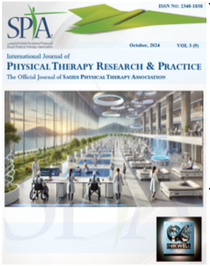

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Original Article

The Effect of Fatigue on Cognitive Tasks Among Young Adults

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Abstract

Background: This study investigates the impact of fatigue on cognitive and motor performance among young adults (18-25 years old) using the Grooved Pegboard Test (GPT). Fatigue is known to affect domains such as attention, memory, and motor skills, with physical fatigue from strenuous activities impairing cognitive performance. The study aims to assess fatigue's effect on motor speed and coordination, evaluate cognitive processing speed, and compare performance between fatigued and non-fatigued states. **Methods:** A Randomized Controlled Trial (RCT) was conducted with 42 participants, averaging 22.12 years of age, who were divided into control and experimental groups. The control group followed regular sleep and rest patterns, while the experimental group underwent a 45-minute high-intensity exercise session to induce fatigue. Performance was measured using the GPT both before and immediately after the fatigue induction. Participants also completed a post-test survey reporting perceived levels of fatigue. **Results:** Survey responses revealed that fatigue significantly affected performance, with 47% of participants strongly agreeing that fatigue impacted their cognitive and motor functions. Significant positive correlations were found between the EXP GPD Score and Control GPD Score (0.8031), and between EXP GPD Errors and Control GPD Errors (0.8595). The regression analysis indicated that for every unit increase in the Fatigue Borg Scale, the EXP GPD Score (time) increased by approximately 0.8036 units. Paired samples t-tests confirmed significant differences in performance and perceived fatigue between control and post-fatigue groups. **Conclusion:** The study confirms the detrimental effects of fatigue on cognitive-motor performance, with significant impairments in motor speed, coordination, and cognitive processing speed. These findings highlight the need for targeted interventions to mitigate fatigue and support optimal performance in various contexts.

Keywords: Fatigue, Cognitive Performance, Grooved Pegboard Test (GPT), Young Adults, International Physical Activity Questionnaire (IPAQ).

Introduction

Fatigue is a prevalent issue among young adults, often resulting from academic, work, and social pressures. It can significantly impact cognitive functions such as attention, memory, and motor skills. The Grooved Pegboard Test (GPT) is a reliable measure for assessing cognitive-motor performance, particularly eye-hand coordination, motor speed, and cognitive processing. Understanding the effects of fatigue on GPT performance can help develop strategies to improve cognitive function and overall well-being in young adults.

Fatigue in Young Adults

The Borg Scale is widely used to assess perceived exertion during exercise across various populations. Studies by Eston et al. (2004) and Pincivero (2010) demonstrated the effectiveness of the Borg 6-20 Scale in regulating exercise intensity and evaluating muscle recruitment and perceived exertion. These studies highlighted the scale's utility in understanding exertion in both young and old adults. Sidney et al. (1977) and Champagne et al. (2009) focused on perceived exertion in elderly populations, showing how aging and physical training impact exertion levels. Innovative approaches, like those by Chen et al. (2016), introduced a Rating of Perceived Exertion Scale using facial expressions for children and young adults, providing a more engaging method to assess exercise intensity. Gurses et al. (2018) emphasized functional assessments in young adults, linking sit-to-stand tests with the 6-minute walk test to physical performance.

The Borg Rating of Perceived Exertion (RPE) scale is a subjective method of measuring the intensity of physical activity and the associated fatigue. It is useful for athletes, trainers, and researchers to gauge exercise intensity. It ranges from 6 to 20, with specific rates corresponding to different levels of exertion and fatigue.

Borg Scale and Fatigue Status

The Borg Scale ranges from 6-8 for minimal fatigue with very low exertion to 9-10 for light activities causing low to moderate fatigue. 11-12 involves slight effort leading to moderate fatigue, while 13-14 signifies somewhat tiring activities causing moderate to high fatigue. 15-16 indicates vigorous activities resulting in high fatigue, 17-18 denotes very strenuous activities with very high fatigue, and 19-20 represents near maximal effort with extreme fatigue.

