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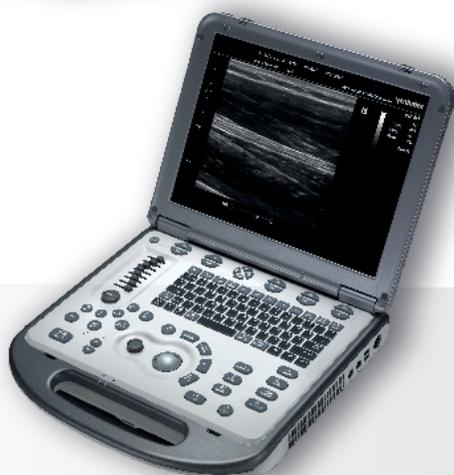
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Vibrotherapy in respiratory disorders, including COVID-19

Wibroterapia w zaburzeniach oddechowych, w tym w COVID-19

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Abstract

Successfully used for years in the rehabilitation of various diseases, the techniques of manual vibration massage and therapeutic vibrations generated by medical devices distinguish a new type of physical therapy – vibrotherapy. Therapeutic vibration stimulates blood and lymph circulation, the neuromuscular system, and, in the form of respiratory vibration therapy, helps clear airways of secretions and strengthens respiratory muscles, improving tissue oxygenation in patients with cystic fibrosis and, more recently, in patients with chronic obstructive pulmonary disease or coronavirus 2019 disease (COVID-19). Although the use of respiratory vibration therapy is well established in cystic fibrosis, it has yet to be sufficiently studied in other pulmonary disorders, and since the clinical potential of respiratory vibration therapy is broad, the authors of this literature review wish to point out that it should not be neglected. Particularly in automated form during pandemic times, as in the case of the COVID-19 pandemic – hindering rehabilitation services, quarantine isolations – respiratory vibration therapy can be crucial in rehabilitation, enriching both hospital and home physiotherapy offers.

Key words:

vibrotherapy, whole body vibration, COVID-19, rehabilitation, respiratory disorders

Streszczenie

Stosowane z powodzeniem już od lat w rehabilitacji różnych schorzeń techniki manualnego masażu wibracyjnego oraz wibracje terapeutyczne generowane przez urządzenia medyczne wyodrębniają nowy rodzaj fizykoterapii – wibroterapię. Wibracje terapeutyczne pobudzają krążenie krwi i limfy, układ nerwowo-mięśniowy, a także, w formie wibroterapii oddechowej, pomagają w oczyszczaniu dróg oddechowych z wydzieliny i wzmacniają mięśnie oddechowe, poprawiając natlenienie tkanek u chorych z mukowiscydozą, a ostatnio także u chorych na przewlekłą obturacyjną chorobę płuc czy w chorobie koronawirusowej z 2019 r. (COVID-19). Jakkolwiek stosowanie wibroterapii oddechowej ugruntowało się w mukowiscydozie, to w innych zaburzeniach pulmonologicznych wciąż nie doczekało się wystarczającej liczby badań, a ponieważ potencjał kliniczny wibroterapii oddechowej jest szeroki, autorzy niniejszego przeglądu literatury pragną zwrócić uwagę, iż nie powinien zostać zaniedbany. Szczególnie w formie zautomatyzowanej w czasach pandemicznych, jak w przypadku pandemii COVID-19 – utrudnienia świadczeń rehabilitacyjnych, odosobnienia na kwarantannach – wibroterapia oddechowa może być kluczowa w rehabilitacji, wzbogacając ofertę fizjoterapii zarówno szpitalnej, jak i domowej.

Słowa kluczowe:

wibroterapia, wibracje całego ciała, COVID-19, rehabilitacja, zaburzenia oddechowe

Introduction

Physiotherapy, a widely developing discipline of medical sciences, is experiencing a renaissance in Poland. With the advancement of technology and the development of physiotherapy techniques, numerous branches are emerging in its field. One of them is physical therapy, which is the use of physical stimuli from nature or generated by medical devices for therapeutic or preventive purposes. Each type of energy that can be used therapeutically defines a new type of physical therapy. In medical rehabilitation, electrotherapy (therapeutic currents), magnetotherapy (magnetic fields) or laser therapy (therapeutic lasers) are well known. Therapeutic vibrations are also used, but although their effects on the human body have been studied for decades, the concept of vibrotherapy has not yet become established in clinical practice.

