Dissertation

The prevalence of long covid disease in (male) conscripts at the military induction board

Submitted by

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2026

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Disclosures

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I confirm that all co-authors have explicitly agreed to the use of their data in this thesis and that I have permission to reproduce all data, figures and tables published in Domanyi et al (1), as this article is published open access under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) license.

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Abbreviations and Definitions

ACE-2	Angiotensin Converting Enzyme 2
BMI	Body Mass Index
CI	Confidence Interval
COPD	Chronisch obstructive Lungenerkrankung
COVID-19	Coronavirus Disease 2019
CRP	C-Reactive Protein
EASO	European Association for the Study of Obesity
FEV1	Forced Expiratory Volume in One Second
ICH	International Council for Harmonization
IQR	Interquartile Range
ME/CFS	Myalgische Enzephalomyelitis / Chronisches Fatigue-Syndrom
NICE	National Institute for Health and Care Excellence
OR	Odds Ratio
PCS	Post-Covid-Syndrom
RSV	Respiratory Synzytial-Virus
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus Type 2
SPSS	Statistical Package for the Social Sciences
VC	Vital Capacity
WC	Waist Circumference
WHO	World Health Organization
WHtR	Waist-to-Height Ratio

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Abstract in German

Einleitung: Anhaltende Beschwerden nach einer COVID-19-Infektion stellen weiterhin eine medizinische Herausforderung dar. Während viele Studien ältere oder vorerkrankte Personen untersuchten, gibt es deutlich weniger Daten zu jungen, gesunden Männern. Aktuelle Studien zeigen, dass Übergewicht mit einem erhöhten Risiko für Post-COVID-19 assoziiert ist, wobei Daten zur abdominellen Fettleibigkeit fehlen. Ziel dieser Arbeit war es somit, die Häufigkeit von Post-COVID-19 bei österreichischen Wehrpflichtigen zu bestimmen und Übergewicht sowie abdominelle Fettleibigkeit als mögliche Risikofaktoren zu analysieren.

Material und Methoden: Im Rahmen einer Querschnittsstudie wurden 500 männliche Wehrpflichtige im Alter von 17 bis 19 Jahren während der militärischen Stellung in Graz zwischen Mai 2024 und Juni 2025 untersucht. Neben der standardisierten medizinischen Untersuchung wurde zusätzlich ein Fragebogen zu COVID-19-Infektion, Impfstatus und anhaltenden Symptomen erhoben. Körpergewicht, Größe und Taillenumfang wurden routinemäßig im Rahmen der Stellung gemessen, woraus der BMI und die Waist-to-Height-Ratio berechnet worden sind.

Ergebnisse: Von 376 Teilnehmern mit durchgemachter COVID-19-Infektion berichteten 21% persistierende oder neu aufgetretene Beschwerden durchgemacht zu haben. Die häufigsten genannten Symptome waren Müdigkeit, Kopfschmerzen sowie Muskel- und Gelenkschmerzen. Zwischen Impfstatus, Laborwerten, Lungenfunktion oder Rauchverhalten und Post-COVID-19 zeigte sich kein signifikanter Zusammenhang. Dagegen waren BMI-definiertes Übergewicht, erhöhter Taillenumfang und erhöhte Waist-to-Height-Ratio signifikant häufiger bei Betroffenen. In multivariablen Analysen erwiesen sich diese Parameter als unabhängige Prädiktoren.

Schlussfolgerung: Post-COVID-19 ist eine Erkrankung die häufig auch junge Männer betrifft. Übergewicht und abdominelle Fettleibigkeit stellen relevante Risikofaktoren dar. Frühzeitige Prävention und Gewichtskontrolle könnten dazu beitragen, das Risiko für anhaltende Beschwerden nach COVID-19 zu reduzieren.

Abstract in English

Introduction: Persistent symptoms after COVID-19 remain a relevant health concern. While most research has focused on older or chronically ill populations, data on young otherwise healthy men are limited. Recent evidence suggests that overweight is associated with an increased risk of post-COVID-19 condition, whereas data on abdominal obesity are still scarce. The aim of this study was to determine the prevalence of post-COVID-19 condition among Austrian male conscripts and to evaluate overweight and abdominal obesity as potential risk factors.

Materials and Methods: In this cross-sectional study, 500 male conscripts aged 17 to 19 years were examined during mandatory military medical screening in Graz, Austria, between May 2024 and June 2025. In addition to standardized clinical assessments, participants completed a survey addressing COVID-19 infection history, vaccination status, and persistent symptoms after the infection. Body weight, height, and waist circumference were routinely measured during the induction examination, and BMI as well as waist-to-height ratio were subsequently calculated.

Results: Among 376 participants with a previous COVID-19 infection, 21% reported ongoing or newly developed symptoms. Fatigue, headache, and musculoskeletal pain were the most frequent complaints. No significant association was found between post-COVID-19 condition and vaccination status, laboratory findings, lung function, or smoking. In contrast, general and central obesity were significantly more common in affected individuals. In regression analyses, BMI-defined obesity, increased waist circumference, and elevated waist-to-height ratio remained independent predictors.

Conclusion: Post-COVID-19 condition also frequently affects young men. Overweight and abdominal obesity may represent relevant risk factors. Early prevention strategies and weight management may help reduce the risk of persistent symptoms following COVID-19 infection.

1 Introduction

1.1 SARS-CoV-2

In 2019, SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus Type 2) was first identified in Wuhan, China. The coronavirus family owes its name to its characteristic appearance under an electron microscope. The virus's surface resembles a crown (Latin: "corona"). SARS-CoV-2 belongs to the genus of beta coronaviruses and is classified as an RNA virus. The genetic material of SARS-CoV-2 contains around 30,000 building blocks, making it the largest genome found in any RNA virus. Coronaviruses have a special repair tool that corrects errors when the virus copies itself. Still, the virus changed a lot during the pandemic. At first, it picked up about two mutations per month, but this speed increased over time. Several important variants appeared, such as Alpha, Beta, Gamma, Delta, and Omicron in late 2021. Each of these carried changes in the Spike protein that made the virus either spread more easily or helped it partly escape the body's immune defenses (2).

Like the earlier SARS-CoV and MERS-CoV, SARS-CoV-2 most likely came from animals. Bats are thought to be the main natural host, but because the virus is still quite different from the closest bat viruses known, it probably did not jump directly from bats to people. Instead, one or more other animal species likely played a role in passing the virus on. It is also known that SARS-CoV-2 can spread from humans back to animals (2).

SARS-CoV-2 can lead to the Coronavirus disease 2019 (COVID-19). This condition was classified as a public health emergency of international concern by the WHO between January 30, 2020, and May 2023. SARS-CoV-2 spread worldwide within a few months and led to several pandemic waves due to a succession of SARS-CoV-2 variants (3,4).

1.1.1 Route of infection and incubation period

SARS-CoV-2 enters the host cell via angiotensin converting enzyme 2 (ACE-2). ACE-2 receptors are found primarily in the respiratory tract, intestinal tract, and vascular cells of the kidneys and heart. Infection usually occurs through droplet infection (coughing, singing, shouting, etc.) over a short distance, but transmission over longer distances is also possible if the air in a closed room is particularly rich in the virus. People are considered infectious from shortly before the onset of symptoms until approximately five days afterward. Even asymptomatic individuals can transmit the virus, even though they do not become ill

themselves. Other routes of transmission are possible—but are likely to play a minor role in the overall spread of the infection (5).

1.1.2 Clinical Symptoms

SARS-CoV-2 primarily causes acute respiratory disease. The most common symptoms include cough, runny nose, fever, sore throat, and breathing difficulties. As the disease progresses, it can lead to pneumonia, which may require hospitalization or even intensive care. The gastrointestinal tract may also be affected. This manifests itself in nausea, abdominal pain, vomiting, loss of appetite, and diarrhea. Neurologically, headaches, dizziness, and confusion may occur, as well as loss of smell and taste. Pre-existing neurological conditions may worsen as a result of a COVID infection. The infection can also lead to heart failure, myocarditis, heart attack, or arrhythmia. Thromboembolic events are also possible, as well as impaired kidney function. Measles-like skin rashes have been reported, as well as papules, skin blisters, and nonspecific skin redness (6,7).

Older people, immunosuppressed patients, and those with certain chronic pre-existing conditions such as diabetes, cancer, cardiovascular, liver, respiratory, and kidney diseases can be particularly severely affected (8).

1.1.3 Diagnostics

Clinically, a COVID-19 infection cannot be distinguished from other respiratory infections. Therefore, a definitive diagnosis can only be made with the help of diagnostic tests to detect the virus. In the laboratory, PCR is the gold standard for detecting COVID-19 in terms of sensitivity and specificity. Antigen testing is available as a rapid test, often also offered as a combined rapid test that also detects RSV or influenza A/B (9).

Similarly, serological detection of antibodies against SARS-CoV-2, which are produced by the human immune system following exposure to the antigen through infection or vaccination, is possible. These tests are primarily used for scientific purposes. Antibodies against the spike protein and the nucleocapsid protein are detected to distinguish between immunity resulting from vaccination and that resulting from SARS-CoV-2 infection. N-Ak proves SARS-CoV-2 infection (9).

1.1.4 Treatment

Immunocompetent, otherwise healthy patients with COVID-19 do not require specific therapy. Treatment is purely symptom-oriented.

However, Individuals who may be at increased risk of severe COVID-19 should be prescribed antiviral therapy as early as possible, ideally within the first five days after symptom onset. Paxlovid, a combination of the protease inhibitor nirmatrelvir and the booster ritonavir, is taken orally over five days and has been shown to lower the risk of hospital admission and death in mild to moderate cases. Another antiviral drug, remdesivir, works by blocking the enzyme that copies the viral genetic material. It was mainly used in hospitalized patients and helped shorten recovery time, although its effect on overall mortality remained limited. A third option, molnupiravir, causes errors during viral replication and was found to reduce the progression to severe illness in high-risk patients when given early. It is important to note that possible drug interactions should be checked before starting any antiviral therapy, and confirmation of the diagnosis by PCR should not delay the beginning of treatment (10).

In more severe cases, such as those involving pneumonia or breathing difficulties, the treatment plan needs to be expanded. Corticosteroids, especially dexamethasone, have proven effective in reducing death rates among patients who need supplemental oxygen or mechanical ventilation by dampening the overactive immune response often seen in critical COVID-19. Additionally, drugs that target specific parts of the immune system, such as the interleukin-6 receptor blocker tocilizumab, have been used to control the excessive inflammation known as cytokine storm. Because COVID-19 can also trigger serious blood clotting problems, including deep vein thrombosis and pulmonary embolism, preventive anticoagulation with low-molecular-weight heparins is considered standard practice for hospitalized patients, particularly those who are older, have other health conditions, or are not fully mobile (10).

1.1.5 Preventive Measures

As with all respiratory infections, people with COVID-19 should limit contact with others during the acute phase of the illness and stay home until their symptoms have significantly improved. If contact with others is unavoidable, a face mask should be worn. Hospitals should ensure that patients with COVID-19 are physically separated from other patients.

To prevent severe disease progression, the Austrian Vaccination Committee recommends an annual COVID-19 vaccination booster in the fall for all individuals aged 60 and older, as well as for those with specific medical conditions, in addition to the primary vaccination series. Specific medical conditions include: pregnancy, individuals with Down syndrome, pre-existing respiratory, cardiac, renal, endocrine, metabolic, neurological, or chronic inflammatory conditions, cancer, immunodeficiencies or immunosuppressive therapy, HIV infection, organ/bone marrow transplantation, obesity (BMI > 30), and residents of nursing homes (11).

1.2 Long-COVID / Post-COVID

According to the current state of scientific knowledge, long or post-COVID illness cannot be viewed as a uniform clinical picture. This is evident simply from the multitude of names used to describe similar conditions, none of which have yet been clearly validated. Rather, the terms “Long/Post-COVID,” “Post-COVID syndrome,” or “Post-COVID-19 condition” are used to describe a wide variety of somatic, cognitive, and psychological symptom complexes in a purely descriptive and inconsistent manner. What these terms have in common is the onset/persistence of symptoms following a previous SARS-CoV-2 infection (12). In the ICD-10 classification, this condition is categorized under U09.9 as “post-COVID-19 condition” (13).

