Return to flying duties of German military pilots after recovery from COVID-19

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ABSTRACT

Background Pilots are working in a unique and exacting environment with hypobaric hypoxia and acceleration forces. In military flying, missions are often challenging with possible combat scenarios and in remote areas with impaired infrastructure.

Methods We analysed all German military pilots and pilot candidates with confirmed SARS-CoV-2 infection, who have all been evaluated prior to their return to flying duties between April 2020 and January 2022 by the German Air Force Centre of Aerospace Medicine. Symptoms, comorbidities, scope of investigations, examination results, vaccination status and aeromedical disposition are described.

Results 90 pilots (82 active pilots and 8 pilot candidates) with a median age of 35 years (IQR 15 years) were included. 78 pilots (87%) reported symptoms, with median duration of 6 days. Symptoms included influenza-like symptoms (70.0%), headache (45.6%), impaired physical fitness (37.8%), anosmia/ageusia (36.7%), fever (27.8%), exertional dyspnoea (8.9%), memory and concentration disorders (4.4%), diarrhoea (3.3%) and dyspnoea at rest (2.2%). Only one pilot (1.1%) was hospitalised, two (2.2%) required outpatient treatment. All pilots were allowed to return to unrestricted flying duties after the assessment, with eight (8.9%) reporting ongoing mild symptoms.

Conclusion Due to their demanding working environment, pilots, and other high-hazard employees, should undergo medical evaluation prior to return to their duties to exclude ongoing symptoms and the development of post-acute COVID-19 or post-COVID-19 syndrome. The scope of examinations may depend on the severity of the disease, comorbidities, the vaccination status, the predominant SARS-CoV-2 variant and the type of aircraft flown.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ COVID-19, caused by an infection with SARS-CoV-2, is a systemic multiorgan disease involving lungs, heart and other organ systems, and possibly leading to post-acute COVID-19 or post-COVID-19 syndrome.

WHAT THIS STUDY ADDS

⇒ Due to the physically demanding and exacting working environment of military pilots, they should undergo medical evaluation prior to return to flying duties to exclude ongoing symptoms, and subclinical pulmonary or cardiac involvement.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ The scope of examinations should depend on the severity of the disease, comorbidities, vaccination status, the predominant SARS-CoV-2 variant and the type of aircraft flown. Medical evaluation may be done primarily by the local flight surgeon and, in case of severe symptoms or abnormal examination results, by specialists at centres for aerospace medicine.

INTRODUCTION

In some patients, the acute symptomatology caused by SARS-CoV-2 infection can be followed by a long COVID-19 or post-COVID-19 syndrome, which is still not completely understood, and which is independent of the severity of the acute disease. Typical symptoms are fatigue, dyspnoea, concentration disorders, joint and muscle aches, anosmia, ageusia, headache, gastrointestinal or cardiac symptoms. These symptoms are reported to last more than 3 months.[1 2] On 6 October 2021, WHO published a clinical case definition of post-COVID-19 condition[3] 2021. According to this definition, post-COVID-19 syndrome occurs in persons with likely or confirmed SARS-CoV-2 infection, usually 3 months after COVID-19 infection, with symptoms lasting for at least 2 months, and which cannot be explained by a different diagnosis. Long COVID-19 or post COVID-19 symptoms can be challenging to investigate for employees in high-hazard occupations with high physical and/or cognitive demands and may entail significant occupational restrictions.[4]

Pilots are working in a unique and exacting environment with potential hypobaric hypoxia and acceleration forces, especially in high-performance aircraft. In military flying, missions are often challenging, may include combat scenarios and are performed in remote areas with impaired infrastructure.[5]

Some organ manifestations have a direct influence on the ability of pilots to cope with physiological challenges, especially in fast jets.[6] Flying in high altitude results in hypobaric hypoxia even in pressurised cabins. Fast jet pilots are breathing through oxygen masks. In some jets, positive pressure breathing is required as a countermeasure against high acceleration forces (G forces) and to maintain adequate oxygenation. But the ACE-2 receptor is present on type II alveolar epithelial cells, and SARS-CoV-2 can lead to alveolar injury and interstitial inflammation. Resulting hypoxia is often silent and paradoxically well tolerated in early disease stages, possibly endangering affected pilots during flying operations. ACE is also present in

several kidney cells, where SARS-CoV-2 can lead to injury via an uncontrolled systemic inflammatory response and alterations in renal haemodynamics. Kidney dysfunction can be deteriorated by dehydration during many flying operations, although it preferably occurs in severe disease manifestations. Haematological manifestations by SARS-CoV-2 can be cytokine-induced lymphopenia, systemic inflammation and blood hypercoagulability with an increased risk of thromboembolism during flying. The higher executive function which is required for flying can be impaired by variable nervous system involvement. Finally, G tolerance can be impaired by cardiac involvement including myocarditis, acute myocardial infarction, heart failure and tachyarrhythmias. Many cardiac manifestations would lead to sudden incapacitation with a total disability to fly an aircraft.

