Blaž Jereb*
Damir Karpljuk
Stojan Burnik

HEART RATE RESPONSES TO UPHILL WALKING IN 9-TO 10-YR-OLD BOYS AND GIRLS

FREKVENCA SRCA 9 IN 10-LETNIH DEČKOV IN DEKLIC PRI HOJI NAVKREBER

Abstract

The objective of our study was to analyse the exercise intensity during uphill walking and to find out if there were any differences in heart rate (HR) between boys and girls. For the purpose of the study, a group of seven boys and twelve girls who were not equally physically fit made three mountain walking trips at different pace (directed pace, paces on the aerobic thresholds of the boys in the best and poorest physical condition). The walking trips took place over three weeks, always on the same day of the week, starting at the same hour. HR of the children was measured with Polar Coach measuring devices every fifteen seconds. Before and after the exercise, no differences in HR were found between boys and girls. The results expressed in percentages of individual aerobic threshold show that walking was too hard for some of the children in the group. If the activity continued, it could be damaging or even dangerous for their cardiovascular system. On those children in the group who walked under their aerobic threshold walking didn't have any physiological impact. Consequently, we would recommend that groups of children taken to mountains should be homogeneous.

Key words: mountaineering, heart rate, aerobic threshold, children

Faculty of Sport, University of Ljubljana, Slovenia

* Corresponding author:
Faculty of Sport, University of Ljubljana,
Gortanova 22, SI-1000 Ljubljana, Slovenia
Tel.: +386 (0)1 5207756,
fax: +386 (0)1 5207750
E-mail: blaz.jereb@sp.uni-lj.si

Izvleček

Namen raziskave je bil ugotoviti, kakšna je intenzivnost hoje posameznika med pohodom v gore, pri katerem je skupina sestavljena iz hodcev, ki so različno kondicijsko sposobni, in če obstajajo razlike v frekvenci srca (FS) med dečki in deklicami. V študiji je sodelovalo sedem zdravih, kondicijsko različno sposobnih dečkov in dvanajst deklic, ki so opravili tri pohode v različnih tempih (voden tempo, v aerobnem pragu kondicijsko najslabšega in v aerobnem pragu kondicijsko najboljšega dečka). Pohode so opravili v treh tednih, vselej na isti dan v tednu, s pričetkom ob isti uri. FS je bila spremljana z merilci Polar Coach na vsakih petnajst sekund. Pred in med aktivnostjo med dečki in deklicami ni opaziti razlik v FS. Rezultati odstotkov odstopanja od individualnega aerobnega praga kažejo na to, da je bila za nekatere hoja prenaporna. Če bi takšna aktivnost trajala dalj časa, bi lahko škodljivo ali celo nevarno vplivala na njihov srčno žilni sistem. Na tiste udeležence pohoda, ki so hodili pod svojim aerobnim pragom, hoja ni imela fizioloških učinkov. Na podlagi rezultatov sklepamo, da je smiselno voditi v gore otroke v homogenih skupinah.

Ključne besede: gorništvo, frekvenca srca, aerobni prag, otroci

INTRODUCTION

The starting points for determination of the strain that an organism is put under involve biomechanical, physiological and biochemical methods. Changes in an organism which appear as a consequence of training are usually monitored by measurement of HR, oxygen consumption and the concentration of lactate in blood (Fox, Bowers, & Foss, 1981). On the basis of the mentioned parameters as well as others, such as cardiac output (Collier, 1956), stroke volume and some cardiovascular variables (Sahn, Demaria, Kisslo, & Weyman, 1978), it is possible to adequately describe the state of an organism before, during and after exercise. The majority of the parameters, however, can be obtained only with laboratory tests, which are too expensive or too complicated to be used in general practice. A simple parameter for assessment of exercise intensity is heart rate (HR) (Edwards, 1994). With the accuracy of an ECG, HR can be easily measured with HR measuring devices (Hinson, 1994), during an exercise. Due to its simple use, direct monitoring, quick data transfer to a computer and data processing, the use of these devices in physical education increases (Hinson, 1994). Some authors (e.g. Anderson, & Godfrey, 1971; Bar-Or, Shephard, & Allen, 1971; Godfrey, Davies, Wozniak, & Barnes, 1971; Katsuura, 1986), who monitored HR during submaximal rate of work in boys and girls, conclude that boys have lower HR than girls. In most of these studies the physical characteristics of boys and girls were not significantly different; hence, the reason of lower HR in boys is most likely unrelated to body size. According to literature, these differences can be due to larger heart volume in boys, which has been reported (Shephard at al., 1969; Wirth at al., 1978). Turley and Wilmore (1997) monitored the HR of 7- to 9-year-old boys and girls during four submaximal tests. There weren't any differences in maximal oxygen consumption and physical characteristics between boys and girls, except for a significantly larger left ventricular mass in boys versus girls (78.8 vs. 66.0 g). The trend was for HR to be lower in boys than in girls, but these differences were only significant at 4 miles.h^{-1} (142.9 vs. 155.5 beats/min, respectively).

