HEART RATE DYNAMICS IN 5.5-YEAR-OLD CHILDREN DURING RELAY RACES

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Original scientific paper
UDC 796.12:611.12-53.4

Abstract:

Fifty-three 5.5-year-old children (25 boys and 28 girls) participated in the research that took place during a 45-minute physical education class. Before the class started, every child's heart rate (HR) in the state of rest had been measured. During the main part of the class, the children participated in relay races, after which the highest values of HR were obtained. On the basis of the results and Karvonen's formula the intensity of effort, ranging from 50% to 100%, was calculated for groups and for individuals. In the state of rest the HR in boys reached 99.28 beats per minute (bpm) (SD 5.08), and in girls - 98.72 bpm (SD 9.11). The highest HR value in boys was 214.24 bpm (SD 8.88), and in girls 213.71 bpm (SD 8.93). Most of the individual results differ from the results of the group, which proves that the HR is an individual feature, and that the levels of intensity of the effort calculated on the basis of HR should not be generalised.

Key words: physical education, heart rate monitors, intensity of effort

HERZFREQUENZDYNAMIK BEI DEN 5,5-JÄHRIGEN KINDERN WÄHREND DES LAUFENS

Zusammenfassung:

Dreiundfünfzig Kinder im Alter von 5,5 Jahren (25 Jungen und 28 Mädchen) nahmen an dieser Untersuchung während einer Schulsportstunde teil. Jedem Kind wurde vor dem Anfang der Stunde das Ruhepuls gemessen. Im Hauptteil der Stunde nahmen die Kinder an einem Staffellaufteil, wobei die höchsten Herzfrequenzen gemessen wurden. Auf Grund der Ergebnisse und der Karvonenschen Formel wurde die Anstrengungsintensität von 50% -100% für die Gruppen, sowie einzelne Kinder ausgerechnet. Bei den Jungen erreichten die Ruhepulswerte 99,28 Schläge pro Minute (SD – 5,08) und bei den Mädchen 98,72 (SD – 9,11). Die höchste beobachtete Herzfrequenz bei den Jungen war 214.24 (SD –8,88) und bei den Mädchen 213,71 Schläge pro Minute (SD – 8,93).

Die meisten individuellen Ergebnisse unterschieden sich von den Gruppenergebnissen - ein Beweis dafür, dass die Herzfrequenz ein individuelles Merkmal sei und dass die Umfänge der Anstrengungsintensität auf Grund der Herzfrequenz nicht verallgemeinert werden sollen.

Schlüsselwörter: Körpererziehung, Herzfrequenz-monitore, Anstrengungsintensität

Introduction

An active involvement in sports since childhood is of great importance. Physical education in kindergartens and schools that stimulates children's interest and involvement in sports can play a major role. It can encourage the children to think about the importance and pleasure of being fit. It also gives the children a chance to know their own motor capabilities, offering professional guidance for developing them. A suitable physical education proramme can help to promote an active, healthy style of living.

Recently, sport among children has attracted even more attention (Wilmore and Costill, 1994). The growing interest for children's competitions and, parallel with that, the need of improved training process elicit a problem of negative physiological and psychological side effects of intensive training (Albinson and Andrew, 1976; Berg and Eriksson, 1980). Here we can mention the doubt whether the children should be allowed to compete in such sports as long distance running and weight lifting (Wilmore and Costill, 1994).

Finding the answers requires an approach from many different points of view. We have to consider the kind of sport, the nature of competitive sport, the rules of competition and the effort required during a competition. Simultaneously, we have to bear in mind children's growth and development that are of crucial importance for effective performance in sports and for an effective realisation of the demands of competitions.

Children are not just miniature adults. A young person is a unique physiological and psychological entity and must be treated differently from an adult (Wilmore and Costill, 1994). Generally, children will adapt quite well to the same type of training routine as may be applied in the case of a mature athlete. Nevertheless, a child's continuous growth and development together with his/her individual physical and psychological differences call for an individualisation, popular in recent years, of an educational process including, of course, sport or physical education, where individual physical differences find the strongest expression (Kelly, 1989; Van Bruggen, 1992; Kramar, 1993). Valuable changes in the educational process can also be achieved by a constant actualisation of the teaching programmes, combining the contents of different subjects, the proper education of professional staff, and last, but not least, by improving the material resources (facilities, equipment). We suggest that training programmes for children and adolescents should be designed specifically for each age group (Karpljuk, 1999), keeping in mind the developmental factors associated with the age (Wilmore and Costill, 1994) and specificity of the work at school.

