ORIGINAL ARTICLE

INVESTIGATION OF THE LONG-TERM EFFECTS OF PANDEMIC VACCINES ON PHYSICAL AND COGNITIVE PERFORMANCE AFTER THE PANDEMIC

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Abstract

Introduction: The present study compared the post-pandemic effects of different vaccines and vaccine combinations administered during the coronavirus disease 2019 pandemic in individuals defined as "young-elderly."

Materials and Method: Participants included 440 volunteers who met the inclusion criteria. They were divided into four groups based on the type of vaccine they had received. During data collection, participants completed a Personal Information Form, the Montreal Cognitive Assessment, the 36-item Short Form Health Survey, and the Alusti Test. The study was conducted between December 15, 2024, and May 29, 2025.Data were analyzed using SPSS version 28.0.

Results: The analyses revealed a statistically significant difference between groups in both the Alusti test (assesses physical performance) and the 36-item Short Form Health Survey (assesses quality of life) ($p<0.05$).This difference was particularly pronounced in the group that received the combination of BioNTech and Sinovac vaccines;it hadlower scores on physical performance and quality of life compared to the other groups. Cognitive performance did not differ significantly between the groups ($p>0.05$).

Conclusion: Therefore,the coronavirus disease vaccines may have varying long-term effects on the individual's overall health status and quality of life.

Keywords: COVID-19; Physical Functional Performance; Cognition; Quality of Life; Vaccines.

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INTRODUCTION

In December 2019, public health officials identified a new strain of coronavirus, SARS-CoV-2, in Wuhan, China, which causedan outbreak in that city.On March 11, 2020, the coronavirus disease 2019 (COVID-19) was declared a global pandemic. Local public health authorities initiated vaccine development processesto prevent the spread of the COVID-19 virus and reduce hospitalization and mortality rates (1).

Apart from the traditional methods used for vaccine production, new techniques such as mRNA technology are also being utilized in the vaccine development process. Vaccines that were developed rapidly and granted emergency use authorization began to be tested on humans in March 2020.The first vaccines to receive emergency use authorization were the Pfizer-BioNTech and Moderna vaccines, both produced using mRNA technology. Researchers announced that both types of vaccines provided over 90% protectionaccording to their phase 3 evaluations(2, 3).

In addition to the vaccines produced using mRNA technology, viral vector-based vaccines (Oxford-AstraZeneca and Sputnik V)and the inactivated virus-based Sinovac vaccine werewidely used across the world(4).

In Turkey, Sinovac and BioNTech vaccines were the first to be used against COVID-19. Additionally, a limited number of Sputnik V vaccines were administered. Although these vaccines were usedto control the spread of the pandemic in Turkey, efforts were undertaken to develop a domestic vaccine. TheTurkovac vaccine, developed by Erciyes University, received emergency use authorization in December 2021 and began to be administered (5).

Early evaluations revealed that mRNA vaccines were significantly effective in reducing pandemic-related complications. This effectiveness was associated with an increase in antibodies and T cells in the immune system(6, 7).

Apart from physiological changes, the administration of vaccines resulted in a decreased rate of transmission, the beginning of normalization, psychological relief, and positive improvements in the sense of trust and social interactions. Additionally, the decrease in mortality rates and shorter hospital stays reduced anxiety among individuals at risk (8).

Therefore, the present study aimed to evaluate the long-term effects of the vaccines administered during the COVID-19 pandemic on individuals after the pandemic. Most studies have conducted short-term evaluations and limited long-term evaluations. This delays a comprehensive understanding of the long-term effects of vaccines (9-11),demonstrating the need to examine their effects on the health status of individuals after the pandemic.

MATERIALS AND METHOD

Ethics

The study protocol was approved by the ArtvinÇoruh University Scientific Research and Publication Ethics Committee onDecember 12, 2024 (Approval Number: E-18457941-050.99-159686).All phases of the study were performed per the Declaration of Helsinki.

