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THE INFLUENCE OF BIOFEEDBACK ON ANAEROBIC WORKING CAPACITY IN JUMP TEST IN THE SCHOOLCHILDREN AGED 11-12

The study objective was to determined the influence of biological feedback on anaerobic working capacity in the schoolchildren aged 11-12.

We determined the power of mechanical work of the whole test, the power of the mechanical work during support repulsion phase, jump frequency, the correlation of support and unsupported phases during the performance of the modified 20-second jump test with and without biological (visual and audible) feedback (BFB) in 30 boys and 30 girls aged 11-12.

*The height of each jump was calculated by the formula: h=tf*g*8-1, where tf – flight phase in seconds, g – acceleration of gravity (9.806665 м·s-2). Based on this indicator, body weight, the duration of support phase and jump cycle, we calculated the power of mechanical work of the whole body (P), the power of mechanical work during repulsion support phase (Pr), jump frequency (Fr), the correlation of support and unsupported phases (R). To assess the dynamics of the studied indicators during the test, we counted their changes at five-second intervals from 5 to 10, from 10 to 15 and from 15 to 20 seconds with respect to the segment from the start of the test up to its fifth second.*

The girls aged 11-12 had higher level of working capacity than boys in the modified 20-second jump test. The application of biological feedback led to the improvement of results in 20-second anaerobic jump test in the boys and had not any influence on the indicators in the girls aged 11-12. The application of biological feedback increased the results in 20-second anaerobic jump test and improved the dynamics of working capacity during its performance in the children aged 11-12 with psychological focus on achieving success. Such influence was low in the schoolchildren with psychological focus on avoiding failure.

The application of biological feedback allows improving the process of training anaerobic opportunities of the schoolchildren aged 11-12 considering their gender and individual psychological features.

***Keywords**: biofeedback, physical working capacity, schoolchildren.*

Introduction

Biological feedback is to provide information about the state or change of own functional state, which allows to learn self-regulation of the studied and controlled function of the body. This approach will have wide possibilities in the practice of physical education and sport [15], rehabilitation [17].

Biological feedback in sport training, fitness and rehabilitation is based on various characteristics: heart rate variability [14, 21], electromyogram [4, 16], tensometric data [24], biomechanical parameters [18, 23], in the studied form of analysis of both visual and verbal information [6, 10, 19].

The application of BFB with visual and verbal analysis was found to reduce the force of landing when jumping [19]. The visual and auditory biological feedback in young men had a significant influence on the indicators of working capacity and its dynamics while performing anaerobic jump test [15].

The aspects of BFB influence on psycho-physiological state of healthy and sick schoolchildren are [5, 8]. However, the problem of using biological feedback to determine the level of physical working capacity and its training, particularly, in schoolchildren, is insufficiently studied.

The study purpose was to determine the influence of biological feedback on anaerobic working capacity in the schoolchildren aged 11-12. To achieve the goal, we have to solve the following tasks: 1) to determine the levels of anaerobic working capacity in jump test in the boys and girls aged 11-12; 2) to study the changes in the results of jump anaerobic test with visual and auditory biological feedback in the boys and girls aged 11-12; 3) to compare the influence of BFB on the results of anaerobic jump test in the schoolchildren with various psychological focus on results.

Materials and methods

The measurements were conducted on 60 healthy schoolchildren aged 11-12 (30 boys and 30 girls) of central Ukraine in compliance with the fundamental bioethical principles of European Council Convention on Human Rights and Biomedicine, World Medicine Association Declaration of Helsinki – Ethical Principles for Medical Research involving Human Subjects. Testing was conducted on Tuesday and Wednesday, the days of the highest level of working capacity [20].

The modified 20-second jump test was conducted using the method of Bosco et al. [3]. In 30-40 minutes, the test was performed again using biological feedback with the visual control of flight time dynamics and the support of monitor screen and with the auditory control of the time of jump flight phase (the frequency of sound signal was 400 Hz). We measured schoolchildren's weight and determined their focus on success or avoiding failure.

