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COVID-19's impact on physical activity and metabolic syndrome in firefighters: A randomized trial of pre- and post-recovery analysis.

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ABSTRACT

Objective: Despite the physical demands of their job, firefighters often experience declining health, a trend that has worsened with coronavirus infection. We investigated the correlation between physical activity (PA) and metabolic syndrome (MS) risk factors in male firefighters following COVID-19 recovery.

Subject and Methods: Pre- and post-COVID-19 MS risk factors were analyzed in 31 male firefighters. Pearson correlation was used to determine the relationship between PA and MS risk factors following recovery.

Results: Post-recovery PA showed a moderate negative correlation with low-density lipoprotein – LDL ($r = -0.39, p = 0.04$). Statistically significant reductions were observed in weight, BMI, cholesterol, and waist-hip ratio (all $p < 0.05$). In contrast, glucose, triglycerides, and LDL showed statistically non-significant increases.

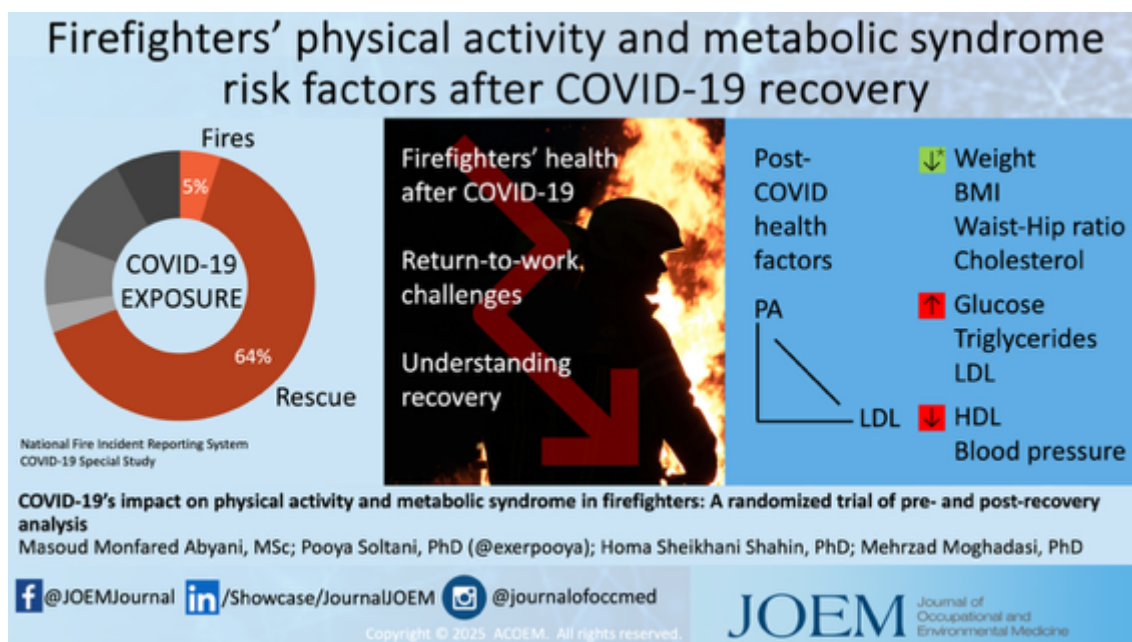
Conclusions: Clinicians should monitor cardiovascular risks in firefighters, as subtle changes post-recovery may indicate increased heart disease risk.

Keywords: Male, Exercise, Occupational health, Coronavirus, Pharmaceutical Preparations

LEARNING OUTCOMES

- Lower physical activity was linked to higher LDL cholesterol in firefighters after COVID-19.
- Firefighters showed significant reductions in weight, BMI, cholesterol, and waist-hip ratio after COVID-19.
- Blood sugar, triglycerides, and LDL cholesterol increased one month after recovery.

VISUAL ABSTRACT



1. INTRODUCTION

The COVID-19 pandemic was a global catastrophe, devastating many families and fundamentally altering life as we know it. The SARS-CoV-2 virus primarily enters the body through the lungs, causing severe respiratory symptoms and acute respiratory distress syndrome (1, 2). Additionally, the pandemic imposed sudden changes in lifestyle and social isolation, resulting in significant cardiometabolic sequelae.