After acute disease, the exceptional strain of flying operations can be aggravated if aircrew have not completely recovered from COVID-19 and have the potential to lead to in-flight incidents and ultimately increase the risk of accidents. Aircrew and those working in aviation can be prevented from performing their duties by such symptoms in combination with fatigue and/or anosmia.[7 8] A medical examination before return to flying duties and sustained medical surveillance are therefore mandatory for pilots, especially in the military. Despite periodical medical examinations (PMEs) of aircrew, studies analysing the ramifications of COVID-19 and post-COVID-19 symptoms on this specific occupational group are lacking.

The aim of this study was to describe symptoms and the course of disease of active German military pilots with confirmed SARS-CoV-2 infection, to analyse their recovery and to derive recommendations for the medical workup before return to flying duties after recovery from COVID-19.

METHODS

We analysed all German military pilots from all services (Air Force, Army and Navy) flying fast jets, fixed wing aircraft, helicopters and remotely piloted aircraft with previous SARS-CoV-2 infection between April 2020 and January 2022. They were all examined at the German Air Force Centre of Aerospace Medicine (GAFCAM) in Fuerstenfeldbruck, Germany, for aeromedical assessment prior to their return to flying duties. Weapon system officers were analysed in the same category as fast jet pilots. Pilot applicants who have already joined the German Armed Forces but who have not yet started their flight training were also captured in the analysis.

The evaluation at the GAFCAM covered pulmonary assessment and an exclusion of cardiac pathology. Other specialties, including ear, nose and throat (ENT), neurology and psychiatry, were also involved depending on the symptomatology. Standard evaluation consisted of medical history, physical examination, laboratory investigations, a 12-lead resting ECG, echocardiography and formal pulmonary function tests (including body plethysmography and diffusion capacity of carbon monoxide to test for cardiac and/or pulmonary pathology). Laboratory testing consisted of blood count, C reactive protein, lactate dehydrogenase, creatine kinase (CK) and its isoenzyme CK-MB. Echocardiography mainly focused on cardiac chamber sizes, left ventricular ejection fraction and the estimation of systolic pulmonary artery pressure in case of a visible tricuspid regurgitation. In case of abnormal findings, CT or MRI was added as appropriate. During pulmonary function testing, the following parameters were captured: FEV_1 (forced expiratory volume in one second in per cent of reference value) and VC (vital capacity in per cent of reference value). DLCO (diffusing capacity of the lung for carbon monoxide in per cent of reference value) and Krogh index (DLCO/alveolar volume in per cent of reference value) were analysed in 69 of 90 cases. Left ventricular ejection fraction (LVEF) was measured during echocardiography and in cases of mild tricuspid regurgitation, systolic pulmonary artery pressure was assessed. LVEF ≥50% was regarded as normal, corresponding with the current European Society of Cardiology (ESC) guidelines on heart failure.[9] Concomitant disease, symptomatology during COVID-19, allergies, age, body mass index (BMI), and nicotine use were all captured and correlated with possible post-COVID-19 symptoms.

Statistical analyses were conducted using IBM SPSS Statistics for Windows V.24 (IBM Corp, Released 2016). Data analysis was primarily descriptive. The Kolmogorov-Smirnov test revealed none of the nominal scale parameters was normally distributed, so median and IQR were calculated. Differences were analysed with Pearson's X^2 test, and for independent samples, Mann-Whitney U test was used. Significance level was defined as $p<0.05$. Additionally, we calculated ORs with 95% CIs to identify possible predictors for long-term symptoms.

RESULTS

In our study, 90 pilots with previous confirmed SARS-CoV-2 infection (82 active pilots and 8 pilot candidates) were evaluated prior to their return to flying duties. Eighty-eight of ninety were male aged between 20 and 62 years of age, with a median of 35 years (IQR 15 years). The median BMI was 25 kg/m^2 (IQR 3.5 kg/m^2). In 88 individuals, SARS-CoV-2 infection was confirmed by PCR, in one case by rapid antigen test, and in one case this was not reported. Seventy-eight of ninety pilots (87%) reported COVID-19 symptoms, but only one pilot (1%) required hospitalisation. Outpatient treatment was required in two cases (2%).

