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Original Article

Influence of massage on respiratory and circulatory parameters in a post-COVID-19 patient: a case study

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Abstract:
Monitoring the S_aO_2 levels and other respiratory function parameters after recovering from COVID-19 can have essential meaning in the assessment of the efficacy of using physiotherapy methods, including classical massage. **Purpose of the research** was to assess the influence of an individual classical back massage session as well as the effects of an entire 8-session back massage therapy on S_aO_2, HR and spirometry parameters in a patient after recovering from COVID-19, with constant monitoring of massage areas' temperature changes. **Data and methods**. The study comprised a case study of a patient who recovered from COVID-19. The patient was subjected to a classical back and spine massage therapy utilising all the basic techniques. The design was based on the results of the following tests: lung x-ray, S_aO_2, HR, spirometry parameters, and the 6-minute walking distance test. The degree of the influence of the classical massage techniques was monitored using the infrared thermography. **Results.** Continuous oxygen saturation monitoring during the massage sessions enabled to observe a decrease in the level of this parameter during utilisation of rubbing and tapotement on muscles of both the right and the left side of the back. During the usage of the intense massage techniques S_aO_2 dropped maximally to 92–93%. Such decrease was noted after massaging the right as well as the left side of the back, during every massage session. I addition it was found that in the case of the patient who recovered from COVID-19 changing the body position from sitting down to lying down after the massage session the level of tissues saturation decreased. The observed changes in the VA/Q ratio that occurred in response to the 8-session massage therapy lasting for 3 weeks might indicate that better conditions for ventilation and oxygen perfusion at the alveolar surface were reached. This translated in the patient who recovered from COVID-19 into 2% increase in oxygen saturation level after completing the massage therapy. **Conclusion.** Utilising the intense rubbing and tapotement techniques has to be carefully considered due to their significant influence on decrease in the level of saturation.
Key Words*: *COVID-19, rehabilitation, massage, infrared thermography, VA/Q, S_aO_2

Introduction

At the end of 2019 a new coronavirus, called SARS-CoV-2, emerged in China and quickly spread to the entire world, bringing millions of infections and hundreds of thousands of deaths (Huang et al., 2020). Early descriptions of the clinical presentation of a disease developing as a result of SARS-CoV-2 infection, called the coronavirus disease 2019 (COVID-19) revealed that one third of patients did not experience dyspnoea (Zhou et al., 2020). Dyspnoea was noted in 18.7% of 1099 patients hospitalised due to COVID-19, of which many showed irregular results of Computed Tomography (86%) and were administered oxygen therapy (Xie et al., 2020). In patients with x-ray indicating pneumonia due to COVID-19, only 50% reported dyspnoea (Huang et al., 2020). Despite growing knowledge, criteria of screening tests and managing the care in a majority of countries, including France, are still based on the three symptoms: fever, cough and dyspnoea. Symptomless patients are asked to isolate themselves at home and individuals experiencing symptoms — to consult a physician. It should be noted, however, that the condition of some COVID-19 patients exacerbates quickly and seemingly without any notice. For instance, in Marseilles, France over two thirds of patients hospitalised at the Intensive Care Unit (ICU) were brought to the ICU directly from their homes or were admitted to the ICU after less than three days of standard hospital care. Moreover, many patients, especially elderly, who later demonstrated respiratory failure experienced hypoxaemia and hypercapnia without any signs of respiratory failure. This was called a "silent hypoxaemia" and was described in patients during the early Wuhan epidemics (Xie et al., 2020). The cause of this symptomless hypoxia is not yet clear. Such condition was described as a frequent clinical symptom of COVID-19 (Boudjema et al., 2020). Some researchers explain this hypoxaemia with the development of clots in lung vessels (Couzin-Franke, 2020). The current target arterial oxygen

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saturation for COVID-19 patients recommended by the National Institutes of Health ranges between 92 and 96% (Luks & Swenson, 2020). From the perspective of this data it seems that monitoring the arterial blood oxygen saturation (S_aO_2) levels and other respiratory function parameters after recovering from COVID-19 can have essential meaning in the assessment of the efficacy of using physiotherapy methods, including classical massage. As it is emphasised in the paper (Sun et al., 2020), rehabilitation guidance for such patients with COVID-19 is based on previous experience. However, as different patients have differing degrees of dysfunction, personalized plans need to be designed according to the patients' age, sex, lifestyle, hobbies, occupation, and physical conditions. The rapid development of remote devices that can monitor patients' real-time physical conditions post-discharge may encourage better adherence to rehabilitation training.