Firefighting is among physically demanding jobs within emergency services. Structural firefighters provide crucial public safety services, including firefighting and emergency medical care, despite the challenges posed by COVID-19. It is widely recognized that firefighters must maintain strong physical fitness, encompassing aerobic capacity, flexibility, muscular endurance, strength, and power (3). Due to their work environment, long shifts, and close contact with the public, firefighters are at heightened risk of infection. The National Fire Incident Reporting System's COVID-19 Special Study found that 63.5% of possible COVID-19 exposures occurred during rescue and EMS incidents, with 4.9% occurring during fires (4).

In addition to occupational risks, firefighters face an increased risk of obesity-related conditions, as the physical demands of their job can put them under additional stress trigger cardiac events (1, 5). Several studies have reported an alarmingly high prevalence of overweight and obesity (body mass index – BMI \geq 25) among career fighters, with rates ranging from 73% to 88% (6-11). In Iran, nearly half of firefighters are classified as overweight, with about 25% categorized as obese (12-14).

Although COVID-19 was first described as a respiratory disease, being overweight and obese has been emerged as the leading factor contributing to infection and exacerbation of the SARS-CoV-2 compared to healthy individuals (15). It is also increasingly clear that the presence of cardiovascular disease (CVD) or CVD risk factors significantly increases the likelihood of severe COVID-19 complications (16, 17). These risk factors include both non-modifiable factors (such as gender, age, and family medical history) and modifiable factors (such as total cholesterol, triglycerides, blood pressure, diabetes, and obesity) (18-20). Furthermore, reduced cardiorespiratory fitness and metabolic syndrome (MS) risk factors can persist following COVID-19 infection (21-25).

Despite the demanding physical fitness required, firefighters often experience declining health, including increased body fat and elevated blood lipid levels like cholesterol and low-density lipoprotein (LDL) cholesterol (18, 20, 26). The high prevalence of obesity, combined with the short- and long-term effects of COVID-19, could significantly challenge their ability to perform their duties safely (18, 20, 27). Studies on physical activity (PA) and MS risk factors in firefighters are limited, as these criteria are not routinely included in occupational readiness programs. Most research compares post-COVID-19 recovery outcomes to unrelated control groups or population norms. A better understanding of changes in PA and MS risk factors following COVID-19 recovery is particularly relevant given the specific demands of firefighting.

In this study, we monitored the MS risk factors of firefighters within three months before contracting COVID-19 and reassessed these parameters after they recovered, following a period of rest and medication. This study aims to 1) explore the correlation between PA levels and MS risk factors following COVID-19 infection, and 2) assess changes in MS risk factors before and after COVID-19 recovery. Understanding these changes is crucial for assessing the immediate impact of COVID-19 on cardiovascular health and for developing strategies to protect firefighters' long-term health, ensuring they can safely perform their duties.

2. METHODS

2.1. Design

This study was conducted in accordance with the Declaration of Helsinki and received prior approval from the Research Institute of Movement Science at Kharazmi University (Process Number: IR-KHU.KRC.1000.174). All participants provided informed consent after being fully informed of the potential benefits and risks of the investigation.

We designed a within-participant, longitudinal cohort study to assess the correlations between PA levels and MS risk factors after COVID-19 recovery. Additionally, we compared the changes in MS risk factors before and after recovery. Pre-COVID-19 data were obtained from 2021 occupational medical evaluations, taken within three months before infection. Post-infection data were collected one month after a two-week recovery period in a cohort of firefighters. Figure 1 illustrates the diagram of study design.

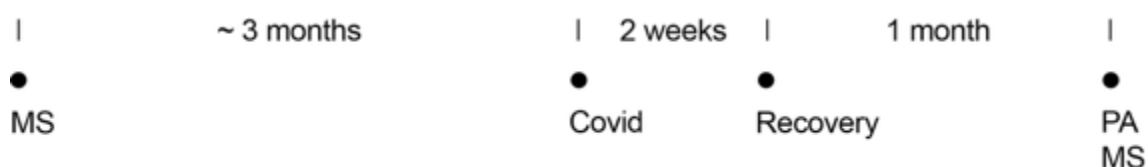


Figure 1. Diagram of the study design.

2.2. Participants

A total of 705 firefighters from 24 fire departments reported experiencing COVID-19 between 2021 and 2022 at the occupational health clinic. Due to the absence of female firefighters, and the resulting inability to examine gender effects, only male firefighters were included. Records were excluded if MS data were not available for both before and after COVID-19 recovery. The final sample consisted of 31 firefighters from 15 Shiraz fire departments in Iran, randomly selected using a one-stage, randomized cluster-sampling approach. These firefighters undergo regular occupational medical evaluations at a single healthcare clinic that measures MS risk factors. The first author enrolled participants and assigned them to interventions.

