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# The Impact of Evening Gaming on Cortisol and Melatonin Levels: Findings from a Randomized Controlled Trial

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A B S T R A C T :

Video games (VGs) are a popular form of entertainment, especially among younger individuals, yet their impact on sleep-related hormonal regulation remains unclear. This randomized controlled trial investigated the effects of evening gaming on cortisol and melatonin—key hormones in the sleep-wake cycle—compared to watching a nature film. Thirty-one male participants (aged 18–37) completed two conditions: 120 minutes of gaming ("League of Legends" or "Counter-Strike: Global Offensive") and 120 minutes of watching a nature film. Salivary samples were collected pre- and post-session and at waking (+15- and +30-minutes post-waking) the next morning.

Cortisol levels showed significant within-condition changes, but no significant differences between conditions were found ($t(180.0) = 1.41$, $p = 0.16$). The cortisol awakening response (CAR) increased 15 minutes post-waking and normalized by 30 minutes. Melatonin levels and the Area Under the Curve for Inhibition (AUCI) analysis for both hormones showed no significant differences between gaming and film.

These findings suggest that evening gaming among regular gamers, under controlled conditions, does not disrupt hormonal balance compared to passive film-watching. Habituation to gaming and environmental controls may have mitigated stress responses. Future research should investigate the effects of game novelty, varying player experiences, and diverse populations to develop guidelines for healthy gaming practices.

VG = video games; SCN = Suprachiasmatic Nucleus; HPA = Hypothalamic-Pituitary-Adrenal (Axis); CAR = Cortisol Awaking Response; AUCI = Area Under the Curve for Inhibition; BMI = Body Mass Index; adc = active digital condition pdc = passive digital condition; IGD = Internet Gaming Disorder

## 1. Introduction

The widespread integration of video games (VGs) into modern culture has become markedly evident (Toth et al., 2020). Over 80 % of U.S. respondents engage in video gaming, with half of smartphone owners playing on their mobile devices every day (Digital Media Trends survey report, Westcott et al., 2022). Among U.S. adults aged 18 to 29 years, 21% reported spending between six and ten hours per week playing video games with 8% playing more than 20 hours per week. (Statista, 2024). VG is predominantly an evening or nighttime activity, largely because daytime commitments such as work, school, and other responsibilities leave limited opportunities for recreational activities during the day (Kemp et al., 2021).

As VGs are deeply embedded in daily life, their potential impact on physical health—particularly on sleep and stress regulation—varies, showing divers effects on both sleep quality and stress levels, with stress often assessed through changes in heart rate (Higuchi et al., 2005; Weaver et al., 2010). Although further studies revealed inconclusive effects on sleep, with most indicating only a modest impact (De Rosa et al., 2024; Klier et al., 2024) - research suggests that both the content and context of media significantly influence hormonal responses (Mitsea et al., 2023a). Playing an arousing VG before bedtime may increase sleep onset latency and reduce sleep efficiency, while habitual, low-intensity VG playing (up to 7 hours per week) shows no association with negative sleep outcomes (De Rosa et al., 2024).

Despite these insights, specific effects of evening gaming on the body's hormonal regulation remain underexplored (Kristensen et al., 2021). Evening gaming may disrupt the sleep-wake cycle by altering the

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secretion of hormones, such as melatonin and cortisol, that are critical for sleep regulation and stress response (Mitsea et al., 2023a; Weaver et al., 2010). The sleep-wake cycle, or circadian rhythm, is regulated by the suprachiasmatic nucleus (SCN) in the hypothalamus, which receives light signals from the retina and adjusts the biological 24-hour cycle accordingly (Panda et al., 2002). This regulation relies on "clock genes," such as CLOCK, BMAL1, PER, and CRY, which control genes involved in daily physiological processes, influencing functions like metabolism and hormone secretion (Partch et al., 2014). A key output of this circadian regulation is melatonin production by the pineal gland, triggered by darkness (J. Reiter et al., 2013). Artificial light, particularly the bluish light from electronic screens, disrupts melatonin production and diminishes sleep quality (Wood et al., 2013).

Cortisol, another key hormone regulated by the hypothalamic-pituitary-adrenal (HPA) axis, peaks in the morning and gradually declines throughout the day to support wakefulness and energy mobilization (Clow et al., 2010a). In the context of gaming, studies show that games featuring violent content or those inducing intense excitement or fear tend to elevate cortisol, while games requiring focus and concentration can lower it (Mitsea et al., 2023a). For instance, a study found that puzzle games reduced cortisol levels by promoting attention and concentration, while runner, exciting, and fear-inducing games increased cortisol (Aliyari et al., 2018).

