Research article

# Effect of COVID-19 infection on the performance of elite adolescent overhead athletes

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## Abstract

**Background:** COVID-19 might have a negative impact on sports performance. There are few studies in the literature that assess how the sports performance of adolescent athletes is affected by COVID-19.

**Objective:** This study aimed to compare the sports performance of adolescent overhead athletes who had COVID-19 infection with those who had not.

**Methods:** The study involved adolescent elite overhead athletes from basketball, volleyball, handball, and tennis. Athletes' performance were assessed using core muscle endurance, hand grip strength, upper extremity functional performance, reaction time and agility performance, and the 3-min step test.

**Results:** Study included 47 adolescent overhead athletes (mean age $15.15 \pm 1.51$ years). The COVID-19 group showed significantly higher Borg Scale scores and decrease in oxygen saturation levels only after the step test ($p = 0.02$, $p = 0.02$, respectively). Additionally, COVID-19 group had lower grip strength in both right and left hands compared to the non-COVID group ($p = 0.01$, $p = 0.05$, respectively). No significant association was found between core muscle power and endurance, upper extremity functional performance, reaction time and agility performance ($p > 0.05$).

**Conclusions:** Our results showed reduced hand grip strength and increased fatigue following COVID-19 infection in adolescent overhead athletes. Time period after COVID-19 infection had a negative correlation with sports performance and core endurance.

## Keywords

pandemic, sports, physical endurance, elite, core, reaction time

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## Introduction

COVID-19 is a highly contagious disease that can be fatal. A recent study reported a mortality rate of 0.17% among individuals under 20 years of age.[1] Symptoms can range from mild flu-like symptoms to pneumonia with acute respiratory insufficiency or severe acute respiratory distress syndrome.[2] The most common symptoms of COVID-19 are fever (88.5%), cough (68.6%), myalgia-fatigue (35.8%), and shortness of breath (21.9%).[3] Symptoms may persist after the disease, known as post-COVID symptoms.[4,5]

COVID-19 can also damage the body systems other than the pulmonary system, particularly the cardiovascular and musculoskeletal systems leading to severe myopathies and arrhythmias.[6] Pulmonary lesions resulting from COVID-19 infection may cause persistent symptoms for months after the disease process.[7] Patients referred to intensive care units may experience musculoskeletal problems due to systemic inflammation, mechanical ventilation, sedation, and long-term bed rest.[8]

Numerous studies have been conducted on the possible consequences of COVID-19 infection. However, there is

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still a lack of information on its effect on athletes. Studies focused on the effects of COVID-19 infection on different populations may provide valuable information for health professionals. The main mechanisms that may result in decreased performance in athletes could be both derangements in the cardiorespiratory and musculoskeletal systems, which directly effect on sports performance, and also physical inactivity in the course of COVID-19 infection.[8] Although one may expect that COVID-19 will reduce the sports performance, there are limited studies in the literature to support this claim. The objective of this study was to compare the sports performance of adolescent athletes who had COVID-19 infection with those who had not.

## Methods

### Subjects

This study included 47 adolescent overhead athletes from basketball, volleyball, handball, and tennis who consented to participate. Athletes were between the ages of 12 and 20 and had been undergoing sports-specific training at least twice a week for a minimum of one year. Athletes who had vertebral, upper, or lower extremity injuries within the last six weeks and had undergone surgery and also had pulmonary and cardiovascular disease that can affect sports performance were excluded from the study.

### Study design

This is a descriptive cross-sectional study approved by the Human Studies Ethical Committee of Atılım University and conducted at the Healthy Life and Sports Center in Kirşehir, Turkey. The Clinical Trial Registration Number is CNCT05298839.

### Demographic information

We recorded the demographic information of all athletes, including gender, age, height, and weight. Additionally, sports-related information such as sports type, sports history, injury history, and the frequency of training were noted. In the COVID group, date of diagnosis, treatment procedure (home isolation, hospital, intensive care unit), and persistent symptoms were recorded, together with the time interval between the date of diagnosis and the date on which the performance tests were conducted.

