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ORIGINAL ARTICLE

CORRELATION BETWEEN COVID-19 SYMPTOMS AND CERTAIN PHYSIOLOGICAL AND BODY COMPOSITION PARAMETERS RELATED TO OBESITY AND OVERWEIGHT

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Summary

Introduction: The high Body Mass Index and high body fat percentage are mentioned as factors influencing the severity of the course of COVID-19 disease. Our aim was to examine, in relation to their symptoms, the measured and estimated parameters of those included in the lifestyle program established by the armed forces suffering from mild to moderate COVID-19 disease.
Sample and Methods: The average age of the examined sample (n=18) was 45.2 years. The average body weight for women was (n=8) 78.5 kg, for men 106.2 kg, the average body fat percentage for women was 40.6% and for men 30.6%. The instruments used for the examination were a BIA 500 (800/µA, 50 kHz), an Omron BF 511 body composition monitor, an ECG Cardioscan monitor, and a DYNA-19 hand grip dynamometer. We applied a two-sample T-test in the examination. Differences with $p<0.05$ were considered statistically. Statistical calculations were performed in R environment with R-Studio program.
Results: The higher phase angle was characteristic at lower (p=0.04) and shorter (p=0.05) body temperatures. Higher body fat percentages were observed in the case of prolonged coughing (p=0.04). Lower cardiac function values were associated with higher fever (p=0.05) and difficulty in breathing (p=0.02), while higher cardiac stress percentage was associated with the appearance of chest pain (p=0.02) and higher fever (p=0.04).
Conclusion: It was not the location of adipose tissue but the magnitude of its amount that was related to the symptoms of mild to moderate COVID-19 in our sample, in contrast to several international observations.

Key words: Military health; COVID-19; Health behaviour; Body composition

Introduction

Since the end of year 2019, the SARS-CoV-2 has spread rapidly worldwide, causing a high number of diseases, including fatal severe acute respiratory syndrome (COVID-19). Since then, more than 10% of COVID-19 patients

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in hospital have been admitted to the Intensive Care Unit (ICU). Descriptive studies show that the number of people in need of hospital treatment, in particular ICU, is associated with age, being a male, BMI, and comorbidities associated with obesity (1-4), for instance, an increase in BMI is directly proportional to the increase in the severity of COVID-19 disease (5), and increases the risk of hospitalisation in the less severely affected individuals under the age of 60 years (6). This effect has also been demonstrated in other similar viral infections (3-7); abdominal obesity has been shown to decrease respiratory volume in obese individuals (3, 7, 8), and there is evidence that obesity results in an unregulated immune response in respiratory infections (2). Obese individuals are more prone to severe COVID-19 because the higher the amount of the adipose tissue, the higher the viral load they are exposed to is, and the amount of adipose tissue also affects the persistence of symptoms (9-12). Furthermore, it is assumed that not only fat percentage but also the location of the adipose tissue can affect the severity of the course of COVID-19, similar to Hepatitis C virus infection, where visceral obesity is associated with a higher viral load (13, 14). BMI does not differentiate between different tissues, nor does it provide a picture of adipose tissue distribution, thus it is not the most adequate choice as a distinguishing factor (15), furthermore, for patients in critical condition, BMI has been proved not to be an independent predictor of mortality (16).

In our study, we compared the severity of the symptoms of the disease caused by SARS-CoV-2 with the physiological and body composition indicators of overweight and obese soldiers participating in the Hungarian Defence Forces Body Composition Program (HTP).

During the examinations, using the BIA 500 body composition gauge, Omron BF511 analyzer, Dyna 16 meter, and the ECG Cardioscan monitor, we examined the severity of the symptoms of the disease in the light of the following parameters: phase angle, body fat percentage, cardiac function and cardiac stress values, maximal hand grip strength, body muscle percentage, and visceral fat rate.

Sample and Methods

We started with WHO data, according to which the disease is typically associated with fever in 88% of patients, dry cough in 68% of cases, and fatigue in 38% of cases. A lower incidence of productive cough (33%), dyspnoea (19%), sore throat (14%), headache (14%), muscle or joint pain (15%), and chills (11%) may occur. Less common symptoms are vomiting (5%) and diarrhoea (4%). The disease most commonly, in about 80% of cases, occurs in a mild to moderate form, in which case the clinical picture can range from mild respiratory infection to mild pneumonia. 14% of cases are severe, and 6% of patients may develop a critical condition with respiratory failure, septic shock, or multiple organ failure.