Jump anaerobic test was performed on the contact platform of two plates with the size of 50x50 cm, connected to a computer through a parallel port. The duration of support phases (SP) and flight phases (FP) while vertical jumping from the platform was analyzed using computer program up to 1 ms in mode MS DOS. Figure 1 shows an operating window of the program with the histogram changes of the duration of the flight phase for 20 seconds of the test. The ordinate axis shows the time of FP, and the abscissa axis shows the number of a jump from the beginning of registration. According to the highest histogram point in real time, the reaching horizontal line is built, concerning which the testee in BFB regime can visually evaluate the changes of working capacity and correct its level. The line level increases when reaching the largest time of FP, and remains in the same position when reaching the least time. The test with BFB was performed using FP dynamics. The duration of the flight phase was assessed by the testee visually according to its current reached level on the histogram and according to the duration of sound signal (by 400 Hz frequency in our measurement), which sounds in the absence of contact between the plates of jumping platform during the period of feet separation before landing.

The height of each jump was calculated by the formula [3]: $h=t_f*g*8^{-1}$, where t_f – flight phase in seconds, g – acceleration of gravity (9.806665 $м \cdot s^{-2}$). Based on this indicator, body weight, the duration of support phase and jump cycle, we calculated the power of mechanical work of the whole body (P), the power of mechanical work during repulsion support phase (Pr), jump frequency (Fr), the correlation of support and unsupported phases (R). To assess the dynamics of the studied indicators during the test, we counted their changes at five-second intervals from 5 to 10, from 10 to 15 and from 15 to 20 seconds with respect to the segment from the start of the test up to its fifth second.

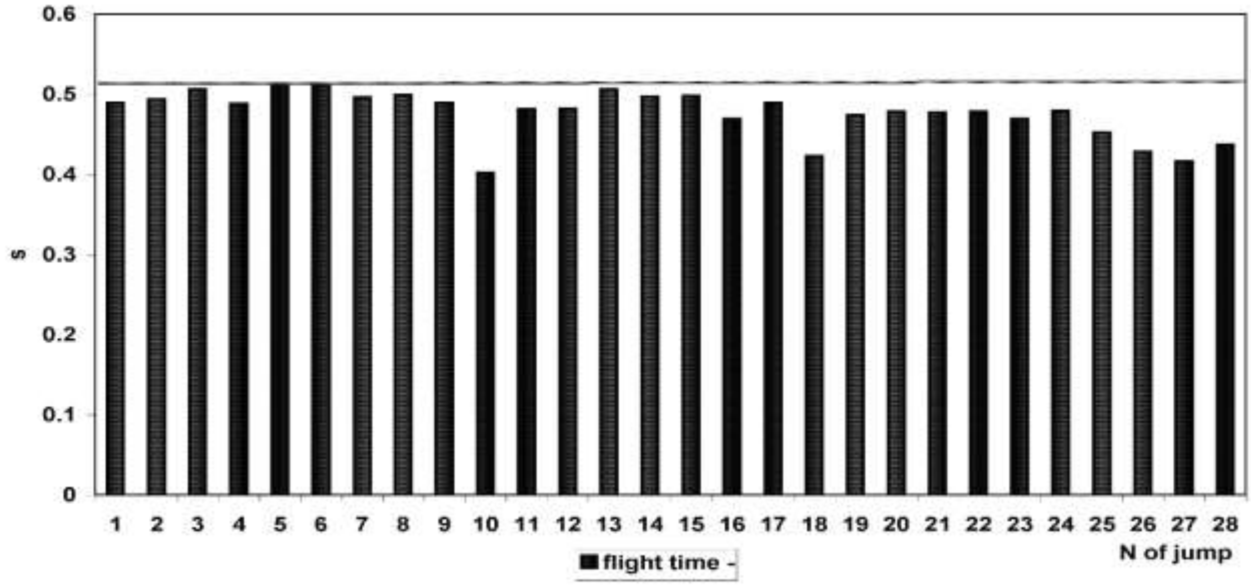

Figure 1. Operating window of the program during jump test

To determine the dominant aspiration of achieving success motive (to achieve success or to avoid failure), we used the method of "success motivation and avoiding failure" developed by A. Rean [12]. This method was composed of 20 statements (e.g. "starting work, I hope to succeed", "solving responsible tasks, I try, if possible, to find a reason to abandon them", etc.), with which a testee either agreed or disagreed. The results were processed using special answer key; the maximum possible number of the gained points was 20. Thus, if a testee gets the sum from 1 to 7 points, it means the dominance of the aspiration to avoid failure; if from 14 to 20 – the aspiration to achieve success. If the sum of points is in the range between 8 and 13 points, it indicates that the motivation pole is not clearly expressed. However, if an adolescent gets the point sum ranging from 8 to 10, it shows that his achievement motive focuses more on his aspiration to avoid failure, if the point sum is from 11 to 13 – to achieve success.