Additional research suggests that prolonged gaming (300 minutes) of intense games like "Counter Strike: Global Offensive" can lower melatonin before sleep and elevate cortisol during gameplay, reducing sleep efficiency and impairing memory recall (Hartmann et al., 2019). The auditory environment during gaming also plays a role; games accompanied by techno music amplify physiological arousal, significantly increasing cortisol levels compared to quiet settings (Hébert et al., 2005).

However, other studies challenge these findings and suggest that not all video games induce stress responses; in fact, some may even have a relaxing effect. For instance, a significant drop in salivary cortisol levels was observed after playing the non-violent game "FIFA 2015 Football," indicating that gaming does not always trigger stress (Aliyari et al., 2015). Similarly, studies found no significant differences in cortisol secretion, whether comparing violent and non-violent games ("Manhunt" vs. "Animaniacs") (Ivarsson et al., 2009) or examining gameplay in "League of Legends" under various conditions, such as playing against others or the computer, and winning or losing (Gray et al., 2018).

These discrepancies can be attributed to different methodologies used, including variations in game content, duration of exposure, and individual characteristics of the participants. However, the extent to which these factors interact to specifically influence hormonal balance and sleep quality remains unclear.

To address this uncertainty, the present study was conducted, implementing a carefully controlled approach that standardized variables such as volume, light exposure, and caffeine intake. Each condition was tested over two consecutive days to ensure the consistent impact of the intervention. By examining the effects not only during gameplay but also the following morning, this research aims to provide more reliable and nuanced insights into how different digital activities might differently impact the sleep-wake cycle through their effects on hormonal regulation.

The study focused exclusively on male participants, which aligns with epidemiological data showing a higher prevalence of Internet Gaming Disorder (IGD) among males (Stevens et al., 2021). This outcome also reflects a pragmatic convenience sampling approach targeting habitual gamers. The male-only sample helped reduce hormonal variability, particularly in cortisol (Kirschbaum et al., 1999) and melatonin secretion (Cain et al., 2010), both of which are known to differ between sexes and across phases of the menstrual cycle. However, this design limits the generalizability of the findings. Future studies should include female participants to explore potential sex-based endocrine differences.

Based on prior studies showing increased cortisol and reduced melatonin after stimulating evening gaming (e.g., Hartmann et al., 2019; Higuchi et al., 2003), we hypothesized that 120 minutes of gaming would lead to higher cortisol and lower melatonin compared to watching a nature film. This is supported by a recent review (Mitsea et al., 2023b), which emphasizes that arousing or fear-inducing games tend to elevate cortisol, while games requiring focused attention may reduce it. Despite mixed findings in the literature, these studies provided a clear rationale for a directed hypothesis in this controlled setting.

## 2. Materials and Methods

### *Study Participants*

Thirty-One male players aged 18-37 (age: $M = 23{,}00 \pm 3{,}53$years, BMI: $M = 25{,}68 \pm 3{,}34$, time of experience: $M = 8{,}69 \pm 4{,}74$ years, and daily gaming time: $M = 1{,}96 \pm 1{,}32$ hours) took part in the study. Only males were included in the study, as hormonal fluctuations due to the menstrual cycle and the use of oral contraceptives can affect cortisol and melatonin levels (Brzezinski, 1997; Kirschbaum et al., 1999).

The study participants were recruited through online tendering and notice boards at the authors institution. After recruitment, study inclusion and exclusion criteria were checked in a standardized interview. Inclusion criteria were being a male between 18-65years, playing the games *League of Legends* (Riot Games, 2009) or *Counter Strike: Global Offensive* (Valve, 2012) and not being a professional e-sport player, in the definition not to earn personal salary by playing videogames. Exclusion criteria were any acute and/or chronic medical illness, mental disorders, or the use of medications that affect heart rate or the central nervous system, such as beta blockers. Additionally, participants who used perception-altering substances (e.g., certain pain relievers, recreational drugs) or medications that specifically alter cardiovascular function were excluded from the study. *League of Legends* and *Counter Strike: Global Offensive* were chosen for this study due to their popularity and their ability to generate high levels of cognitive engagement and competitive pressure, factors that are essential for potentially inducing stress-related hormonal changes (Mitsea et al., 2023b). Both games require complex decision-making, quick reactions, and teamwork, creating conditions that could elevate arousal and affect the secretion of cortisol and melatonin. By focusing on games known for their immersive and competitive nature, we aimed to maximize the potential for observing hormonal responses to high-stress digital environments. Other game genres that lack real-time decision-making or intense competitive engagement were excluded to ensure that the study maintained its focus on environments likely to influence physiological arousal and stress-related hormonal patterns.

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the University of the Bundeswehr Munich, Germany (05/28/2022). All participants were informed of the inherent risks and benefits of the study before signing an informed consent form.

