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# Sleep as a Recovery Factor in Amateur Counter-Strike 2 Players: Examining the Impact of Sleep Duration and Sleep Quality on Cognitive and In-game Performance

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Abstract

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**Keywords:** amateur gamers, Counter-Strike 2 Players, sleep duration, sleep quality, cognitive performance.

This study examined how sleep duration and quality affect cognitive reaction time and gameplay performance in amateur players of Counter-Strike 2 (CS2). Ninety participants were initially targeted to account for an anticipated 10% attrition rate; however, only 73 players met the inclusion criteria and completed the study. The sample consisted primarily of male players, with an average age of approximately 23 years, reflecting the typical demographic profile of amateur esports communities. The study employed a cross-sectional correlational design. Participants recorded their sleep duration daily over two weeks, and sleep quality was assessed twice weekly using the Pittsburgh Sleep Quality Index (PSQI). Cognitive performance was measured through a digital version of the Psychomotor Vigilance Task (PVT), which assessed participants' reaction times. In-game performance metrics, including Kill-to-Death (K/D) ratio and shooting accuracy, were collected from participants' CS2 weekly statistics.

Pearson correlation analysis revealed that longer sleep duration was strongly associated with faster reaction times, while poorer sleep quality was linked to slower cognitive responses. Multiple linear regression analysis showed that sleep duration significantly predicted shooting accuracy, but did not predict K/D ratio. This suggests that gameplay elements such as tactics, team coordination, and opponent skill may dilute the impact of individual cognitive readiness on K/D performance. Although sleep quality correlated with slower reaction time, it did not significantly predict gameplay outcomes when sleep duration was controlled. Overall, sleep duration emerged as a more critical factor than subjective sleep quality in supporting competitive performance.

The study recommends that amateur gamers consistently aim for 7–9 hours of sleep and adopt sleep hygiene practices as part of their training regimen. Notable limitations include reliance on self-reported sleep measures, lack of experimental control over gameplay environments, and the study's cross-sectional design, which restricts causal inference. Despite these limitations, the findings reinforce the growing evidence that sleep, especially its duration, is a vital, low-cost recovery strategy in esports. In amateur competitive play, it can enhance accuracy, decision-making, and reaction speed.

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## List of Abbreviations

| | | |
|---|---|---|
| **CS2** | - | Counter-Strike 2 |
| **FPS** | - | First-Person Shooter |
| **PSQI** | - | Pittsburgh Sleep Quality Index |
| **PVT** | - | Psychomotor Vigilance Task |
| **K/D Ratio** | - | Kill-to-Death Ratio |
| **VIF** | - | Variance Inflation Factor |
| **EEG** | - | Electroencephalography |
| **SHY** | - | Synaptic Homeostasis Hypothesis |
| **ESIC** | - | Esports Integrity Commission |

## 1 Introduction

In recent years, esports have surged into the global spotlight, with competitive gaming evolving into a billion-dollar industry. As of 2023, the global esports market was valued at $1.38 billion and is projected to grow at a CAGR of 9.24% through 2028 (Newzoo, 2023). Counter-Strike 2 (CS2) stands at the forefront of this revolution. CS2, a tactical first-person shooter game, exemplifies the unique cognitive demands of esports. Players must execute 300+ actions per minute, including precise aiming, rapid weapon switching, and real-time communication with teammates, all while processing complex spatial and auditory cues (Ivarsson *et al.,* 2023). Unlike traditional sports, where physical stamina dominates, performance hinges on sustained cognitive endurance. For example, a CS2 match can last 30–45 minutes, requiring players to maintain laser focus to outmaneuver opponents in high-pressure scenarios. This cognitive load is comparable to professions like air traffic control or emergency medicine, where split-second decisions carry significant consequences (Smith *et al.,* 2022).

Sleep, a pillar of recovery in traditional athletics, is equally vital for cognitive restoration. Research in sports science demonstrates that sleep deprivation reduces reaction times by 20–30% and impairs decision-making accuracy in athletes (Fullagar *et al.,* 2015). However, the esports domain, particularly its amateur segment, remains a blind spot. The "amateur segment" here refers to amateur players—individuals who compete without financial compensation and typically dedicate <20 hours/week to gaming, and often balance esports with academic, occupational, and/or social obligations. This multilayered commitment frequently leads to irregular sleep patterns, such as late-night gaming sessions followed by early-morning classes or shifts, disrupting circadian rhythms and impairing recovery (Lee & Bonnar, 2021). Compounding this issue, amateur gaming communities report rising rates of cognitive fatigue and/or burnout, with 68% of players citing exhaustion as a barrier to consistent performance (Poulus *et al.,* 2022). Despite these challenges, few studies have systematically explored how sleep modulates recovery in this population, leaving players without evidence-based strategies to optimize performance or safeguard mental health.

## 1.1 Problem Statement

The cognitive and emotional demands of Counter-Strike 2 (CS2) create a high-pressure environment for amateur players. During matches, players must simultaneously process visual, auditory, and strategic information, such as tracking enemy movements via sound cues, coordinating team tactics through voice chat, and executing pixel-perfect aims under time constraints. For instance, a player may need to react to the footsteps of an opponent within 200 milliseconds while deciding whether to engage in a firefight or retreat, decisions that can determine match outcomes. Despite these intense cognitive demands, the role of sleep in mitigating post-game cognitive fatigue remains underexplored.

Existing esports recovery research primarily focuses on professional players who benefit from structured schedules, access to nutritionists, and even dedicated sleep coaches, resources rarely available to amateurs. In contrast, amateur players often rely on ad hoc methods, such as consuming energy drinks or practicing all night, exacerbating sleep deprivation. A 2022 survey found that 43% of amateur CS2 players sleep less than six hours per night during tournaments, prioritizing practice over rest (ESIC, 2022). This pattern reflects trends in traditional sports, where sleep deprivation correlates with 15–20% declines in strategic thinking and 25% slower recovery from physical fatigue (Mah *et al.,* 2011). However, unlike traditional athletes, esports players also contend with prolonged screen exposure and sedentary lifestyles, which may compound sleep's impact on performance and recovery.

The lack of targeted research leaves some critical questions unanswered: Does sleep duration have a stronger correlation with reaction time than sleep quality? Is there a threshold of sleep duration (e.g., <7 hours vs. >7 hours) where performance declines significantly? Does sleep deprivation increase aggressive or impulsive play styles? How does sleep affect clutch performance (1v1 situations where a player is the last surviving team member)? Without empirical answers, amateur players may unknowingly sacrifice sleep for extra practice, potentially degrading their performance rather than improving it. This study aims to determine whether sleep duration and quality influence reaction time and predict in-game performance among amateur CS2 players.

## 1.2 Objectives

The primary objective of this study is to *investigate the relationship between sleep (duration and quality) and cognitive recovery (reaction time) in amateur CS2 players.* The specific objective is to: (1) determine the relationship between sleep duration, sleep quality, and reaction time in amateur CS2 players; (2) evaluate the predictive influence of sleep duration and quality on the in-game performance of amateur CS2 players.

## 1.3 Research Questions

This thesis addresses the following research questions to achieve the stated objectives. The insights gained from the study stand to provide practical recommendations for enhancing performance and recovery. The question is: (1) What is the relationship between sleep duration, sleep quality, and reaction time in amateur CS2 players? (2) To what extent do sleep duration and quality predict in-game performance among amateur CS2 players?

## 1.4 Significance of Study

This study is significant as it addresses a critical gap in esports research by focusing on amateur Counter-Strike 2 players, a largely overlooked group despite comprising most of the gaming population. Unlike professionals, amateurs often lack structured routines and support systems, making them more vulnerable to the effects of poor sleep on cognitive and gameplay performance. By examining how sleep duration and quality influence reaction time and in-game metrics like K/D ratio and accuracy, the study highlights sleep, particularly its duration, as a measurable and impactful factor in digital performance. This finding will provide actionable insights for players, coaches, and stakeholders, emphasizing the need to treat sleep as a core component of training and recovery. Additionally, the study offers a replicable framework for future interdisciplinary research, combining subjective and objective measures to advance the understanding of cognitive readiness in competitive gaming.

