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Original Article

Evaluation of characteristics of running with an audio stimulation in prepared students from various sports

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Abstract:
Purpose: revealed differences in the running characteristics of students from different sports without and with audio stimulation. *Objects:* prepared students (boys n=26 and girls n= 14). *Methods:* test №1: running for 4 minutes with a gradual increase in pace; test №2: running for 4 minutes in the tempo of the metronome (140; 150; 160; 170 bpm). *Results:* Comparison of test results №1 and №2 in the group of young men revealed the reliability of differences (p<0,05) for: the first and fourth minutes of running; average running speed in the second minute; total number of steps on the second and third minutes. Comparison of the results of tests №1 and №2 in the group of girls revealed the reliability of differences (p<0,05) for: the distance of running in the first minute; average running speed in the first and second minutes; total steps in first and second minutes. *Conclusions:* similar physiological reactions were recorded in boys and girls on exercise, which increases in steps, regardless of the method of stimulation. At the same time, there are certain differences in the strategy of movement, depending on the method of stimulation. This confirms the complex effect of the imposed rhythm on the performance of cyclic locomotion. We expected significant differences between running characteristics with and without auditory stimulation. However, a large number of reliable differences between the results, including for boys and girls, were not found. This may be due to the preparedness of the subjects, as well as indicate the inconsistency of the data, which requires in-depth research. At this stage, we are inclined to think that the selected metronome frequencies are convenient for running with a load that rises stepwise.
Key words: metronome, rhythm, tempo, athletics.

Introduction

The human body is able to perceive and respond to stimulation of the main senses from the outside [18]. An individual is able to arbitrarily choose a specific (with varying degree of awareness) rhythm of motor activity. Obviously, to effectively solve a specific motor task, the rhythm will be different. For example, cyclic locomotion (walking, running, etc.), which are everyday and simple for a healthy person. They have important practical significance for movement, development and control of preparedness and rehabilitation. We can say that the rhythmic performance of cyclic locomotion indicates their quality (economy and efficiency) [42]. Thus, in the area of bimanual coordination P. W. Fink et al. (2000) isolate rhythmic-auditory stimulation (RAS), which can stabilize internal coordination creating an effect called «anchoring» [17]. When a particular point in a cycle of movement (for example, placing a foot on a support) is synchronized with a metronome, an effect called anchoring may occur [7; 9; 16], which showed a more stable connection between the characteristics of the musculoskeletal system and the respiratory system during cyclic movements through locomotor respiratory coupling (LRC). Rhythmic motor actions can be combined with external acoustic stimuli (metronomes and music). This phenomenon is known as sensorimotor synchronization [24; 27; 32]. At the same time, concentration on an external stimulus distracts from internal experiences (uncertainty, fatigue, laziness) [39]. R. J. Bood et al. (2013) showed an increase in time to fatigue due to the use of sound stimuli during exercise. It is assumed that this is due to the parallel processing of external and internal signals. [29]. That is, the main attention when performing physical work is transferred to external stimuli in an attempt to reduce the perception of signals about the tension of the musculoskeletal system and cardio-respiratory system [38]. Also, this may be due to an increased level of relaxation as a result of an exact expectation of the upcoming movement [36]. Perhaps there is a certain «rhythmic pattern» as the most effective strategy for solving a motor problem. C. Karageorghis et al. (2012) identified the frequency of cyclic locomotion in recreational runners between 130 and 200 steps per minute (spm) [21]. Perhaps we should speak only about the individual rhythm of movement. Auditory or visual stimulation is most commonly used in physical exercise. We think that the ability to compare physiological changes (for example, heart rate), external movement parameters (for example, speed) and audio

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stimulation will allow an individual to explore his or her movement. For the study we selected trained individuals. It is assumed that they can better complete the task. Thus, the *purpose of the current study* was to identify differences in the running characteristics of students from different sports without and with auditory stimulation.

