APPLICATION OF NEW METHODS IN DATA ANALYSIS AND INFORMATICS AND THE STUDY OF THE EFFECT OF PHYSICAL EXERCISE ON THE PARAMETERS CHARACTERISING CARDIOVASCULAR REACTIVITY IN BASKETBALL PLAYERS

Doctoral (Ph.D.) thesis

László Rátgéber

Head of the Doctoral School of Health Sciences: Prof. Dr. József Bódis Ph.D., D.Sc.

Programme leader of the Doctoral School of Health Sciences: Dr. Zsófia Verzár

Supervisors: Dr. Attila Cziráki, Prof. Dr. József Bódis Ph.D., D.Sc.

UNIVERSITY OF PÉCS, FACULTY OF HEALTH SCIENCES

DOCTORAL SCHOOL OF HEALTH SCIENCES

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1. INTRODUCTION – AIMS

Application of new methods in data analysis and informatics

There are two solid statistical parameters in basketball: prior to the match both teams have a 50-50% chance to win, and that team will be the winner, which gets less points and throws more than the opponent. Although this basic formula is still valid for one of the most popular sport games in the world, technical development has made it possible to transform almost each element of the game into numbers and to assess the performance of the players and the team as a whole relying on statistical data and algorithms. Scouting the opponents are not only assisted by video recordings, but also can the players' expected movements be predicted and graphically described, more and more sophisticated programmes assist the preparation for a match. For the sake of success, basketball trainers are not only required to follow the latest sport development trends of the game but also should they get familiarised with, and effectively apply, the latest technological devices and programmes assisting training and preparation. In the top basketball teams in Europe, mostly specific professionals working along with the trainers perform the total scouting of the opponents and prepare complex studies for the trainers and players prior to some crucial matches. Effective and modern basketball cannot be imagined without these technological devices.

In the first part of the thesis we aimed to prove the benefit and the method of data mining in basketball by a quantitative analysis. During the study we were interested in finding the answer, which parameters, in what extent have an effect on the outcome of a match, and also if there are any differences in this respect in men and women matches.

The second part of my thesis presents a programme kit, which can give a deeper and a more detailed insight into the tactical steps applied in basketball than a set of statistical numbers. In addition, this tool makes it possible to analyse and create situations, and also to watch back and perform graphical imaging of video recordings.

The most important aims of the first part of the thesis can be summarised as follows:

1. We compared the First senior leagues for men and for women in Serbia during the 2011/2012 season, and from these statistical data, we calculated the influence of certain parameters on a game's outcome.

2. Presentation of the Basketball Coach Board and Modelling Programme.

The study of the effect of physical exercise on the parameters characterising cardiovascular reactivity in basketball players

Non-invasive investigation of the function of the aortic vessels is a widely used method in the adult population in the process of risk estimation regarding individual cardiovascular diseases, as well as in judging the extent of the damage of the target organ. One of the most frequently studied and presented parameters is the aortic stiffness, which can be characterised by the aortic pulse wave velocity, PWV_{ao}. In addition, the total peripheral resistance can be determined, which is described by the aortic augmentation index, Aix_{ao}. Furthermore, the aortic (central) systolic blood pressure, SBP_{ao}, as well as aortic (central) pulse pressure, PPao, can also be calculated. There are more and more publications demonstrating the changes of the function of the aortic vessels in several clinical pictures in children, such as early atherosclerosis, obesity and familiar hypercholesterinaemia. Currently, there have been few studies presented on the values of the aortic vessel function in children and adolescents, who mainly served as controls to the studied groups. Furthermore, the measures were performed by different methods and the data were not balanced regarding the distribution of age, as well as anthropometric phenomena. The third and the fourth parts of the thesis present the measures of the physical parameters, which are also crucial in athletes, the aortic stiffness, i.e. rigidity of the arteries, and the study of vessel reactivity triggered as a response reaction to physical exertion. These investigations were performed by a newly developed, non-invasive device (Arteriográf®, TensioMed Kft., Budapest) operating on the occlusive-oscillometric hypothesis and also validated by an invasive method. The device being small in measure is portable and easy to apply. The method of investigation is fully automatic, user-independent, fast and painless, so it can be performed during trainings at the basketball court.

The main aims of the second part of the thesis, which are discussed in parts 4 and 5 in detail, can be summarised as follows:

1. Determining aortic pulse wave velocity in healthy, normal weight boys aged 3-18 having normal blood pressure and analysing the reference values.

2. Comparing parameters characterising aortic vessel functions at rest in young athletes and young volunteers, who are well balanced regarding age distribution as well as anthropometric phenomena.

3. Investigating the effect of different types of exertion (isometric, dynamic) applied during trainings of young athletes in different age groups (11-16 years of age) on the changes of pulse wave velocity, PWV_{ao} and aortic augmentation index, Aix_{ao}.

2. Comparative Review of Statistical Parameters for Men's and Women's Basketball Leagues in Serbia

In the first part of the thesis, we compared the First senior leagues for men and for women in Serbia during the 2011/2012 season, and from these statistical data, we calculated the influence of certain parameters on a game's outcome.

Modelling was done by using neuron nets. Neuron nets were inspired by the recognition of the complex system of learning within the human brain made up of closely connected units of neurons. The incoming parameters were the following: *p1_percent*, *p2_percent*, *p3_percent*, *def_rebound*, *of_rebound*, *assist*, *steal*, *lost* and *block*. The outcoming parameter was the result.

p1_percent	p2_percent	p3_percent	def_rebound	of_rebound	assist	steal	lost	block	result
0.56	0.57	0.36	22	8	15	12	11	3	win
0.72	0.35	0.42	20	14	9	19	12	4	loss
0.65	0.55	0.20	24	15	13	5	19	1	win
0.73	0.47	0.33	20	6	14	6	25	6	loss
0.84	0.60	0.53	13	4	11	8	13	2	loss
0.65	0.47	0.28	14	8	12	9	12	2	win
0.80	0.49	0.38	24	12	8	13	18	1	loss
...	...	...	...	...	...	...	...	...	...

