WHAT DO WE KNOW ABOUT WHOLE BODY VIBRATION?
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SUMMARY
Introduction
The last decade has been characterized by extremely dynamic development in the field of research and subsequent practical applications of new physiotherapeutic techniques. Whole Body Vibration is a relatively new kinesitherapeutic method that improves muscle activity and, as a result, the patient’s functionality. The effectiveness of this method is still the subject of research.

Aim
The aim of this paper was to review the literature and present a current and evidence based knowledge of Whole Body Vibration.

Material and methods
Medline and Pubmed databases were used for the search of relevant scientific papers results. Keywords in following order were entered: whole body vibration, muscles activity, EMG, strength muscle, body balance, functionality. Only researches from 2012 to 2017 were taken under consideration. Finally 30 papers have been identified and describe in this paper.

Results
Whole Body Vibration has been widely used in clinical and sport practice. The analysis of the presented articles can indicate a positive impact of whole body vibration on muscle strength and body balance.

CO WIEMY NA TEMAT TRENINGU WIBRA-CYJNEGO CAŁEGO CIAŁA?
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STRESZCZENIE
Wstęp
Ostatnia dekada charakteryzowała się niezwykle dynamicznym rozwojem w dziedzinie badań i praktycznych zastosowań nowych technik fizjoterapeutycznych. Wibracja całego ciała jest stosunkowo nową metodą kinezyterapeutyczną, która poprawia aktywność mięśni, a w rezultacie funkcjonalność pacjenta. Skuteczność tej metody jest nadal przedmiotem badań.

Cel
Celem tego artykułu było dokonanie przeglądu literatury i przedstawienie aktualnej i opartej na dowodach wiedzy na temat metody leczniczej wibracji całego ciała.

Materiał i metody

Wyniki
Wibracja całego ciała była szeroko stosowana w praktyce klinicznej i w sporcie. Analiza przedstawionych artykułów może świadczyć o pozytywnym wpływie wibracji całego ciała na siłę mięśni i utrzymanie równowagi ciała.
Conclusions
Based on the available literature, it can be concluded that Whole Body Vibration can improve muscle's activity, strength, endurance and balance control.

Keywords: whole body vibration, muscles activity, EMG, strength muscle, body balance, functionality

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Introduction
Whole Body Vibration (WBV) is a relatively new kinesitherapeutic method that improves muscle activity and, as a result, the patient's functionality. The effectiveness of this method is still the subject of research (Lienhard et al., 2017; Borges et al., 2016). One of the WBV elements evaluated in available publications (Friesenbichler et al. 2014) is a way transmission of mechanical stimuli caused by vibration to individual muscles, and as a result, the results of this transmission to issues related to muscle activity, possible change of their strength, endurance or power, finally affecting postural reactions. It is worth noting here that an important factor quantifying the WBV's effectiveness is its methodological determinants (Tsukahara et al., 2016). For example, Ritzmann et al. (2013) and Perchtaler et al. (2013) have shown that the increase in muscle activity depends on the type of vibration, its frequency, the position of the practicing body during vibration and additional loads during this type of exercise. Similar observations were made by Lienhard et al. (2014). Other authors also came to similar conclusions based on the conducted research (Gidem et al., 2017). Tankisheva together with co-workers (2013) proved that there is a relationship between the posture of the person subjected to vibration and the change in the activity of its muscles. In general, the degree of muscle activation after vibration of the whole body is a derivative of, among others, the individualization of vibration parameters, which is confirmed by the EMG results (Carlucci et al., 2016). The question then arises whether the vibration of the whole body has a local or global range in relation to the activation of individual muscle groups and whether the level of “initial” training affects the value of muscle activity increase as a vibration effect (Lienhard et al., 2015; MacIntyre and Cort 2014, Ashnagar et al., 2016). The effectiveness of WBV was also evaluated through the prism obtained by its use of the increase in strength or muscle power (Yu CH et al., 2015; Stania et al., 2017; Costantino et al., 2017; Dallas et al., 2015; Cheung et al., 2016; Rogan et al., 2015; Hawkey et al., 2016). Another issue assessed was the comparison of the effectiveness of classic methods of muscle activation, i.e. exercise and vibration of the whole body (Fisher et al., 2014). It was also analyzed whether WBV increases the effects of classic methods of muscle activation if it is used simultaneously with them (Marín et al., 2015; Jones et al., 2017; Fisher et al., 2015). Last years were a period of research assessing the impact of vibration of the whole body on the patient's body balance (Ochi et al., 2015; Sonza et al., 2015; Sitjà-Rabert et al.; 2015, Yang et al., 2017; di Cagno et al., 2017).