In clinical settings, fatigue is a common symptom in various health conditions such as fibromyalgia (FM). Studies by Silverman et al. (2010) and Li et al. (2017) explored its impact on pain, sleep interference, and the development of reliable fatigue assessment tools like the MDF-Fibro-17. Papakostidou et al. (2012) identified fatigue as a significant concern in total knee arthroplasty (TKA) patients, affecting their quality of life. Østerås et al. (2014) and Petersen et al. (2014) evaluated the effects of exercise and interventions like knee braces on fatigue in hand osteoarthritis and patellofemoral pain syndrome patients, respectively.

Aoki et al. (2015) explored the impact of surgical outcomes on fatigue in lumbar degenerative diseases. Socioeconomic factors also play a role in fatigue, with Baldassari et al. (2016) finding correlations between parental homeownership, educational levels, and fatigue in African Americans with rheumatoid arthritis.

Fatigue and Cognitive Performance

Fatigue is known to have a profound impact on cognitive performance, affecting various domains such as attention, memory, and motor skills. Understanding the intricate relationship between fatigue and cognitive functioning is essential for developing effective interventions to mitigate its adverse effects. Pilcher and Huffcutt (1996) conducted a meta-analysis examining the effects of sleep deprivation on cognitive performance, revealing significant impairments in attention, reaction time, and memory. Similarly, Lim and Dinges (2010) highlighted that sustained mental effort and inadequate sleep result in diminished cognitive performance, particularly in tasks requiring sustained attention and executive function. These studies underscore the critical role of sleep and mental rest in maintaining optimal cognitive function.

Impact of Physical Fatigue on Cognitive Tasks

Physical fatigue, induced by strenuous activities such as sports or high-intensity training, can impair cognitive performance. Tomporowski (2003) demonstrated that physical exercise, while beneficial for overall health, can lead to temporary cognitive impairments if it results in excessive fatigue, primarily affecting motor skills, attention, and reaction time. This is particularly relevant for young adults who engage in high levels of physical activity.

Grooved Pegboard Test (GPT) and Cognitive-Motor Performance

The Grooved Pegboard Test (GPT; Matthews & Kløve, 1964) is a widely used tool to assess fine motor skills, hand-eye coordination, and cognitive processing speed (Strauss, Sherman, & Spreen, 2006). It is highly utilized in clinical neuropsychology, with 71% of surveyed professionals frequently employing this test (Rabin, Paolillo, & Barr, 2016). The GPT is sensitive to various factors influencing cognitive motor performance, including age, neurological conditions, and fatigue. Research by Kløve and Matthews (1983) indicated that individuals with neurological impairments performed significantly worse on the GPT, demonstrating its utility in detecting cognitive-motor deficits.

The primary outcome measures for the GPT are the time taken to insert pegs with both the dominant and non-dominant hands. Additionally, the test allows for the observation of rule deviations, which can suggest impairments in executive functions or disruptions in frontal-subcortical circuitry. These observations are valuable for generating hypotheses about cognitive deficits but are limited by the lack of numerical norms for comparison.

Fatigue-Induced Impairments in GPT Performance

Research examining the effects of fatigue on Grooved Pegboard Test (GPT) performance is limited but expanding. Smith et al. (2015) investigated how sleep

deprivation affected GPT scores in healthy adults, revealing that participants exhibited slower completion times and more errors under sleep deprivation, suggesting that fatigue impairs fine motor skills and cognitive processing. These findings align with broader research on cognitive performance, reinforcing the detrimental effects of fatigue.

In the context of young adult workers, Budini et al. (2022) conducted a study on the fatigue effect on perceptive and motor function tasks using the GPT in a cohort of 20 young shipyard surface finishing workers. They found significant deterioration in manual dexterity and bimanual coordination in the afternoon, alongside a significant increase in fatigue levels.

Research by Fang et al. (2022) primarily focused on various exposure factors, such as lighting and work posture, and their influence on performance tasks like power grip strength, finger tapping, pegboard tests, and arithmetic tests among young workers. They concluded that performance measures of the pegboard, power grip strength, and finger tapping could not be explained by a single exposure factor. Instead, a multifactorial approach considering work posture, fatigue, task duration, mental effort, work layout, and individual discomfort was necessary (Orrego et al., 2022; Mackay-Roberts et al., 2024; Devlin et al., 2022).