Mountaineering is a part of physical education at school, requiring from teachers a lot of knowledge and responsibility. It is difficult for them to choose the adequate walking pace, since pupils are not equally pre-trained. The chosen pace could be too brisk (damaging) for someone and too gentle (ineffective) for another. The aerobic threshold calculated according to the Karvonen formula (Karvonen, Kentala, & Mustala, 1957) can serve as a criterion for the intensity of an exercise. Walking with the intensity within the boundaries of aerobic threshold improves general physical fitness: burns out fat, strengthens cardiovascular and respiratory system, builds up muscles, and improves endurance (Edwards, 1994). The aerobic threshold, calculated according to the Karvonen formula, could be taken as a basis for setting the suitable walking pace.

The objective of our study was to monitor HR during uphill walking at different pace levels. We wanted to establish the differences in the response of an organism between boys and girls during uphill walking and to determine suitable walking intensity for each child.

METHOD

Participants

The sample group consisted of seven boys (height: M = 137.3 cm; SD = 3.6 cm, weight: M = 35 kg, SD = 4.1 kg, age: M = 9.5 yrs, SD = 0.6 yrs) and twelve girls (height: M = 141.7 cm, SD = 4.4 cm;

weight: M = 35.8 kg, SD = 6.2 kg; age: M = 9.7 yrs, SD = 0.4 yrs). They were all members of the third class of the Raka Primary School. They were not equally physically fit. They were all healthy, when the measurements were taken.

Procedure

The pupils from our sample group and their parents were acquainted beforehand with the procedure and the purpose of the investigation as well as with the measurement technology. The parents signed their written consent allowing their children to take part in the investigation and the use of obtained data.

In a three-week period, three walking tours at different walking pace were organised. The walking path lead uphill, reaching a height difference of 144 m on a distance of 864 m. Walking was continuous, without any periods of rest. The members of the sample group sat quietly for 5 minutes before they started walking. They all started walking at the same time. During the first walking trip, the sample group was walking at the pace set by their teacher. During the second walking trip, they were walking within the aerobic threshold of the weakest member of the group and, during the third walking trip, within the aerobic threshold of the strongest member of the group. Aerobic threshold was calculated according to the Karvonen formula:

$$70\% * (HR_{max} - HR_m) + HR_m$$

Legend:

HR_{max}	maximal HR
HR_m	morning HR

Maximal HR was measured during a 600-m run one week before the first walking tour. Morning HR was measured by the parents of the sample group members at home before getting up in the morning. The results achieved during a 600-m run were used as a measure for determining the weakest and the strongest member of the group. HR after a 600-m run and during the walking tours was measured with Polar Coach frequency meters. The level of aerobic physical strain was calculated according to the following formula:

$$(HR_{av} / HR_{aer.\ thresh.}) * 100$$

Legend:

HR_{av}	average HR
$HR_{aer.\ thresh}$	aerobic threshold

Percentage of walking intensity was calculated according to the following formula:

$$(HR_{av} / HR_{max.}) * 100$$

Legend:

HR_{av}	average HR
HR_{max}	maximal HR

Basic statistical parameters were calculated for each of the walking tours. The results were later relativised. An independent sample t-test was used to compare the results of boys and girls.

