.84
LF	1791.26	3316.95	3124.7	2093.818	.45
HF	1 029.15	1 690.28	2 165.70	1 620.66	.01
LF/HF	1.30	0.94	1.18	0.71	.33
SDNN	61.24	39.38	81.43	26.37	.02

Note. Data are presented as median and interquartile range. BL = Baseline, FU-1 = Follow-up testing session 1, FU-2 = follow-up testing session 2, PSD = Partial Sleep Deprivation

LF/HF Ratio. The difference in medians of the LF/HF ratio changed in the expected direction, but did not significantly increase following PSD while at rest, $r = 0.05$, $p = .43$, or while performing the EAIT, $r = 0.12$, $p = .33$ (Table 4 & Table 5)**.**

SDNN (ms). SDNN significantly increased while participants were at resting state, $r = 0.42$, $p = .03$, and during completion of the EAIT, $r = 0.45$, $p = .02$. These results were in the opposite direction of what was expected, suggesting that PSD led to increased HRV (Table 4 & Table 5).

2.1.2 EAIT

Accuracy. Median accuracy changed in the expected direction, from baseline to after PSD for both conditions. Accuracy did not decrease significantly after three nights of PSD when compared to baseline, $r = 0.365$, $p = .06$ (Table 6).

Reaction Time. Median reaction time across both conditions changed in the expected direction from baseline to after PSD. There was no significant difference in reaction time after three nights of PSD when compared to baseline across both conditions, $r = 0.015$, $p = .534$ (Table 6).

2.2 Exploratory Analysis

Because there was no significant decrease in HRV or performance on the EAIT as measures of ER following PSD there was no need to include it as a comparative timepoint, thus an explanatory analysis was done to observe changes in HRV and EAIT performance at three different timepoints in people that had been partially sleep deprived.

2.2.1 HRV

VLF (ms^2). The distribution of VLF data while at rest is presented in Figure 1. While at rest, there was no statistically significant interaction between the effects of time of testing and condition on VLF, $F(2, 52) = 0.04$, $p = .96$. Simple main effects analysis showed that

Table 6

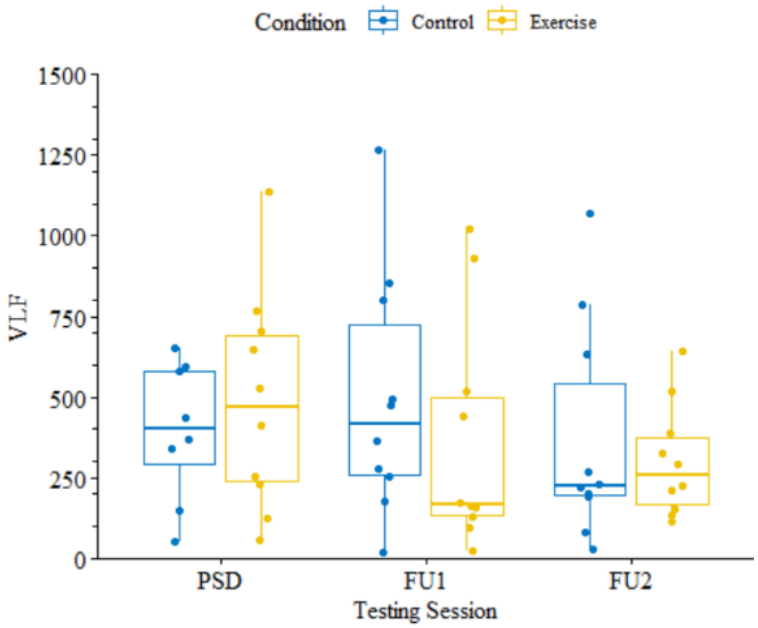
Median and Interquartile Range of EAIT Metrics between Baseline and after Partial Sleep Deprivation (n=9)

Metric	*Mdn*	*median (IQR)*	*Mdn*	*median (IQR)*
	BL		PSD	
Accuracy (%)	79,99	2,13	75,85	6,39
Reaction Time (ms)	557,08	112,59	561,14	133,79

Note. Data are presented as median and interquartile range. BL = Baseline, PSD = Partial Sleep Deprivation. Comparisons between timepoints were made using a paired samples Wilcoxon test.

Figure 1

Boxplot of VLF While at Rest at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

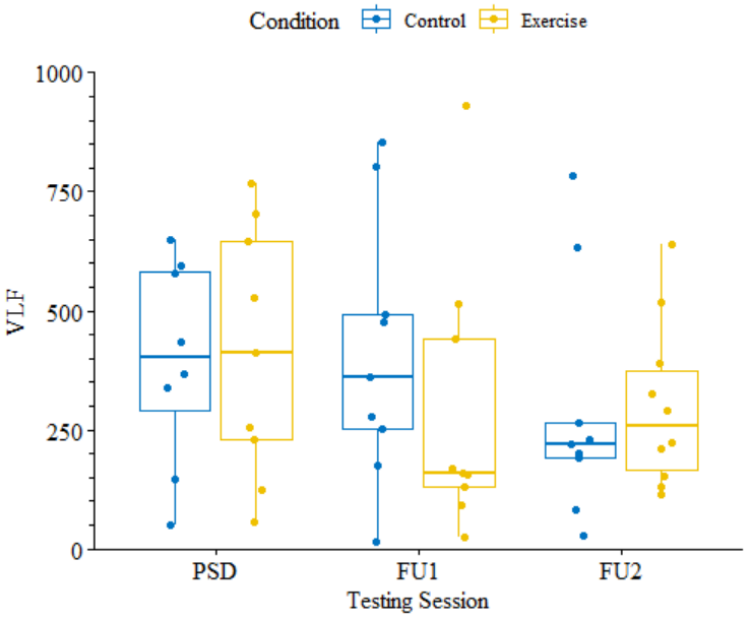
neither condition, $F(1, 52) = 2.00$, $p = .16$, nor time of testing session, $F(2, 52) = 3.15$, $p = .05$, had a significant effect on VLF.

While performing the EAIT, there was also no significant interaction between time of testing and condition on VLF, $F(2, 52) = 0.64$, $p = .53$. Condition, $F(1, 52) = 0.23$, $p = .63$, nor time of testing session, $F(2, 52) = 0.74$, $p = .48$, showed any significant simple main effect on VLF. The distribution of this data at each testing session is presented in Figure 2.

LF (ms^2). The distribution of this data is presented in Figure 3 and Figure 4. There were no significant interactions between condition and time of testing session on LF while at

Figure 2

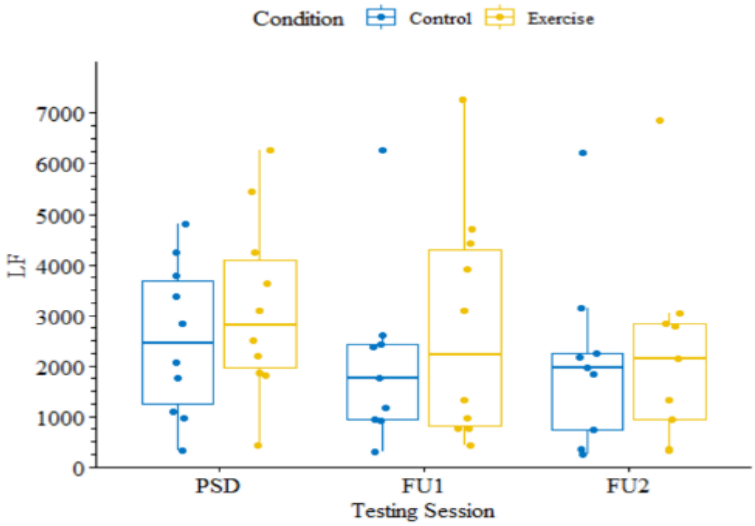
Boxplot of VLF During the EAIT at Each Testing Session for Each



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Figure 3

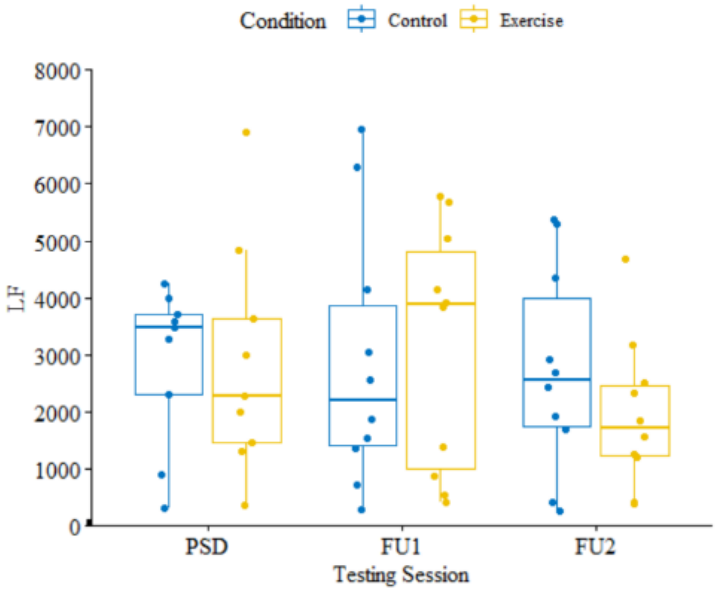
Boxplot of LF While at Rest at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Figure 4

Boxplot of LF While During the EAIT at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

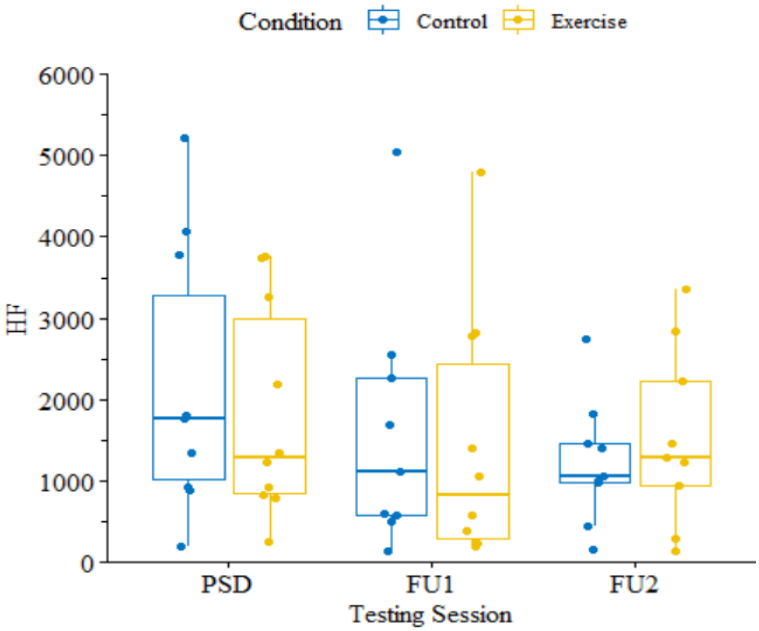
rest, $F(2, 51) = 0.10$, $p = .91$. No significant main effects were found for condition, $F(21, 51) = 1.00$, $p = 0.32$, or time, $F(2, 51) = 0.57$, $p=.57$, either.

While performing the EAIT, there was also no significant interaction between time of testing and condition on LF, $F(2, 51) = 0.68$, $p = .51$. Condition, $F(1, 52) = 0.23$, $p = .63$, nor timepoint, $F(2, 52) = .74$, $p = .48$, showed any significant simple main effect on LF either.

HF (ms^2). The distribution for this data is in Figure 5 and Figure 6. There were no significant interactions between condition and time of testing session on HF while at rest, $F(2, 52) = 0.58$, $p = .57$. No significant main effects were found for condition, $F(1, 52) = .53$, $p=.47$, or time, $F(2, 52) = 0.79$, $p = .46$. The distribution of this data is in Figure 5.

