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# The Impact of Aerobic Exercise on Athletic Performance in Recovered and Uninfected COVID-19 Athletes during Post-COVID-19 Period

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## Abstract

**Background:** The global COVID-19 pandemic has significantly influenced athletes worldwide.
**Objectives:** This research aims to investigate the effects of a 4-week aerobic exercise program on athletic performance in both recovered and uninfected COVID-19 athletes during the post-COVID-19 period.
**Methods:** Fourteen male student-athletes aged 18 - 25 years from Imam Khomeini International University participated in this study. The participants comprised 7 recovered COVID-19 athletes and 7 athletes with no prior COVID-19 infection. The study employed a pre-test/post-test design conducted in 2 phases. During the pre and post-test phases, participants underwent baseline assessments of athletic performance, including maximum oxygen consumption ($VO_2$ max) and anaerobic power. Subsequently, the participants engaged in a 4-week aerobic exercise intervention. Pre- and post-intervention outcomes within groups were compared using paired *t*-tests, while independent *t*-tests were utilized for comparisons between the recovered COVID-19 athlete group and the uninfected athlete group.
**Results:** Independent *t*-tests demonstrated significant increases in $VO_2$ max and peak power after 4 weeks of aerobic exercise in both the recovered COVID-19 group ($P = 0.001$, $P = 0.0001$) and the uninfected COVID-19 group ($P = 0.012$, $P = 0.001$). However, dependent *t*-tests revealed a significant difference between the recovered COVID-19 group and the uninfected COVID-19 group in the post-test of $VO_2$ max ($P = 0.044$) and peak power ($P = 0.001$).
**Conclusions:** This study indicates that a 4-week aerobic exercise regimen can improve athletic performance in both recovered and uninfected COVID-19 athletes. However, recovered COVID-19 athletes exhibited a notably slower rate of improvement compared to their uninfected counterparts. Therefore, it is recommended that, in addition to aerobic exercise, recovered athletes integrate supplementary strategies to optimize their return-to-sport timeline and maximize performance recovery.

*Keywords:* Aerobic Exercise, $VO_2$ Max, Anaerobic Power, Post COVID-19

## 1. Background

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has had a significant global impact (1). The highly contagious nature of the virus has led to widespread quarantine measures to control its spread (2). Both the viral infection and isolation measures elicit medical and psychological complications. Common physiological effects of COVID-19 infection encompass respiratory distress, blood clots, acute organ injury, exacerbated chronic disease, and secondary infections due to systemic impacts (3). Approximately, 14 - 19% of confirmed cases have required hospitalization for oxygen support or intensive care (4). COVID-19 infection was associated with reduced maximum oxygen consumption ($VO_2$ max) and anaerobic threshold in an elite athlete, indicating impaired aerobic and anaerobic exercise capacity. This case study suggests COVID-19 can negatively impact athletic performance (5). However, providing adequate health resources and support can help mitigate these issues (2). To reduce viral transmission and disease spread, preventive measures have emphasized hygiene, physical distancing, ventilation, use of protective equipment, and testing strategies (6). However, Public health measures have significantly disrupted normal sports operations, leading to widespread closures of athletic facilities, event cancellations, and the implementation of distancing requirements in sports organizations worldwide. The sports industry is estimated to face billions in economic losses, primarily due to significantly reduced revenues from spectator events and the closure of venues (7). Sports participation has also precipitously declined, especially for amateur athletics, due to gym shutdowns and fear of infection risks associated with such facilities (8). Beyond organizational impacts, individual athletes have faced significant physical and psychological from the pandemic. Among infected athletes, common symptoms include fatigue, reduced exercise tolerance, dyspnea, tachycardia, muscle soreness and pain, and cognitive impairments - all performance-limiting manifestations (9). These limitations often persist weeks beyond initial infection recovery (10). Pandemic-related training disruptions among both infected and uninfected athletes also threaten performance declines. Researchers estimate just 12-weeks of training cessation diminishes aerobic capacity by 6 - 20%, muscle strength by 12 - 15%, and power by 3 - 5% (11). Athletes also display escalated rates of anxiety, depression, insomnia, loneliness, and eating disorders during quarantine periods involving isolation and distancing rules. All these physical and psychological implications pose barriers for maintaining peak performance (9). Aerobic capacity, measured by $VO_2$ max, represents an athlete's maximum oxygen utilization during intense exercise until exhaustion (12). Greater aerobic power enhances endurance, allowing athletes to train and compete without premature fatigue (13). Anaerobic capabilities also significantly influence performance in sports requiring high-intensity bursts. Anaerobic power depends on glycolytic and phosphagen energy systems to fuel all-out exertion without reliance on oxygen (9). During COVID-19 infection and through recovery, researchers have documented substantially reduced $VO_2$ max among athletes - likely driven by respiratory limitations, muscle wasting, and cardiovascular effects of the virus (14). In a study by Huang et al., individuals recovering from COVID-19 experienced prolonged symptoms like fatigue, muscle weakness, sleep problems, anxiety and depression up to 6 months after initial illness (14). Additionally, the sudden inactivity imposed by quarantine rapidly deteriorates both aerobic and anaerobic fitness without adequate training stimuli (15). Consequently, supporting athletes' safe return to exercise during post-COVID-19 recuperation requires gradually rebuilding these critical energetic capacities. Emerging evidence indicates that even athletes with relatively mild COVID-19 illness display prolonged cardiovascular, respiratory, neurological and other complications impacting health and performance - a phenomenon now recognized as "post-COVID-19 syndrome" (15). Comparison to athlete groups without known infection better elucidates this post-viral pathology versus simple deconditioning. Understanding infection-induced deficiencies and optimal training approaches remains vital for sports medicine staff guiding athletes' post-COVID-19 reconditioning. Recent literature synthesizing complications and rehabilitation considerations in athletic populations is extremely limited.