Since it has been noted beyond any doubt that vibrations of frequencies from a few to about 50 Hz (or even momentary of 300 Hz), with amplitudes in the range of hundredths, tenths of a mm to a few mm, properly dosed, not only are not harmful to health, but can even be curing, scientists have been studying this issue more and more intensively [1, 2]. Therapeutic vibrations, among other things, stimulate neuromuscular tissue, including proprioceptors – deep sensation [3-6], and improve blood [7, 8] and lymph [9, 10] circulation. Thus, they can be used in the therapy / rehabilitation of a wide range of symptoms of many diseases, as well as in prevention [11] or to increase athletic performance [12]. In the opinion of the authors of this article, in light of the growing evidence of the beneficial effect of vibratory stimuli on the human body, it may be time to officially separate vibration therapy as a new species of physical therapy.

A concise definition of vibrotherapy should indicate that it is a type of physical therapy, a form of medical rehabilitation and physical prevention, where specifically parameterized oscillations / mechanical vibrations, referred to as therapeutic or medical vibrations, are responsible for the therapeutic effect. They are generated by medical devices which use, among others, vibrations of vibrating platforms or anvils (placed in the structure of the mattress like device), or vibrations of the air column or sound wave; in physiotherapy practice, vibrations produced manually by the physiotherapist during so-called manual vibration massage are also used [13], which should also be systematized as a type of vibrotherapy and, in order to emphasize the source of the therapeutic stimulus, we should then refer to manual vibrotherapy, as opposed to automated vibrotherapy.

Moreover, due to the method of vibration administration, one can distinguish systemic vibrotherapy (vibrations applied to the whole body, generally affecting internal organs, known in the scientific literature as whole-body vibration) or local / focal vibrotherapy, using vibrations focused on specific parts of the body.

In rehabilitation of pulmonary disorders, mainly local vibrations administered in the region of the respiratory tract (manually or by means of vibrating devices), but also systemic vibrations are used. Here, we are dealing with a type of respiratory physiotherapy, namely respiratory vibrotherapy. Respiratory vibrotherapy has been used for many years in the

cystic fibrosis clinic [14] or chronic obstructive pulmonary disease – COPD [15] clinic, but it is described in such cases as respiratory physiotherapy, not vibrotherapy. For the sake of semantic values, we hope that after the publication of this article, more precise terms, such as respiratory vibrotherapy, will permanently enter the systematic canons of physiotherapy, especially since it has recently gained particular importance in the context of what seems to be the biggest health problem of the last decades – coronavirus 2019 disease (COVID-19) – both acute and chronic forms [16].

Chronic COVID-19

The COVID-19 pandemic has been paralyzing the world for several months. Barker-Davies et al. [17] note that there is still no satisfactory therapy for COVID-19. Treatment of acute COVID-19 is mainly symptomatic and supportive, depending on the severity of the infection. In addition, the disease can result in a significant risk of complications extending up to 3–6 months after onset (intermediate phase of COVID-19) and even, as Barker-Davies et al. [17] predicted several months ago, post-covid patients, because of the persistence of intractable symptoms, are referred for routine rehabilitation services lasting many weeks and months – the chronic phase of COVID-19. Many rehabilitation centres specializing in post-covid rehabilitation are being established, such as the Ministry of Internal Affairs and Administration Hospital in Złocieniec. Patients undergo rehabilitation to activate them physically and mentally. There is a fear of a new “pandemic” breaking out: post-COVID-19 syndrome, or chronic COVID-19.

In chronic COVID-19, as in previous coronavirus outbreaks of SARS and MERS, patients experience long-term pulmonary issues, emotional (stress) issues, reduced physical condition and quality of life [18]. The study by Carfi et al. [19] on Italian patients diagnosed on day 60 after the first symptom of COVID-19 showed that only 13% of patients were completely free of any COVID-19-related symptoms at that time, while 32% presented 1 or 2 symptoms and 55% presented 3 or more symptoms. In addition, none of the patients had fever or symptoms of acute illness. Deterioration in quality of life was observed in 44% of patients. Many patients continued to report fatigue (53%), shortness of breath (43%), joint pain (27%), and chest pain (22%). Garrigues et al. [20] obtained similar results, although additionally including cognitive functions. They described the cases of 120 patients hospitalized for COVID-19 who continued to report persistent and troublesome symptoms such as fatigue (55%), shortness of breath (42%), memory loss (34%), sleep disturbances (31%), and concentration problems (28%) nearly 4 months after admission. Also other authors, such as Goertz et al. [21] or Silva et al. [22], indicate the persistence of various COVID-19 symptoms over an extended period of time.

Can physiotherapy help manage the effects of chronic COVID-19?