1.2.1 Definitions

In 2020, long COVID was first defined by the UK’s National Institute for Health and Care Excellence (NICE) as “health symptoms that persist, recur, or emerge beyond the four-week acute phase of a SARS-CoV-2 infection.” Post-COVID syndrome refers to symptoms that are still present more than twelve weeks after the onset of SARS-CoV-2 infection (longer than two months in children) and cannot be explained by other causes” (14).

In 2021, the WHO published a clinical case definition for post-COVID-19 condition in adults. According to this definition, post-COVID-19 condition occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually within three months from the onset of COVID-19. Symptoms must last for at least two months and must not be explained by an alternative diagnosis. Common symptoms include, but are not limited to, fatigue, shortness of breath, and cognitive dysfunction. These symptoms generally have an impact on everyday functioning. They may either persist from the initial acute infection or newly develop after initial recovery. In addition, symptoms may fluctuate or relapse over time. Importantly, the WHO

definition does not require a specific minimum number of symptoms, and symptoms may involve different organ systems or occur in symptom clusters(15).

In 2023, the WHO published a separate clinical case definition for children and adolescents. This definition also applies to individuals with a history of confirmed or probable SARS-CoV-2 infection and describes symptoms lasting for at least two months that initially occur within three months of acute COVID-19. In children and adolescents, symptoms more frequently reported compared with controls include fatigue, altered smell or anosmia, and anxiety. Other reported symptoms include cognitive difficulties, cough, dyspnoea, headache, loss of appetite, myalgia, joint pain or swelling, gastrointestinal symptoms, palpitations, dizziness, earache or ringing in the ears, and eye or throat symptoms. The WHO emphasizes that symptoms in children and adolescents are often non-specific and may also occur with other childhood infections or illnesses. Therefore, the diagnosis should consider the impact on everyday functioning, including changes in eating habits, physical activity, behaviour, academic performance, social interactions, and developmental milestones. As in adults, symptoms may persist, newly develop after recovery, fluctuate, or relapse over time (16).

1.2.2 Prevalence

It is very difficult to quantify the prevalence of post-COVID condition, as there has long been no standard definition and many studies have lacked a control group. A recent global systematic review and meta-analysis reported an overall pooled prevalence of post-COVID condition of about 42%. However, a large variability was observed across studies, with reported prevalence ranging from 3% to 90% (17).

1.2.3 Symptoms

The range of symptoms associated with post-COVID includes many different physical and/or mental health issues that, whether individually or in combination, significantly impair quality of life, both personally and professionally (17–19).

Typical symptoms include:

- breathing difficulties, shortness of breath, exertional dyspnea, cough
- exhaustion and fatigue, ranging up to fatigue syndrome, and reduced physical capacity at every level, including exercise intolerance (post-exertional malaise)

- impaired sense of smell, up to anosmia
- difficulty concentrating and memory problems
- orthostatic dysregulation, tachycardia
- angina pectoris, palpitations
- headaches
- joint and muscle pain
- nerve pain and other sensory disturbances (“pins and needles and numbness”)
- rashes, hair loss
- sexual dysfunction.

1.2.4 Risk Factors

Several studies have evaluated risk factors for the development of post-COVID-19 condition. Based on systematic reviews and meta-analyses, these factors include older age, hospitalization during the acute phase of COVID-19 infection, smoking, and chronic pre-existing medical conditions like bronchial asthma, COPD, cardiovascular disease, and diabetes. Moreover, women are more likely to develop long COVID. It is believed that both gender-specific differences in the immune system and genetic factors may play a role in this. Additionally, obesity has been identified as a major risk factor for long COVID (20,21).

1.2.5 Pathophysiology

The underlying pathophysiological processes that ultimately lead to the individual long-lasting symptoms after the COVID-19 infection appear to be multifactorial and may vary from person to person. Potential mechanisms include long-term tissue damage, the persistence of viruses or viral components in tissues, chronic hyperinflammation and/or autoinflammation, microbiome dysfunction, reduced mitochondrial function, thrombotic events in the microvasculature combined with impaired function of the vascular endothelium, serotonin reduction, impaired integrity of the blood-brain barrier, and the reactivation of latent viral infections such as EBV, HSV-1/2, or varicella (22–25).

1.2.6 Diagnosis and Treatment

Identifying post-COVID condition in clinical practice remains a major challenge. At present, no single laboratory test or biomarker can confirm the diagnosis with certainty. Standard investigations such as blood tests or imaging studies often return normal results, even when patients report significant ongoing complaints. For this reason, the diagnosis relies mainly on clinical assessment. Physicians must carefully evaluate the patient's history, document all reported symptoms, and rule out other possible medical explanations before attributing symptoms to a prior SARS-CoV-2 infection. A stepwise approach is recommended that begins in primary care and involves specialist referral only when needed. Validated screening tools, such as the Fatigue Assessment Scale and the Post-COVID-19 Functional Status Scale, can help clinicians estimate symptom severity and monitor changes over time (26).

Regarding treatment, no established cure for post-COVID condition currently exists. Management is therefore focused on controlling individual symptoms and supporting patients through their recovery. Non-pharmacological strategies are generally considered the first line of therapy. Among these, pacing plays a central role for patients who experience post-exertional malaise, a hallmark feature in which even mild activity leads to a delayed worsening of symptoms. In patients without post-exertional malaise, supervised and gradually increasing physical activity has been recommended to restore function and prevent deconditioning (26,27).

Based on randomized controlled trials, there is moderate-quality evidence that cognitive behavioural therapy delivered through an online platform can lead to meaningful reductions in fatigue and improvements in concentration among affected individuals. Similarly, a structured rehabilitation program combining supervised physical exercise with psychological support was shown to increase the proportion of patients who experienced clinically relevant recovery, while also reducing depressive symptoms and improving overall quality of life. Furthermore, intermittent aerobic training performed several times per week appeared to offer greater benefits for physical function than continuous exercise at a steady pace (26,27)

In contrast, pharmacological interventions have so far shown limited success. Trials investigating agents such as vortioxetine, coenzyme Q10, a probiotic-prebiotic combination, and several other compounds did not provide convincing evidence of benefit for the core symptoms of the condition. Consequently, drug therapy is not currently regarded as a primary treatment option and is generally reserved for managing specific symptoms on an individual

basis. Given the complexity of this condition, a coordinated, multidisciplinary approach that includes physicians, physiotherapists, psychologists, and occupational therapists is widely considered essential for achieving the best possible outcomes for affected patients (26,27).

1.2.7 Myalgic Enzephalomyelitis and Chronic Fatigue-Syndrom

A specific subform of post-COVID syndrome is myalgic encephalomyelitis and chronic fatigue syndrome (ME/CFS). This condition has been listed in recognized diagnostic manuals for over fifty years. However, very little is known about the nature of this disease complex. ME/CFS has once again come into the focus of medical science due to COVID-19 (28).

This condition is a chronic multisystem disorder that, depending on its severity, can lead to fatigue, an inability to work, or even a complete need for long-term care. The pathogenesis remains unclear. Currently, it is assumed to involve a form of chronic neuroinflammation (29).

ME/CFS occurs in the majority of cases during the post-acute phase of an infection. However, other triggers may include trauma, particularly to the head and neck, or resuscitation procedures. Sometimes, no trigger can be identified at all. About two-thirds of those affected are women of various ages (29).

A specific, confirmatory biomarker for this condition has not yet been identified, which makes diagnosis very difficult. The diagnosis is made based on clinical criteria outlined in various consensus documents, such as the Canadian Consensus Criteria or the “Interdisciplinary, Collaborative D-A-CH Consensus Statement on the Diagnosis and Treatment of Myalgic Encephalomyelitis/Chronic Fatigue Syndrome” (28,30).

There is currently no specific treatment, so patients must receive individually tailored therapies to alleviate their symptoms. Just as there are few treatment options, there are also few experts in this field, meaning that patients often spend years searching for the correct diagnosis and an appropriate treatment. This places an enormous physical, psychological, and often financial burden on those affected. To date, the therapeutic approach has essentially consisted of pacing (a form of activity and energy management) and measures to alleviate symptoms. Unlike other conditions associated with fatigue (such as depression), no therapies based on physical activity are recommended. Physical activity in ME/CFS patients tends to lead to a worsening of their condition (28).

2 Rationale and Study Aims

Long-lasting health problems after COVID-19 have become an important topic in medicine and science. Research shows that adolescents and young adults can also develop symptoms that continue long even after a mild infection (19). These ongoing problems may affect daily physical activities, education, and future job performance. However, evidence for prevalence in young individuals is more limited than for adults (18).

Finding factors that increase risk for post-COVID-19 condition is important for improving patient care, informing the public, and guiding prevention programs. Many host factors and medical characteristics have already been linked to prolonged recovery after acute COVID-19 infection. People of higher age, women, individuals who had severe illness requiring hospitalization, and those with chronic diseases such as heart problems or diabetes are more likely to experience long-lasting complaints. Additionally, excess body fat has been identified as a major risk factor for post-COVID-19 condition (20,21).

Several biological explanations may clarify why higher body fat increase vulnerability for developing post-COVID-19 condition. Stored fat promotes constant low-level inflammation and changes hormone signals that control immunity. This can weaken the body's ability to recover. Increased body fat is also connected to damaged blood vessels, poorer oxygen supply, and elevated clotting activity. All of these processes may support the development of post-COVID symptoms (31).

Many population-based studies have shown that people with a higher body mass index (BMI) are more likely to report ongoing problems after the COVID-19 infection (32–34). Nevertheless, this index as a marker for obesity has clear weaknesses. It cannot separate muscle from fat and gives no information about where fat is located in the body. Although modern techniques exist to measure body composition more precisely, they are expensive and difficult to use in large studies. As a result, most research relies only on basic measurements (35,36).

Research linking obesity to post-COVID-19 condition based on anthropometric parameters beyond BMI is still very limited. To date, only one earlier investigation evaluated waist circumference (WC) as a marker of abdominal obesity in relation to post-COVID complaints and found a positive link (37). However, although WC is commonly used in medical and research settings, WC alone does not adjust for differences in height, which limits comparison between individuals with different height. Hence, it may be less accurate when estimating individual health risks.

For this reason, a majority of the current medical guidelines recommend the waist-to-height ratio (WHtR) as the preferred anthropometric marker for obesity assessment (38,39). The WHtR is considered a better marker of fat accumulation in the abdomen region and for future metabolic risk than weight-based measures or WC (40). Despite this, no previous study has systematically explored its relationship with post-COVID condition.

Austria's compulsory military medical screening program offers a unique opportunity to examine this unaddressed topic in a structured and representative way. Every young man in Austria between the age of 17 to 19 is obliged to undergo the same physical evaluation performed by trained staff during the military induction examinations. Height, weight, and waist size are measured in a standardized way during this procedure, which allows reliable collection of all the different anthropometric indicators for obesity.

Therefore, this cross-sectional investigation had two main objectives:

- First, it aimed to measure how common post-COVID-19 condition is among young Austrian male conscripts.

- Second, it examined whether higher body fat —assessed through the anthropometric measures BMI, WC and WHtR— is linked to a greater probability of persistent symptoms after COVID-19 infection.

3 Materials and Methods

3.1 Setting

This doctoral project was carried out as a single-center study at the Military Hospital Graz, Styria, Austria.

3.2 Study Design

This research project was conducted using an observational, cross-sectional design, meaning that data were collected at a single time point without any additional interventions or follow-ups. Based on the updated 2011 evidence hierarchy system for epidemiological research established by the Oxford Centre for Evidence-Based Medicine, locally conducted cross-sectional studies are categorized as Level 3 evidence. This classification reflects a moderate strength of evidence (41).

Male individuals aged between 17 to 19 years were recruited consecutively while attending their mandatory conscription-related health assessment at the Austrian military induction authority in Graz, Austria, between May 2024 and June 2025. The induction board functions as the centralized national screening body responsible for evaluating all Austrian males prior to their entry into mandatory military or alternative civil service at the age of 18.

