INTRODUCTION

One of the most important effects of regular physical training is the adaptation of the cardiovascular system.
The basic importance of the „athlete's heart" is manifested in two fields.
1. One is the public health, as regular physical training has a definitive role in the prevention of some cardiac diseases.
2. The second is the competitive sport, as it has been recognised that endurance performance is basically determined by the cardiac performance.

1. Protective effect of regular physical training against some cardiac diseases, first of all against coronary heart diseases is realised in several ways. The increased pumping activity helps to achieve a more active way of life, the richer coronary network results in a better blood supply of the cardiac muscle, the better relaxation ability brings about a more economic left ventricular function, the lower cardiac frequency at rest and during mild physical or psychic load elicits relatively longer diastolic periods resulting in more favourite activity/rest ratio and in a better coronary circulation.
2. Energy for a long-lasting sports activity is gained by aerobic way, long-term endurance performance depends, therefore, on the aerobic system (carbohydrate and fat stores, oxygen uptake and transport, oxidative enzymes). Many authors declare that, from the possible limiting factors the most important is the cardiovascular system. A high level endurance performance needs an endurance trained heart.

AIMS, QUESTIONS
In my investigation, I tried to find answers for three questions.

1. The higher E/A quotient of physically active persons can be explained by the training bradycardia, or it can be supposed as an independent effect of regular physical exercise?
Attempts to answer the question were made in two ways.

a) Mean E/A quotients of athletes and non-athletes with similar resting heart rates and ages were compared. Comparisons were made in three different age groups: in children and young groups (<19 yr.), in young adult age (19-34 yr.) and in older age (35-65 yr.).
b) E/A quotients were investigated in the dependence of the heart rate, regression equations of passive and active persons were compared with each other. Comparison was performed in five age groups of male persons.

2. My second question referred on the training characteristics of ball-game-players. My main aim was to investigate differences among the cardiac characteristics of the different ball-game-players, a special interest was paid for the ball-game what I played previously, namely for the volleyball.

3. How cardiac data are related to the relative aerobic power, as an index the most indicative to the endurance performance?
First I had determined correlation coefficients between cardiac data and relative aerobic power in a mixed group of young adult males, than calculations were repeated in competitors of different types of sports and in non-athletes.

SUBJECTS AND METHODS

SUBJECTS

1. Subjects in the investigations of the relationship between E/A quotient and heart rate
In the comparison of the mean E/A values data of 646 male (454 athletes and 192 non athletes) and 602 female (384 athletes and 218 non athletes) subjects were analysed. In the comparable groups data were selected so that mean age and heart rate of athletic and non athletic subjects were identical.
A larger number of data was used in the comparison of regression equations (1237 males, 939 physically active and 298 passive subjects).

2. Subjects in the investigations of the echocardiographic data of ball-game-players
In the males data of national water polo and soccer players and lower class water polo, soccer, handball, basketball and volleyball players were evaluated, in the investigation of females data of national water polo and volleyball players, and of lower class water polo, volleyball, handball and basketball players were analysed.

3. Subjects in the comparison of echocardiographic data and relative aerobic power

In this comparison data of 346 male subjects were used (age 18-35 yr., grouping according to their types of sports was: endurance-athletes, ball-game-players, power-and-sprint-event athletes).

ECHOCARDIOGRAPHIC INVESTIGATIONS

Echocardiographic investigations were made by a Dornier AI 4800 type device by a 2.5 MHz transducer, always at rest in the morning hours. Interventricular septum thickness (IVSTd), left ventricular (LV) posterior wall thickness (LVPWTd) and the internal diameter (LVIDd) were detected in 2D-guided M-mode parasternal depictions. End-diastolic LV wall thickness (LVWTd) and muscle mass were calculated: LVWTd=IVSTd+ LVPWTd and LVMM= ($TEDD^3$-EDV) ·1.053, where TEDD is the total LV diameter (LVWTd+LVIDd), EDV is the LV end diastolic volume ($LVIDd^3$) and 1.053 is the specific gravity of the cardiac muscle. Muscular quotient (MQ) is the ratio LVWTd/ LVIDd. LV contractility was determined by the fractional shortening (FR.SHORT.), FR.SHORT. %=100·(LVIDd-LVIDs)/LVIDd, where LVIDs is the LV end-systolic diameter. LV filling was determined by the ratio of the peak velocity measured during the early and late phase (E/A). Stroke volume (SV) was calculated as the difference of EDV and endsystolic volumes (ESV=$LVIDs^3$), SV multiplied by the heart rate gave the cardiac output (CO). Cardiac measures were referred to the body surface area by fractions in which the exponents of the numerator and denominator are identical.

Statistical analysis (Statistica for windows 6.0)
1. Statistical analysis of the data referring to the diastolic function
Mean E/A ratios of subjects with similar age and heart rate were compared by t-test for independent samples.
In the comparison of the regression equations the first step was to examine whether the slope of the regression lines are the same or not: to this end ‘b’ values were compared by t-tests for independent samples. With similar slopes new, common ‘b’ values were calculated and than it was examined whether they are parallel shifted or not.
2. Statistical analysis for the investigation of the ball-game-players
One-way ANOVA analysis was performed to compare mean values of different ball-game-players groups. In case of group differences, post hoc Tukey-test was used establish, between which groups were significant differences.
3. Statistical analysis for the investigation o the relationship between cardiac data and the relative aerobic power
Relationship between the relative aerobic power and the cardiac variables was investigated by the Pearson correlation coefficient. Significant relationship was accepted at $p < 0.05$ level.

