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COVID-19: IS IT REALLY OVER? – FATIGUE MANAGEMENT IN POST-COVID SYNDROME AND MEASUREMENT OF FATIGUE

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ABSTRACT: *Since the beginning of human-manned flights, it is known that "It is not the resistance of material which limits the aerobatic performance of the artificial bird, but the physiologic resistance of man, who is the brain of the artificial bird" (Louis Blériot).*[1] *Therefore, the protection and measurement of human performance is of utmost importance for aviation safety. Fatigue is among the most common human factor errors that jeopardize the performance and safety of flights.*[2] *The scientific literature on COVID-19 infection, and particularly, post-COVID syndrome, describes fatigue as one of the most common complications after the infection that persists for a very long time. Fatigue is commonly measured only by subjective questionnaires, and there are no commonly used objective methods to measure it. This study examines the prevalence of post-COVID fatigue among national military and civilian aviators to determine its aviation safety risks and search for possible objective measurement methods of fatigue.*

KEYWORDS: *aviation safety, human factor error, post-COVID, human performance, fatigue*

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INTRODUCTION

Aviation safety is a result of complex cooperation among multiple fields of expertise, a factor that we do not really notice; rather, we see the lack of it when aviation safety lines fail, and an aviation incident or accident happens. It requires a well-working integration of the system (the aircraft), the environment, and the human (pilot), known as the Human-System-Integration (HSI). Nowadays, the system (aircraft and aviation assisting software) is very much developed and seemingly reduces workload on humans, but this seeming is an illusion. New age technologies may have more flight-assisting software, but the manoeuvrability, speed, and aerobatic performance of the aircraft are also increased, putting significantly higher physiological stress on the pilots. Besides this, the numerous instruments displaying a lot of information require pilots to give high performance in information pro-

[1] Louis Blériot French pilot and aviation engineer's words from 1922. (Kirkham et al. 1982, 1.)
[2] Buzai 2004.

cessing. Human factor errors – such as fatigue or concentration problems – may severely reduce human performance and lead to aviation safety risks.

Despite the new technologies and software, the human factor is still the weakest point in aviation safety, and the most common reason for aviation accidents. Fatigue, concentration problems, and lack of awareness are among the most frequent and dangerous causes of human factor errors.[3] Therefore, anything that may jeopardize human performance by causing fatigue or concentration problems is of great interest in aviation safety, and we need to search for possible ways of reducing this risk.

Since the beginning of the COVID-19 pandemic, the medical scientific community has been collecting, analysing, and publishing data regarding the symptoms and most common complications of COVID-19 infection in the short term and the long term as well (post-COVID syndrome[4] and long COVID syndrome[5]); however, the aviation safety aspects of these conditions have been very little considered.

The significant decrease in performance (worse reaction time, higher mistake ratio) after COVID-19 infection has been detected since the very beginning of the pandemic.[6] Among the most common symptoms and complications of COVID-19 infection, the long-lasting fatigue and brain fog are even more dangerous from an aviation safety aspect. Fatigue and brain fog develop in cc. 60–70% of all cases of post-COVID syndrome[7] and persist in long COVID in about 40% of all infections. According to recent studies, they may endure up to 8–12 months after infection.[8] Both may jeopardize human performance, especially in attention-demanding professions, such as pilots, air traffic controllers, and aircraft maintenance mechanics.

The importance of fatigue is well known in aviation. The International Civil Aviation Organization (ICAO) issued five different manuals and recommendations for fatigue management to reduce the aviation safety risk aspects of fatigue.[9] NATO also emphasized fatigue management in a Standardization Agreement (STANAG).[10]

Long-lasting chronic fatigue and brain fog development in post- and long COVID syndrome may pose a great aviation safety risk; the also common post-COVID sleeping disorders may further increase the danger of developing chronic fatigue. This survey also aims to confirm the persistence of fatigue after COVID-19 infection among aviators.

Even nowadays, fatigue is only measured by self-evaluated questionnaires, not objectively. Considering the operational pressure and task load in aviation, especially in military aviation, the true validity of such self-evaluations is very much questionable. It would be beneficial to develop an objective measurement method of fatigue instead of self-evaluation.

The aim of this research is to study the prevalence of post-COVID fatigue among aviators, evaluate its aviation safety risk, and mitigate it by identifying an objective measurement method. The questionnaire survey is still going on; therefore, this study reports preliminary results.

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3 Buzai 2004.

4 Magyar Tüdőgyógyász Társaság 2021, 6. Complaints persisting longer than 4 weeks after COVID-19 infection.

5 National Academies of Sciences, Engineering, and Medicine 2024. Complaints persisting longer than 12 weeks after COVID-19 infection.

6 Zhou et al. 2020.

7 Halpin et al. 2021.

8 Peter et al. 2022.

9 ICAO 2020a; ICAO 2016b; ICAO 2015; ICAO 2016a; ICAO 2020b.

10 NATO 2021.

COVID-19: IS IT REALLY OVER?

The COVID-19 pandemic started several years ago. It alerted the whole world, as people had to face severe morbidity and mortality rates that had not been seen for generations. To control the spread of the infection, strict epidemiological regulations were introduced, and the world was locked down for a long time. As the years passed, preventive measures, attention, and the awareness of the population gradually decreased. From 2024 onwards, basically all previously ordered preventive measures and obligations have faded away. Nowadays, COVID diagnostics are rarely done; COVID and seasonal flu are not distinguished among the seasonal flu-like sicknesses, and no one really thinks about COVID-19 as a possible cause of the sickness. After the decreased number of vaccinations worldwide and underreported case numbers due to reduced diagnostic trends, morbidity and mortality rates declined, and people tend to forget about COVID-19 infection and its possible consequences and complications. Nevertheless, international literature and morbidity databases show that the presence of COVID-19 is still the root cause of many sicknesses. The relevant literature also highlights the danger of repeated COVID-19 infections,[11] in which the symptoms may be milder, but the post-COVID complications are shown to be more imminent with every re-infection. In summary, awareness to avoid COVID-19 infection has decreased, vaccinations are no longer obligatory, and the ones given earlier are not effective by now. Preventive measures such as social distancing and using face masks are not commonly taken. Doctors do not conduct COVID-19 tests regularly, but the wastewater proves that COVID-19 and its new variants are still present in rising amounts. Most people do not even know that they are infected (again) with COVID-19. Therefore, the risk and likelihood of repeated COVID infections have even risen. Repeated COVID infections tend to have mild symptoms, so the risk of spreading the infection is also higher, as people may not even recognise their COVID sickness.

