294. Research into the heart rate and blood pressure dependence on loading and time

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(Received 30 May 2007, accepted 04 July 2007)

Abstract. The article deals with the dependence of the effect of physical load on male and female heart rate and blood pressure on the step and constant load with a change in time. It has been established that with the load applied to different male and female age groups and its time increasing, the heart rate and blood pressure increases in terms of non-linear dependence. Characteristic points have been determined to exist in the functional dependence of the heart rate and blood pressure on the time of loading, in which the derivative value of the function is equal to zero. The human fatigue criterion has been established on the basis of the derivative of this characteristic point, which shows the individual's reserve of the working capacity and its duration.

Keywords: the heart rate, blood pressure, constant and step loads, different age groups, gender, time, fatigue criterion.

Introduction

More and more people have been suffering from cardiovascular system diseases in Lithuania recently. Therefore an ever-greater attention is being devoted to research into the cardiovascular system. Many scientists investigate physiological and pathologic features of the heart rate and blood pressure of the cardiovascular system, behaviour and changes in the duration of physical load [1] – [6]. Sources of medical and sport science investigate the heart rate and blood pressure of the cardiovascular system separately [7], [8], applying physical load (constant or step load) in only male or female age groups within different experimental time [9] – [13].

No uniform research into the effect of physical load on the cardiovascular system – the heart rate and blood pressure, as well as fatigue from a constant and step load and its duration in different male and female age groups – has been carried out. Interdependencies of loading of a human organism, the heart rate, blood pressure and fatigue have not been studied in detail either.

Therefore the present work is aimed at analysing the dependence of the heart rate and blood pressure of the cardiovascular system, as well as fatigue in different age and gender groups of people on spasmodically changing and constant load within the course of time.

Applied methods

Participating in the investigations were groups of people of different gender under the age of 21, between the ages of 21 and 30, 31 and 40, 41 and 50, 51 and 60 and over 61 years of age. Each group of different age consisted on average of 10 people. The investigation data were processed statistically. The medical personnel took part in all investigations. The heart rate and blood pressure of all participants in the experiment were registered by means of the computerised *Siemens* and *SpaceLabs Medical* monitoring and data processing system, which is intended for analysing the heart rate and vascular disorders and evaluating the data of functional testing. When carrying out investigations this computerised system is joined with the veloergometer *Kettler* so that the individual under investigation could bear a certain physical load. To investigate the fatigue dependence on time, a constant load of different sizes was used. Loading was measured in watt (W). Veloergometrics was conducted using a constant load, with the initial load of 50 W being applied and increasing it every 20 minutes by 50 W. The heart rate and blood pressure of every individual under investigation were measured every 5 minutes. Three loads were chosen for the investigation: 50 W, 100 W and 150 W. Then veloergometrics was conducted with a step load applying the initial 50 W load for up to 3 minutes, 75 W load for 2 minutes, 100 W load for one minute, 125 W load for 2 minutes, 150 W load for one minute, 200 W load for one minute. In this case the heart rate and blood pressure was measured at the moment the load was increased. Prior to carrying out this investigation the heart rate and blood pressure of every individual under investigation were measured, and warming up with 25 W load was applied for 3 – 5 minutes. People without expressed pathologies participated in the investigation.

Results

Experimental investigations consisted of two parts. Research into the heart rate and blood pressure dependence on a step load in time was conducted in the first part of the experiment. Some of the results of the experiment for different male and female age groups are presented in Fig. 1 – 4. They show that the heart rate dependence on load and its duration in male groups of the age under 40 changes according to a convex curve. With the increase in load it is asymptomatically coming close to a certain magnitude (Fig. 1), whereas the value of the derivative of the function approaches the zero. The nature of the heart rate dependence on load and its duration in the male groups of the age of over 41 changes. It can be described in terms of a concave curve within the range of the load studied. This leads to the conclusion that males over the age of 41 are more trained and their reaction to the given load is weaker. Blood pressure is also increasing with the increase in a step load. However, an opposite phenomenon is observed here: blood pressure increases according to the law of the concave curve in males under the age of 60, whereas in males over the age of 61 the blood pressure dependence on load changes, that is, the organism's reaction to the given load is stronger (Fig. 3).