Throughout the study period, every conscript presenting for the scheduled medical evaluation was assessed for eligibility to participate in the study. Eligible conscripts were informed about the study nature and were invited to participate. Recruitment followed a consecutive sampling approach, meaning participants were included in the order in which they attended the examination sessions.

In addition to the routine medical evaluations performed during the induction assessment, all enrolled study participants filled out a structured and standardized survey. The questionnaire collected detailed information about each participant’s COVID-19 history, including prior infections, vaccination status, presence of post-COVID condition and symptom severity.

Conscript who reported no previous COVID-19 infection were included only to describe the characteristics of the overall study group. They were not included in any analyses related to the post-COVID-19 condition.

3.3 Subjects

Five hundred male young adults between 17 and 19 years of age were systematically recruited while attending their compulsory medical screening at the Austrian military induction board in Graz, Austria, over the period from May 2024 to June 2025. All participants met the predefined study eligibility criteria.

3.3.1 Inclusion criteria

Participants were eligible for inclusion if they met all of the following conditions:

- Attendance at the military induction assessment for conscripts at the Military Hospital Graz
- Participation of medical induction examinations
- Completed study survey
- Provision of written informed consent

3.3.2 Exclusion criteria

Participants were excluded from the study if any of the following conditions applied:

- Missing medical induction examinations
- Incomplete study survey
- Missing written informed consent

No additional inclusion or exclusion criteria were applied, because the study aimed to represent a realistic, population-based sample of young adults in Austria. This approach reduced the risk of selection bias and allowed the sample to better reflect the real composition of the young Austrian population. As a result, the study findings are more likely to be applicable to the general population. This improves the usefulness of the results for scientific research, public health considerations, and future preventive strategies.

3.4 COVID-19 Survey

During the routine medical examination at the induction board, participating conscripts completed a structured questionnaire. The survey included information on history of confirmed or highly probably COVID-19 infection (yes/no). History of confirmed COVID-19 infection was collected retrospectively based on self-reporting measures. Participants were also asked if they received COVID-19 vaccinations (yes/no).

For vaccinated individuals, participants were additionally asked whether they had received only the primary vaccination series or booster doses too. If both vaccination and infection were reported, respondents were further asked whether vaccination had occurred before the COVID-19 infection.

Participants with a previous COVID-19 infection were then asked if they had experienced long-lasting, persistent, or new symptoms following the infection (= post-COVID-19 condition).

All assessed COVID-19 related parameters are summarized in Table 1.

Table 1: List of assessed COVID-19-related Parameters

Parameter	Value
History of COVID-19 infection	yes / no
Received COVID-19 vaccinations	yes / no
Received COVID-19 vaccinations before infection	yes / no
Number of received booster vaccinations	number
Experience of long-lasting, persistent, or new symptoms following the infection (= post-COVID-19 condition)	yes / no

Moreover, the severity of ten common post-COVID-19 symptoms were evaluated on a six-point Likert scale: 0 = none; 1 = very mild – no impact on daily life; 2 = mild – noticeable but tolerable; 3 = moderate – some impact on daily activities; 4 = severe – substantial impact on daily activities; 5 = very severe – marked limitation of daily functioning. The evaluated symptoms commonly associated with post-COVID-19 condition are listed in Table 2. In addition, all individual post-COVID-19 symptom scores were summed to an overall post-COVID-19 symptom burden score (0-50 points), reflecting the total post-COVID-19 symptom burden for each participant.

Table 2: List of assessed post-COVID-19 symptoms

Common post-COVID-19 symptoms	Symptom severity
Fatigue	0 – 5 points
Headache	0 – 5 points
Muscle- and/or joint pain	0 – 5 points
Gastrointestinal (GI) issues	0 – 5 points
Rash/eczema	0 – 5 points
Balance disturbance	0 – 5 points
Reduced or lost sense of smell	0 – 5 points
Shortness of breath	0 – 5 points
Palpitations or chest tightness	0 – 5 points
Cognitive dysfunction	0 – 5 points

3.5 Induction Assessment Protocol

As part of the mandatory military induction process in Austria, all conscripts undergo a comprehensive standardized medical evaluation to assess their general health, physical fitness, and suitability for military service. This examination includes a broad range of clinical and diagnostic assessments aimed at identifying relevant medical conditions, health risks, and functional limitations. The protocol covers a general physical examination, laboratory testing, and evaluation of cardiopulmonary function. These assessments provide a structured and uniform health profile for each conscript. The relevant components of the induction assessment protocol used in this study are outlined in detail below.

3.6 Anthropometric Measures

Anthropometric data, including body weight, body height, and WC, were obtained during the military induction assessment carried out by trained medical personnel. Body weight was measured using a calibrated digital scale, and body height was assessed with a fixed stadiometer. Based on these primary measurements, additional anthropometric indices were calculated, including BMI and WHtR. An overview of all assessed anthropometric parameters is provided in Table 3.

Table 3: List of assessed anthropometric measures

Parameter	Value
Body weight	kg
Body height	cm
Waist circumference (WC)	cm
Body mass index (BMI)	Index, kg/m^2
Waist-to-height-ratio (WHtR)	Index, waist circumference (cm) / body height (cm)

All measurements were performed under standardized conditions to ensure accuracy, consistency, and comparability across participants. Conscripts were measured while wearing only underwear and without shoes in order to minimize measurement error and improve reliability of the anthropometric data.

3.6.1 Body Mass Index

BMI was used as a standardized indicator of general obesity. BMI was calculated by dividing body weight in kilograms by the square of body height in meters (kg/m^2). This widely accepted index provides an estimate of body fat and allows comparison across individuals independent of absolute body size (42).

Participants were classified into BMI categories according to the WHO criteria, distinguishing underweight, normal weight, overweight, and obesity (42). The specific BMI classification thresholds are presented in Table 4.

Table 4: Classification of BMI

BMI category	Value
Underweight	< 18.5 kg/m^2
Normal weight	18.5 – 24.9 kg/m^2
Overweight	25.0 – 29.9 kg/m^2
Obese	≥ 30.0 kg/m^2

3.6.2 Waist Circumference

WC was assessed in accordance with internationally recognized WHO guidelines (43). Measurements were taken using a flexible, non-stretchable measuring tape. WC was recorded directly on the skin at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest (see Figure 1). The measurement was performed at the end of a normal exhalation to minimize variability and improve accuracy.

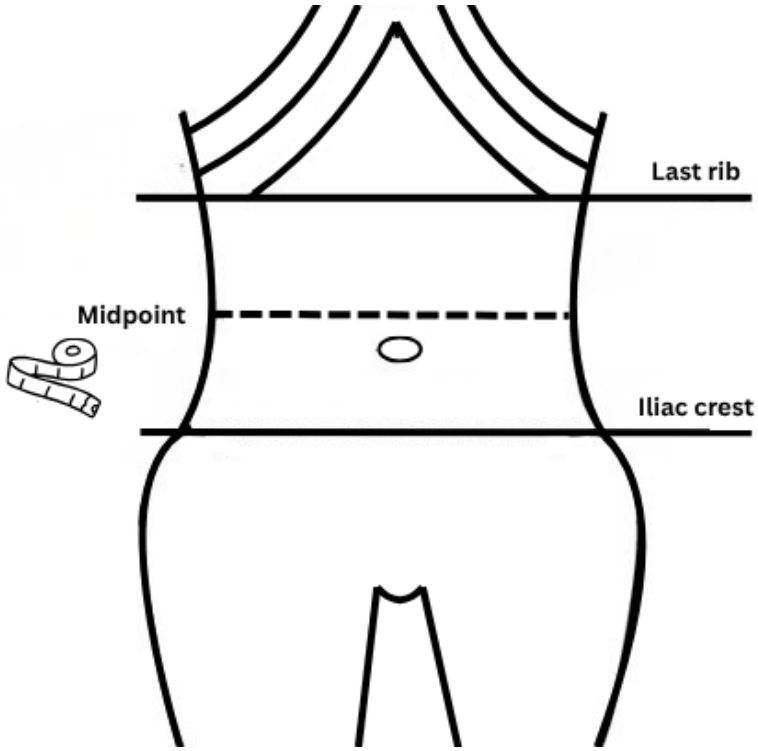

Figure 1: Measurement of Waist Circumference (figure was self-created with Canva)

WC was used as an indicator for central obesity. Because WC cut-off values depend on sex and ethnic background, population-specific thresholds were applied. In line with international recommendations for European adult males, a WC of 94 cm or greater was classified as central obesity (44). Additionally, WC values were classified into three categories reflecting different levels of health risk: low risk, increased risk, and high risk (42). An overview of all WC categories together with the respective cut-off values is provided in Table 5.

Table 5: Classification of WC

WC category	Value
Central obesity categories	
No central obesity	< 94 cm
Central obesity	≥ 94 cm
Health risk categories	
Low risk	< 94 cm
Increased risk	94.0 – 101.9 cm
High risk	≥ 102 cm

3.6.3 Waist-to-Height-Ratio

WHtR was additionally calculated as an anthropometric index to assess central obesity. WHtR was derived by dividing WC in centimeters by body height in centimeters. This index has been recommended by the EASO (38) and the NICE (39) as the most practical and reliable anthropometric marker for central obesity. The generally accepted cut-off values for central obesity are presented in Table 6.

Table 6: Classification of WHtR

WHtR category	Value
No central obesity	< 0.5
Central obesity	≥ 0.5

3.7 Laboratory Assessments

As part of the routine medical induction examination, venous blood samples were obtained to assess key metabolic, inflammatory, and hematological parameters. Laboratory analyses included measurements of total cholesterol (mg/dl), triglycerides (mg/dl), and C-reactive protein (CRP, mg/dl) to evaluate cardiometabolic health and systemic inflammation. In addition, a complete blood count was performed, comprising leukocytes (G/L), erythrocytes (G/L), hemoglobin (g/dl), and platelet counts (G/L).

According to the national Cholesterol Education Program Adult Treatment Panel III guidelines, a total blood cholesterol value of ≥200 mg/dl was considered as hypercholesterolemia and a blood triglyceride value of ≥150 mg/dL as hypertriglyceridemia (45). Based on our local laboratory protocol, a CRP value of >5 mg/dl was considered as pathologic increased.

3.8 Smoking Status

Smoking status was assessed through a brief verbal question during the military induction examination. Participants were asked whether they currently or recently smoked or not, and responses were recorded as a binary variable (yes/no).

3.9 Vital Signs

Resting blood pressure and resting heart rate were measured during the routine medical induction examination by trained medical staff under standardized conditions. Blood pressure was recorded as systolic and diastolic pressure in millimeters of mercury (mmHg), and heart rate was measured as beats per minute (bpm). All measurements were taken while participants were seated and at rest to ensure accurate and comparable results.

Elevated resting blood pressure was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, according to the European Society of Cardiology and European Society of Hypertension guidelines (46). An elevated resting heart rate was defined as ≥90 bpm, in accordance with prior large epidemiological studies identifying this threshold as clinically relevant (47,48).

3.10 Spirometry

Spirometry was performed as part of the standardized medical induction examination to assess pulmonary function. All measurements were conducted by trained medical personnel using calibrated spirometry equipment. Participants were examined in a seated position and were instructed to perform forced respiratory maneuvers according to standard instructions.

The following lung function parameters were recorded: forced expiratory volume in one second (FEV_1), vital capacity (VC), and the FEV_1/VC ratio. Values were documented in liters (L) for FEV_1 and VC, and as a ratio for FEV_1/VC. Lung function measurements were used to describe respiratory status of the study population.

Airflow limitation was defined as an FEV_1/VC ratio < 0.70, in accordance with the criteria of the Global Initiative for Chronic Obstructive Lung Disease 2024 report (49).

3.11 Ethical Considerations

The study was conducted in accordance with the current version of the Declaration of Helsinki, the International Council for Harmonization (ICH) Guideline for Good Clinical Practice, applicable data protection regulations, and the guidelines of the Medical University of Graz on standards of good scientific practice.

3.11.1 Ethics Votum

The study was approved on 8 March 2024 by the institutional Ethics Committee of the Medical University of Graz (IRB00002556, approval code: 36-090 ex23/24).