## 1.5 Justification for the Study

Amateur esports players account for 89% of the global competitive gaming population, yet they face disproportionately high risks of burnout due to unstructured training routines and poor recovery habits (ESIC, 2022). Unlike professionals, they lack access to formal coaching, performance analytics, and sleep management strategies, making sleep deprivation not just a performance issue but a growing public health concern. Studies have shown that amateur gamers sleeping less than five hours a night report 2.5 times higher anxiety rates and nearly double the dropout risk compared to peers who sleep 7–8 hours (Johansson *et al*., 2021). Furthermore, reduced sleep among this group is associated with slower reaction times and increased in-game errors, particularly detrimental outcomes in fast-paced titles like Counter-Strike 2, where success depends on microsecond-level precision. Despite these challenges, existing research primarily focuses on professional esports players, leaving a critical gap in understanding how sleep affects cognitive and gameplay performance among amateurs.

## 1.6 Limitations of the Study

While this study aims to offer valuable insights, it is important to acknowledge several potential limitations. First, the generalizability of the findings is limited, as the results may not apply to other esports genres such as team-based multiplayer online battle arena (MOBA) games like League of Legends, or professional players, since the focus was specifically on amateur CS2 players. Second, using a cross-sectional design restricts the ability to make causal inferences about the relationship between sleep and performance; therefore, future studies employing longitudinal designs that track players across multiple seasons are recommended. Lastly, individual differences such as genetic predispositions, lifestyle habits, and stress levels may have influenced sleep patterns and cognitive performance, potentially confounding the observed effects of sleep.

# 2 Literature Review

Understanding the relationship between sleep and performance requires an interdisciplinary lens, drawing from cognitive psychology, behavioral neuroscience, and esports research. This section critically reviews the literature informing the current study, focusing on how sleep duration and quality influence cognitive functioning and task-based performance. While the connection between sleep and reaction time has been widely established in traditional settings, fewer studies have explored these dynamics within competitive gaming contexts, particularly among amateur Counter-Strike 2 players.

## 2.1 Conceptual Framework

The conceptual framework guiding this study is based on the understanding that sleep is a fundamental biological process significantly influencing cognitive and behavioral performance. It illustrates the theoretical relationship between sleep duration and sleep quality, the independent variables, and crucial performance outcomes in esports: reaction time, Kill-to-Death (K/D) ratio, and accuracy percentage, the dependent variables. This model also acknowledges the multidimensional nature of gaming performance, integrating behavioral, physiological, and skill-based factors.

### 2.1.1 Sleep Duration and Sleep Quality

Sleep duration is the total amount of sleep accumulated by an individual within 24 hours. According to the National Sleep Foundation and recent clinical guidelines, healthy young adults require 9 hours of sleep per night to maintain optimal functioning (Hirshkowitz *et al.,* 2015). Even by 1–2 hours, chronic short sleep duration has been associated with impaired cognitive flexibility, reduced working memory, and slower response speed (Lo *et al.,* 2016). On the other hand, sleep quality is a subjective construct encompassing perceived restfulness, ease of falling asleep, frequency of awakenings, and satisfaction with sleep. This study uses the Pittsburgh Sleep Quality

Index (PSQI) to measure sleep quality. This validated instrument captures multidimensional aspects of sleep disturbances and is widely used in clinical and research settings (Mollayeva *et al.,* 2016).

### 2.1.2 Cognitive Performance and Reaction Time

Cognitive performance refers to the speed at which an individual responds to a visual stimulus. It is determined by measuring reaction time. Reaction time is a central indicator of neurocognitive efficiency and is highly sensitive to sleep-related changes, especially in sustained attention and vigilance tasks. The Psychomotor Vigilance Task (PVT) is a widely accepted tool for evaluating reaction time and detecting lapses in attention due to sleep loss or fragmentation (Basner & Dinges, 2011). This task is sensitive to sleep deprivation, circadian rhythm, sedation, and other fatigue-related conditions. The original task lasts 10 minutes, but a shorter version (5 minutes) is also confirmed to produce similar effects. Numerous studies have shown that even moderate sleep deprivation can significantly slow reaction times and increase attentional lapses, making it an ideal measure for esports settings where rapid decision-making and response are critical (Altena *et al.,* 2020).

### 2.1.3 Performance Metrics in Counter-Strike 2 (CS2)

CS2 is a highly competitive first-person shooter (FPS) that demands rapid reflexes, precise hand-eye coordination, strategic awareness, and teamwork. This study assessed gameplay performance using two core metrics: the kill-to-death (K/D) ratio and shooting accuracy. These indicators provide insights into a player’s mechanical, reflexive, and strategic performance under varying cognitive conditions (Tjønndal, 2022). The K/D ratio reflects the number of enemy eliminations a player achieves relative to how often they are eliminated. It serves as a general indicator of combat effectiveness and survival skills. However, situational factors such as team coordination, match dynamics, map selection, and the opposing team's strength also shape it (Freeman & Wohn, 2017). In contrast, shooting accuracy, defined as the percentage of shots that successfully hit a target, offers a more direct measure of mechanical skill. In CS2, accuracy is affected by aim precision, recoil control, and weapon selection. It is more closely linked to neuromotor coordination and visual tracking, abilities sensitive to sleep-related cognitive decline (Miller et al., 2020).

## 2.2 Sleep and Cognitive Performance

Sleep and cognitive performance are closely linked, impacting attention, memory, and reaction speed. Even minor sleep loss can impair decision-making and response times in high-demand tasks like gaming. Understanding this relationship is essential for assessing how recovery influences performance in esports. Research indicates that insufficient sleep disrupts neural efficiency in the prefrontal cortex, which governs executive functions critical for real-time strategy and motor coordination.

### 2.2.1 Effects of Sleep Duration on Cognitive Functioning

Sleep duration has long been recognized as a critical factor influencing cognitive function. Even modest reductions in total sleep time can impair essential cognitive domains such as attention, working memory, processing speed, and executive control. In healthy adults, short sleep durations (fewer than six hours per night) have been linked to slower reaction times and greater susceptibility to cognitive lapses (Lo *et al.,* 2016). In experimental studies, restricting sleep to four or five hours per night over multiple days results in cumulative cognitive decline, particularly in tasks requiring sustained attention and fast decision-making (Banks & Dinges, 2007). These findings are especially relevant to esports settings, where competitive gameplay depends heavily on rapid visual-motor responses and moment-to-moment decision precision.

### 2.2.2 Sleep Quality and Attentional Efficiency

Beyond the quantity of sleep, quality also plays a vital role in determining cognitive readiness. Poor sleep quality is characterized by frequent awakenings, difficulty starting sleep, or feelings of unrefreshing sleep. This is associated with increased daytime fatigue and reduced attentional control. Studies using the Pittsburgh Sleep Quality Index (PSQI) have consistently shown that individuals reporting poor sleep quality perform worse on vigilance tasks and are more prone to attentional errors (Mollayeva *et al.,* 2016). A meta-analysis by Pilcher and Huffcutt (1996) concluded that both sleep deprivation and poor-quality sleep are associated with moderate to significant impairments in cognitive performance, especially for tasks requiring sustained attention or response inhibition.

## 2.3 Sleep and Esports/Gaming Performance

As esports evolves into a structured competitive discipline, interest in the physiological and cognitive demands placed on players has intensified. One area of growing importance is the role of sleep in shaping in-game performance. Unlike traditional athletes who rely on muscular endurance and gross motor skills for peak performance, esports athletes rely heavily on cognitive sharpness, reaction speed, fine motor coordination, and decision-making under pressure (DiFrancisco-Donoghue *et al.,* 2019).

### 2.3.1 Sleep Duration and Game-Specific Mechanics

Sleep duration directly influences real-time responsiveness and task execution in gaming environments. Research on digital performance has shown that players with longer nightly sleep durations perform better on precision-based tasks such as aiming, target selection, and object tracking. In one study, sleep-deprived participants showed significantly worse performance in first-person shooter games than well-rested participants, with reductions in shooting accuracy and situational awareness (Miller *et al.,* 2020). These findings mirror broader sleep science literature where sleep deprivation is associated with impaired neural timing, reduced inhibitory control, and increased error rates in complex tasks (Goel *et al.,* 2009).

### 2.3.2 Impact of Poor Sleep Quality on Mental Stamina and Decision-Making

Even without reduced duration, poor sleep quality has negatively affected esports performance. In a study by Lee *et al.* (2021), players reporting poor PSQI scores showed greater performance inconsistencies, lower self-rated confidence, and reduced endurance during extended gaming sessions. This aligns with neuropsychological research indicating that fragmented or unrestorative sleep compromises the brain's ability to maintain attentional effort and decision stability over time (Killgore, 2010).