## 2. Objectives

This study aims to investigate the effects of aerobic exercise on athletic performance in recovered and uninfected COVID-19 athletes during the post-COVID-19 period.

## 3. Methods

The current study employs an applied and semi-experimental research design, utilizing a pre-test and post-test measurement approach.

### *3.1. Participants*

Fourteen athletes (college football players) of Imam Khomeini International University (who were recovered and Uninfected COVID-19), were selected using both convenience and purposive sampling methods in two pre-test and post-test phases over a one-month period in June 2022. They were assigned to 2 groups: The recovered COVID-19 group (N = 7) and the uninfected COVID-19 (N = 7).

### *3.2. Protocols*

The participants voluntarily provided their medical history and personal information by completing medical history questionnaires. After agreeing to participate in the study. They were asked to sign an informed consent form indicating their willingness to participate and confirming they understood the study's objectives and procedures. Participants were included in the study if they met the following criteria: (1) collegiate-level football or futsal players prior to the COVID-19 pandemic; (2) free of underlying health conditions per medical history questionnaires; (3) not taking medications, supplements, or alcohol regularly; (4) sports/exercise cessation since onset of pandemic; (5) positive COVID-19 infection 0 - 6 months prior to study enrollment as per Huang et al. (14); (6) no physical activity since COVID-19 pandemic; (7) they were excluded from the study if any of the following occurred; (8) irregular attendance in training sessions; (9) dishonesty or inconsistencies in study participation; (10) injuries preventing completion of the full training program.

Two rounds of testing were conducted - pre-intervention baseline testing and post-intervention testing after the 1-month training period. The 2 key measures assessed were: $VO_2$ max estimated by the Bruce treadmill protocol and anaerobic capacity from the Wingate cycling test. $VO_2$ max was determined using a Pulsar med (3P, Germany) laboratory treadmill and respiratory gas analyzer (MM3B, Germany). Anaerobic power was assessed with a cycle ergometer (Monark 894E, Sweden). The study procedures and ethics were approved by the Qazvin University of Medical Sciences Institutional Review Board (IRB) (ethics code IR.QUMS.REC.1401.171).

### 3.3. Aerobic Exercise Program

The 4-week aerobic training program involved treadmill running at 65 - 85% of estimated heart rate max (HRmax), performed 3 days per week (Table 1). Sessions at the university fitness center included warm-up, main training block per the program, and cool down. Individual target heart rate zones were set prior using the age-predicted formula HRmax = 220 - age (16). Polar heart rate monitors (Pulsar med 3p) continuously monitored intensity. If any concerning symptoms (chest pain, shortness of breath, fainting, etc.) arose during sessions, activity was ceased. Each 30-60-minute session progressed weekly from 65% upwards based on target HR max. Table 1 shows the aerobic exercise program.