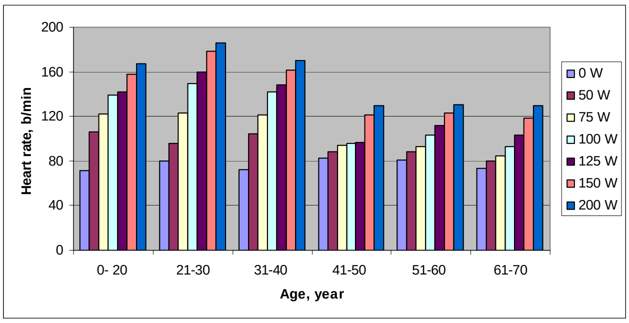

Fig. 1. The heart rate dependence on a step load in male groups of different ages

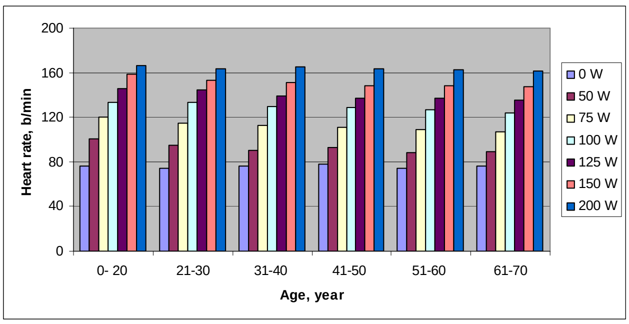

Fig. 2. The heart rate dependence on a step load in female groups of different ages

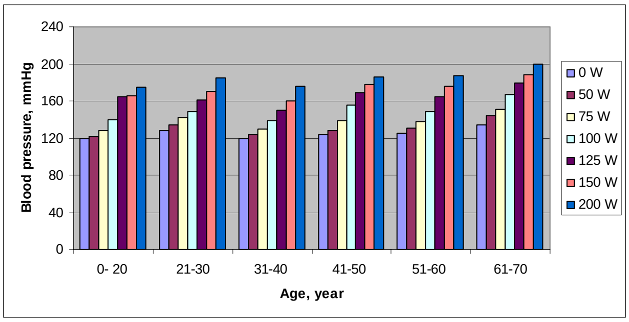

Fig. 3. The blood pressure dependence on a step load in male groups of different ages

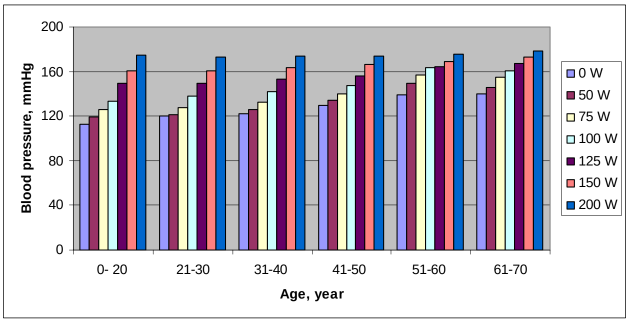

Fig. 4. The blood pressure dependence on a step load in female groups of different ages

The heart rate dependence on load changes insignificantly according to the law of the convex curve in female groups of all ages (Fig. 2). The blood pressure dependence (Fig. 4) on load in female groups of the age under 51 can be described by means of the convex curve, whereas in female groups of the age over 51 the dependence studied changes into the law of the concave curve.

From the Fig. 1, 2, 3 and 4 is clear, that the heart rate decline and blood pressure increase when the loading is enlarging.

In all cases under study the curves asymptomatically come close to a certain magnitude, that is, to a critical point in which the derivative of the function would equal zero.

The heart rate and blood pressure dependence on constant load in time was investigated in the second part of the experiment. Some of the results of the investigation are presented in Fig. 5 and Fig. 6.