Thermography, also known as infrared thermography, is a method of remote and contactless assessment of body surface temperature distribution. Modern infrared thermography methods enable to determine temperature changes in relation to both the values and spatial distribution, from statistical and dynamic perspective. Their essential advantage is the completely non-invasive character and lack of any side effects for the patient, and thus, possibility of repeating the measurements multiple times with no harm to the patient (Ring & Ammer, 2012). Infrared thermography is one of the most useful tools for that purpose, because it allows to assess the effectiveness of the single session and gives the opportunity to follow and assess serial sessions not only in medicine (Hildebrandt et al., 2010; Gómez-Carmona et al., 2020; Kirimat et al; 2020; Lubkowska & Gajewska, 2020; Lubkowska & Hudecka, 2021; Priego-Quesada et al. 2021; Shakhih et al., 2021), but also in the practice of biological regeneration in athletes (Adamczyk et al., 2016; Moreira et al., 2017; Hillen et al., 2020).

The available scientific literature also describes possibilities of using thermovision for the determination of a degree of circulation improvement in the body areas under the influence of massage (Sefton et al., 2010; Blackie et al., 2013; Wälchli et al., 2014; Lee et al., 2017; Radziejowska et al., 2020a; Radziejowska et al. 2020b), acupuncture (Litscher, 2010), electroacupuncture (Fun & Wu, 2015), and after manual therapy combined with diathermy (Wu et al., 2009).

The **purpose of this study** was to assess the influence of an individual classical back massage session as well as the effects of an entire 8-session back massage therapy on SaO2, HR and spirometry parameters in a patient after recovering from COVID-19, with constant monitoring of massage areas' temperature changes. The main assumption of the conducted study was customisation of the classical massage therapy plan after the recovery from COVID-19 and constant evaluation of massaged patient's condition based on intra-procedural monitoring of oxygen saturation and assessment of the degree of the effects of individual massage techniques using the infrared thermography.

Material & methods

Participants

The study was conducted on a male, slightly overweight patient, 45 years old (height – 183 cm, body mass – 92 kg, BMI – 27,8 kg/m^2). On the 9th of October 2020 patient received a positive result of the SARS-CoV-2 test. At the beginning of the isolation period that began after receiving the positive result of the SARS-CoV-2 test, in his self-monitoring diary patient noted headaches in first 2 - 3 days, loss of taste and smell, and perception disturbance.

The symptoms subsided after 10 days. The patient was not hospitalised. During the 2 months after receiving a negative SARS-CoV-2 test result, patient experienced loss of focus to an extent that driving a car became impossible. Three months after the beginning of the infection (on the 15th of December 2020) the patient had a chest x-ray in two views. No complications within lungs was shown in Figure 1.

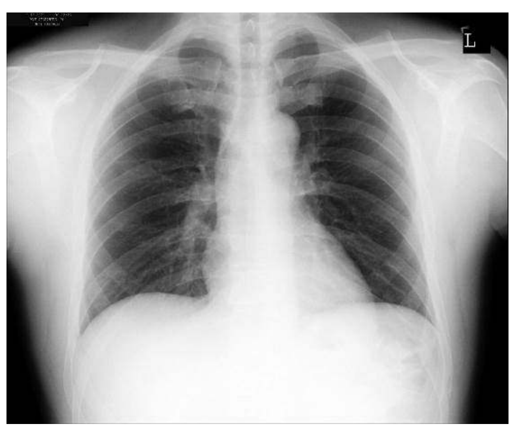

Figure 1. Patient's chest x-ray results (frontal view).

