# Relationship between chronotype and pain threshold in a sample of young healthy adults

**Giulia Zerbini, Peter Justus Göller, Katharina Lembke, Miriam Kunz, Philipp Reicherts**

**Angaben zur Veröffentlichung / Publication details:**

Zerbini, Giulia, Peter Justus Göller, Katharina Lembke, Miriam Kunz, and Philipp Reicherts. 2023. "Relationship between chronotype and pain threshold in a sample of young healthy adults." *PAIN Reports* 8 (4): e1085. https://doi.org/10.1097/pr9.0000000000001085.

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# Relationship between chronotype and pain threshold in a sample of young healthy adults

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**Abstract**

**Introduction:** Chronotype indicates the biological preference for timing of activity and sleep. Being a late chronotype (ie, having a tendency for late sleep times) is associated with several mental and physical health problems. Previous studies found that late chronotypes are also more susceptible to chronic pain, but the relationship between chronotype and pain sensitivity remains unclear.
**Objectives:** The aim of this study was to investigate the relationship between chronotype and heat pain threshold (as an indicator of pain sensitivity) in a sample of young healthy adults.
**Methods:** We analyzed data from 316 young healthy adults participating in 4 different studies run at the Medical Faculty of the University of Augsburg. In all studies, chronotype and other sleep variables (eg, sleep duration) were assessed using the micro Munich ChronoType Questionnaire. Heat pain threshold was assessed with the method of adjustment.
**Results:** Chronotype was not significantly associated with the heat pain threshold. Entering the other sleep variables in separate regression models did also not significantly explain variance in heat pain threshold.
**Conclusion:** Our null findings are in contrast with previous notions that late chronotypes might be more sensitive to pain and more susceptible to chronic pain. Given the scarcity of the literature on this topic, more studies are needed to clarify the relationship between chronotype and pain sensitivity in different age populations, while also considering distinct pain modalities or other types of pain tests.

**Keywords:** Chronotype, Sleep, Pain, Pain threshold, Pain sensitivity

## 1. Introduction

Chronotype is defined as an individual's biological preference for timing of activity and sleep and ranges from very early (larks) to very late (owls) chronotypes.[21] There is a vast literature on the relationship between chronotype and physical/psychological health,[5] with increased health risk in late chronotypes. Reasons for such increased risk lie in a conflict between the circadian clock, involved in the regulation of the sleep–wake cycle, and the social clock, which determines our social schedules (social jetlag).[25] Of the many health indicators studied in the context of chronotype, pain has been quite neglected so far. Some studies have investigated the relationship between chronic pain and chronotype and found that late chronotypes seem to be more susceptible to pain symptoms.[3,11,26]

A link between chronotype and chronic pain could be direct (eg, late chronotypes are more sensitive to pain) or indirect (eg, late chronotypes are more likely to suffer from anxiety or depression,[1] which, in turn, could aggravate pain symptoms[14]). Here, we wanted to investigate whether chronotype per se is associated with heightened pain sensitivity. To the best of our knowledge, only one study has investigated the relationship between chronotype and experimental pain in healthy participants.[9] The authors recruited early and late chronotypes and found that the heat pain threshold of late chronotypes was significantly lower, thus indicating heightened pain sensitivity.

The aim of this study was to contribute to the scarce literature on this topic, by investigating the relationship between chronotype and experimental pain sensitivity (heat pain threshold) in a combined sample of healthy students. Given the relationship between sleep and pain (disturbed sleep usually resulting in more pain),[12,13,18] other sleep variables such as sleep duration and quality were also considered in the analyses.

*Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.*

*Department of Medical Psychology and Sociology, Medical Faculty, University of Augsburg, Augsburg, Germany*

**Corresponding author. Address: Department of Medical Psychology and Sociology, Medical Faculty, University of Augsburg, Stenglinstrasse 2, 86156 Augsburg, Germany. Tel.: +49(0)8215983620. E-mail address: giulia.zerbini@med.uni-augsburg.de (G. Zerbini).*



*PR9 8 (2023) e1085*

*http://dx.doi.org/10.1097/PR9.0000000000001085*

## 2. Methods

Between 2021 and 2022, 4 experimental pain studies were conducted in our laboratory (data have not been published so far). In all studies, chronotype, sleep, and pain threshold were assessed using the same procedures. The experimental protocols were all approved by the Ethics Committee of the University of Munich or Bamberg, Germany, and were conducted in accordance with the Declaration of Helsinki.

