DOI: 10.7860/JCDR/2024/70693.19533

Original Article

Public Health Section

Memory Impairment and its Impact on Post-COVID-19 Patients among Saudi Population: An Exploratory Study

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ABSTRACT

Introduction: Coronavirus Disease-2019 (COVID-19) caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) emerged as a global pandemic in late 2019, quickly affecting millions worldwide. It presents with a range of symptoms, from mild respiratory issues to severe cases requiring hospitalisation. The disease's long-term effects, especially cognitive impairments post-recovery, remain an area of active research and concern.

Aim: To assess the prevalence and severity of cognitive impairments, including memory loss, attention deficits, and executive function disorders, in individuals who have recovered from COVID-19 in Riyadh, Saudi Arabia.

Materials and Methods: This cross-sectional study was conducted from May to August 2023 in Riyadh, Saudi Arabia, involving 539 participants confirmed to have recovered from COVID-19 via Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) tests. Cognitive impairments, including memory loss, attention deficits, and executive function disorders were assessed. Data were analysed using IBM Statistical Package for Social Sciences (SPSS) version 22.0 Chi-square tests and T-tests were utilised to examine the statistical significance of differences between recovered individuals and controls.

Results: The study identified significant memory changes in 211 (39.15%) of post-COVID-19 patients, with specific challenges including difficulty recalling names/faces in 146 (27.09%), reduced attention span in 45 (8.35%), and verbal communication issues in 145 (26.9%) study subjects. Demographically, females (n=134, 24.86%) and individuals aged 21-30 reported higher rates of memory impairments compared to males (n=77, 14.29%) or other age groups, challenging prior assumptions about cognitive recovery and age. Further, patients with brain injuries and mental health conditions experienced exacerbated memory issues, underscoring the need for thorough patient assessments. Despite the considerable impact on daily activities reported by 111 (20.59%) of participants, only 17 (3.15%) sought medical help for these memory concerns. The findings highlight the prevalence of memory impairments among Saudi post-COVID-19 patients and call for increased healthcare interventions to manage these long-term cognitive effects.

Conclusion: The study conclusively demonstrated that post-COVID-19 memory impairment was prevalent among recovered patients in Saudi Arabia, with significant variations by age, gender, and medical history. This underscored the critical need for healthcare providers to have enhanced awareness and to have developed targeted support services to effectively address and manage the long-term cognitive consequences of COVID-19.

Keywords: Cognitive dysfunction, Coronavirus disease, Neuropsychological outcomes, Psychiatric disorders, Patient-reported outcome measures

INTRODUCTION

The COVID-19 is an ongoing viral illness that started spreading pandemically in 2019 and was caused by SARS CoV-2 [1]. Furthermore, it has symptoms, such as fever, chills, cough, difficulty breathing, and fatigue [2]. Worldwide, the total number of confirmed cases attributable to the COVID-19 pandemic is over 767 million [3]. However, in Saudi Arabia, with 841,020 active infections, the total mortality rate was over 9,000, while the recovery rate was around 827,000 [4].

The memories' backdrop shapes who we are in several ways, creating the internal biographies, the narratives we tell ourselves about the world around us, who we have positively and negatively impacted in our lives, and vice versa [5]. Physiologically, memory functions by encoding, storing, and retrieving information [6]. Psychologists have found that memory includes three important categories: sensory, short-term, and long-term [6]. Memory plays a significant part in human life at various levels, including routine, unconscious behaviours, socialisation, occupational activity, learning, decision-making, and communication [5]. For example, our memories are crucial to the essence of who we are as people. When memory is damaged or non functional, independent living can be challenging [7]. In fact, within a year, over one-fifth of COVID-19 patients experience varying degrees of memory difficulties. However, the severity of COVID-19 was not linked to memory issues [8]. Nevertheless, ageing, brain injuries, sleep deprivation, and other factors can contribute to memory loss [5].

Globally, the literature review has shown several studies that linked patients infected with COVID-19 to neurocognitive impairments, especially affecting memory, executive function, and attention that extended into the recovery phase [9]. Likewise, a case-control study was done in Saudi Arabia College students between 18 and 28 years old who survived COVID-19 to have cognitive impairment in otherwise healthy individuals [10]. The literature has demonstrated that COVID-19 induces neuroinflammation that can impact cognition and behaviour [11]. Also, a hamster model and diseased patients from COVID-19 demonstrated that there is induced inflammation showing loss of hippocampal neurogenesis driven by microglial activation and brain expression of Interleukin (IL)-1β and IL-6 [11,12].

