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Analysis of reaction time, psychomotor speed and concentration levels in individuals who had COVID-19 infection

Furkan Bodur[1], Deniz Senol[2], Demet Sencan Senol[3], Cenk Murat Ozer[1]

[1]Zonguldak Bülent Ecevit University, Faculty of Medicine, Department of Anatomy, Zonguldak, Türkiye
[2]Düzce University, Faculty of Medicine, Department of Anatomy, Düzce, Türkiye
[3]Ankara University, Faculty of Medicine, Department of General Surgery, Ankara, Türkiye

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Abstract

This study was conducted to analyse reaction time, psychomotor speed and concentration parameters in individuals who had previously been infected with COVID-19 and to compare these parameters with those of the control group. The study recruited 56 individuals previously diagnosed with COVID-19 with PCR and 56 healthy individuals. COVID-19-related information and sociodemographic characteristics of the participants were recorded. Light Trainer Exercises System (Model LTV2, Türkiye, 2017) was used for the evaluation of reaction time, while the d2 attention test was used for the evaluation of concentration performance. Psychomotor speed percentage ($p<0.05$) and achievement score percentage ($p<0.05$) of individuals who had COVID-19 were found to be statistically significantly lower than those of the control group. In terms of reaction time performance, when compared with the control group, upper extremity reaction time ($p<0.001$) and lower extremity reaction time ($p<0.001$) values were found to be statistically significantly longer in the COVID-19 group. The results showed that when compared with the control group with the same age group, the participants between the ages of 18 and 26 who had previously been infected with COVID-19 were negatively affected in terms of reaction time and psychomotor speed parameters.

Keywords: COVID-19, concentration, psychomotor speed, reaction time

Introduction

COVID-19, a clinical condition caused by SARS-CoV-2 virus, first came out in Wuhan, China in December 2019 and with a rapid spread caused the death of a large number of individuals around the world [1]. After causing an international public health emergency, COVID-19 was declared as a pandemic on March 11, 2020 by World Health Organization (WHO) [2].

While fever, cough, shortness of breath, pneumonia, musculoskeletal system symptoms, loss of smell and taste and gastrointestinal findings are usually observed in individuals infected with COVID-19, it has been reported in different studies that the symptoms may be different in each person [2,3]. However, its ability to influence other organs, such as the central and peripheral nervous system, is its distinguishing feature [4]. While these symptoms have been found to appear usually 2-14 days later, it has been reported that some of the symptoms continued after COVID-19 and had prevalent and long-term effects on human health [5-7].

Reaction time, which is a good criterion in the evaluation of the capacity of cognitive system to process information, is the time from the appearance of a stimulus to the delivery of a response [8,9]. Cognitive processes are among the factors that determine reaction time. Among these processes, attention has been demonstrated in previous studies and it is a variable involved in reaction time [10-12]. Attention is a cognitive function

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Corresponding Author: Deniz Senol, Düzce University, Faculty of Medicine, Department of Anatomy, Düzce, Türkiye
Email: denizanatomi@gmail.com

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related with the activation of psychological activity, selection and regulation of the relevant stimuli [13,14]. In addition to this information, the development of attention is known to be associated with the other dimensions of cognitive processing like memory, executive control or learning [15,16]. Considering all the aforementioned reasons, it can be said that it is very important to develop and evaluate attention in social areas such as clinic, education, work or sports [17,18].

It has been found that individuals who had COVID-19 had a high rate of cognitive dysfunction a few months after contracting this virus, and it is thought that this may be related to underlying inflammatory processes. Studies conducted have found impairment in the executive functions, processing speed, memory coding, recall functions and also attention deficit in patients hospitalized for COVID-19 [19]. During the acute phase and after the disease, approximately one third of patients have been reported to experience impaired memory, concentration or attention, and approximately one fifth of all patients have been shown to have one or more of these cognitive disorders [20]. In line with these data, it is possible for numerous neurological complications to be associated with COVID-19 to be also associated with impairment in motor control and this results in the disruption of central mechanisms involved in planning, executing and adapting motor tasks [21].