## 2.4 Theoretical Justification

The theoretical foundation of this study draws from established frameworks in cognitive neuroscience and performance psychology, particularly the restorative theory of sleep. This theory posits that sleep is essential for recovering cognitive and physiological systems taxed during waking hours. According to this theory, the brain undergoes critical repair, memory consolidation, and neurochemical rebalancing during sleep, all necessary for sustained cognitive performance and sensorimotor coordination (Xie et al., 2013). These restorative processes are particularly relevant to esports, where players must make high-stakes decisions quickly and repeatedly over extended sessions. Closely related is the synaptic homeostasis hypothesis (SHY), which suggests that sleep serves to downscale synaptic strength accumulated during learning and wakefulness, thereby preserving brain efficiency and readiness for subsequent tasks (Tononi & Cirelli, 2014). In competitive gaming, players often engage in pattern recognition, aim training, and real-time decision-making, all involving synaptic potentiation and neural plasticity. The SHY model implies that without sufficient sleep, players may experience cognitive overload and diminishing returns on skill consolidation, particularly in tasks that rely on speed and accuracy.

## 2.5 Gap in Literature

Despite the growing interest in the relationship between sleep and performance, research on esports remains limited, particularly among amateur players who comprise most of the gaming community. Existing studies concentrate on professionals, overlooking amateurs who frequently face irregular sleep patterns due to late-night gaming, work, and academic pressures, heightening their susceptibility to cognitive impairments. Furthermore, most research focuses on general cognitive outcomes without directly correlating sleep variations with objective in-game metrics such as accuracy, Kill-to-Death ratio, or reaction time. Few studies have investigated these effects in real-world gaming settings like Counter-Strike 2, restricting their practical relevance. This research seeks to fill these gaps by combining validated sleep assessments with in-game analytics to explore how sleep duration and quality impact specific gameplay outcomes in amateur CS2 players.

# 3 **Methodology**

This section outlines the research design, sampling and recruitment strategies, data collection instruments, and analytical procedures to investigate the relationship between sleep behavior and in-game performance among amateur Counter-Strike 2 players. The study's objectives guided the methodological approach, which examined the correlational and predictive links between sleep duration, sleep quality, and cognitive and gameplay outcomes. Validated tools such as the Pittsburgh Sleep Quality Index (PSQI), the Psychomotor Vigilance Task (PVT), and in-game performance metrics were utilized to ensure accuracy and relevance.

## 3.1 Research Design

This study employed a quantitative, cross-sectional, and observational research design to investigate the relationships between sleep behavior and performance outcomes in amateur Counter-Strike 2 players. Rather than manipulating variables or assigning participants to groups, naturally occurring data on sleep duration, sleep quality, reaction time, and in-game performance were collected and analyzed. This non-experimental approach is suitable for exploring associations and predictive patterns in real-world settings, aligning with established guidelines for behavioral research (Creswell & Creswell, 2018). Data were gathered over 14 days, from 26 January 2025 to 19 January 2025, using structured self-report tools, including daily sleep logs and the Pittsburgh Sleep Quality Index (PSQI), digital cognitive testing via the Psychomotor Vigilance Task (PVT), and weekly performance metrics from CS2's in-game tracker. Statistical analyses included Pearson correlation to identify relationships and multiple regression to assess the predictive influence of sleep variables on gaming outcomes.

## 3.2 Sampling and Recruitment Strategy

This subsection outlines the sampling method and recruitment process used to select participants for the study. The approach was grounded in the need to access a specific population, amateur Counter-Strike 2 players, within natural online environments. Given the study's observational design, a non-probability sampling strategy was adopted to ensure feasibility and relevance. Details are provided on the platforms used, the inclusion and exclusion criteria, and the practical steps taken to reduce bias and ensure the sample aligned with the research objectives.

### 3.2.1 Sampling Technique

This study employed a non-probability sampling method, specifically purposive sampling. Rather than applying formal randomization techniques (such as simple or systematic random sampling), participants were selected based on predefined inclusion criteria and recruited from relevant gaming communities. Additionally, the recruitment process involved a referral-based strategy, where initial participants informally invited or recommended other eligible players. This grapevine-style approach, while not a formal snowball sampling technique, helped extend the reach of the study through trusted peer networks. It enabled the researcher to access a wider pool of qualified participants who were both eligible and actively engaged in amateur Counter-Strike 2 communities.

### 3.2.2 Recruitment

Participants were recruited through online platforms commonly used by amateur Counter-Strike 2 (CS2) players, including Reddit communities, Discord servers (e.g., Counter-Strike Discord | CSGO & CS2), and Facebook groups (Counter Strike 2 Community). The recruitment process also incorporated grapevine communication, whereby early respondents referred to other eligible individuals within their networks. To qualify for participation, individuals had to be at least 18 years old, self-identify as amateur CS2 players, play the game for a minimum of ten hours per week, and be willing to record their sleep and in-game performance over two weeks. Individuals were excluded if they reported being diagnosed with sleep disorders (e.g., insomnia, sleep apnea), neurological conditions affecting cognition, or irregular gaming patterns (e.g., fewer than five hours of CS2 play per week). Those using sleep medications or other interventions that could alter natural sleep patterns or cognitive performance were also excluded. Although the sampling was not randomized, combining multiple recruitment channels and consistent screening criteria helped minimize selection bias and ensured alignment with the study's target population.

## 3.3 Variables and Data Collection Procedures

This subsection describes the key variables examined in the study and outlines the tools and procedures used to collect data. The study focused on two independent variables related to sleep, sleep duration and sleep quality, and two dependent variables related to gaming performance, Kill-to-Death (K/D) ratio and accuracy %. Validated measurement tools were employed to capture subjective and objective dimensions of sleep, while gameplay metrics were derived from built-in tracking systems within Counter-Strike 2. The procedures were designed to be accessible, consistent, and ecologically valid, aligning with best practices for behavioral research conducted in naturalistic settings.

### 3.3.1 Independent Variable (Sleep)

Sleep duration was tracked objectively over 14 days using wearable devices (e.g., Fitbit, Apple Watch, etc.) or mobile sleep-tracking apps such as Sleep Cycle, Samsung Health, or Pillow. These tools use motion and heart rate data to estimate total sleep time. Participants recorded their nightly sleep duration in a structured sleep log (see Appendix A), referencing their device or app summaries each morning. This method allowed for consistent and accessible data collection while aligning with validated practices for field-based sleep monitoring (Chinoy et al., 2021).

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a widely validated instrument developed by Buysse et al. (1989) to measure subjective sleep quality over one month. The PSQI consists of 19 self-rated items grouped into seven components: sleep latency, duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, daytime dysfunction, and overall sleep quality. Each component is scored on a 0–3 scale, and the sum of the component scores yields a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality. In this study, the PSQI was administered once at the end of the 14-day data collection period to reflect participants' overall sleep experience during the study window. The questionnaire was completed digitally as part of the final survey (see Appendix B), and responses were scored following the PSQI guidelines. This approach provided a standardized, research-based assessment of perceived sleep quality while minimizing respondent fatigue.

### 3.3.2 Dependent Variable

Reaction time was measured using the Psychomotor Vigilance Task (PVT), a validated tool for assessing sustained attention and cognitive alertness. Participants completed the web-based version of the PVT daily over the 14-day study period, with each session lasting approximately three minutes. They logged their scores immediately after each test session. The test required participants to respond to randomly appearing visual stimuli, recording key outcomes such as mean reaction time (in milliseconds), lapses (missed or delayed responses), and false starts (premature responses). Participants accessed a web link at the start of the study, directing them to the platform for completing the Psychomotor Vigilance Task (PVT). This link led to a standardized online interface where the test was administered daily (see Appendix C). This method ensured consistent self-administration while aligning with established research practices in sleep and cognitive performance studies (Basner & Dinges, 2011). This test is suitable because literature has documented that reaction time improves with better sleep, reflecting cognitive recovery (Aminoff, 2012).

In-game performance was measured using two key metrics: the Kill-to-Death (K/D) ratio and shooting accuracy percentage, both extracted from Counter-Strike 2's (CS2) built-in performance tracker. Participants were instructed to access their personal match statistics through the in-game player profile dashboard, which provides weekly summaries of kills, deaths, and accuracy. At the end of each week, players manually recorded their K/D ratio and accuracy percentage in a structured log sheet provided by the researcher (see Appendix A). To enhance data reliability, participants were asked to verify their entries by cross-checking them with their CS2 statistics dashboard. This approach ensured consistent, real-game performance data collection while preserving ecological validity in a natural gameplay environment.

