HEART RATE VARIABILITY AND EMOTIONAL STATE DYNAMICS IN ZUMBA CLASS

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INTRODUCTION

The increasing demand for a healthy lifestyle in society requires increased provision of sports and health-oriented services, and in particular fitness. Fitness can satisfy the need for body activity of people of all ages and genders, because it has great adaptability and a wide range of wellness programs that are accessible and have an emotional component. One of these programs is Zumba®Fitness. Statistics show that Zumba®Fitness has about 15 million members each week and hundreds of new members join every day. The reasons for its popularity may lie in the rhythmic music, the simple, easy steps that beginners learn right from the first session, and of course, the opportunity to express yourself and bolster your self-esteem. Zumba®Fitness has a proven positive effect on the emotional state, helps people lose weight, reduce menstrual pain (SAMY et al., 2019), and we have studied the cardiovascular effects of different types of fitness (IVANOV, 2019; BELOUSOVA, MAMYLINA, 2015), but we have not found any physiological studies to prove it, and Zumba in particular.

Many researchers have shown that while the high level of athletes’ performance is being achieved, the contribution of the factors determining it is complex and differentiated according to the stage of training.

The functional state of a person (including that assessed by the parameters of cardiac regulation) engaged in sports is known to differ from the one of people without physical activity.

For example, a review by J.G. Dong (2016) notes that an ANS comparison between sedentary subjects and recreationally active subjects or athletes of different sports modalities has demonstrated that athletes exhibit a different HRV profile to sedentary control subjects, with an overall increase in HRV and parasympathetic cardiac modulation. The activation of compensatory mechanisms preventing aging processes in elite athletes strengthens the neuro hormonal activation centers and parasympathetic parts of the autonomic nervous system (KOROBEYNIKOV, 2016). Heart rate patterns are sensitive to sport overload as it is shown in recreational endurance athletes following a 3-week overload protocol (COATES, HAMMOND, BURR, 2018). The data of M.V. Lagutina, I.N. Gorbaneva and I.N. Solopov (2013) show that at the stage when sportswomen initially select some specific kind of fitness, their physical efficiency depends on the level of the functional power of systems of autonomic maintenance of muscular activity.

Based on the above, we believe that the choice of means and methods of sports training in the organization of training activity should be carried out considering the purposeful development of the main components of functional preparedness of trainees’ body (KRUCHININA,
Filonov, 2020; Musin et al., 2020). However, at present this approach has not yet found its way into the fitness industry and the human state during fitness training is not paid proper attention to (Serebrovskaya, Suworova, Dunaeva, 2020; Bystritskaya et al., 2021).

In this regard, the aim of our study is to investigate heart rate variability (HRV) and the level of emotional disadaptation (ED) during Zumba® Fitness classes.

METHODS AND METHODS

Methods

The following methods were used in the current research study: theoretical (analysis; synthesis; specification; generalization); empirical and diagnostic (the method of wireless cardiointervalography - event-related telemetry technology (Polevaya et al., 2019), the level of emotional disadaptation (LED)) test; mathematical statistics methods and visual representation of the results.

Event-related telemetry technology provides monitoring and analysis of heart rate variability (HRV) dynamics with regard to the event context: the sequence of time intervals between heart beats (rhythmogram) is recorded by plastic chest electrodes; primary signal processing and data transmission to smartphone is performed by the sensor platform Zephyr HxM™ Smart Heart Rate Monitor (HxM, Zephyr Technology) via Bluetooth channel; specialized application ‘Stress monitor’ in Android OS (version 4 or higher) performs the function of the real-time monitor and provides data transfer to the cloud server; visualization of rhythmograms, spectral analysis and detection of stress episodes are implemented in the specialized Internet service ‘Stress monitor’ (cogni-nn.ru). Thus, continuous monitoring of the functional state of a person in the context of natural activity without limitations on distance and mobility is provided. The technology was tested in a variety of contexts, e.g., during classroom teaching (Demareva, Bovykina, Edeleva, 2019).