Measurements/Instruments

After three months from receiving the negative SARS-CoV-2 test result (the end of January 2020) a back (back and spine) massage therapy was started.

At the beginning patient was asked to show the chest x-ray results (see Figure 1). After making sure that no changes were present in lungs, the patient was asked to complete a 6-minute walking distance test (6MWD). During the 6MWD test carried out before starting the massage therapy, the level of fatigue experienced by the patient amounted to 14 points in the Borg's scale (somewhat hard). However, the patient almost walked the distance appropriate for his age and sex (i.e. 585 m) (Borg, 1982).

The next tests included spirometry, SaO_2 and HR. Measurements of spirometry parameters, arterial blood oxygen saturation (S_aO_2) and heart rate (HR) were conducted according to the rules of appropriate conduction of examinations, i.e. under the same conditions. The spirometry measurements were conducted before and after each of the 8 massage sessions in sitting position (spirometer LUNG-1000, Krakow, Poland).

After lying on the abdomen for 5 minutes before a massage session, during the session (every minute) and after completing the session S_aO_2 and HR were measured and then these measurements were utilised in further analysis. Arterial blood oxygen saturation (S_aO_2) and heart rate (HR) were measured using the "Oxyshuttle" pulse oximeter (Sacramento, CA, USA).

Systolic and diastolic blood pressure (mmHg) was measured on the right arm after 15 min of rest with the patient sitting upright, using an automatic oscillometric device (Omron 705CP, Kyoto, Japan) or, if this failed, a mercury sphygmomanometer. Two measurements were taken 2 minutes apart from each other — if one failed a third was taken. The average of two measurements was used.

Heart stroke volume (SV) was determined according to the Isaak Starr (Starr, 1954) formula for adults:

$$SV = 93 + 0.62 \times (SP - DP) - 0.45 \times DP - 0.61 \times age, (1)$$

where SP—systolic pressure (mm Hg) and DP—diastolic pressure (mm Hg), age in years.

Cardiac output (Q) was determined according to the formula:

$$Q = HR \times SV, (2)$$

where HR—heart rate per minute (bpm) and SV—stroke volume (mL).

Spirometry measurements were conducted using the LUNGTEST-1000 device (Kraków, Poland). Respiratory rate (f) and tidal volume (VT) were chosen for the analysis.

Alveolar volume (VA) was calculated using the following formula:

$$VA = f\,(VT — VD), (3)$$

where VT — tidal volume, f — respiratory rate, VD — dead space volume.

Dead space volume (VD) was calculated assuming that the normal ratio of dead space volume to tidal volume (VD:VT) does not exceed 0.35 (Tusman et al., 2011).

Appropriate adjustment of the level of alveolar volume (VA) to the cardiac output (Q) is essential for proper gas exchange. It is the most efficient when the VA/Q ratio oscillates around 0.8. Every VA/Q ratio change influences the level of O_2 uptake and CO_2 elimination in lungs (Pittman, 2014). Low and high VA/Q ratios cause hypoxaemia, impaired CO_2 elimination and increased work of breathing in chronic obstructive pulmonary disease patients (Pittman, 2014; Peterson & Glenny, 2014). That is why, to determine the probability of hypoxemia, due to both hyper- and hypoventilation, the VA/Q ratio was calculated.

The patient was subjected to the classical back (back and spine) massage techniques. Degree of the influence of the classical massage techniques during the session of classical massage was controlled using the infrared thermography (Flir6 camera, Tallin, Estonia). Using the infrared thermography allowed to visualise temperature distribution on the massaged body area, what enabled constant monitoring of changes in the level of blood circulation during the session.

Procedure

In the study back and spine massage was carried out according to the standards of the classical massage (Zborowski, 2010; Allen & Pounds 2015; Popa & Dobrescu, 2017; Staude & Radzieshevska, 2021; Yuniana et al., 2022). Each massage session lasted for 20 minutes. The entire therapy lasted for 3 weeks and consisted of 8 sessions carried out every 2–3 days. The massage was conducted according to the rules of the safe classical massage methodology (Zborowski, 2010; Allen & Pounds 2015).