In the light of this information, our study was planned considering that there may be changes in reaction time, psychomotor speed and concentration levels. Literature review showed that there are few studies evaluating reaction time, psychomotor speed, attention and concentration levels of individuals who had COVID-19, while there are no studies in which these parameters are evaluated together. Therefore, our aim in this study is to analyse reaction time, psychomotor speed and concentration level in individuals who have previously been infected with COVID-19 and to compare the results with the results of a healthy control group. Our hypotheses were determined as there is difference between individuals who had COVID-19 infection and healthy control group in terms of reaction time, psychomotor speed and concentration level and there is no difference between individuals who had COVID-19 infection and healthy control group in terms of reaction time, psychomotor speed and concentration level.

The hypothesis of this study is that the reaction time, psychomotor speed and concentration levels of individuals with COVID-19 infection will be negatively affected compared to healthy individuals. This hypothesis is based on the assumption that individuals with COVID-19 will have longer reaction times and lower psychomotor speed and concentration levels.

Material and Methods

This study used a descriptive and cross-sectional design to analyse reaction time, psychomotor speed and concentration parameters of individuals who had COVID-19 infection. The study was conducted between January 2022 and May 2022 at the Anatomy Practice Laboratory of Zonguldak Bülent Ecevit University Faculty of Medicine. Zonguldak Bülent Ecevit University Non-interventional Clinical Research Ethics Committee granted permission (2022 dated and 2022/06 numbered) for the study.

Participants

A total of 112 Faculty of Medicine and Faculty of Dentistry students at Zonguldak Bülent Ecevit University who met the inclusion criteria were recruited in the study in two groups as the patient group and control group. While the patient group (COVID-19 group) consisted of the students who had COVID-19 infection and who had spent isolation period at home, the control group consisted of healthy students who did not have COVID-19 infection. Participants were randomly selected and asked to fill in the informed consent form by mentioning the purpose and scope of the study. Then, the participants who filled the Informed Consent Form were evaluated face to face by a single researcher. Inclusion criteria for individuals who have contracted COVID-19: aged between 18 and 30, received a positive result for COVID-19 via polymerase chain reaction (PCR) test within the last 12 months, and completed a 14-day isolation period. The inclusion criteria for the healthy individuals in the control group required them to be aged between 18 and 30, have no prior COVID-19 diagnosis (+), test negative for COVID-19 (-) through a PCR test and exhibit no symptoms related to COVID-19 infection. Exclusion criteria were having communication problems, having undergone any surgical intervention in the last 6 months, having any orthopedic, neurological, psychological or systemic problem, having chronic pain for at least 4 months, having visual problems, and taking sleeping pills or psychiatric drugs.

Sample size was calculated with G Power Version 3.1.9.2 program before starting the study. It was found that a total of 82 individuals, with 41 in each group should be included in the study for an effect size of 0,30 with independent samples test, 80% test power and 95% confidence interval.

Data Collection Process

Psychomotor Speed, Attention and Concentration

Concentration levels of the participants were measured with d2 attention test. The aim of the test is to assess the ability of participants for visual scanning, perceptual speed, mental concentration and sustained attention [22]. Yaycı L. examined the reliability and validity of this test in 2013 [23]. There are 14 lines and 47 marked characters on each line in the test form. These lines also contain the letters ‘d’ and ‘p’ and one, two, three or four dots around the letters. During the test, the main task of the participant is to find and mark the ‘d’ letters with two dots around. The participant to be tested is given 20 seconds to complete the task given in each line and asked to make as many correct markings as possible without making any mistakes within 20 seconds. The test is terminated after completing the

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last line. It takes about 5-6 minutes to administer the test. A total of 7 scores are obtained in the test as TN, E1, E2, E%, CP, FR and TN-E. TN refers to psychomotor speed, E1 refers to the level of selective attention, E2 refers to specific learning disability, E% refers to general attention level, CP refers to concentration performance, FR refers to attention release and TN-E refers to the quality of performance shown in the test (test achievement score) [23].