Shortness of breath and physical inability to perform daily activities are the main reported complaints of patients with chronic COVID-19, and physiotherapy can play an important

role in their treatment, according to the World Health Organization (WHO). The WHO publishes recommendations for adults who have experienced severe deterioration of health due to COVID-19, indicating that an important part of self-recovery from the disease is due attention to physical fitness. Physical exercise can have a positive effect on troublesome post-covid symptoms because it relieves shortness of breath, strengthens muscle strength, improves fitness, balance, motor coordination, mental fitness, reduces stress and improves mood, and promotes self-confidence and energy recovery [23]. Furthermore, as shown by Brown et al. [24], physical exercise has anti-inflammatory properties and, in moderate intensity form, improves immune system function, reducing the risk of infection. The benefits of exercise in rehabilitation programs are widely recommended to patients to develop and maintain cardiorespiratory, musculoskeletal and neuromotor fitness to improve functional status, physical performance, independence and quality of life [25-27].

Anti-covid potential of vibrotherapy

Therapeutic vibrations act on the human body as a kind of passive physical training, which can replace active physical activity of moderate intensity [28-30]. Therefore, vibrotherapy has great potential [16] in the context of the above WHO recommendations for supporting faster recovery of covid patients. This is because it combines 2 key aspects in the COVID-19 epidemic: I – it can provide passive physical activity for those who are isolated and unable to rehabilitate themselves; II – it can also enrich isolation-limited physical activity for those who are independent. In addition, vibrotherapy can be carried out almost unattended (or with minimal support from a physiotherapist) by hospital patients or at home and can be used by weaker individuals, such as patients with COPD [15] or dependent individuals connected to a ventilator [31-33] or elderly persons [34]. Finally, respiratory vibrotherapy, as has been offered for years to patients with cystic fibrosis [35], starts to be offered to hospitalized covid patients with retained pulmonary secretions [33, 36, 37]. In addition, vibrotherapy is being studied in the COPD clinic for enhancing physical performance and quality of life with good results [15, 38]. Therefore, it seems worth considering its use in the context of WHO recommendations for post-covid rehabilitation.

Therapeutic mechanisms of vibrotherapy in respiratory disorders

How does vibrotherapy work? What are its mechanisms from a tissue or molecular point of view? The general and beneficial effects of vibration on blood circulation, lymph and muscle function have already been mentioned. The mechanisms involved may relate to different tissues and different molecular transmission systems. In this article, we focus on pulmonary disorders, and the mechanisms of vibrotherapy related to other systems will be presented in subsequent articles on the cardiovascular or nervous system.

A common problem in pulmonary disorders is the retention of secretions in the airways. Its removal can be aided by airflow

oscillations / vibrations that alter mucus rheology and / or the rate of ciliary movement of airway epithelial cells – mucociliary movement. The natural frequency of ciliary beats is in the range of 7–27 Hz, averaging about 13 Hz [39-42] or, as more recent studies show, averaging 11–13 Hz [43]. Providing air oscillations at frequencies similar to natural frequencies can put the cilia into resonance, increasing the amplitude of their beats, which can have a direct effect on increasing mucus transport [44-46]. The oscillation frequencies of Flutter® and Acapella® – oral expectorant devices – are matched to the frequency of ciliary oscillations. The high effectiveness of manual vibration at frequencies in the range of 7.3–10 Hz in removing pulmonary secretions was also demonstrated [35]. The rate of pulmonary secretion removal may also be increased by the oscillatory motion of the air itself, mechanically accelerating the cephalad motion of the secretions [43], with the rate of mucociliary clearance being strongly influenced by the hydration status, stiffness and viscosity / elasticity ratio of the mucus, and the mucus may be diluted by air vibration [47].

In the case of devices such as mattresses or vests generating therapeutic vibrations, another potential mechanism responsible for the beneficial effect of vibrotherapy on the removal of secretions from the airways should also be pointed out – mechanical, non-specific stimulation of the vagus nerve innervating the lungs. Nerves stimulated with a sufficiently strong nonspecific stimulus, such as mechanical energy, may respond to it as they would to stimulation with a specific ligand. This is indicated, for example, by the effect of stimulation of the retinal photoreceptors, which is known from everyday life. When fingers are pressed against the eyelids of closed eyes, such as when rubbing the eyes or after a bump, despite the eyelids shielding the light and the inability of the light to reach the photoreceptors and thus specifically stimulate them – flashes of light are seen.