Symptoms of COVID-19 differed between aircrew, from 63% for influenza-like symptoms to 2% for dyspnoea at rest. Percentages and absolute numbers are presented in Figure 1.

The median duration of COVID-19 symptoms was 6 days (IQR 9 days) with a maximum of 270 days. At the time of the evaluation (median 85 days after beginning of symptoms), eight (9%) pilots had ongoing COVID-19 symptoms.

Thirty pilots (33%) were vaccinated against SARS-CoV-2 at least once at the time of infection, while 60 (67%) were not. In 17 of those vaccinated, the vaccine Comirnaty by BioNTech (Mainz, Germany) was used, in 10 pilots the Spikevax by

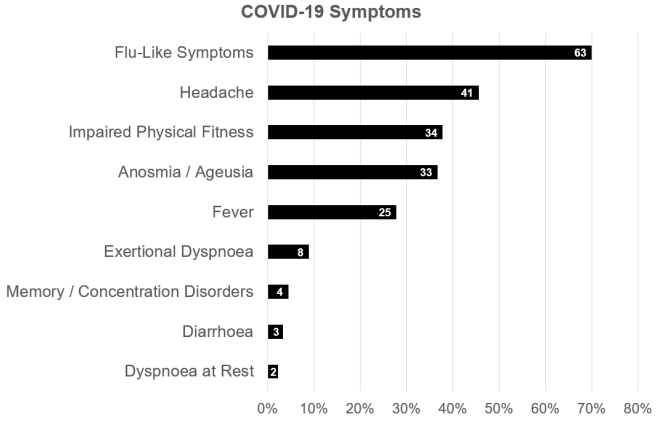

Figure 1 COVID-19 symptoms reported by the 90 pilots analysed (82 active pilots and 8 pilot applicants) in absolute numbers and percentages. Percentages are shown on the x-axis, absolute numbers are added in the bars.

Table 1 Laboratory results with median, IQR and number of pilots with pathologies

			Median (IQR)			Number of pilots with pathologies			
Parameter (unit)	**Normal range**	**n all**	**All**	**Vac**	**n-Vac**	**All**	**Vac**	**n-Vac**	**P value**
CRP (mg/dL)	<5	81	1.0 (0.25)	1.0 (0.0)	1.0 (1.5)	4%	7%	2%	0.279
LDH (U/L)	<225 ♂ <214 ♀	77	169.0 (32.3)	163.0 (30.5)	172.0 (37.5)	5%	4%	6%	0.628
Haemoglobin (g/L)	140–175 ♂ 120–155 ♀	82	150 (10)	150 (6)	160 (10)	11%	17%	8%	0.210
Leucocytes (10^9/L)	4.0–11.0	82	6.0 (2.0)	6.0 (2.0)	6.7 (1.5)	9%	0%	14%	**0.036**
Thrombocytes (10^3/µL)	140–345	82	241.0 (51.5)	238.0 (75.0)	243.0 (44.0)	4%	3%	4%	0.905
CK (U/L)	<225 ♂ <214 ♀	73	115.0 (65.0)	119.0 (93.5)	114.0 (63.5)	19%	23%	17%	0.529
CK-MB (U/L)	<23	72	12.0 (4.0)	12.0 (6.0)	12.0 (4.0)	4%	4%	4%	0.919
ΔFEV_1		82	101% (7%)	102% (7%)	101% (8%)				
ΔVC		82	101% (5%)	102% (4%)	100% (5%)				
ΔFEV_1/FVC		82	99% (4%)	98% (6%)	100 (4%)				

For pulmonary function testing, the current results are compared with the last results before SARS-CoV-2 infection. Differences were calculated by the ratio 'values prior to SARS-CoV-2 infection/values post-SARS-CoV-2 infection'.
The bolded entry means that there is a significant difference (p<0.05).
CK, creatine kinase; CK-MB, creatine kinase isoenzyme MB; CRP, C reactive protein; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; LDH, lactate dehydrogenase; n, number; n-Vac, non-vaccinated; Vac, vaccinated; VC, vital capacity.