Results

Analysis of the oxygen saturation measured before the massage in a sitting position and after the massage 5 minutes after assuming the same body position still showed results with downward trend (see Tab. 1). The trend was more pronounced at the beginning of the therapy; S_aO_2 dropped by 2% from the first to the fourth massage session. At the end of the therapy, during the seventh and eight session, the initial level of oxygen saturation increased by 1% in comparison to the first session and the saturation drop after the massage was only 1%. Heart rate during the entire therapy stayed at almost the same level, although, it had clear tendency to decrease its value after the last massage session of the therapy. The ventilation parameters fell within normal ranges: respiratory rate and tidal volume were within the ranges appropriate for an individual of certain age and sex as described in Table 1.

Table 1. Selected parameters of respiration and circulation of the analysed patient before and after massage session (from the first to the eight session) measured in sitting position, where: (I) – measurements before the massage procedure, (II) – measurements after the massage procedure.

Parameters	SaO_2, %		HR, bpm		VT, mL		f, breaths/min	
Session No.	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
1	97	95	88	86	540	510	14.56	14.60
2	97	95	87	84	550	560	14.30	14.17
3	97	95	86	83	600	580	12.87	13.09
4	97	95	86	85	580	570	13.15	12.98
5	97	96	84	82	570	570	13.10	12.87
6	97	96	85	84	550	540	13.84	13.71
7	98	97	82	82	510	520	13.71	13.56
8	98	97	82	80	520	520	13.12	13.04

At the end of the massage therapy we have observed changes in the VA/Q ratio that can justify simultaneous increase in oxygen saturation. In our opinion, it was the VA/Q ratio improvement and its gradual lowering to the normal range (0.78–0.80) what allowed to reach better conditions for ventilation and oxygen perfusion at the alveolar surface. This in turn resulted in 2% increase in oxygen saturation (see Tables 1, 2).

Table 2. Selected parameters of respiration and circulation of the analysed patient before and after massage session (from the first to the eight session) calculated based on formulas (1), (2), (3), where: (I) – measurements before the massage, (II) – measurements after the massage.

Parameters	SV, mL		Q, mL/ min		VA, mL/ min		VA/Q	
Session No.	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
1	59.81	57.61	5263	4954	5110	4839	0.97	0.98
2	62.99	62.87	5480	5281	5112	5157	0.93	0.98
3	62.74	63.90	5395	5303	5019	4934	0.85	0.93
4	63.04	62.99	5421	5354	4957	4809	0.91	0.91
5	65.64	67.24	5514	5298	4853	4768	0.88	0.90
6	67.67	68.47	5752	5594	4947	4812	0.86	0.86
7	68.26	69.26	5680	5680	4544	4583	0.80	0.81
8	69.31	68.86	5684	5509	4434	4 407	0.78	0.80

The infrared thermography measurements carried out during the course of individual massage sessions allowed to establish that there is a relationship between the intensity of classical massage techniques and the level of temperature increase of the massaged area (see Figure 2). The temperature of the massaged area increased the most at 6^{th}–7^{th} (see Figure 2(b)) and 16^{th}–18^{th} minute of the massage session (see Figure 2(c)).

The analysis of the average temperature of the massaged area enabled to establish that during the course of the massage session this parameter increased by 2.4°C at the right side of the back (Bx1, see Figure 2(b)) which was massaged as the first. In the same time, the average temperature of the left side of the back (Bx2, see Figure 2(b)) increased by 0.8°C.

Using the rubbing and tapotement techniques on the left side of the back increased the temperature of the massaged area even more (by 3.7°C in comparison the level before the massage, by 3.1°C in comparison to the end of using the intense massage techniques at the right side of the back). It was interesting that after the massage of the left side of the back, the temperature of the right side of the back, massaged 12 minutes earlier, also increased by 0.6°C in comparison to the previous measurement. This may indicate spontaneous synergistic character of the massage techniques' activity increasing the blood circulation in the massaged area even after the massage is over. Similar changes in temperature on the massaged areas: the right side (massaged as the first) and the left side (massaged directly after the right side), were observed during every session of the eight massage sessions of which the entire therapy consisted.