Figure 5

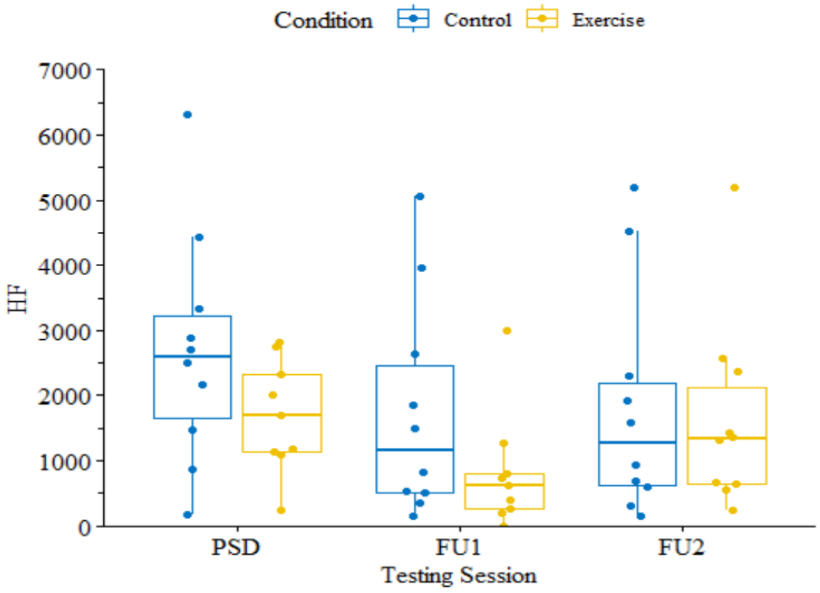
Boxplot of HF While at Rest at Each Testing



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Figure 6

Boxplot of HF While During the EAIT at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

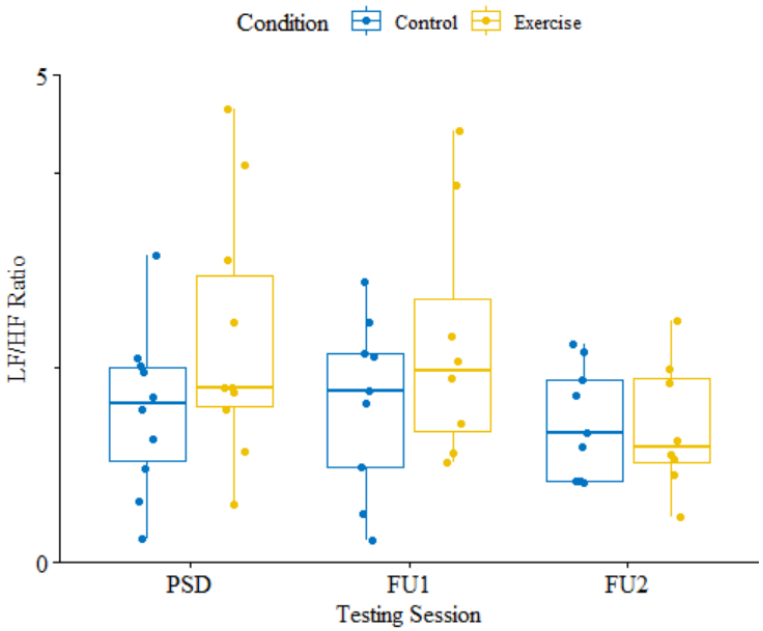
During the EAIT, there was also no significant interaction between time of testing and condition on HF, $F(2, 53) = 0.68$, $p = .77$. Condition, $F(1, 53) = 1.40$, $p = .24$, nor timepoint, $F(2, 53) = 2.62$, $p = .08$, showed any significant simple main effect on HF either.

LF/HF Ratio.

While at rest, there was no significant interaction between condition and time of testing, $F(2, 50) = 1.57$, $p = .22$, and there was no main effect of time, $F(2, 50) = 2.59$, $p = .08$. However, there was a significant main effect of condition. An estimated marginal means was computed for the main effect of condition, this contrast showed that the control condition had a significantly lower LF/HF ratio than the exercise condition, $p = .03$. Distributions for this data can be found in Figure 7.

Figure 7

Boxplot of LF/HF Ratio While at Rest at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

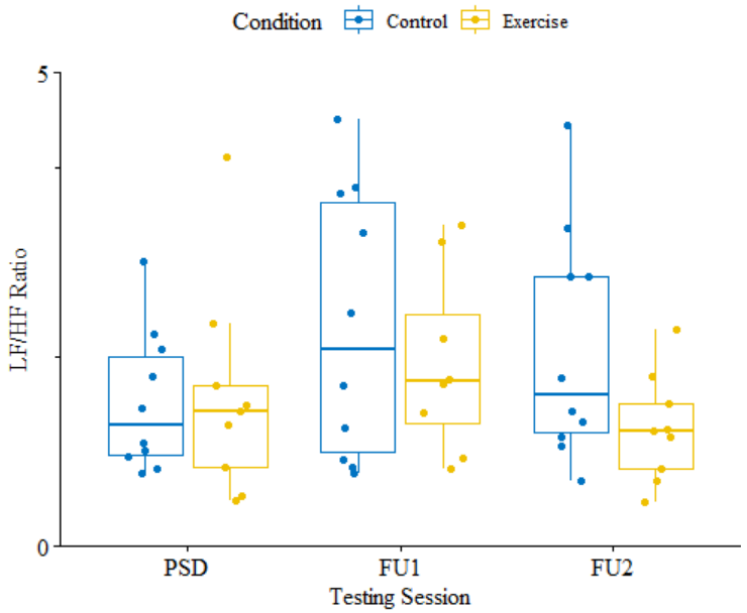
During the EAIT, there were no interaction effects between condition and time, $F(2, 51) = 0.97$, $p = .39$. There were no significant main effects from time, $F(2, 51) = 2.64$, $p = .08$, nor condition, $F(1, 51) = 0.35$, $p = .56$, either. Distribution for this data is in Figure 8.

SDNN (ms). While at rest, there was no significant interaction between condition and time of testing session, $F(2, 504) = 0.15$, $p = .86$. There was no main effect of time, $F(2, 54)= 0.64$, $p= .53$, nor of condition, $F(1, 54) = .38$, $p = .54$. Distribution for this data is in Figure 9.

During the EAIT, there were no interaction effects between condition and time, $F(2, 54) = 0.06$, $p = .94$. There were no significant main effects from time, $F(2, 54) = 1.45$, $p = .24$, nor condition, $F(1, 54) = 0.11$, $p=.74$. Distribution of this data is presented in Figure 10.

Figure 8

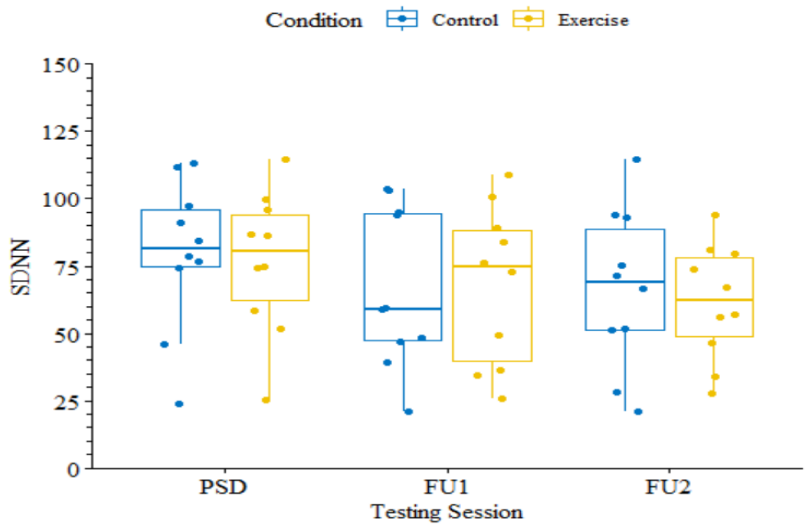
Boxplot of LF/HF Ratio During the EAIT at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Figure 9

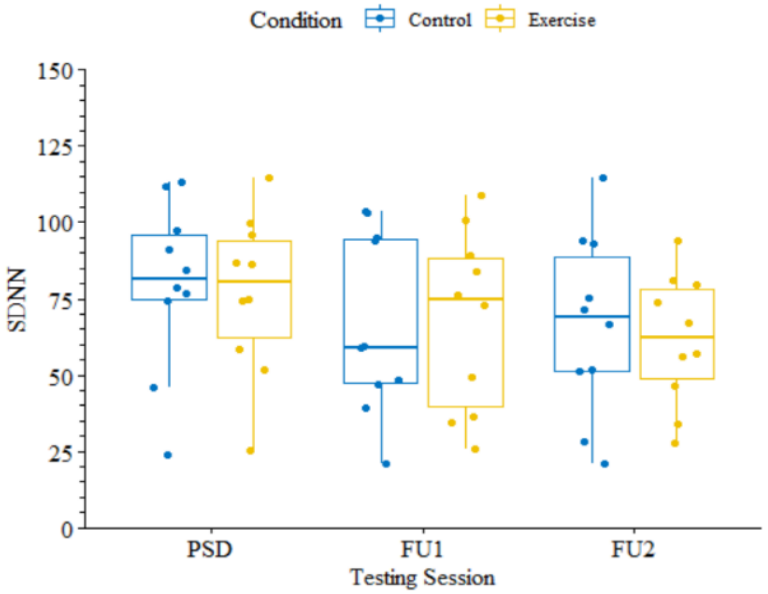
Boxplot of SDNN While at Rest at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU1 = Follow-up session 1, FU2 = Follow-up session 2.

Figure 10

Boxplot of SDNN During the EAIT at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU1 = Follow-up session 1, FU2 = Follow-up session 2.

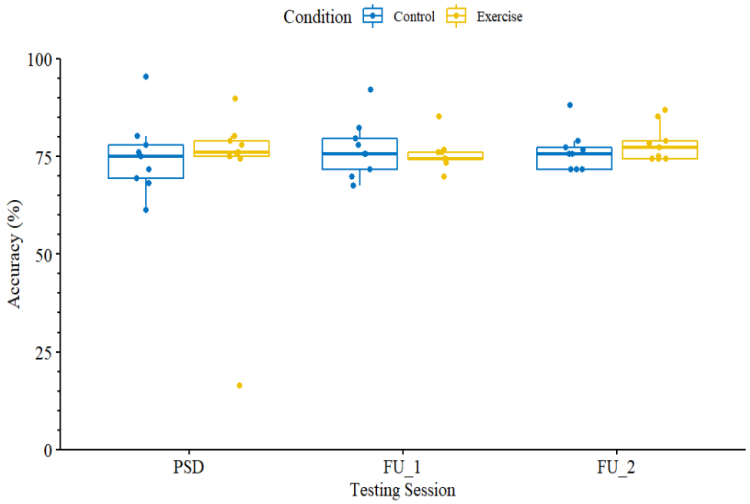
2.2.2 EAIT

Accuracy. There was not a statistically significant interaction between the effects of condition and timing of the testing session on accuracy, $F(2, 48) = 0.306$, $p = .738$. Simple main effects analysis showed that neither condition, $F(1, 48) = 0.10$, $p = .758$, nor timing of the testing session, $F(2, 48) = 0.716$, $p = .494$, had a statistically significant effect on accuracy (Table 7). Figure 11 shows the distribution of accuracy data.

Reaction Time. There was not a statistically significant interaction between the effects of condition and timing of testing session on reaction time, $F(2, 48) = 0.03$, $p = .972$. Simple main effects analysis showed that condition did not have a statistically significant effect on reaction time, $F(1, 48) = 0.05$, $p = .833$, and neither did the timing of testing session, $F(2, 48) = 0.480$ $p = .622$ (Table 7). Figure 12 shows the distribution of this data.