Growth, development and maturation of the organism are terms that label the steps on the road to adulthood (Wilmore and Costill, 1994). The expression growth denotes the enlargement of the body as a whole and of its separate parts. Development stands for the functional changes of the organism; maturation is a way to the complete functional congruity of the human body (Berg and Eriksson, 1980). In the process of estimation of a child's maturity we have to consider (Wilmore and Costill, 1994): the chronological age, the bone structure age and the stage of sexual maturity. Respecting the aforementioned aspects may help us to understand the physiological basis of children's growth and development that are crucial for planning and performing any training process.

Pre-school children can be involved in sports in several ways. One of them is physical education classes at school. The gym practice exerts an influence not only on motor abilities, but also other dimensions such as education, social behaviour, emotions, cognition, etc. (Videmšek, 1996). The duration of a physical education class or of its separate parts depends on many factors. For younger children, because of their lower ability of concentration than in the case of the older ones, shorter physical education classes are usually prepared. The recommended length of a class varies from one author to another. Rajtmajer (1990), for instance, suggested 25 minutes for 4-5-year-old children. However, practice shows that a physical education class, even in case of younger children, can be much longer than was agreed until recently. Of course, this is possible only under certain conditions, such as the proper sport facilities (equipment, requisites) and the high creativity of a physical educator who should be able to organise a large and interesting choice of physical activities for children.

The term endurance refers to the ability to continue the activity effectively without a decrease in its efficiency. Endurance is the important component of physical fitness mostly because it provides a suitable level of physiological processes in the organism and plays an important role in keeping the satisfactory health condition of an individual (Karpljuk, 1994). The fundamental components of endurance are aerobic power and the cardiovascular system efficiency. The latter can be expressed, among the other ways, by individual heart rate (HR) value.

Children's blood pressure in the state of rest and in submaximal effort is lower than the blood pressure in adults. It increases with age and at the end of adolescence reaches the values similar to those in adults. The blood circulation in an active muscular system in children can be higher than in adults due to their lower peripheral pressure (Bar-Or, 1989). The smaller heart and smaller blood volume in children denote a lower stroke volume. During submaximal effort the heart rate value among children is higher than in adults thus compensating for the lower stroke volume. The compensation, however, is not sufficient because in certain circumstances the heart's efficiency is lower than expected in spite of the higher heart rate value (Willmore and Costill, 1994).

The heart rate value during the maximal effort decreases with age. Ten-year-old children (Rowland, 1985; Willmore and Costill, 1994) have a maximal heart rate value of approximately 210 beats/min, while in 20-year-olds it is approximately 195 beats/min (Willmore and Costill, 1994). During maximal effort, similarly as in submaximal effort, children's smaller hearts and smaller blood volume do not allow the achievement of the biggest stroke volume (Rowland, 1991; Willmore and Costill, 1994). It cannot be compensated for even by the highest heart rate value.

The purpose of the basic functions of respiratory and cardiovascular systems is to respond and suitably adapt to external changes, e.g. changes of training conditions such as a low, moderate or high level of the intensity of effort (Rowland, 1991; Wilmore and Costill, 1994). The increase of respiratory and cardiovascular efficiency denotes also an increase of aerobic capacities and of oxygen uptake (Wilmore and Costill, 1994). Aerobic capacities may increase together with the child's development and by the training process. However, generally speaking, children have a lower aerobic efficiency than adults that is expressed in lower oxygen uptake caused by a smaller heart and smaller blood volume that can not be balanced even by a higher heart rate (Rowland, 1989, 1991; Wilmore and Costill, 1994).

An interesting question is how much children's growth is connected with their aerobic capacities. Wilmore and Costill (1994) report that with age, the aerobic capacities increase until approximately 18 years of age, which is a developmental trend. Afterwards the aerobic capacities decrease if not exercised.