Adult obesity also affects the Hungarian army, which is not only an aesthetic problem, as it worsens the military appearance, but can also cause the development of many diseases. In 2015, the Hungarian Defence Forces (HDF) introduced the Hungarian Defence Forces Body Composition Program (HDF BCP) as a new force protection enhancement program.

Those participants of HDF BCP were included in the study who appeared at least 3 times (D+2, first time + 2 controls) in the examinations, have been taking part in the programme for more than half a year, and it has been proved (2 positive PCR tests) that they were infected with SARS-Cov2 virus between January 1 and December 31, 2020, and a maximum of 10 days elapsed between the last measurement and the detection of infection. Furthermore, the course of the COVID-19 disease existed in mild to moderate forms as far as the symptoms were concerned. The participants gave their written consent to participate, and the study was carried out with the approval of the Ethics Committee. Of the 18 individuals studied, 8 were women. The average age of the sample was 45.2 years (SD 4.7 years), their average body weight was 95.0 kg (SD 18.9 kg). The results of the HDF BCP test devices, the BIA 500, the Omron BF 511 body composition meter, and the Cardioscan ECG-accurate three-dimensional heart portrait (Electro Cardio Portrait, ECP), as well as the measured maximal hand grip strength values were examined.

For BIA 500, the relationship between the phase angle (PA), body fat, and muscle mass estimated by the device was examined, while for Omron BF511, the relationship between visceral fat values and the magnitude and length of symptoms during the infection was examined. Furthermore, cardiac stress and cardiac function values generated by the cardioscan device were examined in the context of symptoms during the disease. The symptoms were assessed based on the experience of the WHO with a questionnaire prepared by the Military Hospital Medical Centre of HDF specialists of the Hungarian Defence Forces. The variables examined were *body temperature* (37.5-38.5°C and above 38.6°C), *duration of higher body temperature* (1,2,3 or more than 3 days), *headache* as a symptom (for 1-3, 4-6, 7-10 or more than 10 days), and the presence of *sneezing* or *runny nose*. Other variables included the duration of *cough* (for 1-3, 4-6, 7-10 or more than 10 days), *difficulty in breathing*, *chest pain*, *loss of taste and smell* as a symptom, *gastrointestinal complaints* (abdominal pain, diarrhoea) and the presence of a *feeling of tiredness* or *weakness* (for less or more than 1 week). The questionnaire also included questions on hypertension, diabetes, body weight, smoking and physical activity habits.

Features of the Devices Used

BIA 500

The device used during the examination was the Premium Body Impedance Analyzer 500, produced in Germany (SNr. 13330472/1.0) and distributed by Prémium Health Concept Kft, which carries out body composition estimations, in the light of height and body mass, respective to age and gender with the help of the BIA software based on the bioelectric impedance (800/µA, 50 kHz) established between the four electrodes placed ipsilaterally (two on the back of the hands and two on the upper feet) during the examination. The instrument measures body resistance: the resistance (Rz) is the resistance of body water, the extracellular space and reactance (Xc), the intracellular space. Phase angle and Xc are proportionate, that is, index of cell mass. The size of the phase angle decreases during the decomposition of cell mass which makes the definition of the nutritional level possible. By measuring the phase angle, the nutritional level of the body can be defined. The decreasing phase angle means increasing extracellular mass and indicates a decline in fat-free mass.

Omron BF511

This type of body composition analyser has been standardized in the HDF since 2015. The device also measures body weight, the ratio of body fat to visceral fat, the percentage of skeletal muscle structure, and also capable of evaluating BMI classification value and resting metabolic rate (RMR). The certification of the device as a medical device guarantees its accuracy and reliability. Producer: OMRON HEALTHCARE Co., Ltd. Kunotsubo, item number: OM31-HBF-511B-E.

