Letter to the Editor

Sleep duration regularity as a predictor of the cardiovascular response to acute exercise

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High-intensity exercise represents a challenge for the cardiovascular system, especially under conditions of insufficient sleep. For example, following one night of partial sleep restriction, healthy young men exhibited increased heart rate, minute ventilation, and plasma lactate concentration during submaximal and maximal exercise compared to one night of normal sleep [1]. In addition to sleep duration, day-to-day variability in sleep duration has emerged as a possible risk factor for cardiovascular outcomes (e.g. poorer microvascular function [2]). However, whether sleep duration regularity predicts exercise-induced changes in heart rate, blood pressure, and perceived exertion is unclear. Thus, in the present study, we monitored sleep duration over 1 month before a standardized exercise test. Specifically, we included 18 healthy young adults without reports of sleep problems or cardiovascular complications at the time of investigation (age and body mass index [BMI] [mean ± SD]: 24.6 ± 3.1 years and 23.4 ± 3.2 kg/m²; eight females). The present study complied with the Declaration of Helsinki and was approved by the locally appointed ethics committee (DNR2016/398). Informed consent was obtained from the subjects.

Using a smartphone application (PACO, version 4.2.25, www.pacoapp.com), each participant documented their daily bed and wake times for 1 month (30 days) in real time, i.e. they entered exact times when they turned off the lights in the evening and woke up the following day. These smartphone time-stamped entries were used to approximate each participant’s sleep duration. The individual level of sleep duration regularity was measured by the interquartile range (IQR) of daily sleep duration during the 30-day observational period. Higher IQR values indicated a lower level of sleep regularity. Subjects did not receive any instructions regarding sleep. All participants reported good sleep quality during the observational 1-month period, as indicated by Pittsburgh Sleep Quality Index scores <6 [3].

On the day of exercise testing, subjects participated in the so-called YMCA 3-minute step test. As described elsewhere [4], the YMCA step test started with a 2-minute resting phase while subjects were seated on a chair, followed by a step up and down exercise on a 30-cm box (stepping rate of 24 steps per minute). The subject immediately stopped upon completing the test and then sat down and remained still for 1 minute. Heart rate (Actiheart; Cambridge Neurotechnology, Cambridge, United Kingdom) and brachial blood pressure (Medisana MTP Plus device, Medisana AG, Neuss, Germany) were measured at baseline (at the end of the 2-minute resting phase) and 1 minute post-exercise. At both time points, blood pressure and heart rate were measured three times, and the average of all readings was used. Additionally, before (at the end of the 2-minute resting phase) and 1 minute after the exercise test, the level of perceived exertion was assessed by the Borg Rating of Perceived Exertion scale (20 points indicating maximum exertion [5]). Finally, to evaluate general participants’ physical activity engagement, we asked them how many days they engaged in sweat-inducing physical activities (e.g. swimming and running) in the week before the exercise test. We additionally surveyed how many minutes per day they performed sweat-inducing exercise. Thus, we could estimate the total minutes spent on sweat-inducing exercise during the week before the exercise test (mean ± SD: 116 ± 184 minutes; min, max: 0, 600 minutes).

The 1-month mean for sleep duration, the 1-month IQR for sleep duration, and the sleep duration in the night before exercise testing were entered as predictors in a generalized linear model (SPSS 24.0, SPSS Inc., Chicago, IL). We additionally controlled the model for participants’ age, BMI, sex, and...
and perceived exertion from pre- to post-exercise (Table 1).

The more significant the increase in systolic blood pressure (i.e. indicating a higher degree of sleep duration irregularity), sleep duration during the month preceding the exercise test were observed (mean ± SD): heart rate: +5.9 ± 7.3 beats per minute (min, max: −6.0, +21.0); systolic blood pressure: +14.4 ± 50 minutes, 8 hours and 50 minutes, and the level of sleep duration regularity ranged from 0.86 to 2.23 across individuals (mean ± SD: 1.51 ± 0.41). On the night before exercise testing, sleep duration spanned from 4 hours 46 minutes to 8 hours 52 minutes (mean: 7 hours and 17 minutes). The following absolute changes from before to 1 minute after the YMCA step test were observed (mean ± SD): heart rate: +5.9 ± 7.3 beats per minute (min, max: −6.0, +21.0); systolic blood pressure: +14.4 ± 11.4 mm Hg (min, max: −2.0, +21.0); diastolic blood pressure: +3.8 ± 5.9 mm Hg (min, max: −5.0, +16.0); and perceived exertion: +2.1 ± 3.1 points (min, max: −6.0, +6.0). As revealed by the generalized linear model, the higher the IQR value for daily sleep duration during the month preceding the exercise test (i.e. indicating a higher degree of sleep duration irregularity), the more significant the increase in systolic blood pressure and perceived exertion from pre- to post-exercise (Table 1). No association of sleep duration regularity with heart rate and diastolic BP was found (Table 1). Finally, neither the 1-month mean sleep duration nor sleep duration in the night before the exercise test was a significant predictor of exercise-induced changes (Table 1).

To our best knowledge, our study is the first to suggest that a less stable sleep duration pattern in the month preceding the exercise challenge may be more strenuous for people with cardiovascular exhaustion, such as increased heart rate, in response to an acute bout of strenuous exercise [1]. If confirmed by future studies, our results could suggest that long-term sleep duration patterns may significantly predict a person’s subjective and systolic blood pressure response to an acute bout of exercise.

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References
1. Mougin F, et al. Effects of sleep disturbances on subsequent physical performance. *Eur J Appl Physiol Occup Physiol.* 1991;63(2):77–82.
2. Hoopes EK, et al. Sleep duration regularity, but not sleep duration, is associated with microvascular function in college students. *Sleep.* 2021;44(2). doi:10.1093/sleep/zsaa175
3. Buysse DJ, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 1989;28(2):193–213.
4. Golding LA, ed. *YMCA Fitness Testing and Assessment Manual.* 4th ed. Champaign, IL: Human Kinetics; 2000.
5. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982;14(5):377–381.