### 2.1. Participants

Participants were recruited by flyers or emails and were all students enrolled at the University of Augsburg. The following exclusion criteria were checked by a phone interview: no mental illnesses (in the past or currently), no sleep problems or use of sleep medications, and no (chronic) pain conditions or use of medications, which may affect pain processing for at least 24 hours prior the laboratory session. All participants signed an informed consent and received compensation for their participation.

### 2.2. Measures

#### 2.2.1. Assessment of pain threshold

Pain thresholds were assessed with the method of adjustment. Thermal stimuli were applied using different computerized thermal stimulators ($study_{1\&2}$: TSA II; $study_3$: Pathway CHEPS; $study_4$: TSA-200; all stimulators were purchased from Medoc Ltd, Ramat Yishai, Israel). Stimuli were applied either to the left lower leg ($study_{1\&2}$) or to the left inner forearm ($study_{3\&4}$) using a 3 × 3 $cm^2$ contact probe ($study_3$ diameter of 27 mm). Participants were instructed to adjust the temperature (starting from 38˚C) using heating and cooling buttons until they obtained a temperature that was perceived as being barely painful (pain threshold). A constant press of the buttons produced a heating or cooling rate of 0.5˚C/s. Participants underwent 5 trials, separated by an interstimulus interval (ISI) of about 30 seconds and the average of the last 4 constituted the threshold estimate. The experimental pain sessions were not evenly distributed across the day, with most of the sessions (63%) held in the morning (before 12:00 hours). Given that pain sensitivity has been shown to vary across the 24-hour day,[4,7] the time of day was controlled for in the statistical analyses. In addition, we compared the distribution of chronotypes between sessions taking place in the morning and afternoon (before or after 12:00 hours) to make sure that the chronotype distribution was similar across times.

#### 2.2.2. Assessment of chronotype and sleep

Chronotype, social jetlag, and sleep duration were assessed using the micro Munich ChronoType Questionnaire (microMCTQ).[6] Chronotype was calculated as the midpoint of sleep on work-free days (no alarm clock use) corrected for sleep debt accumulated on workdays ($MSF_{sc}$). If students do not report having workdays, sleep dept correction is not necessary (ie, chronotype = MSF). Social jetlag was calculated as the absolute difference between MSF and MSW (midpoint of sleep on workdays). Sleep quality (problems with sleep and daytime functioning) was assessed with the Athens Insomnia Scale for Non-Clinical Application (AIS-NCA)[22] only in $study_{3\&4}$.

### 2.3. Statistical analyses

Statistical analyses were performed using R software (version 4.0.5).[24] Pain threshold values were z-transformed to control for statistically significant differences between studies (see notes in **Table 1**). Linear regression models were run to assess the relationship between chronotype ($Model_1$), social jetlag and sleep duration ($Model_2$), and sleep quality ($Model_3$) as predictors and pain threshold as a dependent variable. Time of day was added as covariate. Frequentist analyses were complemented by Bayesian linear regression models implemented in JASP (Version 0.17.2),[10] applying a uniform prior [P(M)] of 0.25 for the comparison of $Model_1$ and $Model_3$ against the null model and of 0.0625 for the comparison of $Model_2$ against the null model, respectively. Bayes factor ($BF_{10}$) is reported for all models.

## 3. Results

### 3.1. Demographics

The total sample comprises 316 students (141 males and 175 females; mean age = 22.3 ± SD = 2.7 years). **Table 1** reports the demographics, average chronotype, social jetlag, sleep duration, sleep quality, and heat pain threshold for each study. Average chronotype did not differ between morning and afternoon test sessions ($P > 0.05$).

### 3.2. Chronotype, sleep, and pain threshold

Chronotype was not significantly associated with pain threshold (**Table 2** and **Fig. 1**). Given that studies on chronotype effects often compare only extreme early and late chronotypes, we reran the analysis with chronotype as dichotomous predictor (comparing earliest vs latest 25th percentiles), which did not change

**Table 1**

**Demographics (sex and age), average chronotype, social jetlag, sleep duration and quality, and heat pain threshold by study.**