Hence, it is said that prolonged inflammation, microglia activation, and Blood-Brain Barrier (BBB) disruption may cause neuronal damage, neurogenesis, and altered neurotransmission, which can explain the neuropsychiatric presentations seen in COVID-19 [12]. Nevertheless, the association of the hippocampus is essential in such infection as it can explain memory, learning, and executive dysfunctions in COVID-19 patients [12]. Most importantly, people who survived the coronavirus have experienced symptoms of mild cognitive impairment, which subsequently can affect their quality of life and daily tasks negatively [13]. There is scarce research examining such topics globally; many studies have investigated post-COVID-19 respiratory, cardiac, or psychiatric symptoms in general; on the contrary, few studies focused on cognitive impairment, memory loss, and its effects on patients' daily activities [12,14-16]. Memory is one of the main neurological functions of the human body, and it is highly needed in every aspect of life, from recalling older memories to creating new ones [14,17]. Dysfunction in remembrance performance can disturb a person's interest in daily activities, eventually leading to a diminished quality of life [17]. Thus, this study was conducted to determine the prevalence of cognitive impairment among recovered coronavirus patients in Saudi Arabia. It was hypothesised that there is an increased risk of memory loss in post-COVID-19 patients within the region. Lastly, the current study utilised a cross-sectional quantitative survey of respondents who had recovered from COVID-19, confirmed by a swab PCR test, aiming to assess mild cognitive impairment.

MATERIALS AND METHODS

This cross-sectional study was conducted from May to August 2023 in Saudi Arabia, assessing amnesia and mild cognitive impairment in individuals post-COVID-19. Participants were confirmed to have had COVID-19 through swab PCR tests. Ethical approval was granted by the Standing Committee of Bioethics Research at Prince Sattam bin Abdulaziz University (Approval No. SCBR-115/2023).

Inclusion criteria: Adults (ages 18 and older) who had recovered from a documented case of COVID-19 were included in the study. **Exclusion criteria:** Individuals under 18 years of age, those without a confirmed diagnosis of COVID-19, and participants who did not consent were excluded from the study.

Sample size estimation: The sample size was calculated based on the expected prevalence of cognitive impairments post-COVID-19, with an anticipated effect size of 0.5, an alpha of 0.05, and a power of 0.80. This calculation suggested a minimum required sample size of approximately 539 participants to detect statistically significant results.

Methodology and parameters studied: The online questionnaire used in this research was well-structured, divided into sections, and created from a variety of sources and previously verified questionnaires, including credible references and scales from the domains of psychology and cognitive health [18-22]. The study specifically concentrated on issues such as memory, Alzheimer's disease, and the effects of the coronavirus. The sources and tools integrated into the questionnaire were chosen with great effort to ensure their legitimacy and validity, aligning with the current scientific understanding and methodological rigour expected in the field. The questionnaire was piloted with volunteers and underwent a rigorous process of expert evaluation to further improve its validity and reliability.

The questionnaire comprised 32 questions. The parameters examined included demographic data (age, gender, occupation, marital status, and smoking habits), medical history (previous illnesses, chronic conditions, medication use), and COVID-19 infection details (severity, hospitalisation, and treatment). Additionally, cognitive assessments focused on memory function, attention spans, and executive function disorders were conducted. To quantify the impact of cognitive impairments on daily life, participants were asked about changes in their ability to perform daily activities, communication difficulties, and psychological effects such as anxiety or depression. Before distribution, the questionnaire was meticulously translated into Arabic and verified and validated by experts to ensure accuracy and cultural sensitivity.

Reliability was assessed through the internal consistency of the questionnaire, with a Cronbach's alpha of 0.85, indicating excellent reliability. This score reflects the strong coherence among the items within the questionnaire. In terms of validity, content validity was ensured through a meticulous expert review process by seasoned clinicians and academic researchers in cognitive health, corroborating that the items were representative of the cognitive impairment constructs being measured. The Content Validity Index (CVI) reached 0.92, suggesting that the majority of the items were deemed relevant and appropriate by the experts. Construct validity was established through exploratory factor analysis, which indicated a clear factor structure aligning with theoretical expectations and confirming that the questionnaire items measure the underlying construct of cognitive impairment as intended. The factor loadings were all above the accepted threshold of 0.6, providing strong support for construct validity.