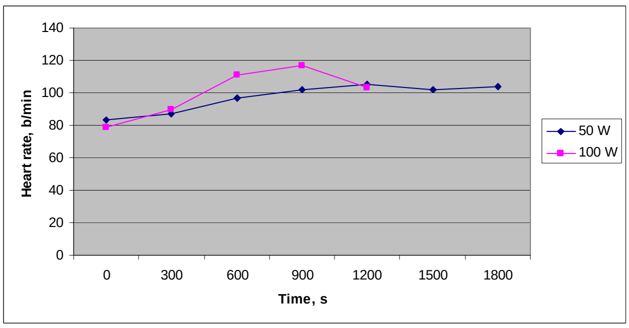

Fig. 5. The heart rate dependence on time in male groups between the ages of 31 and 40 in case of constant load

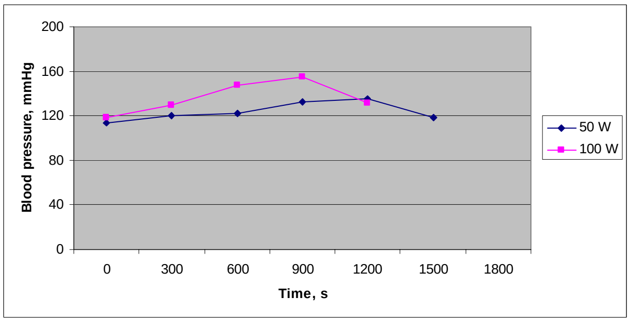

Fig. 6. The blood pressure dependence on time in female groups between the ages of 31 and 40 in case of constant load

The diagrams presented (Fig. 5 and Fig. 6) show that there exist critical points in which the derivative equals the zero in the heart rate and blood pressure diagrams of male and female groups. This critical point shows that certain changes are taking place in the organism and a person begins to feel fatigue. The beginning of fatigue is followed by unpleasant sensations and all the individuals who participated in the experiment complained that they were getting tired and soon they would be no longer able to complete the assignment. Therefore the feature of the specific point of the heart rate and blood pressure, that is, a partial derivative equalling the zero was chosen as signifying the beginning of fatigue. Mathematically it can be described in the following way. Providing that the heart rate and blood pressure dependence is described in terms of the following expressions:

$$H_M=f_1(Q,t) \text{ and } S_D=f_2(Q,t), \tag{1}$$

where H_M is the functional dependence of the heart rate on load and its duration, S_D is the functional dependence of blood pressure on load and its duration, Q is the load, t is the time, the conditions of the beginning of fatigue will be represented as follows:

$$\frac{\partial H_M}{\partial t}=\frac{\partial f_1(Q,t)}{\partial t}=0 \text{ and } \frac{\partial S_D}{\partial t}=\frac{\partial f_2(Q,t)}{\partial t}=0. \tag{2}$$

Expressions of the beginning of fatigue (2) are not too obvious in a physical sense, however, their reverse magnitude would be much more suitable and would show the beginning of fatigue more clearly. Therefore in our further investigations the criterion of the beginning of fatigue N_K shall be used to highlight the beginning of fatigue and it is described as follows:

$$N_K=\frac{1}{\frac{\partial H_M}{\partial t}}=\frac{1}{\frac{\partial S_D}{\partial t}}=\frac{1}{\frac{\partial f_1(Q,t)}{\partial t}}=\frac{1}{\frac{\partial f_2(Q,t)}{\partial t}}, \tag{3}$$

where N_K is the criterion for the beginning of fatigue.

Also, it is possible to introduce the fixed criterion n_K, which is described in the following way:

$$n_K=\frac{N_K}{N_{K1}}=\frac{1}{N_{K1}}\times\frac{1}{\frac{\partial H_M}{\partial t}}=\frac{1}{N_{K1}}\times\frac{1}{\frac{\partial S_D}{\partial t}}= \\ =\frac{1}{N_{K1}}\times\frac{1}{\frac{\partial f(Q,t)_1}{\partial t}}=\frac{1}{N_{K1}}\times\frac{1}{\frac{\partial f_2(Q,t)}{\partial t}}, \tag{4}$$

where N_K is the criterion for the beginning of fatigue, N_{K1} is the initial value of the criterion N_K.

The fixed criterion n_K is characteristic in that its initial value will always be equal to the unity, whereas the initial values of the non-fixed criterion can be very different.

