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EFFECT OF VARIOUS TYPES OF METRO-RHYTHMIC STIMULATIONS ON THE GAIT SYMMETRY IN HEALTHY PEOPLE

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Abstract: *The research aimed to assess the effect of various types of metro-rhythmic stimulation and the manner of their application on gait symmetry in healthy individuals. Research-related tests involved a group of 22 adults without locomotor function disorders. The test participants were divided into two equal groups: group 1 – persons, who were not informed how to behave after hearing sounds (stimulation), group 2 - persons instructed before a test to walk in the rhythm of music (stimulation). The tests of locomotor functions were performed using a Zebris FDM-S treadmill. All of the tests involving sound stimulation were performed for a preferable gait velocity. The analysis involved a change in the index of stepping time symmetry and the length of a step during gait with various types of sound stimulation (arrhythmic stimulus, rhythmic stimuli at a different rate). It was demonstrated that short-term rhythmic sound stimuli at the rate equal to stepping frequency at a preferable gait velocity affected the symmetrisation of stepping time in healthy adults, regardless of whether they had been informed how to react to stimulation. A short-term effect of the RAS on the symmetry of step length was not observed.*

Keywords: Biomechanics, Gait analysis, Rhythmic auditory stimulation, Symmetry index.

1. Introduction

The primary factor affecting the quality of life is the capability of independent and undisturbed locomotion. Locomotor system dysfunctions often lead to social exclusion, deteriorated physical and mental condition as well as the loss of full self-reliance (Jochymczyk-Woźniak et al., 2019). The continuous development of modern technologies enables the understanding of correlations between acoustic stimuli and human locomotor skills. One of the best known areas of music therapy is the application of rhythmic sounds in the rehabilitation of gait (Lindman et al., 2013). The use of rhythmic stimuli in gait rehabilitation was referred to as rhythmic auditory stimulation (RAS) by Thaut et al. in 1996 (Thaut et al., 1996). The team of researchers demonstrated that rhythmic sound signals helped adjust and correct body movements and executive functions in patients suffering from Parkinson's disease. Recent years have seen the emergence of new evidence that the rhythmic auditory therapy reduces neurological dysfunctions and decelerates the deterioration of cognitive functions. According to the research, the therapy based on sound signals brings positive results by improving the patterns of gait. However, it should be noted that the adjustment of proper rhythm requires a personalised approach (Clements-Cortes et al., 2018). The role of information received by humans through the hearing apparatus affects their movement-related ability. As a result, providing appropriate acoustic stimuli may affect the biomechanics of gait. The programme of rhythmic sound stimulation, its frequency, sounds and applied equipment depend on expected results (Romaniszyn et al., 2019, Thaut et al., 2005). Information presented in scientific articles indicated the positive effect of rhythmic auditory stimulation (RAS) on stepping frequency, gait cycle time and gait cycle duration in

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individuals whose gait was asymmetric before the therapy involving the application of acoustic signals. The research results clearly indicate the positive effect of the RAS on time-spatial parameters in healthy individuals, persons suffering from multiple sclerosis, patients after a brain stroke and persons suffering from Parkinson's disease (Ko et al., 2016, Lee et al., 2018, Murgia et al., 2018).

The aim of the study was to assess the immediate effect of rhythmic auditory stimulation on the gait symmetry in healthy people.

2. Methods

The study group consisted of 22 adults without locomotor system disorders. The group was divided into two sub-groups composed of 11 persons. Test participants belonging to group 1 (age: 23.1 ± 1.6 years, weight: 66.1 ± 22.4 kg, body height:171.9 ± 11.6 cm) were not instructed how to react to sounds heard during the tests. Before the tests, persons belonging to group 2 (age: 26.3 ± 7.2 years, weight: 65.9 ± 9.1 kg, body height: 170.3 ± 8.3 cm) were instructed to try and adjust their stepping frequency to the rhythm of music during the tests of gait on the treadmill. The tests of gait were performed using a ZEBRIS FDM-T treadmill (ZebrisMedical GmbH, Isny, Germany). Before the tests, the preferable velocity of gait on the treadmill was identified for each person. Afterwards, a test participant walked on the treadmill for approximately 1 minute. The subsequent phase involved the recording of gait with the preferable velocity (GP) for 60 seconds (GP). The recording also involved the gait of persons accompanied by metro-rhythmic stimulation, during which the treadmill speed was adjusted at the value of preferable velocity declared by the participant.