### *Experimental Design*

This study was conducted as a randomized controlled trial with a within-subject design, ensuring rigorous control of confounding variables to assess the effects of evening gaming compared to a passive digital activity. The entire study was conducted over a 6-month period to allow for the recruitment and testing of all participants. However, each participant was individually assessed within a tightly controlled 2-week window. During these 2 weeks, participants underwent the planned interventions and measurements. Therefore, interim health checks or long-term monitoring over the entire study duration were not necessary, as the health data of participants were collected solely during their specific assessment period. To ensure balance and minimize bias, participants were randomly assigned to one of two starting conditions: Group A starts in week 1 with two consecutive days of 120min gaming (adc) and in week 2 with two consecutive days of 120min watching a film (pdc). Group B started in the opposite order. The time interval between condition 1 and condition 2 was exact one week (see figure 1). The investigations were conducted between 8:00 PM and 11:00 PM. Participants were strictly instructed to refrain from consuming alcohol, caffeine, energy drinks, nicotine, and stimulating teas for 24 hours prior to the experiment, to minimize any short-term effects on melatonin and cortisol. During the experiment, participants were allowed to drink, but only beverages that did not contain these substances. The participants could freely choose for adc between two videogames (*Counter Strike: Global Offensive*; Valve, 2012 or *League of Legends*; Riot Games, 2009) for the study. The DVD *Earth* (Universal Film, 2007) and *Earth: One Amazing Day* (Universal Film, 2017) was used for the control condition (pdc). Participants were instructed to have their last meal until 7pm and check their environment parameters 30min before starting. Given that both light stimulation and posture can influence alertness in both conditions (Zeitzer et al., 2000), dim light conditions were held constant <30lux, distance from the television monitor (an additional light source) was controlled (1 meter), subject were instructed to maintain a semi supine posture, and the volume was controlled to a speaker volume (< 80db). For both conditions a normal pc or laptop were used (see figure 2).

Throughout each intervention, five saliva samples were collected per participant. The first saliva sample was taken 10 minutes before the start of the gaming or film session. The second sample was collected immediately after the conclusion of the session. The third saliva sample was collected upon awakening the next morning, followed by the fourth sample 15 minutes after waking, and the fifth sample 30 minutes after waking (see figure 1). This sampling protocol adheres to the expert consensus guidelines established by the International Society of Psychoneuroendocrinology (ISPNE) for the reliable assessment of the cortisol awakening response (CAR) (Stalder et al., 2016). Both subjective (sleep diaries) and objective (actigraphy) measures were used to verify awakening times, as accurate timing of saliva collection is critical to ensure valid CAR assessment. This approach aligns with the recommended methodological standards to capture peak CAR levels, typically observed within the first 30 minutes after awakening (Pruessner et al., 1997) , and to minimize potential bias due to sampling inaccuracies. As the present study focused specifically on endocrine parameters, sleep diary and actigraphy data were not included in the current analysis. These data have been reported in a separate publication (Klier et al., 2024).

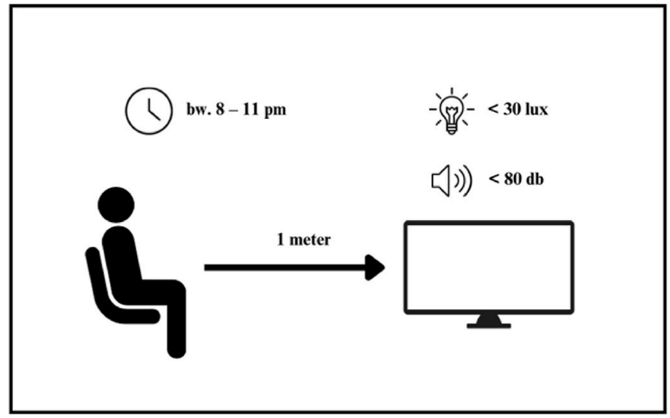


**Figure 2.** Experimental setup during the gaming and film conditions, showing the participant's distance from the screen (1 meter), controlled lighting conditions (<30 lux), sound level (<80 dB), and time window (between 8–11 PM)

*Data analysis*

The sample size was determined through power calculations conducted with G*Power v.3.1 (Faul et al., 2009). Based on a medium effect size of Cohen's $f = .25$, two conditions (film vs. gaming), $n = 4$ repetitions, a significant level of $p = .05$ and power of 80% (1-ß = 0.80), a total sample size of $N = 24$ for two-way ANOVA for repeated measures time x group interaction effect was needed.