| | N | Sex | Age | Chronotype (h) | Social jetlag (h) | Sleep duration workdays (h) | Sleep duration work-free days (h) | Sleep quality (1–5) | Pain threshold (˚C) |
|---|---|---|---|---|---|---|---|---|---|
| | | % females | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD |
| Study 1 | 63 | 52% | 22.0 ± 2.7 | 04:04 ± 00:53 | 01:09 ± 00:54 | 07:03 ± 01:14 | 08:06 ± 00:56 | — | 45.3 ± 0.4 |
| Study 2 | 53 | 55% | 21.5 ± 2.4 | 04:12 ± 01:13 | 01:03 ± 00:38 | 07:27 ± 01:04 | 08:21 ± 01:13 | — | 45.3 ± 0.6 |
| Study 3 | 158 | 57% | 23.0 ± 2.9 | 04:36 ± 01:05 | 01:12 ± 00:44 | 07:23 ± 01:05 | 08:14 ± 01:07 | 2.49 ± 0.52 | 44.3 ± 0.5 |
| Study 4 | 42 | 55% | 21.2 ± 1.7 | 04:42 ± 01:10 | 01:20 ± 00:35 | 07:20 ± 00:57 | 08:11 ± 00:57 | 1.25 ± 0.42 | 44.8 ± 0.6 |

Chronotype, social jetlag, and sleep duration were assessed by the micro MCTQ. Chronotype is reported in local clock time. Based on the classification by Roenneberg et al.,[20] 0.3% of our participants were extremely early, 1.3% moderately early, 13.3% slightly early, 28.3% intermediate, 35.3% slightly late, 15.3% moderately late, and 6% extremely late. Sleep quality was assessed by the AIS-NCA (scores range between 1 and 5, with higher scores indicating more problems with sleep and daytime functioning).

Pain thresholds of $study_1$ and $study_2$ did not significantly differ ($P > 0.05$). Pain thresholds of $study_3$ and $study_4$ were significantly lower compared with $study_1$ and $study_2$ (all $P < 0.0001$), and pain thresholds of $study_3$ were significantly lower compared with $study_4$ ($P = 0.0001$).

AIS-NCA, Athens Insomnia Scale for Non-Clinical Application; microMCTQ, micro Munich ChronoType Questionnaire

**Table 2**

**Linear regression model results—relationship between chronotype, sleep characteristics, and pain threshold.**

| Predictors | Pain threshold (z-score) | | | |
|---|---|---|---|---|
| | Estimates | 95% CI | t | P |
| Model 1 | | | | |
| Intercept | −0.15 | −0.93 to 0.62 | −0.39 | 0.695 |
| Chronotype (h) | 0.03 | −0.07 to 0.14 | 0.61 | 0.545 |
| Time of day (h) | 0.00 | −0.05 to 0.06 | 0.05 | 0.963 |
| Observations | 298 | | | |
| $R^2$ | 0.001 | | | |
| $P$ | 0.832 | | | |
| $BF_{10}$ | 0.030 | | | |
| Model 2 | | | | |
| Intercept | −0.03 | −1.28 to 1.23 | −0.04 | 0.966 |
| Social jetlag (h) | −0.07 | −0.26 to 0.12 | −0.70 | 0.485 |
| Sleep duration workdays (h) | −0.06 | −0.20 to 0.09 | −0.75 | 0.452 |
| Sleep duration work-free days (h) | 0.06 | −0.08 to 0.20 | 0.82 | 0.412 |
| Time of day (h) | 0.00 | −0.06 to 0.06 | 0.06 | 0.956 |
| Observations | 248 | | | |
| $R^2$ | 0.004 | | | |
| $P$ | 0.911 | | | |
| $BF_{10}$ | 0.004 | | | |
| Model 3 | | | | |
| Intercept | −0.12 | −0.99 to 0.74 | −0.29 | 0.775 |
| Sleep quality (AIS-NCA) | 0.01 | −0.20 to 0.22 | 0.05 | 0.957 |
| Time of day (h) | 0.01 | −0.08 to 0.10 | 0.26 | 0.792 |
| Observations | 196 | | | |
| $R^2$ | <0.001 | | | |
| $P$ | 0.956 | | | |
| $BF_{10}$ | 0.038 | | | |

$Model_1$ tests the relationship between chronotype and pain threshold. $Model_2$ tests the relationship between the other sleep variables and pain threshold. The variation in sample size between $Model_1$ and $Model_2$ is due to the fact that not all students reported having workdays. The relationship between sleep quality and pain threshold was tested in a separate model ($Model_3$) because of the smaller N for this variable (the questionnaire AIS-NCA was administered only in $study_3$ and $study_4$). Estimates (unstandardized beta coefficients), 95% confidence intervals (CI), t-values and $P$-values for each predictor are reported together with the $R^2$, the $P$-values, and the $BF_{10}$ for the overall models. Controlling for sex did not change the amount of variance explained by the predictors, despite sex being significantly associated with both chronotype (mean females: 04:15 hours ± SD 01:04 hours; mean males: 04:42 hours ± SD 01:07 hours; $P = 0.0003$) and pain threshold (mean females: 44.67 ± SD 0.66; mean males: 44.84 ± SD 0.68; $P = 0.0196$), in line with previous studies.[2,17,19]
AIS-NCA, Athens Insomnia Scale for Non-Clinical Application.

the results. When looking separately at sessions taking place in the morning vs afternoon, chronotype was still not significantly associated with pain threshold ($P > 0.05$). Social jetlag, sleep duration, and sleep quality were also not significantly associated with pain threshold (**Table 2**). Controlling for sex did not change the results. Bayesian analyses revealed (very) strong[16] support for the null model, suggesting neglectable modulation of pain threshold by the here addressed predictors (**Table 2**).