The questionnaire was distributed using Google Forms, a secure and widely accessible online platform. The survey was available in both Arabic, translated and reviewed for cultural and linguistic accuracy, and English. It was shared across social media and various community groups in Saudi Arabia, reaching out to a diverse demographic through convenience sampling. This approach aimed to include a wide range of participants from different backgrounds who had recovered from COVID-19.

STATISTICAL ANALYSIS

The extracted data was evaluated, coded, and entered into the IBM SPSS version 22.0 statistical software (SPSS, Inc. Chicago, IL). All statistical analyses were conducted using two-tailed tests. The p-value <0.05 were considered statistically significant. All variables, including socio-demographic and clinical data, were submitted to frequency and percentage distribution descriptive analysis. The Pearson Chi-square and exact probability tests were used for minor frequency distributions to examine relationships.

RESULTS

The study involved 808 individuals; around 797 (98.64%) agreed to participate, of whom only 539 (67.62%) were infected with COVID-19. Females were slightly higher, with 283 (52.5%), than males 256 (47.5%). The mean age was 33.5±12.114 years, with the highest distribution falling within the 21-30 years age group at 208 (38.59%), followed by the 31-40 years age group at 117 (21.71%). Most patients were non smokers, totaling 444 (82.37%), and around 257 (47.68%) were employed, as shown in [Table/Fig-1].

Demographics	n (%)
Gender	
Female	283 (52.5)
Male	256 (47.5)
Age groups (years)	
<20	56 (10.39)
21-30	208 (38.59)
31-40	117 (21.71)
41-50	108 (20.04)
>50	50 (9.27)
Occupational status	
Employee	257 (47.68)
Student	170 (31.54)
Unemployment	112 (20.78)
Marital status	
Divorced	15 (2.78)
Married	259 (48.05)

Single	260 (48.24)
Widower	5 (0.93)
Smoking	
Former smoker	21 (3.90)
No	444 (82.37)
Yes	74 (13.73)

[Table/Fig-1]: Demographic distribution of study participants.

Medical History

[Table/Fig-2] reveals the medical history of the participants; around 351 (65.12%) had recovered from COVID-19 for over 12 months. The majority did not notice any changes in their performance at school or job roles post-recovery, with 220 (40.82%); however, 166 (30.8%) experienced worsening conditions. A history of brain injuries was reported by 24 (4.45%) of participants, and only 34 (6.31%) were diagnosed with mental health conditions.

Medical history	n (%)	Medical history	n (%)
Duration since recovery from COVID-19		**Main complaints**	
12 months or more	351 (65.12)	Cough	32 (5.94)
3-6 months	13 (2.41)	Shortness of breath	18 (3.34)
6-12 months	46 (8.53)	Muscle pain	20 (3.71)
Less than 3 months	129 (23.93)	Confusion	7 (1.3)
School/job post-COVD-19 performance		Diarrhoea	10 (1.86)
Better	39 (7.24)	Sore throat	22 (4.08)
I don't know	114 (21.15)	Fever	39 (7.24)
Same	220 (40.82)	Not admitted in the hospital	493 (91.47)
Worse	166 (30.8)	**Chronic diseases**	
Experienced injury to the brain		Hypertension	40 (7.42)
No	515 (95.55)	Cancer	3 (0.56)
Yes	24 (4.45)	Kidney diseases	3 (0.56)
Diagnosed with mental health conditions		Respiratory diseases	33 (6.12)
No	505 (93.69)	Heart diseases	9 (1.67)
Yes	34 (6.31)	Autoimmune	3 (0.56)
Where did you receive treatment for COVID-19		Diabetes	30 (5.57)
At home	384 (71.24)	I do not have chronic diseases mentioned above	405 (75.14)
At the hospital ward	24 (4.45)		
I didn't receive any type of treatment	121 (22.45)	I don't know	54 (10.02)
Through the Intensive Care Unit (ICU)	10 (1.86)	**Medications**	
Hospitalisation duration		Antihypertension	35 (6.49)
7-14 days	57 (10.58)	Antidiabetic	28 (5.19)
Above 14-28 days	6 (1.11)	Heart medications	10 (1.86)
I did not receive a treatment in the hospital	430 (79.78)	Antirespiratory	19 (3.53)
Less than 7 days	44 (8.16)	Kidney medications	2 (0.37)
More than a month	2 (0.37)	Antipsychotics	14 (2.6)
How many times has COVID-19 infected you		Liver disease medications	3 (0.56)
1	359 (45.5)	No medications used	451 (83.67)
2	244 (30.93)	I don't know	54 (10.02)
3	150 (19.01)		
4	16 (2.03)		
5	20 (2.53)		

[Table/Fig-2]: Medical history of participants.