### 3.4. Statistical Analysis

Data normality was first assessed using the Shapiro-Wilk test. Between-group differences were evaluated by independent *t*-tests. Within-group pre-post changes were examined using paired- *t*-tests. IBM SPSS Statistics version 26.0 was used to run all statistical tests with alpha set to 0.05 a priori. One-way ANOVA tested baseline between group differences in demographic variables. Figures were created in Microsoft Excel 2016.

## 4. Results

Participant characteristics are shown in Table 2. No significant differences were observed for demographic characteristics of participants ($P > 0.05$).

Table 3 shows the mean ± SD of athletic performance in the pre-test and post-test for the groups. The Shapiro-Wilk test results indicated that the distribution of pre-test and post-test data in each group was normal, with ($P > 0.05$). Additionally, equality of variances was confirmed. Based on the fulfillment of these assumptions, a paired *t*-test was utilized to analyze differences in anaerobic power and $VO_2$ max between the pre-test and post-test for each group which is shown in Figure 1. Independent *t*-tests were conducted to compare groups at baseline (pre-test) as well as to compare the magnitude of pre-post change between groups for the variables of anaerobic power and $VO_2$ max which is shown in Figure 2.

Figure 1 shows the results of dependent *t*-tests examining changes in peak anaerobic power and $VO_2$ max before and after an aerobic exercise intervention program in 2 groups individuals recovered from COVID-19 and those uninfected with COVID-19. For the recovered COVID-19 group, there was a significant increase of 4.57 mL/kg/min in $VO_2$ max from pre to post intervention (P = 0.001). Additionally, peak anaerobic power showed a significant gain of 21.57 watts following the exercise program (P = 0. 0001). Similar trends were seen in the uninfected group, with $VO_2$ max increasing by 3.28 mL/kg/min (P = 0.012), and peak anaerobic power having a significant enhancement of 25.71 watts (P = 0.001).

Figure 2 shows the results of independent *t*-tests, pre-intervention comparisons between the group recovered from COVID-19 and the unaffected control group showed statistically significant differences in both $VO_2$ max (P = 0.003) and peak anaerobic power (P = 0.0001) before the exercise training program began. Specifically, those recovered from COVID-19 infection demonstrated considerably lower cardiorespiratory fitness as measured by $VO_2$ max along with substantially diminished muscular power generation capacities at baseline testing compared to their unaffected peers. Additionally, post-intervention testing comparisons between this same COVID-19 recovered and unaffected control groups continued to reveal lingering statistically significant differences between the 2 groups in both $VO_2$ max (P = 0.044) and peak anaerobic power (P = 0.0001). In summary, the group previously infected with COVID-19 maintained disadvantages in cardiovascular fitness reflective of $VO_2$ max as well as anaerobic muscular power outputs at post-testing even following completion of the aerobic exercise regimen compared to the unaffected

**Table 1.** Aerobic Exercise Program of Subjects in 4 Weeks

| Weeks | Session (N) | Warmup (min) | Duration (min) | Intensity (%) | Cool Down (min) |
|---|---|---|---|---|---|
| **First** | 3 | 15 | 30 | 65 - 70 | 10 |
| **Second** | 3 | 15 | 40 | 70 - 75 | 10 |
| **Third** | 3 | 15 | 50 | 75 - 85 | 10 |
| **Fourth** | 3 | 15 | 60 | 75 - 85 | 10 |

**Table 2.** Participant Demographic Characteristics

| Variable Groups | Sig | Age (y) | Sig | Height (cm) | Sig | Weight (kg) | Sig | BMI (kg/m$^2$) |
|---|---|---|---|---|---|---|---|---|
| **Recovered COVID-19** | 0.97 | 22.28 ± 2.05 | 0.78 | 175.57 ± 6.37 | 0.57 | 75.38 ± 3.67 | 0.36 | 24.45 ± 0.84 |
| **Uninfected COVID-19** | | 21.71 ± 2.36 | | 171.00 ± 9.09 | | 74.21 ± 2.28 | | 23.79 ± 0.84 |