Some medical devices for vibrotherapy, such as the Vitberg RS modular mattress (Vitberg, Nowy Sącz, Poland) using oscillatory-cycloidal vibrations, in addition to producing the effects described above, such as local controlled amplification of natural tissue vibrations and mobilization of deposits, may also produce beneficial effects more systemically: by stimulating the neuromuscular system, including deep sensation, blood circulation and lymphatic system. The manufacturer of Vitberg RS defines the RS Oxy program within its device as a rehabilitation program combining positioning therapy (procedures are performed in prone position with slightly raised chest) with local and systemic vibrotherapy, targeting respiratory disorders (including removal of lung secretions) as well as muscular and performance disorders.

The presence of vibrotherapy in “pre-covid” pulmonology

The potential of vibrotherapy in the rehabilitation of pulmonary disorders, even the most severe, seems enormous.

As mentioned above, respiratory vibrotherapy techniques have been used in cystic fibrosis patients for a long time, at least since the 1990s, in order to facilitate the removal of secretions

deposited in the airways. Well-known techniques include manual techniques, such as those that involve the physiotherapist performing oscillatory movements combined with compression of the patient's chest wall or tapping, and techniques with oral devices that use air oscillation. A comprehensive review of devices used in cystic fibrosis vibrotherapy was done, for example, by Morrison and Milroy [14], also describing vibrating vests used in the cystic fibrosis clinic. In turn, Chen et al. [31] investigated the use of vibrating pads in clearing airway secretions in mechanically ventilated patients in intensive care units. Patients received routine positioning care (repositioning every 2 hours; control group) or routine positioning care plus thoracic vibration therapy (study group) while lying on their backs on a vibrating pad under their backs for a total of 72 hours (6 times a day for 60 minutes). After the procedures, patients in the study group expectorated significantly more secretions and presented a significantly lower rate of pulmonary collapse.

The use of therapeutic vibration is also being studied with good results in the clinic for apnea in premature infants. Kesavan et al. [48] placed vibrating devices on the proprioceptor fibres of the limbs of premature infants. It was hypothesized that stimulation of limb movement would influence the activation of reflex facilitation of breathing. Promisingly, proprioceptive limb neuromodulation of premature infants with low-amplitude (0.3 mm) vibration at 128 Hz reduced the number of respiratory pauses, accompanying intermittent hypoxia, as well as bradycardia. In turn, Bloch-Salisbury et al. [49] stabilized immature and highly variable respiratory patterns of premature infants using low-amplitude (< 0.1 mm) and 30–60 Hz vibration stimulation, which could positively influence the nonlinear properties of the natural respiratory oscillator in the context of its response to peripheral and central signals. Vibratory stimulation induced an approximately 50% reduction in the variability of breath-to-breath intervals and reduced the frequency of intervals lasting longer than 5 sec between breaths by approximately 50%. This significantly improved oxygen saturation, indicating the potential of vibrotherapy in reducing apnea and hypoxia in premature infants.

The therapeutic potential of vibrotherapy has also recently been expanded to support rehabilitation of lung function after transplantation. In 2015, Brunner et al. [50] published a pilot study on the usability of vibrotherapy as an early hospital rehabilitation tool after lung transplantation. Ten patients in the early post-transplant phase (after leaving intensive care) were included in the study. The use of systemic vibration has proved to be safe and feasible in these patients, and most importantly, has improved their quality of life [50].

Also in adult patients with pulmonary arterial hypertension, systemic vibration improved quality of life as well as exercise and physical performance. Vibration was administered in 16 1-hour sessions over a 4-week period [51].

Gloeckl et al. [30] emphasized, in turn, the importance of endurance and strength training in patients with COPD. At the same time, noting the strong need to improve COPD rehabilitation, they suggested incorporating systemic vibration training, which in their study enhanced the effects of multidisciplinary COPD rehabilitation programs by significantly improving scores on tests diagnosing physical performance and balance.

Vibrotherapy in the COVID-19 pandemic

It seems that the role of respiratory vibration therapy favouring clearing the airway of secretions and activating respiratory muscles in intubated patients, as well as systemic vibration therapy as a substitute for physical activity, especially in pandemic times – isolation of many people or small groups limited to immediate family members – should be especially considered in effective and safe covid rehabilitation. Basically at any stage: preventively, during the acute phase of the disease, as well as in chronic COVID-19. It is also worth emphasizing the possibility of performing vibration exercises on your own, which is provided by home vibrating mattresses or platforms, as well as the possibility of combining vibrotherapy with other physical therapy techniques.