Inclusion criteria were as follows: 1) Firefighters of the fire departments; 2) History of COVID-19 infection with at least one month since recovery; 3) Non-smokers; 4) Similar medication use during COVID-19 infection; and 5) At risk for MS. According to the International

Diabetes Federation – IDF (28), MS is diagnosed if a person meets at least three of the following five criteria: 1) Serum triglycerides ≥ 150 mg/dL; 2) Systolic blood pressure ≥ 130 mmHg; 3) Diastolic blood pressure ≥ 85 mmHg; 4) Fasting blood glucose ≥ 100 mg/dL; and 5) High-density lipoprotein (HDL) cholesterol < 40 mg/dL. Hypertension was also defined as systolic blood pressure ≥ 130 mmHg and diastolic blood pressure ≥ 85 mmHg (29).

2.3. Processes

The medical evaluation was performed by a single occupational health clinic. The following measures were recorded by a single experienced cardiologist before and after COVID-19 recovery.

2.4. Measures

Personal characteristics and medication use: We collected information on participants' work history, activity level, family history of chronic diseases, history of COVID-19 infection, and their daily medication use. The medications included Montelukast (tablet form, once every 8 hours), Dexamethasone (injection form, once every 24 hours, 5 cc), Amoxicillin (tablet form, once every 8 hours), Diphenhydramine (tablet form, once every 8 hours), Alprazolam (tablet form, once every 24 hours), and Codeine/Paracetamol (tablet form, once every 8 hours).

Body composition – weight, BMI, and waist circumference: Waist circumference was measured at the end of a normal expiration at the narrowest point between the last rib and the iliac crest, measured in centimeters and recorded (30). Hip circumference was measured at the most prominent part of the gluteal muscles, with the participant standing straight without contracting the buttocks muscles. The examiner measured hip circumference from the side and recorded the measurement in centimeters (30).

Self-report of PA: We used the Bone-specific Physical Activity Questionnaire – BPAQ to measure individuals' daily PA based on their occupation (31). The BPAQ has three subscales, which assess individuals' PA under occupational activity, sports activities, and leisure-time activities. Each 16 item was rated on a five-point Likert scale, ranging from 1 (never) to 5 (always). Higher scores on this questionnaire indicate higher levels of PA (31).

MS risk factors – blood pressure and cholesterol: Blood pressure was assessed three times with a one-minute interval, using a sphygmomanometer on the left upper arm at heart level after 5 to 10 minutes of sitting. The first blood pressure was discarded, and the last two were averaged to obtain each participant's blood pressure. After 12 to 14 hours of fasting, 10 milliliters of blood were drawn to measure glucose, total cholesterol (TC), HDL, LDL, and serum triglycerides using the CardioChek® Professional Analyzer (Polymer Technology Systems, Inc., USA). We estimated LDL based on the Friedewald's formula (32):

$$\text{LDL} = \text{TC} - \text{HDL} - \text{TG}/5$$

2.5. Statistics

To assess the correlation between PA levels and MS risk factors after COVID-19 recovery, we used Pearson correlation tests. Normality of the data and linearity of the relationship were checked and in the case of non-linearity, alternative statistics was used. To compare MS risk factors including triglycerides, TC, HDL, LDL, systolic and diastolic blood pressure, fasting blood glucose, and waist-hip ratio before and after COVID-19 recovery, we used paired t-test. All analyses were performed using IBM SPSS Statistics (version 28, Chicago, USA) with a significance level of 0.05. The thresholds for effect size statistics were as follows: 0.0-0.19 (trivial); 0.20-0.49 (small); 0.50-1.19 (moderate); 1.2-1.9 (large); ≥ 2.0 (very large) (33). To reflect the variability in the different values between before and after COVID-19 recovery, we used the standard deviation of the differences (standardizer) value.

3. RESULTS

A total of 31 career male firefighters who reported that they had COVID-19 between 2021 and 2022 volunteered to participate in this study. Table 1 shows demographic and health characteristics of the participants. When controlling for age and BMI, there were moderate correlations between PA levels and LDL ($r = -0.39$, $p = 0.04$) after COVID-19 recovery. The correlations between PA and other MS risk factors were not statistically significant ($p > 0.05$) and relatively weak ($|r| = 0.005$ to 0.1). There was a statistically significant difference in weight ($t(30) = 2.06$, $p = 0.04$, $d = 2.08$), BMI ($t(30) = 2.104$, $p = 0.04$, $d = 0.66$), cholesterol ($t(30) = 2.879$, $p = 0.01$, $d = 0.90$), and the waist-hip ratio ($t(30) = 2.257$, $p = 0.03$, $d = 0.04$), before and after COVID-19 recovery. Other MS risk factors were not statistically significantly different ($p > 0.05$).

