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EFFECTS OF EARLY OR LATE-EVENING FATIGUING PHYSICAL ACTIVITY ON SLEEP QUALITY IN NON-PROFESSIONAL SPORTSMEN

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Abstract

Aims: This study aims to understand whether night sleep-quality is distorted by fatiguing physical activity (PA) when conducted early or late in the evening.

Methods: Participants and Intervention: 9 males (18-38yrs) performed sessions of fatiguing-PA over 3 consecutive days (Mon-Wed), for 2 weeks. One week the PA was performed at 17h, and in the other week at 21h. A Control-week included no PA (PA_{ABSENT}). The fatiguing-PA sessions comprised several sets of the 20m Shuttle-Run-Test (20mSRT). Sleep was assessed by actigraphic recordings acquired over 3 nights each week. It included the nights following the PA-sessions and the same days in the week of PA_{ABSENT}. Sleep-quality perception was evaluated by mean of the National Sleep Foundation-Sleep Diary. The heart-rate (HR) and body-temperature (BT) at bed-time and waking-up were also registered.

Results: Neither the 20mSTR-estimated VO_{2max} nor the number of maximal 20mSRT sets were different in the PA_{17h} and PA_{21h} sessions. Compared to the PA_{ABSENT}, the PA_{17h} and PA_{21h} sessions increased the HR at bedtime, which recovered to baseline level after the night of sleep. BT was also reduced when waking-up compared to bed-time, but this was also observed in PA_{ABSENT}. Sleep parameters measured by means of actigraphy were not modified by fatiguing activity when compared to $PA_{ABSENT.}$ Nevertheless, the subjective perception of sleep-quality was negatively altered by fatiguing PA.

Conclusions: Fatiguing PA performed early or late at the evening has no impact on objective sleep-quality but, subjectively, a deterioration of sleep-quality is perceived by the subjects.

Key words: Physical Activities; Sleep; Fatigue

Introduction

The relation between physical activity (PA) and sleep has been studied from different perspectives, mainly trying to understand how sleep quality influences PA physiological processes [1-3]. On the other side, PA is recommended in a number of diseases in which sleep disturbances are major signs [4-7]; nonetheless, the effect of some PA features on sleep seems not to have been fully investigated. For instance, the time of the day at which the PA is performed might impact on sleep quality. This is why the American Academy of Sleep Medicine (AASM) recommends absence of vigorous exercise close to bed-time [7], but this point might have mixed support [8, 9]. In this regard it has recently been shown that high intensity cycloergometer or treadmill PA in a laboratory setting did not distort sleep, as assessed by actigraphy [9] and polysomnography [8]; and such effect also seems to be unrelated to exercise duration [9].

Taking into account the proliferation of public and private sport facilities which offer high intensive PA programs late in evening for non-professional sportsmen, it is of interest to know the effects of fatiguing PA on sleep when studied within the daily living activities, away from laboratory settings, in non-professional sportsmen. It is also important to consider the effect of the same activity scheduled earlier in the evening, to compare both to the absence of PA [8].

Therefore, our study included a group of young non-professional sportsmen and was conducted so that the subjects kept all their daily activities unmodified. Sleep assessments (actigraphy and sleep diary) were performed in their own homes. Our hypothesis was that late-evening fatiguing PA distorts sleep quality compared to early-evening fatiguing PA, or PA absence.

Materials and Methods

Subjects

12 healthy males initiated the study (18-38 yrs). All subjects were used to performing exercise about 3 times per week, for at least one hour per day, but none were professional sportsmen. 3 subjects experienced muscle cramps or sprains due to the high intensity of the protocols. 9 subjects performed all the scheduled sessions and were included in the study the analyses.

All subjects were screened for incompatibilities with high intensity exercise by means of the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire [10], and were informed about the nature and risks of the maximal effort protocol. Subjects consented to participate in the study, which conformed to the Declaration of Helsinki and was approved by the Ethics Committee of the University of A Coruña.

Fatiguing Physical Activity Protocol

The protocol involved the evaluation of the effect of early and late evening fatiguing PA on sleep quality (Figure 1). Sleep parameters (see below) were recorded by means of actigraphic sensors during 3 consecutive days and nights (from Monday to Wednesday). The experimental blocks (organized in weeks) included the execution of fatiguing PA at 17h (PA_{17h}), fatiguing PA at 21h (PA_{21h}), and Control condition (lack of PA; PA_{ABSENT}); the order of the weeks was randomized. Subjects refrained from performing any other

PA the day of testing, but also from consuming any food, drink or drug known to affect the arousal state. They were not allowed to take a nap on the days of testing.