Cardioscan

The Cardioscan (serial number: CS-3 SN: 045090639) digitizes the pulses delivered by the heart through 4 electrodes and converts the ECG trace to ECP on a connected PC or laptop. The shape and colour of the image shows the state of health immediately and traceably. From the digitized ECG registry, the cardioscan analyzes heart rate variability (HRV), which changes with the stress on the heart, and can be used to detect the individual heart stress factor. The ECG as a function of time and the pulse rate spectrum also provide information on the extent of the psychological and physiological load on the heart. For the reference range of values measured and calculated by Cardioscan see Table 1. The measuring system of the German Energy-Lab Technologies GmbH (Hamburg) generates an ECP from the ECG signal.

Table 1. Reference range of values measured and calculated by Cardioscan (cardiac function 0-5 and cardiac stress 0-100%).

	good	normal	worrying	critical
Cardiac function	5.0-4.1	4.0-3.0	2.9-1.0	<1.0
Cardiac stress	<17%	17-50%	50-90%	<90%

Dyna 16

In addition, a DYNA 16 two-channel universal strength meter was used; which makes it possible to measure the grip strength of both hands at the same time (Bretz, produced in Hungary; SNr: C-0379). The result is shown in Newton as the unit of measurement.

All of the test subjects gave written consent to use the data for statistical purposes. We placed great emphasis on following the ethics rules in relation to data collection and analysis (informed consent form, analysis inadequate for personal identification), the results will be communicated with the compliance of ethics rules hereinafter. We applied a two-sample T-test in the examination. Differences with $p<0.05$ were considered statistically. Quantitative data are expressed as mean standard deviation (SD). Statistical calculations were performed in R environment with R-Studio program. (Version 4.0.2, 2021.09.1+372).

Results

For PA, values ranged from 4.6º to 8.4º, with a mean value of 6.23º (SD 0.9 º). Among the symptoms of COVID-19-induced disease, a significant correlation was found between the increase in body temperature (p=0.04), the presence of fever as a symptom and its duration (p=0.05). In the context of PA magnitude and the disease caused by SARS-Cov-2, fever as a symptom (body temperature higher than 37.5ºC) was significantly higher among those with lower PA. We also found an inverse proportionality regarding the duration of fever with respect to PA. Smaller PA was associated with a prolonged fever. No significant differences were found for the other symptoms (Table 2).

Table 2. Correlation between the phase angle measured by the BIA 500 body composition meter (800/µA, 50 kHz) and the symptoms of Covid-19 disease.

Phase angle (average 6.23º SD 0.9) **vs.**	**t-value**	**df**	**p-value**
increase in body temperature (> 38.5˚C)	2.24	13.3	0.04*
fever time	-2.11	15.6	0.05*
headache	0.39	12.2	0.70
sneezing	1.21	10.6	0.25
cough	0.33	15.6	0.74
difficulty breathing	0.55	5.7	0.60
chest pain	0.42	15.9	0.68
loss of taste, smell	1.66	7.4	0.14
fatigue	0.29	11.8	0.77
gastrointestinal complaints	1.41	16.0	0.18
	(*) p< 0.05		

When tested for body fat, the results ranged from 24.8% to 49.9%, with a mean of 35.58% (SD 7.98%). Regarding body fat, we found a significant difference (p=0.04) only in the length of cough among the symptoms. No significant differences were found for the other symptoms (Table 3).

Table 3. Correlation between the percentage of body fat measured by the BIA 500 body composition meter (800/µA, 50 kHz) and the symptoms of Covid-19 disease.

Body fat percentage (average 35.58% SD 7.98%) **vs.**	**t-value**	**df**	**p-value**
magnitude of fever	-0.22	15.97	0.83
fever time	-2.07	11.48	0.06
headache	-0.98	16.00	0.34
sneezing	-0.57	15.56	0.58
cough	-2.30	12.98	0.04*
difficulty breathing	0.07	6.03	0.94
chest pain	0.59	12.53	0.56
loss of taste, smell	-0.48	10.08	0.64
fatigue	-1.08	13.29	0.30
gastrointestinal complaints	-1.26	13.32	0.23
	(*) p< 0.05		

For cardiac function, the measured values ranged from 3.2 to 4.9, with a mean value of 4.46 (SD 0.42). Cardiac function values were inversely related to the magnitude of fever (p=0.05) as well as difficulty in breathing (p=0.02). Lower values were associated with higher body temperature and the development of difficulty in breathing. No significant differences were found for the other symptoms. When tested for cardiac stress, the results ranged from 9% to 41%, with a mean of 21.0% (SD 9.55%). For cardiac stress, among the symptoms induced by COVID-19, we found a significant difference between the values in relation to fever (p=0.04) and chest pain (p=0.02). No significant differences were found for the other symptoms (Table 4).