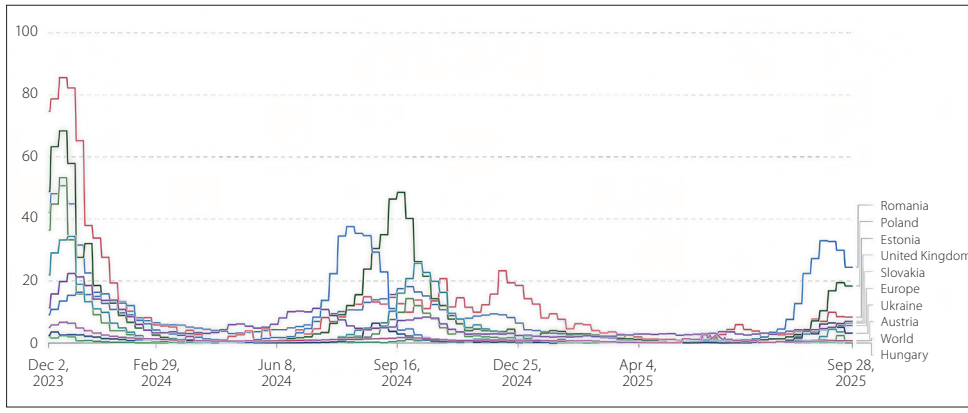


Figure 1 *Daily new confirmed COVID-19 cases per million people between 2023 and 2025*
Source: *World Health Organization 2025, https://ourworldindata.org/COVID-cases*

Figure 1 shows an overview of newly diagnosed COVID-19 cases from December 2023, when new vaccinations effectively reduced the contagion rates, and the number of new cases rapidly declined. The chart shows a significant reduction in numbers from 2023 to

[11] Schmidt 2023.

2024, but during flu season, the number of new cases in 2024 and 2025 remained stagnant. Therefore, COVID-19 is still among us every year, and the peaks do not tend to decrease. If we also consider the problem of likely underreported numbers due to the lack of COVID testing in everyday practice, we can assume that these new COVID-19 infection numbers are way higher in reality. Most of these can be repeated COVID infections as the virus is circulating through the entire population year by year, with new variants of the same virus.

The COVID-19 content of wastewaters confirms this suspicion. Figure 2 shows the trends of the COVID presence in the wastewaters of the USA, seasonally returning with the same peaks every year. Meanwhile, Figure 3 shows the obviously rising trend of the COVID virus presence in wastewaters in Hungary: the peak is shown to climb back upwards close to the levels measured in 2023 again.

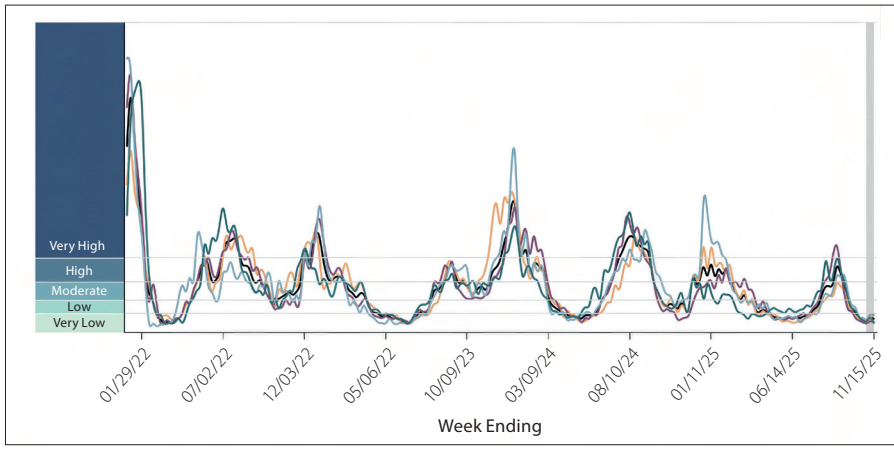


Figure 2 *COVID-19 virus presence in wastewater trends in the USA between 2022 and 2025*
Source: *https://cdc.gov/nwss/rv/COVID19-national-data.html, all results view*

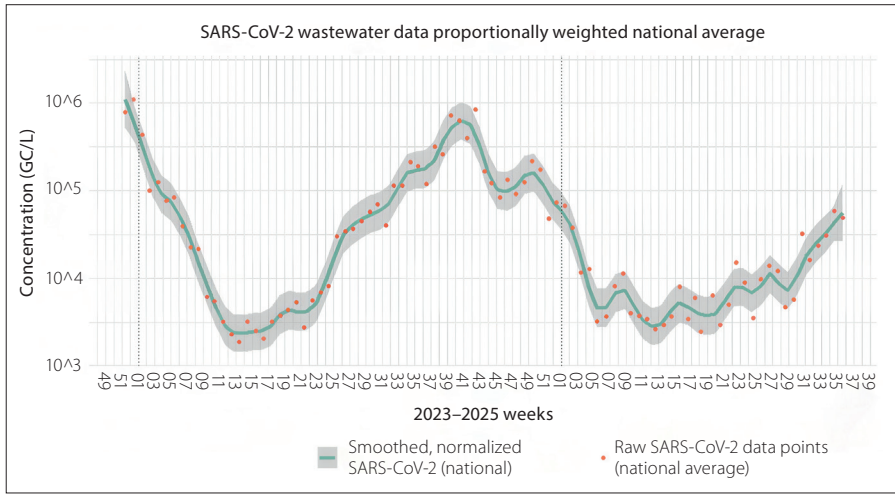


Figure 3 *COVID-19 virus presence in wastewater in Hungary between 2023 and 2025*
Source: *https://nngyk.gov.hu/hu/tovabbi-hirek/2025-35-heti-szennyvizvizsgalat-eredmenyek.html*

Reported new cases have indeed decreased by 2024, but from an aviation safety aspect, COVID is still with us every year, especially during flu season. Even if diagnosed COVID-19 cases are reported in low numbers, the presence of the virus is detected more objectively in the wastewater; we cannot forget the risks of post-COVID fatigue and brain fog in any high-demand profession.