Fatiguing PA

The fatiguing PA was the *20m Shuttle Run Test* (20m-SRT) [11-13], and subjects executed several sets of the 20m-SRT each PA session (Figure 1). Briefly, for each set, subjects were asked to cover 20m as many times as possible (shuttle-way) at increasing velocities. Velocity feed-back was provided by auditory signals progressively more frequent, so that subjects had to increase their running velocity to cover the 20m in time with the auditory signals, until subjects could not keep up with the velocity demands. The start velocity of the test was 8.5 km/h (Stage 1) which was increased by 0.5 km/h every minute (subsequent Stages).

The subjects completed up to 5 sets of the 20mSRT each day (see Fig. 1 for details of the protocol). Periods of 6 min rest between sets, during which subjects walked and hydrated, were allowed. The number of sets executed during each day of the 2nd week of PA was the same as during the 1st week.

A light standardized warm-up was scheduled each day before the first 20m-SRT set. The subjects performed 15 min of active joint mobilization. No stretching was allowed before or during the protocol, but it was standardized at the end of each session.

Sleep quality evaluation

The Actiwatch system (Actiwatch, CamNtech Ltd., Cambridge, UK) registered the sleep parameters. Actigraphy is useful for the assessment of sleep quality [14] and its use has been validated in reference to polysomnography [15]. Actiwatch recordings are based on registration of movement by the means of a piezo-electric accelerometer (built into the wrist-watch-like device), sampled at 0.5Hz. Determination of sleep and wakefulness relies on an algorithm which looks at each data point and its surroundings (Cambridge NeuroTech Ltd.). Subjects wore the Actiwatch attached to the wrist of the non-dominant hand for a period of three days and three nights during each of the experimental weeks (Control PA_{ABSENT}, PA_{17h}, PA_{21h}). Participants were instructed to press the Actiwatch button when turning lights off and again when getting out of bed. Subjects woke-up with alarm clock-watches, at their usual daily schedule. In addition, to obtain an estimation of subjective sleep quality (see below), the National Sleep Foundation Sleep Diary (NSFSD [16-18]) was filled in.

Objective Sleep Assessment

Actigraphic variables considered (all their units are defined in the figures):

- Sleep latency: Latency before sleep onset following bed-time.

- Sleep efficiency: Percentage of time spent asleep whilst in bed.

- Movement and fragmentation index: It is an indicator of restlessness, defined as the addition of “ the percentage time spent moving” and “the percentage immobility phases of 1 minute”; where the “percentage time spent moving” is the percentage of time moving while assumed sleep (so higher during poorer sleep), and “the percentage of immobility phases of 1 minute” is the percentage of immobility phases lasting up to 1 min with regards to the total number of immobility phases (so again higher, means poorer sleep).

Subjective Sleep Assessment, NSF diary

After each night, the subjects rated how the sleep quality of the previous night was self-perceived [16-18], reporting if they felt "Refreshed", "Somewhat Refreshed", or "Fatigued". Due to ethical reasons, subjects were not asked to report their sexual activity before bed-time.

Effect of fatiguing PA on basal Heart Rate and body temperature

The heart rate (HR) and the body temperature (BT) were registered at bed-time, and after waking up, before getting out of bed. Temperature values were recorded (3 times, 1 min apart) by means of a digital skin thermometer. The subjects also self-recorded their HR for 30s, (3 times, 1 min apart). When this procedure was performed at bed-time, it was done after 10 minutes spent recumbent on the bed. At waking up, it was done before getting out of bed. Subjects were instructed on the procedure before starting the experiments to obtain good to excellent intra-subjects test-retest reliability.

Environmental conditions during PA sessions

The temperature and the relative humidity in the air were recorded at the beginning and at the end of each of the PA sessions by means of an electronic Thermo-Hygrometer LUFFT-E200. The mean was calculated for every session.

The experiments were conducted at a time of the year when it dusked between 20.10h and 18.00h in A Coruña (Spain).

Statistical Analysis

Physical performance during the 20mSRT

All subjects performed the same number of sets of the 20mSRT for each of the days of the PA_{17h} and the PA_{21h}. Therefore, for each subject, we computed the mean maximal oxygen consumption (VO_{2max}) across all sets, for the three days of PA_{17h} and the PA_{21h}. Then we compared whether the mean VO_{2max} in the PA_{17h} sessions differed from that of the PA_{21h} days by means of a Student T-test, after normality checking (Kolgomorov-Smirnov test for one sample (KS test). Provided all subjects were adult males, the VO_{2max} was defined as 2.75 x Number of Half Stages Completed in the 20mSRT + 28.8,[19].

Environmental conditions

The mean temperature at PA_{17h} and PA_{21h} were compared by using a Student's t Test, after normality checking. The same procedure was followed for the level of humidity on air.

Impact of fatiguing PA on Sleep Quality

The impact of fatiguing PA on Sleep Quality was analyzed with an $ANOVA_{RM}$ test with repeated measures, after checking normality. The same model, explained below, was repeated for the three sleep variables evaluated: Sleep Latency, Sleep Efficiency and Fragmentation Index.