The heart rate changes, during physical activity reveal certain regularities. Typically, the heart rate value increases rapidly at the beginning of the effort. In moderate effort it reaches its plateau in 30 to 60 seconds and remains almost constant until the end of the effort. The heart rate value in this case is proportional to the individual's effort. If the effort is extreme (ten or more times bigger than the basic HR value at rest), then the heart rate value increases until exhaustion. In the first two or three minutes after the beginning of the physical activity the heart rate decreases with the speed resembling the speed of the previous increase. After the initial decrease the heart rate value decreases more slowly with speed related to the intensity and duration of the effort (De Vries, 1976).

In the case of children different levels of effort can be achieved in several ways. During a gym class we can incorporate various contents using different forms and methods of work. Children can also perform the same training with different levels of intensity. An objective feedback about the intensity of an effort during different sport activities can be obtained by monitoring the heart rate value (HR). In practice it can be realised by measuring a child's heart rate by the pulse palpation at the wrist (Nees-Delaval, 1995; Rajtmajer, 1995) and, in an easier and a more exact way, by electronic heart rate monitors (Rajtmajer, 1997; Videmek and Karpljuk 1997; Karpljuk, 1999). The second method becomes even more popular because of its simplicity and the possibility of a direct data analysis by a specially designed computer program.

In the presented research we tried to explore how the body of 5.5-year-old children responds to different levels of effort. Monitoring the heart rate values in the state of rest (HRrest) and during maximal effort (HRmax; relay race) was employed. We tried to analyse the HR changes (dynamics) during maximal effort, as well as any possible differences between the sexes in HRrest, HRmax and HR dynamics.

Methods

Our research was based on the heart rate frequency during physical activity and in the state of rest before activity. The assessment of the load was calculated by Karvonen's formula (Karpljuk, 1996). That way we obtained the data for establishing different levels of effort (Karpljuk, 1994; Uaj, 1996; Karpljuk, 1996 b). As a result we received the maximal heart rate (HRmax), the heart rate in the state of rest (HRrest) and the curve of the heart rate dynamics during physical activity.

During a 45-minute physical education class fifty-three 5.5-year-old children (25 boys and 28 girls) participated in the research that was conducted in a gymnasium for pre-school children at the Faculty of Sport in Ljubljana. Before the lesson started, every child's heart rate value at rest (HRrest) was measured at 7-minute intervals. The children were lying on the floor and not allowed to speak with each other. The distance between the children was at least one metre. During the course of the class the children participated in a 70 sec long (5sec) relay race, which was a basis for assessing the maximal heart rate values (HRmax). The children competed in two mixed groups. In both cases the heart rate values were measured by Polar Vantage NV Heart Rate Monitors (5 sec intervals). New models of Polar heart rate monitors are already coded, which means that not even closeness or the contact between two users can cause any disturbance of the frequency. The data were analysed by computer programms SPSS for Windows (Descriptives, ANOVA - One-Way) and Polar Precision Performance 2.0 for Windows.

Results

Tables 1 and 2 present the basic statistical parameters of the heart rate at rest and during a relay race for boys and girls, respectively. Tables 3 and 4 show a calculation of different levels of the intensity of effort for boys and girls, respectively. Their levels of the intensity of effort were obtained according to Karvonen's formula (after Karpljuk, 1996) on the basis of the heart rate in the state of rest and the maximal heart rate achieved during the relay race. Figure 1 demonstrates the dynamics of HR changes during the relay race, while Table 5 presents the results of a one-way analysis of the variance for differences in HR between boys and girls during their relay race.

Discussion

In the study we tried to analyse the intensity of the effort reached by 5.5-year-old children during their physical education class and, at the same time, to present the possibility of the application of HR monitors in small children's sport. Tables 1 and 2 present the heart rate values in two different conditions. The heart rate values in the state of rest (HRrest) vary from 94 to 108 bpm (mean = 99.28) for boys and from 82 to 106 bpm (mean = 98.72) for girls. For comparison, Horvat and Magajna (1989) report 85 to 105 bpm in the state of rest for 5-6-year-old children; Nees-Delaval (1995) obtained the HRrest of 100 bpm for 4-year-olds. Rajtmajer (1995) estimated approximately 97.3 bpm in the state of rest on the large sample of 6.5-year-old children. In a later study, involving children of the same age, the same author (Rajtmajer, 1997) measured HRrest with the average of 96.4 bpm (99.6 for girls and 93.1 for boys). Videmšek and Karpljuk (1997) report 101 bpm for 5.5-year-old boys and 97 bpm for girls. Also Karpljuk (1999) established 85 bpm in the state of rest on a sample of 565 eleven-year-old children.