Figure 11

Boxplot of Accuracy at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Table 7

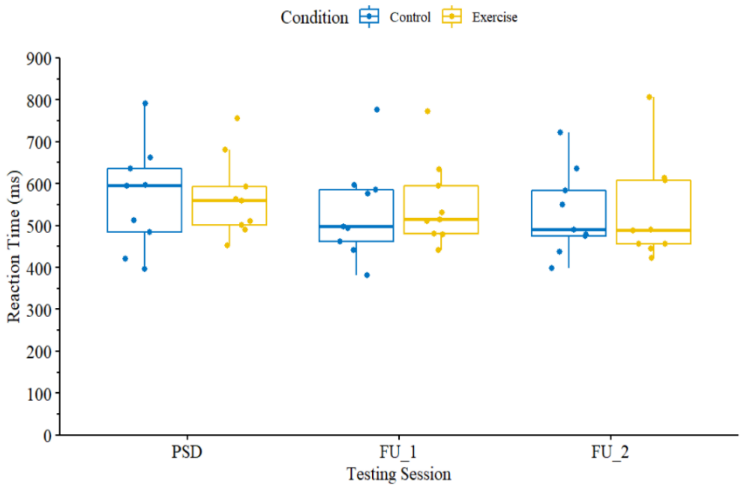
Median and Interquartile Range of EAIT Metrics For Each Timepoint For Each Condition

Metric	PSD		FU-1		FU-2	
	Mdn	*median (IQR)*	*Mdn*	*median (IQR)*	*Mdn*	*median (IQR)*
			Exercise			
Accuracy (%)	76.14	4.83	74.43	2.56	77.27	7.67
Reaction Time (ms)	558.8	141.63	514.6	134.73	487.89	161.04
			Control			
Accuracy (%)	75.00	10.23	75.57	10.23	75.57	6.53
Reaction Time (ms)	594.14	197.04	496.98	139.39	490.32	154.1

Note. Data are presented as median and interquartile range. FU-1 = Follow-up testing session 1, FU-2 = follow-up testing session 2, PSD = Partial Sleep Deprivation. Between timepoints comparisons were made using paired samples Wilcoxon tests.

Figure 12

Boxplot of Reaction Time at Each Testing Session for Each Condition



Note. Data are presented as median and interquartile ranges. PSD = Partial Sleep Deprivation, FU_1 = Follow-up session 1, FU_2 = Follow-up session 2.

Discussion

The aim of this study was to determine whether a session of moderate intensity aerobic exercise could mitigate the negative effects of PSD on ER among healthy adults.

Manipulation checks were conducted to determine whether the PSD protocol was successful in decreasing HRV parameters and performance on the EAIT as measures of ER in comparison to baseline. HRV along with accuracy and reaction time, as measures of performance on EAIT, that were measured at baseline and after PSD were compared. These manipulation checks showed that no significant differences were present between baseline and after PSD, while at rest and during performance of the EAIT, the LF/HF ratio and the VLF metric. On the other hand, HF power, LF power, and SDNN each had significant effects following PSD. Higher HF power is associated with increased PNS activation, which is

related to higher HRV (Shaffer & Ginsberg, 2017). Previous research found that PSD results in lowered PNS activation (Arslan et al., 2019; Cohen-Zion, 2020; Dettoni et al., 2012). Interestingly, our results indicated that HF power increased following three nights of PSD at both resting state and during performance of the EAIT. While these results indicate that PSD positively affected PNS activation, this result cannot be interpreted in isolation. Therefore, SNS activity was analysed in conjunction with vagal stimulation.

Our study found increased LF power, a marker of SNS activity, after PSD while at rest. This activation of the SNS contrasts findings of Bourdillon et al. (2021), who found no increases in SNS activation following three consecutive days of PSD, but is in accordance with results of other studies which found increased SNS activity after PSD (Arslan et al., 2019; Cohen-Zion, 2020; Dettoni et al., 2012). Even though the LF component of HRV, which is associated with SNS dominant activity, showed a significant increase following PSD, this was only the case when participants' HR was recorded at rest, not during performance of the EAIT. The results of the manipulation check were inconclusive, and we cannot state that PSD affected HRV. Since an increased HRV is known to be related to improved ER, we can conclude that since autonomic activity was not affected by PSD, neither was the participants' emotional regulatory capacities (Appelhans & Luecken, 2006; Mather & Thayer, 2018; Quintana et al., 2012). This contradicts previous findings that suggest that PSD would affect HRV and thus ER (Arslan et al., 2019; Dettoni et al., 2012; Haiblum-Itskovitch et al., 2018). Our study also implemented a cognitive measure of ER to confirm whether emotional regulatory capacity changed in relation to HRV.

The manipulation check showed that there was no significant difference in reaction time or accuracy after three nights of PSD when compared to baseline across both conditions. This differs from the results found by Alger et al. (2020) that reaction time slowed after a period of sleep deprivation. Our results indicate that PSD did not lead to a decreased

performance on the EAIT as a measure of ER across conditions. This conclusion contrasts with previous findings from Alger et al. (2020) who found that performance on the EAIT decreased after one night of TSD. The difference in these findings could be due to the fact participants were completely deprived of sleep for 40 hours in the study conducted by Alger et al. (2020), whereas participants in our study were only partially sleep deprived over three days.

We hypothesised that participants would show increased HRV and performance on the EAIT as measures of ER following a session of moderate intensity aerobic exercise after a period of PSD, in comparison to when they did not perform a session of moderate intensity aerobic exercise after a night of PSD. Because of the results found from the manipulation checks, our main hypothesis could not be sufficiently answered. Therefore, the subsequent analyses were explanatory in nature, and were done to determine whether exercise improved ER, as indicated by HRV and performance on the EAIT.

The testing session that took place after the three-day period of PSD, showed no significant changes in HRV. Firstly, the time at which testing occurred and condition (exercise or control) did not result in any significant changes. This suggests that exercise, when compared to no exercise, does not result in an increased HRV. Secondly, no significant changes to PNS activity were found, contrasting results of Imai et al. (1994), who observed PNS dominance following exercise. However, our findings are in accordance with the findings by Rae et al. (2017) and Cincin et al. (2015), who found no effect of exercise on PNS reactivation. It must be noted that these studies did not use HRV as indicators of ANS functioning though. Considering that parasympathetic activation was similar for the control and exercise groups at follow-up session 1, it can be argued that intensity of exercise may have played a role in producing similar PNS activation between both conditions (Michael et al., 2017). The 40-minute run our participants performed in the exercise condition pushed

them to 90-95% of their maximum HR. Despite them being experienced runners, exercise of this intensity may have played a role in the predicted slower PNS recovery throughout the day (Michael et al., 2017). Similarly, the expected SNS decline following PSD also did not occur (Imai et al., 1994). These results contradict with the view that exercise improves HRV, and thus ER (Goit et al., 2018; Murad et al., 2012; Stein et al., 1999).

We hypothesised that reaction time on EAIT would decrease and accuracy on EAIT would increase after exercise when compared to that measured after a period of PSD. We also hypothesised that reaction time would increase or remain the same and that accuracy would decrease or remain the same at each testing session after baseline in the control condition.

Our results show that neither the timing of the testing session nor condition affected reaction time or accuracy. In a study conducted by Zhang et al. (2022) investigating effects of moderate-intensity exercise on emotional regulation using an Emotional Flanker Task, it was also found that there were no significant main or interaction effects of condition and testing time on performance. Overall, our findings indicate that according to EAIT performance, moderate intensity aerobic exercise cannot improve ER.

Limitations

There are four main limitations of this study, the first limitation concerns the PSD protocol. Manipulation checks showed that three nights of PSD did not significantly decrease HRV and performance on the EAIT as measures of ER. This means that we could not investigate the effects of exercise in mitigating the negative effects of PSD on ER and rather had to explore the effects of exercise on ER more generally. This could be due to the fact that our sample consisted of healthy, active individuals who may be less prone to changes in HRV when compared to the general population (Liu et al., 2022).

A second limitation of this study concerns time. It took 21 days for each participant to complete the protocol and in the initial stages we could only test one participant at a time

as we were learning how to administer tests correctly. After the initial stage we could test a maximum of three participants at a time as the protocol was so time-consuming and lengthy. Due to the time constraints, this was not sufficient to reach our proposed sample size of N=17.

According to the power analysis, we needed a sample size of N = 17 to obtain a statistical power of .8, we only managed to recruit and test 10 participants which means that our results are statistically underpowered. Due to the small sample size, internal and external validity of results are undermined as there is an increased risk of Type II errors (failure to reject the null hypothesis when it is in fact false) due to inadequate power (Blackford, 2017). If we had a larger sample size, the results may have been different.

Finally, the smartphone application *EliteHRV*, used to record participants' HRV, could not produce ECG tracings on *Kubios*. As a result, the HRV data used for analysis could not be sufficiently cleaned by removing the noise and ectopic beats. We suggest that to improve the reliability of future research, a different application should be used for recording participants' HRV to avoid this issue.

Directions for future research

This study's insignificant changes in HRV, coupled with the insignificant changes found in performance of the EAIT, currently do not provide an accurate account of whether exercise can enhance ER. Furthermore, since the PSD did not result in significant changes in ER, through measures of HRV and performance on the EAIT, future research should take several things into account.

Firstly, future research should investigate the relationship between PSD, ER and exercise. The limited amount of research done on this topic needs to be addressed, especially since PSD is so common and can lead to several other negative effects, besides decreased ER (Hairston & Cohen-Zion, 2020; Pilcher & Huffcutt, 1996). Secondly, to our knowledge, this

is the first study to have used HRV as a measure of ER to investigate the negative effects of PSD on ER. Considering that HRV is understood to be a non-invasive measure of ER, not many studies have incorporated this measure into its protocol. Future research could include a more diverse sample of participants with varying levels of daily exercise, to investigate whether exercise can alleviate the presumed negative effects of PSD on ER. Future studies could use a larger sample size and collect data over a longer period of time.

Although this study has various limitations and we could not determine whether exercise can mitigate the negative effects that PSD has on ER, it does raise a variety of intriguing questions for future study, such as whether HRV is more sensitive in individuals who do not exercise as well as whether exercise mitigates the negative effects of PSD on ER.

Conclusion

This study was unable to investigate how exercise may be used to mitigate the negative effects of PSD on ER and no conclusive results about how exercise affects ER were found. Despite these limitations the results from this study add to the current body of literature which explores PSD, exercise and ER and can be seen as a step towards integrating research on these topics. Future research into PSD, exercise and ER should make use of HRV as a non-invasive measure of ER and should collect data from a large, diverse sample over a longer time period.

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Appendix A

Participant Recruitment: Student Research Participation Programme (SRPP) Announcement

Announcement: Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults

Dear Students,

I am a Masters student conducting a lab-based study through the Department of Psychology at UCT. This study will be looking at the effects of exercise on cognition (i.e. mental processes such as attention, memory etc.), mood and heart rate variability (i.e. are you in rest and digest mode or fight and flight mode?) during partial sleep deprivation.

What does the study entail?

The study consists of a screening and sleep deprivation phase. You will be required to complete an online screening questionnaire which should take about **20 minutes to complete**. If you are deemed eligible and willing to participate, you will advance to the sleep deprivation phases of the study. Even if you are not eligible, we will provide you with personal feedback relating to your sleep, circadian rhythms and mental health.

The sleep deprivation phases will be conducted at the Sleep Science Laboratory at the Division of Physiological Sciences, UCT. It is best explained by the diagram below! But in case you prefer words: You will be required to attend the lab on three occasions.