3.11.2 Informed Consent

All eligible participants received comprehensive verbal information about the study from a trained study investigator prior to enrollment. The study was explained in detail, and sufficient time was provided to address any questions or concerns. Individuals were invited to participate only after confirming that they fully understood the study information. Participants were explicitly informed that their participation was entirely voluntary and that they could withdraw their consent at any time without providing a reason. Written informed consent was obtained from all participants before inclusion in the study.

3.11.3 Data Management

Data management was performed in accordance with the General Data Protection Regulation (DSGVO). Upon study enrollment, each participant was assigned a unique consecutive numerical study code (e.g., 001, 002, etc.) to ensure pseudonymization. The link between personally identifiable information (name, date of birth) and the assigned study code was stored exclusively in a secure identification log. The collected study data were then entered into a Microsoft Excel database and subsequently transferred into an SPSS dataset for statistical analysis.

3.12 Statistical Analysis

The SPSS statistical software, version 29.0 (IBM ©, Armonk, NY) was used for statistical analysis. The threshold for statistical significance was set at a two-sided p-value < 0.05.

Continuous variables are reported as means ± standard deviations, whereas categorical variables are presented as absolute frequencies and percentages. The Levene test was applied to assess homogeneity of variances for continuous data. Group comparisons of continuous variables between two independent samples were conducted using the independent samples t-test when variances were equal; in cases of variance heterogeneity, Welch's t-test was applied. Ordinal variables were compared between two independent groups using the Mann–Whitney U test, and comparisons across more than two independent groups were performed using the Kruskal–Wallis test. Associations between categorical variables were assessed using Pearson's chi-square test. When expected cell counts were less than five, Fisher's exact test (Fisher–Yates correction) was employed. For contingency tables larger than 2×2, Bonferroni-adjusted Z-tests were used for post-hoc pairwise comparisons. Effect sizes for statistically significant categorical analyses were expressed using the φ-coefficient for 2×2 tables and Cramer's V for larger tables. To identify potential predictors of post-COVID-19 condition, binary logistic regression analysis with a stepwise model was performed.

4 Results

The study included 500 male conscripts with an age between 17 to 19 years, who underwent a military induction examination. Among these, 376 individuals (75%) reported having had a confirmed COVID-19 infection in the past, whereas 124 individuals (25%) reported no previous infection. The latter group was included to characterize the overall study population and was excluded from analyses focused on post-COVID-19 outcomes. First, clinical characteristics were summarized for the entire cohort and systematically compared between individuals with and without prior COVID-19 infection to evaluate baseline comparability. Subsequently, analyses focusing on post-COVID-19 outcomes were performed within the group of previously infected participants. Figure 2 displays the study flow diagram.

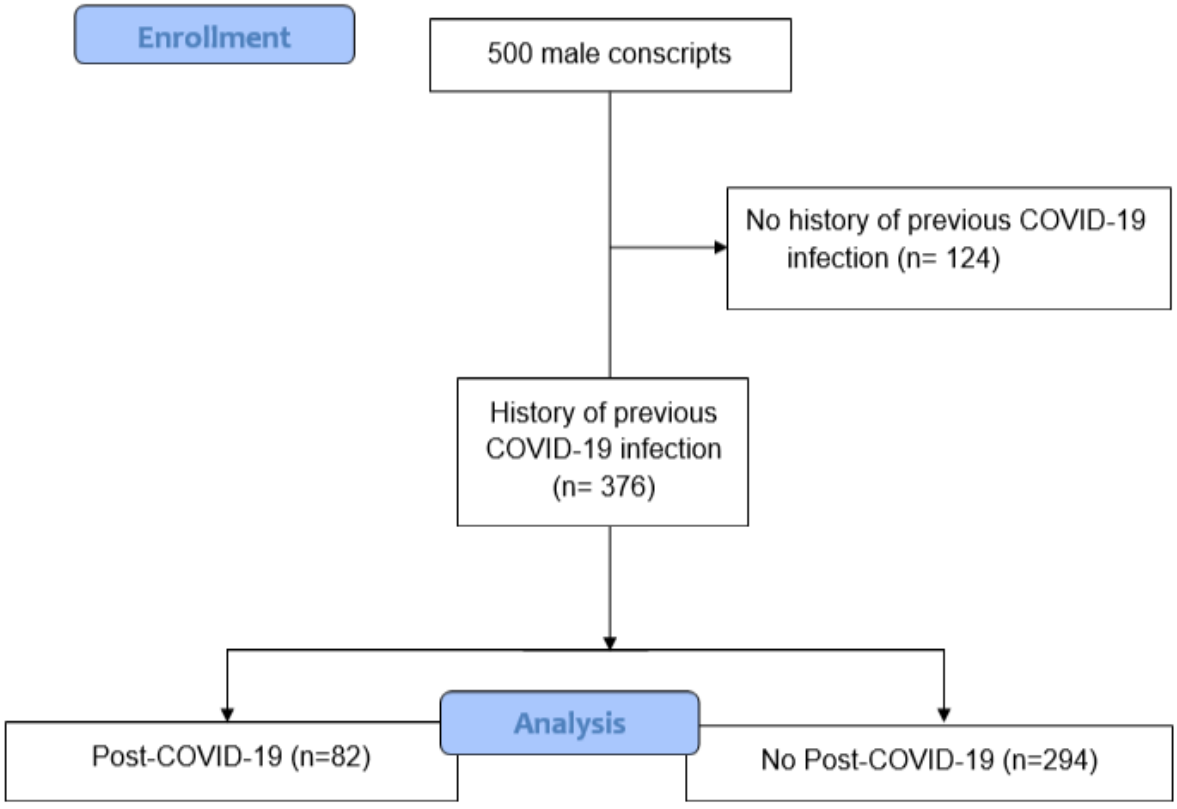

Figure 2: Study flow diagram

4.1 Clinical Characteristics of the Total Cohort

The mean body height and body weight of the total cohort were 178 ± 6 cm and 75.7 ± 14.5 kg, respectively. The mean BMI was 23.7 ± 4.1 kg/m^2. Based on BMI classification, 32 participants (6%) were underweight, 327 (65%) had normal weight, 104 (21%) were overweight, and 37 (7%) were classified as obese. The mean WC and WHtR was 79.8 ± 10.3 cm and 0.4 ± 0.1, respectively. Central obesity was identified in 44 participants (9%) based on WC criteria and in 80 participants (16%) based on WHtR.

Elevated resting blood pressure was observed in 18 conscripts (4%), while an elevated resting heart rate (≥90 bpm) was present in 62 participants (12%).

The mean blood cholesterol and triglycerides were 167.6 ± 32.4 mg/dl and 90.9 ± 46.8 mg/dl, respectively. Hypercholesterolemia (≥200 mg/dL) was detected in 74 individuals (15%), and hypertriglyceridemia (≥150 mg/dL) in 46 individuals (9%). The mean CRP level was 0.10 ± 0.20 mg/dL, and no participant exhibited pathologically elevated values.

A total of 57 conscripts (11%) reported a positive smoking history. Regarding lung function parameters, the mean FEV1, VC, and FEV1/VC ratio was 4.7 ± 0.6 L, 5.4 ± 0.7 L, and 0.8 ± 0.1, respectively.

Overall, 376 participants (75%) reported a previously confirmed COVID-19 infection, whereas 124 participants (25%) reported no history of infection. COVID-19 vaccination had been received by 391 individuals (78%).

Participants clinical characteristics according to history of confirmed previous COVID-19 infection are listed in Table 7. There were no statistically significant differences between individuals with and without history of confirmed previous COVID-19 infection regarding all clinical characteristics (p>0.05).

Table 7: Clinical characteristics of the total cohort stratified by history of prior COVID-19 infection

Parameter	History of COVID-19 infection (n=376)	No COVID-19 infection (n=124)	p-value
Body height (cm)	178 ± 6	178 ± 6	0.973
Body weight (kg)	74.8 ± 12.8	76.0 ± 15.1	0.442
BMI (kg/m²)	23.8 ± 4.3	23.5 ± 3.7	0.428
Underweight (BMI <18.5)	23 (6%)	9 (7%)	0.825
Normalweight (BMI 18.5 – 24.9)	243 (65%)	84 (68%)	
Overweight (BMI 25 – 29.9)	81 (21%)	23 (22%)	
Obesity (BMI ≥30)	29 (7%)	8 (7%)	
WC (cm)	80.0 ± 10.8	79.5 ± 8.7	0.622
WC-defined central obesity (≥ 94 cm)	38 (10%)	6 (5%)	0.098
WHtR	0.4 ± 0.1	0.4 ± 0.1	0.660
WHtR-defined central obesity (≥ 0.5)	61 (16%)	19 (15%)	0.888
Elevated resting blood pressure	13 (4%)	5 (4%)	0.783
Elevated resting heart rate	46 (12%)	16 (13%)	0.875
Positive smoking status	39 (10%)	18 (14%)	0.253
Total Blood cholesterol (mg/dl)	169.9 ± 33.8	166.9 ± 31.9	0.382
Hypercholesterolemia (≥200 mg/dl)	57 (15%)	17 (14%)	0.772
Blood triglycerides (mg/dl)	94.5 ± 51.8	90.9 ± 46.8	0.326
Hypertriglyceridemia (≥150 mg/dl)	31 (8%)	15 (12%)	0.211
CRP (mg/dl)	0.1 ± 0.2	0.1 ± 0.2	0.641
FEV1	4.6 ± 0.6	4.7 ± 0.6	0.383
VC	5.3 ± 0.7	5.4 ± 0.7	0.253
FEV1/VC	0.86 ± 0.1	0.86 ± 0.1	0.827
FEV1/VC <0.70	4 (1%)	2 (1%)	0.641
Received COVID-19 vaccinations	296 (79%)	95 (77%)	0.707

4.2 Prevalence and Symptom Burden of Post-COVID-19

Out of the 376 participants with previous COVID-19 infection, 82 subjects (21%) experienced post-COVID-19 condition while the remaining 294 participants (79%) reported full recovery after the infection without ongoing complaints. These findings indicate that approximately one in five previously infected conscripts experienced prolonged symptoms following a COVID-19 infection.

Participants with post-COVID-19 condition were asked to rate the severity of ten common post-COVID-19 symptoms using a standardized rating scale. The highest median severity scores were observed for fatigue (median 3, IQR 2–4), headache (median 3, IQR 2–4), and muscle and/or joint pain (median 2, IQR 1–3). In contrast, rash/eczema was reported as the least severe symptom (median 0, IQR 0–1). The mean overall post-COVID-19 symptom burden score was 16.9 ± 7.3.

A detailed overview of symptom severity across all assessed post-COVID-19 manifestations is presented in Figure 3.