Initially, we analyzed whether the quality of sleep was impaired along the days by a putative effect of fatigue accumulation day after day of PA. For this, the ANOVA included two within-factors: factor PA_{HOUR}, accounting for the time of the day when PA was taken (PA_{17h} or PA_{21h}) and DAY (the first and the last days of PA). The analysis revealed (see results section) that the sleep parameters did not worsen at the third day of PA vs. the first. Therefore, for the subsequent analyses, we averaged the recordings from the three nights, either for PA_{17h} and PA_{21h}, and these analyses also included the average value of the three days with no PA (PA_{ABSENT}).

Then, to compare the effect of PA_{17h} and PA_{21h} on sleep quality, in relation to $PA_{ABSENT,}$ we performed an $ANOVA_{RM}$. The only within-subjects factor was the kind of PA, which included three levels (PA_{ABSENT}, PA_{17h} and PA_{21h}).

Impact of fatiguing PA on actigraphic variables in the first hours of sleep

It has been reported that maximal PA executed late in the evening impacts on autonomic responses (HR) during the three first hours of sleep[9]. For this reason we evaluated if actigraphic sleep parameters were modified during the three first sleep hours after PA protocols. We performed an ANOVA, similar to that mentioned above, but including a factor allowing the evaluation of the sleep quality in the 1st, 2nd and 3rd first-hours after bed-time. The variable sleep latency was not analyzed with this last ANOVA model, because in all the cases the sleep latency parameter is included within the first hour of sleep.

Association between sleep quality and time elapsing from PA to bed-time

We performed a correlation analysis to evaluate a putative association between the time taken from the moment activity started (17h or 21h) to the bed-time, and how this lag-period was related to the actigraphic variables evaluated. For this, Pearson's correlation coefficients were calculated.

Impact of fatiguing PA on Subjective Sleep Quality (NSF-Diary)

Finally we evaluated the sleep quality perception reported by the subjects. The difference on how the subjects felt after sleep ("Refreshed", "Somewhat Refreshed", or "Fatigued") was analyzed as a function of the kind of PA in the preceding evening (PA_{ABSENT}, PA_{17H}, and PA_{21H}). This was done by means of a 3x3 Chi-Square. If significant, follow-up One-way Chi-Square was performed for each kind of PA. The analysis included the absolute frequencies, even though they were expressed as percentages in the results section.

Normality of distribution was assessed of by means of the K-S test for one sample. During the ANOVA analysis, the sphericity was assessed by means the Mauchly's Test, and, if in violation, the degrees of freedom were corrected by Greenhouse-Geisser coefficients. In all cases the differences were considered significant if $p<0.05$.

Results

Physical Performance and Environmental Conditions

The mean temperature and the level of air humidity during the sessions at 17h and 21h were not significantly different, $t_{10.712}=0.527$ $p=0.609$, and $t_{16}=0.338$ $p=0.740$, respectively. The three days mean temperature was 20.7ºC (SEM 0.3) at PA_{17h} and 21.0ºC (SEM 0.6) at PA_{21h}. The mean level of air humidity in the three days of PA was 56.1% (SEM 5.7) during PA_{17h}, and 59.3 (SEM 7.7) for PA_{21h}.

Under these environmental conditions the estimated mean VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) was not significantly different for the PA_{17h} and PA_{21h} sessions, $t_8=1.088$ $p=0.308$ (50.8 SEM 1.0 for the PA_{17h} sessions; and 51.4 SEM 1.1 for the PA_{21h} sessions), and the subjects executed the same number of 20mSRT sets both weeks (Fig. 2a).

Sleep Evaluation

The subjects took longer to go to the bed after PA_{17h} (vs. PA_{21h}), $t_8=20.984$ $p<0.001$ (498.5 min SEM 15.4 vs. 275.9 SEM 12.1), but they remained in bed a comparable number of minutes regardless which set of nights were evaluated $F_{2,16}=0.412$ $p=0.669$. Thus the subjects remained in bed a mean of 413.4min SEM 10.7 after the three days of PA_{ABSENT}; 410.1min SEM 13.2 after PA_{17h}; and 399.8 SEM 19.4 after PA_{21h}.

Lack of worsening of objective sleep quality with the progression of the PA sessions

Afterwards, we analyzed if fatigue accumulation with progression of PA sessions impacted sleep quality. Its putative effect was not observed for any sleep variable. The example of the Sleep Latency (with the smaller p-value) shows that the difference between the 1st and 3rd days of PA was not significant $F_{1,8}=1.931$ $p=0.202$, and this was not different for PA_{17h} or PA_{21h} $F_{1,8}=0.492$ $p=0.503$.