Consent and familiarisation (±2h; in lab):

- Sign the consent form
- Have your height and weight measured, and practise the cognitive test battery
- Do running test on a treadmill to establish your maximum heart rate

Lead-in week (To check your sleep and activity habits over 7 days):

- Wear a small watch and keep a diary to log your sleep, exercise and dietary habits
- Do baseline tests (cognitive, mood and heart rate variability) - researchers will come to the place you are staying for the testing session (±1.5h)

Sleep deprivation phase 1 (4 days; last night and following day in lab):

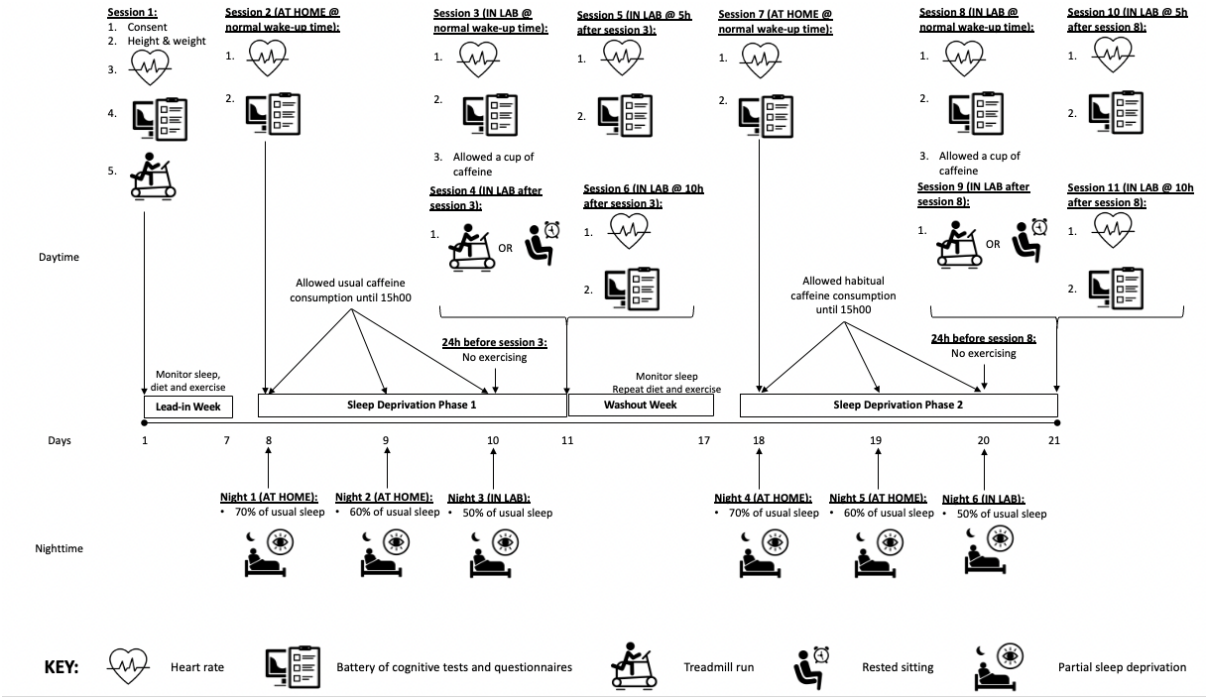
- Three consecutive nights of partial sleep deprivation (70%, 60% and 50% of your usual sleep length). First two nights at home, third night in the lab.
- Day after night three: You will remain in the lab for the day as we repeat the baseline tests at three time points (15min, 5h and 10h after usual wake time). On this day, you will also do either a 40min treadmill run, or sit quietly for 40min in the morning after the first test battery.

Wash out week (To recover and return to your usual sleep patterns)

- Wear a small watch and keep a diary to log your sleep, exercise and dietary habits again
- Do baseline tests (cognitive, mood and heart rate variability) again - researchers will come to the place you are staying for the testing session (1.5h)

  Sleep deprivation phase 2 (4 days; last night and following day in lab):
- Another three consecutive nights of partial sleep deprivation (70%, 60% and 50% of your usual sleep length). First two nights at home, third night in the lab.
- Day after night three: You will remain in the lab for the day as we repeat the baseline tests at three time points (15min. 5h and 10h after usual wake time). On this day, you will also do either a 40min treadmill run, or sit quietly for 40min in the morning after the first test battery.

See the diagram below for an overview of the study:



Who can participate?

I am looking for males and females who:

- are between the ages of 18 and 45 years old
- regularly sleep 7-9 hours per night
- are runners or take part in a sport where running is a feature (e.g. hockey, soccer, rugby players etc.)
- for the past 6 months have regularly performed aerobic (preferably running) exercise on at least 2 days of the week for at least 30 minutes per session (i.e. at least 60 min per week)
- are not on any chronic medication (for sleeping, depression, anxiety or other mood disorders or any other cardiometabolic disease)

If you are interested and meet the above criteria, please follow the link below. You'll first need to read and sign the informed consent form before being able to complete the screening questionnaire. I will contact you to inform you of whether or not you are eligible for this study.

https://docs.google.com/forms/d/e/1FAIpQLSd2DvuxibxSAZHfq0NTpxCkCHVm51PioIWVy26-qqJNdm8rzA/viewform?usp=sf_link

Please note that all personal information such as your name, surname and contact details (e.g. cellphone number, email address) as well as your survey responses will be kept strictly confidential and will only be used for research purposes.

Please email LRXCEL003@myuct.ac.za, vghjes001@myuct.ac.za or jpphes001@myuct.ac.za if you have any questions or would like more information.

Kindest regards,
Celine le Roux (Researcher)
Heshaam Jappie
Jessica Vaughan
Dr Gosia Lipinska (Supervisor)
Dr Dale Rae (Co-supervisor)

Appendix B

Participant Recruitment: Social Media Advertisement

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

YOU ARE INVITED TO PARTICIPATE IN A UCT RESEARCH STUDY!

This study aims to investigate the effects of exercise on cognition, mood and heart rate variability during partial sleep deprivation

You are eligible to take part in this study if you:

1) Are 18-45 years old
2) Usually sleep 7-9 hours per night
3) Are a runner or take part in a sport where you run e.g. hockey, rugby
4) For the past 6 months have included at least 2 aerobic training sessions for at least 30 minutes per week
5) Are not on any chronic medication (for sleep, depression, anxiety or other mood disorders or any cardiometabolic disease)

Please click the link below to complete an online screening survey if you meet the above criteria. You will be contacted to let you know if you are eligible to participate in the study.
(Insert link here)

Should you be interested in more information or have any queries, please contact the researcher below:

Celine le Roux
LRXCEL003@myuct.ac.za
073 945 5923

PLEASE PASS THIS INVITATION ON!

Appendix C

Psychometric Properties and Additional Information of Measures and Apparatus

Measure	Properties
The Horne-ostberg morning-evening personality questionnaire (MEQ-HO)	The MEQ-HO comprises 19 items and is a valid and reliable measure (Horne & Östberg, 1976). The scale consists of 4 point Likert-type items as well as time-scale items (Horne & Östberg, 1976).
The Insomnia Severity Index	Each item is rated using a 5-point Likert scale (Morin et al., 2011). The ISI is a valid and reliable instrument and has been psychometrically validated for use among the African population and for online delivery (Albougami & Manzar, 2019; Thorndike, et al., 2011).
The Patient Health Questionnaire-8 (PHQ-8)	Each item is rated on a 4-point Likert scale (Peters et al., 2021). The PHQ-8 is a valid and reliable measure and has previously been used in Africa (Osborn et al., 2020).
The Generalized Anxiety Disorder scale-7 (GAD-7)	Each time is scored using a 4-point Likert scale (Spitzer et al., 2006). This measure is valid and reliable for the identification of GAD and for use within the South African context (Bezuidenhout, 2018; Peters, et al., 2021).
The Primary Care Post Traumatic Stress Disorder Screen for DSM5 (PC-PTSD-5)	This measure has excellent reliability and validity and has previously been used in the South African context (Bovin, et al., 2021; van Wijk & Meintjies, 2021).
The Alcohol Use Disorders Identification Test-Consumption (AUDIT-C)	The AUDIT-C is a valid and reliable measure and has previously been used in

	studies conducted in South Africa (Eyawo, et al., 2018; Lundin et al., 2015).
The Drug Abuse Screening Test (DAST-10)	The DAST-10 is a reliable and valid screening tool and has previously been used for research in South Africa (Evren, et al., 2013; Peltzer et al., 2009). The items are binary choice items, and scores range from 0-10 (Evren, et al., 2013).

Measure	**Procedure**
Ramp incremental running protocol on the treadmill	Participants will warm up for 5-10 minutes, after which the test will begin. The participants will start running on the treadmill at 10km/h for 30 seconds with no gradient. After the initial 30 second run, the speed will be increased by 0.5km/h for 30 seconds and then increased at the same increment for another 30 seconds. For the following minute, the speed will remain constant while the gradient is increased by 1%. The speed and gradient will continue to increase at the same increments for alternating minutes. The participant will continue to run while the speed and gradient increases until they get to a point where they cannot maintain the pace, at which point they will step off of the treadmill.
Emotion-attentional Interference Task	A fixation cross is shown for 1500ms. Following this an image will be shown at the centre of the screen with two peripheral bars, this figure shown for 200ms (Erthal, et al., 2005; Luo et al., 2010). The white bars were positioned at 9º to the right and left of the centre of the picture (Alger et al., 2020; Erthal, et al., 2005). The screen then turns grey which remains until the participant responds or

	1500ms lapses (Alger et al., 2020; Erthal, et al., 2005). The participants need to indicate whether the peripheral bars were the same (by pressing s) or different (by pressing d) (Alger et al., 2020; Luo, et al., 2010; Erthal, et al., 2005; Luo et al., 2010). Following this, there is a blank screen for 600ms (Alger et al., 2020; Erthal et al., 2005). There are 88 pleasant images and 88 non-pleasant images. There are high load conditions in which the bars were either 45° clockwise rotation from vertical or the bars differed from one another by one bar being at a 15° counterclockwise rotation from the other and low load conditions in which the bars were orientated in the same way or by a 90° rotation from the other (Alger et al., 2020; Erthal, et al., 2005). The validity and reliability of this measure has not yet been validated.

Appendix D

Online Screening Survey

(All information provided is treated confidentially)

Socio-Demographic Questionnaire

1. Name and Surname: _____
2. Age: _____
3. Date of birth: _____
4. Gender: _____
5. First language: _____
6. Years of schooling (incl. primary, seconding and tertiary education):

   _____
7. Telephone: _____
8. Email address: _____
9. Preferred method of contract:
   - SMS
   - WhatsApp
   - Telegram
   - Call
   - Email

Medical History

1. Have you been ill within the past 2 weeks?
   - Yes
   - No
2. Have you gotten any physical injuries within the past 6 weeks?
   - Yes
   - No
3. Are you taking any anti-depressants or psycho-tropic medication? If so, please provide the name.
   - Yes

- No

---

4. Do you suffer from any sleeping disorder? E.g. insomnia, sleep apnea, narcolepsy. If yes, please state the disorder that applies to you.
   - Yes
   - No

---

5. Are you taking any medication to help you sleep better? If so, please provide the name.
   - Yes
   - No

---

6. Do you suffer from daytime sleepiness?
   - Yes
   - No
7. What is your bedtime? _____
8. How many hours of sleep do you get per night? _____
9. Do you suffer from any medical conditions (epilepsy, head injury, HIV, heart condition, hypertension, hyperlipidaemia, diabetes etc.)? If yes, please state the condition that applies to you.
   - Yes
   - No

---

10. Are you taking any chronic medications for your health? If yes, please provide the name.
    - Yes
    - No

---

11. How many cups of caffeine do you drink in a typical day?
    - 1
    - 2
    - 3
    - 4
    - +5

12.1 Do you smoke?

- Yes
- No

12.2 If so, how many cigarettes per day? _____

Training History

Do you currently participant in any sports / physical activities?

- Yes
- No

If "Yes", please describe and state how long you've been partaking in this type of exercise:

_____

_____

Please use the table below to complete information about your usual weekly training during the past six months:

	Mon	Tue	Wed	Thurs	Fri	Sat	Sun
Type	Yoga	Walk		Run	Pilates		Run
Duration	1	30min		40min	1h		1.5
Distance		3km		8km			12km

What is your personal best 10km run time?

_____

_____

Have you ever run on a treadmill before?

- Yes
- No

Horne–Östberg Morningness–Eveningness Personality Questionnaire

INSTRUCTIONS

a) Please read each question very carefully before answering.

b) Answer ALL 19 questions.

c) Answer questions in numerical order.

d) Each question should be answered independently of others. **DO NOT** go back and check your answers.

e) For some questions, you are required to respond by placing a cross alongside your answer. In such cases, select **ONE** answer only.

f) Please answer each question as honestly as possible. Both your answers and results will be kept in strict confidence.

QUESTION 1

Considering your own feelings about when you are "at your best", at what time would you get up if you were entirely free to plan your day?

Time: _____

QUESTION 2

Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your day?