Dependence of blood pressure on the loading duration at Q = 50 W was expressed as follows:

$$S_D=-0{,}00083+114t+2{,}22t^2-0{,}372t^3+0{,}0324t^4. \tag{5}$$

According to the experimental research results were calculated coefficients of other polynomials, which expressed the relations of the blood pressure and heart rate on the load and loading duration.

Calculated results of the fatigue criterion are presented on the Fig. 7 and Fig. 8:

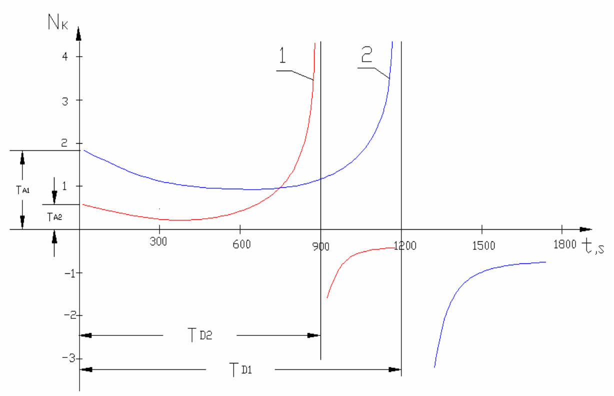

Fig. 7. Graphics of the criterion of the beginning of fatigue for male groups between the ages 31 and 40: 1 – 50 W, 2 – 100 W

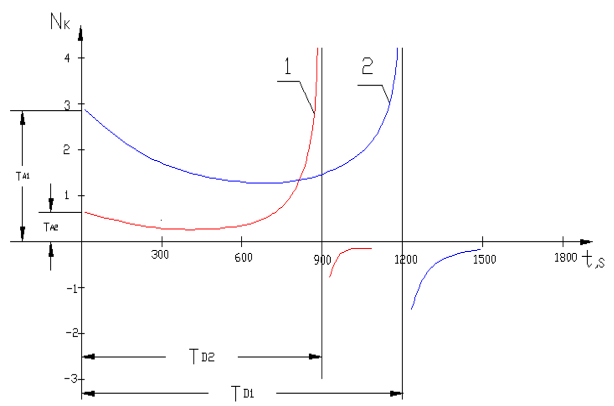

Fig. 8. Graphics of the criterion of the beginning of fatigue for female groups between the ages 31 and 40: 1 – 50 W, 2 – 100 W

When analysing the diagrams (Fig. 7 and Fig. 8) we see that a different reserve of working capacity T_{D1} and T_{D2} expressed in terms of the time co-ordinates and T_{A1} and T_{A2} – the characteristics of the working efficiency – correspond to different loads. For example, the diagram (Fig. 7) shows that with 50 W load the beginning of fatigue starts within 1200 sec. However, if load is increased up to 100 W, the reserve of working capacity decreases to 900 s. The diagram (Fig. 8) shows that with the same 50 W load the reserve of working capacity for the same more trained female expressed in terms of time is one and a half times higher than that at 100 W. Characteristics of people's capacities also change accordingly. With an increase in load characteristics the working efficiency decreases (Fig. 7 and Fig. 8). To ensure working capacity of a working person it is necessary to make breaks following T_D time. During the experiment it was noticed that making breaks to take rest following T_D time, at least 5 minutes rest was needed in the female groups and in male groups the break lasted for at least 3 minutes.

The analysis shows that the criterion and methods presented enable a histogram of the heart rate and blood pressure to be created individually for every person.

The methods presented can be used when testing sportsmen of high class, and determining the allowable load for patients at treatment institutions.

Conclusions

1. Methods for determining working capacity and the criterion, which enables the highest load and a rest schedule for each individual to be designed, have been established.
2. It has been shown that the heart rate and blood pressure increase with an increase in load and its duration. However, having reached a certain limit they have a tendency to decrease. Therefore there exist points in interdependence of functions, in which derivatives of the functions of the heart rate and blood pressure points are equal to the zero, and the duration of load corresponding to these points shows the reserve of a person's working capacity.
3. It has been established that reaction of the people under 40 in male groups to load is stronger. The heart rate and blood pressure of these people are much higher that that of the males over 41. This can be accounted for by the fact that people of older age are usually more trained.

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