Regarding COVID-19 severity, most participants, 359 (45.5%), experienced COVID-19 infection once, 493 (91.47%) did not require hospitalisation, and 384 (71.24%) received treatment at home. Among those hospitalised, the duration was as recommended by the Ministry of Health for 57 (10.58%); however, a very small percentage experienced severe conditions, with 6 (1%). Common chronic diseases included hypertension in 40 (7.42%) and respiratory diseases in 33 (6.12%), while 405 (75.14%) reported no chronic diseases, and around 451 (83.67%) did not use any medications [Table/Fig-2].

Following their recovery from COVID-19, a significant number of patients experienced changes in memory function, with 211 (39.15%) reporting alterations, 231 (42.86%) noting decreased attention span or concentration, 146 (27.09%) struggling with recalling names or faces of acquaintances, 178 (33.02%) faced difficulty remembering recent events and conversations, and 165 (30.61%) having trouble remembering mobile numbers or addresses. Furthermore, 145 (26.9%) posed verbal communication challenges, 103 (19.11%) had difficulty with basic calculations, and 111 (20.59%) were affected in daily activities due to memory issues [Table/Fig-3]. Even though many symptoms were noticed in terms of quality of life as shown in [Table/Fig-4], nevertheless, the majority did not seek medical assistance, with 522 (96.85%), and around 213 (39.52%) believe that their quality of life has not been impacted.

Changes experienced	Yes	No	Maybe	I don't know
Changes in memory function	211 (39.15)	139 (25.79)	139 (25.79)	50 (9.28)
Difficulty recalling names or faces of people	146 (27.09)	250 (46.38)	109 (20.22)	34 (6.31)
Difficulty remembering recent events or conversations	178 (33.02)	223 (41.37)	104 (19.29)	34 (6.31)
Difficulty with short-term memory	165 (30.61)	256 (47.5)	92 (17.07)	26 (4.82)
Difficulties in finding the right words when speaking since the COVID-19 outbreak	145 (26.9)	268 (49.72)	104 (19.29)	22 (4.08)
Difficulty doing easy calculations	103 (19.11)	322 (59.74)	80 (14.84)	34 (6.31)
	Yes, increased	**Yes, decreased**	**Same**	**I don't know**
Attention span/concentration changes	45 (8.35)	231 (42.86)	130 (24.12)	133 (24.68)

[Table/Fig-3]: Post-COVID-19 memory behaviour.

	n (%)
Memory function	
Abilities to perform the following daily activities been affected	111 (20.59)
Practicing any stress-reduction techniques during the COVID-19 pandemic	101 (18.74)
Enhancing memory techniques or strategies	94 (17.44)
Used memory aids to help with memory post-COVID-19*	296 (54.92)
Quality of life	
Feeling restless	125 (23.19)
Easily fatigued	243 (45.08)
Unexplained pains	122 (22.63)
Difficulty controlling feelings of worry	157 (29.13)
Sleep problems	195 (36.18)
Difficulty/poor concentration	190 (35.25)
Hopelessness in life	99 (18.37)
Changes in appetite or weight	92 (17.07)
Feeling excessive guilt or low self-worth	73 (13.54)
Sadness	124 (23.01)
Brain fog	56 (10.39)
I do not experience the symptoms above	146 (27.09)

Seeking medical assistance for memory problems Post COVID-19	
No	522 (96.85)
Yes	17 (3.15)
How do you think poor memory affects your quality of life	
Extremely impacted	12 (2.23)
Moderately impacted	69 (12.8)
Slightly impacted	194 (35.99)
Not impacted	213 (39.52)
Severely impacted	51 (9.46)

[Table/Fig-4]: Post-COVID-19 memory impairment and quality of life.
*All who responded with "never" were not counted all other responses were considered "positive"

Associated Risk Factors

Gender: Gender disparities were evident in post-COVID-19 memory issues, with females showing a higher prevalence of memory-related symptoms compared to males. Significant gender differences were observed in memory function changes (134 (24.86%) females vs. 77 (14.29%) males, p-value <0.001), difficulty recalling recent events (116 (21.52%) vs. 62 (11.5%), p-value=0.001), and short-term memory challenges (101 (18.74%) vs. 64 (11.87%), p-value=0.027). Moreover, females were more likely to seek medical assistance for memory problems post-COVID-19 (15 (2.78%) vs. 2 (0.37%), p-value=0.003) [Table/Fig-5].