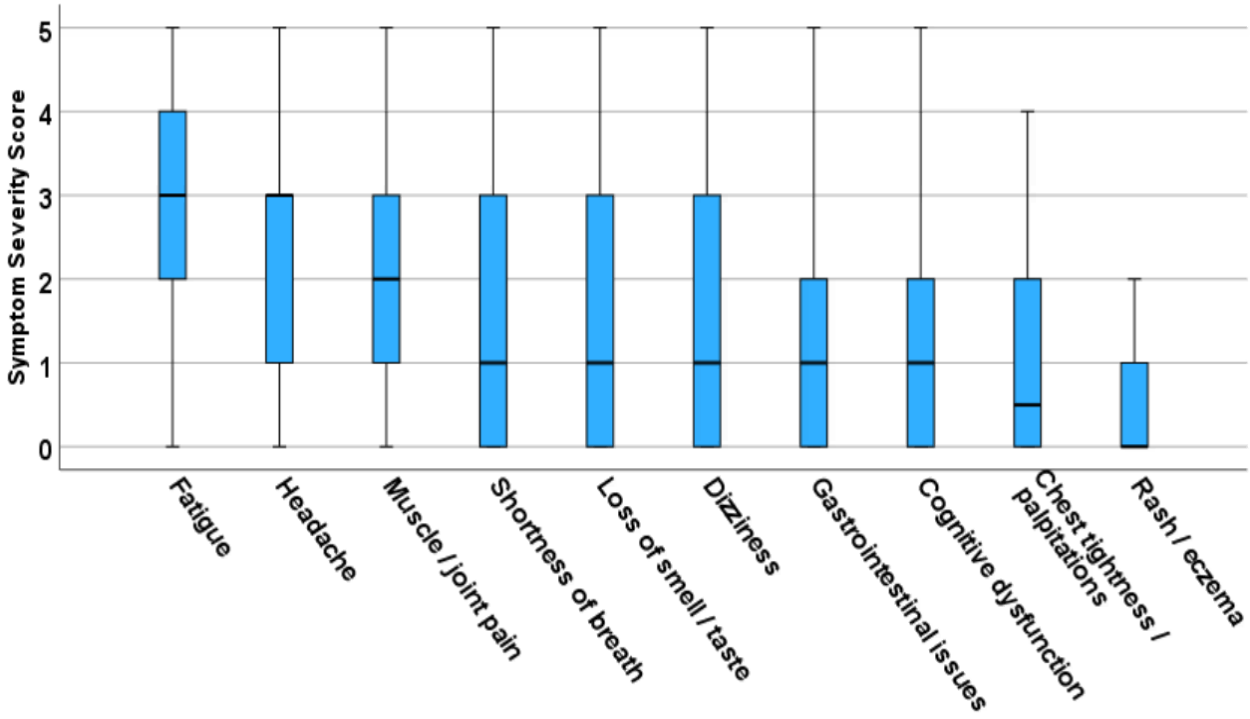

Figure 3: Symptom severity of common post-COVID-19 symptoms

4.3 Impact of Vaccination Status on Post-COVID-19

Among the 376 participants with a history of COVID-19, 296 subjects (78%) had received a COVID-19 vaccination. Of these, 167 individuals (56%) completed the primary two-dose series, whereas 129 (44%) received booster vaccinations.

In total, 232 participants (78%) had been vaccinated partially or fully prior to their COVID-19 infection. An overview of vaccination-related characteristics is presented in Table 8. No statistically significant differences were observed in vaccination-related parameters between participants with post-COVID-19 condition and those without persistent symptoms (all $p>0.05$).

Table 8: Comparison of COVID-19 vaccination parameters between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
History of vaccination	66/82 (80%)	230/294 (78%)	0.761
Additional booster doses	30 /66 (45%)	99/230 (43%)	0.779
Vaccination before infection	53/66 (80%)	179/230 (78%)	0.737

Categorical variables are presented as absolute numbers and percentages (%). Reproduced from (1).

4.4 Body Mass Index and Post-COVID-19

Among participants with a documented history of COVID-19 infection (n=376), BMI categories showed the following distribution: 23 individuals (6%) were classified as underweight, 243 (65%) as normal weight, 81 (22%) as overweight, and 29 (8%) as obese.

When comparing prevalence of BMI categories between participants with and without post-COVID-19 condition, the overall chi-square test did not indicate a statistically significant difference [$\chi^2(3)=7.19$, $p=0.066$). However, Bonferroni-adjusted post-hoc analyses demonstrated that obesity was significantly more prevalent among participants with post-COVID-19 than among those without prolonged symptoms (15% vs. 5%).

A detailed overview of BMI category distributions stratified by post-COVID-19 status is provided in Table 9.

Table 9: Prevalence of BMI categories stratified by post-COVID-19 status

BMI Category	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p=0.066
Underweight (BMI < 18.5)	4 (5%) a	19 (7%) a	
Normal weight (BMI 18.5–24.9)	49 (60%) a	194 (66%) a	
Overweight (BMI 25–29.9)	17 (20%) a	64 (22%) a	
Obesity (BMI ≥ 30)	12 (15%) a	17 (5%) b	

Categorical variables are presented as absolute numbers and percentages. Each subscript letter (a, b) denotes a subset of post-COVID-19 groups whose proportions do not differ significantly from each other at the Bonferroni-adjusted significance level. Reproduced from (1).

An exploratory analysis was conducted to examine whether the severity of post-COVID-19 symptoms differed across BMI categories. No statistically significant differences in symptom severity were observed between BMI groups for any of the assessed symptoms (all p>0.05). Detailed results of symptom severity stratified by BMI category are presented in Table 10.

Table 10: Comparison of post-COVID-19 symptom severity between BMI groups

Post-COVID-19 symptoms	BMI Category				p-value
	Underweight (n=4)	Normalweight (n=49)	Overweight (n=17)	Obesity (n=12)	
Fatigue	4 (3.5-4)	3 (2-4)	3 (2-4)	3 (2-4)	0.603
Headache	1.5 (0.5-3)	2 (1-3)	3 (2-3)	3 (2-4)	0.384
Muscle- and/or joint pain	2.5 (1.5-3)	2 (1-3)	3 (2-3)	2 (1-4)	0.813
Gastrointestinal (GI) issues	0.5 (0-1.5)	1 (0-2)	1 (0-3)	1 (1-2)	0.206
Rash/eczema	0.5 (0-2)	0 (0-0)	0 (0-3)	0 (0-4)	0.673
Balance disturbance	1 (0.5-2.5)	1 (0-2)	1 (0-3)	2 (1-2)	0.097
Reduced or lost sense of smell	0 (0-0.5)	2 (0-3)	1 (0-4)	0.5 (0-2.5)	0.573
Shortness of breath	1.5 (0.5-2.5)	1 (0-3)	0 (0-3)	0 (0-2.5)	0.104
Palpitations or chest tightness	1.5 (0.5-2)	0 (0-2)	0 (0-3)	1 (0-3)	0.619
Cognitive dysfunction	0.5 (0-2)	1 (0-2)	1 (0-2)	1 (0.2,5)	0.169

Ordinal variables are presented as median and interquartilrange (IQR25%-75%).

As next, to evaluate the influence of BMI on total symptom burden of post-COVID-19, the overall post-COVID-19 symptom burden score was compared across the BMI categories. This analysis revealed no statistically significant differences [$H(3)=1.08$, $p=0.780$]. Detailed results of overall post-COVID-19 symptom burden scores stratified by BMI are presented in Figure 4.

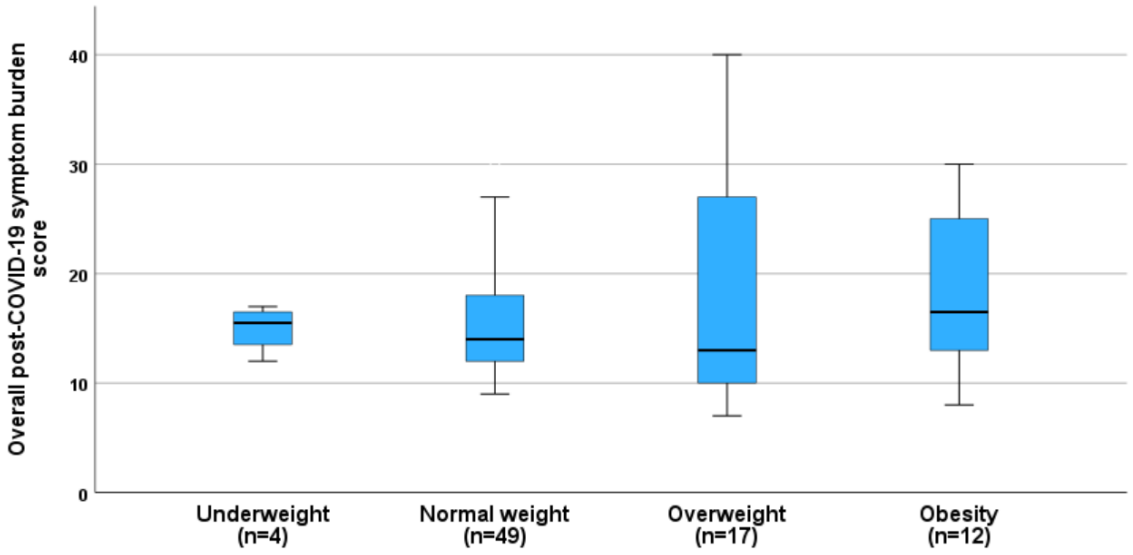

Figure 4: Distribution of overall post-COVID-19 symptom burden scores across BMI categories

4.5 Waist Circumference and Post-COVID-19

Within the group of participants with a confirmed history of COVID-19 infection, 38 individuals (10%) met the WC criteria for central obesity. When WC-defined central obesity was compared between participants with and without post-COVID-19 condition, a significantly higher prevalence of WC-defined central obesity was observed among those reporting persistent symptoms [18% vs. 7%; $\chi^2(1)=7.74$, $p=0.008$, $\varphi=0.14$]. Results are displayed in Table 11.

Table 11: Comparison of WC categories between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
Waist circumference			p=0.008
No central obesity (<94 cm)	67 (82%)	271 (93%)	
Central obesity (≥94 cm)	15 (18%)	23 (7%)	

Categorical variables are presented as absolute numbers and percentages (%). Reproduced from (1).

WC was further classified into health risk categories. An analysis of conscripts with prior COVID-19 showed, that 335 individuals (89%) were classified as low risk, 16 individuals (4%) as increased risk, and 25 individuals (7%) as high risk. Comparative analyses revealed a statistically significant difference in WC-based health risk distribution between participants with and without post-COVID-19 condition [$\chi^2(2)=5.90$, $p=0.046$, $V=0.12$]. Prevalence of low-risk WC was significantly higher in conscripts without post-COVID-19 (91% vs 82%). Comprehensive data of WC-related risk categories stratified by post-COVID-19 status is presented in Table 12.

Table 7: Prevalence of WC-bases health risk categories stratified by post-COVID-19 status

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
WC-based health risk			p=0.046
Low risk (<94 cm)	67 (82%) $_a$	268 (91%) $_b$	
Increased risk (94.0 – 101.9 cm)	6 (7%) $_a$	10 (3%) $_a$	
High risk (≥94 cm)	9 (11%) $_a$	16 (5%) $_a$	

Categorical variables are presented as absolute numbers and percentages (%). Each subscript letter (a, b) denotes a subset of post-COVID-19 groups whose proportions do not differ significantly from each other at the Bonferroni-adjusted significance level.

To explore whether abdominal obesity has an influence on the intensity of the various post-COVID-19 symptoms, symptom severity scores were compared across WC-based central obesity categories. This analysis did not reveal any statistically significant differences in symptom severity scores between WC groups for any of the assessed post-COVID-19 symptoms (all p>0.05). A comprehensive overview of symptom severity distributions according to WC category is displayed in Table 13.

Table 13: Comparison of post-COVID-19 symptom severity between WC groups

post-COVID-19 symptoms	WC Category		p-value
	Central obesity (≥94 cm)	No central obesity (<94 cm)	
Fatigue	3 (2-4)	3 (2-4)	0.783
Headache	3 (1-3)	3 (1-4)	0.263
Muscle- and/or joint pain	2 (1-3)	3 (1-4)	0.368
Gastrointestinal (GI) issues	1 (0-2)	1 (0-2.5)	0.372
Rash/eczema	0 (0-4)	0 (0-0)	0.244
Balance disturbance	1 (1-2)	1 (0-3)	0.907
Reduced or lost sense of smell	0 (0-3.5)	1 (0-3)	0.511
Shortness of breath	1.5 (0.5-2.5)	1 (0-3)	0.556
Palpitations or chest tightness	1 (0-3.5)	0 (0-2)	0.090
Cognitive dysfunction	2 (0.5-3.5)	1 (0-2)	0.200

Ordinal variables are presented as median and interquartilrange (IQR25%-75%).

To investigate whether WC–defined central obesity is associated with overall post-COVID-19 symptom severity, the overall post-covid-19 symptom burden score was compared between participants with and without WC-defined central obesity. Individuals classified as centrally obese showed a median score of 14 (IQR 12–26.5), which was comparable to the median score of 14 (IQR 12–18) observed in participants without central obesity. Statistical testing revealed no significant difference in total symptom burden between the two groups (Z=0.55, p=0.576). The distribution of overall post-COVID-19 symptom burden scores by WC category is illustrated in Figure 5.