Effect of fatiguing PA on objective sleep evaluation

The analysis (averaging the three consecutive days of PA) shows that Sleep Efficiency was not significantly different between PA_{ABSENT}, PA_{17h} and PA_{21h} $F_{2,16}=0.503$ $p=0.614$ (Fig. 2b). The same is true for the Sleep Latency, $F_{2,16}=0.318$ $p=0.732$, and for the

Fragmentation Index, $F_{2,16}$=0.404 p=0.674 (Fig. 2cd). Thus, the fatiguing PA at 17h or 21h did not distort sleep quality compared to a day without PA.

If focusing on the three first hours of sleep time, the Fragmentation Index was not different for PA_{ABSENT}, PA_{17h} and PA_{21h}, $F_{2,16}$=1.057 p=0.371, and this was not different for the first, the two first, or the three first hours of sleep $F_{4,32}=0.264_{\varepsilon=0.467}$ p=0.757 (Fig. 3a). The same was true for the Sleep Efficiency: it did not depend of PA, $F_{2,16}$=0.528 $_{\varepsilon=0.591}$ p=0.525; and this was not different for the first, the two first or the three first hours of sleep $F_{4,32}$=0.260 $_{\varepsilon=0.365}$ p=0.902 (Fig. 3b).

Association between the time-lag from the fatiguing PA and sleep quality

None of scores of the three objective sleep quality variables was significantly associated to the time elapsing from the fatiguing PA to the time of going to bed (CC=-0.14 p=0.317 for Fragmentation Index; CC=0.04 p=0.774 for sleep latency; and CC=0.09 p=0.514 for sleep efficiency).

Heart Rate and Body Temperature before and after Sleep

We found a trend showing the HR to be different at waking-up and bed-time, depending on the kind of PA, $F_{2,16}$=3.008 p=0.078. We therefore performed follow-up analysis split by PA, showing that for PA_{17h} and PA_{21h} the HR's were significantly higher compared to PA_{ABSENT} at bed-time (p=0.023; and p=0.016 respectively), but no differences were observed between PA_{17h} and PA_{21h} (p=0.278). At wake-up time, the significant differences were absent, therefore HR recovered over night (Fig. 3c).

On the other hand, the night-sleep reduced the body temperature significantly, $F_{1,8}$=14.381 p=0.005; notwithstanding this pattern was not different as a function of the

PA, $F_{2,18}$=1.348 p=0.288 (i.e. the BT was always lowered at waking-up compared to the time of getting bed; Fig. 3d).

Effect of fatiguing PA on subjective sleep quality during the night following exercise

Finally, Figure 4 shows the different proportion in the rates of perceived sleep quality. A 3x3 Chi-square analysis showed a significant effect of the kind PA on the proportions of the sleep quality ratings. Subsequent One-Way Chi-square, split by kind of PA, showed that the subjects perceived a refreshing sleep after PA_{ABSENT}, which was distorted if fatiguing PA was executed before going bed (Fig. 4).

Discussion

This work shows that objective sleep quality is not distorted by fatiguing PA. Interestingly, subjects subjectively perceived a lack of refreshing sleep after early or late-evening fatiguing PA. These results enlarge previous reported effects of late-evening fatiguing PA on sleep quality [8, 9], and add new (and complementary) data including the effect of the same kind of activity in an earlier-schedule. Based on our results, recommendation of the AASM to avoid high intensity exercise late in the evening cannot be supported [8, 9].

However, the lack of objective sleep distortion subsequent to fatiguing PA is not matched if evaluated subjectively. Subjective sleep quality is reported while subjects are awake; so it is possible that sleep quality is poorly rated in the mornings after PA because subjects have not fully recovered from PA. For instance, subjects might be experiencing delayed physical manifestations related to high intensity exercise, like delay onset muscle soreness [20, 21]. In agreement with this possibility, there are reports indicating that physiological adaptations after fatiguing activity are maintained during sleep without distorting its quality [22]. It seems also relevant the role of the PA intensity and duration on sleep quality, previously 1set PA at 75% of the VO_{2max} did not distort subjective sleep quality, if PA was executed 5h prior to bed time [9], however, our protocol included several sets of maximal intensity PA. Our results are based, exclusively, on the different schedule of the PA, controlling the number of sets executed in both protocols (the same), and their maximal intensity. Notwithstanding, the high intensity of PA might have an impact on outcomes; thus, an improvement in sleep patterns after PA if light in intensity [6] might not have been revealed in our protocol due to the higher intensity of the PA.

PA raised the HR at rest after activity [8]. Body temperature decreased significantly throughout the night-time [23], but this was observed regardless of the presence of fatiguing PA in the preceding day, thus resembling a classic circadian profile. An earlier study had suggested that an increase in the BT subsequent to PA had a sleep-inducing effect [24], but the time-lag to bed time in this study was shorter than in our study. Finally, despite our results support the view that high intensity PA does not distort sleep quality, there might be some un-addressed variables related to fatiguing PA with a significant impact on sleep quality. Thus, the emotional load in our protocol and other studies [8, 9] is hardly comparable to that induced by fatiguing PA with an emotional reward, such as an Olympic or Championship medal event. Stressful events have an impact on sleep quality [25], so this aspect might deserve further research.