Wnioski
Na podstawie analizy dostępnej literatury sugeruje się, że wibracja całego ciała może poprawić aktywność mięśni, siłę, wytrzymałość oraz równowagę.

Słowa kluczowe: wibracja całego ciała, aktywność mięśni, elektromiografia, siła mięśniowa, równowaga ciała, funkcjonalność

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Data zaakceptowania: 18 lutego 2018
Aim
The aim of this paper is to review the literature and present a current and evidence based knowledge of Whole Body Vibration.

Materials and methods
A systematic review of the literature found in PubMed and Medline database was conducted. Keywords in following order were entered: whole body vibration, muscles activity, EMG (electromyography), strength muscle, body balance, functionality. Only researchers from 2012 to 2017 were taken under consideration.

Results
Finally 30 papers have been identified and describe in this paper. Twenty publications were chosen and presented in Table 1.

Discussion
The last decade has been characterized by extremely dynamic development in the field of research and subsequent practical applications of new physiotherapeutic techniques. A significant place among them is taken by WBV. It uses the effects of vibration which the patient's body is subjected to improve muscle activity, strength, endurance and power, which in turn translates into its greater physical fitness, more precise postural reactions and, finally, a higher level of functionality. For the understanding of the effect of vibrations on the body in general terms, it seems that the results of studies by Friesenbichler et al. (2014) are crucial because they are indicating that the effect of vibration depends on the type of muscle and the frequency of vibrations, although these tests were performed on animals.

As with any new method used to treat a patient, the question arises whether it is possible to apply to every patient, and if so whether there are any factors determining its usefulness in specific clinical cases. Lienhard et al. (2015) showed a significant increase in muscle activity as a result of vertical vibration. It is worth noting, however, that the authors assessed the activity of lower limb muscles. Further, almost the same authors (Lienhard et al. 2017), using the age criterion, showed that an important positive effect of vertical WBV has higher effectiveness in elderly people comparatively to young people. Mentioned authors, by the use of surface EMG, showed greater muscle activity tibialis anterior, gastrocnemius medialis, soleus, vastus lateralis, vastus medialis, and biceps femoris in older people. Similarly, Hawkey et al. (2016) showed that vibratory training improves the motor skills of people in middle age. Important insights on the impact of vibration on the increase in lower limb muscle activity were those made by Lienhard et al. (2015). According to these authors, the level of muscle activation is not affected by the previous physical activity of the subjects.

Although WBV is a very popular method of rehabilitation used both in sport and in rehabilitation, not all studies have proven that it gives positive therapeutic effects. Borges et al. (2016) have shown that vibration does not positively affect the center of feet pressure (COP) oscillations, the normalized peak of force generated by the muscles after its use (maximal peak torque), the total work that muscles can do after vibration al training (total work), the average muscle power after vibration and ultimately did not observe an increase in muscle activity in EMG studies. Another important issue related Stania et al. (2017) showed in their research that a 4-week training on a vibrating platform with a frequency of 60 Hz results in a significant increase in the mean values of peak torque, average peak torque and total work for knee flexors at high angular velocity of movement in knee joint especially with respect to knee flexors. Also Dallas et al. (2015) showed that WBV strengthens the muscles of the lower limbs, which can be observed immediately after the end of vibration.

Another interesting problem connected with WBV was the attempt to answer the
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question whether it affects only selected muscle groups or has a global range. This is important because in most of the research results presented here, the patient stood on the vibrations platform with slightly flexed lower limbs at knee joints. Tsukahara et al. (2016) showed in their work on young, healthy volunteers that the support of the elbows on the knees during vibration results in the transfer of vibrations to the upper limbs and the activation of their muscles and not only the muscles of the lower limbs. The vibration effect