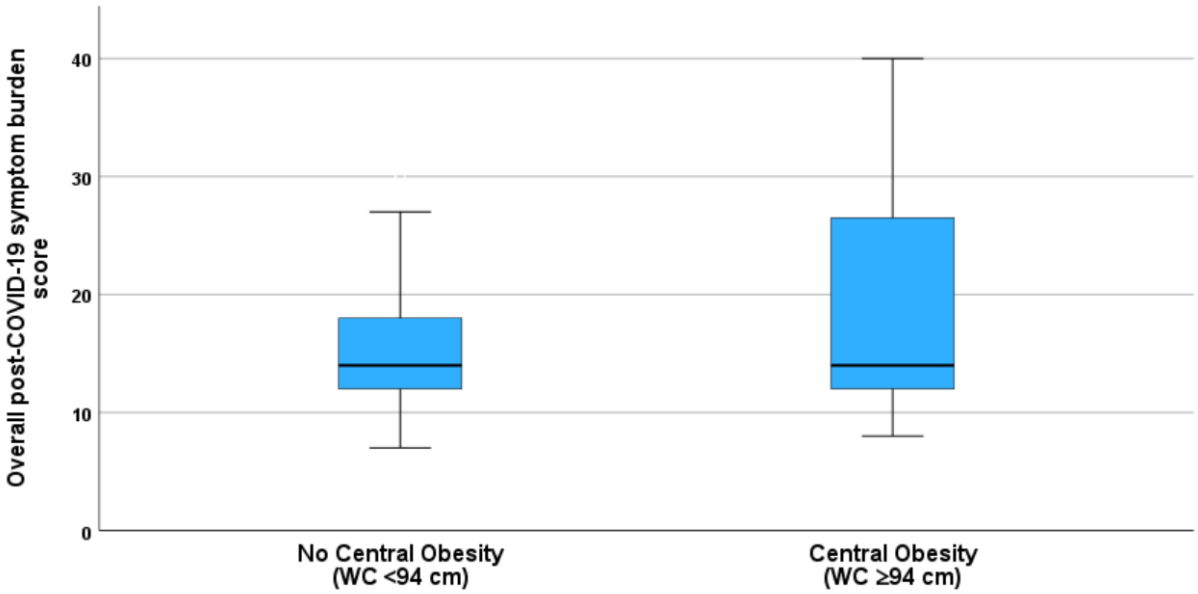

Figure 5: Overall post-COVID-19 symptom burden score according to WC-defined central obesity

4.6 Waist-to-Height-Ratio and Post-COVID-19

Within the group of participants who reported a prior COVID-19 infection, 61 individuals (16%) met the WHtR criterion for central obesity (WHtR ≥ 0.50). When WHtR-defined central obesity prevalence was compared between participants with and without post-COVID-19 condition, a significantly higher proportion was observed among those with post-COVID-19 condition [26% vs. 14%; $\chi^2(1)=6.79$, $p=0.012$, $\varphi=0.13$]. Full results of WHtR-based group differences are provided in Table 14.

Table 14: Comparison of WHtR categories between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
Waist-to-Height ratio			p=0.012
No central obesity (<0.5)	61 (74%)	254 (86%)	
Central obesity (≥0.5)	21 (26%)	40 (14%)	

Categorical variables are presented as absolute numbers and percentages (%). Reproduced from (1).

To examine whether post-COVID-19 symptom severity differed between participants with and without WHtR-based central obesity, an exploratory comparison of symptom severity scores was performed. This analysis identified a statistically significant difference in headache severity, with higher headache scores among individuals classified as centrally obese (Z=2.28, p=0.023). No significant differences were observed for any of the other assessed post-COVID-19 symptoms (all p>0.05). Detailed results of post-COVID-19 symptom severity comparisons between WHtR groups are presented in Table 15.

Table 15: Comparison of post-COVID-19 symptom severity between WHtR groups

Post-COVID-19 symptoms	WHtR Category		
	Central obesity (≥0.5)	**No central obesity (<0.5)**	**p-value**
Fatigue	3 (2-4)	3 (2-4)	0.638
Headache	3 (2-4)	2 (1-3)	0.023
Muscle- and/or joint pain	3 (1-4)	2 (1-3)	0.163
Gastrointestinal (GI) issues	1 (0-2)	1 (0-2)	0.552
Rash/eczema	0 (0-3)	0 (0-0)	0.471
Balance disturbance	2 (0-2))	1 (1-3)	0.815
Reduced or lost sense of smell	1 (0-4)	1 (0-3)	0.535
Shortness of breath	0 (0-4)	1 (0-3)	0.750
Palpitations or chest tightness	0 (0-3)	1 (0-2)	0.518
Cognitive dysfunction	1 (0-2)	1 (0-3)	0.261

Ordinal variables are presented as median and interquartilrange (IQR25%-75%).

The association between central obesity, defined by WHtR, and post-COVID-19 symptom burden was examined by comparing the overall post-covid-19 symptom burden score between WHtR groups. This analysis showed no statistically significant difference (Z=0.30, p=0.761). Detailed results of overall post-COVID-19 symptom burden scores stratified by WHtR groups are illustrated in Figure 6.

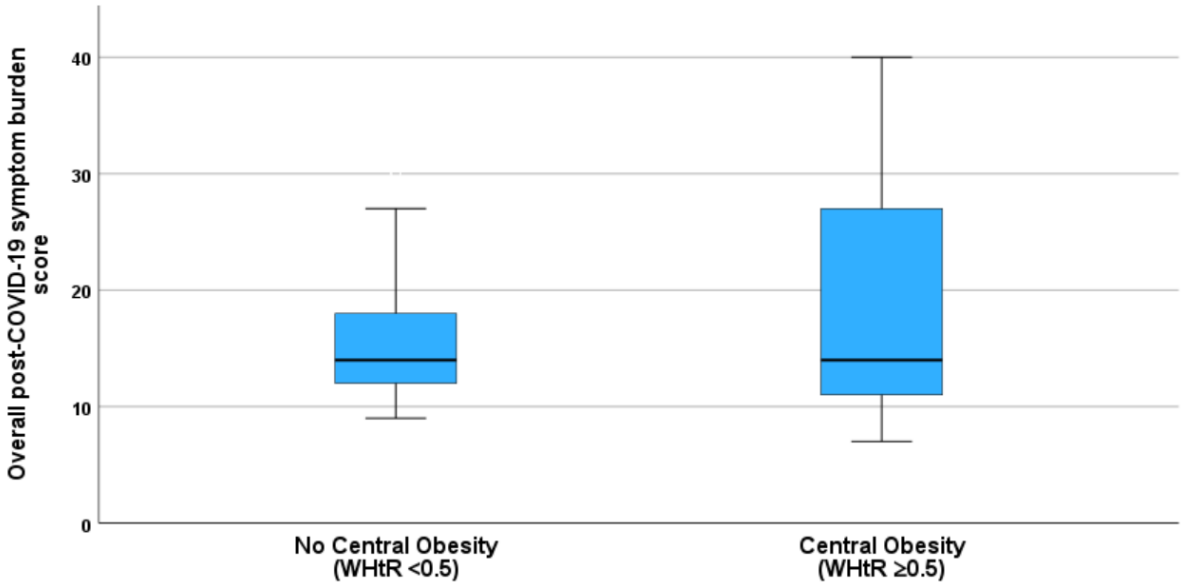

Figure 6: Overall post-COVID-19 symptom burden score according to WHtR-defined central obesity

4.7 Laboratory Markers and Post-COVID-19

No statistically significant differences in laboratory markers were observed between individuals with and without post-COVID-19. Comprehensive results are presented in Table 16.

Table 86: Comparison of laboratory markers between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
Total cholesterol (mg/dl)	166.3 ± 32.3	167.1 ± 31.8	0.835
Hypercholesterolemia (≥200 mg/dl)	12 (14%)	45 (15%)	0.881
Triglycerides (mg/dl)	94.3 ± 59.7	88.4 ± 40.1	0.300
Hypertriglyceridemia (≥150 mg/dl)	8 (10%)	23 (8%)	0.649
CRP (mg/dl)	0.13 ± 0.23	0.10 ± 0.26	0.294
Leukocytes (G/L)	7.0 ± 1.6	6.6 ± 1.4	0.320
Erythrocytes (G/L)	5.3 ± 0.3	5.3 ± 0.3	0.172
Hemoglobin (g/dl)	15.8 ± 1.1	15.5 ± 1.3	0.523
Platelet counts (G/L)	235.3 ± 50.7	238.2 ± 53.8	0.659

Continuous variables are presented as mean + standard deviation and Categorical variables as absolute numbers and percentages (%).

4.8 Smoking Status and Post-COVID-19

Within the 376 participants who reported a prior COVID-19 infection, 39 individuals (10%) had a positive history of smoking. Of these, 9 participants with post-COVID-19 condition and 30 participants without post-COVID-19 condition were smokers. Smoking prevalence did not differ significantly between individuals with and without post-COVID-19 condition [11% vs. 10%; $\chi^2(1)=0.04$, $p=0.839$].

4.9 Vital Signs and Post-COVID-19

Among the 376 conscripts who had a previous COVID-19 infection, 13 participants (4%) had an elevated resting blood pressure and 46 persons (12%) an elevated resting heart rate. Participants with post-COVID-19 had a 5% significantly higher prevalence of elevated resting blood pressure compared those without [7% vs. 2%; $\chi^2(1)=4.68$, $p=0.031$, $\varphi=0.11$]. There was a statistically significant difference in prevalence of elevated resting heart rate between conscripts with and without post-COVID-19. [12% vs. 12%; $\chi^2(1)=0.0$, $p=0.990$]. Detailed results are provided in Table 17.

Table 97: Comparison of vital signs between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
Elevated resting blood pressure	6 (7%)	7 (2%)	0.031
Elevated resting heart rate	10 (12%)	36 (12%)	0.990

Categorical variables are presented as absolute numbers and percentages (%).

4.10 Lung Function and Post-COVID-19

There were no significant differences in all lung function parameters between conscripts with and without post-COVID-19 [11% vs. 10%; $\chi^2(1)=0.04$, $p=0.839$]. Comprehensive data of spirometry comparisons are presented in Table 18.

Table 108: Comparison of lung function parameters between participants with and without post-COVID-19

Parameter	Post-COVID-19 (n=82)	No Post-COVID-19 (n=294)	p-value
FEV1	4.6 ± 0.6	4.7 ± 0.5	0.209
VC	5.3 ± 0.7	5.5 ± 0.7	0.157
FEV1/VC	0.8 ± 0.6	0.8 ± 0.6	0.873
FEV1/VC <0.70	1 (1%)	3 (1%)	0.877

Continuous variables are presented as mean + standard deviation and categorical variables as absolute numbers and percentages (%).

4.11 Predictors of Post-COVID-19

To identify independent predictors of post-COVID-19 condition, binary logistic regression analyses were performed using the stepwise method. Because BMI, WC, and WHtR reflect closely related measures of adiposity, these parameters were not included simultaneously in a single model. In an exploratory analysis, substantial multicollinearity between these anthropometric measures was confirmed, with strong correlations observed between them ($r>0.8$).

To address this issue and ensure model stability, three separate regression models were performed, each including one adiposity-related variable (Model A: BMI category, Model B: WC category, or Model C: WHtR category, respectively). In addition to the adiposity marker of interest, all models were adjusted for clinically covariates including smoking status, hypercholesterolemia, hypertriglyceridemia, received COVID-19 vaccinations before infection, elevated resting blood pressure, and elevated resting heart rate.

All assumptions required for binary logistic regression were met in each model. The dependent variable showed appropriate linearity with independent variables, and multicollinearity among included predictors was excluded, as correlation coefficients between covariates were low.

Across all three multivariable logistic regression models, adiposity-related parameters were significantly associated with the presence of post-COVID-19 condition, while the other covariates did not reach statistical significance ($p>0.05$). In Model A, BMI-based obesity emerged as a significant independent predictor of post-COVID-19 condition ($p=0.012$). Similarly, Model B demonstrated that WC-defined central obesity was independently

associated with post-COVID-19 condition (p=0.008). In Model C, WHtR-defined central obesity was also identified as an independent predictor (p=0.010). Elevated resting blood pressure showed a borderline association in some models but was not consistently retained across all analyses. Detailed results are provided in Table 19.