Inclusion Criteria for the Study:

- Voluntaryparticipation in the study
- Willingness to provide written informed consent for participation
- History of COVID-19 confirmed by PCR or antibody test
- Received at least two doses of vaccines
- Sufficient cognitive capacity to comprehend and perform the required study procedures
- No history ofserious pathological conditions (such as cancer, heart failure, etc.) that would prevent participation in the study

Exclusion Criteria:

- Unwillingness tooffer written informed consent for participation
- Not vaccinated or incomplete vaccination doses
- Severe neurological and/or psychiatric disorders
- History of a serious acute infection within the last six months
- Suspected pregnancy

Sample Size Calculation

In determining the sample size, the primary hypothesis of our study — "*There is a significant difference in physical performance among different COVID-19 vaccines and vaccine combinations*" — was taken as the basis. This hypothesis is grounded in the biological premise that different vaccine platforms (mRNA-based, inactivated virus, or their combinations) may elicit varying immune responses, inflammatory profiles, and post-vaccination symptom patterns, which in turn can influence muscle function, fatigue levels, and cardiopulmonary performance. Such physiological effects are particularly relevant in older or near-elderly populations, where baseline functional reserve is lower and immune responses may differ from those in younger individuals. This assumption is supported by previous studies conducted in older or near-elderly populations that examined differences in physical health indicators (12,13). Based on the mean differences and variances reported in these studies, Cohen's d value was estimated at 0.5, corresponding to a medium effect size. For the sample size calculation, the G*Power 3.1.9.4 software was used with an alpha level of 0.05, a power (1–β) of 0.80, and an effect size of 0.5. The calculation indicated that a minimum of 48 participants per group was required. Given that the study included four groups, the total minimum sample size was determined to be 192. Considering potential dropouts and missing data, additional participants were recruited.

Procedure

The present study did not include retrospective evaluation and was structured as a prospective, intergroup observational comparison. As part of the study, parents of students studying at Artvin Çoruh University's Vocational School of Health Services were contacted. Those who met the inclusion criteria were provided with detailed information and invited to participate in the study.

Subsequently, the participants were invited for face-to-face interviews.Those who provided written informed consent voluntarily were included in the study. Thedata collection was conducted in the physiotherapy laboratory, which provided an appropriate environment for administering the tests and scales. Participants' demographic characteristics were collected using a personal information form consisting of four questions (sex, age, body mass index (BMI), and education level). This was followed by the Alusti Test to evaluate their physical status. This test was conducted in the presence of an independent physiotherapist, who was not involved in the study and was not informed about the group assignments of the individuals. Subsequently, the Montreal Cognitive Assessment (MoCA) was administered by an independent researcher to assess cognitive performance, and the 36-item Short Form Health Survey (SF-36) was administered to assess quality of life

Measures

Personal information form. Researchers created this form to collectparticipants' demographic information. It included questions about their sex, age, body mass index (BMI), and education level.

Alustitest: This test was developed by physiotherapist Josu Alustiza Navarro to assess the physical status of geriatric individuals. Itevaluates

individuals' normal joint range of motion; muscle strength; ability to move from supine to sitting, stand up from sitting, balance while standing, stand with eyes closed, and stand on one leg with eyes closed; and walking and walking distance. Each evaluation parameter is scored according to the individual's ability to perform it.The maximum score on this test is 100.A high score indicates good physical performance. The Turkish validity and reliability of this test have been established by Kesikbaş(14).

Montreal Cognitive Assessment Form. This test, developed by Dr. Ziad Nasreddine to evaluate cognitive functions, allows the assessment of individuals' memory, visuospatial skills, executive function, verbal fluency, abstract thinking, attention, concentration, working memory, language, and orientation to time and place. The total score can range from 0 to 30,with a high score indicating good cognitive capacity. The Turkish validityof this scale has been established by Selekler et al. (15).

36-itemShort Form Health Survey. This 36-item form was developed by Ware and Sherbourne to evaluate individuals' quality of life. It is applicable to several broad areas and is not limited by factors such as age or disease. Thetotal score on this scale can range from 0 to 100, with a high score indicating better quality of life. The Turkish validity and reliability of this test have been established by Koçyiğit et al. (16).

Statistical Analysis

The data were analyzed using IBM SPSS Statistics version 28.0. Prior to the analyses, the distribution of variables was assessed using both statistical tests and graphical methods. Since the sample size in our study exceeded 50 and the data did not deviate markedly from symmetry, the Kolmogorov–Smirnov test was applied, in conjunction with visual assessments such as histograms and outlier checks, to evaluate normality. Continuous variables with a normal distribution were presented as mean ± standard deviation, whereas non-normally distributed data were expressed as median (Q1–Q3).