RESULTS AND DISCUSSION

1. How the higher E/A quotient of physically active persons can be explained by the training bradycardia, or it can be supposed as an independent effect of regular physical exercise?

Investigation of the E/A with the help of average quotient values of athletic and non-athletic subjects of similar age and heart rate
- In subjects younger than 19 yr. E/A was identical in athletes and non-athletes.
- In the age group between 19 and 34 yr. E/A was nearly similar, significant difference was only seen in the male group with heart rate between 70 and 80 bpm, quotient of the athletic group was higher.
- Above 34 yr. E/A was higher in all athletic groups, difference was significant in all the three heart rate ranges in the males, in the females difference was only significant in the heart rate range between 60 and 70 bpm.

Investigation of the E/A quotient with the help of regression equations
- When E/A quotients were plotted against the heart rate, no difference between regression equations of athletes and non-athletes was seen in the children, young and young adult ages.
- In the age range between 31 and 44 yr. the slope of the regression lines was not different; a significant shift was seen, however between the parallel equations.
- In the oldest age (> 44 yr.), in the group of physically passive subjects no significant relationship was seen between E/A and heart rate, in the active males relationship was only borderline significant ($p<0.1$). E/A quotient of the physically active elderly males was substantially higher in the low heart rate range, difference disappeared, however, above 80 bpm of cardiac frequency.

2. Athletic characteristics of the ball-game players

Male ball-game-players

- Cardiac data of the national players were more characteristic to the athlete's heart than those of non-athletes. Although in most indices water polo players showed more characteristic values than soccer players, there were no significant differences between these two groups. There were, however, some indices (E/A, relative cardiac output) in which data of water polo players differed significantly from those of non-athletes, data of the soccer players did not.
- In most cardiac data, lower class ball-game-players displayed also values different from those of non-athletes: they had lower heart rate, higher relative LV wall thickness and muscle mass. It was only the group of volleyball players, values of which did not differ significantly from those of non-athletes. There were also some differences between the groups of the different ball-games. Cardiac dimensions were the highest in the water polo players, the lowest in the volleyball players. The resting heart rate was the lowest in the soccer, handball and water polo players. E/A quotient was the highest in the basketball players, followed by the volleyball and water polo players.

Female ball-game-players

- Results of the elite players were highly different than those of the non athletic females. Data in the water polo players were more characteristic to the athlete's heart than in the volleyball players: lower heart rate and cardiac output, larger LV wall thickness and muscle mass. LV internal diameter and the E/A quotient were, however higher in the volleyball players.
- Lower class players of all of the ball-games showed larger LV wall thickness and muscle mass and lower heart rate than the non-athletes, it was the LV muscle mass of the volleyball players only where the difference did not reach the significance level. The muscular quotient was higher and the relative cardiac output was lower in all of the ball-game groups, the analysis of variance, however, did not show significant difference between the groups. The E/A quotient was higher only in the volleyball players than in the passive persons.

3. How cardiac data are related to the relative aerobic power, as an index the most indicative to the endurance performance?

In the pooled groups of all athletic and non-athletic subjects, significant relationship was found between the relative aerobic power and several cardiac data (relative LV wall thickness, internal diameter and muscle mass, as well as heart rate and E/A quotient).

In the endurance athletes the significant relationship still existed in almost all of the cardiac data, correlation coefficient of the LV internal diameter only did not reach the significance level. Ball-game-players displayed significant relationship in the relative LV wall thickness, muscle mass and the E/A quotient. In the power-and-sprint-event athletes the E/A and the heart rate only related significantly with the relative aerobic power, in the non-athletes no significant relationship was found.

CONCLUSIONS

1. In the young age (<18 yr.) regular physical training does not elicit an increase of the E/A quotient, if the E/A is higher in an athletic group, it is the consequence of the training bradycardia.
2. In some athletic groups of young adults (endurance athletes, long training carrier, and high performance level) the higher E/A can be caused independently by the regular physical training.
3. In the older age, the physically active way of life results in a higher E/A independently from the heart rate.
4. In females the age-related decrease of the E/A quotient was only manifest in the oldest age group and the beneficial effect of the physically active way of life was also visible only in this age.
5. Among the heart rate ranges, it was the middle range, followed by the low one, in which differences between the E/A of the active and passive groups was the most often manifest.
6. Heart rate must always be taken into consideration when differences in the E/A quotient are evaluated. This can be achieved by a formation of a heart rate adjusted E/A quotient, or by the investigation of the extents of differences or by a determination of regression equations between heart rate and E/A quotients.
7. In the cardiac measures and in the training bradycardia, data of volleyball players were less characteristic to the athlete's heart than those of water polo, handball and basketball players, but data were much better than those of non-athletes. E/A quotient was, however the highest in the basketball players.
8. For the long lasting games, for the longer competitive periods, for the continuous, high intensity training sessions, it seems very probable that the use of a special endurance training program would be necessary for volleyball players.

9. Volleyball appears to be basically suitable to achieve athletic characteristics of the heart.
10. In a common group of athletes and non-athletes most of cardiac indices or data (heart rate, relative LV wall thickness, internal diameter and muscle mass, E/A) significantly correlates with the maximal oxygen uptake.
11. Athletic groups (endurance athletes, ball-game-players, power-and-sprint-event athletes) showed the higher relationship with the relative aerobic power, the higher were the endurance activity in their training and competition program.
12. With the help of the different equations between cardiac indices and relative aerobic power cardiac data and relative aerobic power of the individuals can be evaluated and direct advice can be given referring to their training program.

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