Table 19: Predictors retained in the final stepwise binary logistic regression models for post-COVID-19

Predictor	Coefficient B	Standard error	Odds Ratio	*p*-value
Obesity (BMI ≥30)	0.39	0.18	2.8	0.012
WC	1.04	0.39	2.8	0.008
WHtR	0.87	0.33	2.3	0.010

Note: Adiposity markers were evaluated in separate stepwise models

5 Discussion

The present study investigated the prevalence, symptom burden, and associated factors of post-COVID-19 condition in a large, population-based cohort of young male conscripts undergoing mandatory military induction in Austria. Among participants with a confirmed history of COVID-19 infection, approximately one in five reported persistent symptoms after infection consistent with post-COVID-19 condition. Fatigue, headache, and musculoskeletal pain were the most prominent symptoms, whereas rash/eczema and chest tightness/palpitations were the least severe ranked symptoms. Vaccination status, laboratory markers, smoking behavior, resting vital signs and lung function parameters showed no relevant association with post-COVID-19 condition. In contrast, obesity-related measures showed a clear and consistent significant relationship with post-COVID-19 condition. BMI-based general obesity and WC- as well as WHtR-defined central obesity were all significantly more prevalent among affected conscripts and remained significant in regression analyses. These results indicate that obesity is an important factor associated with post-COVID-19 condition in young adult men. The subsequent sections discuss these findings in greater detail, beginning with the prevalence and symptom burden of post-COVID-19 condition observed in this cohort, followed by the association of obesity and post-COVID-19.

5.1 Prevalence and Symptom Burden of Post-COVID-19

In this population-based study of young male conscripts, about one in five participants with a previous COVID-19 infection experienced persistent or new symptoms after the infection. Specifically, 21% of infected individuals had post-COVID-19 condition. This prevalence is clearly lower than estimates reported in many large international meta-analyses, which often describe pooled rates between 40% to more than 50% (17,18).

A recent global systematic review and meta-analysis reported an overall pooled prevalence of post-COVID condition of about 42%. However, substantial variability was observed across studies, with reported prevalence ranging from 3% to 90%. When prevalence was examined according to time since acute infection, rates remained relatively stable, with 45% at three months or later, 41% at six as well as twelve months or later. Regional differences were modest, with pooled estimates of 46% in Europe and in the USA, 49% in Asia, 50% in Africa and 42% in Australia, suggesting a consistently high global burden of post-COVID condition (17). Similar, another meta-analysis including solely prospective studies reported that 56% of

people with prior COVID-19 infection had one or more persistent symptoms three to six months after the infection. This number was even higher for the follow-up period of one year and beyond, counting 77%. The systematic review also analyzed the experienced symptoms of post-COVID-19 condition. The most frequently reported complaints were ongoing fatigue, breathing difficulties, problems with memory, sleep or concentration, low mood, headache, arthralgia and myalgia. Challenges in re-entering the work routine were mentioned more often than any other functional outcome (18). A further meta-analysis covering over 13 million individuals confirmed fatigue and breathing difficulties as the leading symptoms, followed by psychological and cognitive problems as well as musculoskeletal pain (20).

Several reasons may explain why the prevalence in the present study was lower than the pooled prevalence in these international reports (20). Our study population consisted only of young males aged 17 to 19 years. First, females tend to have higher risk to develop post-COVID-19 condition (17,18). Then, existing epidemiological evidence indicates that younger individuals experience post-COVID symptoms less frequently than older adults (18,20). Importantly, the average age reported in the above-mentioned systematic review was substantially higher than that of our participants. Supporting this age-related pattern, a recent meta-analysis focusing exclusively on individuals younger than 18 years found that approximately 25% experienced post-COVID-19 condition (19). A number of reasons may account for why long-lasting symptoms after COVID-19 infections appear less common in children and adolescents. To begin with, younger individuals have often a stronger initial defense in the upper airways, which may stop the virus from spreading deeper into the lungs. At the same time, their still-maturing immune system may respond in a different way to the infection, resulting in a less severe inflammation (50,51). Another factor is that the COVID-19 virus uses a protein called ACE2 to enter cells, and prior reports indicated that young people have fewer levels of these proteins in the airway mucosa than adults, which could reduce symptom intensity (52). In general, children and adolescents experience milder COVID-19 infections than adults (53), and lower acute symptom severity has been linked to a lower prevalence of ongoing symptoms (54,55). Moreover, young adults are generally healthier ess likely to have chronic conditions such as diabetes or cardiovascular disease. The presence of such comorbidities has been linked to an increased risk of developing post-COVID-19 condition, which may further explain the lower prevalence observed in our cohort (21,56). Another factor is the lack of a uniform definition of post-COVID. Some studies define post-COVID as symptoms lasting more than four weeks, while others require symptoms to persist for at least two months. These methodological differences may contribute to the wide range in reported prevalence rates.

Although the overall prevalence was lower, the pattern of symptoms observed in the present cohort closely matches with findings from the existing literature. Fatigue was the most severe symptom, followed by headache and muscle or joint pain. In contrast, skin symptoms such as rash or eczema and chest tightness/palpitations were rated as rare and mild. This symptom profile is consistent with several systematic reviews, which identified fatigue as the dominant long-term complaint, often accompanied by cognitive problems, musculoskeletal pain and breathing difficulties (17–19).

In the present study, vaccination status was not significantly associated with post-COVID-19 condition. Participants who had received COVID-19 vaccines did not differ from unvaccinated individuals in terms of persistent symptoms after infection. However, the relatively small sample size and homogenous study design may have limited the ability to detect subtle differences. In contrast, several larger epidemiological studies in more diverse populations have reported lower rates of post-COVID condition among vaccinated individuals, with additional benefit from booster doses. The lack of association observed in the present study may therefore be related to the homogenous study population and limited sample size. Nevertheless, current evidence supports vaccination as important public health measure to reduce overall post-COVID-19 burden (57).

5.2 Obesity and Post-COVID-19

Obesity is characterized by an excessive accumulation of body fat that exceeds physiological needs and negatively affects health. Obesity develops in most cases due to a combination of several factors and cannot be explained by a single cause. Genetic factors can increase a person’s tendency to gain weight, but everyday habits play the major role. Low levels of physical activity, long periods of sitting, and frequent intake of high-calorie foods lead to an imbalance between energy intake and energy use. In addition, modern living conditions, such as urban lifestyles, easy access to processed foods, and socioeconomic disadvantages, further support weight gain across populations. Obesity is associated with a wide range of adverse health effects. Excess body fat increases the risk of non-communicable disorders such as cardiovascular diseases, respiratory diseases or type 2 diabetes, as well as the risk of cancer. Obesity has become one of the most prevalent chronic health conditions worldwide and represents a major public health challenge (58). Recent estimates by the NCD Risk Factor Collaboration based on 3663 endemiological studies indicate that in 2022, approximately 2.5 billion adults aged 18 years and older were categorized as overweight, of whom more than

890 million were classified as obese. Overall, this means that around 43% of the global adult population was affected by overweight. This represents a substantial rise compared with 1990, when only about one quarter of adults were considered overweight (58,59). The increasing condition of excess body weight is not limited to adults. In 2022, more than 390 million children and adolescents were affected by overweight and obesity, representing approximately 20% of individuals in this age group worldwide. It must be noted that the rate of overweight/obesity varies substantially between regions. In 2022, lower prevalence rates were observed in South-East Asia, where 32% of the population was affected by excess body weight, whereas substantially higher rates were reported in Western countries. In the United States for instance, around two thirds of adults were classified as overweight or obese (58). Data from the European Union further indicate that excess body weight is already common among young individuals. According to EUROSTAT, 20.6% of people aged 16–24 years were overweight or obese in 2022, with Austria showing even higher rates of approximately 26% in this age group (60). In line with these national estimates, our study found that 28% of Austrian 18-year-old male conscripts examined between 2024 and 2025 were classified as overweight or obese. This close agreement with population-based statistics supports the representativeness of our cohort. At the same time, the high proportion of overweight and obesity observed in our study adds to growing concerns about a continuing increase in excess body weight among young adult men in Austria. A previous analysis by Gensthaler et al. based on Austrian military conscription records has shown a steady rise in overweight and obesity over several decades. Specifically, the prevalence of overweight and obesity in Austrian male conscripts rose from approximately 15% and 5% in 2003 to 20% and 9% in 2018, respectively, indicating a continuous upward trend (61). These observations emphasize the importance of early and sustained prevention strategies aimed at young populations to reduce long-term health and economic consequences.

Obesity has been consistently identified as a factor that increases the risk of developing long-lasting symptoms after COVID-19 infection. A few population-based studies have shown that people with higher BMI are more likely to experience persistent health problems following a COVID-19 infection (32–34).

Vimercati and colleagues conducted a retrospective cohort study among healthcare workers at a university hospital in Southern Italy during the pandemic to examine factors associated with prolonged symptoms following a COVID-19 infection. During the study period, more than 5,700 healthcare workers were screened, of whom 352 were tested positive for COVID-19. Persistent symptoms lasting for more than 30 days defined as long-covid were observed in

nearly half of the infected individuals. When comparing healthcare workers with and without prolonged symptoms, people with long-lasting complaints had a significantly higher BMI (25.9 kg/m2 vs. 24.8 kg). Moreover, the prevalence of a BMI greater than 25 kg/m^2 was significantly higher in individuals with long-COVID (51% vs. 38%). Further, they did not find any significant difference in blood cholesterol, triglycerides and fasting glucose values between individuals with and without long-COVID (32). This observation is consistent with the findings of the present study, in which no meaningful differences in lipid parameters were detected between post-COVID-19 groups. Several large-scale cohort studies have demonstrated an elevated risk of incident dyslipidemia in the post-acute phase of COVID-19 infection. Notably, these associations were more pronounced in older individuals and in those with more severe acute infections (62,63). One possible explanation for our results may the young age and generally good baseline health, as metabolic consequences of obesity may not yet be reflected in standard laboratory values at early stages of life.

In a Spanish study by Torres-Romero et al. with a case-control design, the authors invited individuals with persisting symptoms after a COVID-19 infection and healthy controls who fully recovered, to fill out an electronic survey. Individuals with overweight or obesity before COVID-19 infection were significantly more likely to develop post-COVID-19 condition compared with those of normal weight, with an OR of 2.85 (CI 1.38–5.87). Higher BMI was also associated with greater functional limitations in daily routine activities. Moreover, higher BMI was linked to an increased frequency of several specific post-COVID-19 symptoms, including fatigue, shortness of breath, headache, cognitive complaints, and musculoskeletal pain. In our cohort, similar symptoms were rated as most severe among conscripts with post-COVID-19. However, our study did not identify significant differences in symptom severity across BMI categories in these individuals. This discrepancy may be explained by differences in age, overall health status, and different scoring systems between the study cohorts (33).

Loosen and colleagues retrospectively analyzed data from 50,402 individuals, with documented COVID-19 infection, using the IQVIA Disease Analyzer database, which includes medical records from 1,056 outpatient practices across Germany. Out of these individuals with a previous infection, 3% (n=1708) presented persistent chronic symptoms or developed new typical symptoms suggestive for post-COVID condition. Similar to our approach, the authors applied binary multivariate logistic regression analyses to distinguish relevant risk factors for the development of post-COVID (34). They reported that BMI-defined obesity and lipid metabolism disorders were significantly related to the occurrence of post-COVID condition (OR 1.46, 95% CI 1.28–1.65 and OR 1.25 95% CI 1.08–1.44, respectively). These findings align

with the results of the present study, in which BMI ≥30 emerged as a significant predictor of post-COVID-19 condition with an odds ratio of 2.8. Interestingly, the association obesity and long-covid were more pronounced in women than in men in the study by Loosen and colleagues. As we included only male conscripts, we were not able to evaluate the influence of sex on the development of post-COVID. Further, lipid metabolic disorders were not present in our cohort, likely reflecting the young age of the participants. Loosen et al also identified hypertension as significant predictor of long-COVID, whereas elevated resting blood pressure showed only a borderline association in some of our regression models. This partial overlap in identified risk factors may be explained by the markedly different study populations. While Loosen et al. analyzed a broad outpatient cohort with a wide age range and a higher burden of pre-existing conditions, the present study focused exclusively on young, generally healthy male conscripts. As a result, classical cardiometabolic comorbidities such as dyslipidemia and established hypertension were largely absent in our cohort, potentially limiting their detectable impact. In this context, anthropometric markers of obesity may represent earlier indicators of metabolic vulnerability, whereas metabolic disorders typically emerge later in life (34).