Continuous S_aO_2 monitoring during the massage sessions allowed to observe a decrease in the level of this parameter during using the intense massage techniques (rubbing and tapotement), both on the right side of the back at the 6^{th}–8^{th} minute of the procedure and on the left side at the 16^{th}–18^{th} minute of the procedure. Such character of the changes was observed during every massage session (see Figure 3).

During the usage of the intense massage techniques S_aO_2 dropped maximally to 92–93%. Such decrease was noted after massaging both the right and the left side of the back during every massage session (see Figure 3).

After completion of the massage therapy consisting of 8 sessions and lasting for 3 weeks, the 6-minute walking distance test was carried out every month (12 times). The results of the 18-month observation showed that the distance walked during the test did not change significantly and ranged from 580 to 600 m, but what is important, the level of fatigue gradually shifted from 14 points in Borg's scale (somewhat hard) before the therapy to 11 points (fairly light) after the therapy. The patient had not noted any signs of discomfort or other complaints resulting from the conducted massage therapy.

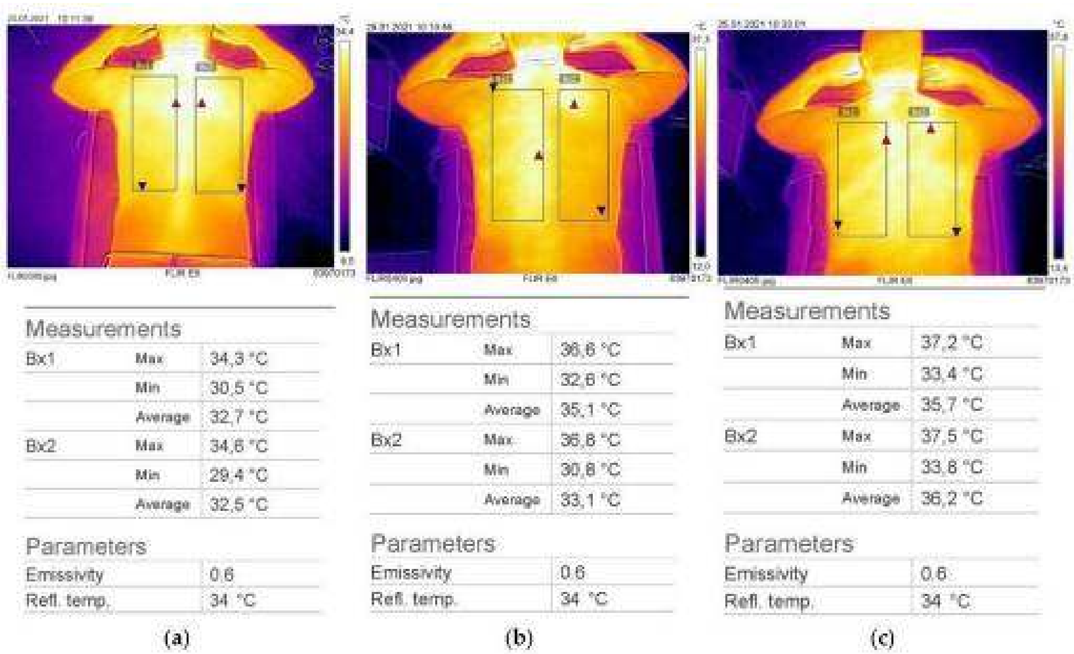

Figure 2. Temperature of the massaged areas of the back during the classical massage session in the analysed patient: a – before the massage session; b – after rubbing and tapotement at the left side (6th minute); c – after rubbing and tapotement at the right side (18th minute).