Methods and objects

Ethical Statement. The study was approved by the Ethics Committee of the Kharkov State Academy of Physical Culture and all subsequent procedures were consistent with the Helsinki Declaration.

Object: prepared students (boys n = 26 and girls n = 14) are practically healthy, who have the following characteristics: body mass (m) = male: 68,12±9,92 kg; CV = 14,56; female: 53,36±6,54 kg; CV = 12,25; height (h) = male: 177,73±7,30 sm; CV = 4,11; female: 165,79±3,51 sm; CV = 2,12; heart rate (HR) = male: 70,00±6,52 bpm; CV = 9,31; female: 69,93±5,30 bpm; CV = 7,58.

Before the study, the participants (n = 40) were instructed about the rules and differences of tests №1 and №2.

Test №1. Students (groups of 5 people) at the command “Go!” Performed a run for 1 min. in a free rhythm, which the test person had to independently raise every minute (only 4 m). The benchmark was the average heart rate (HR) and the average running speed (V № … min; m/s), which was reported to the test person at the end of each minute. Each subsequent minute, it was recommended to run at an elevated rhythm based on perceived running speed and physiological sensations. Running was performed on a platform with a ground covering, on a plot of 20 m with bright markings every meter, which was limited by cones. At the end of 1, 2, 3 minutes, HR (bpm) was recorded, the distance covered (Dist. after № … min; m) and Rating of Perceived Exertion (RPE after № … min; score) by Borg «6-20» (from 6 («Easy») to 20 («maximum effort») [4]. After this, the test person returned to one of the cones for the start of the next minute of the run (a total of 15±5 s were used to record and report the indicators). As soon as all the test participants were ready, a signal was given to start running. At the end of 4 minutes or in case of refusal to continue, HR and Dist. were recorded after 1-4 min. Indicator changes were reported to test person only to select running speed.

Two hours later, the test person proceeded to perform a second test.

Test №2. Students (groups of 5 people) at the command «Go!» Performed a run for 1 min. (4 min in total) to the rhythm of the metronome, which rises every minute (140, 150, 160, 170 bpm). Running was performed on the same platform as in test № 1. The digital metronome signal was fed through a portable audio system. At the end of 1, 2, 3 minutes record HR, Dist. after № …. min and RPE. At the end of each minute, the test person returned to one of the cones to start the next minute of the run (a total of 15 ± 5 s were used to record the indicators). As soon as all the test participants were ready, the signal was given to start running the race at a given rhythm. Recorded HR and Dist. after 1-4 min: at the end 4 m; in case of refusal to continue running; in case of apparent inconsistency with a given rhythm of running (>10 SPM).

Measurements

All test sessions were recorded on a video camera, which was located frontally on a tripod at a height of 1 m above the ground, at a distance of 10 m from the line of movement of the subjects. Video filming was carried out according to the standard technique [15]. The result of the run, as well as the time was recorded with an electronic stopwatch Fastime 14 Stopwatch (UK). The average running speed was calculated by the formula: dis. after № ... min. running ÷ 60 s. The frequency of the running steps was determined from the video, counting the total number of steps in each minute of running using the formula: total steps № ... min ÷ 60. Running rhythm was reported using a Boss TU-88 Black (Japan) metronome tuner connected to an Air Music CUP portable speaker system (China). The delay caused by the wireless sound transmission was negligible. Columns were located next to the video camera. With the help of the Polar H10 cardiac sensor (Finland) and the Polar M400 sports watch (Finland), the average HR was recorded at the end of each minute of running. Information from the cardio sensor was instantly transmitted via Bluetooth to the Acer Aspire E1-510 laptop (China). The video analysis was performed using the software Dartfish (Switzerland) determined the frequency of the running steps, the correspondence of the rhythm of the run and the rhythm of the metronome.