Moreover, these studies emphasize the importance of cognitive tasks. For instance, arithmetic and pegboard tests assess a subject's ability to perform repetitive simulation tasks accurately and quickly, similar to some industrial tasks. The decline in these performances due to fatigue or boredom is significant.

Therefore, this study aims to comprehensively examine the effects of fatigue on cognitive tasks in young adults, with the goal of informing potential interventions to mitigate these effects and enhance performance in real-world settings. Specifically, the study seeks to assess the impact of fatigue on motor speed and coordination using the Grooved Pegboard Test, evaluate its influence on cognitive processing speed, and compare performance outcomes between fatigued and non-fatigued states.

Methodology

Participants and Study Design

Forty-two young adults aged 18–25 years were recruited from local universities and communities to participate in this study. All individuals reported regular physical activity and were free of any neurological or musculoskeletal disorders. The study employed a randomized controlled trial design to examine the effects of fatigue on cognitive performance. Participants were randomly assigned to either a control or experimental group. The control group maintained their usual sleep and rest patterns, engaging in daily activities without any fatigue induction to serve as a baseline for comparison. The experimental group underwent a fatigue induction protocol involving sports activities such as running, jumping, and resistance training, with levels of fatigue closely monitored to ensure consistency.

Grooved Pegboard Test Overview

To assess motor speed, fine motor skills, and hand-eye coordination, the study utilized the Grooved Pegboard Test (GPT), originally developed by Matthews and Kløve in 1964. The GPT requires participants to insert 25 grooved pegs into a 5x5 array of slotted holes, each with grooves in varying orientations. The task begins with the dominant hand, followed by the non-dominant hand, and participants are instructed to work as quickly as possible while following a specified order: left to right for the right hand and right to left for the left hand. Participants are required to use only one hand at a time, and corrective feedback was provided immediately if they used the non-tested hand or deviated from the correct order.

Performance Measures

Performance on the Grooved Pegboard Test was evaluated through three key measures: the time taken to insert the pegs, the number of deviations from the specified order, and instances of using the non-tested hand. These measures provided insights into the participants' motor speed, fine motor control, and coordination under both fatigued and non-fatigued conditions. This approach allowed for a comprehensive evaluation of how fatigue impacts motor and cognitive performance.

Procedure

The study procedure included a baseline assessment, fatigue induction for the experimental group, post-fatigue evaluations, and comprehensive data collection and analysis. Both groups began with a pre-test baseline assessment using the Grooved Pegboard Test (GPT) to measure fine motor skills, hand-eye coordination, and cognitive function.

The fatigue induction protocol, applied only to the experimental group, lasted approximately 45 minutes and was supervised by a trained instructor. The protocol included a 5–10 minute warm-up involving light cardio exercises such as jogging or cycling, followed by a high-intensity interval training (HIIT) circuit. The circuit comprised 4–6 rounds of exercises with minimal rest, including burpees, high knees, jump squats, mountain climbers, push-ups, and planks, each performed for 30 seconds. The session concluded with a 5–10 minute cool-down consisting of stretching and light cardio. Meanwhile, the control group followed their regular activities and rested for an equivalent period without induced fatigue.

Immediately after the fatigue induction session, both groups retook the GPT to assess changes in performance. Key performance metrics included completion time and the number of errors. Following the post-fatigue assessment, participants completed a survey to report their perceived levels of fatigue and any difficulties experienced during the GPT. A second cognitive performance assessment was conducted immediately after the fatigue protocol to reinforce findings.

Randomization ensured that participants were evenly assigned to the control and experimental groups, minimizing selection bias. Data collection included quantitative metrics, such as GPT performance (completion time and number of errors), demographic information, and fatigue perception ratings, as well as qualitative data from Likert-scale survey responses regarding participants' experiences during the test. Statistical analyses evaluated the impact of fatigue on cognitive performance, accounting for interaction effects between group assignments and variables such as gender and baseline fitness levels.

Ethical Considerations

Ethical protocols were strictly followed to ensure participant safety and confidentiality. Informed consent was obtained from all participants prior to their involvement in the study. Data were kept confidential and used solely for research purposes. Additionally, safety measures were implemented to protect participants during the fatigue induction protocol, ensuring their well-being throughout the study.