### Performance assessment

*Core muscle endurance.* Four tests were used to evaluate core stabilization. The *Sorensen test* was used to evaluate extensor muscle endurance. In the Sorensen test, athletes laid supine, pelvis fixed and body hanging out of the bed, and they were asked to maintain this position as long as possible.[9] *Endurance of the core flexor muscles* were measured knees fixed at 90° and athletes were asked to flex the body up to 60° from the bed and maintain this position as long as possible. To assess *overall core muscle power*, athletes laid prone and asked to raise their body on their forearms and toes (plank), and maintain this position as long as possible.[10] To test the *lateral core muscle endurance*, athletes were instructed to assume left and right decubitus positions and raise their body using their ipsilateral forearm and foot (side plank). They were again asked to maintain this position as long as possible. All tests were terminated when the position was lost, and the time was verified with a chronometer.[9]

*Hand grip strength.* Hand grip strength was assessed using a Jamar hand dynamometer. The measurement was taken three times for both the right and left sides while the subject was seated on a chair with their shoulder adducted, and elbow flexed at 90 degrees. A 20-s rest was given between each measurement. The mean value of the three results was calculated and recorded in kPa.[11]

*Upper extremity functional performance.* The Health Ball Throwing Test was used to assess the explosive power of the upper extremity. Athletes hold a 3 kg health-ball with both hands and asked to throw as far as possible in a horizontal direction. The distance between the starting point and the first contact point of the ball on the floor was measured in centimeters.[12] The test was repeated three times and the mean value was recorded.

*Reaction time and agility performance.* Reaction time was measured with the 'Fitlight TrainerTM' (Fitlight Trainer Corporation, Thensvej, Risskov, Denmark). Athletes were instructed to turn off the randomly illuminated LED lights on the wall by pressing on the lights. The number of lights turned off and their corresponding reaction times were recorded in seconds.[13]

Agility performance was assessed using the Pro-agility test. Markers were positioned on the either sides 5 yards (4.57 m) away from the starting point, and a photocell gate placed at the starting point to record the athletes' passing times. Athletes were instructed to first touch the right marker, then the left marker, and return to the starting point, and their mean speed was recorded.[14]

### Minutes step test

The test equipment included a step board with a height of 30 cm, an oxygen saturation probe, a pulse-oximeter, a metronome, and a chronometer. Prior to the test, athletes were informed about the procedure and given time to adapt to the rhythm of the metronome. They were asked to use their preferred foot.

**Table 1.** Demographic characteristics.

| | Non-COVID group n = 27 | | COVID group n = 20 | | |
|---|---|---|---|---|---|
| | N | % | n | % | P |
| ***Gender*** | | | | | |
| Female | 16 | 59.3 | 15 | 75 | 0.26 |
| Male | 11 | 40.7 | 5 | 25 | |
| ***Dominant Side*** | | | | | |
| Right | 22 | 88.0 | 15 | 78,9% | 0.41 |
| Left | 3 | 12.0 | 4 | 21.1 | |
| | Mean | Min - Max | Mean | Min - Max | |
| Age | 15.1 ± 1.51 | 12–19 | 15.2 ± 1.1 | 12–17 | 0.64 |
| Height (cm) | 169.5 ± 10.4 | 146–198 | 168.6 ± 10.4 | 155–190 | 0.53 |
| Weight (kg) | 64.7 ± 13.4 | 50–103 | 59.8 ± 17,5 | 40–105 | 0.10 |
| BMI (kg/m$^2$) | 22.4 ± 3.4 | 17.7–33.9 | 20.7 ± 4.3 | 14.6–30.5 | 0.10 |