For the statistical analysis, all primary outcome measures (e.g., cortisol, melatonin) were log-transformed (logarithm naturalis +1) to approximate normal distributions. Baseline comparisons between conditions were analyzed using dependent t-tests. Subsequently, the effects of condition (gaming vs. film) on outcome parameters across measurement points were analyzed using a linear mixed-effects model. This model incorporated random intercepts for participants to account for intra-individual variability and improve the robustness of the results. The model included condition, time (pre vs. post), and the condition x time interaction as fixed effects, with the intercept treated as a random effect to account for intra-individual variability. Additional post hoc analyses with Bonferroni corrections were performed for significant

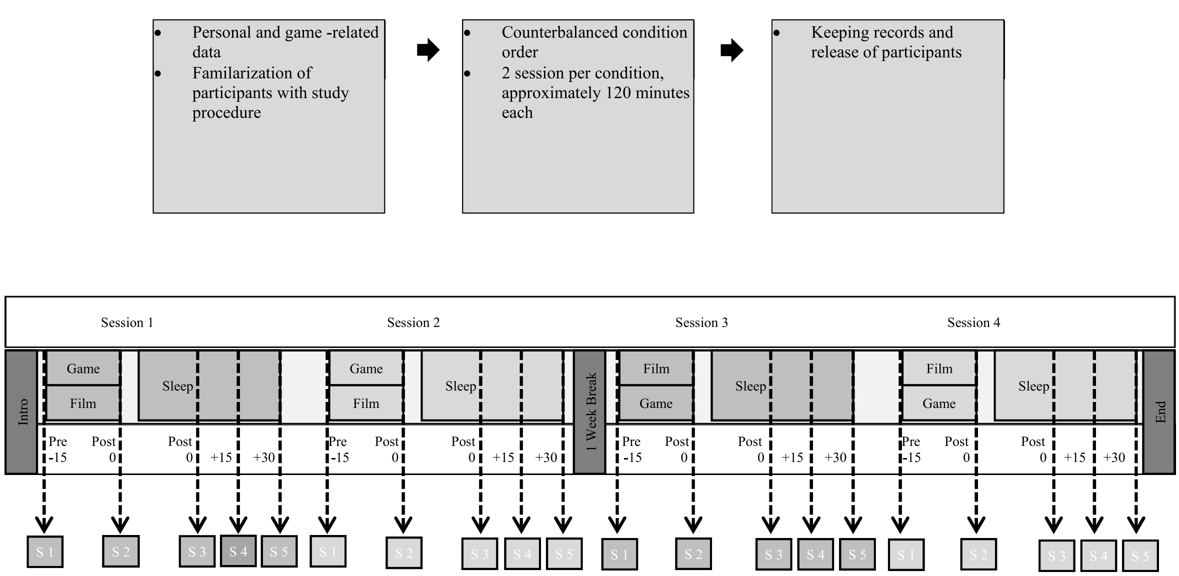


**Figure 1.** Flow Chart of the Examined Study Protocol. Sample 1 (S1): 15min before Game/ Film; Sample 2 (S2): immediately after Game/ Film; Sample 3 (S3): after waking up; Sample 4 (S4): 15min after waking up; Sample 5 (S5): 30min after waking up

interactions to further explore the directional effects. All analyses were conducted using JAMOVI (Gallucci, 2019).

## 3. Results

### 3.1. Cortisol

*Pre-Post Analysis*

There was no significant difference in baseline cortisol values between the gaming and film condition ($t(30.0) = -1.88$, $p = 0.07$). The pre-post difference was analyzed using a paired t-test, which showed a significant decrease in cortisol levels within each condition ($t(30.0) = -2.71$, $p = 0.01$). To investigate differences between conditions, a linear mixed-effects model was applied. The model included 'Condition' (Gaming vs. Film) and 'Measurement Time Point' (Pre vs. Post) as fixed effects, with participant ID as a random intercept to account for within-subject variability. The mixed model revealed no significant effect of condition on cortisol levels ($t(180.0) = 1.41$, $p = 0.16$) (see Table 1)

*Cortisol-Awakening Response (CAR)*

The post-waking cortisol levels were analyzed using a linear mixed-effects model. The model included 'Measurement Time Point' (Baseline, +15min, +30min), 'Condition', and their interaction as fixed effects, with participant ID as a random intercept. A significant increase in cortisol levels was observed at +15min compared to baseline ($t(330.0) = 2.35$, $p = 0.02$), but this effect dissipated by +30min ($t(330.0) = 0.90$, $p = 0.37$). No significant interaction between condition and measurement time point was detected (see Table 3)

### 3.2. Melatonin

*Pre-Post Analysis*

There was no significant difference in baseline melatonin values between the gaming and film condition ($t(30.0) = 0.17$, $p = 0.86$). The pre-post difference in melatonin levels was analyzed using a paired t-test, which did not reveal a significant difference ($t(210.0) = 1.76$, $p = 0.08$). A linear mixed-effects model was used to assess differences between conditions, with 'Condition', 'Measurement Time Point', and their interaction as fixed effects, and participant ID as a random intercept. The model found no significant effect of condition on melatonin levels ($t(210.0) = 1.32$, $p = 0.19$) and no significant interaction between pre-post and condition ($t(210.0) = 1.41$, $p = 0.161$) (see Table 2)

*Post-Awakening Melatonin Levels*

Post-waking melatonin levels were also analyzed using a linear mixed-effects model. For the +15min measurement point, a trend toward significance was observed compared to baseline ($t(330.0) = 1.70$, $p = 0.09$), but no significant difference was found at +30min ($t(330.0) = -0.02$, $p = 0.98$). No significant interaction effect between condition and measurement time points was detected (see Table 4).