For group comparisons, one-way analysis of variance (ANOVA) was used for normally distributed continuous variables, while the Kruskal–Wallis H test was applied for skewed distributions. Categorical variables were analyzed using the chi-square test or Fisher's exact test when expected frequencies were low. In cases where multiple comparisons were significant, Tukey's test or appropriate non-parametric post-hoc tests were applied.

In addition, multiple linear regression analyses were conducted using the enter method, whereby all predictor variables were entered into the model simultaneously to identify independent predictors of SF-36 and Alusti Test scores. Prior to model estimation, the assumptions of multiple linear regression — including linearity, independence of residuals (Durbin–Watson statistic), homoscedasticity, absence of multicollinearity (Variance Inflation Factor < 10), and normal distribution of residuals — were evaluated and met. The explanatory power of each model was reported using the coefficient of determination (R^2) and adjusted R^2, and statistical significance was set at $p < 0.05$.

RESULTS

Table 1 presents the participants' demographic information. Statistically significant differences were observed among the groups in terms of age and body mass index (BMI) ($p < 0.05$), whereas no significant differences were found with respect to sex and educational status ($p > 0.05$)(Table 1).

This table presents the comparative analysis of physical performance (Alusti Test), cognitive function (Montreal Cognitive Assessment), and quality of life (SF-36) scores across the four vaccine groups. Variables with a normal distribution are expressed as mean ± standard deviation (SD) and analyzed using one-way analysis of variance (F

Table 1. Demographic characteristics of the participants.

Variables	Group 1 (Unvaccinated)	Group 2 (BioNTech)	Group 3 (Sinovac)	Group 4 (BioNTech+Sinovac)	p-value
Age	69.00(69.00-71.00)	67.00 (67.00–69.00)	69.00 (68.00–72.00)	68.00 (66.00–69.00)	0.010**[1]
BMI	24.73(22.54–27.25)	27.80 (25.30–31.10)	26.70 (22.41–27.80)	27.80 (24.30–32.90)	0.020**[1]
Sex, n (%)					
Female	84(76.3)	60(54.5)	58 (52.7)	61(55.4)	0.170*[2]
Male	26(23.7)	50(45.5)	52(47.3)	49(44.6)	
Educational status, n (%)					
Primary School	88(80.0)	68(61.8)	84(76.3)	88(80.0)	
High school	6(5.4)	28(25.4)	26(23.7)	22(20.0)	0.331*[3]
University	16(14.6)	14(12.8)	0(0.0)	0(0.0)	

Note.[1]Kruskal–Wallis H test, [2]Chi-square test, [3]Fisher's exact test,** p<0.05Abbreviations: BMI: Body Mass Index; p-value:Significance level

Table 2. Comparison of Physical Performance, Cognitive Function, and Quality of Life Scores by Vaccine Group

Outcome measure	Group 1 (n=110)	Group 2 (n=110)	Group 3 (n=110)	Group 4 (n=110)	Test Statistic
Alusti test	65.60 ± 19.53	71.12 ± 10.06	67.72 ± 13.91	57.40 ± 20.97	F(3, 436) = 3.96, p=.033
Montreal Cognitive Assesment	21.00(16.00-21.00)	23.00(20.00-26.00)	22.00(13.00-26.00)	17.00(11.00-26.00)	H(3) = 3.82, p=.662
SF-36	78.92 ± 11.20	80.48 ± 9.84	79.32 ± 11.76	70.44 ± 11.28	F(3, 436) = 4.36, p=001

Note.SD = Standard deviation; Q1–Q3 = interquartile range; SF-36 = 36-item Short Form Health Survey; F = one-way ANOVA test statistic; H = Kruskal–Wallis test statistic. *Post-hoc comparisons indicate significant differences at p < .05.

statistic). Variables without a normal distribution are expressed as median (Q1–Q3) and analyzed using the Kruskal–Wallis test (H statistic). SF-36=36-Item Short Form Health Survey; Q1–Q3=interquartile range. Post-hoc comparisons indicate statistically significant differences at the $p < 0.05$ level. Post-hoc analysis revealed that, in the Alusti Test, the BioNTech group demonstrated significantly higher physical performance scores compared to the BioNTech+Sinovac group (p<.05), while no significant differences were observed among the other groups (p>.05). In terms of SF-36 quality of life scores, the BioNTech+Sinovac group had significantly lower scores than both the BioNTech and unvaccinated groups (p<.05). However, no significant differences were identified between the Sinovac group and the other groups (p>.05). For Montreal Cognitive Assessment scores, no significant differences were observed across the four groups (p>.05) (Table 2).