Results

A total of fifty-four participants initially responded to the pre-final test. Among them, twenty assessed the face validity of the Arabic version of the survey by scoring each item via an online form distributed through email. For the main study, forty-two young adults aged 18 to 25 years were recruited from local universities and communities. These participants had a mean age of 22.12 years (SD = 1.94), an average height of 169.66 cm (SD = 5.92) within a range of 160 to 180 cm, and a mean weight of 65.98 kg (SD = 6.62), with weights ranging from 54 to 76 kg.

The analysis focused on the survey responses and performance metrics of these 42 participants, who completed the Grooved Pegboard Test under fatigue conditions. This test assessed fine motor skills and cognitive performance. The accompanying survey, illustrated in Figure 1, aimed to evaluate participants' subjective experiences, focusing on their engagement, the impact of fatigue, and perceived changes in performance.

Participants rated their experiences using a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The survey statements addressed key areas, including engagement with the task, the difficulty encountered, the effect of fatigue on performance, and their willingness to participate in future tests.

The collected data provide valuable insights into the influence of fatigue on cognitive and motor tasks. These findings contribute to understanding how fatigue impacts performance and inform potential interventions for improving outcomes. A summary of survey responses for each statement is presented in Figure 1.

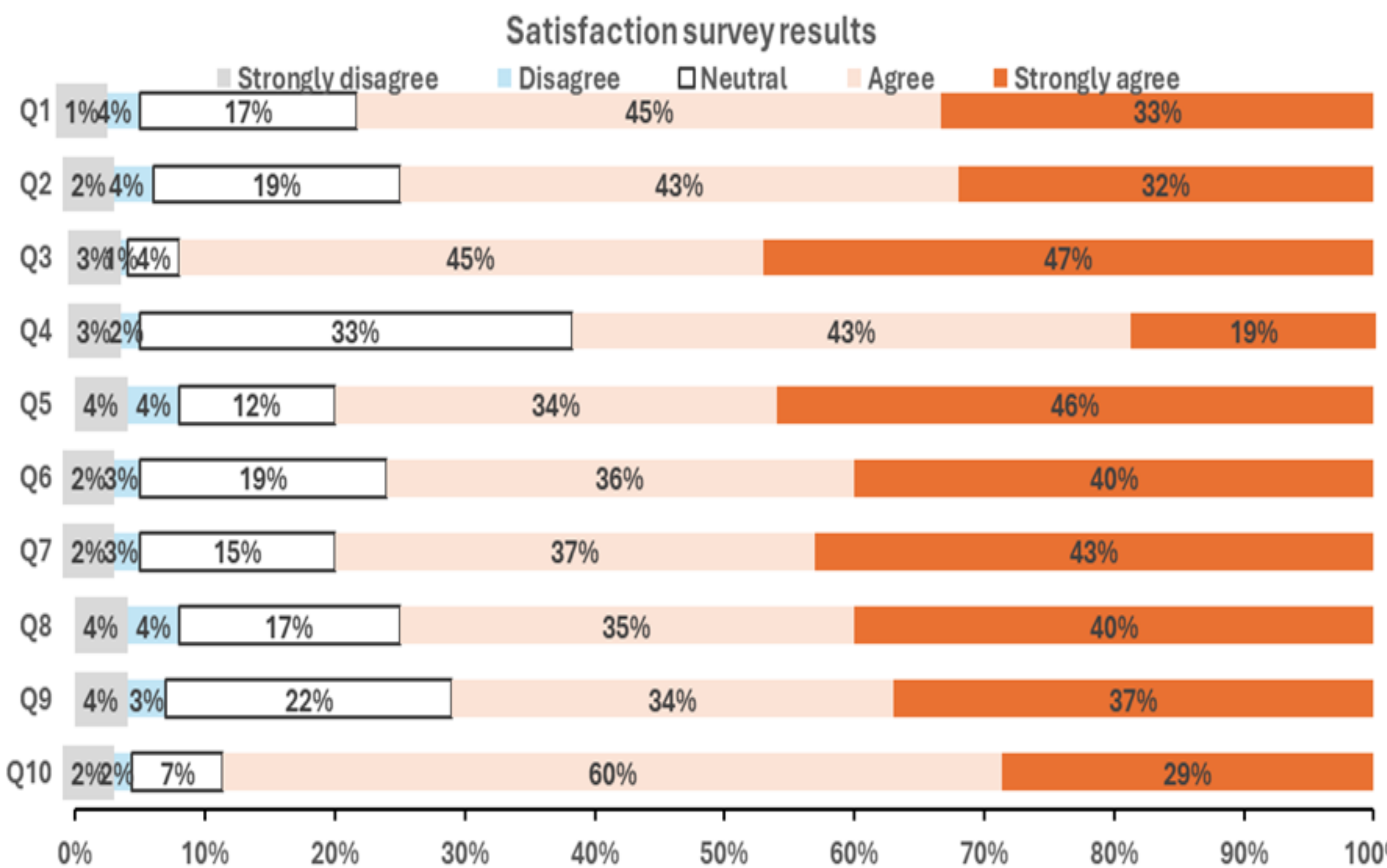

Figure 1. illustrates the analysis of survey responses collected from participants who undertook the Grooved Pegboard Test.

The analysis of survey responses from participants who completed the Grooved Pegboard Test under fatigue conditions provided valuable insights into their experiences. Most participants found the test engaging, with 33% agreeing and 45% remaining neutral, while a smaller proportion disagreed (17%) or strongly disagreed (4%). The test was widely regarded as challenging, as 43% agreed and 32% strongly agreed, with only a minority expressing disagreement (4%) or strong disagreement (2%).