Conclusions

Fatiguing PA, performed early or late in the evening, has not a distorting effect on sleep quality if assessed objectively, but it does impact self-reported sleep parameters. Further research is needed in order to clarify whether AASM recommendations on avoiding intensive PA close to bed-time are grounded on a known physiological substrate or, conversely, if this kind of activity does not distort a good sleep at night.

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TITLE OF FIGURES

Figure 1. Protocol. Sleep was evaluated over three consecutive nights, each following a fatiguing PA session. PA sessions were performed from Monday to Wednesday, for three weeks. In one of the weeks subjects performed the fatiguing PA at 17h, in another week at 21h. A control-week included absence of PA, and the order was randomized. Sleep evaluations included Actigraphic recordings throughout night and day, and a sleep diary; the HR and BT were also recorded, both at bed-time and at waking-up. The fatiguing PA comprised the execution of several sets the 20mSRT. During each day of the first week of PA, the subjects perform up to 5 sets of the 20mSRT (with a 6 min inter-set rest interval); the progression of the sets was cancelled when the performance in a given set was below the 80% of the previous best, within the session. In all cases, one set included the execution of the 20mSRT to the point when subjects could not keep up with the velocity demands. Velocity was controlled by an auditory beep of increasing frequency, pacing the time allowed to cover the 20m. The physiological impact of the PA_{17h} and PA_{21h} weeks was controlled, so that the amount of sets performed during each of the three days in the first PA week was repeated in the second PA week.

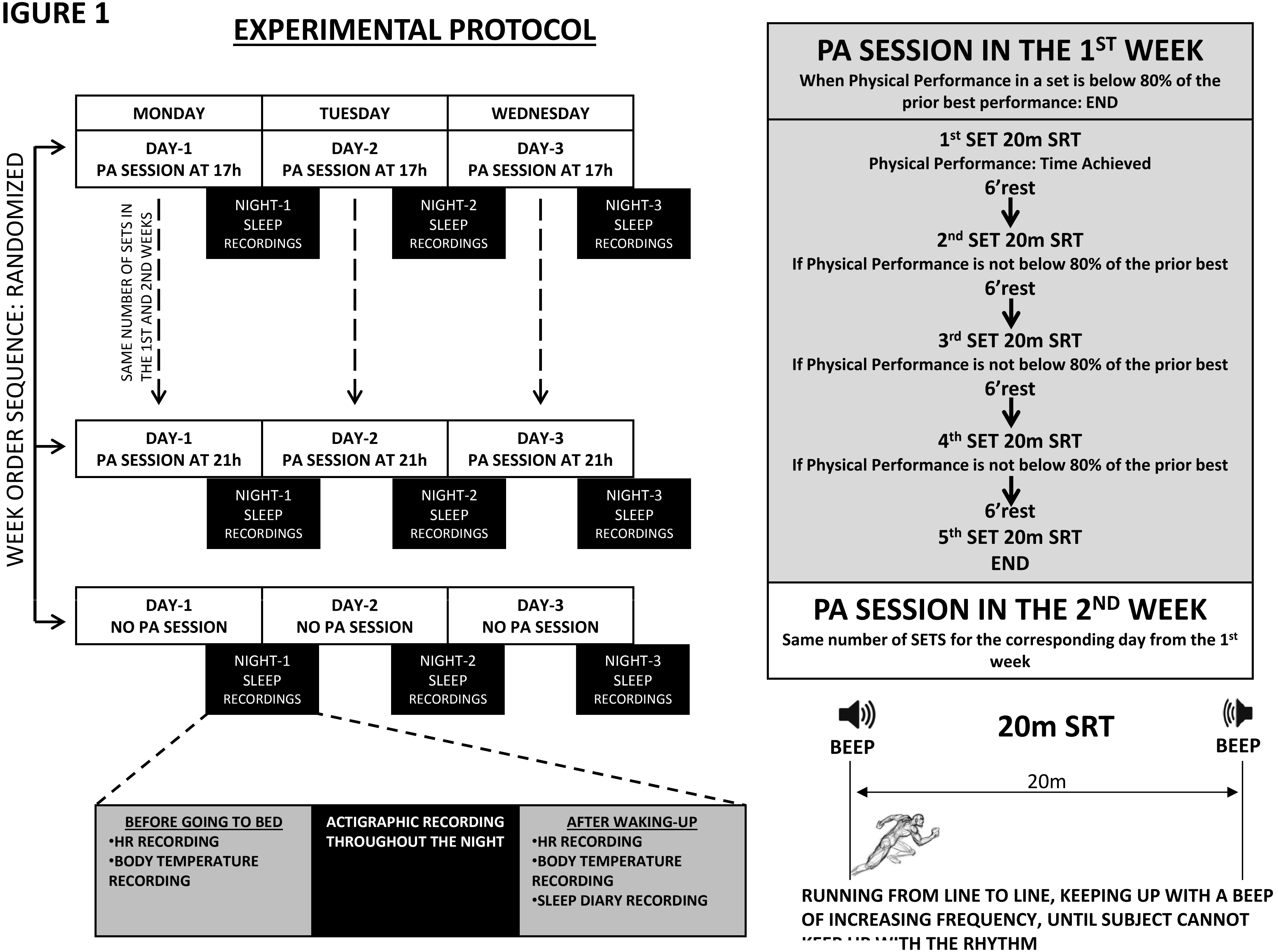
Figure 2. Amount of fatiguing sets executed by each subject and effect of fatiguing PA on objective sleep quality parameters. a) Number of fatiguing 20mSRT executed by each subject on the three days of testing. The same number of sets was performed in the PA_{17h} and $PA_{21h.}$ **b)** The efficiency of sleep was not influenced by fatiguing PA sessions at 17h or 21h, if compared to lack of PA. **c)** The sleep latency was not significantly changed by the fatiguing PA. **d)** The movement and fragmentation index, indicator of sleep restlessness, was not significantly different in the three conditions evaluated.