Statistics

Statistical analysis was performed using the software package Statistica 10 (USA). The analysis of compliance of sample data with the normal distribution law was performed using the Kolmogorov-Smirnov test. Parametric and non-parametric methods of analysis were used to describe, assess interconnections, and differences in results: descriptive statistics; Pearson correlation coefficient; Mann-Whitney U-test; Student's t-test paired samples. For all analyzes, the level of statistical significance was set at p<0,05.

Result

All participants were able to complete the test №1 and №2. The measured running characteristics and heart rate had a different approximation to the normal distribution law. Based on the results of the Kolmogorov-

Smirnov test, an appropriate statistical criterion was chosen to compare the results. Kinematic characteristics and physiological responses recorded in the process of running with audio stimulation are presented in Table 1.

The coefficient of variation of heart rate in the group of young men during 4 minutes of running decreased (CV = 13,96; 10,62; 7,51; 7,53), and in the group of girls it changed in a wave-like manner (CV = 11,59; 9,26 ; 10,09; 11,59). The group variation of the running distance in the group of young men decreased in the third and fourth minutes, and increased in the second minute of the test (CV = 13,97; 24,07; 17,10; 10,66), while in the group of girls it increased (CV = 5,90; 8,67; 12,12; 12,40). The average running speed had a similar dynamics, as well as the running distance of the subjects of both groups. The coefficient of variation in the number of steps per minute in the subjects of both groups increased (CV male: 1.62; 1.59; 1.56; 2.53; CV female: 1.11; 1.32; 1.28; 1.73), and for RPE decreased (CV male: 15,76; 13,53; 14,99; 6,86; CV female: 40,67; 11,61; 11,29; 4,76).

The kinematic characteristics and physiological responses recorded during the run without audio stimulation are presented in Table 1. The coefficient of variation of heart rate in the groups decreased (CV male: 15.10; 10.99; 9.57; 7.57; 7.39; CV female: 13.42; 11.94; 11.62; 7.32). Group variation of distance running in test groups dynamically changed (CV male: 16,05; 22,72; 16,85; 3,54; CV female: 14,74; 15,42; 5,58; 17,93). The average running speed of the test person of both groups had a similar dynamics, as well as the distance of the run. The coefficient of variation in the number of steps per minute of test person of both groups dynamically changed (CV male: 6,44; 5,09; 3,52; 4,45; CV female: 1,84; 4,19; 1,21; 3,64), and for RPE decreased (CV male: 14,50; 20,03; 11,95; 6,00; CV female: 18,49; 21,83; 8,02; 6,61).

Comparison of test results №1 between groups revealed the reliability of differences (p <0,05) for: heart rate in the first minute of the race; running distance in the second and fourth minutes.

Comparison of the results of test №2 between the groups revealed the reliability of differences (p <0.05) for: heart rate in the first minute of the race; running distance in the first, second and fourth minutes; average run speed in the third minute; total number of steps in the third minute.