Participants overwhelmingly reported that fatigue impacted their performance, with 45% agreeing and 47% strongly agreeing, while only 1% disagreed and 3% strongly disagreed. Similarly, increased errors following fatigue were noted by 43% of participants who agreed and 19% who strongly agreed, with minimal disagreement (2% disagreed and 3% strongly disagreed). A substantial 46% strongly agreed, and 34% agreed, that fatigue decreased their coordination, while 12% were neutral, and small percentages disagreed (4%) or strongly disagreed (4%).

The need for greater concentration post-fatigue was reported by many participants, with 40% strongly agreeing and 36% agreeing, compared to 19% who were neutral and a combined 5% who disagreed or strongly disagreed. Fatigue-induced stress was another significant finding, as 43% strongly agreed and 37% agreed, while 15% were neutral, and minimal disagreement was noted (3% disagreed and 2% strongly disagreed). Physical effects of fatigue were also commonly observed, with 40% strongly agreeing and 35% agreeing, and smaller groups remaining neutral (17%) or expressing disagreement (4% disagreed and 4% strongly disagreed).

The impact of fatigue on cognitive performance was evident, with 37% strongly agreeing and 34% agreeing, while 22% were neutral, and only a small proportion disagreed (3%) or strongly disagreed (4%). Despite these challenges, participants demonstrated a high willingness to participate in future tests, with 60% agreeing and 29% strongly agreeing, while only 7% were neutral and a minimal percentage disagreed (2% disagreed and 2% strongly disagreed). These findings underscore the significant influence of fatigue on motor and cognitive performance while highlighting participants' engagement and willingness to contribute to further research.

Correlation and Significance of Fatigue Measures

The analysis examined correlations and significance levels between various pre- and post-fatigue measures, including Grooved Pegboard Test (GPD) scores, errors, and subjective fatigue experiences.

A strong positive correlation (0.8031) was observed between the experimental GPD (EXP GPD) scores and the control GPD scores, which was statistically significant. Similarly, control GPD errors showed moderate positive correlations with both control GPD scores (0.5099) and EXP GPD scores (0.6964), both significant. EXP GPD errors exhibited a moderate positive correlation with control GPD scores (0.7046) and a strong positive correlation with EXP GPD scores (0.7916), both of which were significant. Moreover, a strong positive correlation (0.8595) between EXP GPD errors and control GPD errors was also significant.