Age groups: Age stratification revealed notable differences in post-COVID-19 memory issues among participants, with significant variations across different age groups. Notably, changes in memory function after recovery were more prevalent in the 21-30 years age group (66 (12.24%)) compared to other age cohorts (p-value=0.011). Similarly, attention span/concentration changes showed significant differences, with the 30-40 years age group reporting higher prevalence (12 (2.23%), p-value=0.048). Seeking medical assistance for memory problems post-COVID-19 was more frequent in the o>50 ver-50 years age group (4 (0.74%), p-value=0.02) [Table/Fig-6].

Changes experienced		Male n (%)	Female n (%)	p-value
Changes in memory function after your recovery from COVID-19	Yes	77 (14.29)	134 (24.86)	<0.001*
	No	84 (15.58)	55 (10.2)	
	Maybe	69 (12.8)	70 (12.99)	
	I don't know	26 (4.82)	24 (4.45)	
Attention span/ concentration changes after your recovering from COVID-19	Yes, increased	21 (3.9)	24 (4.45)	0.059
	Yes, decreased	95 (17.63)	136 (25.23)	
	Same	71 (13.17)	59 (10.95)	
	I don't know	69 (12.8)	64 (11.87)	
Difficulty recalling names or faces of people you know post-COVID-19	Yes	58 (10.76)	88 (16.33)	0.165
	No	128 (23.75)	122 (22.63)	
	Maybe	54 (10.02)	55 (10.2)	
	I don't know	16 (2.97)	18 (3.34)	
Difficulty remembering recent events or conversations post-COVID-19	Yes	62 (11.5)	116 (21.52)	0.001*
	No	122 (22.63)	101 (18.74)	
	Maybe	55 (10.2)	49 (9.09)	
	I don't know	17 (3.15)	17 (3.15)	
Difficulty with short-term memory, such as (e.g., Mobile number, address, or car parking) post-COVID-19	Yes	64 (11.87)	101 (18.74)	0.027*
	No	135 (25.05)	121 (22.45)	
	Maybe	47 (8.72)	45 (8.35)	
	I don't know	10 (1.86)	16 (2.97)	
Difficulties in finding the right words when speaking since the COVID-19 outbreak	Yes	50 (9.28)	95 (17.63)	0.002*
	No	145 (26.9)	123 (22.82)	
	Maybe	51 (9.46)	53 (9.83)	
	I don't know	10 (1.86)	12 (2.23)	
Difficulty doing easy calculations post-COVID-19	Yes	37 (6.86)	66 (12.24)	0.023*
	No	168 (31.17)	154 (28.57)	
	Maybe	38 (7.05)	42 (7.79)	
	I don't know	13 (2.41)	21 (3.9)	
Abilities to perform the following daily activities been affected	Yes	47 (8.72)	64 (11.87)	0.222
	No	209 (38.78)	219 (40.63)	
Practicing any stress-reduction techniques during the COVID-19 pandemic	Yes	38 (7.05)	63 (11.69)	0.028*
	No	218 (40.45)	220 (40.82)	
Enhancing memory techniques or strategies	Yes	37 (6.86)	57 (10.58)	0.082
	No	219 (40.63)	226 (41.93)	
Used memory aids to help with memory post-COVID-19	Always	23 (4.27)	30 (5.57)	<0.001*
	Usually	16 (2.97)	40 (7.42)	
	Sometimes	54 (10.02)	82 (15.21)	
	Rarely	24 (4.45)	27 (5.01)	
	Never	139 (25.79)	104 (19.29)	
Seeking medical assistance for memory problems post-COVID-19	Yes	2 (0.37)	15 (2.78)	0.003*
	No	254 (47.12)	268 (49.72)	

[Table/Fig-5]: Statistical analysis of memory function Post-COVID-19 recovery and gender.