To estimate the LED, a participant is offered to indicate a zone of his/her current state in the “circular space of states”. The boundaries of the space are defined in four points of intersection of diagonals with a circle. The boundaries are sets of synonymous adjectives describing emotions according to modality (positive/negative) and activity level (tension/relaxation) in relation to four basic personality needs: a) safety; b) independence; c) achievement; d) unity (closeness). Depending on the position of the indicated zone, the number of points a person scores for each need is determined. The average score indicates the LED as follows:

- 0 points - absence of emotional disadaptation (physiological relaxation);
- 1 - weakly expressed emotional disadaptation (physiological tension);
- 2 - moderately expressed emotional disadaptation (pathological tension);
- 3 - extremely expressed emotional disadaptation (pathological relaxation).

PARTICIPANTS

20 female subjects (ages 15-35) took part in the study. All the subjects belonged to two categories: beginners and professionals (attending Zumba® Fitness classes for more than 5 months). This factor will be referred to as “experience” in the remainder of the paper.

Study Design

The design of the study is shown in Figure 1. Each experimental test was conducted individually for each subject and included:

- Time of rest prior to the training Ehe LED test before the class
- Continuous cardiohythm recording during a Zumba® Fitness class (1 hour)
- The LED test after class
Figure 1. Study design

Source: Search data.

The factor “time” was added to the analysis, which marked different stages of the study:

1. Before training;
2. During Training:
   a. Start (15 minutes);
   b. Middle (15 minutes);
   c. End (15 minutes);
3. Stretching (5 minutes).

Data Analysis
The personalized analysis of the autonomic regulation dynamics was carried out based on spectral indices of HRV. The following indices were calculated using the dynamic Fourier analysis with a window of 100 s and a step of 10 s: total power of the spectrum of HRV - TP (ms²), characterizing the adaptive potential rate; power of the spectrum in the frequency range from 0.04 to 0.15 Hz - LF (ms²), characterizing the activity of the sympathetic nervous system on heart rhythm modulation; spectrum power in the frequency range from 0.15 to 0.4 Hz - HF (ms²), characterizing the activity of the parasympathetic nervous system; LF to HF ratio - index of cardiac sympathovagal balance, characterizing the tension of regulatory systems (MCCRATY, SHAFFER, 2015).

The full list of the indicators that were calculated is given below:

- LED (level of emotional disadaptation) before training
- RR (cardiorhythm intervals) before training
- LF (sympathetic activity rate) before training
- HF (parasympathetic activity rate) before training
- TP (the adaptive potential rate) before training
- LF/HF (index of cardiac sympathovagal balance) before training
- RR (cardiorhythm intervals) at the beginning of training
- RR (cardiorhythm intervals) in the middle of training
- RR (cardiorhythm intervals) at the end of training
- LF (sympathetic activity rate) during training
Heart rate variability and emotional state dynamics in Zumba class

- HF (parasympathetic activity rate) during training
- TP (the adaptive potential rate - total power of HRV spectrum) during training
- LF/HF (index of cardiac sympathovagal balance) during training
- RR (cardiorhythm intervals) during stretching
- LED after training

The following methods were used for statistical analysis: descriptive statistics and correlation analysis. Statistical processing of the results was performed using Statistica 13.0 software. We used the following criteria: Mann-Whitney U-criterion, Wilcoxon T-criterion, and Spearman Rank Correlation.

RESULTS
1. At the first stage, we analyzed the differences in HRV and the adaptive potential rate, according to the factor of experience.

Using the Mann-Whitney U-criterion, we obtained significant differences (U = 21.6; p < 0.05) between the total power index (TP) of beginners (M = 480 ms²) and professionals (M = 1500 ms²). There was no significant difference between the beginners and the professionals on other parameters.

2. At the second stage, we analyzed the differences in HRV depending on the time factor, that is, at different stages of training.

Using the Wilcoxon T-criterion, the following significant differences were obtained:

1. Duration of RR intervals before training was significantly higher than duration of RR intervals at the beginning of training (T=10; p<0.001).
2. Duration of RR intervals before training was significantly higher than duration of RR intervals in the middle of training (T=1; p<0.001).
3. Duration of RR intervals before training was significantly higher than duration of RR intervals at the end of training (T=1; p<0.001).
4. Duration of RR intervals before training was significantly higher than duration of RR intervals during stretching (T=8; p<0.001).
5. Duration of RR intervals at the beginning of training was significantly higher than duration of RR intervals in the middle of training (T=7; p<0.001).
6. Duration of RR intervals of the beginning of training was significantly higher than duration of RR intervals at the end of training (T=13; p<0.001).
7. Duration of RR intervals in the middle of training was significantly lower than duration of RR intervals during stretching (T=0; p<0.001).
8. Duration of RR intervals at the end of training was significantly lower than duration of RR intervals during stretching (T=0; p<0.001).