Table 1. Kinematic characteristics and physiological responses

Type of measurement	male		female	
	M±SD			
	rhythm	no rhythm	rhythm	no rhythm
HR start	105,00±12,73	97,46±16,33	102,86±8,10	100,29±11,39
HR №1 min	131,46±18,35	129,81±19,60	151,86±17,60	149,29±20,04
HR №2 min	155,69±16,53	154,62±17,00	165,86±15,36	164,57±19,65
HR №3 min	166,00±12,47	169,15±16,19	171,36±17,28	170,86±19,86
HR №4 min	173,42±13,06	176,46±13,35	173,71±20,14	177,43±13,00
Dist. after №1 min	139,33±19,46*	127,79±20,51*	108,21±6,39*	120,54±17,76*
Dist. after №2 min	151,96±36,57	160,33±36,43	112,50±9,76	118,93±18,34
Dist. after №3 min	167,88±28,70	170,19±28,68	167,14±20,26	173,57±9,69
Dist. after №4 min	160,18±19,87*	174,64±6,19*	142,79±15,22	152,88±27,42
V №1 min	2,32±0,32	2,13±0,34	1,80±0,11*	2,01±0,30*
V №2 min	2,53±0,61*	2,67±0,61*	1,88±0,16*	1,98±0,31*
V №3 min	2,80±0,48	2,84±0,48	2,79±0,34	2,89±0,16
V №4 min	2,67±0,33	2,91±0,10	2,38±0,25	2,55±0,46
Total steps №1 min.	140,23±2,27	141,92±9,14	140,14±1,56*	137,36±2,53*
Total steps №2 min.	150,38±2,38*	153,81±7,83*	150,29±1,98*	155,14±6,50*
Total steps №3 min.	158,46±2,47*	163,69±5,77*	160,07±2,06	162,00±4,54
Total steps №4 min.	167,81±4,25	167,65±7,47	167,71±2,89	165,57±6,03
RPE after №1 min	9,54±1,50	9,35±1,35	9,07±3,69	9,00±1,66
RPE after №2 min	9,81±1,33	10,12±2,03	10,93±1,27	10,14±2,21
RPE after №3 min	13,62±2,04	13,42±1,60	14,93±1,69	14,36±1,15
RPE after №4 min	15,92±1,09	16,38±0,98	15,64±0,74	16,36±1,08

*Significant differences with the auditory stimulation and without auditory stimulation <0,05

Calculation of the correlation relationship between similar running characteristics performed with and without audio stimulation. In the group of young men revealed a significant correlation for: heart rate at the first (r=0,79), the second (r=0,96), the third (r=0,80) and the fourth (r=0,41) minutes of running; distance running at the second (r=0,84) and the third (r=0,88) minutes. In the group of girls, a significant correlation was found for: heart rate at the first (r=0,56), second (r=0,59) and third (r=0,77) minutes of running; running distance in the fourth (r=0,58) minute. For all other indicators, no significant correlations were found.

Discussion

In our study, a metronome was used as an auditory stimulation. When choosing rhythms for running, we were guided by data from previous studies. J. Edworthy & H. Waring (2006) suggested 200 or 70 bpm music for running. C. Karageorghis et al. (2006) investigated walking at a pace of 80, 120 and 140 bpm. F. Styns et al. (2007) argue that people can synchronize with musical tempos in the range 50-190 bpm. We chose a range of rhythms: the transition from fast walking to running (140 bpm) to comfortable and effective running cadence (170 bpm) [10]. They also took as a basis the assertions that the transition from walking to running in humans usually occurs at a speed of about 2,1 m/s [2; 19; 40], which corresponds to the average speed of movement recorded in our study.

During test №1, high rates of heart rate (> 185 bpm) were recorded in 12 boys and 8 girls. During the test №2 high rates of heart rate were recorded in 6 boys and 3 girls. Heart rate is a complex value, which depends on different characteristics. In our opinion, the high performance of individual subjects may be explained by individual characteristics, emotion or passion. However, a decrease in the number of participants with high rates of heart rate in the second trial may indicate: the positive effect of auditory stimulation on the rhythm of the run and the dynamics of the heart rate; the selected metronome frequencies are suitable for stimulating physiological responses while running at a certain level, regardless of gender. However, this requires in-depth research.

The heart rate increased every subsequent minute in test №1 and №2 for students of both groups. The difference in the physiological response was only an increase in the variation in the group of girls at the last minute of the run with audio stimulation. Obviously, both versions of the test did not cause difficulties for trained students. Most of the students managed to gradually dose the load and achieve high heart rate. A decrease in the length of the distance in the fourth minute in the subjects of both groups indicates the exhaustive nature of the tests. The increase in the distance of running in the group of young men in the fourth minute of running without audio stimulation can be explained by a motivational factor and greater endurance, unlike girls. However, this contradicts the assumption that the rhythm, which is synchronized with the pace of the individual's work, may contribute to an increase in endurance when performing exercises [39]. The absence of significant differences in the dynamics of the physiological response indicates a similar task of testing to follow the rhythm or gradually independently increase the speed of running. The test person of both sexes demonstrated the ability to mobilize in the process of solving a motor task regardless of the method of stimulation. This confirms the ability of trained individuals to evaluate and dose the amount of exercise. The selected frequency can serve as an exhaustive exertion stimulus for the contingent represented.