Public awareness of COVID-19 infection is decreasing. Still, health care data show rising numbers of long COVID syndrome and no reduction in the prevalence of significantly limiting symptoms. With time, the risk of re-infection due to lower preventive and diagnostic levels increases; therefore, the long COVID syndrome is expanding silently (Figure 4) and causes more and more complications even recently (Figure 5).

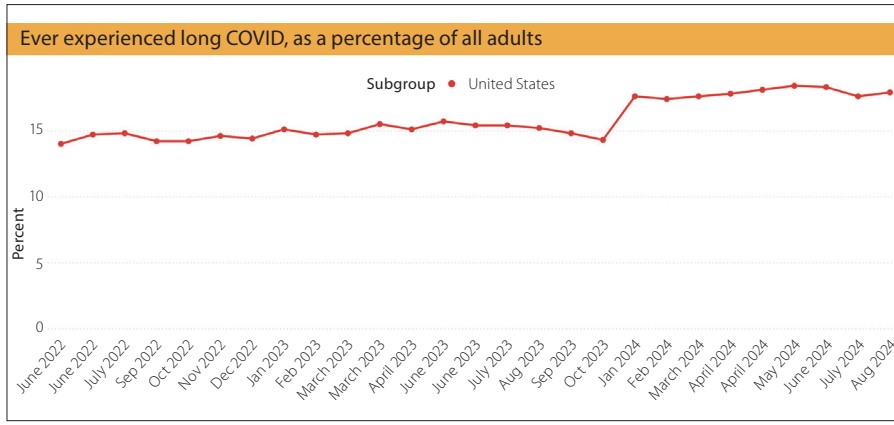


Figure 4 *Prevalence of long COVID syndrome between 2022 and 2024*
Source: *https://cdc.gov/nchs/COVID19/pulse/long-COVID.htm, National estimate view*

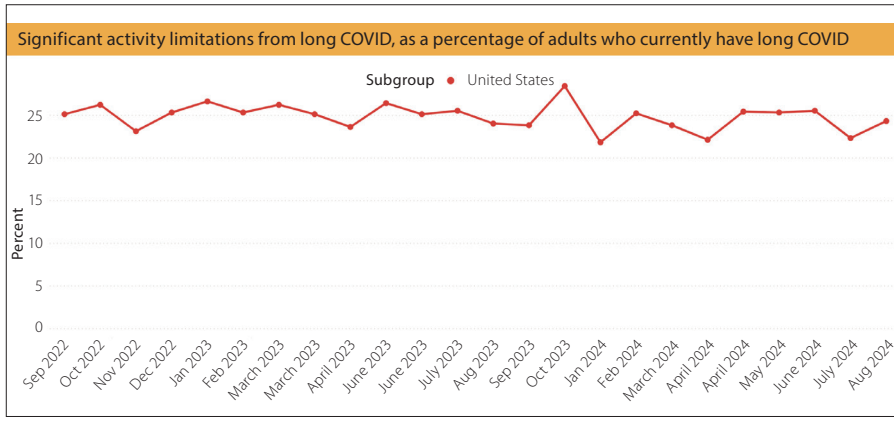


Figure 5 *Prevalence of significant activity limitations in long COVID syndrome between 2022 and 2024*
Source: *https://cdc.gov/nchs/COVID19/pulse/long-COVID.htm, National estimate view*

Can we really say that the COVID-19 pandemic is over? Not nearly. Our awareness and protective walls have faded – if not fallen – by now, while the virus is still taking its victims and causing even more severe post-COVID and long COVID infections. Fatigue and brain fog

have always been well-known threats to aviation safety. Unfortunately, the false sense of safety, thinking that the COVID-19 pandemic is over, only raises this risk as people themselves do not consider having COVID-19 infection anymore and do not consider the post-COVID and long COVID fatigue and brain fog, jeopardizing their daily work performance. Due to the recent lack of awareness about COVID-19, realising and monitoring fatigue, preferably in an objective way, is more important for aviation safety nowadays than ever.

PREVALENCE OF POST-COVID SYNDROME AMONG AVIATORS IN HUNGARY (PRELIMINARY RESULTS)

As described in the introduction, post-COVID and long COVID syndrome complications may pose a significant risk for aviation safety. To demonstrate my hypothesis, I conducted an online survey among professionals working in aviation-related fields on COVID-19 infections, repeated infections, characteristics of their symptoms, persistence of the virus, and self-reported aviation safety risks that the post-COVID syndrome might have caused in aviation work. The questionnaire was anonymous and voluntary. Data collection started in October 2024 and is still ongoing; the results are preliminary, based on 66 answers. The statistical analysis was performed by the RStudio program (t-test, Fisher's exact test, Wilcoxon test, and Cronbach's alpha determination). The significance level used during the analysis was $p \leq 0.05$.

METHOD AND SAMPLE OF THE SURVEY

The questionnaire had 50 questions in 5 main domains, such as sociodemographic data, the individual's COVID vaccination status and risk factors, COVID infection(s) with symptoms and severity during the months after the infection (I followed symptom prevalence up to 12 months), the individual's working characteristics (workload, working hours, work intensity, work and rest ratio), the individual's possible performance influencing post-COVID symptom complaints when returning to work after COVID infection, and finally, the general well-being (WHO Well-Being WBI-5) and sleep quality (Athens Insomnia Scale, AIS) before and after COVID-19 infection. Because sleeping disorders and well-being challenges may significantly worsen the severity of fatigue and the development of chronic fatigue, these data have high importance in determining the aviation safety risk of post-COVID and long COVID syndromes.

The sample of the survey involved 66 people working in aviation-related fields (pilots, air traffic controllers, aircraft mechanics, and candidates for these jobs). 79% of the answers came from men and 21% from women. The mean age of individuals was 44.85 years ($s = 13.65$). The prevalence of answers by age groups is shown in Table 1.