Moderna (Cambridge, Massachusetts, USA), and in 3 Janssen by Johnson & Johnson (New Brunswick, New Jersey, USA).

Fifty-three of ninety (61%) pilots had no concomitant disease, while 23 (26%) had known allergies, 2 (2%) had known bronchial asthma, 15 (17%) had known cardiovascular disease, and in 8 (9%) of cases, an autoimmune disease was reported including autoimmune thyroiditis.

The results of the laboratory testing are shown in Table 1. Most of the pilots have shown no abnormal values. In nearly one-fifth, CK was above normal range. A comparison of vaccinated and non-vaccinated pilots shows that leucocytes were significantly higher in non-vaccinated than in vaccinated pilots.

No abnormality was detected with echocardiography, and in eight pilots (9%), DLCO was slightly below 80% of the predicted value, without any signs of pulmonary disease and without any significant difference regarding the vaccination status (p=0.568). A comparison between pulmonary function test results before and after SARS-CoV-2 infection shows no reduction of FEV_1, VC or FEV_1/forced VC in any pilot. All pilots returned to flying duties after the evaluation by the GAFCAM.

Eight pilots still reported symptoms beyond the time of their last examination. In median, the last examination of these eight pilots was 148 days after their positive test result (minimum 26, maximum 314 days). From all infected pilots, eight could be classified with 'ongoing symptomatic COVID-19' (symptoms 4–12 weeks following initial symptoms) and additional six with 'post-COVID-19-syndrome' (symptoms beyond 12 weeks following initial symptoms) according to National Institute for Health and Care Excellence guidelines.[2] Table 2 shows ORs for the association between variable conditions and the presence of symptoms beyond the time of evaluation.

A prediction of 'ongoing symptomatic COVID-19' or 'post-COVID-19 syndrome' was not possible in our cohort. The analysed parameters showed no significant association with the persistence of symptoms beyond the time of examination. On the other hand, none of the pilots without influenza-like symptoms had ongoing symptoms beyond the time of examination.

DISCUSSION

To the best of our knowledge, this is the first systematic analysis of military pilots infected by SARS-CoV-2 published. Pilots work in a demanding environment with particularly high physical strain on the cardiorespiratory systems of many military aviators, secondary to sustained acceleration, hypobaric hypoxia, operational pressure, circadian disruption and poor infrastructure in the military environment.[5] A sudden incapacitation in-flight for medical reasons could endanger not only the pilots themselves but also others affected by a possible aircraft accident and/or mission abortion. Therefore, a medical examination before return to flying duties is mandatory.[10] The manner and extent of such an examination, however, may be different between different countries and licensing authorities[4 10]; and it has to be adapted to the particular situation with regard to vaccination status of the population or collective, the SARS-CoV-2 variant, the type and severity of symptoms, and the type of aircraft flown.

During the data acquisition phase of this study, the Delta variant was the predominant variant, with just one-third of the pilots vaccinated against SARS-CoV-2. Due to the lack of significant pathology detected, all pilots were allowed to return to

Table 2 ORs for the association between variable conditions and the persistence of symptoms beyond the time of examination

Condition	OR (95% CI)
Duration of symptoms ≥7 days	1.56 (0.37 to 6.70)
Anosmia/ageusia	1.04 (0.23 to 4.66)
Impaired physical fitness	1.73 (0.40 to 7.44)
Fever	0.86 (0.16 to 4.55)
Exertional dyspnoea	4.22 (0.70 to 25.63)
Headache	1.22 (0.29 to 5.20)
Allergies	1.86 (0.41 to 8.48)
No concomitant disease	1.18 (0.26 to 5.28)
Smoker	2.63 (0.46 to 15.04)
Previous vaccination (SARS-CoV-2)	1.22 (0.27 to 5.50)

None of the listed conditions had the potential to predict ongoing symptoms and a possible development of a 'post-COVID-19 syndrome'.

flying despite persisting mild symptoms in eight (9%) of them. Only one required hospitalisation and two medical support due to COVID-19 symptoms. These low numbers are probably caused by the good health status of this medically preselected, regularly examined and comparatively young cohort.