Table 4. Correlation between cardiac function as measured by Cardioscan, cardiac stress values and symptoms of Covid-19 disease.

Cardiac function (average 4.46 SD 0.42) + **Cardiac stress** (average 21.0 SD 9.55) ++	t-value		df		p-value	
	+	++	+	++	+	++
magnitude of fever	2.23	-2.10	13.6	14.32	0.05*	0.04*
duration of fever	1.10	0.14	8.4	14.97	0.31	0.99
headache	1.14	0.70	6.2	11.71	0.30	0.50
sneezing	0.32	1.85	8.2	14.71	0.76	0.08
cough	1.09	-0.05	8.35	14.75	0.31	0.96
difficulty breathing	2.58	0.36	13.9	6.39	0.02*	0.73
chest pain	-2.70	0.15	13.7	7.38	0.88	0.02*
loss of taste, smell	0.88	-0.27	13.9	8.48	0.39	0.80
fatigue	-0.12	-0.67	8.25	12.11	0.91	052
gastrointestinal complaints	0.80	0.43	6.10	10.74	0.45	0.67
(*) p< 0.05						

+ statistical values for cardiac function
++ statistical values for cardiac stress

The mean maximum hand grip strength was 463.53 Newtons (SD 140.88N) and the mean body muscle percentage was 28.48% (SD 3.95%). When measuring visceral fat, the mean value was 11.73 (SD 4.78). No significant difference was found between maximal clamping force, body muscle percentage, visceral fat values and the symptoms of Sars-Cov2 virus-induced disease (Table 5).

Table 5. The relationship between maximal hand grip strength, body muscle percentage, visceral fat levels and symptoms of Covid-19 disease.

Maximal hand grip strength (average 463.53N SD 140N) + **Body muscle percentage** (average 28.48% SD 3.95%) ++ **Visceral fat value** (average 11.73 SD 4.78) +++	t-value			df			p-value		
	+	++	+++	+	++	+++	+	++	+++
magnitude of fever	0.36	0.17	-0.45	13.88	14.56	12.42	0.73	0.87	0.66
duration of fever	1.30	1.92	1.33	14.50	11.57	15.00	0.22	0.08	0.20
headache	0.35	0.62	-0.16	12.64	14.93	14.95	0.73	0.54	0.88
sneezing	1.25	0.43	0.90	13.17	14.95	14.56	0.23	0.67	0.39
cough	0.99	1.65	-0.77	13.76	13.65	13.98	0.34	0.12	0.45
difficulty breathing	0.45	-0.08	0.63	7.89	6.57	5.85	0.66	0.94	0.55
chest pain	0.96	0.04	1.03	11.53	10.90	7.64	0.36	0.97	0.33
loss of taste, smell	1.60	1.08	1.75	11.42	9.84	14.98	0.14	0.30	0.10
fatigue	0.14	0.37	-1.09	7.70	11.00	8.78	0.89	0.72	0.31
gastrointestinal complaints	-0.10	0.84	-0.47	14.85	13.78	14.84	0.93	0.42	0.64
(*) p< 0.05									

+ values for maximum hand grip strength
++ values for body muscle percentage
+++ values for visceral fat

Discussion

The PA has repeatedly been shown to predict morbidity and mortality in other patient groups (18-20). Some data demonstrate the potential of PA in predicting the severity of the disease in COVID-19 patients (21), and there is also a strong correlation with the clinical course of the disease (21-23). In our study, in the context of PA magnitude and symptoms of the disease caused by SARS-Cov-2, fever as a symptom (body temperature higher than 37.5ºC) was significantly higher among those with lower PA. We also found an inverse proportionality for the duration of fever with respect to PA – the lower PA was associated with a prolonged fever. In patients with non-severe COVID-19 disease, the magnitude and length of fever as a symptom have been associated with changes in PA values.