Table 1 *Prevalence of age groups in the survey (Source: author)*

Age group	Prevalence
> 25 years	13.63%
26-35 years	10.60%
36-45 years	21.21%
46-55 years	31.81%
56-65 years	18.18%
> 65 years	4.54%

The mean age in the survey is relatively higher than the mean age among military aviation personnel. The explanation is that the survey also targets civilian aviators, as one of the hypotheses is that there would be a significant difference in the prevalence and severity of post-COVID symptoms in the case of military and civilian aviators. The hypothesis is based on the fact that military aviators are more regularly and strictly screened medically than civilians, and that the mean age among civilian aviators, especially holiday pilots, is higher. Ageing and the upper limit of age in aviation medicine are among the most pressing challenges nowadays. In terms of aviation safety risk of ageing pilots, the risk is obviously higher, as in their case, both the prevalence and severity of complications in post-COVID and long COVID syndromes are expected to be higher according to COVID-19 literature.

As for the **health condition** of the participants, the mean **Body Mass Index** (BMI) was 27.68 kg/m^2 (s = 5.77). The categories of BMI are shown in Table 2.

Table 2 *Prevalence by BMI categories in the survey (Source: author)*

BMI categories	Prevalence
Normal	33.33%
Overweight	37.87%
Obese I.	19.69%
Obese II.	4.54%
Obese III.	4.54%

Obesity is clearly a high-risk factor when it comes to more severe symptoms and complications after COVID-19 infection, according to international COVID-19 literature. Based on the preliminary data, 37.87% of individuals were overweight, and 19.69% were in the Obese I. stage. These rates are higher than among military aviators in general, and the reason again is the presence of civilian aviators in the sample. Further analysis would be necessary to look into the age-related and the state- or civilian-related prevalence of obesity in the participants. These data are important in determining the aviation safety risk of post-COVID syndrome, highlighting the probability of more severe consequences and aviation safety risks in the obese groups. Health promotion, such as regular physical activity and a healthy diet, may help maintain a normal weight range and also reduce the risk of illnesses. How to avoid obesity is part of the medical education of aviators in state flying and civilian aviation forums.

The prevalence of already **existing chronic diseases** was also relatively high (44.8%). The reason for this might be the participation of civilian aviators, who are faced with fewer medical regulations and have a higher average age, which indicates more chronic diseases. Further analysis is necessary to differentiate the prevalence of already existing chronic illnesses in the military and civilian groups to study one of the hypotheses of the research: whether there is a significant difference in this matter (safety risk level in post-COVID and long COVID syndromes) between the military and civilian samples. The most common chronic disease was high blood pressure (50%), the second was chronic thyroid gland sickness (15.6%), and surprisingly, the third was sleep apnoea (9.4%). The first two belong to typical civilisation illnesses, also highly related to stress, and stress in aviation work is imminent in the majority of the sample. Participants answered that the stress level of their work was 4 on a 1–5 scale, meaning very stressful (Figure 6). Contributing factors are the previously described higher prevalence of obesity that leads to high blood pressure, often

accompanied by thyroid gland hypoactivity. Flying in high altitudes may expose aviators to higher cosmic radiation that might contribute to thyroid gland diseases, too. Sleep apnoea, being the third most common chronic illness, is also in connection with obesity. It raises attention as apnoea itself – if not diagnosed and treated well – may result in dangerously high likelihood of daytime sleepiness, which, combined with the post-COVID and long COVID syndromes' long-lasting fatigue, may even increase the safety risk of these aviators going back to work after COVID infections.

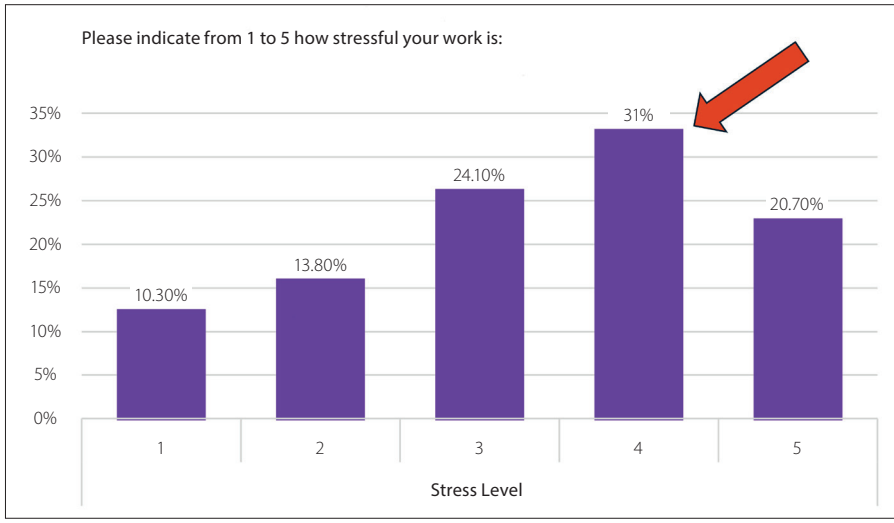


Figure 6 *Self-reported stress level of aviation work (Source: author)*

As the international COVID literature evaluates existing chronic diseases as risk factors for developing more severe symptoms and complications in post-COVID syndrome, I used Fisher's exact test to investigate the possible correlation between existing chronic diseases and the timely manner of symptoms to determine if these persist longer in those patients who already have existing chronic diseases. This test did not show significant results ($p = 0.6217$), which means I have found no connection in the sample. It is against the international scientific results, but we must also consider data bias due to the relatively low number of answers and the relatively high mean age (44.85 years), as well as the consecutive higher number of age-related chronic diseases. The younger, healthy population should also be included in the survey in the future to reduce the data bias.

Regarding **COVID-19 vaccinations**, the tendency of the sample shows a reduction, while 88% took the first dose of vaccination and 83% the second, only 56% took the third, and only 8% of answerers had 4 doses of COVID-19 vaccinations.

As for **previous COVID-19 infections**, 53.7% of the sample had at least once a PCR- or quick test-verified COVID-19 infection, and 25.4% were repeatedly infected with COVID. It is interesting that despite the very high vaccination rate with one and two doses, the majority of the sample was infected with COVID-19, and every fourth of them repeatedly. These numbers might even be higher due to falling awareness and reduced COVID-19 testing, as well as milder symptoms of repeated COVID-19 infections, which may result in undetected re-infections. The symptoms may be milder in repeated infections, but the

post-COVID and long COVID complications are still imminent in these cases. Out of the repeated COVID infection cases, 21% had more severe post-COVID symptoms than during the previous infection, 31% reported milder post-COVID symptoms, and 21% reported no post-COVID syndrome during the repeated COVID infection (Figure 7).