## 4. Discussion

Our analysis of data collected in 316 healthy young students could not identify any significant association between chronotype, as well as other sleep variables, and heat pain threshold. Only one previous study by Jankowski et al. investigated the relationship between chronotype and heat pain threshold in healthy young adults and found a clear effect of chronotype, with late chronotypes being more sensitive to pain.[9] In their study, however, pain threshold was assessed using another protocol (method of limits), resulting in relatively high pain thresholds (between 47°C and 51°C) compared with our study. Thus, it is possible that an association between chronotype and pain sensitivity only becomes apparent at higher pain intensities.

The fact that chronotype seems to be associated with pain symptomatology in chronic pain patients is not necessarily at odds with our null finding in healthy individuals.[15] In clinical and subclinical samples, additional factors such as sleep quality and general health indicators, that are both associated with chronotype and pain, could in fact explain their relationship.[8]

Although it is not yet clear whether chronotype influences pain sensitivity, there are some new findings suggesting that pain sensitivity is circadian regulated. The results from a recent laboratory study show that pain sensitivity is lower during the day and higher at night.[4] This finding confirmed previous modeling results of a meta-analysis, which also found that peak pain sensitivity is in the middle of the night.[7] Still, it remains to be

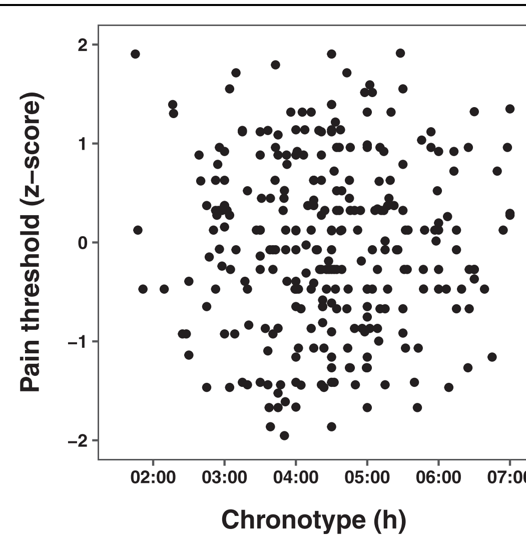


Figure 1. Relationship between chronotype and pain threshold. Chronotype was assessed by the microMCTQ and is reported in local clock time. $R^2 = 0.001$, $P > 0.05$. microMCTQ, microMunich ChronoType Questionnaire.

established whether this 24-hour variation in pain sensitivity is the same for early and late chronotypes.

Similar to chronotype, we also did not find any significant association between the other sleep variables and heat pain threshold. Maybe, an effect of sleep on pain is more easily found in clinical populations (eg, chronic pain patients).[23] In healthy individuals, in fact, hyperalgesia is usually reported following substantial perturbations of sleep.[12,13,18]

### 4.1. Limitations

The homogeneity of the sample and the fact that further demographic variables were not assessed (eg, race/ethnicity) limit the generalizability of our results. Moreover, the time of day of testing was not equally distributed across the day. However, the time of day was statistically controlled for in the models, and the average chronotype of the students did not significantly differ between sessions taking place in the morning (before 12:00 hours) and in the afternoon (after 12:00 hours).

## 5. Conclusions

We did not find a significant association between chronotype and pain threshold in our sample of young healthy students. There are just a few and contrasting findings on the relationship between chronotype and experimental pain sensitivity, highlighting the need for more research on this topic. Future studies should consider different pain modalities as well as different age groups, and they should systematically test different chronotypes at different times of day.

## Disclosures

The authors have no conflict of interest to declare.

## Acknowledgments

The authors thank the intramural research funding of the Medical Faculty, University of Augsburg (Intramurale Forschungsförderung), awarded to G. Zerbini and P. Reicherts.
Data are available on request from the corresponding author.

**Article history:**
Received 16 December 2022
Received in revised form 15 March 2023
Accepted 29 April 2023

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