RESULTS

Physical characteristics of the members of our sample group (morning HR, max HR of a 600-m run, individual aerobic threshold and 600-m run time) are presented in Table 1. There were no significant differences between physical characteristics of boys and girls except for their height. The girls were significantly ($p < 0.05$) higher (141.7 vs. 137.3 cm).

Table 1: Basic physical, functional and motoric characteristic of participants

Boys n = 7	Age (yr)	Weight (kg)	Height (cm)	HR_m	HR_{max}-600 m	AER. THRESH.	TIME-600 m
M	9.5	35	137.3 *	67	201	160.9	3.16
SD	0.6	4.1	3.6	8.7	5.1	5.3	0.8
Girls n = 12	Age (yr)	Weight (kg)	Height (cm)	HR_m	HR_{max}-600 m	AER. THRESH.	TIME-600 m
M	9.7	35.8	141.7	66.91	200.6	160.2	3.31
SD	0.4	6.24	4.4	7.5	5.3	5.1	0.6

Legend:

n	*numerus*
HR_{max}-600 m	*maximal HR at a 600-m run (beats/min)*
HR_m	*morning HR (beats/min)*
AER. THRESH	*aerobic threshold (beats/min)*
TIME-600 m	*time at a 600-m run (min)*
*	*$p < 0.05$*

The first walking tour was carried out at a set pace (Table 2). The most distinctive were the results of the weakest boy in the sample group (the poorest result in a 600-m run). He exceeded his aerobic threshold by 18%. The results of two of the boys were within their aerobic thresholds, while the results of four of the boys were below their aerobic thresholds by 7 to 9%. While walking at the set pace, six girls exceeded their aerobic thresholds, two of them by more than 10%. Three girls found the pace acceptable; they were walking within the aerobic threshold. For three girls the pace was too gentle, they walked with the intensity accounting for only 93 to 94% of their aerobic thresholds.

Table 2: Parameters of uphill walking at directed pace.

	I.				
Boys	HR_{max}	HR_{avr}	%int	%at	time
1	215	198	98	118.6	17.00
2	188	162	80	100.6	17.00
3	173	148	73	91.36	16.30
4	176	149	74	93.13	17.00
5	174	155	82	102.67	17.00
6	172	148	72	91.36	15.30
7	170	154	77	93.90	16.30
Mean	181.1	159.1	79.4	99	16.6
SD	16.4	17.6	9	10	0.6
Girls	HR_{max}	HR_{avr}	%int	%at	time
1	174	145	75	92.95	16.00
2	193	177	88	112.74	16.30
3	188	172	86	109.55	16.00
4	213	157	78	98.125	17.00
5	194	165	81	100.61	16.00
6	200	167	81	103.09	17.00
7	202	178	89	109.88	16.00
8	182	153	74	92.73	15.30
9	203	172	88	114.67	15.30
10	179	157	75	94.01	16.30
11	190	169	88	108.33	16.00
12	182	165	84	105.1	15.30
M	191.7	164.8	82.3	103.6	17.5
SD	11.5	10	5.7	7.9	0.6

Legend:

I	*directed pace*
HR_{max}	*maximal HR at the pace (beats/min)*
HR_{avr}	*average HR at the pace (beats/min)*
%int	*percentage of maximal HR (%)*
%at	*percentage of individual aerobic threshold (%)*
time	*walking time (min)*

When the boys from the sample group were walking within the aerobic threshold of the weakest boy (Table 3), they were walking at 5 to 15% under their aerobic thresholds. Walking pace that would suit the weakest boy in the group was not intense enough for all the others to affect their aerobic capacities. One girl exceeded her aerobic threshold (105%). Two girls walked within their aerobic thresholds, while the others were walking below their aerobic threshold (6 to 17%).

Table 3: Parameters of uphill walking at a pace on the aerobic threshold of the weakest boy at the 600-m run.