Recently, the predominant variant of SARS-CoV-2 has changed to Omicron. This variant is more contagious than the Delta variant; however, the severity of symptoms and the number of hospitalisation seem to be lower.[11] Meanwhile, now most German pilots are fully vaccinated and boosted. Consequently, while there are more pilots infected by SARS-CoV-2, most are completely asymptomatic or with very mild symptoms. As our data show, even pilots who were infected by the Delta variant and, at the time not vaccinated, all returned to flying duties with very few needing hospitalisation or outpatient treatment. Fully vaccinated German military pilots can now be evaluated by the local flight surgeon with a reduced scope of examinations including medical history, physical examination, basic laboratory tests, ECG and spirometry after SARS-CoV-2 infection. Further examinations are added depending on symptoms and in the event of abnormal examination results. If physical fitness is unclear prior to return to flying duties, especially in high-performance pilots, an exercise ECG including measurement of oxygen saturation (SpO_2) may be performed.

As the lack of symptoms during or after recovery from SARS-CoV-2 infection does not exclude subclinical pulmonary and/or cardiac involvement, some authors recommend long-term monitoring for all subjects after recovery.[12] The authors observed a correlation of the severity of post-COVID-19 manifestation with the severity of the infection and the presence of comorbidities. The study was based on a questionnaire about demographic data, COVID-19 status, comorbidities and COVID-19 manifestations, which COVID-19 survivors had to complete. For pilots, this long-term monitoring could be done during their annual PME.

Similar to our approach during the previous COVID-19 waves, many Air Forces of other countries examine their pilots after recovery from COVID-19 prior to return to flying duties.[5] The Israeli Aeromedical Center's recommendations to flight surgeons on the medical workup required before military aviators return to flight duties after recovery from COVID-19 have been published by Gilad and coworkers.[10] Their recommended scope of standard examinations includes complete blood count, basic metabolic panel, urinalysis, chest radiography, ECG, basic pulmonary function tests, audiology and examination by an ENT specialist and by an ophthalmology specialist, flight surgeon evaluation and referral to an aeromedical psychiatrist in case of suspected psychosocial impact. Ancillary tests recommended for high-performance aviators and pilot cadets include pulmonary plethysmography, diffusion capacity of carbon monoxide and reduced oxygen breathing device training.[10] For other flying classes, these ancillary tests are only undertaken in case of pathology found in standard aeromedical evaluation. In contrast to our initial approach, diffusion capacity of carbon monoxide is only measured in high-performance aviators and pilot cadets. A transthoracic echocardiography is only performed in case of abnormalities in their standard examinations. From our perspective, an adaptation of this comprehensive approach to the current situation could be discussed, as in our cohort, all pilots were able to return to flying duties, even though most of them were infected with the Delta variant. Currently, we would recommend a standard evaluation consisting of medical history, physical examination, 12-lead resting ECG and spirometry. A measurement of SpO_2 at rest and after a simple standardised stress test (eg, 6 min walk test, two flights of stairs) can be added, as recommended in a recently published review article.[4] Individuals with abnormal test results or with severe courses of disease should be referred for further assessment.

The presented study has particular strengths and some limitations. One of the strengths is the comprehensive analysis of all pilots infected with SARS-CoV-2 in the German Armed Forces. All the assessments were done at GAFCAM. A limitation of this study is the low number of included pilots limiting the value of the statistical analysis. This low number, however, reflects the situation prior to the emergence of the Omicron variant, when the number of cases increased. Additionally, it is possible that pilots without, or with very mild, symptoms were not tested, and that under-reporting exists. However, the development of ongoing symptomatic COVID-19 or post-acute COVID-19 syndrome in such pilots would be unlikely.

CONCLUSION

Due to their demanding working environment, pilots, and other high-hazard employees, should undergo medical evaluation prior to return to their duties. Ongoing symptoms, and subclinical pulmonary or cardiac involvement possibly leading to post-acute COVID-19 or post-COVID-19 syndrome, must be excluded to ensure full physical and mental fitness to safely execute their tasks. The scope of examinations will depend on the severity of the disease, comorbidities, vaccination status, the predominant SARS-CoV-2 variant and the type of aircraft flown. This should be done primarily by the local flight surgeon and, in case of severe symptoms or abnormal examination results, by specialists at centres for aerospace medicine.

Contributors TA and NJG designed the study, TA and NJG collected the data. SS did the statistical analysis. TA, NJG and EN drafted the manuscript. All authors critically revised the manuscript for critical intellectual content. All authors gave their final approval and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the article are appropriately investigated and resolved. NJG acted as a guarantor taking full responsibility for the content of the article.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval According to the regulations of the Bavarian Medical Association, the responsible authority for this study, a vote of the ethics committee was not necessary for this retrospective analysis.

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Data availability statement Data are available upon reasonable request.

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