Lower extremity reaction time – Upper extremity reaction time

Light Trainer Flash Light Exercise System (Model LTV2, Türkiye, 2017) reaction time device was used to measure lower and upper extremity reaction time. The participants waited in the prepared test area with their hands/feet on an A point line. There were four light reaction modules placed in front of the participants. While the distance from the midpoint of the modules to point A was determined as 50 cm, the distance between the modules was set to 15 cm. A trial test was made by each participant before the actual test and they were given information about the content of the test. A command to start was given when the participants were ready. During the test, the participant waiting at A point was asked to deactivate any activated module by reacting only with hand for upper extremity reaction time test and only with foot for lower extremity reaction time test. The participants were told that they had to deactivate the module in shortest time possible, at once. At the end of both tests, data were obtained for mean reaction time, fastest reaction time, slowest reaction time, number of deactivated modules [24].

Statistical Analysis

Statistical analysis was conducted by using SPSS 20.0 (Statistical Package for Social Science). Shapiro Wilk test was used to examine whether the data were normally distributed. Quantitative variables were examined with Mann-Whitney-U Test, while Chi-square test was used to examine qualitative variables. Median, minimum and maximum values were used to present quantitative variables, while number-percentage (n%) were used to present qualitative variables. Study and control groups were compared with the non-parametric Mann Whitney U Test. $p<0.05$ was considered as the level of significance. The data were taken from the thesis "Analysis of balance, reaction time and concentration parameters of individuals who had COVID-19 infection" and the data were reanalysed for the article.

Results

A total of 112 individuals, 56 (28 female and 28 male) individuals previously been diagnosed with COVID-19 by a PCR test who had completed their isolation period and 56 (28 female and 28 male) individuals who did not have COVID-19 infection before and who formed the control group, all of whom were studying at Zonguldak Bülent Ecevit University between January 2022 and May 2022 and met the inclusion criteria were recruited in our study.

Age, height, weight and BMI data of both groups are shown in Table 1. Mann-Whitney- U test and Chi-square test showed that the groups had no statistically significant differences in terms of age, weight, height, BMI, dominant hand-foot preference, cigarette-alcohol use, chronic disease and drug use ($p<0.05$).

When the COVID-19-related characteristics were examined, the rate of the participants with COVID-19 vaccination was higher than 95%. It was found that Biontech and Sinovac vaccines were preferred and a great majority of the participants had had 2 or 3 doses of vaccine. Chi-square test showed statistically significant difference between the groups in terms of having COVID-19 vaccine, the number of vaccine doses the participants had and the vaccine the participants had ($p<0.05$).

Attention and Concentration results of the groups are shown in Table 2. The groups were found to be statistically significant different in terms of psycho-motor speed (TN), psycho-motor speed percentage (TN%), test achievement score (TN-E) and achievement score percentage (TN-E%) ($p<0.05$).

The reaction time results of the participants can be seen in Table 3. The Mann-Whitney U test results showed that there was a statistically significant difference between the reaction time values between the groups, except for the slowest reaction time of the upper and lower extremities ($p<0.05$).

Table 1. Sociodemographic characteristics of the participants and statistical analysis results between groups

Sociodemographic characteristics	COVID-19 group Median (Min.-Max.)	Control group Median (Min.-Max.)	p*
Age (years)	20.00 (18-26)	20.00 (18-26)	0.891
Height (cm)	170.00 (153-191)	168.50 (155-193)	0.610
Weight (kg)	65.30 (47.60-111)	62.55 (44-107.20)	0.255
BMI (kg/m²)	22.70 (16.70-31.90)	21.85 (17.20-30.30)	0.106

*: Mann-Whitney-U Test, n: number of individuals, %: percentage, BMI: body mass index, Min: minimum value, Max: maximum value