II.					
Boys	HR_{max}	HR_{avr}	%int	%at	time
1	192	172	84	102.99	23.00
2	170	145	71	90.06	23.00
3	164	143	70	88.27	23.00
4	166	138	69	86.25	23.00
5	162	144	76	96	23.30
6	170	137	67	84.57	23.00
7	172	155	77	94.51	23.00
M	170.9	147.7	73.4	91.8	23.00
SD	10	12.2	5.9	6.4	0.1
Girls	HR_{max}	HR_{avr}	%int	%at	time
1	150	129	67	82.69	23.00
2	183	165	82	105.10	23.30
3	175	152	76	91.57	23.30
4	170	142	71	88.75	23.30
5	169	151	74	92.07	23.00
6	178	152	74	93.83	23.30
7	180	158	79	97.53	23.00
8	178	140	68	84.85	23.30
9	162	141	72	94	23.30
10	168	148	70	88.62	24.00
11	162	144	75	92.31	23.30
12	176	153	78	97.45	23.00
M	170.9	147.9	73.8	92.4	23.3
SD	9.4	9.4	4.5	6	0.3

Legend:

II	*pace on the aerobic threshold of the weakest boy at a 600-m run*
HR_{max}	*maximal HR at the pace (beats/min)*
HR_{avr}	*average HR at the pace (beats/min)*
%int	*percentage of maximal HR (%)*
%at	*% of individual aerobic threshold (%)*
time	*walking time (min)*

When the boys from the sample group were walking within the aerobic threshold of the strongest boy (Table 4), the weakest boy of the group exceeded his aerobic threshold by 16%; one boy exceeded his aerobic threshold by 3% and one by 6%. For those three boys in the sample group the walking pace was too brisk. Other three boys were walking under their aerobic thresholds. Walking within the aerobic threshold of the strongest boy was too fast for five of the girls. They exceeded their aerobic threshold by 6 to 12%. Seven of the girls were walking close to their aerobic thresholds.

Table 4: Parameters of uphill walking at a pace on the aerobic threshold of the strongest boy at the 600-m run.

		III.			
Boys	HR_{max}	HR_{avr}	%int	%at	time
1	213	194	96	116.17	20.00
2	186	160	79	99.38	17.30
3	184	167	82	103.10	14.30
4	185	153	76	95.63	17.30
5	184	160	84	106.7	17.30
6	175	160	78	98.77	14.30
7	172	153	76	93.29	17.00
Mean	185.6	163.9	81.6	101.9	16.8
SD	13.3	14.2	7	7.7	2
Girls	HR_{max}	HR_{avr}	%int	%at	time
1	167	150	78	96.15	14.30
2	189	176	88	112.10	17.3
3	191	176	88	106.02	16.3
4	179	152	76	95	17.3
5	192	169	83	103.05	18.3
6	184	158	77	97.53	19
7	190	177	88	109.26	15
8	194	157	76	95.15	15
9	184	166	85	110.66	16.3
10	188	161	77	96.407	19
11	191	166	86	106.41	18
12	174	162	82	103.18	14.3
Mean	185.3	164.2	82	102.5	16.7
SD	8.2	9.2	5	6.3	1.7

Legend:

III	*pace on the aerobic threshold of the strongest boy at a 600-m run*
HR_{max}	*maximal HR at the pace (beats/min)*
HR_{avr}	*average HR at the pace (beats/min)*
%int	*percentage of maximal HR (%)*
%at	*% of individual aerobic threshold (%)*
time	*walking time (min)*

DISCUSSION

Our study describes HR responses to uphill walking in 9- to 10-year-old boys and girls. It can be clearly seen that the HR of boys as well as girls changed with the change of walking pace. There were no significant differences in HR between boys and girls. The literature on similar topics states a few different results of HR for submaximal exercise. Katsuura (1986) studied a group of boys (mean age 11.2 yrs) and girls (mean age 11.0 yrs) whose physical characteristics and VO_{2max} values were not significantly different. They cycled at 300 and 450 kpm/min. They found that the HR of the boys was significantly lower ($p < 0.05$). In contrast, Bar-Or and colleagues (1971) had 27 boys (mean age 11.6 yrs) and 29 girls (mean age 11.3 yrs) who per-