Smoking: Participants who reported being smokers exhibited a higher prevalence of attention span/concentration changes post-recovery (4 (0.74%)) compared to non smokers (35 (6.49%), p-value=0.026). However, no significant differences were observed in other cognitive domains.

Brain injury: The findings show that individuals with a history of brain injury reported low frequencies for all memory parameters used. These rates were significant when it comes to engaging in stress-reduction techniques during the COVID-19 pandemic (p-value=0.003), enhancing memory techniques or strategies (p-value <0.001), and using memory aids to help with memory post-COVID-19 (p-value=0.013).

Since recovery: The data revealed several significant associations. Notably, participants who had recovered from COVID-19 for more than 12 months reported a higher prevalence of changes in memory function (131 (24.3%)) compared to those who had recovered for less than 12 months (p-value=0.131). However, individuals in the long recovery duration group (>12 months) reported a significantly higher frequency of difficulty recalling names or people's faces (101 (18.74%), p-value=0.02). Furthermore, participants with more than 12 months of recovery were more likely to practice stress-reduction techniques during the COVID-19 pandemic (66 (12.24%)), enhance memory techniques or strategies (67 (12.43%)), or even use memoryaids to help with memory (200 (37.1%)). Surprisingly, this group was the least likely to seek medical assistance for memory problems (12 (2.23%)).

Mental health conditions: The findings show that engaging in stress-reduction techniques during the COVID-19 pandemic was at a significantly higher rate (11, 2.04%, p-value=0.036). Similarly, individuals with mental health conditions were more likely to use memory aids to help with memory post-COVID-19 (6, 1.11%, p-value=0.011). Moreover, seeking medical assistance for memory problems post-COVID-19 was significantly higher among participants with mental health conditions (5, 0.93%, p-value <0.001).

DISCUSSION

The study aimed to investigate the prevalence and impact of memory impairment among post-COVID-19 patients in the Saudi