*BMI: Body Mass Index.*

**Table 2.** Types of sports and duration.

| | Non-COVID group n = 27 | | COVID group n = 20 | | |
|---|---|---|---|---|---|
| | Mean ± SD | Min – Max | Mean ± SD | Min – Max | p |
| Sports year | 5.3 ± 2.2 | 2–12 | 4.6 ± 2.1 | 1–10 | 0.35 |
| Frequency of exercise (day) | 12.8 ± 32 | 2–150 | 3.3 ± 1.5 | 2–7 | 0.07 |
| Duration of exercise (min) | 118.8 ± 66.2 | 60–390 | 111 ± 39 | 60–240 | 0.35 |
| Sports | n | % | n | % | p |
| Basketball | 10 | 37.0 | 4 | 20.0 | 0.30 |
| Volleyball | 9 | 33.3 | 12 | 60.0 | |
| Handball | 7 | 25.9 | 3 | 15.0 | |
| Tennis | 1 | 3.7 | 1 | 5.0 | |

Athletes performed the test by stepping on and off the board in pace with the metronome for 3 min. At the end of the test, oxygen saturation, pulse rates, and the Modified Borg Scale score, which is used to identify fatigue, were recorded.[15]

### Data analysis

Data analysis was conducted using SPSS for Windows version 22.0. The distribution of variables was evaluated using both visual (histogram) and analytical (Shapiro-Wilk test) methods. Mean ± standard deviation values are reported. If the data did not exhibit normal distribution, the correlation between variables was evaluated using the Mann Whitney U analysis. A significance level of 0.05 was used in this model. Correlations between the time elapsed after COVID-19 infection and physical performance tests were assessed by Pearson Correlation analysis. A coefficient of > 0.9 reflected a very high correlation, 0.7–0.9 a high correlation, 0.5–0.7 a moderate correlation, 0.3–0.5 low correlation and 0.3-.00 negligible correlation.[16]

### Sample size calculation

With reference to Dhokane et al.[17] results of aerobic capacity and using G*Power Software (Version 3.1.9.2, Düsseldorf University, Düsseldorf, Germany), the minimum required sample size was calculated as 47 for the anticipated effect size of 1.11 with the probability level of 0.05 and statistical power level of 95% [t test].

## Results

The study involved 47 young athletes, 27 of whom had not been infected with COVID-19 (defined as the non-COVID group) and 20 of whom had been infected (defined as the COVID group). The two groups did not differ in terms of demographic data or sports activity level ($p > 0.05$) (see Table 1 and Table 2).

The mean period after COVID-19 infection was 197 ± 102 days for the COVID group. All athletes with COVID-19 infection received home care, and none required

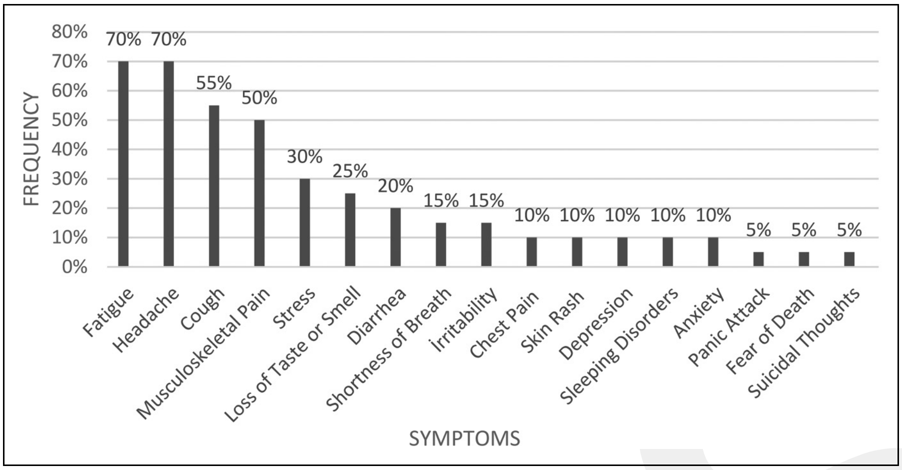


**Figure 1.** Frequency of COVID-19 symptoms.

hospitalization. Table 1 shows the frequency of symptoms in the COVID group, with fatigue (70%), headache (70%), cough (55%), and musculoskeletal pain (50%) being the most common symptoms (Figure 1).