Discussion

As a result of the conducted study it has been established that when patient who recovered from COVID-19 shifts from sitting to lying down position after the massage session the level of tissues saturation decreases. Different body positions can cause changes in tissue perfusion. This should be considered in patient follow-up along with the perfusion index (Ceylan et al., 2016). In this case, similarly to healthy individuals, sitting position is more comfortable and more beneficial for obtaining better conditions for alveolar perfusion (Tapar et al., 2018). As reported in (Busana et al., 2021), significant role in the pathogenesis of severe cases of COVID-19 is played by abnormal alveolar ventilation to cardiac output ratio. Studies carried out on a model showed that a large fraction of the blood flow was likely distributed in regions with very low VA/Q ($Q_{mean} = 0.06 \pm 0.02$) and a smaller fraction in regions with moderately high VA/Q. Overall LogSD, Q was 1.66 ± 0.14, suggestive of high VA/Q inequality. The most current report on understanding the influence of coronavirus on human organism (Gando & Wada, 2022) mentions that lung immunothrombosis in type L ARDS results from neutrophil extracellular traps containing platelets and fibrin in the lung microvasculature, leading to hypoxemia due to impaired blood flow and a high ventilation/perfusion (VA/Q) ratio. COVID-19-associated ARDS is more vascular centric than the other types of ARDS. D-dimer levels have been monitored for the progression of microvascular thrombosis in COVID-19 patients. Early anticoagulation therapy in critical patients with high D-dimer levels may improve prognosis, including the prevention and/or alleviation of ARDS. That is why deviations of VA/Q towards values both higher and lower than the normal levels draw attention of many authors analysing the VA/Q ratio during therapeutic and physiotherapeutic interventions after the recovery from COVID-19 (Gattoni et al, 2020; Carsana et al., 2020; Poissy et al, 2020; McDonald, 2021).

However, still in the studies determining the general parameter for the entire normal alveolar surface, with no chronic lung diseases, the suggested normal VA/Q value amounts to about 0.8 (Pittman, 2011; Rinieri et al., 2012). Increase in this parameter to over 0.9 can indicate alveolar hyperventilation as a cause of hypoxaemia, whereas decrease below 0.7 indicates that VA is not adjusted to Q in the context of weak lung ventilation (Pittman, 2011; Rinieri et al., 2012). The changes of the VA/Q ratio observed in this study under the influence of the 8-session massage therapy lasting for 3 weeks may suggest that better conditions for ventilation and oxygen perfusion at the alveolar surface were reached and this translated into 2% increase in the level of oxygen saturation measured in a patient at rest in a sitting position after the last session of the massage therapy (the 8th session). Utilising the infrared thermography method enabled to determine the degree of temperature changes of the massaged areas under the influence of individual massage techniques. The results supported the traditional opinion on the influence of rubbing and tapotement on the massaged area, what manifested itself in the highest possible thermogenic influence on the massaged tissues (Sefton et al., 2010; Radziejowska et al., 2020a; Radziejowska et al., 2020b). Temperature of the massaged areas increased the most after using the rubbing and tapotement techniques at 6th–8th and 16th–18th minute of massage. The effect of increased temperature of the massaged areas remained for a long time and even increased after the massage of the opposite side of the body.