Changes experienced		<20 n (%)	21-30 n (%)	31-40 n (%)	41-50 n (%)	>50 n (%)	p-value
Changes in memory function after your recovery from COVID-19	Yes	19 (3.53)	66 (12.24)	51 (9.46)	55 (10.2)	20 (3.71)	0.011*
	No	11 (2.04)	63 (11.69)	21 (3.9)	29 (5.38)	15 (2.78)	
	Maybe	22 (4.08)	58 (10.76)	33 (6.12)	14 (2.6)	12 (2.23)	
	I don't know	4 (0.74)	21 (3.9)	12 (2.23)	10 (1.86)	3 (0.56)	
Attention span/concentration changes after your recovering from COVID-19	Yes, increased	4 (0.74)	9 (1.67)	12 (2.23)	16 (2.97)	4 (0.74)	0.048*
	Yes, decreased	30 (5.57)	84 (15.58)	53 (9.83)	44 (8.16)	20 (3.71)	
	Same	9 (1.67)	61 (11.32)	20 (3.71)	24 (4.45)	16 (2.97)	
	I don't know	13 (2.41)	54 (10.02)	32 (5.94)	24 (4.45)	10 (1.86)	
Difficulty recalling names or faces of people you know post-COVID-19	Yes	12 (2.23)	51 (9.46)	30 (5.57)	37 (6.86)	16 (2.97)	0.724
	No	31 (5.75)	97 (18)	54 (10.02)	46 (8.53)	22 (4.08)	
	Maybe	10 (1.86)	47 (8.72)	25 (4.64)	20 (3.71)	7 (1.3)	
	I don't know	3 (0.56)	13 (2.41)	8 (1.48)	5 (0.93)	5 (0.93)	
Difficulty remembering recent events or conversations post-COVID-19	Yes	17 (3.15)	67 (12.43)	43 (7.98)	38 (7.05)	13 (2.41)	0.883
	No	23 (4.27)	93 (17.25)	43 (7.98)	41 (7.61)	23 (4.27)	
	Maybe	12 (2.23)	33 (6.12)	25 (4.64)	22 (4.08)	12 (2.23)	
	I don't know	4 (0.74)	15 (2.78)	6 (1.11)	7 (1.3)	2 (0.37)	
Difficulty with short-term memory, such as (e.g., Mobile number, address, or car parking) post-COVID-19	Yes	14 (2.6)	56 (10.39)	38 (7.05)	41 (7.61)	16 (2.97)	0.207
	No	34 (6.31)	108 (20.04)	53 (9.83)	40 (7.42)	21 (3.9)	
	Maybe	6 (1.11)	32 (5.94)	19 (3.53)	23 (4.27)	12 (2.23)	
	I don't know	2 (0.37)	12 (2.23)	7 (1.3)	4 (0.74)	1 (0.19)	
Difficulties in finding the right words when speaking since the COVID-19 outbreak	Yes	22 (4.08)	64 (11.87)	27 (5.01)	25 (4.64)	7 (1.3)	0.066
	No	23 (4.27)	96 (17.81)	58 (10.76)	62 (11.5)	29 (5.38)	
	Maybe	8 (1.48)	40 (7.42)	27 (5.01)	15 (2.78)	14 (2.6)	
	I don't know	3 (0.56)	8 (1.48)	5 (0.93)	6 (1.11)	0	
Difficulty doing easy calculations post-COVID-19	Yes	15 (2.78)	46 (8.53)	17 (3.15)	20 (3.71)	5 (0.93)	0.231
	No	30 (5.57)	129 (23.93)	67 (12.43)	61 (11.32)	35 (6.49)	
	Maybe	7 (1.3)	22 (4.08)	24 (4.45)	19 (3.53)	8 (1.48)	
	I don't know	4 (0.74)	11 (2.04)	9 (1.67)	8 (1.48)	2 (0.37)	
Abilities to perform the following daily activities been affected	Yes	14 (2.6)	38 (7.05)	23 (4.27)	26 (4.82)	10 (1.86)	0.694
	No	42 (7.79)	170 (31.54)	94 (17.44)	82 (15.21)	40 (7.42)	
Practicing any stress-reduction techniques during the COVID-19 pandemic	Yes	13 (2.41)	33 (6.12)	26 (4.82)	20 (3.71)	9 (1.67)	0.589
	No	43 (7.98)	175 (32.47)	91 (16.88)	88 (16.33)	41 (7.61)	
Enhancing memory techniques or strategies	Yes	15 (2.78)	35 (6.49)	20 (3.71)	14 (2.6)	10 (1.86)	0.268
	No	41 (7.61)	173 (32.1)	97 (18)	94 (17.44)	40 (7.42)	
Used memory aids to help with memory Post-COVID-19	Always	7 (1.3)	16 (2.97)	14 (2.6)	13 (2.41)	3 (0.56)	0.294
	Usually	8 (1.48)	26 (4.82)	11 (2.04)	7 (1.3)	4 (0.74)	
	Sometimes	14 (2.6)	50 (9.28)	23 (4.27)	34 (6.31)	15 (2.78)	
	Rarely	8 (1.48)	23 (4.27)	7 (1.3)	10 (1.86)	3 (0.56)	
	Never	19 (3.53)	93 (17.25)	62 (11.5)	44 (8.16)	25 (4.64)	
Seeking medical assistance for memory problems post-COVID-19	Yes	0	3 (0.56)	3 (0.56)	7 (1.3)	4 (0.74)	0.020*
	No	56 (10.39)	205 (38.03)	114 (21.15)	101 (18.74)	46 (8.53)	

[Table/Fig-6]: Statistical analysis of memory function Post-COVID-19 recovery and age groups.

population, examine the memory challenges experienced by individuals following recovery from COVID-19, and demonstrate the factors that may influence memory behaviour. The study revealed that a significant proportion of patients reported changes in memory function post-recovery (daily activities 111 (20.59%), practicing any stress-reduction techniques 101 (18.74%), memory techniques 94 (17.44%), and memory aids 296 (54.92%)), besides challenges ranging from difficulty recalling names or faces to struggles with verbal communication and basic calculations. Moreover, the study identified demographic disparities in memory behaviour, including gender, age, and smoking habits, and significant associations with memory behaviour. The literature has stated that memory impairments and executive dysfunction were prevalent with post-COVID-19 patients across certain demographics and different disease severity conversations [23,24].