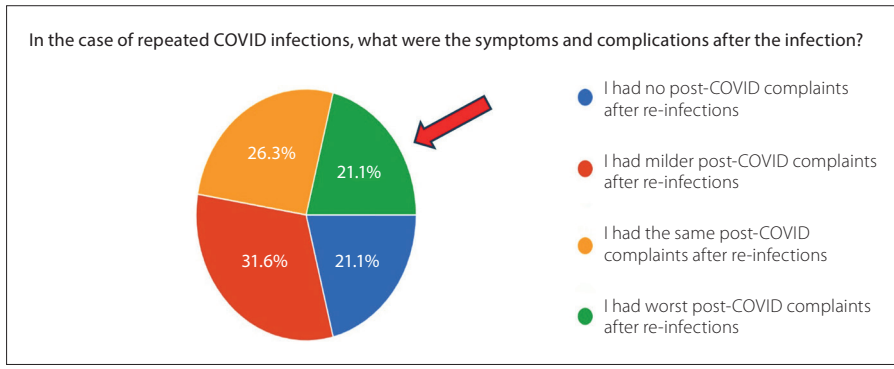


Figure 7 *Post-COVID complaints during repeated COVID infections (Source: author)*

Among the **symptoms of COVID-19 infections** (Figure 8), fatigue is the most common, which is in accordance with the international COVID-19 literature. The prevalence of fatigue as a post-COVID symptom was 73.1%, accompanied by malaise in 67.2%. Fatigue persisted for three months after the infection in 34% of the cases, for six months in 21%, and although it showed a slight decrease by the ninth month with 15%, it increased again to 21% by 12 months after the infection. Based on these preliminary data, we can assume that the hypothesis saying fatigue is significant and persists not just for a few months but much longer among aviators after COVID-19 infection seems to be confirmed. Every fifth of the answering aviators suffered from fatigue even 12 months after the infection. More worrisome is that these data show a gradual decrease until the ninth month, but an increase in fatigue prevalence again around a year after the infection. This characteristic, combined with the lower attention and falling awareness of COVID-19 and post-COVID syndromes nowadays, suggests that most people working in aviation would not even suspect having any performance risk due to a previous COVID infection when it is still present and threatening safety. A possible undiagnosed re-infection with mild symptoms, combined with a common flu, might result in intensification of post-COVID symptoms, which may lead to a severe, unrecognised safety risk and perhaps a mishap during work.

When it comes to fatigue, especially chronic fatigue, **sleeping disorders** are key factors. Unfortunately, sleeping disorders also often occur in post- and long COVID syndromes. In this survey, sleeping disorders develop in 16.4% of all cases, and persist in about 10% during the whole post- and long COVID period up to 12 months, without showing a reduction.

Fatigue and poor quality of sleep have a cumulative negative effect on human performance, resulting in a higher number of human mistakes. To evaluate the prevalence and severity of sleeping disorders in the post-COVID period, I used the Athens Insomnia Scale and compared the results before and after COVID infection. The AIS is used for evaluating sleeping disorders and diagnosing insomnia.[12] The Hungarian version also has good

[12] Soldatos et al. 2000; 2003.

psychometric features.[13] The AIS was outstandingly reliable with the samples; Cronbach's alpha value was 0.909 on both the pre- and post-COVID scales. The general **AIS point before COVID infection was 0.59** (SD = 1.128), while the average **AIS point after COVID infection was 6.36** (SD = 5.184). Paired with a t-test, the results showed a significant difference between the groups (t = –9.1877; df = 65; p = 2.317e-13), which means that participants had a significantly higher AIS point, referring to a significantly worse sleep quality in the post-COVID period (Figure 9).

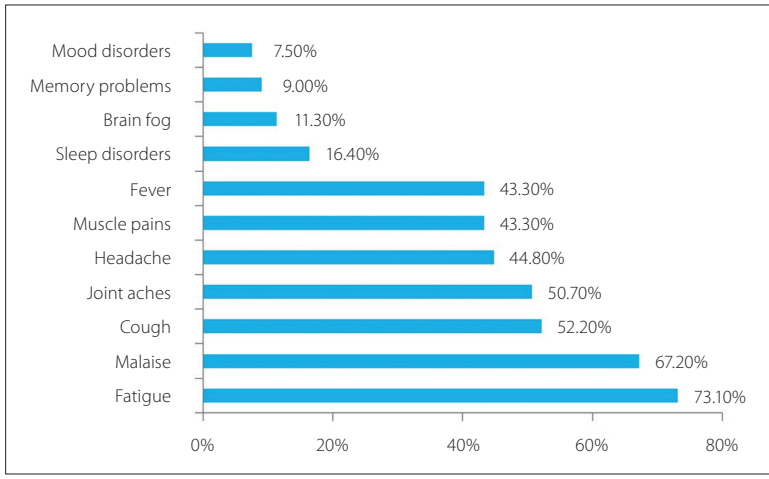


Figure 8 *Typical COVID-19 symptoms and their prevalence (N = 66) (Source: author)*

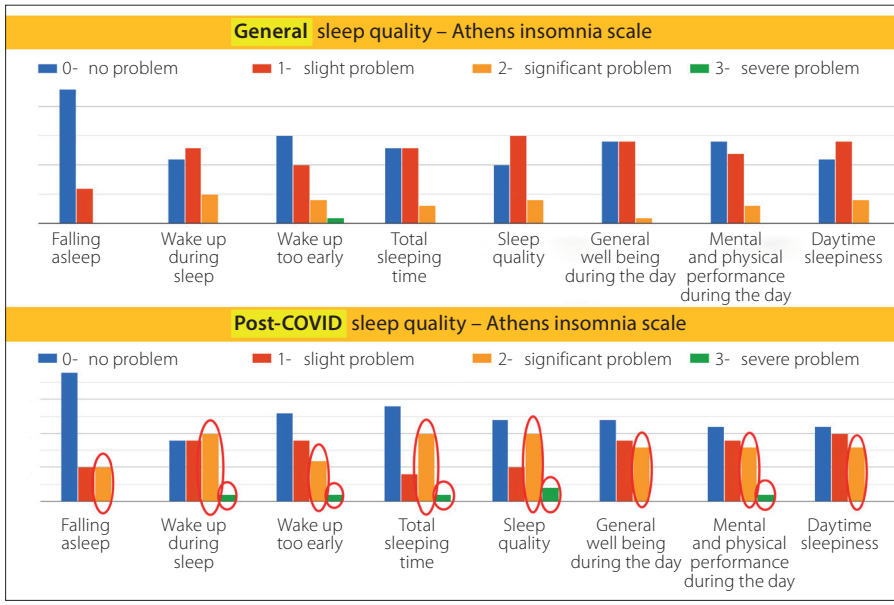


Figure 9 *Pre- and post-COVID sleeping quality (AIS) (Source: author)*

[13] Novák 2004.