The results of the final multiple regression models with variable selection are presented in Table 3. According to the findings, the Montreal Cognitive Assessment (MoCA) score was a significant positive predictor in both models ($p < 0.001$). In the SF-36 model, both MoCA (B=0.4196, $p < 0.001$) and Alusti Test scores (B=0.2123, $p < 0.001$) contributed positively to quality of life, whereas the

Table 3. Multiple Regression Analysis Results for SF-36 and Alusti Test

Variables	B (SF-36)	p (SF-36)	B (Alusti)	p (Alusti)
Montreal Cognitive Assessment.	0.4196	0.000	0.5289	0.000
Alusti Test.	0.2123	0.000	-	-
Vaccine Group_4	-5.9708	0.033	-7.3828	0.112
SF-36	-	-	0.704	0.001

Note.B = unstandardized coefficient; p = significance level; Significant values ($p < 0.05$) are shown in bold. Model fit (SF-36): $R^2 = 0.386$, Adjusted $R^2 = 0.367$, $F(3, 96) = 20.13$, $p < 0.001$, Durbin–Watson = 1.712. Model fit (Alusti): $R^2 = 0.225$, Adjusted $R^2 = 0.217$, $F(1, 98) = 28.44$, $p < 0.001$, Durbin–Watson = 1.561.

BioNTech+Sinovac vaccine combination (Vaccine Group 4) was associated with significantly lower SF-36 scores (B=–5.9708, p=0.033). In the Alusti model, both MoCA (B=0.5289, $p < 0.001$) and SF-36 scores (B=0.704, p=0.001) significantly predicted physical performance, while none of the vaccine groups showed significant effects ($p > 0.05$). All assumptions of multiple linear regression, including linearity, independence of residuals, homoscedasticity, absence of multicollinearity, and normality of residuals, were evaluated and satisfied (Table 3).

DISCUSSION

The present study concluded that physical performance and quality of life variables varied according to different vaccines or vaccine combinations, whereas no difference was observed in cognitive performance. Notably, both physical performance and quality of life scores were significantly lower among geriatric individuals who received the BioNTech+Sinovac vaccine combination compared to the other groups.

The literature review indicates that most studies have generally focused on immunity and general physiological parameters after vaccination.However, comprehensive studies comparing the effects of vaccines on variables such as physical performance, quality of life, and cognitive performance are scarce. Therefore, the present study is a pioneering and contributory work in this area of the literature.

A meta-analysis study conducted by Li et al. (12) investigatedthe safety of COVID-19 vaccines and their effects on the immune system in geriatric individuals. Theresults revealed that mRNA-based vaccines (such as BioNTech) demonstrated a higher level of effectiveness; however,the risk of side effects was also significantly higher. Furthermore, inactivated and vector-based vaccines provided an adequate level of protection and had lower levels of risk in terms of side effects. Moreover, the use of more than one dose was associated with a higher level of protection compared to a single dose. In another study, Babicki et al. (13)examined the COVID-19 registry system andfollowed up with individuals who had contracted COVID-19 over a 12-month period. Theresults indicated that while the vaccination had positive effects on some existing symptoms, it had no effect on symptoms such as exercise intolerance and fatigue during the 12-month follow-up period. It further concluded that these symptoms could continue over an extended period after vaccination.The evaluation of the results of both these studies highlighted that COVID-19 negatively impacted physical performance in geriatric individuals. The different efficacies of vaccines administered for COVID-19 led them to affect physical performance to varying degrees. These findings support the results of the present study, whichdemonstratedthat different types of vaccines affected physical performance to different extents.

Another study conducted by Silva et al. (17) examined the relationship between exercise habits and responses to COVID-19 vaccines in geriatric individuals aged above 60 years. The study demonstrated that individuals who developed a regular exercise habit gained stronger immunity to the CoronaVac and AstraZeneca vaccines. Althoughthis study did not directly evaluate physical performance, it assessed variables related to the immune system, which affects functional capacity. No significant difference was found among the vaccines included in the study in terms of generating an immune response.This situation underscores the importance of individuals' lifestyles in maintaining physical performance. Also falling within the scope of our study, the adverse situation observed in the BioNTech+Sinovac vaccine group suggests that the variations may have been influenced by individuals' lifestyles apart from the vaccines administered.