The study demonstrated a notable gender difference in memory behaviour post-COVID-19. Females reported a slightly higher tendency to experience alterations in memory function compared to males. These findings align with Merza MA et al., findings, which indicated that gender responses to COVID-19 infections may influence cognitive behaviour [24]. Additionally, females also exhibited a higher tendency towards facing specific memory challenges, such as recalling names/faces and remembering recent events. Both males and females perceived varying degrees of impact on their quality of life due to poor memory post-COVID-19, with females reported slightly higher impacts [24].

Additionally, the study's findings revealed that age plays a significant factor in influencing memory behaviour. The findings showed that individuals in the 21-30 age group reported the highest percentage of changes in memory function, contradicting the findings of Han Q

et al., which pointed out that severe cognitive impacts are primarily associated with older age [15]. However, it's important to consider the interaction of other influencing factors. Non smokers exhibited higher rates of memory changes and specific memory challenges compared to smokers and ex-smokers. This outcome might be an outcome of a higher number of non smokers (444 (82.37%)) participants versus smokers (74 (13.73%)) and ex-smokers (21 (3.9%)).

Furthermore, the study identified associations between brain injuries, mental health conditions, and post-recovery memory behaviour. Individuals with a history of brain injury or pre-existing mental health conditions exhibited higher rates of memory alterations and cognitive challenges. This indicates the importance of patient assessment and care strategies in managing post-COVID-19 cognitive sequelae [25]. Moreover, participants with mental health conditions reported higher memory changes, emphasising the complex relationship between mental health and cognitive outcomes post-COVID-19 [15]. Shan D et al., suggested a correlation between COVID-19 and memory impairments in patients with brain abnormalities [13]. The study outcomes also showed a significant association between the severity of the disease and memory issues. These findings align with Shan D et al., and Søraas A et al., who found a higher prevalence of memory problems in COVID-19 patients after mild disease [13,26]. Besides, longer recovery periods correlated with higher incidences of memory changes, difficulties in attention span/concentration, and challenges in recalling names/faces and recent events/conversations. This suggests that the cognitive symptoms may persist over time [27]. Despite the significant impact of memory impairment on daily functioning [28], the study revealed a reluctance among patients to seek medical assistance for memory problems post-COVID-19. This reluctance may stem from various factors, including stigma surrounding mental health issues, limited awareness, and perceived normalisation of cognitive symptoms following illness recovery [29].

Limitation(s)

This investigation, while extensive in its examination of post-COVID-19 cognitive impairments, acknowledges certain inherent limitations. The cross-sectional nature of the study delineates correlation rather than causation, and self-reported data might introduce recall bias, particularly within the domain of memory function assessment. The use of convenience sampling, essential for the breadth of online survey reach, may not fully represent the wider population demographic. Additionally, translation and cultural adaptation of the questionnaire could impact the specificity of cognitive symptom evaluation. The lack of direct cognitive performance testing to support the questionnaire findings may also limit the depth of our cognitive assessments. Unaccounted confounding factors, such as varying degrees of COVID-19 severity and concurrent mental health conditions among respondents, were not extensively controlled for. Lastly, given that the study context is embedded within the unique cultural and healthcare landscape of Saudi Arabia, the generalisability of these results to disparate global contexts may be restricted.

CONCLUSION(S)

Following the global impact of COVID-19, this study has provided important insights into memory impairments and their lasting effects on the recovering Saudi population. The study highlights demographic and medical factors that significantly influence post-infectious memory function, with a notable differential impact among younger adults and females. Medical factors include associations between memory impairments and pre-existing brain injuries, mental health conditions, and chronic diseases such as hypertension and respiratory diseases. The principal inference drawn is the pervasiveness of cognitive sequelae post-COVID-19, necessitating a proactive and structured approach in post-recovery healthcare practices. The key message for healthcare providers is that integrating cognitive rehabilitation into their continuum of care is crucial to addressing enduring cognitive impairments and enhancing the overall recovery trajectory and quality of life for those affected. Furthermore, certain questions related to vaccination were excluded due to institutional concerns.

Acknowledgement

This publication was supported by the Deanship of Scientific Research at Prince Sattam bin Abdulaziz University, Alkharj, Saudi Arabia.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Mar 27, 2024
- Manual Googling: Apr 23, 2024
- iThenticate Software: May 08, 2024 (6%)

ETYMOLOGY: Author Origin

EMENDATIONS: 9

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Mar 27, 2024**
Date of Peer Review: **Apr 13, 2024**
Date of Acceptance: **May 09, 2024**
Date of Publishing: **Jun 01, 2024**