## 3.4 Data Analysis

*Descriptive Statistics* was used to summarize the dataset, providing insights into the mean, median, standard deviation, and range for key variables such as sleep duration (in hours), sleep quality (PSQI), reaction time (measured in milliseconds using the *PVT*), and in-game performance metrics (Kill-to-Death ratio and accuracy percentage). Additionally, a histogram was generated to visualize data distributions. *Pearson's Correlation Analysis* will assess the strength and direction of relationships between *sleep variables* and *performance outcomes*. Specifically, the study will determine the correlations between *sleep (duration* and *quality) and reaction time*. Since these are all continuous numerical variables, Pearson's correlation is the most appropriate statistical test for measuring linear associations. *Multiple Regression Analysis* will be used to explore further how sleep (duration and quality) predicts performance outcomes. *Multivariate Regression* is a statistical technique for modeling and analyzing the relationship between multiple independent variables and a single dependent variable (Kaya Uyanık & Güler, 2013).

### 3.4.1 Sample Size Determination

The required sample size was determined using Cohen's effect size formula for regression analysis to ensure adequate statistical power for detecting a meaningful relationship between the predictors and the dependent variable. This is expressed as:

$$f^2 = \frac{R^2}{1 - R^2}$$

To find $f^2$, an R2 value of 0.225 was chosen because previous studies, such as Yu et al. (2020) and Ferrie et al. (2011), explored similar variables and reported $R^2$ values in the range of 0.20 to 0.25 for models involving similar predictors. This provides a reasonable balance between statistical power and the predictive strength of the model.

Then, the total sample size *N* is determined using the formula:

$$N = \frac{(k+1)\left(z_{1-a/2} + z_{Power}\right)^2}{f^2}$$

Where: $f^2$ = 0.29, *k* = 2 (number of predictors)

$Z_{1-a/2}$ = 1.96 (z-value for a two-tailed test at a = 0.05)

$Z_{power}$ = 0.84 (z-value corresponding to 80% power)

By substituting these values, *N* = 81 (approx.)

### 3.4.2 Model Specification

This research examined the relationship between sleep variables (independent variables) and cognitive recovery (dependent variable) among amateur CS2 players. The model is specified as follows:

$Y_{K/D\ ratio} = \beta_0 + \beta_1$ (Sleep Duration) + $\beta_2$ (Sleep Quality) + $\varepsilon$ . . . . (1.1)

$A_{ccuracy\%} = \beta_0 + \beta_1$ (Sleep Duration) + $\beta_2$ (Sleep Quality) + $\varepsilon$ . . . . (1.2)

## 3.5 Justification for the Model

The chosen model is justified for its efficiency, simplicity, and ability to effectively capture the relationships between sleep duration, sleep quality, and in-game performance (K/D ratio and Accuracy% %) in amateur CS2 players. Descriptive statistics provide a clear summary of data distribution, while Pearson's correlation identifies the strength and direction of relationships between key variables. Linear regression is essential for determining whether sleep variables significantly predict cognitive and in-game performance, allowing for better insight beyond simple correlations.

## 3.6 Ethical Considerations

All participants were provided with clear and comprehensive information about the study, its purpose, procedures, and potential risks. Written informed consent was obtained before participation. Participants' data were anonymized, and all personal identifiers were removed before analysis. Data was securely stored and protected. Participants were informed that they could withdraw from the study without facing any penalties or loss of benefits.

# 4 Results

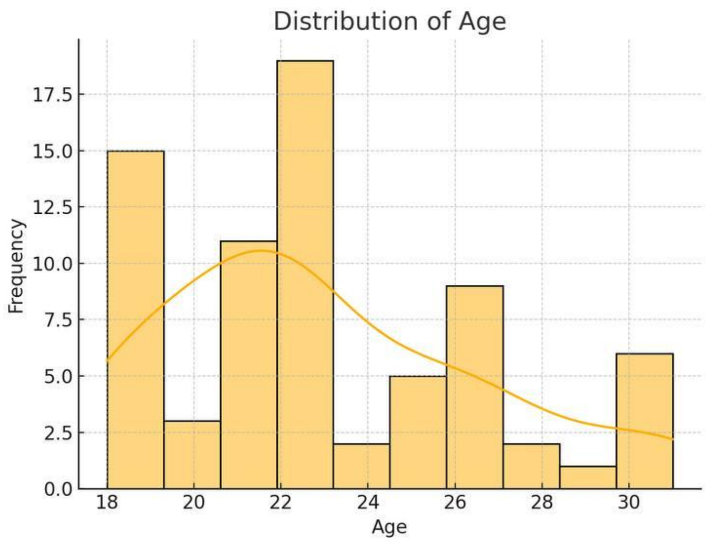
This section presents the results of the statistical analyses conducted on data collected from amateur Counter-Strike 2 players. A total of 90 participants were initially recruited. However, during data screening, 17 responses were excluded due to incomplete or inconsistent entries, leaving 73 valid cases for final analysis. These participants form the analytical sample for this study. The findings are presented according to the two research objectives. The analysis begins with respondent demographics, descriptive statistics, diagnostic and assumption checks, and the correlation and regression results.

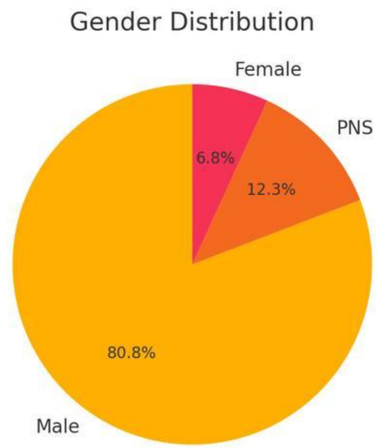
## 4.1 Descriptive Statistics

This subsection presents the descriptive statistics for both the demographic and study variables. Demographic data, including age and sex, are summarized to provide context about the participant population. The subsection also includes descriptive statistics for the primary study variables: the independent variables (sleep duration and sleep quality) and the dependent variables (reaction time, PVT lapses, PVT false starts, Kill-to-Death (K/D) ratio, and accuracy percentage). For each variable, measures of central tendency (mean), variability (standard deviation), and range (minimum and maximum) are reported. These values offer a foundational overview of the participants' profiles and performance patterns within the two-week data collection period.

### 4.1.1 Demographic Data

The histogram in *Figure 1* reveals that most participants are between 18 and 25 years old, with a noticeable concentration in their early twenties. This suggests a youthful participant base, which aligns with the typical demographic of amateur esports communities. The distribution shows a slight right skew due to a few older participants, though the central trend remains focused around the early twenties. The pie chart in *Figure 2* illustrates the gender distribution, showing a clear dominance of male participants. This visual highlights a significant gender imbalance, reflecting broader trends in the gaming sector where male involvement remains disproportionately high. A smaller percentage of respondents identified as female, while a few selected "PNS" (Prefer Not to Say), a category included for participant privacy. The overall visual data confirms that the study sample is predominantly young and male.




Figures 1 and 2: *Histogram (Left) and Pie chart (Right) Showing Age Distribution and Gender of Participants, respectively* (n = 73)

#### 4.1.2 Sleep, Cognitive, and In-Game Performance

The average sleep duration among participants was 6.73 hours (See Table 4.2), ranging from 4.40 to 8.47 hours. While some individuals met or exceeded the recommended 7–9 hours of nightly sleep for young adults, a considerable number fell short, indicating moderate sleep deprivation. Additionally, the mean PSQI score measuring sleep quality was 11.79. This is substantially higher than the clinical cutoff of 5, suggesting that most participants perceived their sleep as poor. Some scores reached 18, signaling severe sleep disturbances in certain individuals.

Regarding cognitive performance, the average reaction time recorded during the Psychomotor Vigilance Test (PVT) was 617.92 milliseconds (See Table 4.2), with significant variability across the sample. The slowest response exceeded 1,000 milliseconds, indicating marked attentional fatigue in at least one participant. On average, PVT lapses, defined as responses slower than 500 milliseconds, averaged 4.04 per session, pointing to decreased vigilance. Additionally, false starts averaged 3.06, reflecting a tendency toward impulsive responses and irregular attentional control.

Regarding in-game performance, the average kill/death (K/D) ratio was 1.13 (See Table 4.2), ranging from 0.53 to 1.80. This indicates a performance spectrum from subpar to notably skilled players, with some consistently achieving more kills than deaths. The mean accuracy percentage was 30.13%, peaking at nearly 45%. This level of shooting precision is relatively competitive, especially considering that professional players typically exceed 35%. Overall, the data reflect significant individual differences in sleep behavior and gaming ability, providing a solid basis for analyzing whether and how sleep metrics impact cognitive function and in-game outcomes.