Before each test involving metro-rhythmic stimulation, a tested participant walked on the treadmill for 30 seconds, after which a sound stimulus was played. Gait accompanied by sounds lasted 60 seconds.
Studies were conducted for the following types of stimulation:

- GA - arrhythmic stimulus played at a rate of 120 BPM, time 4/4, ambient style. There are no accents in the stimulus, the transitions between the different tones are smooth. There is lack of accents in the stimulus and the transition between individual tones is gradual. Changes in tempo could not be sensed by the listeners in respect of the effect on audio-motor synchronisation. The music had a relaxing function, which could influence the symmetry and calming of the gait.
- GR - rhythmic stimulus played at a rate corresponding to the frequency of gait and determined during tests of preferable speed, time 4/4, motivating music. Rhythmed periodic stimulus with accents in strong parts of the bar (quarter notes in the 1st and 3rd measure) and an 8-bar phrase. Additional non-accentuated rhythmic units were at regular intervals in the weak parts of the bar (quarter notes in the 2nd and 4th measure). The stimulation was of a motivating nature, characteristic of music played during sports training (e.g. aerobics).
- GR110 - rhythmic stimulus as above, played at a rate corresponding to gait frequency increased by 10 %; the tempo was determined during the tests of gait at a preferable speed.
- GR200 - rhythmic stimulus as above, played at a rate corresponding to doubled gait frequency; the tempo was determined during the tests of gait at a preferable speed.

The assessment was focused on the susceptibility of healthy adults to metro-rhythmic stimuli and their effect on the primary biomechanical parameters of gait. A detailed analysis was concerned with the changes in the symmetry index (SI) of stepping time and step length determined in accordance with the following formula:

$$SI = \left| \frac{(X_L - X_R)}{0.5(X_L + X_R)} * 100\ \% \right|, \tag{1}$$

where: X_L, X_R – gait parameter value for the left / right lower limb.
When SI = 0, the gait parameter is symmetrical. The degree of deviation from 0 indicates the level of asymmetry of a parameter.

3. Results and discussion

Figs. 1 and 2 present values of the symmetry index for step time (SI_st) and step length (SI_sl) in relation to the tests without sounds and the tests accompanied by various metro-rhythmic stimulations in groups 1 and 2. The average values of the SI of step time (Fig. 1) revealed that, in both groups, the lowest value of the SI was recorded in relation to test GR. Based on the average values of SI_st, it can be concluded that the rhythmic stimulus presented at a rate corresponding to the stepping frequency of gait at a preferable velocity led to the symmetrisation of step time, regardless of whether the test participants had been informed about how to react to metro-rhythmic stimulation. The average values of the SI of stepping time in test GR decreased by approximately 50 % in both groups. In group 1, a lower average value of the SI in relation to the stepping time in comparison with that obtained in test GP was also recorded for the remaining tests involving the use of sound stimuli. In group 2, metro-rhythmic stimulation in tests GA and GR led to the reduction of the average values of SI_st. In turn, in the tests where metro-rhythmic stimuli were presented either at a rate increased by 10 % or equal to the double stepping frequency, the gait of group 2 was characterised, on average, by higher stepping time asymmetry than that identified in test GP.

The analysis of the values of the step length symmetry index revealed that the aforesaid parameter was more symmetric in group 1 in relation to all of the tests except for GA. In group 1, the average value of SI_sl in relation to the tests accompanied by metro-rhythmic stimulation (GR, GR110, GR200) was lower than that determined in test GP. In turn, in group 2, the average value of SI_sl between tests GP and GR was similar and adopted higher values in relation to tests GR110 and GR200. On the basis of the results obtained in the tests, it is not unequivocally indicated that the short-term auditory stimulation has a positive effect on the symmetry of step length. However, taking into consideration the fact that the rhythmic stimulus presented at the rate corresponding to the stepping frequency of gait at a preferable velocity led to the symmetrisation of step time, it can be expected that longer stimulation of persons with the foresaid sounds can also result in the symmetrisation of step length.