Obesity also has a major effect on normal lungs in terms of function. Fat deposits during obesity alter lung function and the chest wall, thereby reducing lung adequacy (21). Obesity and longer hospitalisation with severe or moderate COVID-19 have also been shown to be associated with a higher risk of sarcopenia (24). Many studies have also reported that excess accumulation of intramuscular fat is associated with increased production of inflammatory cells and induces respiratory hypersensitivity (25-28). In a patient with Acute Respiratory Distress Syndrome, the breathing work increases (breaths per minute and air volume) to meet the body's need for oxygen. This physiological response is complicated by obesity. Body fat has been associated with COVID-19 in observational and MR analyses, however, the appearance and duration of mild to moderate symptoms have not been studied (29). In our sample, we found a correlation only between the length of cough symptoms. The higher the body fat percentage was, the longer the cough lasted during the illness. Some observational studies suggested that the association with central body fat distribution was stronger than BMI or even fat mass (30). Notwithstanding, we did not find a significant difference between visceral fat values and symptoms in those with higher visceral fat values, so we could not confirm these results with our method on the sample tested.

HRV is a consequence of continuous external and internal stimuli to which the body must respond, for instance a stressful situation or an increased mental strain. The autonomic nervous system, which produces sympathetic and parasympathetic effects, affects the internal clock of the heart, the sinus node. The information channels of the autonomic nervous system are related to the processes of the central nervous system (brain) on the one hand, and to the peripheral stimuli on the other hand, and indirectly to the load of the tasks to be solved. The parasympathetic nervous system (vagus) is mainly responsible for the inhibitory effects, the sympathetic nervous system for the activating functions. Thus, the measurement of HRV can provide indications not only of the central regulatory functions but also of the status of individual organs (31). Higher HRV predicts greater chances of survival, especially in patients with COVID-19 aged 70 years and older, regardless of major prognostic factors, while low HRV predicts referral to intensive care and admission more often in the first week after hospitalisation (32). From the digitized ECG registry, Cardioscan analyses HRV, which changes as a result of cardiac stress, and can be used to detect individual cardiac stress factor. From the measured values, a direct proportionality was found between heart stress and fever, and with lower heart stress value, lower body temperature was observed. Cardiac function, in addition to an increase in body temperature, also correlated with difficulty in breathing, in relation to non-severe COVID-19.

In general, each study evaluates the results of COVID-19 patients treated in moderate to severe clinical settings. These results are important where the civilian population is concerned, however, the impact of mild and moderately severe COVID-19 among soldiers, who do not require clinical level care, is also extremely important in terms of military adequacy and combat value.

Conclusion

Adult obesity also affects the Hungarian army, which is not only an aesthetic problem, as it worsens the military appearance, but can also cause the development of many diseases. Adherence to physique recommendations and acceptable physical condition for soldiers, police officers, and those working in penal institutions are essential for long-term work-capacity and maintaining their ability to serve. For prevention and the organization of therapeutic protocols and health care, it is essential to explore that, in relation to the course of the disease, which factors influence susceptibility to severe COVID-19.

The results of the investigation showed, among other things, that the location of adipose tissue, not just magnitude, was associated with the symptoms of mild to moderate COVID-19 in our sample, in contrast to several international observations. Phase angle and heart rate variability have so far demonstrated their prognostic significance in several diseases. In our study, in case of mild to moderate COVID-19, cardiac function values and cardiac stress percentage were associated with some symptoms. The non-invasive testing devices we used may be suitable for monitoring the fitness for service of overweight and obese individuals. If studies performed on other populations support these results, the values of these parameters can provide therapeutic options that can be developed more easily even in the case of pre-clinical COVID-19.

Author contributions statement

AN conceptualized the study design, developed the protocol and drafted the manuscript. SZSZ collected and analysed data. HB, and AS collected dat. CSNY supervised the drafting of the protocol and drafted the manuscript. All authors read and approved the final version of the manuscript.

Conflicts of interest

All authors – none to declare.

Adherence to Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study.

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