Table 4.1: *Descriptive Statistics of Study Variables*

| Variable | Mean | Std. Dev. | Min | Max | Size (n) |
|---|---|---|---|---|---|
| Sleep Duration (hrs) | 6.73 | 1.11 | 4.40 | 8.47 | 73 |
| Sleep Quality (PSQI) | 11.79 | 3.19 | 5.00 | 18.00 | 73 |
| Reaction Time (ms) | 617.92 | 206.59 | 291.96 | 1016.75 | 73 |
| PVT Lapses | 4.04 | 1.00 | 2.19 | 5.90 | 73 |
| PVT False Starts | 3.06 | 0.69 | 1.72 | 4.55 | 73 |
| K/D Ratio | 1.13 | 0.32 | 0.53 | 1.80 | 73 |
| Accuracy (%) | 30.13 | 7.92 | 18.56 | 44.96 | 73 |

## 4.2 Diagnostic and Assumption Checks

Before interpreting the regression results, key assumptions of multiple linear regression were examined and met. Linearity was confirmed through scatterplots of the sleep variables against both K/D ratio and accuracy, which showed no strong curvilinear trends; residual plots further supported this assumption (See Appendix D). The normality of residuals was assessed using histograms of standardized residuals, which approximated a normal distribution. Homoscedasticity was evaluated using residual-versus-fitted value plots, and no significant violations of equal variance were observed (See Appendix D). Finally, multicollinearity was ruled out, as the Variance Inflation Factor (VIF) values for sleep duration and PSQI score were 1.07. The VIF values quantify how much a regression coefficient's variance is inflated due to collinearity with other predictors. A VIF below 5 is generally considered acceptable, with values under 2 indicating a very low risk of multicollinearity. Both sleep duration and sleep quality meet this criterion, meaning they provide unique, non-redundant contributions to the regression models.

Table 4.2: *Variance Inflation Factor (VIF) for Predictors*

| Feature | VIF | Size (n) |
|---|---|---|
| Sleep Duration | 1.07 | 73 |
| Sleep Quality | 1.07 | 73 |

## 4.3 Pearson Correlation

To address the first research objective, Pearson correlation analysis examined the relationship between sleep duration, sleep quality, and reaction time among amateur CS2 players. This statistical test measures the strength and direction of a linear association between two continuous variables. Table 4.3 presents the correlation coefficients (r) and p-values.

Table 4.3: *Pearson Correlation Between Sleep Variables and Reaction Time*

| Variable Pair | Size (n) | Correlation (r) | P-value | Interpretation |
|---|---|---|---|---|
| Sleep Duration vs. Reaction Time | 73 | -0.63 | 0.0043 | Strong, significant negative correlation |
| Sleep Quality (PSQI) vs. Reaction Time | 73 | 0.59 | 0.0036 | Moderate, significant positive correlation |

The analysis revealed a *strong, negative, statistically significant correlation between sleep duration and reaction time* (r = -0.63). This indicates that as sleep duration increases, *reaction time decreases, meaning participants respond more quickly*. This finding is consistent with existing sleep science literature, which links longer sleep duration to enhanced cognitive alertness and faster reaction speeds (Lo *et al.,* 2016; Goel *et al.,* 2009). Similarly, a *moderate, positive, statistically significant correlation was observed between sleep quality and reaction time* (r = 0.59). Given that higher Pittsburgh Sleep Quality Index (PSQI) scores reflect poorer sleep quality, this positive correlation suggests that worse subjective sleep is associated with slower reaction times. In other words, participants who experienced lower-quality sleep tended to perform more sluggishly in cognitive tasks.

## 4.4 Multiple Regression Results

Multiple linear regression analyses were conducted to address the second objective, evaluating the predictive influence of sleep duration and sleep quality on in-game performance. Each outcome variable (K/D ratio and accuracy percentage) was modeled separately with sleep duration and sleep quality (PSQI score) as predictors.

### 4.4.1 Model 1: Predicting K/D Ratio

The first regression model assessed whether sleep duration and sleep quality (measured by PSQI) could significantly predict players' Kill-to-Death (K/D) ratios in Counter-Strike 2 players. The model explained approximately 9% of the variance in K/D performance ($R^2$ = 0.09), with an adjusted $R^2$ of 0.064 after accounting for the number of predictors and sample size. While the overall model was not statistically significant at the conventional $p < 0.05$ level, it approached marginal significance, $F(2, 70) = 2.59$, $p = .074$, suggesting a potential trend worth noting. When examining the individual predictors, sleep duration showed a marginally significant positive relationship with the K/D ratio. This implies that players who slept longer tended to perform slightly better in combat situations, reflected by higher K/D ratios. However, the effect was weak and fell just outside the threshold for statistical significance. In contrast, sleep quality (PSQI) was not a significant predictor of K/D ratio, indicating that perceived sleep quality had no meaningful relationship with combat performance in this model. Overall, the results suggest a weak but possible association between sleep duration and in-game survivability, while subjective sleep quality showed little predictive value. (See Table 4.4 below)

Table 4.4: Multiple Regression Result Predicting K/D Ratio

| Predictor | Standardized Coefficients | Standard Error | t-stat | p-value |
|---|---|---|---|---|
| Intercept | 1.037 | 0.246 | 4.204 | 7.604E-05 |
| Sleep Duration | 0.286 | 0.151 | 1.897 | 0.062 |
| Sleep Quality | 0.080 | 0.111 | 0.722 | 0.473 |

Model Summary: $R^2$ = 0.09, *Adjusted* $R^2$ = 0.064, $F\ (2,70)$ = 2.59, $p$ = 0.074

### 4.4.2 Model 2: Predicting Accuracy Percentage

The second model investigated how sleep duration and quality predicted players' shooting accuracy, a critical indicator of mechanical skill and reflex performance in esports. This model yielded a much stronger result, explaining 23% of the variance in accuracy scores ($R^2 = 0.23$), with an adjusted $R^2$ of 0.208. The overall regression model was statistically significant, $F(2, 70) = 10.45$, $p = .0001$, indicating that the sleep-related predictors collectively contributed meaningfully to differences in shooting accuracy among participants. Sleep duration emerged as a statistically significant and positive predictor of shooting accuracy. This suggests that participants who reported longer sleep durations during the two-week study period tended to exhibit higher shot precision in gameplay, underscoring adequate sleep's cognitive and motor coordination benefits. On the other hand, sleep quality did not significantly predict accuracy performance. Although the negative coefficient hints that poorer subjective sleep quality might be associated with lower accuracy, the relationship was not strong enough to reach statistical significance (See Table 4.5 below).

Table 4.5: Multiple Regression Result Predicting Accuracy Percentage

| Predictor | Standardized Coefficients | Standard Error | t-stat | p-value |
|---|---|---|---|---|
| Intercept | 24.224 | 5.542 | 4.371 | 4.2E-05 |
| Sleep Duration | 0.127 | 0.053 | 2.39 | 0.002 |
| Sleep Quality | -0.282 | 0.251 | -1.13 | 0.264 |

Model Summary: $R^2$ = 0.23, *Adjusted* $R^2$ = 0.208, $F(2,70)$ = 10.45, $p$ = 0.0001

## 4.5 Summary of Key Findings

This study examined the impact of sleep behavior on cognitive functioning and in-game performance among amateur Counter-Strike 2 players. Out of 90 recruited participants, 73 satisfied the inclusion criteria and completed all study requirements. The sample consisted mainly of male players (n = 59), with an average age of 23 years, reflecting the typical demographic of amateur competitive gaming communities. Descriptive statistics indicated an average sleep duration of 6.73 hours, with most participants falling short of recommended sleep levels. The average PSQI score was 11.79, suggesting poor subjective sleep quality across the sample. Cognitive performance data showed an average reaction time of 617.92 milliseconds, while in-game metrics averaged 1.13 for K/D ratio and 30.13% for shooting accuracy.

In addressing the first research objective, Pearson correlation analyses revealed significant relationships between sleep behavior and reaction time. Sleep duration demonstrated a strong negative correlation with reaction time (r = -0.63, p = 0.0043), indicating that longer sleep was associated with faster responses. Similarly, sleep quality (PSQI score) showed a moderate positive correlation with reaction time (r = 0.59, p = 0.0036), suggesting that poorer subjective sleep quality was linked to slower cognitive performance. These findings align with existing literature highlighting the detrimental effects of inadequate sleep on cognitive speed and attentional control.