### 3.3. Combined AUCI Analyses for Cortisol and Melatonin

*Cortisol AUCI*

The analysis of the area under the curve for inhibition (AUCI) revealed no significant difference between the gaming and film conditions ($AUCI_{Gaming} = 6.06 \pm 5.01$, $AUCI_{Film} = 6.70 \pm 5.63$, $t(80.6) = 0.83$, $p = 0.41$; see Table 5).

*Melatonin AUCI*

Similarly, the AUCI analysis for melatonin showed no significant difference between the gaming and film conditions ($AUCI_{Gaming} = -0.97 \pm 7.48$, $AUCI_{Film} = -9.99 \pm 56.68$, $t(90.0) = 0.75$, $p = 0.46$; see Table 5).

## 4. Discussion

The present study contributes to the growing body of research by examining the impact of evening gaming on cortisol and melatonin, two hormones critical for regulation of the sleep-wake cycle (Clow et al., 2010b; J. Reiter et al., 2013). Conducted in a controlled environment, the study compared gaming to a passive activity, watching a nature film, to investigate potential differences in hormonal response. Contrary to expectations of heightened arousal effects from gaming, our findings showed no significant differences in cortisol or melatonin levels between the gaming and film conditions. While there was a significant pre-post difference in cortisol levels within each condition, this did not differ between gaming and film, indicating that both activities had a comparable effect on physiological arousal. This study provides additional insight by focusing on cortisol and melatonin—two key hormones involved in sleep regulation (Kim et al., 2015)—showing that these remain unaffected by habitual gaming, even under cognitively demanding video gaming conditions. These findings align with prior research suggesting that habitual and casual video gaming does not negatively impact sleep (De Rosa et al., 2024)

There is evidence that games featuring violent content or inducing intense excitement or fear are generally associated with elevated cortisol levels, whereas games requiring attention and concentration may lower cortisol (Mitsea et al., 2023b). For example, a study involving 80 participants aged 18 to 30 found that puzzle games reduced cortisol levels, whereas runner, exciting, and fear-inducing games increased them, demonstrating the distinct effects of different game genres on the autonomic nervous system and stress hormone release (Aliyari et al., 2018).

In the present study, the selected games, "League of Legends" and "Counter-Strike: Global Offensive", are well-known for their competitive and high-stimulation gameplay, which would typically be expected to provoke significant hormonal changes. Yet, no substantial increase in cortisol was observed. Previous research has also shown that video gameplay can reduce salivary cortisol levels, suggesting a calming effect on players during gaming (Aliyari et al., 2015), even when playing a violent game against either human opponents or a computer (Gray et al., 2018). Similarly, in this study, cortisol levels decreased in both conditions—after gaming and film watching (see Figure 3). This effect may be attributed to the intense focus required during gameplay, which directs players' attention toward precision and strategy. As a result, game-induced emotional responses were moderated, leading to reduced cortisol levels (Feinstein et al., 2011).

While the present study focused on habitual gamers without clinical impairment, it is worth noting that hormonal responses to gaming may

**Tab. 1**
Fixed Effects Parameter Estimates from the Mixed Model Examining the Interaction between Cortisol Levels, Pre-Post Measurements, and Film-Gaming Condition.

| | | | | 95% Confidence Interval | | | | |
|---|---|---|---|---|---|---|---|---|
| Names | Effect | Estimate | SE | Lower | Upper | df | t | p |
| (Intercept) | (Intercept) | 1.0876 | 0.147 | 0.8003 | 1.375 | 30.0 | 7.418 | < .001 |
| MTP | Post - Pre | -0.4964 | 0.183 | -0.8551 | -0.138 | 30.0 | -2.713 | 0.011 |
| Condition | Film - Gaming | 0.2202 | 0.156 | -0.0861 | 0.526 | 180.0 | 1.409 | 0.160 |
| MTP ✻ Condition | Post - Pre ✻ Film - Gaming | -0.2709 | 0.313 | -0.8834 | 0.342 | 180.0 | -0.867 | 0.387 |

Note: MTP= Measurement Time Point

**Tab. 2**
Fixed Effects Parameter Estimates from the Mixed Model Examining the Interaction between Melatonin Levels, Pre-Post Measurements, and Film-Gaming Condition.