In contrast, the Rest Borg Scale demonstrated weak negative correlations with control GPD scores (-0.2772) and EXP GPD scores (-0.3011), neither of which reached statistical significance. Additionally, weak correlations were noted between the Rest Borg Scale and control GPD errors (0.0288) as well as EXP GPD errors (-0.1460), none of which were significant. The Fatigue Borg Scale displayed a weak positive correlation with control GPD scores (0.1118), which was not significant. However, it exhibited moderate positive correlations with EXP GPD scores (0.4182), control GPD errors (0.4662), and EXP GPD errors (0.4692), all of which were statistically significant. The correlation between the Fatigue Borg Scale and the Rest Borg Scale was weak and negative (-0.1044), and it was not significant.

These findings highlight several significant positive correlations among GPD scores and errors, indicating a strong interrelationship between these measures, particularly under fatigue conditions. In contrast, correlations involving the Rest Borg Scale were generally weak and not statistically significant, suggesting a minimal relationship with GPD performance. The Fatigue Borg Scale, however, showed moderate positive correlations with specific GPD measures, suggesting a potential link between fatigue levels and GPD performance.

Table 1. illustrates the correlation analysis between various Grooved Pegboard Test (GPD) scores/errors and Borg Scale measurements.

Variable	by Variable	Correlation	Lower 95%	Upper 95%	Signif Prob
EXP GPD Score	Control GPD Score	0.8031	0.6580	0.8907	<.0001*
Control GPD Errors	Control GPD Score	0.5099	0.2398	0.7067	0.0007*
Control GPD Errors	EXP GPD Score	0.6964	0.4948	0.8269	<.0001*
EXP GPD Errors	Control GPD Score	0.7046	0.5069	0.8319	<.0001*
EXP GPD Errors	EXP GPD Score	0.7916	0.6397	0.8839	<.0001*
EXP GPD Errors	Control GPD Errors	0.8595	0.7502	0.9230	<.0001*
Rest Borg Scale	Control GPD Score	-0.2772	-0.5389	0.0333	0.0793
Rest Borg Scale	EXP GPD Score	-0.3011	-0.5571	0.0072	0.0558
Rest Borg Scale	Control GPD Errors	0.0288	-0.2813	0.3335	0.8579
Rest Borg Scale	EXP GPD Errors	-0.1460	-0.4342	0.1692	0.3622
Fatigue Borg Scale	Control GPD Score	0.1118	-0.2029	0.4055	0.4866
Fatigue Borg Scale	EXP GPD Score	0.4182	0.1269	0.6431	0.0065*
Fatigue Borg Scale	Control GPD Errors	0.4662	0.1851	0.6768	0.0021*
Fatigue Borg Scale	EXP GPD Errors	0.4692	0.1888	0.6788	0.0020*
Fatigue Borg Scale	Rest Borg Scale	-0.1044	-0.3992	0.2100	0.5160

Significant Impact of Fatigue on Performance Scores

The analysis revealed a significant impact of fatigue on performance scores. Participants in the Control group (Baseline) had significantly lower Grooved Pegboard Test (GPD) scores (M = 32.77, SD = 2.01) compared to the Post-Fatigue group (M = 40.08, SD = 2.13). A paired samples t-test confirmed this difference as statistically significant, $t(41)=-154.46, p<.001$, with a 95% confidence interval of $[-7.41, -7.21]$.

Similarly, the Control group had significantly fewer errors (M = 1.45, SD = 0.92) compared to the Post-Fatigue group (M = 4.10, SD = 1.19). This difference was also statistically significant, $t(41)=-27.73, p<.001$, with a 95% confidence interval of $[-2.84, -2.45]$. The significant pp-values ($p<.001p<.001$) led to the rejection of the null hypothesis, indicating that the two samples were drawn from different populations.

In terms of fatigue perception, the Control group had significantly lower Fatigue Borg Scale values (M = 6.33, SD = 0.48) compared to the Post-Fatigue group (M = 15.55, SD = 1.11). A paired samples t-test confirmed this difference was statistically significant, $t(41)=-48.15, p<.001$, with a 95% confidence interval of $[-9.6, -8.83]$. This significant result also led to the rejection of the null hypothesis, further supporting the distinct impact of fatigue on performance measures.