Figure 3. Effect of fatiguing PA on objective sleep quality parameters in the three first hours of sleep, and on Heart Rate and Body Temperature at bed-time and waking up. Neither the Sleep Efficiency **a)**, nor the Movement and Fragmentation Index **b)** were significantly impacted by taking fatiguing PA at 17h or 21h, compared to PA absent. In all the three conditions, the Sleep efficiency was lower within the first hour of sleep-time. The HR **c)** was significantly increased at bed-time after fatiguing PA; and this was observed regardless of whether sessions had been performed at 17h or 21h (with a lack of significant difference between them). However, at waking up, all differences were not significant. **d)** The body temperature was not significantly different at bed-time if comparing days with or without PA. For all kinds of PA, however, BT reduced overnight, to become significantly different at the moment of waking up compared to the bed-time.

Figure 4. Effect of fatiguing PA on subjective sleep quality. Subject's sleep quality perception differed depending on the kind of PA prior to sleep $\chi2(4)=23.14$ $p<0.001$. Subsequent analysis for each kind of PA (statistics within the corresponding circle) reflects than if PA was absent a significantly greater proportion of subjects perceived

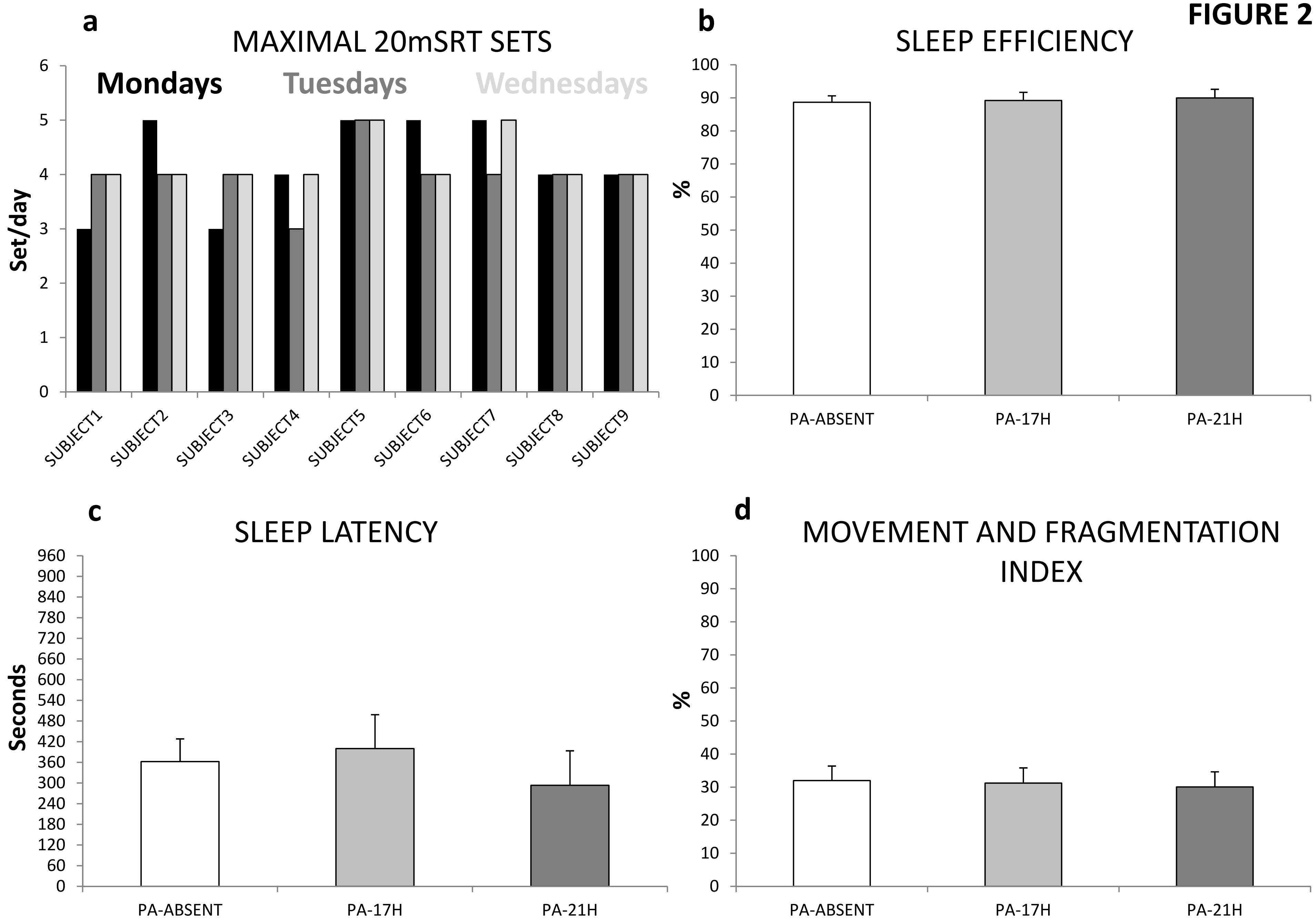
their sleep was refreshing. This was not the case if the sleep night was preceded by fatiguing PA. Each whole circle represents 100% of the nights tested for each condition.