Significant differences were found ($p<0,05$) in the length of the running distance in the first and fourth minutes minute in the group young men and in the first minute in the group of girls. Only girls in the first minute without an auditory stimulation ran a greater, and the young men a smaller distance. Thus, running with audio stimulation helped test young men to more accurately measure running and the length of a running step, since there were no significant differences between the number of steps in the first minute. The girls in the first minute ran more without audio stimulation, with fewer running steps. Therefore, running in the rhythm of the metronome made it possible to more accurately dose the frequency and length of the running steps. Similarly observed F. Styns et al. (2007) for a stride length with a walking frequency of 130 spm or higher. This is also indicated by differences in the length of the distance covered in the fourth minute in the group of young men. It is interesting that the choice of a comfortable pace of running among girls and, to a lesser extent, among young men was not significantly different from the selected rhythms of the metronome. It is assumed that this is due to the short duration of the test, the preparedness of the subjects and, possibly, a good choice of the rhythms of the metronome.

The average running speed was significantly different ($p <0,05$) in the group of young men in the first minute, and in the group of girls in the first and second minutes. Thus, this contingent of test persons is able to accurately determine the dosage of exercise. Only girls needed 2 minutes for this, and 1 minute for boys. The variation of the running speed in the group of young men changed when the auditory stimulation was applied, and dynamically changed when it was not there. In girls, the variation increased in the race with auditory stimulation and decreased without it. Significant differences in the number of running steps in the third minute of running in the group of young men and their absence for the average running speed indicates a change in the strategy of movement by changing the length of the running step.

The number of running steps in the group of young men was significantly different ($p <0,05$) in the test №1 and №2 in the second and third minutes, and the group of girls in the first and second minutes. This partially confirms the assumption that trained individuals are better able to perceive the imposed rhythm, as well as solve the problem of an independent stepwise increase in physical activity. Moreover, in the group of young men, cadence jogging was more without auditory stimulation (except the fourth minute) than the rhythm of the metronome at the same minute in test №2. The test boys were prone to greater frequency of steps, but at the moment of fatigue the rhythm naturally slowed down. The girls in the first and fourth minutes of the run without the auditory stimulation lagged behind the rhythm set in test №2, and in the second and third ahead of them. The variation of this characteristic in the subjects of both groups increased with auditory stimulation, and dynamically changed when it was not. This indicates the individual characteristics of the perception of the imposed rhythm. It was interesting that the number of steps in the test persons of both groups in half of the time of testing did not differ, regardless of stimulation. Moreover, the young men had significant differences in the middle of test №1 and №2, which may indicate a lack of warming-up (at the beginning) and the effect of fatigue (at the end). In turn, in the group of girls there were no significant differences in the number of steps in the second half of test №1 and №2, which may indicate a choice of a more comfortable rhythm, regardless of stimulation.

In the run with audio stimulation, the frequency of the running step different from the rhythm of the metronome was recorded in the group of young men on the first (SD=2,27) and second (SD= 2,38) minutes, and in the group of girls on the first (SD=1,56), the second (SD=1,98) and the third (SD=2,06) minutes. The frequency of the running step is lower than the rhythm of the metronome in the group of young men on the third (SD=2,47) and fourth (SD=4,25) minutes, and in the group of girls on the fourth (SD=2,89) minute. This may indicate the effect of fatigue on the ability to maintain the imposed rhythm and motivation to improve the result in the first part of test №1. This confirms the data of G. Tenenbaum et al. (2004) that motivating audio stimulation does not reduce the perception of stress for maximum intensity work. Obviously, due to fatigue, the length of the running step was also reduced. SD constantly increased in the subjects of both groups, which indicates the individual characteristics of running in conditions of increasing fatigue and the subjects begin to focus on the rhythm and the task, rather than on each other and their feelings [11]. We found contradictory reductions in the frequency of the step due to lagging, which is consistent with the recorded changes in other studies [8; 11]. In turn, H. Kyröläinen et al. (2000) & N. Place et al. (2004) observed an increase in step frequency.