Table 1. Participants' personal characteristics and MS risk factors before and after COVID-19 recovery.

Parameter				
	Before COVID-19	After recovery	Difference (before – after)	Cohen's <i>d</i>
Age (years)	44.77±6.65			
Years in the fire service	11.03±1.30			
Height (cm)	177.55±7.18			
Weight (kg)	87.51±12.69	86.74±13.44	0.77±2.08*	2.08
BMI (kg/m ²)	27.83±4.80	27.58±5.03	0.25±0.66*	0.66
Waist-hip ratio	0.96±0.05	0.94±0.03	0.02±0.04*	0.04
PA	-	8.35±0.98	-	-
Fasting blood glucose (mg/dL)	121.25±43.88	121.31±43.89	-0.07±0.74	0.74
Triglycerides (mg/dL)	235.41±155.74	235.45±155.93	-0.05±1.31	1.30
Total cholesterol (mg/dL)	163.95±37.08	163.48±36.98	0.46±0.90*	0.90
HDL (mg/dL)	40.76±5.79	40.51±6.04	0.25±0.97	0.97
LDL (mg/dL)	90.71±28.60	90.91±28.64	-0.21±1.34	1.33
Systolic blood pressure (mmHg)	119.74±10.26	119.58±10.69	0.16±1.31	1.32
Diastolic blood pressure (mmHg)	76.83±4.23	76.35±4.75	0.48±1.77	1.77

BMI: Body mass index; PA: Physical activity; HDL: High-density lipoprotein cholesterol; LDL: Low-density lipoprotein cholesterol; *: $p < 0.05$. Data are presented as Mean±SD.

4. DISCUSSION

The aims of the current study were to explore the correlation between PA and MS risk factors after COVID-19 infection, and to assess the changes in these risk factors before and after recovery in male firefighters. We found a moderate negative correlation between PA levels and LDL cholesterol following COVID-19 recovery. Additionally, weight, BMI, waist-hip ratio and TC decreased statistically significantly after recovery. However, fasting blood glucose, triglycerides and LDL cholesterol increased, while HDL cholesterol and blood pressure components decreased, though these changes were not statistically significant.

Our results suggest that increased PA is associated with lower LDL cholesterol levels, which is generally beneficial for cardiovascular health and aligns with previous research (34). This finding is particularly relevant for firefighters, who face a higher risk of cardiovascular disease and significant emotional stress on the job. However, our results contrast with other studies indicating that improvements in VO_2 through exercise did not lead to LDL reduction (35). One possible explanation for the observed increase in lipid levels among firefighters could be related to behavioral changes during the COVID-19 pandemics (36). Additionally, reducing LDL cholesterol may require longer durations and higher intensities of aerobic exercise (37-39).

Reductions in BMI, waist-hip, and TC were consistent with longitudinal studies in non-COVID participants (5). Notably, a reduction in BMI accompanied by an increase in LDL cholesterol can signal a persistent cardiovascular risk factor (40). Other research suggests that firefighters with higher inflammatory diet tend to have greater BMI, fasting blood glucose, and TC levels (35). This suggests that while PA may influence MS risk factors, it should be combined with dietary adjustments. In our study, the lack of correlation between PA and TC further suggests that TC reductions may be more influenced by dietary factors.

The increase in triglycerides and LDL cholesterol observed in our study, with large effect sizes, aligns with findings from a long-term (5 years) study of healthy firefighters, which linked these changes to reduced VO_2 (41). This study also noted that improvements in VO_2 did not lead to improvements in these parameters, potentially underscoring the need for better nutrition. In contrast, our findings on fasting blood glucose differ from previous research (42), which showed improved (decreased) glucose levels with enhancements in exercise, sleep, and nutrition. The average increase in LDL cholesterol post-recovery is also concerning, as LDL levels of 100 mg/dL or higher are an independent predictor of heart disease (43). This increase in LDL despite weight loss further highlights the critical role of PA, alongside nutrition and diet, in managing cardiovascular risk.