FIGURE 1



EXPERIMENTAL PROTOCOL
WEEK ORDER SEQUENCE: RANDOMIZED
MONDAY
TUESDAY
WEDNESDAY
DAY-1
PA SESSION AT 17h
DAY-2
PA SESSION AT 17h
DAY-3
PA SESSION AT 17h
NIGHT-1 SLEEP RECORDINGS
NIGHT-2 SLEEP RECORDINGS
NIGHT-3 SLEEP RECORDINGS
SAME NUMBER OF SETS IN THE 1ST AND 2ND WEEKS
DAY-1
PA SESSION AT 21h
DAY-2
PA SESSION AT 21h
DAY-3
PA SESSION AT 21h
NIGHT-1 SLEEP RECORDINGS
NIGHT-2 SLEEP RECORDINGS
NIGHT-3 SLEEP RECORDINGS
DAY-1
NO PA SESSION
DAY-2
NO PA SESSION
DAY-3
NO PA SESSION
NIGHT-1 SLEEP RECORDINGS
NIGHT-2 SLEEP RECORDINGS
NIGHT-3 SLEEP RECORDINGS
BEFORE GOING TO BED
•HR RECORDING
•BODY TEMPERATURE RECORDING
ACTIGRAPHIC RECORDING THROUGHOUT THE NIGHT
AFTER WAKING-UP
•HR RECORDING
•BODY TEMPERATURE RECORDING
•SLEEP DIARY RECORDING
PA SESSION IN THE 1ST WEEK
When Physical Performance in a set is below 80% of the prior best performance: END
1st SET 20m SRT
Physical Performance: Time Achieved
6'rest
2nd SET 20m SRT
If Physical Performance is not below 80% of the prior best
6'rest
3rd SET 20m SRT
If Physical Performance is not below 80% of the prior best
6'rest
4th SET 20m SRT
If Physical Performance is not below 80% of the prior best
6'rest
5th SET 20m SRT
END
PA SESSION IN THE 2ND WEEK
Same number of SETS for the corresponding day from the 1st week
BEEP
20m SRT
BEEP
20m
RUNNING FROM LINE TO LINE, KEEPING UP WITH A BEEP OF INCREASING FREQUENCY, UNTIL SUBJECT CANNOT
TH THE RHYTHM

FIGURE 2



a
MAXIMAL 20mSRT SETS
Mondays
Tuesdays
Wednesdays
Set/day
0
1
2
3
4
5
6
SUBJECT1
SUBJECT2
SUBJECT3
SUBJECT4
SUBJECT5
SUBJECT6
SUBJECT7
SUBJECT8
SUBJECT9
b
SLEEP EFFICIENCY
%
0
10
20
30
40
50
60
70
80
90
100
PA-ABSENT
PA-17H
PA-21H
c
SLEEP LATENCY
Seconds
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
PA-ABSENT
PA-17H
PA-21H
d
MOVEMENT AND FRAGMENTATION INDEX
%
0
10
20
30
40
50
60
70
80
90
100
PA-ABSENT
PA-17H
PA-21H