Time: _____

QUESTION 3

If there is a specific time you have to get up in the morning, to what extent are you dependent on being woken up by an alarm clock?

a. Not at all dependent _____☐

b. Slightly dependent _☐

c. Fairly dependent __☐

d. Very dependent ___☐

QUESTION 4

Assuming adequate environmental conditions, how easy do you find getting up in the morning?

a. Not at all easy ____☐

b. Slightly easy _____☐

c. Fairly easy _____☐

d. Very easy _____☐

QUESTION 5

How alert do you feel during the first half hour after having woken in the morning?

a. Not at all alert ____☐

b. Slightly alert _____☐

c. Fairly alert _____☐

d. Very alert _____☐

QUESTION 6

How is your appetite during the first half hour after having woken in the morning?

a. Not at all good ____☐

b. Slightly good _____☐

c. Fairly good _____☐

d. Very good _____☐

QUESTION 7

During the first half hour after having woken in the morning, how tired do you feel?

a. Very tired _____☐

b. Slightly tired _____☐

c. Fairly refreshed ___☐

d. Very refreshed ____☐

QUESTION 8

When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?

a. Seldom or never later ☐

b. Less than one hour later ☐

c. 1-2 hours later ☐

d. More than 2 hours later ☐

QUESTION 9

You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him/her is between 7.00-8.00 am. Bearing in mind nothing else but your own inclinations, how do you think you would perform?

a. Would be on good form ☐

b. Would be on reasonable form ☐

c. Would find it difficult ☐

d. Would find it very difficult ☐

QUESTION 10

At what time in the evening do you feel tired and in need of sleep?

Time: _____

QUESTION 11

You wish to be at your peak for a test which you know is going to be mentally exhausting and last for two hours. You are entirely free to plan your day. When would you do this task?

a. 8.00 am – 10.00 am ☐

b. 11.00 am – 1.00 pm ☐

c. 3.00 pm – 5.00 pm ☐

d. 7.00 pm – 9.00 pm _____ ☐

QUESTION 12

If you went to bed at 11.00 pm at what level of tiredness would you be at that time?

a. Not at all tired _____ ☐

b. A little tired _____ ☐

c. Fairly tired _____ ☐

d. Very tired _____ ☐

QUESTION 13

For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Will you:

a. Wake up at the usual time and not go back to sleep _____ ☐

b. Wake up at the usual time and doze _____ ☐

c. Wake up at the usual time and go back to sleep __ ☐

d. Wake up later than usual _____ ☐

QUESTION 14

One morning you have to remain awake between 4.00 am and 6.00 am in order to carry out a watch duty. You have no commitments the next day. Which ONE of the following alternatives suits you best?

a. Would NOT go to bed until 6.00 am _____ ☐

b. Nap before 4.00 am and sleep after 6.00 am _____ ☐

c. Sleep before 4.00 am and nap after 6.00 am _____ ☐

d. Only sleep before 4.00 am and remain awake after 6.00 am ____ ☐

QUESTION 15

You have to do 2 hours of hard physical work. If you were completely free to plan your day, and considering only your “feeling best” rhythm, which hours would you prefer to do it between:

a. 8.00 am – 10.00 am _____☐

b. 11.00 am – 1.00 pm _____☐

c. 3.00 pm – 5.00 pm _____☐

d. 7.00 pm – 9.00 pm _____☐

QUESTION 16

You have decided to engage in some physical exercise. A friend suggests that you do this between
10.00 pm and 11.00 pm twice a week. How do you think you would perform?

a. Would be on good form _____☐

b. Would be on reasonable form ____☐

c. Would find it difficult _____☐

d. Would find it very difficult _____☐

QUESTION 17

Suppose that you can choose your own work hours, but had to work FIVE hours in the day. Assume that your job is interesting and paid by results. Which FIVE CONSECUTIVE HOURS would you choose?

Hours: _____

QUESTION 18

At what time of day do you feel at your best?

Time: _____

QUESTION 19

One hears of “morning” and “evening” types. Which do you consider yourself to be?

a. Morning type _____ □

b. More morning than evening _____ □

c. More evening than morning _____ □

d. Evening type _____ □

Insomnia Severity Index (ISI)

For each question, please select the number that best describes your answer. Please rate the current (i.e. last 2 weeks) severity of your insomnia problem(s).

Insomnia Problem	**None**	**Mild**	**Moderate**	**Severe**	**Very Severe**
1. Difficulty falling asleep	0	1	2	3	4
2. Difficulty staying asleep	0	1	2	3	4
3. Problems waking up too early	0	1	2	3	4

4. How SATISFIED/DISSATISFIED are you with your CURRENT sleep pattern?

Very satisfied	Satisfied	Moderately satisfied	dissatisfied	Very dissatisfied
0	1	2	3	4

5. How NOTICEABLE to others do you think your sleep problem is in terms of impairing the quality of your life?

Not at all noticeable	A little	Somewhat	Much	Very much noticeable
0	1	2	3	4

6. How WORRIED/DISTRESSED are you about your current sleep problem?

Not at all worried	A little	Somewhat	Much	Very much worried
0	1	2	3	4

7. To what extent do you consider your sleep problem to INTERFERE with your daily functioning (e.g. daytime fatigue, mood, ability to function at work/daily chores, concentration, memory, mood, etc.) CURRENTLY?

Not at all interfering	A little	Somewhat	Much	Very much interfering
0	1	2	3	4

Patient Health Questionnaire (PHQ-8)

Over the last 2 weeks, how often have you been bothered by any of the following problems?

	0 - Not at all	1 - Several days	2 - More than half the days	3 - Nearly every day
1. Little interest or pleasure in doing things				
2. Feeling down, depressed, or hopeless				
3. Trouble falling or staying asleep, or sleep too much				
4. Feeling tired or having little energy				
5. Poor appetite or overeating				
6. Feeling bad about yourself – or that you are a failure or have let yourself or your family down				
7. Trouble concentrating on things, such as reading the newspaper or watching television				

8. Moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual				

Generalised Anxiety Disorder (GAD-7)

Over the last 2 weeks, how often have you been bothered by the following problems?

	0 - Not at all	1 - Several days	2 - More than half the days	3 - Nearly every day
1. Feeling nervous, anxious or on edge				
2. Not able to stop or control worrying				
3. Worrying too much about different things				
4. Trouble relaxing				
5. Being so restless that it is hard to sit still				
6. Becoming easily annoyed or irritable				
7. Feeling afraid as if something awful might happen				

Primary Care Post-Traumatic Stress Disorder Screen for DSM-5 (PC-PTSD-5)

Sometimes things happen to people that are unusually or especially frightening, horrible, or traumatic. For example: 1) a serious accident or fire, 2) a physical or sexual assault or abuse,

3) an earthquake or flood, 4) a war, 5) seeing someone be killed or seriously injured, 6) having a loved one die through homicide or suicide.

Have you experienced this kind of event? Yes / No

*Note: If "No", screen total = 0; if "Yes", continue with screening.

In the past month, have you…	Yes	No
Had nightmares about the event(s) or thought about the event(s) when you did not want to?		
Tried hard not to think about the event(s) or went out of your way to avoid situations that reminded you of the event(s)?		
Been constantly on guard, watchful, or easily startled?		
Felt numb or detached from people, activities, or your surroundings?		
Felt guilty or unable to stop blaming yourself or others for the event(s) or any problems the event(s) may have caused?		

Alcohol Use Disorders Identification Test-Consumption (AUDIT-C)

For each question, please select the option that best describes your alcohol use in the past 12 months.

1. How often do you have a drink containing alcohol?
    - Never
    - Monthly or less
    - Two to four times a month
    - Two to three times a week
    - Four or more times a week

2. How many standard drinks containing alcohol do you have on a typical day when you are drinking?
    - N/A
    - One or two
    - Three or four
    - Five or six
    - Seven to nine
    - Ten or more

3. How often do you have six or more drinks on one occasion?
    - N/A
    - Never
    - Less than monthly
    - Monthly
    - Weekly
    - Daily or almost daily

Drug Abuse Screening Test (DAST-10)

When the words “drug abuse” are used, they mean the use of prescribed or over-the-counter medications/drugs in excess of the directions and any non-medical use of drugs. The various classes of drugs may include:

a) Cannabis (e.g. marijuana and hash)
b) Solvents
c) Tranquilizers (e.g. Valium)
d) Barbiturates
e) Cocaine
f) Stimulants (e.g. speed)
g) Hallucinogens (e.g. LSD)
h) Narcotics (e.g. heroin)

It is important to remember that the questions DO NOT include alcohol or tobacco. If you have difficulty with a statement, then select the response that is mostly right or accurate. You

are required to answer ALL the questions. The following questions refer to the past 12 months:

1. Have you used drugs other than those required for medical reasons?
   - No
   - Yes
2. Do you abuse more than one drug at a time?
   - No
   - Yes
3. Are you always able to stop using drugs when you want to?
   - No
   - Yes
4. Have you had “blackouts” or “flashbacks” as a result of drug use?
   - No
   - Yes
5. Do you ever feel bad or guilty about your drug use?
   - No
   - Yes
6. Does your spouse (or parents) ever complain about your involvement with drugs?
   - No
   - Yes
7. Have you neglected your family because of your use of drugs?
   - No
   - Yes
8. Have you engaged in illegal activities in order to obtain drugs?
   - No
   - Yes
9. Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking drugs?
   - No
   - Yes

10. Have you had medical problems as a result of your drug use (e.g. memory loss, hepatitis, convulsions, bleeding, etc.)?
    - No
    - Yes

    Thank you for taking the time to complete this survey! I will be in contact with you if you are eligible for the study. If anything distressed you while completing this survey, please feel free to contact any of the resources offered below. You are also more than welcome to contact me directly if you would like to chat more.

Referral Resources	**Contact Details**
South African Depression and Anxiety Group (SADAG)	011 234 4837 www.sadag.org
Families South Africa (FAMSA)	021 447 7951 www.famsawc.org.za
Student Wellness Center	021 650 1017 http://www.dsa.uct.ac.za/student-wellness/counseling-services/overview

Appendix E

Borg's Rating of Perceived Exertion (RPE) Scale

6	No exertion at all
7	
	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	

17 Very hard

18

19 Extremely hard

20 Maximal exertion

Borg's RPE Scale Instructions:

While exercising we want you to rate your perception of exertion, i.e., how heavy and strenuous the exercise feels to you. The perception of exertion depends mainly on the strain and fatigue in your muscles and on your feeling of breathlessness or aches in the chest.

Look at this rating scale; we want you to use this scale from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion".

9 corresponds to "very light" exercise. For a normal, healthy person it is like walking slowly at his or her own pace for some minutes.

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Don't underestimate it, but don't overestimate it either. It's your own feeling of effort and exertion that's important, not how it compares to other people's. What other people think is not important either. Look at the scale and the expressions and then give a number.

Any questions?

Appendix F

Modified Consensus Sleep Diary (M-CSD)

COMPLETE BEFORE BEDTIME								
Start date:	**Example day** Monday PM	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
Today was a work/ school / off / sick day:	Work							
What time and for how long did you nap or doze today?	17h30 20min							
How many products with caffeine did you have today? And at what time(s)?	3 7am, 10am, 3:30pm							
How many alcoholic drinks did you have today? What time was the last one?	2 8:30pm							
What did you eat for breakfast today? And at what time?	Oats 7am							
What did you eat for lunch today? And at what time?	Cheese sandwich 12:30pm							

What did you eat for dinner today? And at what time?	Spaghetti bolognaise 7:00pm							
What snacks did you eat today? And at what time?	Apple, nuts 10am, 3pm							
How many nicotine products did you have today What time was the last one?	3 7:30pm							
Note any medication, supplements or drugs you took today: (e.g. over-the counter or prescription medications, recreational drugs, homeopathic formulations, vitamins)	**Name:** Panado Dose: 500mg Time: 13h35	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:
	Name: Multivitamin Dose: 1 caps Time: 07h00	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:
	Name: Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:	**Name:** Dose: Time:
Note any illness / symptoms you had today:	I had a cold and headache							

Note any exercise session you did today (type, time):	Gym 18h30-19h30							
Note your exercise session rating of perceived exertion (RPE)	5							
COMPLETE IN THE MORNING								
	Example day Tuesday AM	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
Last night, I got into bed at:	10pm							
Last night I tried to go to sleep at (lights out, eyes closed):	10:20pm							
I woke up for the last time this morning at (eyes open, lights on)**:**	6am							
Was this a typical night? (Yes or No)	Yes							

FAQs and GENERAL INSTRUCTIONS

What is a Sleep Diary? An instrument designed to gather information about your daily sleep patterns and possible factors which might affect your sleep.