Statistical calculations were performed in Excel-2003 spreadsheets and Statistica-5 program. Due to the normality of data distribution, we determined the average values of the indicators and their error. The reliability of differences was assessed according to Student's t-criterion for pair and group comparison [9].

Results

Table 1 shows the indicators of anaerobic working capacity in children aged 11-12 when performing 20-second anaerobic test. It was found that there were significant individual differences in the level of these indicators in the examined group. So, maximum values of Fr, H and P prevailed minimum values by 1.8-2 times, and for P and R, the correlation was 4.2.

Table 1.

Indicators of working capacity in jump anaerobic test in children aged 11-12 with and without biological feedback (n=60)

Indicators	Before				With Biofeedback		P
	X	SD	Max	Min	X	SD	
Fr, $c \cdot s^{-1}$	1,71	0,03	2,13	1,05	1,68	0,03	0,614
H, m	0,47	0,01	0,59	0,33	0,49	0,01	0,002
P, $Wt \cdot kg^{-1}$	7,89	0,11	8,95	4,84	8,05	0,11	0,036
P_r, $Wt \cdot kg^{-1}$	46,31	1,45	66,99	16,01	48,76	1,52	0,021
R, n.u.	1,89	0,06	2,73	0,65	1,99	0,06	0,021

The reliability of differences was determined by the method of pair comparison

When performing the test with biological feedback, the children improved the levels of almost all indicators except Fr.However, the value of this improvement was within 2.17%-5.57% for different indicators. In this case, we observed significant individual features of changes of anaerobic working capacity. The changes of P_r were the most variable; maximum changes were +35.67 $Wt \cdot kg^{1}$, and minimum – -14.72 $Wt \cdot kg^{-1}$. In this case, the coefficient of reactive variation on BFB was 319.05%, and for P – 360.87%. Thus, along with the positive influence of BFB in general in the group, there were significant individual features of its influence on anaerobic working capacity of the children aged 11-12.

Consequently, the levels of most indicators of working capacity determined in anaerobic jump test in girls were higher than in boys (Table 2).

When performing the test with biological feedback, these differences are leveled. It is explained by different reactivity of these indicators in boys and girls on the application of BFB. Thus, if compared with the girls, the boys had their positive changes which were expressed to a larger extent for the indicators of mechanical work power. Therefore, the application of BFB had a positive influence on the level of working capacity shown in the anaerobic jump test only in the boys aged 11-12.

Table 2.

Indicators of working capacity of boys and girls when performing anaerobic jump test with and without BFB

Indicators	Girls		Boys		P
	X	SD	X	SD	
Without Biofeedback					
Fr, $c \cdot s^{-1}$	1,78	0,03	1,64	0,04	<0,01
H, m	0,47	0,01	0,46	0,01	>0,05
P, $Wt \cdot kg^{-1}$	8,24	0,10	7,54	0,17	<0,001
Pr, $Wt \cdot kg^{-1}$	51,32	1,56	41,30	2,08	<0,001
With Biofeedback					
Fr, $c \cdot s^{-1}$	1,71	0,04	1,66	0,05	>0,05
H, m	0,48	0,02	0,49	0,01	>0,05
P, $Wt \cdot kg^{-1}$	8,14	0,15	7,97	0,16	>0,05
Pr, $Wt \cdot kg^{-1}$	50,31	2,26	47,27	2,04	>0,05

We analyzed the dynamics of anaerobic working capacity indicators with the application of BFB separately in the girls and boys for 5-second intervals when performing the test. Thus, for girls, there were no reliable changes compared to the first 5-second interval (as an example, Figure for P). At the same time, the reactions for BFB were statistically larger in boys than in girls. The variability of these reactions was high (Figure 2).