These significant differences in the duration of RR intervals at different stages are shown in Figure 2.
Figure 2. Mean values of RR intervals duration during different time stages (** - p<0.001, T criterion)

Source: Search data.

Thus, the maximum duration of RR intervals was noted in the pre-training phase, then the duration decreased significantly, indicating a sharp increase in the tension of regulatory systems immediately after the start of training. In addition, the Wilcoxon T-criterion revealed a significant decrease in LF, HF, TP index in the process of training compared with the data before training, which is shown in Figure 3.

Figure 3. Mean values of HRV frequency domain indicators before and during training (* - p<0.05, T criterion)

Source: Search data.

The analysis revealed that the LF index critically decreased (T=17, p<0.01) in across the whole sample during the exercise, indicating a deficit of sympathetic activation during ZUMBA fitness classes.
It was found that HF index value before training was significantly higher than HF index during training \((T=47, p<0.05)\) (Figure 3).

The analysis of the results showed that the value of TP before training was significantly higher than TP during training \((T=22, p<0.01)\) (Figure 3).

The dynamics of changes in the average values of HRV in beginners and experienced participants are presented in Table 1.

Table 1. Average values of HRV indicators according to the factor of experience of occupation

| HRV     | Beginners | Experienced | Beginners | Experienced | Beginners | Experienced |
|---------|-----------|-------------|-----------|-------------|-----------|-------------|
|         | LF before training | LF before training | LF before training | LF before training | HF before training | HF before training | HF before training | HF before training | TP before training | TP before training | TP before training |
| Mean value \((\text{ms}^2)\) | 950 | 150 | 1450 | 450 | 380 | 30 | 330 | 350 | 2500 | 400 | 3500 | 1500 |
| \(p\) (T criterion) | <0.05 | <0.05 | <0.05 | - | <0.05 | - | <0.05 | - | <0.05 | - | <0.05 | - |

Source: Search data.

3. At the third stage, the correlations of HRV indicators at different stages of training were analyzed.

During the analysis of the obtained data using the Spearman’s rank correlation criterion, we found the following relations (Figure 4).

Figure 4. Correlations between HRV features at different time stages (red arrows denote positive correlations, blue arrows denote negative correlations)

Source: Search data.

The durations of all RR intervals at different stages of training, including stretching, were found to be positively correlated to each other. The duration of RR intervals at the beginning of training was positively related to the duration of RR intervals in the middle of training \((R=0.47, p<0.05)\), the duration of RR intervals at the beginning of training was positively related to the duration of RR intervals at the end of training \((R=0.51, p<0.05)\), the duration of RR intervals at the beginning of training was positively related to the duration of RR intervals during stretching \((R=0.58, p<0.01)\). The duration of RR intervals in the middle of training was positively related to the duration of RR intervals at the end of training \((R=0.88, p<0.001)\), the duration of RR intervals in the middle of training was positively related to the duration of RR intervals during stretching \((R=0.86, p<0.001)\). The duration of RR intervals at the end of training was positively related to the duration of RR intervals during stretching \((R=0.92, p<0.001)\).

Interestingly, the duration of RR intervals during training and during stretching was in no way related to the duration of RR intervals before training.
But we found that this parameter is inversely related to LF during training ($R=-0.72$, $p<0.001$), the duration of RR intervals before training is inversely related to HF during training ($R=-0.76$, $p<0.001$), the duration of RR intervals before training is inversely related to TP during training ($R=-0.73$, $p<0.001$). Pre-exercise RR interval duration was positively related to LF/HF during training ($R=0.48$, $p<0.05$).

4. At the fourth stage, we analyzed the dynamics of LED before and after training.

When studying the level of emotional disadaptation in the subjects, we obtained the results presented in Table 2.

**Table 2. Distribution of the sample according to the value of the LED**

| LED | No emotional disadaptation | Weakly expressed emotional disadaptation | Moderately expressed emotional disadaptation | Extremely expressed emotional disadaptation |
|-----|---------------------------|------------------------------------------|---------------------------------------------|---------------------------------------------|
| Before training | - | 25% | 65% | 10% |
| After training | 40% | 60% | - | - |

*Source: Search data.*

The dynamics of changes in the LED of beginners and experienced participants are shown in Figure 5.