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Table 2. Results of the participants on attention and concentration and statistical analysis results between groups

d2 Attention test parameters	COVID-19 group (N: 56) Median (Min-Max)	Control group (N: 56) Median (Min-Max)	p*
Psycho-Motor Speed (TN)	501.00 (337-613)	528.50 (368-651)	**0.028**
Psycho-Motor Speed (TN%)	94.50 (27.40-100)	97.65 (42.10-100)	**0.029**
Selective attention (E1)	21.50 (1-99)	27.50 (2-104)	0.356
Difficulty of learning (E2)	1.00 (0-38)	1.00 (0-5)	0.573
Concentration performance (CP)	176.00 (100-254)	182.00 (134-285)	0.216
Attention release (FR)	6.00 (3-17)	6.00 (2-9)	0.638
General attention (E%)	4.56 (0.59-22.36)	5.76 (0.39-17.94)	0.607
Achievement score (TN-E)	464.50 (314-609)	487.00 (362-641)	**0.040**
Achievement score (TN-E%)	93.30 (24.20-100)	96.75 (50-100)	**0.032**

N: number of individuals, Min: minimum value, Max: maximum value, p<0.05, *: Mann Whitney U Test

Table 3. Reaction time results of the participants and statistical analysis results between groups

Reaction time parameters	COVID-19 group (N: 56) Median (Min-Max)	Control group (N: 56) Median (Min-Max)	p*
UE-Mean RT (sec)	0.75 (0.57-0.97)	0.67 (0.56-0.85)	**<0.001**
UE-Slowest RT (sec)	1.20 (0.80-2.13)	1.35 (0.70-1.83)	0.919
UE-Fastest RT (sec)	0.60 (0.43-0.83)	0.53 (0.40-0.67)	**<0.001**
UE- Final RT (sec)	0.70 (0.52-1.40)	0.67 (0.53-1.33)	**0.040**
UE-NDM (number)	39.50 (28-52)	44 (35-53)	**<0.001**
LE- Mean RT (sec)	0.85 (0.61-1.10)	0.72 (0.63-0.96)	**<0.001**
LE- Slowest RT (sec)	1.56 (0.80-2.40)	1.38 (0.73-2.13	0.060
LE- Fastest RT (sec)	0.67 (0.40-0.87)	0.57 (0.47-0.73)	**<0.001**
LE- Final RT (sec)	0.80 (0.57-2.03)	0.73 (0.50-1.33)	**<0.001**
LE- NDM (number)	35 (27-49)	41 (31-47)	**<0.001**

UE: upper extremity, RT: reaction time, NDM: number of deactivated modules, LE: lower extremity, N: number of individuals, Min: minimum value, Max: maximum value, p<0.05, *: Mann Whitney U Test

Discussion

This study reveals the cognitive and motor effects of COVID-19. In particular, the lower performance of individuals with COVID-19 in psycho-motor speed and achievement scores suggests that SARS-CoV-2 infection may lead to negative effects on cognitive functions. In addition, significant differences were also found between the groups in reaction time measurements; in terms of upper and lower extremity reaction times, individuals with COVID-19 reacted more slowly, indicating that the disease may also affect motor functions.

While early clinical studies conducted on COVID-19 showed clinical findings related with pulmonary system such as cough, fever and shortness of breath in the majority of COVID-19 patients, evidence about extrapulmonary involvement of the disease emerged in the later periods [25]. It has been reported that neurological problems that occurred with the involvement of the nervous system did not occur only during the course of active disease, but they also continued to be seen in the form of post-neurological problems after the patients no longer had the infection [25]. Studies conducted mostly focused on the nervous system-related effects and possible neurological complications

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of COVID-19 [26-28]. However, there are still limited numbers of studies examining different parameters such as reaction time, psychomotor speed and concentration, which are controlled by the nervous system. Based on this perspective, our study aimed to analyse reaction time, psychomotor speed and concentration parameters in individuals who had previously been infected with COVID-19 and to compare these parameters with those of individuals who did not have COVID-19 infection before.

Individuals diagnosed with COVID-19 with PCR test within the last 12 months and healthy individuals who not diagnosed with COVID-19 before were included in the study. It was found that all of the individuals who had COVID-19 infection had various COVID-19 symptoms during the disease period including cough, fatigue, as fever, loss of taste/smell. In line with these data, according to the guide by T.R. Ministry of Health, individuals who had COVID-19 were considered to have mild or moderate disease [29]. The results showed that healthy individuals had statistically significantly better psycho-motor speed, psycho-motor speed percentage, achievement score and achievement score percentage, and better reaction time values except for the slowest reaction time value than the individuals who had COVID-19.