Using two longitudinal British birth cohorts, a recent study evaluated the influence of obesity onset on the risk to develop post-COVID-condition. The authors reported that individuals with an early-onset of overweight and obesity had a twice-to third-fold higher probability to develop long-COVID as those persons who started to being overweight or obese later in life. These findings support the idea that longer exposure to excess body fat may increase vulnerability to post-COVID conditions (64).

In line with the above-mentioned studies, we found a significant association between BMI-based obesity and the development of post-COVID-19 condition. People with persistent or newly-emerged symptoms were 3-fold more obese than those without post-COVID-19. This result was further confirmed by binary logistic regression analyses, which identified BMI-based obesity as significant predictor of post-COVID. Contrarily, BMI-based underweight and normal weight did not show a significant relationship with experiencing post-COVID-19. However, all the prior-discussed studies have relied solely on BMI in their identified associations between obesity and post-COVID-19 condition. BMI has long been used as the main way to identify obesity in both healthcare and public health. Although BMI is quick and easy to calculate, it has many weaknesses. First, BMI does not show where most fat is actually stored in the body. Thus, it is not reliable to assess abdominal obesity. Second, it cannot separate muscle weight from fat weight. This can be misleading, especially in young adults, where a higher BMI may reflect greater muscle rather than excess body fat (35,36). For example, one study found that

men with a BMI of 27 had body fat percentages ranging from about 10% to 32%. This means that some men labeled as “overweight” actually had low body fat, while others had fat levels typical of obesity (65). And third, it does not reliably predict cardiometabolic health. For these reasons, recent clinical guidelines have incorporated in their diagnosis of obesity additional anthropometric markers, such as WC or WHtR. According to the consensus statement of the European Association for the Study of Obesity, a BMI ≥30 or a BMI ≥25 together with a WHtR ≥0.5 is necessary of the diagnosis of obesity (38). Similarly, the Lancet Diabetes & Endocrinology Commission recommends defining obesity using measures like WC and WHtR rather than relying only on BMI (66). The National Institute for Health and Care excellence also advises that BMI should be used carefully and that central adiposity should be additionally assessed through WHtR (39).

Evidence linking obesity to post-COVID-19 condition based on anthropometric parameters other than BMI is still very limited. So far, only one epidemiological study has specifically evaluated WC as a marker of abdominal obesity in this setting. In the Isfahan COVID cohort, which followed 4008 individuals after confirmed infection, approximately two thirds reported persistent symptoms, while the remaining participants recovered without long-term complaints. Participants with long-COVID showed higher average values of both BMI and WC, and abdominal obesity defined by WC was significantly more common in this group. Our findings are consistent with these observations. In the present cohort, centrally obese male conscripts had almost double the likelihood of developing post-COVID-19 condition compared with those without central obesity. However, whereas the Isfahan study reported an elevated risk of cardiovascular and respiratory complaints among participants with abdominal obesity, we did not observe meaningful differences in symptom intensity between WC-based obesity groups within our post-COVID-19 population. This discrepancy may reflect differences in age distribution, baseline health status, or symptom assessment methods between the two cohorts (37).

Although WC is commonly used to describe abdominal obesity, it does not adjust for differences in height and body build. For this reason, it may be less accurate when estimating individual health risks. The WHtR offers a clear advantage in this respect. By relating waist size to body height, WHtR allows a better assessment of fat distribution in the abdominal region. Further, a recent systematic review and meta-analysis has reported that WHtR outperform BMI and WC as a risk factor for cardiometabolic outcomes (40). As a result, most of the current clinical recommendations now recognize WHtR as the preferred anthropometric marker for obesity assessment (38,39). Until now, however, WHtR had not been evaluated in

relation to post-COVID-19 condition. Our study is, to the best of our knowledge, the first to explore this relationship. We observed that central obesity defined by WHtR (≥0.50) was nearly twice as frequent in participants with post-COVID-19 condition compared with those who fully recovered. This finding was further strengthened by regression analysis, which demonstrated that individuals with elevated WHtR showed more than a twofold increased likelihood of experiencing persistent symptoms after COVID-19. These results indicate that WHtR may identify obesity-related vulnerability to post-COVID-19 condition more effectively than BMI alone. Because WHtR is easy to measure and highly informative, it could serve as a practical screening tool to detect young people at increased risk for prolonged recovery. This is especially important given the rising rates of obesity in younger populations. The early adult years plays a key role in shaping future health, and ongoing post-COVID-19 symptoms may negatively affect education, work participation, and physical activity levels.

The exact pathophysiological pathways underlying the association between obesity and prolonged symptoms after COVID-19 infection are still not fully understood. A few mechanisms may explain why obesity increases the risk of the post-COVID-19 condition. A few biological processes may contribute to the increased susceptibility to post-COVID-19 condition among people with obesity (31). One important factor is reduced lung function and impaired oxygen delivery. Excess fat in the abdomen and chest limits pulmonary expansion and limits diaphragm motion. This leads to lower pulmonary volumes and higher airway resistance. As a result, this mechanical impairment can worsen oxygen exchange during acute infection and may contribute to persistent breathing problems afterward (67–70). In patients with long COVID, obesity has been associated with exaggerated breathing effort, reduced lung reserve, and lower oxygen saturation during physical activity. These changes may explain persistent dyspnea and exercise intolerance (70). Another possible mechanism is viral persistence in fat tissue. Adipose tissue appears to provide a favorable environment for viruses to persist. Previous studies in other viral infections have shown that fat tissue can harbor active virus particles and promote long-term immune stimulation (71–73). Similar findings have been reported for SARS-CoV-2. Autopsy and laboratory studies demonstrated that the virus can infect human adipocytes and replicate inside adipose tissue, suggesting that fat may act as a viral reservoir (74). This persistent viral presence may prolong inflammation and delay full recovery, even after the acute infection has resolved (31,75,76). Obesity is also characterized by chronic low-grade inflammation. Enlarged fat cells release higher amounts of inflammatory substances such as interleukin-6 and tumor necrosis factor, while protective anti-inflammatory signals are reduced. At the same time, immune function is impaired, leading to a weaker antiviral response. This combination promotes prolonged inflammation and may delay viral

clearance, allowing symptoms to persist for longer periods (31,77–80). Another contributing factor may be vascular dysfunction. Chronic inflammation in obesity weakens endothelial integrity and promotes abnormal blood clotting. Microclots have been detected in long COVID patients. Further, disturbed blood flow downstream of blocked capillaries has also been observed in patients with persistent symptoms. Reduced oxygen supply caused by these microvascular changes may contribute to fatigue, cognitive symptoms, and cardiovascular complaints in pos-COVID-19 condition (31,81,82). Individuals with obesity show increased levels of fibrinogen, von Willebrand factor, and plasminogen activator inhibitor-1, creating a hypercoagulable state that favors microthrombus formation (83,84). Endothelial dysfunction occurs earlier in obese patients, driven by chronic inflammation and lipid deposition, leading to premature vascular injury and enhanced exposure of procoagulant phospholipids (85,86). Impaired fibrinolysis further worsens this condition. Depletion of fibrinolytic factors reduces clot clearance, allowing microthrombi to persist and progressively obstruct pulmonary and systemic microcirculation (87,88). All together, these mechanisms suggest that obesity creates a biological environment marked by impaired lung mechanics, persistent inflammation, endothelial dysfunction, and increased thrombotic activity. This may explain why individuals with obesity are especially prone to delayed recovery and long-lasting symptoms after COVID-19 (31).

5.3 Strengths and Limitations

This study has several important strengths. First, it included a large, homogenous and well-defined sample of 500 young male conscripts aged 17 to 19 years who attended the mandatory military induction examination in Austria. Because participation was consecutive and only very few exclusion criteria were applied, the study population closely reflects the real composition of young adult men in Austria. This reduces selection bias and increases the general value of the results for strengthening public health strategies. Another major strength is the standardized medical assessment. All participants underwent the same routine clinical examination performed by trained medical staff. A further strength is the detailed anthropometric assessment of obesity. Instead of relying only on BMI, this study also evaluated WC and WHtR. These measures better reflect abdominal fat and allowed a more complete view of obesity-related risk. Importantly, obesity defined by all three parameters remained significantly associated with post-COVID-19 condition in multivariable regression analyses, even after adjustment for other factors. This strengthens the main finding that obesity may be an independent predictor of post-COVID-19 in young men.

Despite these strengths, several limitations must be considered. First, the study used a cross-sectional design, with all data collected at one single time point. Therefore, causal relationships cannot be proven. While obesity was associated with post-COVID-19 condition, it cannot be stated with certainty that obesity directly caused the persistent symptoms. In addition, BMI was measured only at the time of the induction examination. Information about participants' BMI before COVID-19 infection and possible weight changes after infection was not available. Therefore, it remains unclear whether obesity was already present prior to infection or developed afterward. Second, only young male conscripts were included. Women, older adults, and people with chronic diseases were not part of this study. Consequently, the results cannot be directly generalized to the broader population, and potential sex-related or age-related differences in post-COVID-19 risk could not be examined. Third, COVID-19 history was assessed by self-report. This may lead to recall bias. Objective confirmation of the infection through medical records or PCR results was not available. Furthermore, the exact timing of COVID-19 infection was not recorded, and the duration of post-COVID-19 symptoms was not assessed. These missing temporal data limit interpretation of symptom persistence and recovery patterns. Fourth, although superior anthropometric markers for obesity were used, the study did not include specialized techniques to assess body fat or deep abdominal fat. More advanced approaches, e.g. bioelectrical impedance analysis, dual-energy X-ray absorptiometry or magnetic resonance imaging, could have helped describe fat patterns in greater detail and better estimate metabolic health.

6 Conclusion

This dissertation project investigated the prevalence, symptom burden, and association of obesity and post-COVID-19 condition in a large, population-based cohort of young male conscripts undergoing mandatory military induction in Austria. Among participants with a confirmed history of COVID-19 infection, approximately one in five reported persistent or newly developed symptoms, demonstrating that post-COVID-19 condition represents a relevant health issue even in young, predominantly healthy men. All assessed obesity-related markers, BMI, WC and WHtR, were consistently associated with the presence of post-COVID-19 condition. This study is the first to demonstrate that central obesity assessed by WHtR and WC is linked to increased risk for post-COVID-19 condition. Given the recognized limitations of BMI alone, these findings underscore the added value of simple anthropometric indices including WC and WHtR, reflecting abdominal adiposity. As more and more young adults develop obesity, these simple measurements could help recognize people who may face longer recovery after COVID-19 infection.

More high-quality research is needed to understand how excess body fat affects recovery after COVID-19 infection. Future research should follow people for longer periods and include more detailed methods to measure body fat, such as imaging or impedance techniques. It would also be helpful to assess physical fitness, heart and lung function, and markers of inflammation to better explain why obesity increases the risk of persistent symptoms. Studies should also include women and older adults to see whether similar patterns exist in other population groups. Finally, future work should examine whether improving lifestyle habits, reducing body weight, or enhancing cardiovascular health can help prevent post-COVID-19 condition or support faster recovery.

7 Bibliography

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8 List of AI Tools Application

Solely for linguistic optimization of the text, the following artificial intelligence tool was used:

- **Name and version of the tool:** ChatGPT 5.2
- **Provider:** OpenAI
- **Date of content creation:** January - March, 2026
- **Address (URL of the tool):** https://chat.openai.com

For creation of individual visual elements of Figure 1, the following artificial intelligence tool was used:

- **Name and version of the tool:** Canva
- **Provider:** Canva Pty Ltd
- **Date of content creation:** February, 2026
- **Address (URL of the tool):** https://www.canva.com