**Figure 5. Average LED values of beginners and experienced participants before and after training (* - $p<0.05$; ** - $p<0.01$, T criterion)**

*Source: Search data.*

**DISCUSSION**

The American Institute of Medicine and Sports (2000) reports that the growing popularity of fitness reflects the needs of people who have an active lifestyle and seek to maintain and enhance health, improve their physical and psychological qualities. Every year fitness programs and dance training are becoming more and more popular around the globe. The Internet is full of headlines about the positive effects of Zumba® Fitness. Coaches talk about the positive effect of dancing for the cardiovascular system, they are supposed to help “work out” the heart muscle, as well as lift one’s spirits and help lose weight. But there are no research studies which would look at HRV during such training.
We analyzed the differences in HRV as a function of time, that is, at different stages of training (Figure 2). Based on the data presented in Figure 2 that the maximum duration of cardio rhythms (RR-intervals) is marked at the stage before training, and then the duration significantly decreases corresponding to a sharp increase in tension of regulatory systems immediately after the beginning of training (Thompson, 1999; Vasilyeva, 2001). On this basis, we can assume that people who came to training in a more mobilized state, that is, their duration of RR intervals is lower, will be more prepared for physical loads imposed by Zumba®fitness training (LEKOMTSEVA, MAYASOVA, 2015).

The analysis of the results presented in Figure 3 revealed that during training all participants of the study had a critical decrease in the activity of the sympathetic system (LF), which indicates a deficit of sympathetic activation during Zumba®fitness classes. Such dynamics are prominent both for the beginners and for the experienced participants. In general, this corresponds to the data found in the literature that physical training can reduce sympathetic activation by reducing neuronal activation in cardiovascular brain regions (GRANTS, CORBETT, DAVIES, 2002), and that during intense physical activity the level of sympathetic nervous system activation is lower than during moderate exercise (ROMANCHUK, 2005; CHERNYSHEVA, 2005). Thus, Zumba®Fitness can be considered a high-intensity training.

We also studied the dynamics of the parasympathetic system activity rate (HF) (figure 3). We found that this index decreases towards the end of the training for the whole data sample. Evaluating the dynamics of parasympathetic system activity index (HF) in people with different training experience (Table 1), it appeared that this index significantly decreases in the beginners by the end of training. For the experienced participants this index increases by the end of training, but insignificantly. This effect is also confirmed in in the respective literature which states that the HF rate in professional athletes does not decrease by the end of training (SIDORENKO, KOMISAROVA, 2007).

The value of the adaptive potential rate (TP) before training is significantly higher than the TP during training \(T=22, p<0.01\) (Figure 3). This effect indicates the state of the subjects after intense physical activity, which proves the above-mentioned statement with regard to excessive loads During the analysis of literature sources, our results were confirmed. I.F. Taminova, N.P. Garganeeva and I.N. Vorozhtsova (2008) proved that there is a significant decrease in the TP rate during intensive aerobic exercise. According to V.F. Tikhonov, T.V. Agafonkina and E.V. Oreshnikov (2010), the state after intense physical activity in athletes is accompanied by a drop in TP.

Our analysis revealed correlations between the indicators. It appears that the durations of all RR intervals at different stages of training, including stretching, are positively correlated with each other. However, the duration of RR intervals during training and during stretching had no relation to the duration of RR intervals before training. This parameter appeared to be inversely related to LF during exercise, while the duration of RR intervals before training was inversely related to HF during training and inversely related to TP during training. Analysis of the results suggests that the lower the pre-training RR interval duration, the higher the HF and TP during training will be. Thus, people who came to training in a more mobilized state, that is, the duration of RR intervals is lower, will be more prepared for physical loads (TALIBOV, DALSKY, NAUMENKO, 2013).