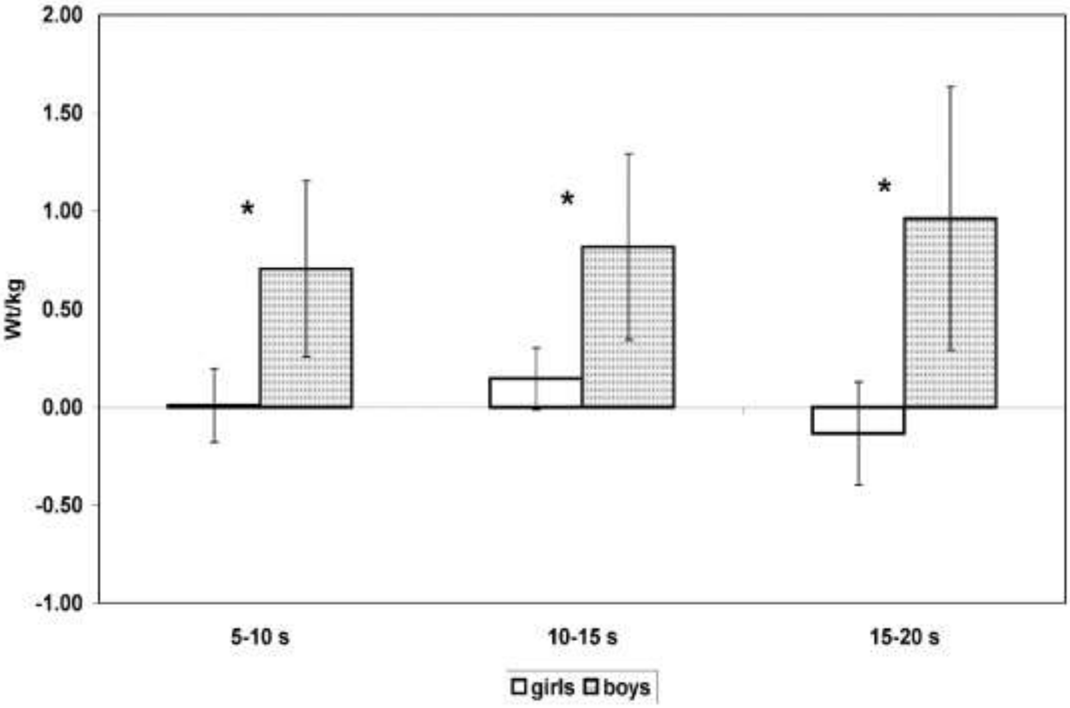

Figure. 2. Dynamics of changes in general mechanical power when performing anaerobic jump test with regard to the level of the first 5-second interval with the application of biological feedback. * – $p<0.05$ between the values of the boys and girls

Thus, biological feedback has a greater influence on the level of anaerobic working capacity in the boys aged 11-12 and can be applied for the improvement of training this feature in them. We have found the peculiarities of biological feedback influence in the groups of children with different focus on avoiding failure (group I, n=14) or achieving success (group II, n=46). The changes of P with BFB in the children of group I were 0.05±0.10 $Wt \cdot kg^{-1}$, and for group II – 0.26±0.10 $Wt \cdot kg^{-1}$ ($p<0.05$). Such differences for P_r between the groups were more expressed (0.28±1.37 $Wt \cdot kg^{1}$ and 3.82±1.39 $Wt \cdot kg^{-1}$, respectively, $p<0.05$).

The analysis of dynamics of mechanical work power with and without BFB in the groups with different focus on achieving results also shows the positive influence of BFB on the children of group II.

Discussion

The levels of anaerobic working capacity reached in 20-second jump test in the children aged 11-12 were lower than in adults. Thus, in the research of Bosco et al. [3], general mechanical power of work during 60-second jump test was 20 $Wt \cdot kg^{-1}$ of body weight, and in our research, it was in average 7.89 $Wt \cdot kg^{-1}$ during shorter interval of physical work. Descriptive survey of data from both invasive and noninvasive studies from 1970 till 2015 conducted by Armstrong et al. [1] shows that the level of aerobic metabolism development in children predominates over anaerobic. Engel et al. [7] conducted a series of successive Wingate Anaerobic Tests on 23 boys aged 11.5 and 25 men aged 29.7. It was found that the reached maximum level of lactate in the blood was lower in the boys than in the men чоловіків

(12.6±3.5 μmol·L^{-1} and 16.3±3.1 μmol·L^{-1}, respectively; $p<0.01$). Based on the analysis of hormonal metabolic and cardio-respiratory indicators, authors conclude that the exercises of anaerobic focus require significant activation of hormonal system in the children of such age.

The marked differences in the levels of anaerobic working capacity in boys and girls in our research can be explained by the different rates of maturation noted by some authors [2]. Thus, Ivashchenko et al. [13] showed that there was the significant increase of results in jumps with "additions" in the girls aged 9-10. At the same time, according to our research, the weight of girls and boys did not differ and was 44.90±1.54 kg та 44.48±1.53 kg in average respectively. According to Szakály et al. [22], the weight and height of 46 boys and 63 girls aged 10-12 did not differ either.