**Table 3.** Changes in Athletic Performance (Maximum Oxygen Consumption, Anaerobic Power) in Groups

| Variables | $VO_2$ Max (mL/min/kg) | | Change (%) | Peak Power (W) | | Change (%) |
|---|---|---|---|---|---|---|
| | Pretest | Posttest | | Pretest | Posttest | |
| **Recovered** | 30.14 ± 1.57 | 34.71 ± 1.49 | 15.16 | 480.14 ± 34.81 | 501.71 ± 29.53 | 4.49 |
| **Uninfected** | 33.71 ± 2.05 | 37.00 ± 2.23 | 9.75 | 592.71 ± 18.94 | 618.42 ± 23.81 | 4.33 |

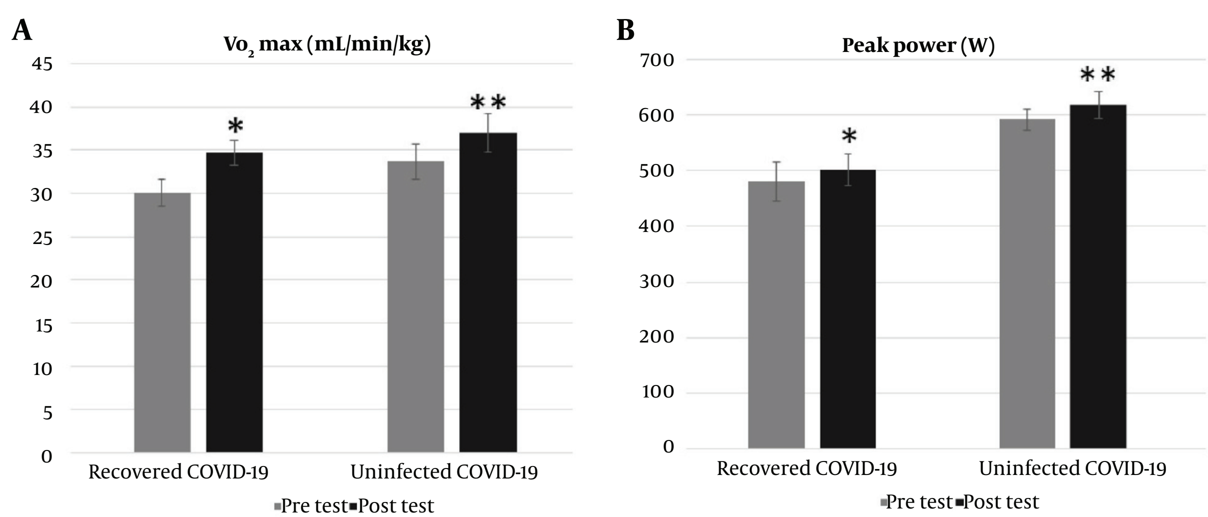


**Figure 1.** Results of paired *t*-tests comparing maximum oxygen consumption ($VO_2$ max) and anaerobic power between pre-test and post-test for COVID-19 recovered and uninfected groups. *: Significant difference between pre-test and post-test for the recovered COVID-19 group; **: Significant difference between pre-test and post-test for the uninfected COVID-19 group).

group.

## 5. Discussion

The COVID-19 pandemic has had a significant impact on athletes and their performance capabilities. The first aim is to quantify the degree of $VO_2$ max and peak power improvements with a structured aerobic training program in competitive athletes during the post-COVID-19 pandemic period. This will allow us to identify any persistent influences of the disease itself on post-intervention athletic capabilities. The purpose of this study was to evaluate the effects of a 4-week structured aerobic exercise program on measures of $VO_2$ max and