A review published by Soizaet al. (18) examined the efficacy and safety of vaccines among geriatric individuals. BioNTech, Moderna, and AstraZeneca vaccines were used in the study. Theresults indicated that high immune responses were obtained after vaccination. The absence of any adverse situation in both physical function and activities of daily living among vaccinated individuals was presented as the most important finding of the study.These results contradict the results of the present study. Although researchers indicate that mRNA and vector-based vaccines were safe and enhanced the immune response, studies regarding vaccine combinations are scarce.

Previous studies have also examined the effects of the pandemic vaccines onindividuals' overall quality of life. However, these studies have generally focused on single-type vaccine administrations. For example, Wu et al. (19) examined the effects of COVID-19 vaccines on the quality of life of individuals who had undergone heart transplantation. Eighty-eight patients, who had experienced heart transplantation and were included as participants, were administered the Sinovac vaccine as part of the study. The 36-item Short Form Health Survey was used to assess their quality of life. The study reported that vaccinated individuals had higher quality of life scores than unvaccinated individuals. This finding demonstrates the effect of vaccination on quality of life and supports our study's conclusion that quality of life varies according to the type of vaccination.

In another study, Yacoub et al. (20) evaluated the quality of life, psychological status, and sexual function indicators following vaccination among postmenopausal women. The results revealed that participants experienced both physical and emotional improvements and reported increased life satisfaction after vaccination.This result supports our study's conclusion that quality of life and physical performance are affected differently by different types of vaccines.

Di Fusca et al. (21) concluded that, among individuals who received the BioNTech vaccine, a reduction in symptoms was accompanied by significant improvements in both activities of daily living and quality of life.Shrestha et al. (22) investigated the efficacy of two vaccines developed using different methods—AstraZeneca and Covaxin. The study found that the overall quality of life remained unchanged,without any significant declines.In their study, Kitano et al. (23) indicated that, in addition to eliciting strong immune responses, vaccines produced using mRNA technology contributed positively to one's quality of life.Therefore,it can be concluded that different vaccines have varying effects on the quality of life. This result supports one of the main conclusions of our study, namely, that quality of life is affected differently by different types of vaccines.

The literature contains a limited number of studies investigating the effects of COVID-19 vaccines on cognitive performance in geriatric individuals. In this context, Roh et al. (24) conducted a study using

South Korea's national database to evaluate 558,017 individuals aged above65 years.In the study, they reported that 1) the risk score determined for the development of Alzheimer's disease changed significantly following the use of vaccines produced with mRNA technology and2) the risk score for mild cognitive impairment was at a more pronouncedly elevated level. However, researchers emphasized the necessity to investigate whether this situation is due to COVID-19 vaccines or to the psychological and biological impact of the pandemic.

Flegr and Latifi (25) conducted a research project utilizing the internet, in which 4,445 participants were evaluated. They reported that cognitive performance was adversely affected in cases in which individuals had experienced infection and had suffered from severe cases of COVID-19. Furthermore, they reported that vaccination had a positive effect on sub-parameters of cognitive performance, such as intelligence and information-processing speed. However, they emphasized that this effect may not be directly attributable to vaccination, but could be related to the participants' education levels.Therefore, it is suggested that COVID-19 vaccination may have an impact on cognitive performance. However, this raises the question of whether the observed effects are biologically based or stem from sociodemographic factors. This finding is consistent with the present study's findings. Our study demonstrated that different vaccine groups were able to alter physical performance and quality of life, but no significant differences were observed in cognitive performance. This indicates that it is necessary to consider the cognitive biological basis, sociodemographic factors, and lifestyle characteristics when evaluating participants' cognitive performance.

CONCLUSION

The present study found that different types of vaccines resulted in changes in individuals' physical performance and quality of life after the pandemic; however, no changes were observed in their cognitive performance. Additionally, the group towhich both BioNTech and Sinovac vaccines were administered had lower scores in physical performance and quality of life. These results indicate that vaccine combinations affected individuals' overall health status. Therefore, future studies should comprehensively investigate the effectiveness of vaccine combinations.

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Conflict of Interest: The authors declare that there is no conflict of interest.

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