formed a cycle exercise at different work rates. Physical characteristics of the children were not different, but the boys had significantly ($p < 0.05$) higher VO_{2max} (1.79 vs. 1.43 L/min) than the girls. In addition, they found that the HR of the boys was significantly ($p < 0.05$) lower at 250 and 525 kpm/min, but not at 450 kpm/min. Among 57 boys and 60 girls, aged 6 to 16 years, who cycled at one-third and two-thirds of their maximal working rate, Godfrey et al. (1971) found that the HR of the girls was higher than that of the boys at a given rate of steady-state work. Furthermore, they reported that the boys achieved higher maximal rates than girls. In one of the few studies that used the treadmill as the stimulus to investigate cardiovascular responses to exercise in children, Anderson and Godfrey (1971) exercised 20 boys and 21 girls, 5 to 15 years of age, at two different work rates. They held the treadmill speed constant and varied the slope, so that the lower work rate resulted in a HR of ~150 beats/min and the higher work rate a HR of ~180 beats/min. They reported that the girls had a higher HR. It is important to point out that these reported differences were not analysed statistically. The aim of the last study (Turley, & Wilmore, 1997) was to investigate whether differences exist between boys and girls in submaximal cardiovascular responses to exercises on both the treadmill and cycling ergometer. Twenty-four 7- to 9-year-old children (12 boys and 12 girls) participated in two maximal (one treadmill and one cycle) and four submaximal tests (two treadmills and two cycles). There were no significant differences between the boys and girls in maximal oxygen consumption (L/min or mL/kg min) or physical characteristics, except for a significantly larger left ventricular mass of the boys versus the girls (78.8 vs. 66.0 g). The trend of the HR was to be lower in boys than in girls, but this difference was only significant at 4 miles/h (142.9 vs. 155.5 beats/min, respectively). The mentioned study resembles our study most. In terms of age and other physical characteristics (see Table 1) boys and girls don't differ much. As regards the characteristics of the HR (HR in the morning, HR at rest, HR max) and during a 600-m run (aerobic threshold, the results of the 600-m run; Table 1) no differences can be noticed. After studying the literature and processing the results of our investigation, it can be concluded that some investigators found differences in HR results of boys and girls, while others didn't.

It has to be noted that all investigations involved small sample groups, which can also be the cause of the differences in results. Another cause could be the age. Once they reach the age of 10, boys respond differently to intense exercise than girls (Turley, & Wilmore, 1997). In our study, as in that performed by Turley and Wilmore, no differences between boys and girls could be found. In both studies children were more than two years younger from those participating in the studies that showed that the HR of boys was lower than that of girls (Katsuura, 1986; Bar-Or et al., 1971; Godfrey et al., (1971). Another reason for the differences between boys and girls can be a larger left ventricle in boys (Shephard at al., 1969; Wirth at al., 1978). That causes an increase in SV and, consequently, a drop in HR. Lastly, the differences in HR can be due to the fact that the girls finished some of the difficult exercises prematurely (Bar-Or et al., 1971). In our study, the average HR before and during the exercise shows that there were no significant differences between boys and girls. If we considered only the average results, we could, in this age group, plan a mountain walking trip for boys and girls together.

Individual results, which are an important part of the study, however, show a completely different picture. According to these results the walking trip was too hard for some of the children and might be even damaging for their cardiovascular systems, for they reached anaerobic intensity at some pace levels (Edwards, 1994). By the time they reach puberty, children are but poorly equipped with anaerobic abilities (Willmore, & Clostill, 1994). In cases in which children exercised with high intensity and consequently died, the major causes of death were head injuries, heart diseases and heat stroke (Anderson, 2001). That is a strong reason for avoiding

over-exercising children. There weren't any statistically significant differences between the results in boys and girls. However, as many as eight girls and only three boys exceeded their aerobic threshold while walking at a set pace (see Table 2). Individual differences became even more distinct when they were walking at the pace of the strongest boy (see Table 4). Seven girls and two boys exceeded their aerobic thresholds. On the other hand, many of the children who participated in our study didn't even reach their aerobic thresholds during the walking trips at gentle walking pace (see Tables 3 and 4). The walking intensity that was reached at walking pace of the weakest child resulted in about 70% of the maximum HR. This intensity doesn't have any considerable physiological impacts (Anderson, 2001). We have to keep in mind, however, that the differences between boys and girls appeared also at this pace. All the boys were walking under their aerobic threshold, while two of the girls almost reached their aerobic thresholds and one even exceeded it by 5% (see Table 3). The results of our investigation are in this matter consistent with the results of those authors who also determined the differences in HR between boys and girls.