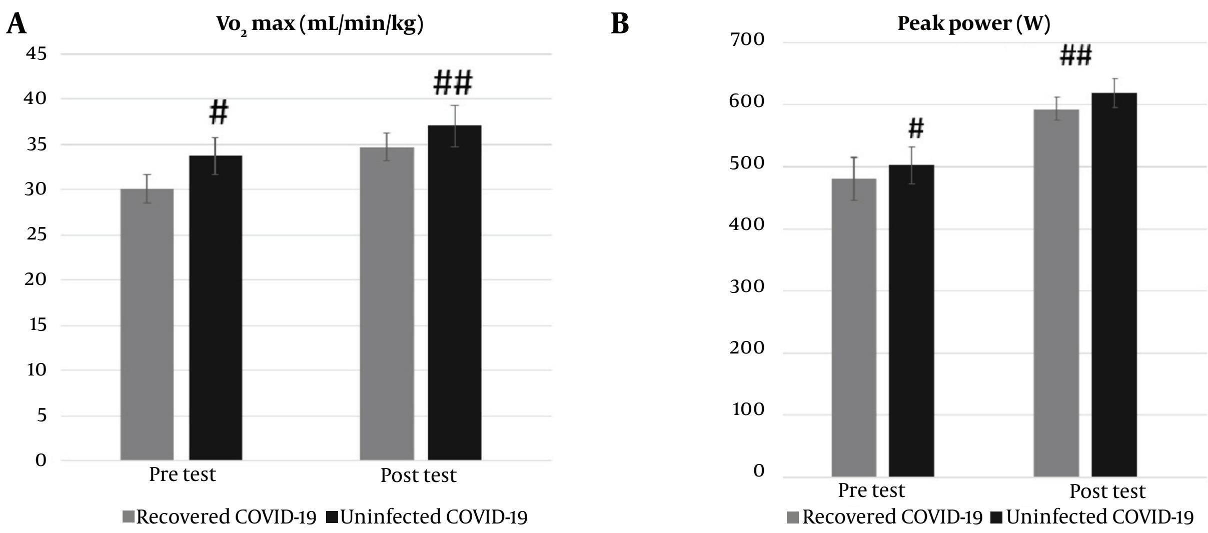


**Figure 2.** Results of independent *t*-tests comparing maximum oxygen consumption ($VO_2$ max) and anaerobic power between pre-test and post-test for COVID-19 recovered and uninfected groups. #: Significant difference between groups in pre-test; ##: Significant difference between groups in post-test).

peak power in both recovered COVID-19 and uninfected competitive athletes during the post-COVID-19 return to sport period. We hypothesized that a moderate-intensity aerobic training regimen would lead to significant improvements in athletic performance in this population. The results demonstrated significant improvements from baseline to post-intervention in both $VO_2$ max and peak anaerobic power in the recovered COVID-19 athlete group and uninfected control group following completion of the 12 sessions of aerobic training program. Specifically, the 4.57 mL/kg/min enhancement of $VO_2$ max among recovered COVID-19 athletes reflects over a 15% gain in maximal aerobic capacity. Peak power output showed similar relative improvements around 4.5% in this group. The improvements in aerobic capacity ($VO_2$ max) and anaerobic peak power align with previous studies on endurance exercise. The positive impacts on cardiovascular and muscular fitness have been well-documented. The exact mechanisms for the crossover anaerobic performance benefits are still debated. However, hypotheses propose that aerobic conditioning may enhance oxygen kinetics, intramuscular buffering, and recruitment of fast-twitch fibers during high-intensity efforts (17, 18). Research also shows sprint interval and other high intensity interval training can more directly target anaerobic energy pathways and adaptations leading to power development (19). Moreover, some studies like Keren and Epstein found limited transfer effects of aerobic-focused regimens on maximal or explosive strength gains compared to dedicated resistance training, implying specificity of training responses (20). The physiological mechanisms underlying performance and adaptations in purely aerobic versus largely anaerobic efforts may be distinct enough that each requires tailored conditioning even if some crossover effects occur (21-25). As anaerobic activities rely heavily on immediate yet rapidly depleting ATP-PCR and glycolytic energy sources, they induce particular muscular adaptations like increased myofibrillar size and anaerobic enzyme activity that lower intensity aerobic work may not substantially stimulate. Ultimately, while moderate or vigorous endurance training appeared to yield sizeable improvements in both aerobic and anaerobic indicators here, further research is warranted regarding optimizing training mode, volume, and intensity combinations to maximize crossover physiological effects. More investigation into the specifics of mitochondrial, cardiopulmonary, neurological, metabolic, and morphological adaptations elicited by programs blending aerobic and anaerobic stimuli could provide additional insights (26). The pre-intervention comparisons showing significantly lower baseline $VO_2$ max and peak power in the recovered COVID-19 group compared to the uninfected controls implies lasting detrimental impacts of the viral infection itself on cardiovascular capacity and muscular function. The over 10% disparities in aerobic capacity and 8 - 13% gaps in anaerobic power outputs align with evidence of organ damage and persistent physical limitations among athletes resuming training after symptomatic COVID recovery (9). These baseline deficiencies likely reflect a combination of residual respiratory constraints, heart or muscle tissue inflammation, neurological disruptions, and simply greater detraining losses associated with isolation and illness downtime in this group (27). By comparing the post-test results, a significant difference was observed between the 2 groups, which can be attributed to the initial disparity observed in the pre-test measurements. This discrepancy may be attributed to the complications of COVID-19, as the group that had recovered from COVID-19 experienced a decrease in their initial sports performance despite having similar demographic characteristics and sports backgrounds to the unaffected group. Therefore, it seems that the COVID-19 disease has had a direct effect on the decrease in anaerobic capacity. Indeed, Korkmaz et al. demonstrated compromised strength, power, and flexibility among football players following COVID-19 quarantine detraining (27). Additionally, Parpa and Michaelides findings of markedly reduced aerobic capacity in infected football players reinforces conclusions that the virus itself hampers components of athletic fitness (28). Beyond just quarantine deconditioning effects, symptoms of so-called "long COVID" including fatigue, chest pain, labored breathing, brain fog, and headache can also persist for months and delay complete return to sports among previously infected athletes (29). The post-intervention testing results here showing ongoing $VO_2$ max and power disadvantages in the recovered COVID cohort despite completion of the 4 weeks reconditioning regimen likely reflects this longer-term athletic impairment associated with the illness itself. The study provided important initial evidence that COVID-19 infection may have lingering impacts on athletic performance, as recovered athletes continued to demonstrate disadvantages in $VO_2$ max and power output compared to uninfected controls after a 4-week reconditioning program. However, the current research was facing some limitations. One limitation was the small sample size of only 14 participants reduces the statistical power and generalizability of the findings. Additionally, because testing occurred during the post-COVID-19 recovery period, it is unclear if these performance gaps would persist outside of this unique context. Longitudinal data tracking athletes over a longer follow-up period after COVID-19 pandemic could delineate any lasting impacts on athletic performance. Expanded sample sizes would also allow for more robust statistical analyses to confirm the significance of these preliminary results. Moving forward, further investigation optimizing multi-faceted rehab strategies to mitigate viral effects and fully restore athletic performance is warranted. Tailored return-to-play programming may be needed to bridge fitness gaps among athletes recovering from COVID-19.