In the COVID-19 group, the period after COVID-19 infection showed a moderate negative correlation with plank and health ball ($r = -0.49$, $p = 0.02$; $r = -0.51$, $p = 0.02$) (Table 3). Athletes in the COVID-19 group showed significantly higher Borg Scale, $O_2$ saturation change, and lower oxygen saturation levels after 3-min step test ($p = 0.02$, $p = 0.02$, $p = 0.02$, respectively). There was no difference in pulse and pulse change between the groups (Table 4).

There was no significant difference between the groups in terms of core muscle power and endurance ($p > 0.05$). However, athletes in the COVID-19 group exhibited lower grip strength in both their right and left hands compared to the non-COVID group ($p = 0.01$ and $p = 0.05$, respectively) (Table 4). Additionally, there was no significant difference between the groups in terms of health ball, strike number, reaction time, speed, and agility ($p = 0.18$, $p = 0.59$, $p = 0.67$, $p = 0.43$, $p = 0.33$, respectively) (Table 4).

**Table 3.** Correlation between time period after COVID and physical performance parameters.

| | r | p |
|---|---|---|
| ***Core muscle endurance and strength*** | | |
| Sorenson test (sec.) | −.31 | 0.17 |
| Flexion endurance | −.08 | 0.74 |
| Plank | −.49*** | 0.02* |
| Side plank Right | −.30 | 0.19 |
| Side plank Left | −.40*** | 0.07 |
| ***Hand grip strength*** | | |
| Right grip mean | −.33 | 0.14 |
| Left grip mean | −.36 | 0.11 |
| ***Reaction time and agility upper extremity functional assessment*** | | |
| Number of strikes | .17 | 0.44 |
| Reaction time (sec.) | .00 | 0.9 |
| Health ball (cm) | −.51** | 0.02* |
| Speed | .34 | 0.15 |
| Agility | .54** | 0.01* |
| ***Cardiovascular/Pulmonary findings*** | | |
| $SpO_2$initial | −.00 | 0.90 |
| $SpO_2$last | .23 | 0.32 |
| Pulse initial | .08 | 0.72 |
| Pulse last | −.24 | 0.30 |
| Borg Scale Score | −.07 | 0.75 |

Pearson Correlation analysis.
$p < 0.05$ *: Statistically significant, **: moderate correlation, ***: low correlation $SpO_2$: Oxygen saturation.

## Discussion

Our study comparing the performance of young athletes with and without COVID-19 infection, showed that lower hand grip strength, higher fatigue level after endurance test and lower oxygen saturation in the COVID-19 group.

The cardiovascular performance was assessed using a 3-min step test. Although the first and last oxygen saturation levels were within normal limits for both groups, athletes in the COVID-19 group showed relatively lower levels after the 3-min test with a higher change in oxygen saturation. The Borg Scale Scores indicated that the COVID-19 group experienced higher levels of fatigue during the test period. This could be due to abnormalities in pulmonary function, such as a disturbance in lung diffusion capacity and decreased lung volumes, as well as general fatigue and muscle weakness caused by COVID-19 infection.[17,18] Cardiovascular system is one of the most significant indicators of performance in athletes. Lower oxygen saturation levels after the test may indicate that COVID-19 infection can cause relative hypoxia in young athletes with no previous lung disease. CT scans of asymptomatic passengers on the Diamond Princess cruise ship at the beginning of the pandemic showed lung opacities in 54% of cases,[19] and