In the presented study HRmax values are heart rate results obtained during a relay race (Tables 1, 2, 3, 4). In the case of boys the heart rate values during effort varied from 199 to 231bpm (mean = 214.24) and for girls from 198 to 231 bpm (mean = 213.71).

In both investigated conditions (state of rest and maximal effort) girls obtained somewhat lower results of HR than boys. For comparison in the similar study by Videmšek and Karpljuk (1997), conducted among the children of the same age and in similar

Table 1: Basic statistical parameters of HRrest and HRmax for boys.

HR (beats/min)	Mean	SD	Min	Max	No
HRrest	99.28	5.08	94	108	25
HRmax1	214.24	8.88	199	231	25

Table 2: Basic statistical parameters of HRrest and HRmax for girls.

HR (beats/min)	Mean	SD	Min	Max	No
HRrest	98.72	9.11	82	106	28
HRmax1	213.71	8.93	198	231	28

Table 3: Levels of intensity of effort for boys.

Percent	(n=25) average
50	**157**
60	**168**
70	**180**
80	**191**
90	**203**
100	**214**

Table 4: Levels of intensity of effort for girls.

Percent	(n=28) average
50	**157**
60	**168**
70	**180**
80	**191**
90	**203**
100	**214**

Table 5: Differences in heart rate values between boys and girls during a relay race (one-way analysis of variance).

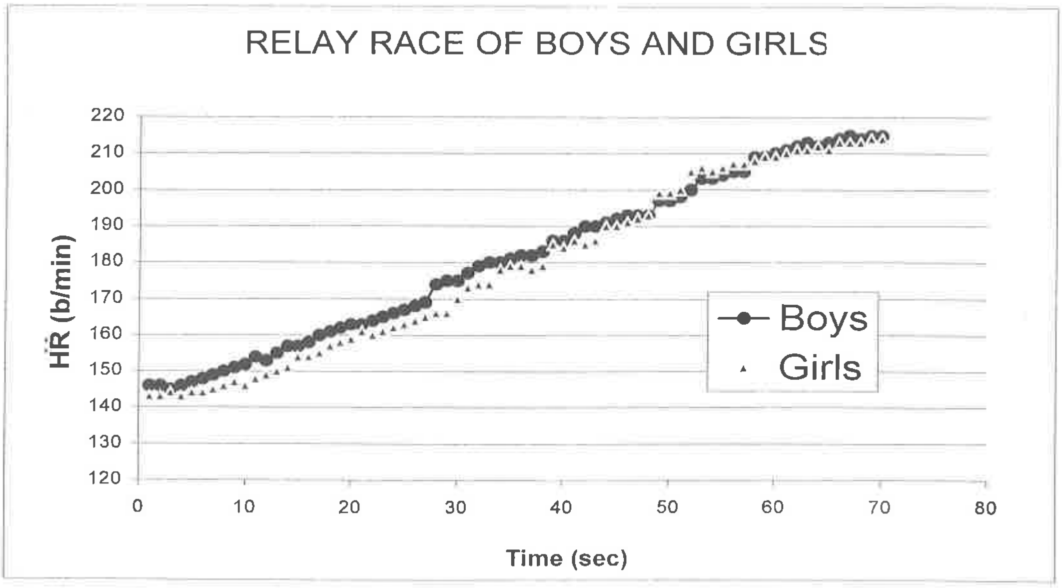
	No.	Mean	SD	SE	Min.	Max.	*p*
Boys	25	180.1538	22.3638	6.2026	146.00	215.00	0.004
Girls	28	178.6923	23.2644	6.4524	143.00	214.00	

conditions, the girls also achieved lower heart rate results than the boys both at rest and during the physical activity: HRrest 96.64 bpm (8.88) and HRmax 211.31 bpm (7.90). In both cases the results undermine the theory (De Vries, 1976) stating that in all conditions females usually have heart rate 5 to 10 heartbeats higher than males. The possible explanation could be that the girls may not reach their maximal heart rate because of insufficient activation of the organism during the effort. Another possibility is that in the case of children of the aforementioned age the rules concerning the heart rate dissimilarities between the sexes are different and demand further study.