FIGURE 3

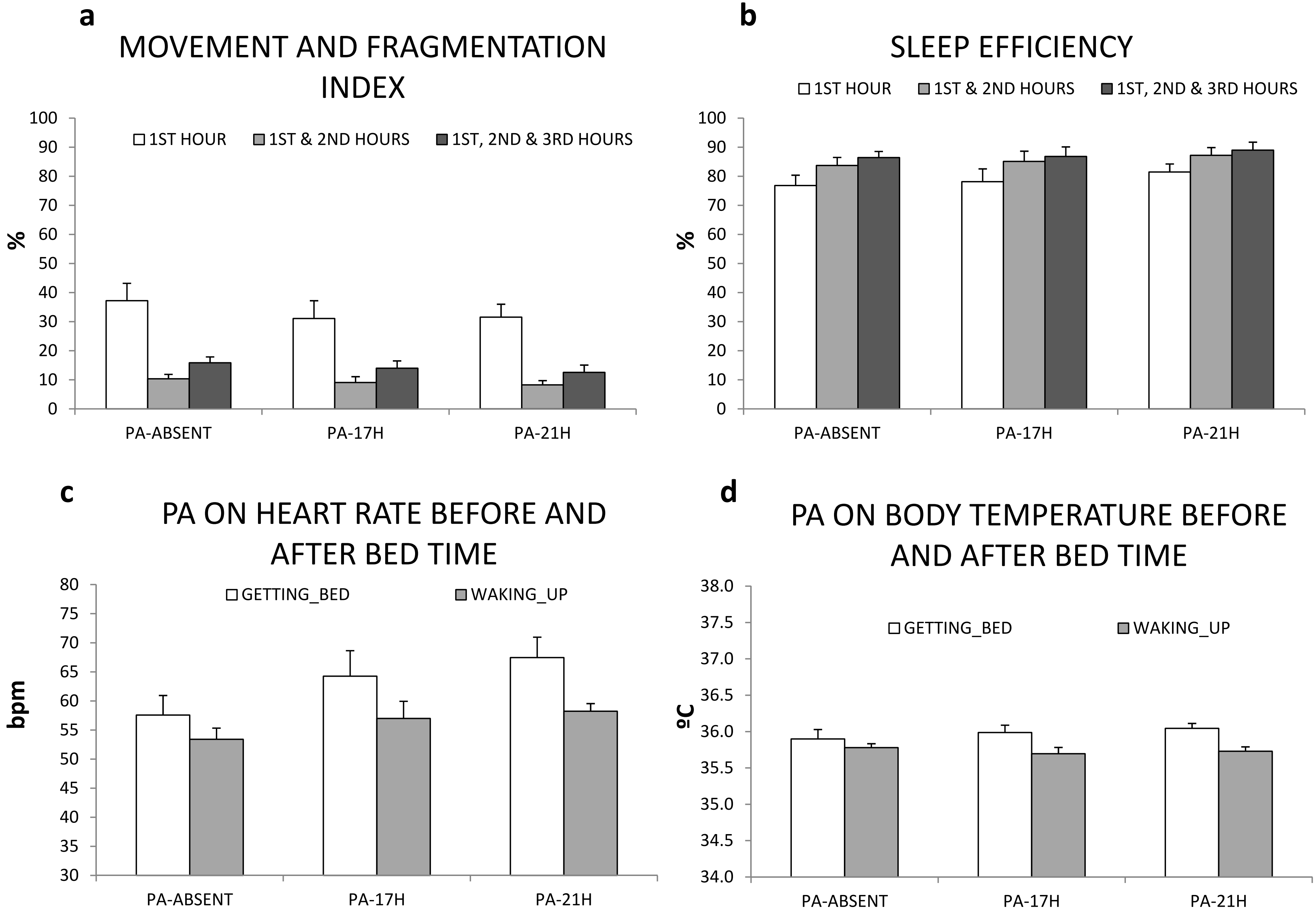

a
MOVEMENT AND FRAGMENTATION INDEX
1ST HOUR
1ST & 2ND HOURS
1ST, 2ND & 3RD HOURS
%
100
90
80
70
60
50
40
30
20
10
0
PA-ABSENT
PA-17H
PA-21H
b
SLEEP EFFICIENCY
1ST HOUR
1ST & 2ND HOURS
1ST, 2ND & 3RD HOURS
%
100
90
80
70
60
50
40
30
20
10
0
PA-ABSENT
PA-17H
PA-21H
c
PA ON HEART RATE BEFORE AND AFTER BED TIME
GETTING_BED
WAKING_UP
bpm
80
75
70
65
60
55
50
45
40
35
30
PA-ABSENT
PA-17H
PA-21H
d
PA ON BODY TEMPERATURE BEFORE AND AFTER BED TIME
GETTING_BED
WAKING_UP
ºC
38.0
37.5
37.0
36.5
36.0
35.5
35.0
34.5
34.0
PA-ABSENT
PA-17H
PA-21H

FIGURE 4

SUBJECTIVE SLEEP QUALITY PERCEPTION.
SELF-PERCEPTION AFTER SLEEP SUBSEQUENT TO PA