How often and when do I fill out the Sleep Diary? Please complete your sleep diary every day for either 7 or 14 days (depending on what has

been asked of you). The "Complete before bedtime" section should be completed before you go to bed at night. The "Complete in the morning" section should be completed within one hour of getting out of bed in the morning.

What should I do if I miss a day? If you forget to fill in the Sleep Diary or are unable to finish it, leave the diary blank for that day.

What if something unusual affects my sleep or how I feel in the daytime? If you experience an unusual event (such as an illness, or an emergency) on a given day, you may wish to make brief notes in the "Additional Comments" section below.

Use the guide below to clarify what is being asked for each item of the Sleep Diary.

1. **Today was a work/ school / off / sick day:** Please note whether or not you worked or went to school/college/university today. Off-days may include weekend days, public holidays, sick days.
2. **What time and for how long did you nap or doze**? A nap is a time you decided to sleep during the day, whether in bed or not in bed. "Dozing" is a time you may have nodded off for a few minutes, without meaning to, such as while watching TV. Note all the times you napped or dozed from when you first got out of bed in the morning until you got into bed again at night. If you did not nap, write "N/A" (not applicable).
3. **How many products with caffeine did you have today? And at what time(s)?** Record the total number of food or drink products containing caffeine you had today (e.g. coffee, coffee beans, tea, soft drinks, energy drinks, dark chocolate, gels or bars with caffeine). Note the time(s)-of-day you consumed each caffeinated product. If you did not eat or drink anything containing caffeine, write "N/A".
4. **How many alcoholic drinks did you have today? What time was the last one?** Record the total number of drinks containing alcohol you had today, where 1 drink is defined as 1 can of beer (330ml), 1 glass of wine (150ml) or 1 shot of liquor (40ml). Note the time-of-day of your last drink. If you did not drink alcohol, write "N/A".
5. **What did you eat for breakfast today? And at what time?** Record what you ate for breakfast today. If you did not eat anything, write "N/A".

6. **What did you eat for lunch today? And at what time?** Record what you ate for lunch today. If you did not eat anything, write "N/A".
7. **What did you eat for dinner today? And at what time?** Record what you ate for dinner today. If you did not eat anything, write "N/A".
8. **What snacks did you eat today? And at what time?** Record what snacks you ate today. If you did not eat anything, write "N/A".
9. **How much nicotine did you have today? What time was the last one?** Record the total number of nicotine containing products you had today. (e.g. cigarettes). Note the time-of-day of your last nicotine product. If you did not use nicotine, write "N/A".
10. **Note any medication, supplements or drugs you took today** (e.g. over-the counter or prescription medications, recreational drugs, homeopathic formulations, vitamins): Record any over-the counter or prescription medications, recreational drugs, homeopathic formulations or vitamins/minerals that you used – whether usual or once-off. Record the name, dose and time you took each product today.
11. **Note any illness / symptoms you had today:** Please note down any illness and / or symptoms you experienced during this day. If you did not experience any illness/symptoms, write "N/A".
12. **Note any exercise session you did today** (type, time): Record the type of exercise session you did today (e.g. walk, hike, yoga, gym, run, swim, tennis etc) as well as time-of-day you started and ended the session. If you did not exercise, write "N/A".
13. **Note your exercise session rating of perceived exertion (RPE): Record your RPE for the exercise session you did today. If you did not exercise, write "N/A".**
14. **Last night, I got into bed at:** This is the time you physically get into bed, perhaps to read, but are not yet trying to sleep.
15. **Last night I tried to go to sleep at** (lights out, eyes closed): Record the time that you began "trying" to fall asleep (i.e. lights out and eyes closed).
16. **I woke up for the last time this morning at** (eyes open, lights on)**:** Record the time you woke up in the morning to begin your day (i.e. lights on and/or eyes open, you are no longer trying to sleep).
17. **Was this a typical night** (Yes or No): Note whether this night was representative of what you usually experience.

SESSION RATING OF PERCEIVED EXERTION (RPE) INSTRUCTIONS:

Approximately 30 minutes after your training session, answer the following question using the scale down below:
How was your workout?

Look at the scale and the expressions and then give a number.

RATING OF PERCEIVED EXERTION (RPE) SCALE:

Rating	Descriptor
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	-
7	Very Hard
8	-
9	-
10	Maximal

ADDITIONAL COMMENTS (Please feel free to make additional notes about the week here)**:**

Appendix G

Pre-screen Participant Information Sheet and Informed Consent Form

Title of Study: Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults

Dear Participant,

We are pleased to invite you to take part in an online screening survey. This is the first phase of a lab-based study being conducted by a Masters and two Honours students in the Department of Psychology at the University of Cape Town (UCT). Please read this form carefully and ask any questions should you have any before continuing.

Purpose of the study: Briefly – we want to know whether a morning exercise training session can help us cope better during the day after a period of very poor sleep. This study will help us to learn how exercise influences our thinking processes (e.g. attention, memory etc.),mood and fight or flight response that are seen following partial sleep deprivation (getting less than a normal night's sleep for a few nights in a row).

Screening Procedure: The screening procedure involves filling in an online survey which should take about 20 minutes to complete. This survey will collect information relating to your personal details (e.g. name, surname, cellphone number, email address, age, sex), medical and training history, "chronotype" (i.e. your preferred time-of-day for thinking, sleeping and being active) sleep difficulties, psychological symptoms and substance use (alcohol and drugs). I will then contact you to inform you of whether or not you are eligible for this study. If you are eligible to take part in the actual study and you are still interested in further participation, you will be told about the next step in the process. Even if you are not eligible, we will still provide you with personal feedback regarding your sleep, circadian rhythms and mental health based on the screening questionnaire.

Study overview: The study consists of a screening and sleep deprivation phase. You will be required to complete an online screening questionnaire (explained above). If you are deemed eligible and willing to participate, you will advance to sleep deprivation phases of the study.

The sleep deprivation phases will be conducted at the Sleep Science Laboratory at the Division of Physiological Sciences, UCT. It is best explained by the diagram below! But in case you prefer words: You will be required to attend the lab on three occasions.

Consent and familiarisation (±2h; in lab):

- Sign the consent form
- Have your height and weight measured, and practise the cognitive test battery
- Do running test on a treadmill to establish your maximum heart rate

Lead-in week (To check your sleep and activity habits over 7 days):

- Wear a small watch and keep a diary to log your sleep, exercise and dietary habits
- Do baseline tests (cognitive, mood and heart rate variability) - researchers will come to the place you are staying for the testing session (±1.5h)

Sleep deprivation phase 1 (4 days; last night and following day in lab):

- Three consecutive nights of partial sleep deprivation (70%, 60% and 50% of your usual sleep length). First two nights at home, third night in the lab.
- Day after night three: You will remain in the lab for the day as we repeat the baseline tests at three time points (15min, 5h and 10h after usual wake time). On this day, you will also do either a 40min treadmill run, or sit quietly for 40min in the morning after the first test battery.

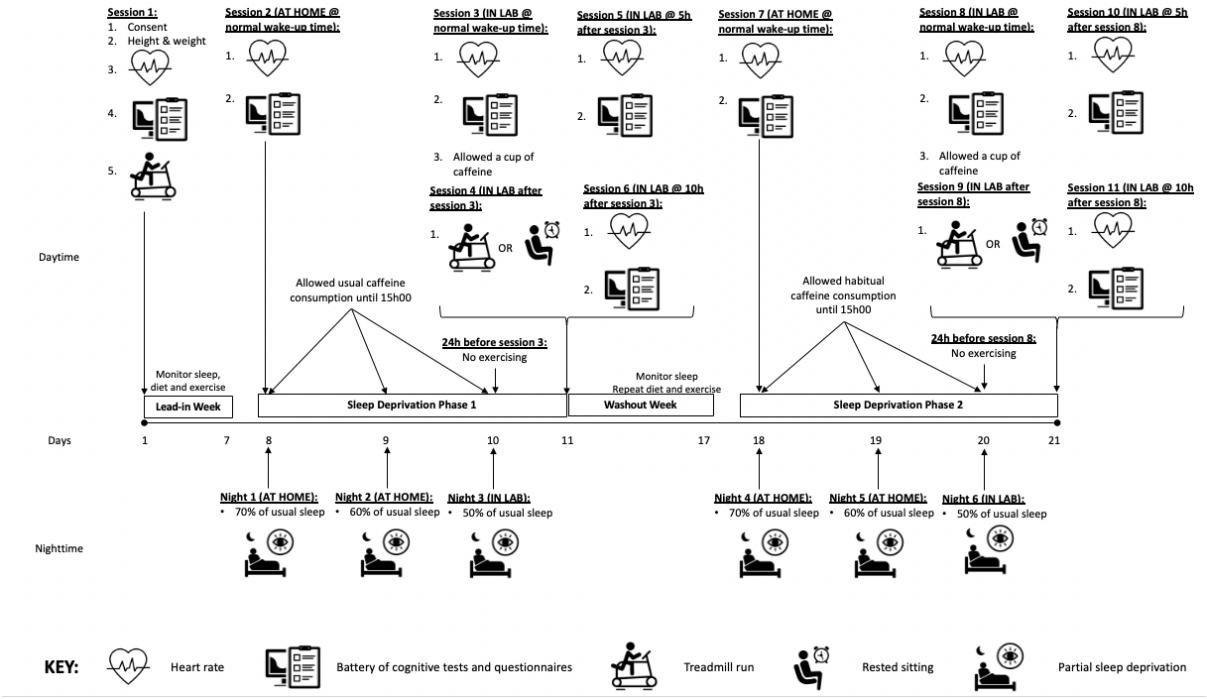
Wash out week (To recover and return to your usual sleep patterns)

- Wear a small watch and keep a diary to log your sleep, exercise and dietary habits again
- Do baseline tests (cognitive, mood and heart rate variability) again - researchers will come to the place you are staying for the testing session (±1.5h)

Sleep deprivation phase 2 (4 days; last night and following day in lab):

- Another three consecutive nights of partial sleep deprivation (70%, 60% and 50% of your usual sleep length). First two nights at home, third night in the lab.
- Day after night three: You will remain in the lab for the day as we repeat the baseline tests at three time points (15min, 5h and 10h after usual wake time). On this day, you will also do either a 40min treadmill run, or sit quietly for 40min in the morning after the first test battery.

See the diagram below for an overview of the study:



Possible Risks: There are no major risks associated with completing the online screening survey. However, you may feel uncomfortable as some of the questions are of a personal nature. If you are experiencing feelings of discomfort or distress, you may immediately withdraw participation without any consequences. If anything distresses you, please feel free to contact any of the resources below. You are also more than welcome to contact me directly if you would like to chat more.

- SADAG at 011 234 4837 or www.sadag.org
- FAMSA at 021 447 7951 or www.famsawc.org.za
- Student Wellness at 021 650 1017 or http://www.dsa.uct.ac.za/student-wellness/counseling-services/overview
- 24-hour UCT Student Careline at 0800 24 25 26 (free from a Telkom line) or SMS 31393 for a “UCT student call-me-back" service
- A private psychologist if you have one

Possible Benefits: There are no direct benefits for participating in the study, however, the data gathered from this study will help us to understand whether exercise is a possible strategy to combat the effects of partial sleep deprivation.

Confidentiality: All information gathered from this survey will be kept confidential. This means that the answers you provide will be kept in secure computer files on a password-protected laptop. Only the researcher and their supervisors have access to your personal information (e.g. name, surname and contact details like your cellphone number and email

address) and other responses collected. Your name and contact details will not be used in the research records, only your participant identification number.

Voluntary Participation/Withdrawal: Participation in this screening procedure is completely voluntary. You are allowed to change your mind and decide to withdraw from the study at any point in time. There will be no consequences if you do so.