The features of biofeedback application in the children with different motives of achieving success or avoiding failure showed that the influence was efficient to the greatest extent in the group focused on achieving success. According to the research of Heckhausen [11], the feedback of adolescent's performance results in activities plays an important role in the process of forming achievement motive. Conducting a series of studies, the author points out that the lack of feedback on success or failure in the activity of schoolchildren focused on achieving success causes less fear than in those focused on avoiding failure. Besides, without feedback, the adolescents focused on achieving success achieve success quicker while solving difficult problems than the pupils focused on avoiding failure. However, the work productivity of adolescents focused on avoiding failure, increase with a large amount of feedback on current results of activity with stimulation and even forcing achievement. In Heckhausen's [11] opinion, it is associated with the fact that stimulation and feedback in activity process focused on achieving success distract the adolescent focused on avoiding failure from thinking about the situation of achievement and promote successful performance. However, the application of feedback to the adolescents whose achievement motive focused on success, will have negative consequences since feedback and stimulation of the pupils will reduce their confidence to be reflected in the final results.

However, these studies were conducted on adolescents when solving intellectual (mathematical, logic, etc.) tasks but not physical training. We should note that Heckhausen [11]. Conducted his research on adolescents while solving logic tasks and feedback was carried out by the teacher through praise that was external stimulus. In our study, the feedback was held through registering and displaying current results on the monitor; it acted as a stimulus in this case. According to the study of Ilin [12], stimuli have negative influence on pupils focused on avoiding failure since they tried to avoid stressful situations. The results of the study allow to improve the process of training anaerobic opportunities of schoolchildren applying biological feedback.

Conclusions

The girls aged 11-12 had higher level of working capacity in the modified 20-second jump test than boys.

The application of biological feedback led to the improvement of results in 20-second anaerobic jump test in boys and had no influence on its indicators in the girls aged 11-12.

The application of biological feedback increased the results in 20-second anaerobic jump test and improved the dynamics of working capacity during its performance in the schoolchildren aged 11-12 with psychological focus on achieving success. This influence was insignificant in the children with psychological focus on avoiding failure.

References

1. Armstrong, N., Barker, A.R., McManus, A.M. (2015). Muscle metabolism changes with age and maturation: How do they relate to youth sport performance? *British Journal of Sports Medicine*, 49(13), 860-864. https://doi:10.1136/bjsports-2014-094491