| | | | | 95% Confidence Interval | | | | |
|---|---|---|---|---|---|---|---|---|
| Names | Effect | Estimate | SE | Lower | Upper | df | t | p |
| (Intercept) | (Intercept) | 5.83 | 1.92 | 2.077 | 9.587 | 30.0 | 3.044 | 0.005 |
| MTP | Pre-Post | 2.64 | 1.50 | -0.307 | 5.591 | 210.0 | 1.756 | 0.081 |
| Condition | Film - Gaming | 1.98 | 1.50 | -0.971 | 4.928 | 210.0 | 1.315 | 0.190 |
| MTP ✻ Condition | 2 - 1 ✻ Film - Gaming | 4.23 | 3.01 | -1.669 | 10.127 | 210.0 | 1.405 | 0.161 |

Note: MTP= Measurement Time Point

**Tab. 3**
Fixed Effects Parameter Estimates from the Mixed Model Examining the Interaction between Cortisol Levels, Time Points (+15min, +30min), and Film-Gaming Condition.

| | | | | 95% Confidence Interval | | | | |
|---|---|---|---|---|---|---|---|---|
| Names | Effect | Estimate | SE | Lower | Upper | df | t | p |
| (Intercept) | (Intercept) | 29.728 | 16.2 | -2.02 | 61.48 | 30.0 | 1.83533 | 0.076 |
| MTP1 | +15min - 0 | 35.228 | 15.0 | 5.81 | 64.65 | 330.0 | 2.34703 | 0.020 |
| MTP2 | +30min - 0 | 13.556 | 15.0 | -15.86 | 42.97 | 330.0 | 0.90317 | 0.367 |
| Condition | Film - Gaming | 0.543 | 12.3 | -23.48 | 24.56 | 330.0 | 0.04430 | 0.965 |
| MTP1 ✻ Condition1 | +15min - 0 ✻ Film - Gaming | 32.924 | 30.0 | -25.91 | 91.76 | 330.0 | 1.09675 | 0.274 |
| MTP2 ✻ Condition1 | +30min - 0 ✻ Film - Gaming | 16.882 | 30.0 | -41.96 | 75.72 | 330.0 | 0.56236 | 0.574 |

Note: MTP= Measurement Time Point

**Tab. 4**
Fixed Effects Parameter Estimates from the Mixed Model Examining the Interaction between Melatonin Levels, Time Points (+15min, +30min), and Film-Gaming Condition.

| | | | | 95% Confidence Interval | | | | |
|---|---|---|---|---|---|---|---|---|
| Names | Effect | Estimate | SE | Lower | Upper | df | t | p |
| (Intercept) | (Intercept) | 37.404 | 16.9 | 4.37 | 70.44 | 30.0 | 2.2193 | 0.034 |
| Condition | Film - Gaming | 12.391 | 13.1 | -13.30 | 38.08 | 330.0 | 0.9454 | 0.345 |
| MTP1 | +15min - 0 | 27.321 | 16.1 | -4.14 | 58.78 | 330.0 | 1.7019 | 0.090 |
| MTP2 | +30min - 0 | -0.323 | 16.1 | -31.79 | 31.14 | 330.0 | -0.0201 | 0.984 |
| Condition1 ✻ MTP1 | Film - Gaming ✻ +15min - 0 | 23.486 | 32.1 | -39.44 | 86.41 | 330.0 | 0.7315 | 0.465 |
| Condition1 ✻ MTP2 | Film - Gaming ✻ +30min - 0 | 3.287 | 32.1 | -59.64 | 66.21 | 330.0 | 0.1024 | 0.919 |

Note: MTP= Measurement Time Point

**Tab. 5**
Results of The Analysis of the Interaction between AUCI of Cortisol and Melatonin and Gaming-Film Condition.

| Outcome | M ± SD | df | t | p |
|---|---|---|---|---|
| Cortisol | $AUCI_{Gaming} = 6.06 \pm 5.01$<br>$AUCI_{Film} = 6.70 \pm 5.63$ | 80.6 | 0.8284 | 0.410 |
| Melatonin | $AUCI_{Gaming} = -0.97 \pm 7.48$<br>$AUCI_{Film} = -9.99 \pm 56.68$ | 90.0 | 0.750 | 0.455 |

Note: AUCI= Areas Under the Curve with respect to the Increase

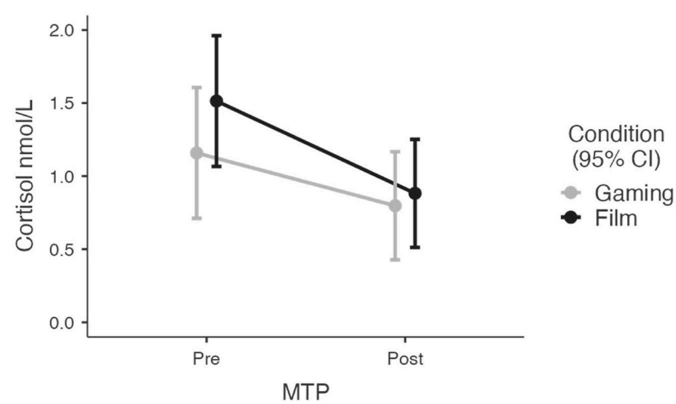


**Figure 3.** Cortisol responses to two measurement points (MTP) (pre/post). Pre was before the condition; Post was after the condition.