The second research objective focused on predicting in-game performance using multiple regression models. For the K/D ratio, the model accounted for 9% of the variance and was marginally significant ($F(2,70) = 2.59$, $p = .074$). Sleep duration was a borderline significant predictor ($B = 0.286$, $p = .062$), suggesting a possible trend where players who slept longer performed slightly better in combat. Sleep quality, however, did not significantly predict K/D outcomes. This model indicates that while sleep may influence survival metrics to a limited extent, other factors likely play a more dominant role in K/D performance.

In contrast, the regression model predicting shooting accuracy yielded stronger results. It explained 23% of the variance and was statistically significant ($F(2,70) = 10.45$, $p = .0001$). Sleep duration positively affected accuracy ($B = 0.127$, $p = .002$), indicating that better sleep duration enhances players' mechanical precision and neuromotor coordination. Sleep quality again was not a significant predictor, though its negative coefficient suggests a potential inverse trend. Overall, the findings reinforce that, more than subjective sleep quality, sleep duration is a consistent and valuable contributor to improved cognitive and performance outcomes in competitive esports.

# 5 Conclusion

This section interprets and contextualizes the results presented in section 4 (results), linking the statistical findings with relevant literature in sleep science, cognitive psychology, and esports performance. The analysis was structured around two central research objectives: first, to determine the relationship between sleep duration, sleep quality, and reaction time among amateur Counter-Strike 2 players; and second, to evaluate the predictive influence of these sleep variables on in-game performance metrics, specifically, Kill-to-Death (K/D) ratio and shooting accuracy. The section begins by discussing each research objective in light of empirical evidence, followed by a conclusion that reflects on the implications of the findings. The final section outlines practical, evidence-based recommendations for amateur esports players, coaches, and researchers, and highlights key limitations that frame the direction for future work.

## 5.1 Objective One: Relationship Between Sleep Variables and Reaction Time

The primary objective of this study was to examine how sleep duration and sleep quality relate to reaction time among amateur Counter-Strike 2 players. A Pearson correlation analysis revealed a strong negative correlation between sleep duration and reaction time ($r = -0.63$, $p < .001$), suggesting that longer sleep durations are linked to faster response times. Additionally, sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), showed a moderate positive correlation with reaction time ($r = 0.59$, $p < .001$), indicating that poorer subjective sleep quality is associated with slower cognitive responses.

These findings align with existing literature linking inadequate sleep to diminished cognitive performance. Prior research has shown that shorter sleep durations impair attentional control, slow psychomotor response, and reduce overall alertness (Basner & Dinges, 2011; Banks & Dinges, 2007). The use of the Psychomotor Vigilance Task (PVT) in this study, which measures sustained attention and processing speed, further supports its sensitivity for assessing sleep-related cognitive effects (Lim & Dinges, 2008). In the context of esports, these findings reinforce conclusions by Bonnar et al. (2019) and Lee et al. (2021), who discovered that poor sleep compromises visual processing speed and increases mental fatigue among competitive players.

The strong association between PSQI scores and reaction time supports the utility of the PSQI as more than just a subjective metric. It reflects actual performance outcomes, corroborating prior findings by Curcio et al. (2006) linking poor sleep quality with attention deficits. Together, these results underscore that both sleep quantity and quality play an important role in maintaining cognitive sharpness, a vital attribute for reaction-based tasks in esports environments.

## 5.2 Objective Two: Predictive Influence on In-Game Performance

The second objective of the study was to assess whether sleep duration and sleep quality could predict specific in-game performance outcomes: Kill-to-Death (K/D) ratio and shooting accuracy. Two separate multiple regression models were analyzed. The model predicting K/D ratio was marginally significant, explaining approximately 9% of the variance ($R^2 = 0.09$, Adjusted $R^2 = 0.064$, $F(2,70) = 2.59$, $p = .074$). Sleep duration emerged as a borderline significant predictor of K/D ratio ($B = 0.286$, $p = .062$), while sleep quality was insignificant. This suggests a weak trend where longer sleep may slightly improve survival-based performance, though other variables are likely to account for most variance in K/D ratios.

In contrast, the regression model for shooting accuracy was statistically robust. It explained 23% of the variance ($R^2 = 0.23$, Adjusted $R^2 = 0.208$, $F(2,70) = 10.45$, $p < .001$), with sleep duration emerging as a significant predictor ($B = 0.127$, $p = .002$). This indicates that players who slept longer were more accurate in their shots, directly reflecting enhanced motor coordination and neuromechanical consistency. Sleep quality remained a non-significant predictor, but the negative coefficient suggests a potential inverse trend that did not achieve statistical significance.

These results reinforce that sleep duration is a more reliable determinant of performance outcomes than subjective sleep quality, especially for mechanical tasks like aiming. The findings align with studies by Lo et al. (2016) and Bonnar et al. (2019), which report improved accuracy and reduced error rates among individuals with longer sleep durations. The lack of predictive power for sleep quality supports conclusions by Pilcher et al. (1997), who found that perceived sleep quality is more closely linked to mood than to measurable task performance. Notably, the limited influence of sleep on K/D ratio also suggests that this metric is affected by broader factors such as opponent strength, match dynamics, and team coordination, elements not fully captured by sleep-related variables.

## 5.3 Implications of the Study

The findings of this study have meaningful implications for amateur esports. They emphasize the importance of physiological readiness, particularly sleep, in achieving optimal in-game performance. While most training efforts in esports focus on refining technical skills and tactical awareness, this research shows that cognitive sharpness, strongly influenced by adequate sleep, is just as critical. The consistent relationship between sleep duration and key metrics suggests that sleep should be treated as a core component of competitive preparation.

For amateur players, the practical takeaway is clear: getting sufficient sleep can lead to measurable improvements in game performance. Unlike professional esports athletes who benefit from structured support systems, including sleep coaches and performance analysts, amateur players often overlook rest as a performance factor. Nevertheless, this study shows that sleep duration directly affects crucial execution-based skills in CS2, underscoring the need for amateur gamers to approach sleep with the same seriousness as training routines.

On a broader scale, these findings support cognitive neuroscience and performance psychology theories that view sleep as a powerful cognitive enhancer. In high-stakes digital environments where success depends on split-second decisions and precision, well-rested individuals benefit from faster neural processing, better attention control, and reduced cognitive fatigue. This has implications for individual players, esports organizations, and digital platforms aiming to improve player outcomes through education and behavioral strategies.

The study also raises valuable questions about the role of subjective sleep quality in performance. Although PSQI scores correlated with slower reaction times, they failed to predict performance metrics in regression analysis, suggesting a disconnect between perceived sleep and actual gameplay effectiveness. This points to future studies integrating objective sleep measurement tools, such as wearables or sleep trackers, to better understand sleep's influence on digital performance. Overall, the research advocates for a shift in how amateur players conceptualize success, not just through practice, but through a holistic model that includes rest, recovery, and physiological wellness.

## 5.4 Recommendations

Based on the findings of this study and grounded in evidence from the broader literature on sleep, cognition, and esports performance, this section presents two categories of recommendations: (1) practical recommendations for amateur players and esports stakeholders, and (2) directions for future research to address the study's limitations and extend its contributions.

### 5.4.1 Practical Recommendations

Prioritize a Consistent Sleep Duration of at Least 7 Hours Per Night: Given the strong predictive influence of sleep duration on accuracy percentage, amateur players should aim for a minimum of 7 to 9 hours of nightly sleep, consistent with the recommendations from the National Sleep Foundation (Hirshkowitz *et al*., 2015). Regular, sufficient sleep may offer a natural, performance-enhancing benefit by improving vigilance, motor precision, and reaction, which is essential for competitive gameplay.

Integrate Sleep Hygiene Education into Esports Coaching: Coaches, team managers, and content creators working with amateur or aspiring players should incorporate sleep hygiene principles into training regimens. These include fixed sleep-wake schedules, limiting caffeine and blue light exposure before bed, and engaging in wind-down routines (Bonnet & Arand, 2007). Such interventions have improved sleep quality and task performance, especially in digitally active young adults.

Treat Sleep as a Cognitive Recovery Tool: Amateur gamers often focus on technical skill drills and in-game decision-making, but neglect recovery. This study highlights that sleep is not just rest but part of the training cycle. Fullagar *et al.* (2015) noted that recovery through sleep enhances neural efficiency and sensorimotor integration, which are key to achieving mechanical consistency in high-intensity gameplay.

Use Technology for Sleep Monitoring and Feedback: Players can consider incorporating wearable sleep trackers (e.g., smartwatches, sleep bands) to obtain objective feedback about their sleep duration and patterns. While not as precise as lab-based actigraphy, commercial devices can raise awareness, support habit tracking, and help link behavioral patterns to performance outcomes (Chinoy *et al.,* 2021).