Mountain walking is very popular among the Slovenians. Public opinion research has shown that it is at the top of the list of recreational activities. Many children, however, dislike endurance sports such as mountain walking. Given the unsuitable pace, we can even support their dislike. Too brisk a pace overburdens the cardiovascular and respiratory system and consequently causes fatigue, even exhaustion, and can as such be damaging for the organism. Walking at a gentle pace, on the other hand, doesn't have the desired physiological effect and most children find such walks boring. In both cases the dislike of mountain walking increases. Consequently we would recommend that groups of people, particularly children, taken to mountain walking should be homogeneous.

REFERENCES

Anderson, O. (2001). Otroci lahko tečejo maraton, ne da bi škodili svojemu zdravju [Children can run marathon without causing damage to their health]. In Penca J. (Ed.), *Vrhunski dosežek* (pp. 10-14). Novo Mesto: Penca in drugi.

Anderson, S.D., & Godfrey, S. (1971). Cardio-respiratory response to treadmill exercise in normal children. *Clinical science*, 40, 433-442.

Bar-Or, O., Shephard, R.J., & Allen C.L. (1971). Cardiac output of 10- to 13-year-old boys and girls during submaximal exercise. *Journal of applied physiology*, 30, 219-223.

Collier, C.R. (1956). Determination of mixed venous CO2 tensions by rebreathing. *Journal of applied physiology*, 9, 25-29.

Edwards, S. (1994). *The heart rate monitor book*. Finland: Polar Electro Oy.

Fox, E., Bowers, R., & Foss. L. (1981). *The Physiological basis of physical education*. Philadelphia: Saunders College.

Godfrey, S., Davies, C.T.M., Wozniak, E., & Barnes., C.A. (1971). Cardio-respiratory responses to exercise in normal children. *Clinical science*, 40, 419-431.

Hinson, C. (1994). Pulse power: A heart rate physiology program for children. *Joperd*, 1, 62-68.

Karvonen, M., Kentala, K., & Mustala, O. (1957). The effects of training heart rate: A longitudinal study. *Annals of Medicine and Experimental Biology Fenn* 35, 307-315.

Katsuura, T. (1986). Influences of age and sex on cardiac output during submaximal exercise. *Annals of physiological anthropology*, 5, 39-57.

Sahn, D.J., Demaria, A. Kisslo, J., & Weyman. A. (1978). The Committee on M-mode standardization of the American Society of Echocardiography: Results of a survey of echocardiographic measurements. *Circulation*, 58, 1072-1083.

Shephard, R.J., Allen, C., Bar-Or, O., Davies, C.T., Degre, S., Hedman, R., Ishii, K., Kaneko, M., LaCour, J.R., Di Pampero, P.E., & Seliger, V. (1969). The working capacity of Toronto schoolchildren. *Canadian medical association journal*, 100, 560-566.

Turley, K.R., & Wilmore, J.H. (1997). Cardiovascular responses to submaximal exercise in 7- to 9-yr-old boys and girls. *Medicine and Science in Sport Exercise*, 29 (6), 824-832.

Willmore, J.H., & Costill, D.L. (1994). Physiology of sport and exercise. Champaign: Human Kinetics.

Wirth, A., Trager, E., Scheele, K., Mayer, D., Diehm, K., Reischle, K., & Weicker, H. (1978). Cardiopulmonary adjustment and metabolic response to maximal and submaximal physical exercise of boys and girls at different stages of maturity. *European journal of applied physiology*, 39, 229-240.

Acknowledgements:

The authors thank Slavka Tomažin for technical assistance and the children for their co-operation.

Received: 28 October 2002 - Accepted: 2 June 2003