vary in clinical populations. For instance, one study found no alterations in diurnal cortisol or α-amylase levels among adolescents diagnosed with IGD compared to healthy controls (Killer et al., 2024). In contrast, another study reported attenuated cortisol reactivity and increased negative affect following acute stress exposure in male adolescents with IGD (Kaess et al., 2017). These mixed findings underscore the role of individual differences and clinical characteristics in shaping endocrine stress responses during or after gaming.

The intensity of game content is also an important factor, as playing a highly engaging and intense game like “Counter-Strike: Global Offensive” for five hours has been shown to elevate cortisol during gameplay, leading to reduced sleep efficiency and impaired memory recall in adolescents compared to playing a board game like “Monopoly” (Hartmann et al., 2019). Interestingly, the significant cortisol differences observed in these earlier studies dissipated after the sessions, similar to the current findings (Hartmann et al., 2019). In the present study, participants either played video games or watched a nature film in two sessions, each lasting two hours, on consecutive days before bedtime. Despite this varied time-based approach, no significant differences in cortisol levels between the conditions were measured. The findings suggest that the timing and intensity of gaming may influence hormonal responses during gameplay, but these effects may not persist after the activity.

A recent study in non-gamers under comparable, controlled conditions likewise reported no negative effects of evening gaming on sleep.

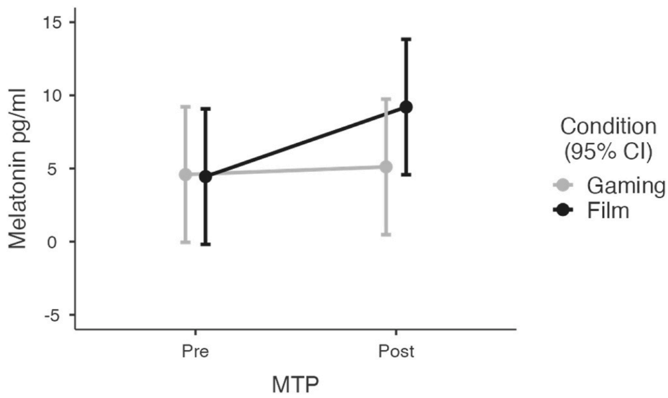


**Figure 4.** Melatonin response to two measurement points (MTP) (pre/post). Pre was before the condition; Post was after the condition.

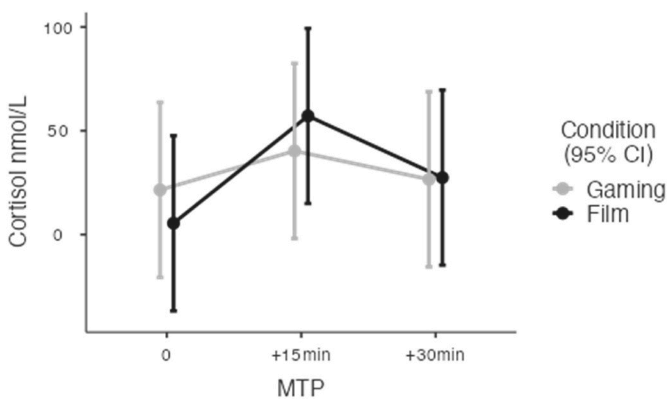


**Figure 5.** Cortisol response to three measurement points (MTP) (awake, +15min, +30min)

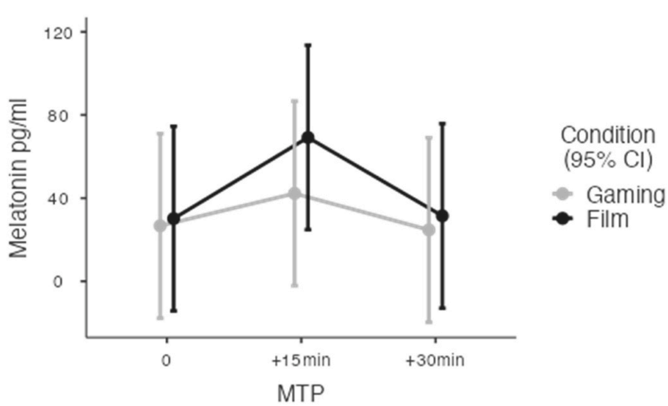


**Figure 6.** Melatonin response to three measurement points (MTP) (awake, +15min, +30min)

On the contrary, participants showed improved cognitive performance and reduced perceived stress (De Rosa et al., 2025). These findings support the notion that short, structured gaming sessions—even in individuals without prior gaming experience—may not necessarily provoke physiological stress responses. In our study, prior gaming experience may have further buffered hormonal reactivity. Future studies should directly compare gamers and non-gamers under identical conditions to better understand the role of habituation.