2. Benítez-Porres, J., Alvero-Cruz, J.R., Carrillo de Albornoz, M., Correas-Gómez, L., Barrera-Expósito, J., Dorado-Guzmán, M., Carnero, E.A. (2016). The Influence of 2-Year Changes in Physical Activity, Maturation, and Nutrition on Adiposity in Adolescent Youth. *PLOS ONE,* 11(9), e0162395. https://doi:10.1371/journal.pone.0162395
3. Bosco, C., Luhtanen, P., Komi, P.V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology*, 50(2), 273-282. https://doi:10.1007/bf00422166
4. Cheung, E., Yu, K., Kwan, R., Ng, C., Chau, R., & Cheing, G. (2019). Effect of EMG-biofeedback robotic-assisted body weight supported treadmill training on walking ability and cardiopulmonary function on people with subacute spinal cord injuries - a randomized controlled trial. BMC neurology, 19(1), 140. https://doi.org/10.1186/s12883-019-1361-z
5. Crevenna, R., Krammer, C., Keilani, M. (2015). Feasibility and acceptance of biofeedback-assisted mental training in an Austrian elementary school: a pilot study. *Wiener Medizinische Wochenschrift*., 166(5-6), 179-181. https://doi:10.1007/s10354-015-0397-y
6. Crowell, H.P., Milner, C.E., Hamill, J., Davis, I.S. (2010). Reducing Impact Loading During Running With the Use of Real-Time Visual Feedback. *Journal of Orthopaedic & Sports Physical Therapy*, 40(4), 206-213. https://doi:10.2519/jospt.2010.3166
7. Engel, F., Härtel, S., Strahler, J., Wagner, M.O., Bös, K., Sperlich, B.. (2014). Hormonal, Metabolic, and Cardiorespiratory Responses of Young and Adult Athletes to a Single Session of High-Intensity Cycle Exercise. *Pediatric Exercise Science*, 26(4), 485-494. https://doi:10.1123/pes.2013-0152
8. Friedrich, E.V., Sivanathan, A., Lim, T., Suttie, N., Louchart, S., Pillen, S., Pineda, J.A. (2015). An Effective Neurofeedback Intervention to Improve Social Interactions in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, 45(12), 4084-4100. https://doi:10.1007/s10803-015-2523-5
9. Glantz S.A. *Primer of biostatistics* (seven editionsth ed.). McGraw hill. 2012. 320 p.
10. Hasegawa, N., Takeda, K., Mancini, M., King, L. A., Horak, F. B., & Asaka, T. (2020). Differential effects of visual versus auditory biofeedback training for voluntary postural sway. PloS one, 15(12), e0244583. https://doi.org/10.1371/journal.pone.0244583
11. Heckhausen, H. (2003). *Motivation and action*. SPb: Smyisl. 2003. 860 p.
12. Ilin, E.N. (2000). Motivation and motives. SPb: Piter. 2000. 512 p.
13. Ivashchenko, O.V., Yermakova, T.S., Cieslicka, M., Muszkieta, R. (2015) Discriminant analysis as method of pedagogic control of 9-11 forms girls' functional and motor fitness. *Journal of Physical Education and Sport*, 15(1), 576–581. https://doi:10.7752/jpes.2015.03086
14. Jiménez Morgan, S., & Molina Mora, J. A. (2017). Effect of Heart Rate Variability Biofeedback on Sport Performance, a Systematic Review. Applied psychophysiology and biofeedback, 42(3), 235–245. https://doi.org/10.1007/s10484-017-9364-2
15. Kovalenko, S., Nechyporenko, D. (2014). Application of biological feedback for estimation of anaerobic performance in jumping test. *Physical Education of Students*. 2014; 18(5): 20-24. https://doi:10.15561/20755279.2014.0504
16. Lepley, A.S., Gribble, P.A., Pietrosimone, B.G. (2012). Effects of Electromyographic Biofeedback on Quadriceps Strength: A Systematic Review. *Journal of Strength and Conditioning Research*, 26(3), 873-882. https://doi:10.1519/jsc.0b013e318225ff75
17. MacIntosh, A., Desailly, E., Vignais, N., Vigneron, V., & Biddiss, E. (2020). A biofeedback-enhanced therapeutic exercise video game intervention for young people with cerebral palsy: A randomized single-case experimental design feasibility study. PloS one, 15(6), e0234767. https://doi.org/10.1371/journal.pone.0234767
18. Mullineaux, D.R., Underwood, S.M., Shapiro, R., Hall, J.W. (2012). Real-time biomechanical biofeedback effects on top-level rifle shooters. *Applied Ergonomics,* 43(1), 109-114. https://doi:10.1016/j.apergo.2011.04.003
19. Onate, J.A., Guskiewicz, K.M., Sullivan, R.J. (2001). Augmented Feedback Reduces Jump Landing Forces. *Journal of Orthopaedic & Sports Physical Therapy*, 31(9), 511-517. https://doi:10.2519/jospt.2001.31.9.511
20. Podrigalo, L., Iermakov, S., Rovnaya, O., Zukow, W., Nosko, M. (2016). Peculiar features between the studied indicators of the dynamic and interconnections of mental workability of students. *Journal of Physical Education and Sport,* 16(04), 1211–1218. https://doi:10.7752/jpes.2016.04193
21. Prinsloo, G.E., Rauch, H.L., Derman, W.E. (2014). A Brief Review and Clinical Application of Heart Rate Variability Biofeedback in Sports, Exercise, and Rehabilitation Medicine. *The Physician and Sportsmedicine,* 42(2), 88-99. https://doi:10.3810/psm.2014.05.2061
22. Szakály, Z., Bognár, J., Barthalos, I., Ács, P., Ihász, F., Fügedi, B. (2016). Specific heart rate values of 10-12-year-old physical education students during physical activity. *Journal of Physical Education and Sport*, 03, 800–805. https://doi:10.7752/jpes.2016.03127

23. Tate, J.J., Milner, C.E. (2010). Real-Time Kinematic, Temporospatial, and Kinetic Biofeedback During Gait Retraining in Patients: A Systematic Review. *Physical Therapy*, 90(8), 1123-1134. https://doi:10.2522/ptj.20080281
24. Tirosh, O., Cambell, A., Begg, R.K., Sparrow, W.A. (2012). Biofeedback Training Effects on Minimum Toe Clearance Variability During Treadmill Walking. *Annals of Biomedical Engineering*, 41(8), 1661-1669. https://doi:10.1007/s10439-012-0673-6

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