The potential of vibrotherapy in supporting the treatment of COVID-19 is best illustrated by already published scientific papers describing the results of studies on the effects of using a various regimen of administration and type of therapeutic vibration. In study by Choi and Mizukami [34], vibrotherapy had a beneficial effect not only on physical health but also on mental health, improving fitness and mood in elderly, weak people who could not freely use physiotherapists' visits and were unable to leave their homes. In contrast, scientists from Shahid Beheshti University (Tehran, Iran) studied the effects of pulmonary rehabilitation with several physical therapy techniques (including vibration) and exercise therapy in a patient with COVID-19. The interventions used reduced COVID-19 symptoms and improved quality of life. Numerous indicators improved, such as general health (from 61 to 76 points), mental health (from 59 to 81 points), and physical health (from 50 to 79 points); shortness of breath (from 42 to 15 points) and difficulty breathing (from 70% to 10%) decreased as well as anxiety (from 56 to 47 points) [37]. In another study by scientists at Infanta Leonor University Hospital (Madrid, Spain), there were examined 10 mechanically ventilated covid patients in critical condition with pneumonia. Vibrations applied to the lower and posterior regions of the lungs in the prone position were used to mobilize secretions deposited in the airways. The effect of vibrotherapy on the ratio of the partial pressure of oxygen present in the arteries to the concentration of oxygen derived from the inhaled respiratory mixture delivered by the ventilator ($\text{PaO}_2/\text{FiO}_2$) was analyzed, with a higher value of the $\text{PaO}_2/\text{FiO}_2$ relationship indicating improved respiratory function. It was observed that the average $\text{PaO}_2/\text{FiO}_2$ level in the supine position without vibration was 114.86, in the prone position without vibration was 144.7, while in the prone position with vibration therapy additionally included was 162.7 [33], so the blood oxygenation index in covid patients in critical condition increased with vibration additionally by 12.4% relative to pronation.

Infection with SARS-CoV-2 (the virus that causes COVID-19) can cause a cytokine flood and immune overreaction, leading to damage to the lung epithelium and alveoli by increasing their secretory function, preventing normal gas exchange in intact alveoli. This increases the risk of severe atelectasis due to the formation of mucous plugs, which completely close the bronchial opening [33]. Atelectasis is common in mechanically ventilated patients. It is associated with a state of incomplete filling of the alveoli with respiratory gases, leading to collapse of the lungs [52]. As noted by Sancho et al. [33], changing position

from supine to prone may improve $\text{PaO}_2/\text{FiO}_2$, enhancing pulmonary ventilation and perfusion and mobilization of secretions. In addition, with the help of vibrating mechanical systems, the effect of prone positioning can be intensified. This prevents the formation of bronchial obstruction by mucus plugs and improves the $\text{PaO}_2/\text{FiO}_2$ ratio [33].

The experiment presented above, published in the Spanish Journal of Anaesthesiology and Resuscitation [33], although showing beneficial and promising effects of respiratory vibrotherapy in the treatment of acute COVID-19, comes with some limitations. The effect of vibration administration on patients on whom the effect of prone positioning alone was studied just before vibration administration seems to be the most important limitation. It is therefore difficult to discuss the pure effect of the vibrations themselves. However, other studies cited above clearly indicate the facilitation of clearance of airway secretions (in various pulmonary disorders) with manual vibration or therapeutic vibration devices.

In addition, it should be noted that intubation exposes mechanically ventilated patients to respiratory muscle weakness. As mentioned above, vibrotherapy can effectively activate muscle neuromotility and, with the benefit of accelerating healing, force respiratory muscles to remain active, protecting them from atrophy. Thus, the presented issue of application of vibrotherapy in COVID-19 requires further research and brings hope for improvement of physiotherapy in covid wards with the intensified need for mechanical ventilation globally now in 2020 and 2021.

Conclusions

Respiratory, as well as systemic (whole-body vibration), vibrotherapy can improve respiratory function, enhancing physical performance and quality of life in severe conditions such as COVID-19, cystic fibrosis, COPD or after lung transplantation. Vibrotherapy may also improve respiratory problems in premature infants. In addition, systemic vibrotherapy has a beneficial effect on mood and shape in the elderly, can even be administered to patients in intensive care units, and can be self-administered by anyone (especially in the supine position), which can be especially important in epidemics where exposure of hospital staff to possible pathogen contact must be kept to a minimum so as not to lock health care workers in quarantines, let alone risk their health and lives.

It is therefore important to draw the attention of authoritative entities recommending therapeutic programs in respiratory disorders to the availability and ease of use of effective approaches, such as respiratory and / or systemic vibrotherapy, which can be self-administered at home or significantly support the work of medical staff in hospitals, especially in epidemic settings.

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