Table 1. Literature review on the use of WBV and obtained results.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Study</th>
<th>Participants</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>muscle activity</td>
<td>Lienhard K et al. Int J Sports Med. 2015</td>
<td>30 active and 28 inactive patients</td>
<td>EMG</td>
<td>+</td>
</tr>
<tr>
<td>muscle activity</td>
<td>Marin PJ &amp; all J Musculoskelet Neuronal Interact. 2015</td>
<td>28 recreationally active students</td>
<td>EMG</td>
<td>+</td>
</tr>
<tr>
<td>muscle activity</td>
<td>Ochi A et al. Arch Gerontol Geriatr. 2015</td>
<td>20 women: 2 groups</td>
<td>EMG</td>
<td>+</td>
</tr>
<tr>
<td>muscle activation</td>
<td>Tankisheva E et al. J Strength Cond Res. 2013</td>
<td>8 healthy subjects</td>
<td>Accelerometer</td>
<td>+</td>
</tr>
<tr>
<td>muscle activation</td>
<td>Carlucci F et al. J Strength Cond Res. 2016</td>
<td>29 students</td>
<td>EMG</td>
<td>+</td>
</tr>
<tr>
<td>lower-limb muscle activity</td>
<td>Lienhard K et al. J Biomech. 2017</td>
<td>30 young and 30 older individuals</td>
<td>EMG accelerometer</td>
<td>+</td>
</tr>
<tr>
<td>muscle strength</td>
<td>Tsukahara et al. (2016)</td>
<td>65 years or older elderly individuals</td>
<td>Literature search (38 articles)</td>
<td>+</td>
</tr>
<tr>
<td>muscle strength</td>
<td>Stania M et al. Biol Sci. 2017</td>
<td>49 male subjects: 7 comparative groups</td>
<td>The isokinetic strength tests</td>
<td>+</td>
</tr>
<tr>
<td>muscle power</td>
<td>Hawkey A et al. J Strength Cond Res. 2016</td>
<td>25 active women: middle-aged (WBVT and control group) younger (WBVT and control group)</td>
<td>Probotics Just Jump Mat Sit-and-reach box</td>
<td>+</td>
</tr>
<tr>
<td>muscle strength after ACL reconstruction</td>
<td>Costantino C et al. Clin J Sport Med. 2017</td>
<td>38 female volleyball/basketball players: WBV group and control group</td>
<td>Biodex dynamometer</td>
<td>+</td>
</tr>
<tr>
<td>flexibility and explosive strength of lower limbs</td>
<td>Dallas G et al. Biol Sport. 2015</td>
<td>18 male and female divers: 3 protocols</td>
<td>the S&amp;R test (a flex-tester box) Jump tests (a switch mat)</td>
<td>+</td>
</tr>
<tr>
<td>neuromuscular performance and postural control</td>
<td>Borges DT et al. Man Ther. 2016</td>
<td>60 physically active women: control group, 30 Hz and 50Hz groups</td>
<td>EMG isokinetic performance baropodometry</td>
<td>–</td>
</tr>
<tr>
<td>balance and muscle performance</td>
<td>Sitjà-Rabert M et al. J Am Med Dir Assoc. 2015</td>
<td>159 participants: WBV plus exercise group and exercise group</td>
<td>Tinetti test TUG STS test SmartCoach encoder</td>
<td>–</td>
</tr>
</tbody>
</table>
expressed by the increase in muscle activity is a derivative of the vibration frequency parameter and a specific body position during its lifetime that generates additional load on vibrated muscles. Also Ashnagar et al. (2016) observed that vibratory training with the simultaneous performance of specific exercises activating the muscles of the shoulder girdle and upper limbs (modified push-up position) leads to their significant activation in the EMG assessment. This observation concerned muscles: upper trapezius, serratus anterior, biceps brachii and brachii brachii. Ritzmann et al. (2013) proved that during the vibration, the posture with the plantarflexion of feet (position of standing on fingers) and knees flexed to 60°, results in greater activation of the knee flexor muscles than in other positions, and what is more the activation level in this position is straightforward proportional to the vibration frequency used. According to Tankishev et al. (2013) the influence of knee flexion angle on the degree of activation of the muscles of the iliac girdle and lower limbs is not clearly defined. Also the relation between muscle activity vs. the frequency and amplitude of vibrations is not unambiguous.

The contrary opinion was expressed on the basis of the research carried out by Fisher et al. (2015). These authors put forward the thesis that the influence of knee flexion angle and frequency of vibrations on the increase in the activity of lower limb muscles is not unequivocally resolved and what is more, vibration does not significantly strengthen the lower limb muscles compared to isometric exercises. Carlucci et al. (2016) pointed out in their research to the need to individualize the parameters of the vibration and body posture of the person subjected to it. Also these authors showed the dependence of the increase in muscle activity of the lower limbs from the angle of the knees flexion and the frequency of vibrations. Also Cider et al. (2017) highlighted the importance of the body position during vibrations and the resulting dynamic interactions between the body and the ground, affecting the degree of muscle activation during vibration. What’s more, they proved that the vibration effect is all the higher the higher the vibration frequency was applied.