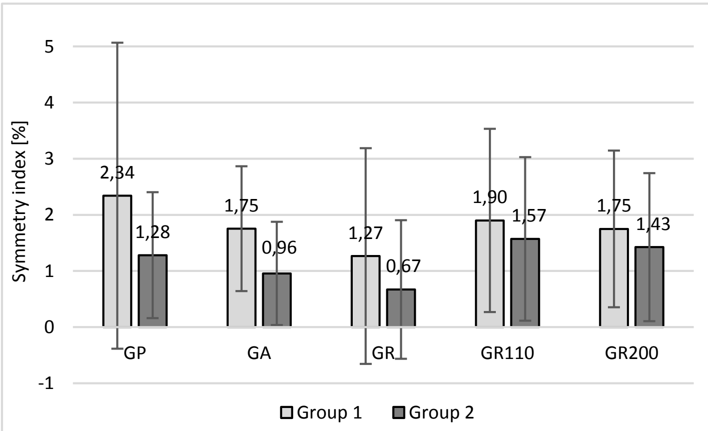

Fig. 1: Symmetry index of step time for the test without sounds and the test with metro-rhythmic stimulation.

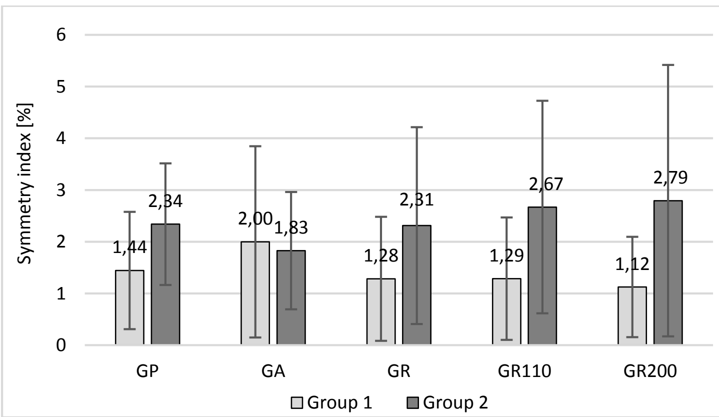

Fig. 2: Symmetry index of step length for the test without sounds and the test with metro-rhythmic stimulation.

In addition, the analysis also involved values of the symmetry index of step time and that of step length in relation to each test participant from group 1 and group 2. The number of the test participants in relation to whom the symmetry of analysed parameters remained the same or improved as a result of sound stimuli is presented in percentage in Figs. 3 and 4. In both groups, the greatest effect leading to a decrease in the SI of step time was recorded in relation to test GR (6 persons in group 1 and 5 persons in group 2). The improved symmetry of step time or the lack of a change in the aforesaid parameter was recorded for more than 80 % of the participants in groups 1 and 2 in relation to tests GA and GR. In group 2, metro-rhythmic stimulation had a greater contribution to the improvement of the symmetry index of step length in tests GA, GR and GR200.

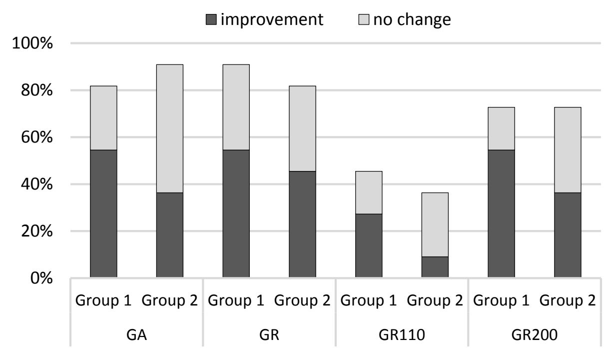

Fig. 3: Number of test participants (in %), in relation to whom the symmetry of step time remained the same or improved as a result of the application of sound stimuli.

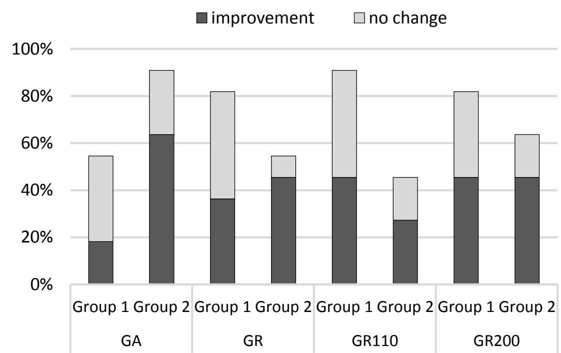

Fig. 4: Number of test participants (in %), in relation to whom the symmetry of step length remained the same or improved as a result of the application of sound stimuli.

4. Conclusions

Short-term rhythmic sound stimuli at the rate equal to stepping frequency at a preferable gait velocity affected the symmetrisation of stepping time in healthy adults. Greater symmetry of the stepping time was observed both in individuals who had been informed how to react to sounds and in those test participants who had not received any instructions. The clear short-term effect of the RAS on the symmetry of step length was not observed.

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