Zhao et al. evaluated the cognitive levels of 53 individuals who had a mean age of 28.6 and who had COVID-19 infection 5, 4 months ago on average with Cognitive Failures Questionnaire (CFQ). The results showed that individuals who had COVID-19 had a significant decrease in 9-minute sustained visual attention task performance when compared with the control group [30]. In another study conducted, sustained and selective attention levels of 29 patients (18 male and 11 female) aged between 30 and 64 who had COVID-19 infection were evaluated with Continuous Performance Test (CPT), while their concentration levels were evaluated with Digital Span Test (DST). As a result of the evaluation, only some parts of the CPT tests showed mild cognitive impairment in patients with SARS-CoV-2 infection [31]. Individuals with COVID-19 infection and control group showed significant differences in sustained attention, while concentration levels were not significantly different [31].

Our study also supports the presence of mild cognitive impairment in individuals after COVID-19 infection, while attention performances of the groups were not found to be different. We believe that the reason for this difference may be the fact that neuropsychological evaluations were conducted a short while after the patients recovered, generally two or three weeks after the infection and showed acute effects in the study by Zhou et al [31]. Our evaluations were made 7,9 months after the COVID-19 infection on average. The results of Zhou et al.'s study showing no significant differences between the concentration levels of groups supports the results of our study.

The mechanisms underlying post- COVID-19 cognitive impairment are still uncertain. Although the effect of the virus being permanent on the brain cannot be ruled out, evidence obtained from postpartum studies show that the presence of the virus is very low in the brain in COVID-19 patients [32]. The virus may have indirect effects on cognitive function through a series of possible mechanisms, including immunological and microvascular changes [33]. In a study conducted on individuals who had COVID-19 infection, it was found that the patients who were most severely affected in terms of cognition showed cognitive impairment to a certain extent accompanied by hypermetabolism in frontoparietal regions [34]. These regions are associated with sustained attention and episodic memory [35-37].

Reaction time includes a cognitive process to choose the most appropriate response to multiple stimuli and responses vary depending on stimuli type and form. Mental processing period, afferent nerve conduction period, movement analysis period and device response period are the components of reaction time [38]. Reaction time is a very important parameter especially in competitions, in getting ahead of opponents in sports competitions, increasing safety in traffic and preventing accidents [39].

Zhou et al. evaluated the effects of COVID-19 on cognitive functions in patents who recovered after SARS-CoV-2 infection, and used Sustained Performance Test (SPT) to evaluate reaction time of individuals [31]. The study included 29 (18 male and 11 female) individuals who had COVID-19 infection and 29 (12 male and 17 female) healthy individuals between the ages of 30 and 64. The results showed that individuals who had COVID-19 infection had significantly worse reaction time in the first and second parts of SPT than the control group [31]. It was also concluded in our study that COVID-19 group showed significantly slower reaction in reaction time performance. This result supports the study conducted by Zhou et al. [31] and we believe that it contributes to this subject which is included in few studies in literature.

Examining the cerebrum, cerebellum and subcortical structures of 56 individuals who had COVID-19 infection and 56 healthy individuals in the study through radiological methods could give us clearer results on the cognitive effects of the disease and help us to make direct associations with our results. However, requesting radiography from each participant was not appropriate in terms of hospital expenses and the negative effects of X rays.

Conclusion

In conclusion, it was found in our study that although approximately 7-8 months had passed since the infection, young adults who had mild or moderate severity of COVID-19 infection had statistically worse results than young adults at the same age group in reaction time and psychomotor speed parameters. We believe that future studies should evaluate long term changes in neuroperformance skills of individuals who had COVID-19 infection and examine cerebrum, cerebellum and subcortical structures in detail. In addition, there is also a need to explain the underlying pathophysiological mechanisms more clearly and

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in more detail. We believe that determining post- COVID-19 impairment even in individuals who had mild and moderate level of COVID-19 infection will shed light on planning rehabilitation according to actual needs.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
This study was approved by the Ethics Committee of Zonguldak Bülent Ecevit University (Decision Number: 2022/06).

Patient Informed Consent
Written informed consent was obtained from the participants.

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