Regarding melatonin, Hartmann and colleagues (2019) demonstrated significantly lower melatonin levels after gaming compared to playing a board game (Hartmann et al., 2019). Also, Higuchi et al. (2003) reported melatonin suppression and delayed sleep onset following highly arousing gaming (Higuchi et al., 2005). In the present study, we observed no differences in melatonin levels between the two conditions. These findings align with research indicating that melatonin can remain robust under certain short-term behavioral interventions (McHill et al., 2021). This stability may reflect the influence of individual habituation to gaming, as observed in habitual players in the present study

The measurements of the CAR revealed a significant peak in cortisol levels 15 minutes after awakening, consistent with findings from Pruessner et al. (1997), who observed that cortisol levels typically increase by 50–75% within the first 30 minutes after awakening, with the peak often occurring early in this window (Pruessner et al., 2003). For melatonin, post-waking levels remained stable across both conditions, indicating that evening gaming did not significantly alter its early morning secretion. Together, these findings suggest that evening gaming, under controlled conditions, did not lead to significant hormonal disruptions compared to the passive activity of film watching.

Furthermore, the analysis revealed no significant effect of chronotype on the cortisol awakening response (CAR), nor any significant interaction between measurement time points (MTP), condition (film vs. gaming), and chronotype. These results indicate that chronotype did not influence the hormonal response upon awakening under the conditions studied.

A key strength of this study lies in its approach to minimizing confounding variables. By employing a standardized protocol where both groups performed the same condition over two consecutive days, the influence of random variation, including daily form, mood, and level of immersion, was effectively reduced. Strict participation criteria were enforced, excluding professional e-sport players, individuals with sleep disorders, those diagnosed with gambling disorders, and participants taking perception-altering or cardiovascular-affecting medications. High levels of standardization were maintained during evening assessments, including controlled brightness, sound levels, and distance from the screen. Conducting the study within the familiar home environment of participants further minimized potential laboratory-induced stress and allowed for more authentic hormonal responses. Additionally, the randomized crossover design and adherence to best practices in cortisol measurement, including actigraphy for awakening time determination and strict sample collection protocols, further strengthened the validity of our findings, as highlighted in established CAR assessment guidelines (Stalder et al., 2016).

However, several limitations warrant consideration. Standardizing gameplay difficulty and participant skill levels posed challenges, as individual differences in focus and adaptability likely influenced hormonal responses. Additionally, attempts to control daily routines may not have fully eliminated external influences, contributing to variability in results. Moreover, the study did not include a non-activating video game condition or a control group of non-habitual gamers. Including both would have allowed for a more nuanced interpretation of how game intensity and prior gaming experience interact with hormonal stress responses. Future research should consider incorporating a broader range of game genres as well as participants with varying degrees of gaming experience to better understand the role of arousal and habituation. The exclusive inclusion of male participants also limits the generalizability of the findings to broader populations. Future research should address these limitations by including a more diverse participant pool and exploring a wider range of gaming genres and durations.

In conclusion, this study showed that evening gaming does not disrupt the cortisol or melatonin levels compared to a passive film-watching activity. This outcome points to the importance of habituation among regular gamers and controlled environmental conditions in mitigating stress responses. These findings contribute to the understanding that not all gaming scenarios negatively impact sleep-related hormonal response, emphasizing that individual experience and environmental factors are critical determinants.

Future research should extend these findings by investigating the effects of gaming over longer durations and across multiple nights to capture potential cumulative impacts on sleep-related hormonal regulation. Additionally, expanding participant demographics to include individuals of different age groups, gaming expertise levels, and genders will provide a more comprehensive understanding of how diverse populations respond to gaming. Exploring variations in game types, levels of arousal, and the timing of gaming sessions could further clarify the nuanced relationship between video gaming, stress physiology, and sleep health.

## CRediT authorship contribution statement

**Andre Daniel Alesi:** Writing – original draft, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Kristina Klier:** Resources, Methodology, Investigation, Conceptualization. **Benedict Herhaus:** Validation, Software, Methodology, Conceptualization. **Klara Brixius:** Supervision, Conceptualization. **Ingo Froböse:** Supervision. **Matthias Wagner:** Supervision, Conceptualization. **Katja Petrowski:** Writing – review & editing, Supervision, Project administration, Conceptualization

## Declaration of Competing Interest

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

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