In aviation-related work, flying through time zones, causing jet lag, shift work, overnight shifts, and long working hours all contribute to developing fatigue, as these work schedules and circumstances cause circadian dysrhythmia and result in sleeping disorders. Similarly to the surprisingly high prevalence of sleeping apnoea, this very long persistence of sleeping disorders among post-COVID and long COVID symptoms highlights the aviation safety risk of the post-COVID period, related to increased fatigue and fatigue management challenges to preserve safe human performance. In recent years, I participated in aviation incident and accident investigations as an aviation safety human factor expert. In these cases, fatigue and human errors were always detectable and, many times, the root cause of the incident or accident. This research and the preliminary survey results may predict an increase in fatigue-related human factor errors in aviation incidents and emphasize the importance of proper aviation safety risk assessment in the post-COVID period, with all possible mitigation methods available or yet to be developed. For example, a post-COVID-related fatigue management education could be built into the aviation industry, and innovations in fatigue measurement technologies could be promoted.

The prevalence of the most common COVID symptoms can be seen in Figure 10. The chart shows that these aviation safety-related symptoms persist for a long time in the post-COVID and long COVID periods, sometimes not decreasing but even increasing with time.

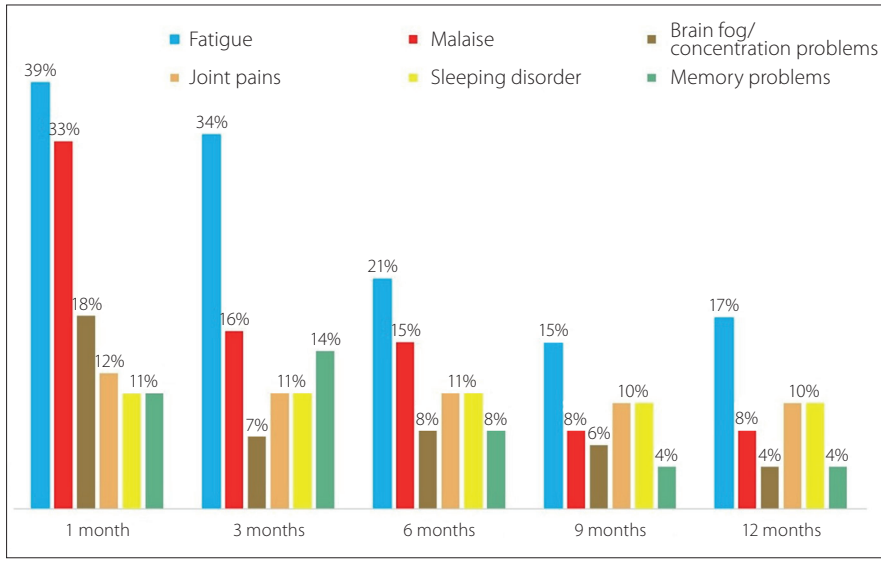


Figure 10 *Prevalence of post-COVID symptoms in relation to time (Source: author)*

Concentration problems or brain fog in post-COVID (11.3%) **and memory problems** (9%) are relatively lower in prevalence than fatigue. However, as Figure 10 shows, they also persist longer, and their prevalence might even increase over 12 months. Brain fog only starts to reduce after the ninth month, and the accompanying memory problems reach the peak prevalence (14%) after the third month, when we have already forgotten about COVID and post-COVID consequences. These two factors are synergic in significantly influencing human performance, especially the information processing ability; therefore, these are also considerable aviation risk factors in post-COVID syndrome.

Joint and muscle pains are rarely mentioned as aviation risks. Still, long-lasting joint and muscle pains may result in physical movement limitations, which can cause difficulties in executing aviation or maintenance tasks safely and lead to human factor errors. For example, performing anti-G manoeuvres during high-performance flights is essential to avoid gravitational loss of consciousness (G-LOC). Failure to perform these with the necessary strength due to muscle pains may significantly increase the risk of sudden incapacitation of the pilot during flight. In the short term, following COVID infection, joint and muscle pains (50.7% and 43.4%) are almost as frequent as fatigue. However, joint and muscle pains reduce significantly after one month (12%), but even these symptoms can persist for up to 12 months with a constant 10% prevalence. Therefore, we cannot forget about these contributing safety risk factors in post-COVID either.

Analysing the prevalence of different **post-COVID symptoms in relation to time** shows that many of the initial symptoms persist for a long period. Fatigue and malaise, as leading complaints, occur in a very high number of cases; however, their prevalence shows a continuously reducing trend over time, as they persist for up to 12 months. Concentration and memory problems also occur often, but their prevalence does not start to reduce until six months. More surprisingly, sleeping disorders do not significantly improve over time; they persist in 10% of cases through 12 months and contribute to the performance-degrading effect of fatigue, increasing the chance of developing chronic fatigue.

WORKLOAD AND PERFORMANCE

The average working hours of the participants were between six and nine hours per day, 35% worked more than this and 12% worked less (Figure 11). Figure 11 also involves participants working just a few hours a day in aviation, reflecting the civilian pilots who fly just occasionally, as a hobby in their free time. By nature, our circadian rhythm has a circadian low between 3 and 5 a.m. and p.m., during which time, our body is rather sleepy; thus, the probability of concentration- or fatigue-related human factor errors is higher. Interestingly, participants reported a bit different **hour of the day when they feel the most tired**, between 12 p.m. and 3 p.m., and the afternoon circadian low from 3 to 5 p.m. We also asked them about work intensity, and the results show the highest intensity between 9 a.m. and 12 p.m., when the subjective fatigue level is still relatively low. After this, between 12 and 6 p.m., the work intensity is still high, but it coincides with the most fatigued time (Figure 12). The risk analysis reveals a highly dangerous timeframe from 12 to 3 p.m. and a similar but slightly less dangerous one in the afternoon circadian low between 3 and 5 p.m., when participants feel the most fatigued, and yet, this is the most intensive working time of the day. A condition like this (high fatigue and the highest workload) can breed human factor errors. When it comes to the aviation safety aspects of post-COVID, due to the increased fatigue long time after the infection, a work schedule should be considered in which the workload in this sensitive time slot of 12–3 p.m., and perhaps 3–5 p.m. as well, is reduced.