The significance of the vibration frequency and its amplitude for the obtained activation of the lower limb muscles was also pointed out by Perchthaler et al. (2013) proving in research on middle-aged people that better results are obtained at higher frequencies and amplitudes. Interestingly, the aforementioned authors have proved that vibration training activates the knee extensors to a greater extent than the flexors depending on the angle of flexion.

In the assessment of the impact of vibration on the electromyographically recorded increase in muscle activity, the decisive role is played, in opinion of Lienhard et al. (2015), by way of registration. EMG is a very sensitive diagnostic method that reacts to the vibration of the occurrence of artifacts in the record which may significantly influence the assessment of the results in terms of the expected therapeutic effect. These researchers have recommended the use of spectral linear interpolation or a multiple harmonics in the registration of sEMG performed during vibrations if such methodical assumptions were accepted in the test protocol.

Interesting observations were made by Sonza et al. (2015), investigating the effects of different frequency vibrations on sensitivity for the touch on the lower limbs, surface temperature and the quality of the body balance. According to these authors, the vibration, especially the one with the higher frequency, reduces the sense of touch, the decrease in the surface temperature of the lower limbs probably caused by vasoconstriction and deterioration of the body balance in the tests performed 10 minutes after the end of vibration.

According to Jones et al. (2017) the vibration effect in relation to the muscle power of the upper body is the largest after 10 minutes from its completion. Researchers
have found that the power value obtained is influenced by the body position during vibration with the additional upper body load (plyometric push-up). Similarly, Marin et al. (2015) proved in their research on young, healthy volunteers that the level of muscle activity increase of the person subjected to vibrations is decisively influenced by their additional load. Such a load is most often the exercises performed during vibrations and directed to specific muscles whose activation we are interested in. The authors proved that the use of battling rope exercises during vibration significantly activates the muscles: gastrocnemius medialis, vastus medialis oblique, vastus lateralis, rectus abdominis, multifidus, brachii biceps, and brachii triceps.

The need to include additional exercises during vertical WBV for maximum muscle activation was also noticed by Lienhard et al. (2014). Research on the effects of vibration on muscle activity does not always indicate its positive effect. For example, MacIntyre et al. (2014) showed that vibration does not significantly activate the muscles of the back and what is more, it negatively influences postural reactions.

A separate issue assessed in the research on vibration was the answer to the question whether WBV can lead to symmetry of activities corresponding topographically single-man muscle groups. Performed by Yu et al. (2015) studies have shown that WBV leads to symmetry of the activity of the lower limb muscles in cases when there are differences at the beginning. This observation may have significant clinical significance in a number of dysfunctions occurring in rehabilitation practice.

A very interesting field of research on the usability of WBV recently, are projects assessing the impact of this methodology of improvement on postural stability. Yang and co-workers (2017) proved that vibration training significantly strengthens the muscles and improves dynamic stability in obese people. The authors suggested that this is due to improved control of the segmental movement of the trunk. Also Cheung et al. (2016) proved the positive impact of WBV. They showed that the vibratory training used for a period of one year with high frequency and low amplitude improves muscle balance and strength in the elderly. Sitja-Rabert et al. (2015) in their studies did not show positive effects of WBV in the area of improved balance, gait quality, muscle strength and overall functionality in people the elderly. In the assessment of di Cagno et al. (2017) vibration of the whole body used in blind people does not affect qualitatively and quantitatively postural reactions in the assessment performed on the balance platform immediately after the end of the training, which recommends it as a safe method improvement.

Generally, the increase in the activity of lower limb muscles has a functional dimension that can be used in clinical practice. For example, Ochi et al. (2015) found that vibration increases the speed of walking by increasing the activity of the flexor of the foot. It also causes an increase in muscle activity of the extensor and knee flexors. The results of the study by Constantin et al. (2017) are very important from clinical point of view. Authors have proved that the addition of WBV to the standard rehabilitation program used in patients after ACL reconstruction may significantly increase strength of lower extremities muscles. Last one, a comprehensive assessment of WBV’s effectiveness was made based on a meta-analysis of the available literature by Rogan et al. (2015). By evaluating the resources of PubMed, Cochrane Central Register of Controlled Trials, Physiotherapy Evidence Database and CINAHL electronic databases and the International Clinical Trials Registry from the World Health Organization and without eliminating any methodological vibrations in the evaluation of its application mode, amplitude and frequency of vibrations showed that it has a positive impact on the elderly, regardless of their
level of functionality, which is particularly important for people having problems with performing the simplest exercises.

Conclusions
Based on the available literature, it can be concluded that Whole Body Vibration can improve muscle activity, strength, endurance and balance in different populations.
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