A regression analysis provided a predictive equation for the experimental GPD (EXP GPD) score:

$$\text{EXP GPD Score} = 27.87 + 0.80 \times \text{Fatigue Borg Scale}.$$

This equation indicates that the predicted EXP GPD score (in seconds) can be calculated using the Fatigue Borg Scale. The constant (27.87) represents the predicted EXP GPD score when the Fatigue Borg Scale is zero. The coefficient for the Fatigue Borg Scale (0.80) suggests that for every one-unit increase in the Fatigue Borg Scale, the EXP GPD score is expected to increase by approximately 0.80 seconds. In simpler terms, higher levels of perceived fatigue correspond to slower performance times.

These results highlight the substantial effects of fatigue on both objective performance metrics and subjective fatigue measures, providing valuable insights for designing interventions aimed at mitigating fatigue-induced declines in performance.

Discussion

The findings from this study offer critical insights into the effects of fatigue on cognitive and motor performance, particularly as measured by the Grooved Pegboard Test. Through robust statistical analysis and significant correlations, the study underscores the profound impact of fatigue on various performance metrics.

Impact on Performance: The strong positive correlations between the EXP GPD Score and Control GPD Score (0.8031) and between EXP GPD Errors and Control GPD Errors (0.8595) clearly highlight a consistent pattern of performance degradation due to fatigue. This relationship is further reinforced by the regression analysis, which indicates that as the Fatigue Borg Scale rises, the EXP GPD Score also increases. These findings align with previous research, illustrating that fatigue impairs both cognitive and motor performance (van der Linden, Frese, & Meijman, 2003; Hockey, 2013).

Cognitive and Physical Effects: The study found significant correlations between increased errors and decreased coordination post-fatigue, suggesting that fatigue has a substantial impact on both cognitive and motor functions. Participants' subjective experiences, such as feeling more stressed and noting physical symptoms of fatigue, corroborate these findings. The strong positive correlation between the Fatigue Borg Scale and various performance measures supports the conclusion that mental fatigue significantly affects cognitive and motor functions (Richter, 2016).

Engagement and Motivation: Despite the adverse effects of fatigue, participants exhibited high levels of engagement and a strong willingness to participate in future tests. This suggests that the test protocol was well-designed and perceived as valuable and meaningful. The positive correlation between engagement and the need to concentrate harder after fatigue indicates that participants remained motivated to perform well despite the challenges. This observation aligns with the work of Persson et al. (2011), who found that participants often maintain motivation and engagement even under fatigue-inducing conditions.

Statistical Significance: The paired samples t-test results confirm that the differences in performance and perceived fatigue between the control and post-fatigue groups are statistically significant. The significant p-values and confidence intervals demonstrate that the observed effects are not due to chance, further validating the reliability of the findings. These results are consistent with similar studies (Ackerman, 2011; Zohar et al., 2005), underscoring the robustness of the study's methodology and outcomes.

Practical Implications: The insights gained from this study are crucial for understanding the effects of fatigue on cognitive and motor performance. The significant correlations and regression analyses provide a comprehensive understanding of how fatigue impacts performance metrics. These findings can inform the development of targeted interventions to mitigate the effects of fatigue, thereby enhancing performance and well-being in real-world settings.

Conclusion

This study highlights the significant impact of fatigue on motor and cognitive performance, with post-fatigue conditions showing slower task completion, higher error rates, and greater perceived difficulty. Strong correlations between fatigue measures and performance outcomes emphasize the need for targeted interventions to mitigate fatigue's effects. These findings provide a foundation for developing strategies to enhance performance and well-being in fatigue-prone environments.

Future Research

This study underscores the importance of addressing fatigue in contexts requires sustained cognitive and motor effort. Future research should explore interventions to reduce fatigue and support optimal performance. Additionally, investigating the modulating factors that influence the extent of cognitive performance fatigue, such as age, sex, health conditions, and task characteristics, could provide a more nuanced understanding of how to effectively mitigate fatigue-related performance decrements.

Author Contributions

All authors significantly contributed to the work reported, including conception, study design, execution, data acquisition, analysis, and interpretation. They actively participated in drafting, revising, or critically reviewing the manuscript, provided final approval of the version to be published, agreed on the journal submission, and accepted accountability for all aspects of the work.

Data Availability Statement

The authors will transparently provide the primary data underpinning the findings or conclusions of this article, without any unjustified reluctance. If need from editorial team.

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Conflicts of Interest

The authors declare no potential conflicts of interest related to the research, writing, or publication of this work.

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