Regarding **stress and monotony**, participants replied on a five-point Likert scale. 56.7% rated the aviation-related work as very stressful, which shows that it poses a lot of stress to workers. Stress increases human performance only in the very short acute stress phase, then it continues in reduced performance and exhaustion.[14] In aviation-related works, this

[14] Selye 1965, 102.

acute stress reaction is not present, but rather the chronic stress reaction with the highly increased fatigue. In post-COVID syndrome, we have to take into consideration the safety risk from synergic effects of COVID-related fatigue and the exhaustion caused by work-related chronic stress, possibly also worsened by the COVID-related sleeping disorders and concentration problems.

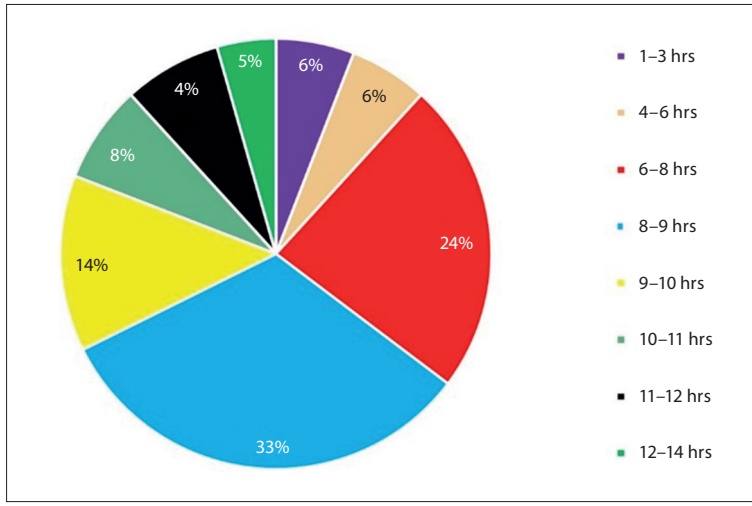


Figure 11 *Average working hours per day among participants (Source: author)*

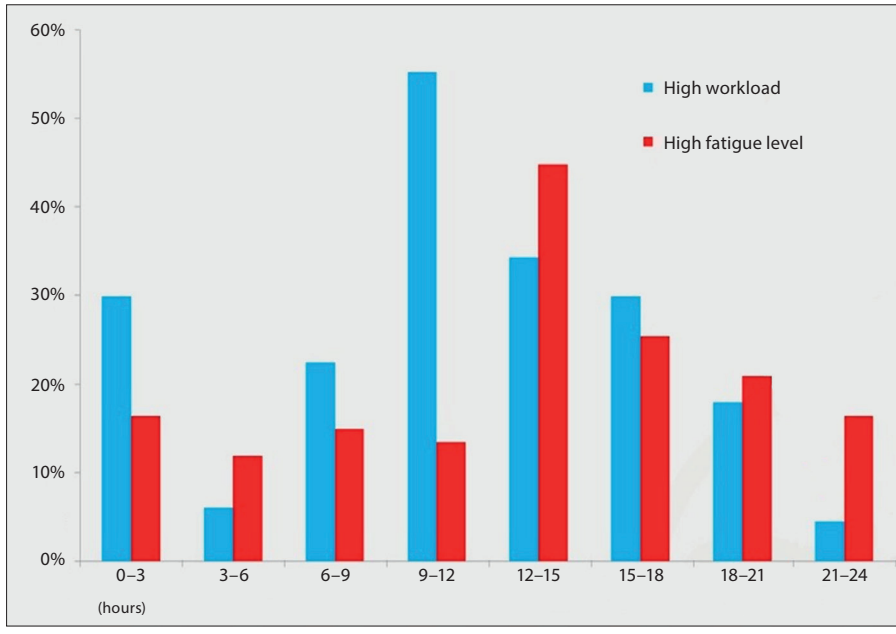


Figure 12 *Workload and subjective fatigue in time zones (Source: author)*

Monotony is another risk for human factor errors, especially when combined with fatigue. 64.1% of responders reported their job as not typically monotonous, while 19.4% reported middle-scale monotony. It might seem a minority, but if we consider the type of work exposed to this monotony, we see that it impacts highly important jobs, like air traffic controllers (surveying monitors for a long time) or flight directors (supervising flight tasks, monitoring reports and data), whose mistake would have a greater impact on aviation safety than that of other aviation workers. It is necessary to study the monotony scale in connection with work type to identify the workers in danger due to monotony-related increased safety risk in post-COVID syndrome.

From these aspects, we can see that post-COVID syndrome poses a very complex cascade of performance-degrading factors, which means obviously higher aviation safety risks in all fields of aviation-related work.

RETURNING TO WORK AFTER A COVID-19 INFECTION

Returning to work after a COVID-19 infection might be difficult for employees due to the long-lasting post- and long COVID symptoms and aviation-related work challenges described before. Based on the answers of the participants, the biggest challenge was the increased fatigue and malaise, which caused them to get tired at work faster than usual. The second most common difficulty reported was sleeping disorders, and the consequent increased chronic fatigue and perceived higher stress levels.

In the survey, I asked participants to **self-report whether they had committed any mistakes at work after returning from a COVID infection**, which led or might have led to an aviation safety risk. It is a sensitive topic, even in an anonymous survey. In an optimal aviation safety culture, reporting such mistakes would not be harmful for the person reporting the mistake in any way (just culture). I assumed that, being anonymous, participants would honestly report their possible mistakes. However, as I described earlier, many times the patient does not recognise a possible returning COVID-19 infection and its post-COVID consequences; therefore, I also assume that mistakes committed due to post-COVID syndrome are underreported simply because of being unaware of the post-COVID period. Figure 13 shows a surprising result: many of the participants reported committing mistakes at work after COVID infection. Errors occurred mainly within one month after returning to work, and not just once, but some of the answerers reported committing mistakes multiple times. For more aviation safety considerations, there were participants reporting mistakes even for a period of three months after returning to work. These results show that people working in aviation noticed mistakes they made in the post-COVID period and clearly justify the aim of this study. Besides the reported cases, many mistakes might have remained unnoticed, or other defence lines from James Reason's Swiss Cheese Model[15] could effectively prevent the mistake from developing into an incident or accident.