**Table 4.** Comparison of groups.

| | Non-COVID group n = 27 | | COVID group n = 20 | | |
|---|---|---|---|---|---|
| | Mean ± SD | Min – Max | Mean ± SD | Min – Max | p |
| ***Cardiovascular/Pulmonary findings*** | | | | | |
| Borg Scale Score | 11.7 ± 2.6 | 7–15 | 14.1 ± 2.8 | 7–19 | 0.02* |
| $SpO_2$ initial | 97.1 ± 0.9 | 95–99 | 97.6 ± 0.9 | 96 - 99 | 0.07 |
| $SpO_2$ last | 96.2 ± 1.5 | 93–99 | 95.4 ± 2,0 | 90–99 | 0.02* |
| $O_2$ change | −0.8 ± 1.7 | −5–3 | 2.4 ± −9.0 | (−2.5) - 2 | 0.02* |
| Pulse initial | 103.3 ± 16.3 | 70–132 | 84 ± 15.5 | 110–146 | 0.33 |
| Pulse last | 160.6 ± 29.9 | 86–205 | 162–25.4 | 118–199 | 0.83 |
| Pulse change | −.85 ± 1.7 | −5–3 | 2.4 ± -9 | 2–(−2.5) | 0.45 |
| ***Core muscle endurance and strength*** | | | | | |
| Sorenson Test | 91.4 ± 47.9 | 23.6–245.4 | 71.6 ± 42.7 | 20–167 | 0.18 |
| Flexion Endurance | 121.6 ± 68.7 | 33.5–308 | 109.8 ± 56.3 | 23–180 | 0.70 |
| Plank | 68.6 ± 93.4 | 13–520 | 52.3 ± 42.5 | 10–180 | 0.43 |
| Side plank Right | 26.6 ± 13.7 | 5–64 | 28.1 ± 19 | 7–72.9 | 0.67 |
| Side plank Left | 28.0 ± 14.5 | 6–68 | 27.6 ± 16.6 | 10–61.7 | 0.81 |
| ***Hand grip strength*** | | | | | |
| Right grip mean | 30.52 ± 8.06 | 15.7–52.6 | 27.8 ± 9.0 | 17.2–49.3 | 0.01* |
| Left grip mean | 29.14 ± 8.79 | 17.5–53.8 | 27.1 ± 9.6 | 16.1–51.7 | 0.05* |
| **Agility and reaction time** | | | | | |
| Health ball mean | 359.6 ± 106 | 236–516 | 348.4 ± 93.1 | 255–570 | 0.18 |
| Number of strike | 37.1 ± 5.0 | 20–47 | 36.6 ± 3.4 | 30–42 | 0.59 |
| Time | 0.6 ± 0.1 | 0.5–1.1 | 0.6 ± 0.09 | 0.5–0.8 | 0.67 |
| Speed | 3.6 ± 0.3 | 2.8–4.2 | 3.6 ± 0.41 | 2.6–4.5 | 0.43 |
| Agility | 5.8 ± 0.5 | 4.9–6.9 | 6.0 ± 0.6 | 4.9–7.4 | 0.33 |

P values for differences in means between groups calculated using Mann-Whitney U test based.
*: Statistically significant $SpO_2$: Oxygen Saturation.

similar X-ray findings were observed in quarantined asymptomatic or minimally symptomatic patients in the city of Codogno, Italy.[20] The virus can affect the lungs in three ways: acute respiratory distress syndrome (ARDS) with diffuse alveolar damage, diffuse thrombotic alveolar microvascular occlusion, and inflammatory mediator-related airway inflammation.[9,10] These effects can disrupt alveolar oxygenation and lead to hypoxia. Although athletes in the COVID-19 group did not exhibit marked hypoxia, their oxygen saturation levels were significantly lower than those of healthy individuals, indicating a disturbance in oxygenation, which may reduce the athlete's sports performance.

Our study also showed that fatigue is one of the most common symptoms of COVID-19 infection. Fatigue levels were higher in the 3-min step of the COVID-19 group. A study examining the recovery of performance and the persistent symptoms in athletes after COVID-19 infection also found that the most common symptom were fatigue and decreased performance which have improved within 3 months.[21] A systematic review published in 2022 which analyzed acute and post-acute presentations of COVID-19 in athletes revealed that fatigue was a common complaint which could persist permanently.[22] The cause of fatigue in COVID-19 infection has not yet fully understood.[23] Some suggest that it may be caused by direct infection of the skeletal muscle cells, which carry high number of ACE2 receptors that the virus can attach to, or by indirect systemic cytokine release and disruption of homeostasis. Other potential sources of fatigue might be changes in neurotransmitter levels, systemic inflammation caused by the virus, and increased stress levels.[24]

The Sorensen test, flexion endurance test, and plank and side plank tests were performed to evaluate core muscle endurance. The results showed no significant difference between the groups. This lack of difference may be attributed to young age of the participants, and low morbidity of the disease where all athletes were treated at home for COVID-19 infection with no need for hospitalization. Additionally, these athletes had a history of regular exercise and could returned to sports early after COVID-19 infection. The correlation between the time period after COVID-19 infection and the plank time may be explained by relative muscle weakness, which may extend to the post-infection period.[23] To our knowledge, no study has evaluated core muscle endurance after COVID-19 infection, against which we can compare our results.