Positive impact of aerobic training on sports performance was observed in both groups. However, it is important to note that individuals who have contracted COVID-19 may experience lingering complications that negatively affect their athletic abilities, even after recovery. Therefore, we recommend implementing longer rehabilitation and training programs specifically designed for individuals who have been infected with and recovered from COVID-19. These extended programs aim to help these individuals regain their pre-COVID-19 sports performance levels.

### 5.1. Conclusions

The findings of this study suggest that a 4-week aerobic exercise intervention can enhance athletic performance in athletes without a history of COVID-19 infection. However, the recovered COVID-19 athlete cohort demonstrated smaller gains in comparison to their uninfected counterparts over the 4 weeks training period. While aerobic training conferred fitness and sports performance benefits to all participants, those recovering from COVID-19 illness experienced a lagged progression pace and delayed return to pre-infection activity levels. To better support the full reinstatement of athletic prowess in rehabilitating COVID-19 patients, supplementary strategies could be combined with aerobic conditioning. Additional modalities may include nutritional optimization, sport psychology approaches, and the integration of resistance or high-intensity interval training once clearance for more rigorous exercise is established. Further inquiry is warranted to ascertain optimal rehabilitation protocols for restoring competitive athletic status in post-COVID-19 populations.

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## Footnotes

**Authors' Contribution:** Study concept and design: A. R., and E. Sh.; analysis and interpretation of data: E. Sh., drafting of the manuscript: E. Sh., M. E., and E. Gh.; critical revision of the manuscript for important intellectual content: A. R., I. D., and T. L.; statistical analysis: A. R.

**Conflict of Interests:** The authors report no conflict of interest.

**Data Availability:** The data that support the findings of this study are openly available upon request from the corresponding author.

**Ethical Approval:** The current study was reviewed and approved by the Review Board in Qazvin University of Medical Sciences (ethical code: IR.QUMS.REC.1401.171).

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**Informed Consent:** Informed written consent was obtained from all participants.

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