### 5.4.2 Recommendations for Future Research

Future studies should incorporate objective sleep measurement tools such as actigraphy or EEG-based monitors to enhance the accuracy of sleep data. While the PSQI provides valuable subjective insights, it may not fully capture the physiological realities of sleep quality. Using objective tools would help clarify inconsistencies between perceived and actual sleep states and strengthen the reliability of findings related to performance outcomes (Kelly *et al*., 2012).

Future research should adopt longitudinal or experimental designs to establish clearer causal links between sleep and performance. Tracking players over time or manipulating sleep conditions in controlled experiments would provide more definitive evidence on how changes in sleep behavior directly influence gameplay metrics (Lo *et al*., 2016). This approach would move the field beyond correlational insights and allow for stronger inferences about sleep's role in digital performance. Additionally, upcoming studies should include a broader range of covariates in their statistical models. Factors such as caffeine consumption, daily screen exposure, stress levels, and practice duration are all known to affect both sleep patterns and cognitive performance (Goel *et al.,* 2009). Controlling these variables would allow for more refined regression analyses and help isolate the specific impact of sleep on gameplay.

Expanding the scope of research to include other esports genres and competitive levels is also essential. While this study focused on CS2 and amateur players, replicating the methodology across different game types, such as MOBAs, real-time strategy games, or sports simulators, and among semi-professional and professional players would test the generalizability of sleep-related performance effects across contexts and skill levels. Finally, future investigations should examine the team-based dynamics of sleep and performance. Since metrics like K/D ratio are heavily influenced by team coordination, future studies could explore how shared sleep schedules, in-game communication, and team synchronization influence collective success in multiplayer esports. This would contribute to a deeper understanding of how sleep behavior operates at the individual level and within coordinated team environments.

### 5.5 Limitations of the Study

While this study offers valuable insights into the relationship between sleep and esports performance, several limitations should be acknowledged. These methodological, statistical, and contextual limitations influence how the findings can be generalized or interpreted accurately.

Sampling Size and Statistical Power: Although the final sample consisted of 81 participants, which met the minimum threshold determined through a priori power analysis, the study design assumed a 10% attrition rate. It aimed to recruit 90 people. Falling slightly below this target may have compromised the ideal statistical power of 0.80. Particularly for the regression model predicting K/D ratio, where the p-value approached but did not cross the conventional significance threshold, a larger sample might have increased power and potentially revealed statistically meaningful effects.

Cross-Sectional Design: The study employed a cross-sectional observational design, capturing data at a single point in time. While significant correlations and predictive relationships were identified, the design does not permit causal inferences. For instance, while it is plausible that poor sleep leads to slower reaction times, sustained cognitive fatigue or stress from gameplay may also contribute to poorer sleep, suggesting a bidirectional relationship. A longitudinal or experimental design would be necessary to establish complete causality.

Self-Reported Sleep Quality: Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a well-validated but subjective instrument. As a self-report tool, it is vulnerable to recall bias, misestimation, and the influence of mood or personality traits. Participants may have under- or overestimated their sleep disturbances, affecting the reliability of the PSQI scores. The lack of objective sleep measures (such as actigraphy or polysomnography) limits the precision of conclusions about sleep quality.

Measurement of Performance Variables: In-game performance metrics were extracted from self-reported gameplay sessions or digital logs. While these indicators are relevant to CS2 performance, they are also influenced by contextual variables not captured in this study, including team coordination, opponent difficulty, map type, and game mode. The K/D ratio is known to be multifactorial and may not reflect individual skills alone. This adds variability and potential noise to the outcome measures.

## 5.6 Final Thought

This study explored how sleep is a recovery factor, specifically sleep duration and quality, influences cognitive performance (reaction time) and in-game performance metrics (K/D ratio and accuracy) among amateur CS2 players. The findings demonstrate that sleep, particularly duration, plays a vital role in shaping player responsiveness, execution speed, and shooting accuracy. The Pearson correlation analysis confirmed that longer sleep duration is associated with faster reaction times. In contrast, poorer subjective sleep quality is linked to slower responses, reinforcing established links between sleep and cognitive performance.

The multiple regression analyses offered even stronger insights, showing that sleep duration significantly predicts both in-game accuracy and reaction time, even after controlling for sleep quality. These highlight sleep quantity as a uniquely influential factor in digital performance, especially in reaction-intensive esports settings. While sleep quality showed significant correlation in isolation, it lacked predictive power when tested alongside sleep duration, suggesting that how long players sleep may matter more than how they perceive the quality of that sleep.

Despite limitations such as self-reported data, a cross-sectional design, and the absence of contextual control variables, the study adds valuable evidence to the growing field of performance neuroscience and esports research. It underscores the practical importance of sleep for amateur players and esports coaches, reframing it as a critical performance asset rather than just a health necessity. Future studies should adopt longitudinal methods, use objective sleep tracking, and examine diverse gaming populations to better understand how biological readiness influences digital competition.

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Appendices

## A. Sample of the Survey sheet shared with Participants.

**Participant Questionnaire and Logbook**

**Study Title:** Sleep as A Recovery Factor in Amateur Counter-Strike 2 Players: Examining the Impact of Sleep Duration and Sleep Quality on Cognitive and In-game Performance.

**Purpose:** To examine the relationship between sleep and performance in CS2 players.

**Section 1: Participant Screening and Background**

1. Age: ________ (Participants must be 18–35 years old)

2. Gender: ________

3. Country of residence: ______________________

4. Are you diagnosed with sleep disorders (e.g., insomnia, sleep apnea)?
   [ ] Yes (ineligible) [ ] No

5. Do you take medications that affect sleep or alertness (e.g., melatonin, stimulants)? [ ] Yes (ineligible) [ ] No

6. Have you been diagnosed with any neurological or psychiatric conditions?
   [ ] Yes (ineligible) [ ] No

7. How many hours do you typically play CS2 per week?
   [ ] Less than 5 (ineligible) [ ] 5–9 [ ] 10–14 [ ] 15–20 [ ] More than 20

8. Do you regularly play CS2 using your device and internet connection?
   [ ] Yes [ ] No (ineligible)

9. Do you own or have access to a sleep-tracking device or app?
   [ ] Yes [ ] No

10. Will you track your sleep and gaming performance for 14 days?
    [ ] Yes [ ] No (ineligible)

**Section 2: Daily Sleep and Reaction Log (14 Days)**

| Day | Total Sleep (hrs.) | Reaction Time (ms) - *pvt* | Lapses (>500ms) *- pvt* | False Starts *- pvt* |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |

**Section 3: Weekly In-Game Performance Log**

| Week | Average K/D Ratio | Accuracy (%) | Avg Game Session Length (mins) | Total Matches Played |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |

**Section 4: Final Feedback (End of Study)**

1. Did you maintain a consistent sleep schedule during the 14 days?
   [ ] Yes [ ] No

2. Did you notice any changes in your gameplay performance during the study?
   [ ] Yes [ ] No

3. Did any external factors affect your sleep or gameplay during the study?
   [ ] Yes [ ] No

B. Sample of Pittsburgh Sleep Quality Index (PSQI)

Name:_______________________________________________ Date: __________________

## Pittsburgh Sleep Quality Index (PSQI)

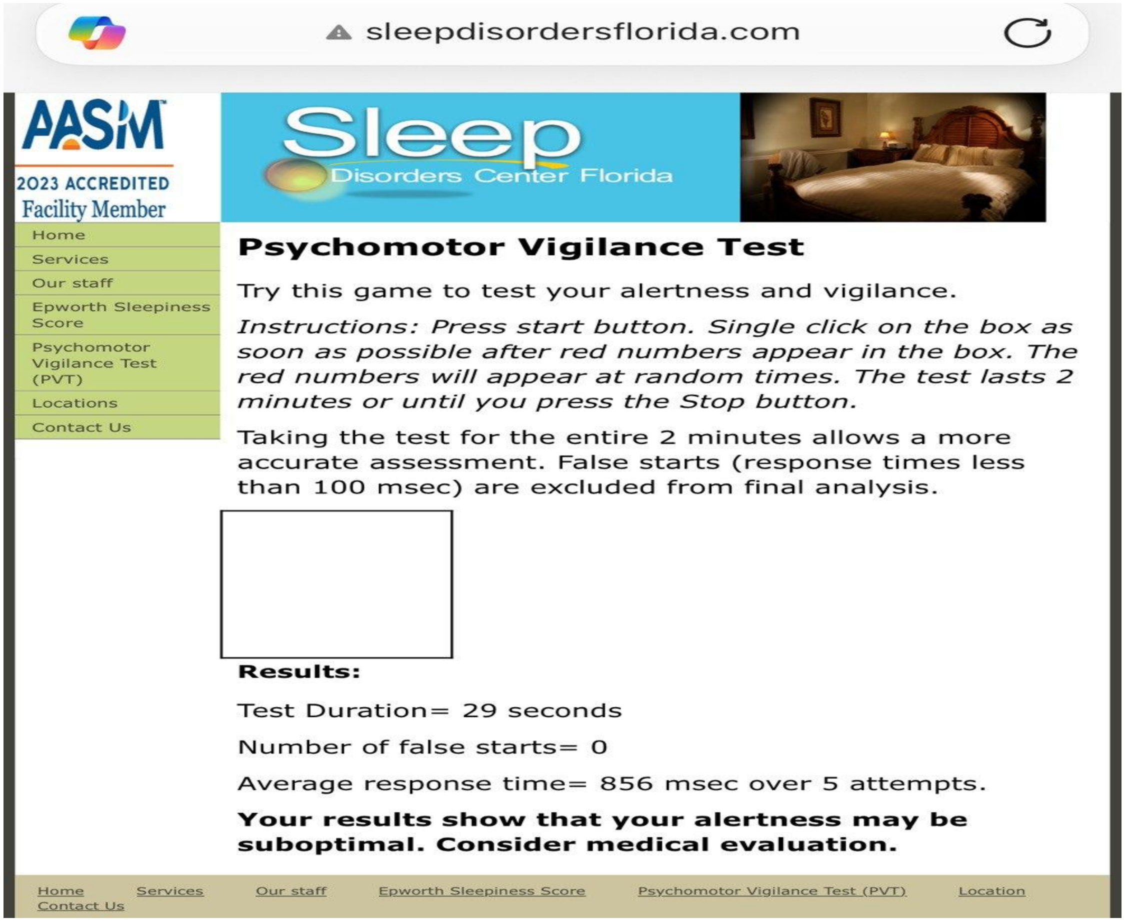
Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. **Please answer all questions.**

1. During the past month, what time have you usually gone to bed at night? ____________________
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night? __________
3. During the past month, what time have you usually gotten up in the morning? ____________________
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) ____________________

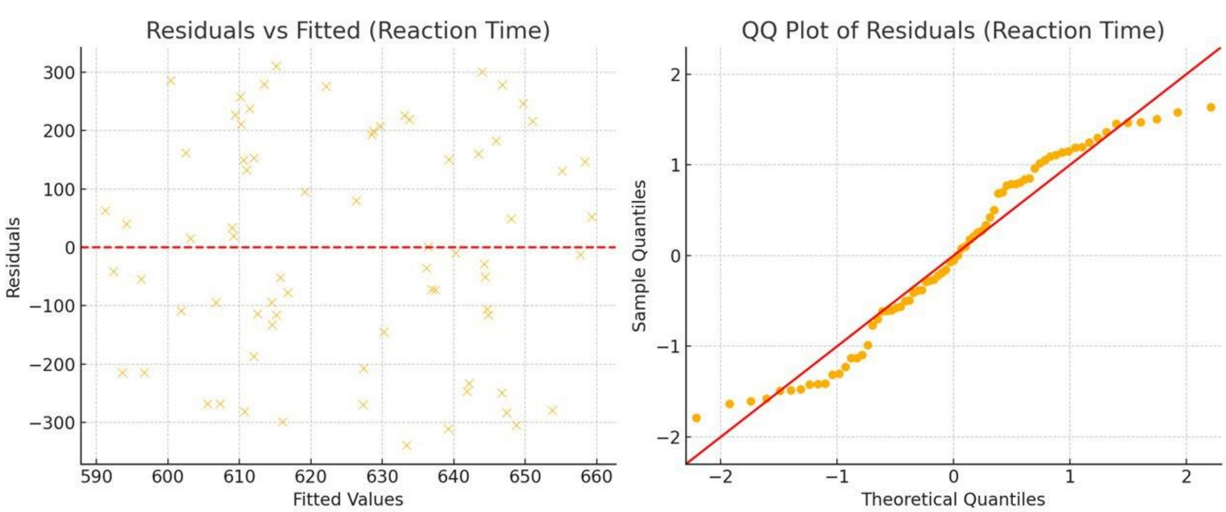
| 5. During the past month, how often have you had trouble sleeping because you… | Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |
|---|---|---|---|---|
| a. Cannot get to sleep within 30 minutes | | | | |
| b. Wake up in the middle of the night or early morning | | | | |
| c. Have to get up to use the bathroom | | | | |
| d. Cannot breathe comfortably | | | | |
| e. Cough or snore loudly | | | | |
| f. Feel too cold | | | | |
| g. Feel too hot | | | | |
| h. Have bad dreams | | | | |
| i. Have pain | | | | |
| j. Other reason(s), please describe: | | | | |
| 6. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")? | | | | |
| 7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity? | | | | |
| | No problem at all | Only a very slight problem | Somewhat of a problem | A very big problem |
| 8. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done? | | | | |
| | Very good | Fairly good | Fairly bad | Very bad |
| 9. During the past month, how would you rate your sleep quality overall? | | | | |

| | No bed partner or room mate | Partner/room mate in other room | Partner in same room but not same bed | Partner in same bed |
|---|---|---|---|---|
| 10. Do you have a bed partner or room mate? | | | | |
| | Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |
| If you have a room mate or bed partner, ask him/her how often in the past month you have had: | | | | |
| a. Loud snoring | | | | |
| b. Long pauses between breaths while asleep | | | | |
| c. Legs twitching or jerking while you sleep | | | | |
| d. Episodes of disorientation or confusion during sleep | | | | |
| e. Other restlessness while you sleep, please describe: | | | | |

C. Screenshot Image of Psychomotor Vigilance Test (PVT) layout




D. Residual vs. Fitted and QQ Plot for Homoscedasticity and Normality



## E. Frequency Distribution Table of Participant Response Gathered

Table 1: Sleep duration (n = 73)

| Sleep Duration | Frequency |
|---|---|
| 4.46 - 5.10 | 19 |
| 5.11 - 5.75 | 12 |
| 5.76 - 6.39 | 5 |
| 6.40 - 7.04 | 10 |
| 7.05 - 7.68 | 12 |
| 7.69 - 8.32 | 15 |

Table 2: Sleep quality (n = 73)

| PSQI Score | Frequency |
|---|---|
| 5.1 - 7.0 | 14 |
| 7.1 - 9.0 | 9 |
| 9.1 - 11.0 | 13 |
| 11.1 - 13.0 | 13 |
| 13.1 - 15.0 | 13 |
| 15.1 - 17.0 | 11 |

Table 3: False Starts (n = 73)

| PVT False Starts | Frequency |
|---|---|
| 1.10 - 1.58 | 12 |
| 1.59 - 2.06 | 12 |
| 2.07 - 2.54 | 9 |
| 2.55 - 3.02 | 13 |
| 3.03 - 3.50 | 16 |
| 3.51- 3.98 | 11 |

Table 4: Sleep duration (n = 73)

| Reaction Time Range | Frequency |
|---|---|
| 293.92 - 402.84 | 14 |
| 402.85 - 511.12 | 8 |
| 511.13 - 619.39 | 14 |
| 619.40 - 727.66 | 11 |
| 727.67 - 835.94 | 12 |
| 835.95 - 944.21 | 14 |

Table 5: Sleep duration (n = 73)

| PVT Lapses Range | Frequency |
|---|---|
| 1.33 - 2.19 | 5 |
| 2.20 - 3.04 | 17 |
| 3.04 - 3.89 | 20 |
| 3.90 - 4.74 | 13 |
| 4.75 - 5.59 | 9 |
| 5.60 - 6.44 | 9 |

Table 6: Sleep duration (n = 73)

| K/D Ratio Range | Frequency |
|---|---|
| 0.57 - 0.76 | 12 |
| 0.77 - 0.95 | 14 |
| 0.96 - 1.13 | 7 |
| 1.14 - 1.32 | 17 |
| 1.33 - 1.50 | 10 |
| 1.51 - 1.69 | 13 |

Table 7: Sleep duration (n = 73)

| Accuracy (%) Range | Frequency |
|---|---|
| 13.68 -18.11 | 11 |
| 18.12 - 22.52 | 11 |
| 22.53 - 26.92 | 14 |
| 26.93 - 31.33 | 19 |
| 31.33 - 35.73 | 6 |
| 35.73 - 40.14 | 12 |