Tables 3 and 4 present the estimation of the intensity of effort zones for children (boys and girls separately), which is an example of the practical usage of data gathered by heart rate monitors. The aforementioned values can be used for planning exercise in the physical education process. We suggest (Karpljuk, 1999) a 3-level intensity scale that would include effort at a low, moderate, and high intensity. Preliminary studies showed that even young children, after a few more or less successful attempts, were able to differentiate between fast and slow running at least for a short time. In such cases the children learned the differences more easily when we, as demonstrators, ran together with them.

Figure 1 presents the differences of heart rate values between boys and girls during a 70-second relay race. For the first 50 seconds of the relay race the heart rate value in girls is

Figure 1: Heart rate changes during a relay race for boys and girls (p=0.004).



somewhat lower than in boys; then, during the next 10 sec, it rises and exceeds the average heart rate value for boys. The maximal heart rate values at the end of the relay race were equal for boys and girls. We assume that the girls had probably started their relay race with a somewhat lower intensity, which increased with the course of the race and that could be estimated also on the base of the heart rate curve. Both curves (for boys and girls) reveal that the heart rate value increased in a steady way for the first 60 seconds. Later on (in the next 10 sec) the sharp curve changes into a more moderate one preserving the direction of increase, which was not so intensive any more. We assume that the children's effort was during the last 10 seconds at an extremely high (maximal) level, particularly if considering the fact that just then the children were approaching their goal and were passing the baton to their team-mates. A similar curve of the heart rate value can be obtained from Conconi's test (Åstrand, 1986; Ušaj, 1996) where, for the purpose of the estimation of the anaerobic threshold, we search for a heart rate deflection point (the point where the sharp part of the curve changes to a more moderate one) (Ušaj, 1996). In the case of children involved in our research (5.5-year-olds) the estimation of the anaerobic threshold would not be logical. As the theory says (Ušaj, 1996), most of the children's physiological needs during maximal effort are accomplished by the respiratory system because the enzymes that catalyse the anaerobic energetic processes start to discharge their function only around the age 13.

Observing the children using the Polar monitors during our research we found out that the heart rate monitors proved themselves to be of valuable help for increasing the children's motivation for exercising. In our opinion the wider use of this kind of technology among pre-school children and, especially, among primary and secondary school students could notably increase their motivation for involvement in sport activity at school as well as in their leisure time. Karpljuk (1999), in a study of over 565 eleven-year-old boys and girls, established that the Polar heart rate monitors enable a control of up to 20 children at the same time. In that study the children had determined their own individual limits of the effort and controlled themselves with the help of the Polar monitors during their gym lesson. A sound signal that was activated whenever a child was too little or too much active (i.e. when one was exceeding the estimated zone of the intensity of effort) had the important role. The author (Karpljuk, 1999) found out that the experimental group, which had used the Polar heart rate monitors during all physical education classes had reached statistically better results in the HR adaptation to effort than the control group that did not use the monitors.

Conclusion

The results of the current research, as well as of the earlier studies (Videmšek and Karpljuk, 1997), indicate a different direction of the heart rate discrepancies between the sexes that is known from earlier theories (De Vries, 1976). In all conditions girls appeared to have lower heart rate values than boys. The authors understand that the sample studied was very small and that the obtained results cannot be generalised for a wider population. Nevertheless, the aforementioned divergence between the results and theory may be a stimulation for further explorations.

In our research we also presented the possibility of the application and usefulness of modern technology in physical education for small children. Heart rate monitors do not only allow us to control children's intensity of effort and to reasonably plan the training, but they have also proved themselves as a good aid to increase children's motivation and interest in sports. We hope that in the future heart rate monitors will become a widely spread aid in the teaching process that will help individualise the training practice. The individualisation of training allows us in the best way to utilise the individual's potentials and abilities that can be important particularly for constant development in children. At the same time we have to remember not to over-use professional equipment, especially among pre-school children because their biggest motivation to take part in sports is not a sensible scientific approach, but simply the pleasure of exercising, running, and playing with others.

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