Questions: If you have any questions or comments about the study before, during or after participation, please feel free to contact the following individuals:

Celine le Roux at 073 945 5923 or lrxcel003@myuct.ac.za

Jessica Vaughan at 074 704 3561or vghjes001@myuct.ac.za

Heshaam Jappie at 078 510 7220 or jpphes001@myuct.ac.za

Alternatively, you may contact my supervisor, Dr Gosia Lipinska, at gosia.lipinska@uct.ac.za or my co-supervisor, Dr Dale Rae, at dale.rae@uct.ac.za.

If you have any questions about your rights as a research participant or feel that there were any ethical violations or other research misconduct, you can raise your concerns by contacting Rosalind Adams at rosalind.adams@uct.ac.za or 021 650 3417 at the Department of Psychology.

Consent to Participate in this Research Study: By clicking "I agree", I confirm that I have read and understood this entire consent form, including the potential risks and benefits involved, and I agree to t complete this screening questionnaire to determine my eligibility for this research study. I am aware that my participation is entirely voluntary and that I am allowed to withdraw from the study at any point in time without any consequences. I hereby give permission for the researchers to use the information that is collected in the screening phase. A copy of this consent form will you emailed to you to keep.

- I agree
- I do not agree

Appendix H

Screening Debrief Form

Dear <Name>,

Thank you for completing this online survey. Unfortunately you do not meet all the criteria necessary to participant in this study and therefore are not eligible for further participation. We thank you for showing interest in participating in this study and taking the time to fill out the screening survey.

Remember that all the information you have provided will remain confidential meaning that only the researcher and their supervisors will have access to your identifying information such as your name, surname and contact details and survey responses.

We would like to send you feedback relating to your personal sleep and mental health states, based on your responses to the screening questionnaire. This we will email to you shortly.

If you experienced any feelings of discomfort or distress while answering the survey, please feel free to contract any of the resources below. You are also more than welcome to contact me (see below for contact details) directly if you would like to chat more.

- SADAG at 011 234 4837 or www.sadag.org
- FAMSA at 021 447 7951 or www.famsawc.org.za
- Student Wellness at 021 650 1017 or http://www.dsa.uct.ac.za/student-wellness/counseling-services/overview
- 24-hour UCT Student Careline at 0800 24 25 26 (free from a Telkom line) or SMS 31393 for a “UCT student call-me-back" service
- A private psychologist if you have one

If you have any questions or comments, please feel free to contact Celine le Roux, at 073 945 5923 or per email at LRXCEL003@myuct.ac.za, Jessica Vaughan at 074 704 3561or per email at vghjes001@myuct.ac.za or Heshaam Jappie at 078 510 7220 or per email at jpphes001@myuct.ac.za. Alternatively, you may contact my supervisor, Dr Gosia Lipinska, at gosia.lipinska@uct.ac.za or my co-supervisor, Dr Dale Rae, at dale.rae@uct.ac.za. If you feel that there were any ethical violations or other research misconduct you can raise your concerns by contacting Rosalind Adams at rosalind.adams@uct.ac.za or 021 650 3417 at the Department of Psychology, UCT.

Kindest regards,

Celine le Roux (Researcher)

Heshaam Jappie (Co-researcher)

Jess Vaughan (Co-researcher)

Dr Gosia Lipinska (Supervisor)

Dr Dale Rae (Co-supervisor)

Appendix I

Participant Information Sheet (Sleep Deprivation Phases)

Title of Study: Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults

Dear Participant,

We are pleased to invite you to take part in this research study. Please read this form carefully and ask us any questions before you agree to be in the study. This study is being conducted by a Masters student and two Honours students in the Department of Psychology at the University of Cape Town (UCT).

What is the purpose of this study?

Briefly – we want to know whether a morning exercise training session can help us cope better during the day after a period of very poor sleep. This study will help us to learn how exercise influences our thinking processes (i.e. attention, memory etc.), mood and fight or flight response following partial sleep deprivation (getting less than a normal night's sleep for a few nights in a row).

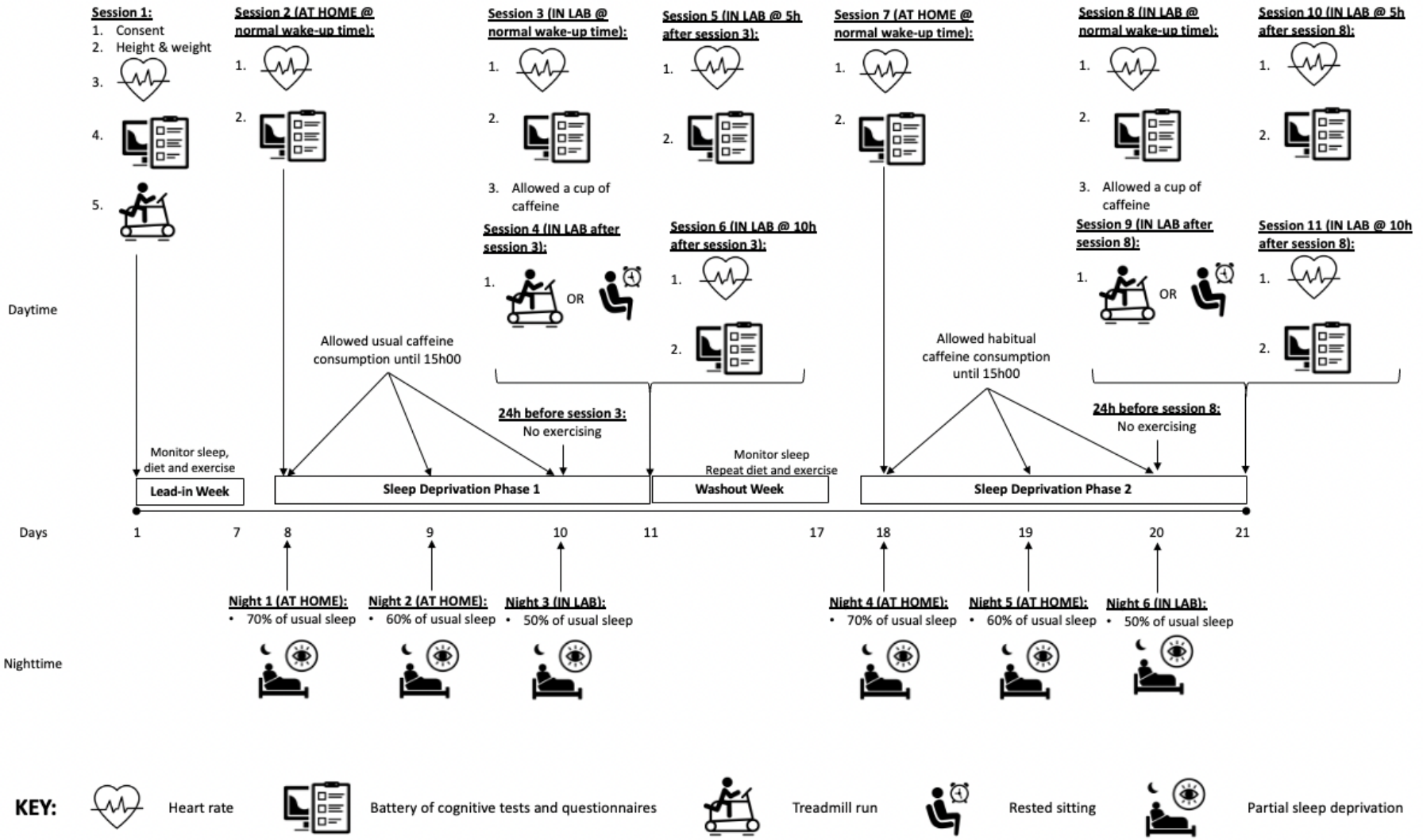
How long will this study last?

This study will span about 3 weeks. The study consists of (1) Consent and familiarisation (±2h), (2) Lead-in week (7 days), (2) Sleep deprivation phase 1 (4 days), (3) Washout week (7 days) and (4) Sleep deprivation phase 2 (4 days).

What does the study entail?

Below is a diagram summarising the study procedure. For a more detailed explanation, see the text below the diagram.

Overview of study:



Consent and familiarisation session:

We will carefully explain all aspects of the study to you and you will have the opportunity to ask any questions you might have. Should you choose to take part, we will ask you to sign a consent form. You will then complete a battery of cognitive tests and afterwards we will measure your height and weight. After this, you will do running test on a treadmill to establish your maximum heart rate. We will progressively increase the speed and inclination of the treadmill to challenge you maximally. During the test, we will measure your heart rate continuously (using a chest heart rate strap) and ask you to rate your exertion (i.e. effort) every minute during the run. The test will end when you feel you are no longer able to keep going. We will then give you a small watch and diary to wear for the duration of your enrolment in the study to wear so that we can monitor your sleep, exercise and dietary habits.

Lead-in and washout weeks:

The lead-in week precedes Sleep Deprivation phase 1 and the washout week separates sleep deprivation phases 1 and 2. During the lead-in and washout weeks, you should follow your usual routine and practises as they relate to sleep, work, exercise and diet. You should aim for your usual bedtime and wake-up time especially for the last night of the lead-in and washout week. We will ask you to record your exercise sessions, meals, snacks, caffeine and alcohol use in a diary. In the wash-out week, we will ask that you try to replicate (as best as possible) these behaviours.

Sleep deprivation phases 1 & 2:

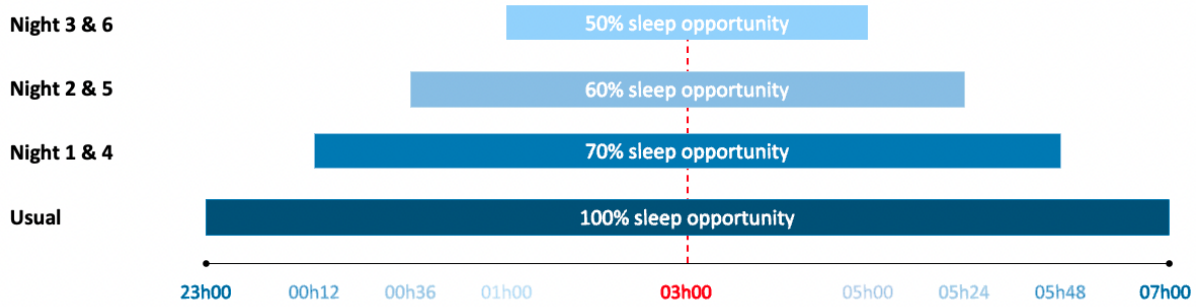
Phases 1 and 2 follow the same procedures. There is one exception: in one of the phases you will do a submaximal exercise session on the treadmill (40min at 90% of maximum heart rate, with 5x1min speed intervals); while in the other phase you will not do the exercise session, instead you will sit quietly for 40min.

On the mornings after the lead-in week (day 8) and the washout week (day 18), one of the researchers will come to where you are staying to do an at-home testing session (sessions 2 and 7) which will take place within 15min of your usual wake-up time. This session will take approximately 1.5h to complete. First you will complete a mood questionnaire. Then you will sit quietly for 10 minutes so that we can measure

your heart rate variability following which you will rate your sleepiness. Thereafter you will do a battery of cognitive tests; during one of these test we will again measure your heart rate variability. Your three nights of sleep deprivation will commence following these sessions.

For the three sleep deprivation nights in each phase you will be allowed to sleep for 70%, 60% and 50% of the time that you usually sleep. On all three nights, the midpoint of your sleep will be the same as for your usual sleep, but we will progressively shorten your sleep by making bedtime later and wake-up time earlier. Take a look at the figure below to visualise what this might look like for a person who usually goes to sleep at 23h00 and wakes up at 07h00.

Bedtime and wake up time example:



A researcher will contact you via WhatsApp, Telegram or SMS 1h before your bedtime and give you a call 30min before your bedtime to make sure you are still awake. In the morning, a researcher will give you a call as you are scheduled to wake up and send you message via WhatsApp, Telegram or SMS 1h later to check-in on you. You will be required to stay in the lab on Nights 3 and 6 (arrive 2h before you set bedtime) where a researcher will stay up with you, but also so that we can commence post-sleep deprivation testing early the next morning.