We found statistically significant differences between pre- and post-training LED values (Table 2). After the training all subjects had either no emotional disadaptation or it was weakly expressed. It is remarkable, that for the beginners the level of emotional disadaptation before training is reliably higher than the level of emotional disadaptation after training \(T=0, p<0.05\) and for the experienced participants the level of emotional disadaptation before training is higher than the level of emotional disadaptation after training \(T=1.5, p<0.01\) (Figure 5). Based on these findings, we can assume that Zumba Fitness classes positively influence the dynamics of emotional state, because after training all the subjects had the absence of emotional disadaptation or weak expression of this index.
CONCLUSION
Therefore, we examined the dynamics of HRV and emotional dysadaptation and found that Zumba Fitness can be viewed as a high-intensity training session. We found that Zumba® Fitness had a significant effect on both heart rate variability and LED. During a Zumba® Fitness training session, there is a rapid increase in regulatory tension as soon as the activity begins. The difference in HRV between people with different training experience is seen in the reduction in parasympathetic nervous system activation for beginners. This decreased sympathetic activation and decreased RR-intervals reflect the stressor effect of Zumba® Fitness on the body. Zumba® Fitness significantly reduces emotional disadaptation.

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Heart rate variability and emotional state dynamics in zumba class
Variabilidade da frequência cardíaca e dinâmica emocional do estado na aula de zumba
Variabilidad de la frecuencia cardíaca y dinámica del estado emocional en la clase de zumba

Resumo
A relevância da questão de pesquisa surge da necessidade de avaliar a segurança e os benefícios das aulas de Zumba®Fitness, bem como da falta de ferramentas diagnósticas e metodológicas para planejar o treinamento e prever os resultados do condicionamento físico. O objetivo deste artigo foi examinar a variabilidade da frequência cardíaca (VFC) e a desadaptação emocional (DE) durante as aulas de Zumba®Fitness. A cardiointervalografia sem fio e o teste LED (nível de desadaptação emocional) foram usados como métodos de pesquisa empírica. O artigo mostrou o efeito do Zumba®Fitness na VFC, bem como no LED. Significado prático: O presente estudo comprova a necessidade de controlar os estados funcionais durante o treinamento físico, que é um fator importante no planejamento do processo de treinamento e na previsão de seus resultados. Ao mesmo tempo, bons resultados do treinamento físico requerem o uso de tecnologias de diagnóstico modernas baseadas em métodos de pesquisa objetivos.

Palavras-chave: Variabilidade da frequência cardíaca (VFC). Nível de desadaptação emocional (LED). Zumba®Fitness. Estado funcional.

Abstract
The relevance of the research question arises from the need to assess the safety and benefits of Zumba®Fitness classes as well as from the lack of diagnostic and methodological tools to plan the training and predict fitness outcomes. The aim of this article was to examine heart rate variability (HRV) and emotional disadaptation (ED) during Zumba®Fitness classes. Wireless cardiointervalography as well as the LED (level of emotional disadaptation) test were used as empirical research methods. The paper showed the effect of Zumba®Fitness on HRV, as well as on LED. Practical significance: The current study proves the necessity to control functional state during fitness training, which is an important factor in planning the training process and predicting its results. At the same time, good results of fitness training require the use of modern diagnostic technologies based on objective research methods.

Keywords: Heart rate variability (HRV). Level of emotional disadaptation (LED). Zumba®Fitness. Functional state.

Resumen
La relevancia de la pregunta de investigación surge de la necesidad de evaluar la seguridad y los beneficios de las clases de Zumba®Fitness, así como de la falta de herramientas de diagnóstico y metodológicas para planificar el entrenamiento y prever los resultados del fitness. El objetivo de este artículo fue examinar la variabilidad de la frecuencia cardíaca (VFC) y la desadaptación emocional (DE) durante las clases de Zumba®Fitness. La cardiointervalografía inalámbrica y la prueba de LED (nível de desadaptación emocional) se utilizaron como métodos de investigación empíricos. El documento mostró el efecto de Zumba®Fitness en HRV, así como en LED. Importancia práctica: el estudio actual demuestra la necesidad de controlar el estado funcional durante el entrenamiento físico, que es un factor importante para planificar el proceso de entrenamiento y prever sus resultados. Al mismo tiempo, los buenos resultados del entrenamiento físico requieren el uso de tecnologías de diagnóstico modernas basadas en métodos de investigación objetivos.

Palabras-clave: Variabilidad de la frecuencia cardíaca (VFC). Nivel de desadaptación emocional (LED). Zumba®Fitness. Estado funcional.