To evaluate the correlation between sleeping disorders and human factor errors, I compared the AIS average points in the subgroup that did not report committing human error(s) after returning to work from a COVID-19 infection and in the subgroup of participants who reported human error(s) after returning to work. The average post-COVID AIS point of

[15] Dudás 2020.

the subgroup not reporting mistake(s) was 8.04, while that of the subgroup reporting mistake(s) was 5.80. The t-test revealed **a tendency to commit mistakes in the post-COVID group that also suffers from sleeping disorders** (t = –1.7115; df = 53.259; p = 0.09281). The research survey's preliminary data confirmed that those who suffered from sleeping disorders also had a higher tendency to make mistakes after returning to work.

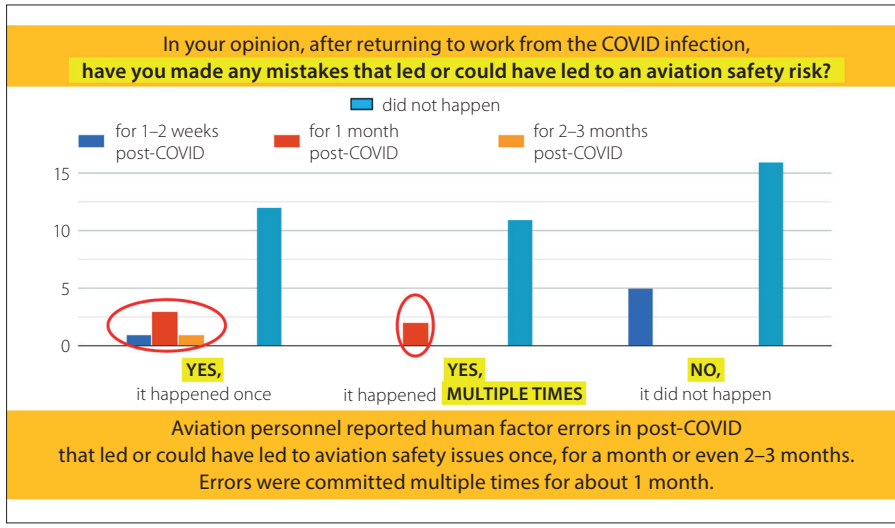


Figure 13 *Self-reported committed mistakes at work after returning to work from COVID-19 infection (Source: author)*

WELL-BEING IN POST-COVID SYNDROME

To evaluate the general well-being of participants in post-COVID syndrome, I used the WHO Five Well-Being Index (WBI-5). The Hungarian version was validated in 2006.[16] The Hungarian population has an average point of 7.8 (SD = 3.8). The sample's **average point before COVID infection was 10.1**, which means the aviation-related personnel's well-being is better in general than the Hungarian average. This may be explained by the greater health-awareness of this population due to the regular medical screening. Also, those working in aviation are better paid because of the shortage of professionals. The **average well-being point in post-COVID was only 7.38** (SD = 3.550); a paired t-test between the pre- and post-COVID values proved a significantly worse well-being after COVID infection.

Interestingly, the average WBI-5 point among professional and contract soldiers in a 2022 survey, conducted with 172 participants, was 9.01 points (SD = 2.52, Cronbach's alpha: 0.82),[17] which means that aviation personnel's general well-being is higher than that of the

[16] Susánszky et al. 2006.
[17] Hornyák 2022.

military in general. The explanation for this result might be the inclusion of civilian aviators in the present survey, many of whom are hobby pilots, and the fact that both military and civilian aviators are well paid. Both of these factors can explain the higher well-being results of aviators compared to either the Hungarian national or the general military population average.

SUMMARY

The human factor is a key component in aviation safety. Despite modern aviation technologies and flight assistant systems, human factor error remains the main source of mistakes in aviation. Therefore, every condition that might increase the likelihood of human errors must be identified, analysed, and addressed to mitigate the risks. The most common and long-lasting symptoms of post-COVID and long COVID syndromes belong to the group of factors highly influencing human performance (such as fatigue, brain fog, and sleeping disorders). It means that post-COVID syndrome poses a relatively high risk to aviation safety.

In this study, I aimed to investigate the prevalence, severity, and time factor of aviation safety-related post-COVID symptoms in the Hungarian military and civilian aviation population, evaluate their aviation safety risks, and make recommendations to mitigate these risks. The preliminary results of the survey confirmed the hypothesis that the above-mentioned post-COVID symptoms occur and persist for a long time after the COVID infection. Some of the discussed problems, like sleeping disorders, not only last long, but their prevalence does not significantly decrease over a period of 12 months. Therefore, we should pay more attention to the long-term cumulative performance-reducing effects of these to avoid aviation safety risks.

The general validity of the data published in this article is limited, as the survey is still in progress. The preliminary results are based on 66 participants' answers, with a slightly higher average age (44.85 years) and, therefore, a higher prevalence of existing chronic diseases among the participants (44.8%). To avoid data bias, the survey has to be continued to collect more data and improve validity for the aviation population.

According to these preliminary data, we have to keep in mind that the cumulative effect of many post-COVID symptoms builds up a complex human performance-degrading system, which may significantly increase the likelihood of human errors related to aviation safety risks. One of the most common human factor errors is fatigue, and post-COVID syndrome develops severe and long-lasting fatigue, which can be aggravated by other post-COVID symptoms as well. Until today, a subjective questionnaire is used to measure fatigue, and self-evaluation might be deceiving in a highly task-oriented aviation environment. Thus, it would be beneficial to research the possible methods of measuring fatigue objectively. For this aim, the next part of this study will investigate the possible use of electroencephalography (EEG) biosensors for fatigue measurement.

The available preliminary results of the research already provide deductions that can offer new aviation safety recommendations, such as education programs to highlight the importance and prevalence of post-COVID fatigue and other human performance-challenging aviation safety-related post-COVID symptoms, while also raising attention to implement fatigue management preventive measures, even more importantly in the post-COVID period.

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