We found that hand grip strength is lower in athletes who had COVID-19 infection. Hand grip strength is commonly associated with the muscle strength of other muscle groups and is widely accepted as an indicator of general muscle power.[25] Furthermore, lower hand grip strength during adolescence is a well-known indicator of poor health quality and is associated with disease and all-cause mortality during adulthood.[26,27] The risk factors and underlying mechanisms of muscle loss caused by COVID-19 infection have not yet been fully described. A study evaluating the effects of COVID-19 infection on the musculoskeletal system using magnetic resonance imaging has revealed signs of muscle edema and atrophy.[28] Muscle atrophy caused by COVID-19 infection may result from numerous interrelated factors, including degeneration of the muscular structure triggered by a cytokine storm. Additionally, virus-induced myotoxicity has been reported in rare cases.[18] Furthermore, the COVID-19 pandemic has led to reduced physical activity, which may also lead to a decrease in hand grip strength. Previous studies have shown a negative correlation between muscle strength and risk factors for cardiovascular disease in young individuals.[29] Most of the studies on COVID-19 in athletes have examined lower extremity muscle strength.[30,31] Our study presents negative effects of COVID-19 infection on hand grip strength, which should be considered in athletes engaged in sports where grip strength is important. Hand grip strength is also an important factor for performance in overhead sports. Therefore, these results highlight the importance of specific exercise program that would increase hand grip strength in athletes who have recovered from COVID-19.

Many symptoms of COVID-19 such as fatigue, muscle weakness, joint pain, dyspnea and cognitive disturbances are known to persist after the infection.[32] Agility, which may be affected by these above mentioned symptoms and many other additional physical and cognitive factors may change the correlation between the agility performance and the COVID-19 infection. However, we have not found any difference between the agility parameters of the study groups, but a positive correlation was observed between the time period after COVID-19 infection and agility parameters.

To our knowledge this study is the first to evaluate the performance of adolescent overhead athletes after COVID-19 infection. It is important to note that a wide range of factors may impact sports performance, and COVID-19 can affect multiple systems in the human body. The study assessed the effects of COVID-19 infection on sports performance by measuring core muscle endurance, hand grip strength, upper extremity functional performance, reaction time, agility, and cardiopulmonary performance. Future studies that include different performance parameters for various sports are required to describe the definitive effects of COVID-19 on sports performance.

## Limitations

Our study has some limitations. The first limitation is that the study included athletes from different sport groups in the overhead sports group. Study groups should be selected from the same sports type for more homogenous results. Secondly, athletes included in the study had a large range for age (12 to 20 years), which could be a factor that may affect our results. Borg Scale test, used to describe fatigue level in the athletes, could be supported by an objective test such as blood lactate levels after training.

## Conclusion

Growing data from clinical studies reveal potential consequences of COVID-19 infection beyond its acute effects. Our study found that athletes experienced decrease in hand grip strength and increase in fatigue after COVID-19 infection. Our study found a negative correlation between the time-period after COVID-19 infection and certain parameters of sports performance in adolescent athletes. This finding may serve as a reference for assessing sports performance after COVID-19 infection and establishing training programs for the affected type of performance. Research on various populations, including athletes from different sports, who have recovered from COVID-19, could aid in the development of rehabilitation and exercise programs for post-disease recovery.

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### Statements and declarations

#### *Ethical considerations*

Ethical approval for this study was obtained from Human Studies Ethical Committee of Atılım University (E-59394181–604.01.02–13774).

#### *Informed consent*

Informed consent was obtained from all participants.

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