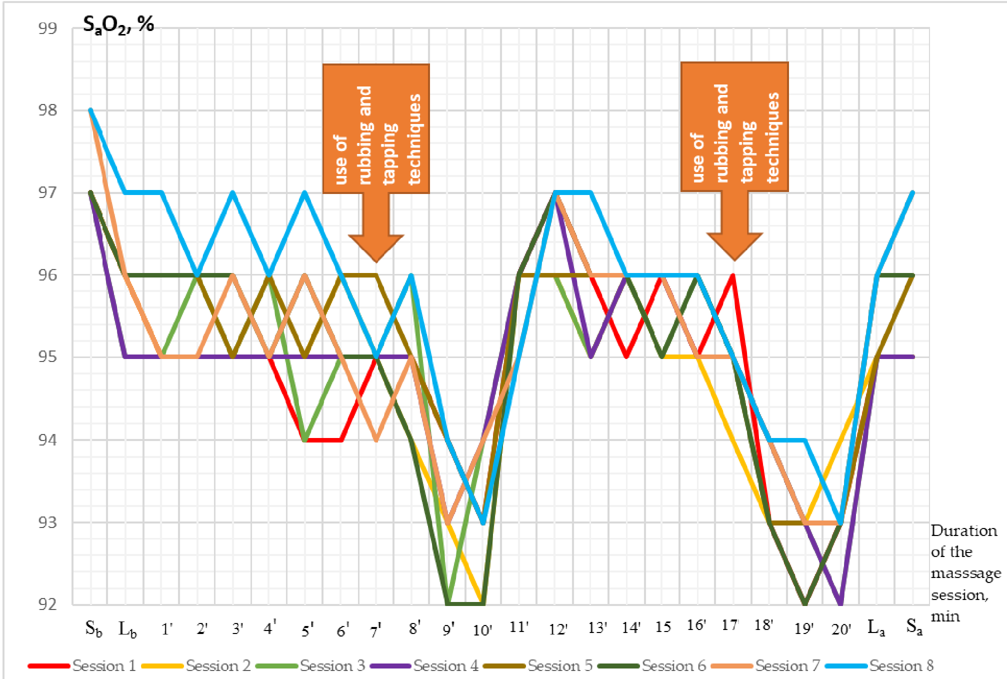

Figure 3. Changes in oxygen saturation (S_aO_2) during every of the eight massage sessions carried out on a patient who recovered from COVID-19, where S_b and L_b – initial body position before the massage, sitting and lying down, respectively; L_a – lying down position directly after the massage, S_a – sitting position, 5 minutes after completing the massage.

The conducted study showed that massage sessions caused significant changes in the S_aO_2 in a patient who recovered from COVID-19 in comparison to healthy individuals (Radziejowski et al., 2021). The patient's baseline S_aO_2 was at the level similar to healthy individuals (97–98% and 96.83 ± 0.75% (Radziejowski et al., 2021), respectively). During massage sessions decrease in S_aO_2 to values as low as 92–93% was observed (see Figure 3). Whereas, in healthy individuals the highest deviation from the baseline was observed during the massage of left and right intercostal muscles (7th and 14th minute of the massage, respectively); S_aO_2 decreased to 94.0 ± 0.63% (7th minute, left side) and 94.16 ± 0.75% (14th minute, right side).

Decrease in S_aO_2 to 94.5 ± 0.55% was also noted at the end of the session, after employing the tapotement techniques (hacking and cupping). Five minutes after the massage, the level of S_aO_2 increased to 97.0 ± 0.63% (Poissy et al., 2020). In the case of the studied patient who recovered from COVID-19 similar trend was not found, the S_aO_2 level increased in the 5-minute period after the massage session and it did not return to the baseline level, although it always stayed within the range recommended by the National Institutes of Health (Luks & Swenson, 2020) *and amounted to* 95–97%. Changes in S_aO_2 observed during the massage session can indicate that the alveolar ventilation to blood flow velocity ratio changes during the massage are similar to the changes observed during low-intensity physical activity, due to increased temperature of the massaged area.

Conclusions

The back massage therapy conducted over 3 weeks positively influenced levels of S_aO_2 and VA/Q of a patient who recovered from COVID-19. Due to adaptation to mechanical stimuli applied to the area of the posterior surface of the chest, the VA/Q ratio showed clear tendency to normalise, what manifested in 2% increase in S_aO_2 at rest in a sitting position after the massage session at the end of the therapy. Using intense massage techniques (rubbing and tapotement) during back massage sessions resulted in the highest increase in the massaged area's temperature with simultaneous decrease in S_aO_2. Decreased S_aO_2 fell within the normal range, although it was lower by 2–3% in comparison to individuals who did not suffer from COVID-19 (Radziejowski et al., 2021).

Based on the conducted study we can conclude that utilising classical back massage in order to improve condition of a patient who recovered from COVID-19 requires constant monitoring of S_aO_2 during massage sessions with simultaneous cautious utilisation of intense massage techniques, such as rubbing and tapotement. Exercising caution is necessary due to significant decrease in the level of S_aO_2 during using the intense massage techniques in a patient who recovered from COVID-19.

Conflict of Interest. The authors declare that there is no conflict of interest.

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