There are three important things to note about the sleep deprivation phases:

1. During the days between Nights 1 and 2, 2 and 3, 4 and 5, 5 and 6, you are allowed to consume the same amount of caffeine that you would usually use, but this must be before 15h00 each day.

2. We ask that you keep your eating and alcohol use as close to your usual habits as possible in this time.
3. You are not allowed to do any form of exercise during the days between Nights 2 and 3, and 5 and 6.

The day after nights 3 and 6 will be spent in the lab and comprise of four testing sessions (sessions 3-6 for phase 1 and sessions 8-11 for phase 2). Sessions 3, 5, 6, 8,10 and 11 will be an exact repeat of sessions 2 and 7, which you completed at home following the lead-in and wash-out weeks. Sessions 3 and 8 will take place within 15 minutes of your usual wake-up time. Sessions 4 and 9 will take place immediately after sessions 3 and 8, during which you will either run on the treadmill for 40 minutes or stay seated for 40 minutes. Sessions 5, 10 and 6, 11 will take place 5h and 10h, respectively, after usual wake-up time. After session 11, you would have completed the entire study. There are a few important things to note about the two testing days in the lab:

1. You will be allowed 1 cup of caffeine immediately after sessions 3 and 8 (if you habitually use caffeine) but no more throughout the rest of the day.
2. You will be asked to bring in your own food (dinner, breakfast, lunch and snacks) and drinks for each phase.
3. We suggest that you bring in something to keep yourself occupied (e.g. work or a book) between testing sessions.

After completing phase 2, you will be debriefed about the study. You will also be able to ask any questions you might be left with and we'll provide you with your own personal feedback at the end of the entire study.

What are the possible risks?

There are no major risks associated with completing the study. However, the six partial sleep deprivation nights may cause discomfort (three nights for each phase). During this time, you will be in contact with the researchers. After a normal night of sleep, the discomfort will subside. Additionally, sleeping in an environment that you are unfamiliar with may feel uncomfortable. Great precautions will be taken to ensure your safety and comfort. The sleep laboratory is situated in a secure building and equipped with a proper bed, clean bedding, and restrooms.

A strict COVID protection protocol will be implemented to ensure your and the investigator's safety. Upon each lab visit, you will undergo COVID screening. The venue will be sanitised and thoroughly cleaned between and during testing procedures.

You will be required to run on the treadmill however the risk of sustaining an injury is very minimal.

What happens if I get injured during the study?

This research study is covered by an insurance policy taken out by the University of Cape Town if you suffer a bodily injury because you are taking part in the study. The insurer will pay for all reasonable medical costs required to treat your bodily injury, according to the SA Good Clinical Practice Guidelines 2006, which are based on the Association of the British Pharmaceutical Industry Guidelines. The insurer will pay you without you have to prove that the research was responsible for your bodily injury. You may ask the researcher for a copy of these guidelines. Please note that the insurer will not pay for harm if, during the study, you:

- Use medicines or other substances that are not allowed
- Do not follow the researcher's instructions
- Do not tell the researcher that you have or experience any bad side effects from the study procedures
- Do not take reasonable care of yourself during the study procedures

If you are harmed and the insurer pays for the necessary medical costs, usually you will be asked to accept that insurance payment as a full settlement of the claim for medical costs. However, accepting this offer of insurance coverage does not mean you give up your right to make a separate claim for other losses based on negligence, in a South African court. It is important to follow the researcher's instructions and to report straight away if you have or experience any side effects from participating in the study.

What are the possible benefits?

There are no direct benefits for participating in the study, however, the data gathered from this study will help us to understand whether exercise is a possible strategy to combat the effects of partial sleep deprivation.

Are there any costs to take part in this study?

You will be asked to bring in your own food and drinks for each phase of the study. There are no other costs that you need to cover.

Will I receive compensation?

You will receive R750 for each lab visit you attend. Therefore, if you complete the entire study (i.e. both lab visits) you will receive R1 500 remuneration for your time and travel.

How will the information collected from me be kept a secret (confidential) in order to protect my privacy?

All information gathered from the screening questionnaire and the actual study will be kept confidential. This means that the answers you provide will be kept in secure computer files on a password-protected laptop. Only the researcher and their supervisors have access to your personal information (e.g. name, surname and contact details like your cellphone number and email address) and other responses collected. Your name and contact details will not be used in the research records, only your participant identification number. Your research records will not be released without your permission unless required by law or a court order.

Can I withdraw from this study?

Participation in this study is completely voluntary. You are allowed to change your mind and decide to withdraw from the study at any point in time. There will be no consequences if you do so. However, please note that any information collected prior to withdrawal may still be used.

Questions:

If you have any questions or comments about the study before, during or after participation, please feel free to contact Celine le Roux, at 073 945 5923 or per email at LRXCEL003@myuct.ac.za, Jessica Vaughan at 074 704 3561or per email at vghjes001@myuct.ac.za or Heshaam Jappie at 078 510 7220 or per email at jpphes001@myuct.ac.za. Alternatively, you may contact my supervisor, Dr Gosia Lipinska, at gosia.lipinska@uct.ac.za or my co-supervisor, Dr Dale Rae, at dale.rae@uct.ac.za.

If you feel that there were any ethical violations or other research misconduct you can raise your concerns by contacting Rosalind Adams at rosalind.adams@uct.ac.za or 021 650 3417 at the Department of Psychology.

Appendix J

Informed Consent Form (Experimental Phase)

By signing this form, I, _____, confirm that I have read and understood the entire participant information sheet, including the potential risks and benefits involved, and have been fully informed about the study entitled "Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults".

I hereby give permission for the researchers to use the information that is collected in the screening phase and actual study for research purposes. I understand that all the information gathered, including personal and contact details, will be kept confidential and will not be released without my permission unless required by the law or a court order.

I am aware that my participation is entirely voluntary and that I am allowed to withdraw from the study at any point in time without any consequences.

I agree to take part in this research study.

You will receive a copy of this consent form to take home.

_____ _____

Signature of Participant Date

_____ _____

Signature of Person Obtaining Consent Date

_____	_____
Printed Name of Person Obtaining Consent	Time

Appendix K
Debriefing form

You have completed your participation in the study titled “Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults”. You spent two non-consecutive nights in the sleep lab where you were partially deprived and performed a bout of running the one visit and sat quietly the other visit. There were also multiple test sessions where you completed numerous cognitive tasks designed to measure your attention span, memory etc. and were asked to answer various questions about your mood and sleepiness. Your results will help us to learn more about how exercise influences the cognitive (i.e. mental processes such as attention, memory etc.) and mood effects that are seen following partial sleep deprivation (getting less than a normal night’s sleep) as well as to contribute to this body of research.

It was hypothesized that:

1. After partial sleep deprivation, participants will display diminished performance on measures of attention, reaction time, working memory, inhibition and neutral declarative memory, and report lowered mood in comparison to baseline (i.e. a night of habitual sleep); and
2. After partial sleep deprivation followed by a bout of moderate intensity aerobic exercise, participants will display enhanced performance on measures of attention, reaction time, working memory, inhibition and neutral declarative memory, and report enhanced mood in comparison to when they did not perform a bout of moderate intensity aerobic exercise following PSD (i.e. control condition).

Remember that all the information that you provided during this study will be kept private and confidential.

Thank you for your participation in this study!

If you have any further questions or comments, please feel free to contact me, Celine le Roux, at 073 945 5923 or per email at LRXCEL003@myuct.ac.za, Jessica Vaughan at 074 704 3561or per email at vghjes001@myuct.ac.za, or Heshaam Jappie at 078 510 7220 or per email at jpphes001@myuct.ac.za. Alternatively, you may contact my supervisor, Dr Gosia Lipinska, at gosia.lipinska@uct.ac.za or my co-supervisor, Dr Dale Rae, at dale.rae@uct.ac.za.

If you experienced any feelings of discomfort or distress from any aspect of this study, please feel free to contract any of the resources below. You are also more than welcome to contact me (see below for contact details) directly if you would like to chat more.

- SADAG at 011 234 4837 or www.sadag.org
- FAMSA at 021 447 7951 or www.famsawc.org.za
- Student Wellness at 021 650 1017 or http://www.dsa.uct.ac.za/student-wellness/counseling-services/overview
- 24-hour UCT Student Careline at 0800 24 25 26 (free from a Telkom line) or SMS 31393 for a “UCT student call-me-back" service
- A private psychologist if you have one

If you have any complaints or questions about your rights and welfare or if you feel that there were any ethical violations or other research misconduct you can raise your concerns by contacting the Human Research Ethics Committee at hrec-enquiries@uct.ac.za or 021 650 1236.

Appendix L

Receipt of Reimbursement Form

Study: Investigating the effects of exercise on cognitive performance, mood and heart rate variability following partial sleep deprivation in healthy adults

I, (name and surname) _____ confirm receiving R750 reimbursement for participation in phase 1 of this study.

Signature: _____

Date:_____

I, (name and surname) _____ confirm receiving R750 reimbursement for participation in phase 2 of this study.

Signature: _____

Date:_____

Appendix M

Ethical Approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room G50- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec.enquiries@uct.ac.za
Website: www..health.uct.ac.za/fhs/research/humanethics/forms

13 October 2021

HREC REF: 553/2021

Dr G Lipinksa
Department of Psychology
Rm 2.04 PD Hahn Building
Email: gosia.lipinska@uct.ac.za
Student: lrxcel003@myuct.ac.za

Dear Dr Lpinska

PROJECT TITLE: EXERCISE AS A STRATEGY TO MITIGATE THE NEGATIVE COGNITIVE AND MOOD EFFECTS OF PARTIAL SLEEP DEPRIVATION IN HEALTHY ADULTS (MASTER'S DEGREE – MISS CELINE LE ROUX)

Thank you for your response letter, addressing the issues by the Faculty of Health Sciences Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

This approval is subject to strict adherence to the HREC recommendations regarding research involving human participants during COVID -19, dated 17 March 2020; 06 July 2020 & 01 July 2021.

Approval is granted for one year until the 30 October 2022.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Miss Celine le Roux will also be involved in this study.

Please quote the HREC REF 553/2021 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

UNIVERSITY OF CAPE TOWN

Department of Psychology

University of Cape Town Rondebosch 7701 South Africa
Telephone (021) 650 3417
Fax No. (021) 650 4104

06 July 2021

Celine Le Roux
Department of Psychology
University of Cape Town
Rondebosch 7701

Dear Celine

I am pleased to inform you that ethical clearance has been given by an Ethics Review Committee of the Faculty of Humanities for your study, *Exercise as a strategy to mitigate the negative cognitive and mood effects of partial sleep deprivation in healthy adults*. The reference number is PSY2021-023.

I wish you all the best for your study.

Yours sincerely

Lauren Wild (PhD)
Associate Professor
Chair: Ethics Review Committee

Faculty of Humanities
Postgraduate Administration
University of Cape Town

Room 110, Beattie Building
Private Bag X3, Rondebosch 7701
Tel: +27 (0) 21 650 4175
E-mail: Kerewin.Parfitt@uct.ac.za
Website:http://www.humanities.uct.ac.za/hum/postgraduate/studies/aboutus/overview

13-08-2021

Miss Celine le Roux
E-mail:LRXCEL003@myuct.ac.za
Student no: LRXCEL003

Dear Miss Celine le Roux,

ACCEPTANCE OF MASTERS PROPOSAL BY HUMANITIES FACULTY BOARD

I have pleasure in advising that your research proposal as detailed below has been approved by the Department, and the Faculty of Humanities in the Dean's Circular HUM 06/2021.

Kind regards
Kerewin.Parfitt@uct.ac.za
Miss Kerewin Parfitt
Faculty of Humanities: Postgraduate Office

cc Supervisor: Dr G Lipinska and Dr D Rae

CANDIDATE	STUDENT NO.	DEPT	SUPERVISOR	CO-SUPERVISOR	TITLE
le Roux, C	LRXCEL003	PSY	Dr G Lipinska	Dr D Rae	Exercise as a strategy to mitigate the negative cognitive and mood effects of partial sleep deprivation in healthy adults