There was a reduction in HDL cholesterol, and no correlation between PA and HDL, contrary to previous research that showed improved HDL with increase VO_2 (41). Other studies have shown that maintaining both VO_2 and BMI is necessary for HDL improvements (41). Thus, it is reasonable to consider managing both weight and PA simultaneously. Similar to previous research, BP decreased (44). These reductions could be attributed to lifestyle changes, including balanced nutrition, regular PA, restorative sleep, positive social and family connections

with resiliency strategies, and the avoidance of tobacco and other toxic substances (5, 44, 45). Additionally, while none of the medication used had antihypertensive properties, some, like Alprazolam, may have calming effects that could help reduce stress-related BP (5).

Our findings are consistent with research on chronic obstructive pulmonary disease (COPD), which shows similarities with respiratory diseases like COVID-19 (46). While no differences in sedentary behavior and PA levels were found between those with COPD alone and those with COPD plus MS, it was observed that individuals who engage in PA (even light-intensity) had a lower prevalence of MS. Moreover, waist circumference and glucose levels showed significant associations with the amount of time spent engaging in low- to high-intensity PA (46).

4.1. Clinical relevance

Our findings are particularly relevant for occupational cohorts in public safety professions, where physical health and fitness are critical. The large effect sizes, despite non-significant *p*-value for triglycerides and LDL, suggest that these changes could be clinically important given their direct relation to cardiovascular risk. Similarly, changes in blood pressure components might indicate an increased risk of heart disease or stroke. Overall, PA appears to influence certain MS parameters, including weight and subsequently BMI and waist-hip ratio, and cholesterol. However, comprehensive improvement in all MS risk factors likely requires a combination of exercise, nutrition, sleep and stress reduction. A larger sample size could also enhance the study's power and generalizability of the findings. Clinicians might still consider these changes when managing patient care, such as adjusting treatment plans for cardiovascular risk or assessing return-to-work for firefighters. Healthcare providers, particularly those working with firefighters, should closely monitor these parameters, as significant changes in cardiovascular risk factors might not be apparent to individuals. Additionally, training instructors and incident commanders should be aware of potential declines in physical performance following COVID-19, as pre-illness levels of work output may no longer be achievable.

4.2. Limitations

Our findings should be considered in light of several limitations. COVID-19 diagnosis and symptom onset were self-reported, which may introduce recall bias. We were not able to control the severity of COVID-19 illness. Data for this study were collected during the later part of COVID-19 pandemic, after vaccines were available in Iran, which might affect the generalizability to other time periods. Due to the very low number of female volunteers, we did not include this gender, limiting the generalizability of our findings to women. Additionally, to capture realistic nutritional patterns during COVID-19 without influencing participants' usual habits, we did not collect detailed information on participants' dietary habits, as relying on

participant recall may not have provided accurate data; this omission may also influence metabolic syndrome risk factors.

A particular strength of this study was access to occupationally active, middle-aged firefighters who underwent biannual medical exams including MS risk factors before and after COVID-19 recovery, allowing for longitudinal assessment. The changes observed reflect those of firefighters in a natural setting rather than as a result of a research intervention. In our study, all pre-assessments were conducted within six months prior to COVID-19 infection, and post-assessments were done at a specific time after recovery. This approach allowed us to examine the impact of time since COVID-19 on MS risk factors, a design not commonly used by other studies that measure physiological measurements at specific post-COVID-19 time points. Future research could also incorporate nutrition and sleep as potential modifiers of MS.

5. CONCLUSIONS

We observed reductions in BMI, waist-hip ratio, and cholesterol in occupationally active firefighters following COVID-19 infection. Fasting blood glucose, triglycerides, and LDL cholesterol increased, while HDL and blood pressure components decreased. It remains unclear whether these changes are solely due to viral infection or if altered activity levels also contributed to the increased MS risk factors. In general, higher MS risk is concerning for firefighters (and potentially other public safety professionals) who may need to perform strenuous work. Further research is needed to understand how MS risk factors change in different groups, such as those with mild, moderate, or severe COVID-19 infections, those who have been vaccinated, those who have experienced multiple COVID-19 infections, or those dealing with Long COVID. Additionally, exploring the mechanisms behind impaired exercise tolerance (e.g., mitochondrial dysfunction, endothelial dysfunction and autonomic nervous system imbalances) and evaluating whether targeted interventions could help restore pre-COVID-19 health and fitness more rapidly would be beneficial.

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