No significant differences were found for the test groups between test №1 and №2 in terms of RPE. The coefficient of variation was reduced for two tests in both groups. This confirms the ability of trained individuals to qualitatively evaluate and dose perceived loads when solving a motor task, regardless of the method of stimulation. [13]. Thus, both tests were quite tedious for the subjects of both groups, as indicated by high RPE scores at the end of the test and a decrease in the intro group variation of the score. Our data contradicts the fact that dissociation caused by focusing on the auditory stimulus can change the perception of effort, allowing runners to work more intensively longer [13]. Perhaps with a different character of stimulation (motivational music) we would have recorded other results.

Significant differences in the characteristics of running with auditory stimulation between groups confirm the boys' advantage over girls in endurance. This was expressed in the predominance of the length of the distance that the young men ran through during the greater part of the test (with a similar speed of movement and heart rate). The same applies to the comparison of results in running without auditory stimulation in test groups. At the same time, the strategy of the movement, in general, was similar in both groups of subjects. This is evidenced by the single significant differences in the frequency of running steps. It is also characteristic that there are no significant differences between the test groups for most of the indicators of running without auditory stimulation. Only in two stretches did the young men run a significantly greater distance than the girls. Significant differences in heart rate in the first minute of running in boys and girls can be explained by different features of physiological adaptability to physical activity. Differences between the number of steps in a 3-minute run with auditory stimulation partially confirm the hypothesis of D. L. Priest et al. (2004) better tempo seizure for women.

The above assumptions are confirmed by correlation for the results of running in the test №1 and №2. Direct correlation forces of different physiological reactions in the test groups indicate the ability of this contingent to qualitatively dose physical stress, regardless of the method of stimulation. Too, but to a lesser extent, indicate changes in the length of the race in the group of young men. In the group of girls there is one weak link for the distance running. This indicates that girls are less able to vary their physical tension. In general, it can be said that the physiological reactions in both groups of subjects were similar. However, there is no significant relationship between the performance of the solution of the motor task of running. Moreover, in the group of girls there is only one correlation for the characteristics of running, which indicates a different way to solve the motor problem depending on the method of stimulation, despite the similarity of the physiological response. In the group of young men, there are more such correlations, which may indicate a more persistent behavioral reaction in this cohort. This is consistent with the results of research where it is indicated that trained individuals as a whole tend to focus on the objectives of the proposed exercise, and not on external stimulation. [5; 28].

The results of the study confirm the previously stated data by different authors on the effect of the tempo of music on the performance of cyclic exercises [12; 20; 26; 31; 41]. The adjustment of the pace of the run relative to the cadence of the subjects created optimal conditions for sensorimotor synchronization as a whole [32; 33]. This is consistent with the findings of the research of M. Roerdink et al. (2011) & K. Kudo et al. (2006) for cyclic locomotion.

Limitations

The limitation may be the level of preparedness of the subjects and the joint execution of the run, which creates the possibility of "copying" the rhythm of the run. Information about the study was not distributed to the subjects deliberately. We wanted to conduct tests under conditions similar to a natural experiment. He is characterized by what is being conducted in conditions close to the subject's usual activities, but he does not know that he is participating in the study. Due to this, a greater purity of the experiment is achieved. The main methods are observation and conversation with the subject. The study of the motor characteristics of the individual (or subject to formation) is carried out in the process of learning and assessment [22; 34].

Aknowledgement

The study was performed in accordance with the plan of scientific work of the Kharkov State Academy of Physical Culture.

Conflict of interest

The authors declare the absence of any conflicts of interest.

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