Due to this fact, the net has nine incoming and one outcoming knots. Apart from this, there is a hidden layer in the net. The used net is a feed-forward neuron net.

Each layer of the net is connected with all the knots in the previous level as well as with all the knots in the following level of the net. The net training is done with the method of the back propagation of errors, which is based on the generalised delta rule. For every syllable brought to the net during the training, the information goes through the net in advance, so that it can anticipate the outcoming layer. This anticipation is compared with the real outcoming value of the given datum, and the difference between the real and the anticipated value is then sent back through the net in order to adjust the heavy factors and to improve the anticipation of the syllables which follow. The point is to prevent the net from saving the input as well as to prevent the wrong result as the other data are modelled. After the net training is done with the input data, we can see how much the final outcome of the game is determined by certain parameters. The validation was performed with the IBM SPSS Statistics Programme.

RESULTS

In the Serbian First basketball league for men, the network correctly predicted 195 outcomes from the 240 total (120 games, in which every team had either to win or lose), which is 81.25% of total number of input data. Therefore, the model failed 45 times to predict the outcome correctly, which is 18.75% of all cases. From the 120 wins documented, the algorithm correctly predicted 99, while for 21 wins, it predicted losses. Regarding losses, the algorithm correctly predicted 96 from the 120 losses, while for 24 losses, it predicted wins. The confidence matrix is shown in Table 8. In the Serbian First "A" basketball league for women, the network correctly predicted 304 from the 362 outcomes or 83.98% of the total number of input data. Therefore, the model did not correctly predict 58 outcomes, which is 16.02% of all outcomes. From the 181 wins documented, the algorithm correctly predicted 144, while for 37 wins, it predicted losses. Regarding losses, the algorithm correctly predicted 160 losses, while for 21 losses, it predicted wins.

The model including the most relevant basketball parameters has a relatively high prediction precision for game outcomes based on the input parameters. More than eighty percent of the input data would correctly predict the outcome of the game.

Table 2

Model precision for the Serbian First basketball league for men

True	195	81.25%
False	45	18.75%
Total	240	

Table 3

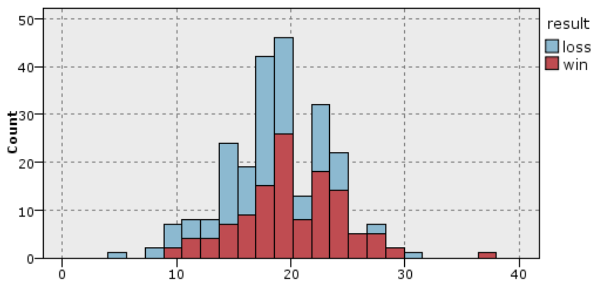
Model precision for the First "A" basketball league for women

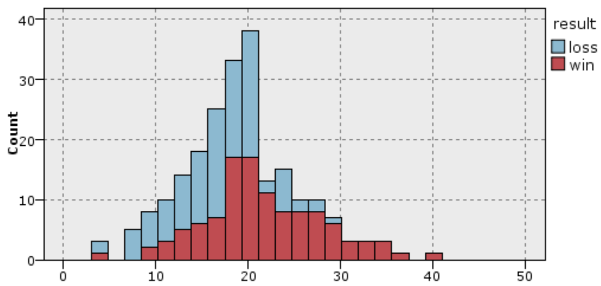
True	181	82.27%
False	39	17.73%
Total	220	

The results obtained by the neural network were confirmed by the C5.0 decision tree.

A prediction correctness of over 80% confirms that the model used was correct. Greater correctness was hindered by the fact that, in keeping basketball statistics, a large number of events were not noted. Programs like BSV are used in real time, during the game, so we have to decide which events are to be documented and which are not. In order to obtain an even more complex knowledge regarding a game and find some new patterns, we need to obtain a richer data set, or apply some software being able to record all relevant events while watching the match back.

Using modelling data from the Serbian First basketball league for men and the Serbian First "A" basketball league for women, we obtained knowledge about the way of playing and the factors influencing the outcome of the game. In both leagues, defensive rebounds have the greatest influence on winning the game.





Graph 1

Effects of defensive rebounds on the outcome of the game in the Serbian First basketball league for men (above) and the Serbian First “A” basketball league for women (below)

Men's basketball is based on a faster game and more shots, so precision and good training are crucially important. Women's basketball pays more attention to defence, so there are other important elements, such as steals and turnovers. In addition to these, it is important to maintain a high level of two-point shots and not to miss "safe shots". In team sports, there are several methods and ways to prepare athletes for competition. The results presented here were obtained from the application of a neuron net to the collected data.

3. BASKET COACH BOARD AND MODELLING PROGRAMME

In team sports there are a number of methods to prepare athletes for competitions. There are physical, technical, tactical, psychological and integral ways of preparations. Each has its own fundamental importance in forming the athletes and the team, which may lead to successful performance and good results. Effective and high quality scouting is unimaginable today without modern information technologies. In static aspect of the system, the Use Case Model and Class Diagram Model were used, and for dynamical aspect the Activity Diagram was used. The Activity Diagram describes a process with its starting point (initial point) for action or activity necessary to describe a job or a function, and its final or end point. By the Activity Diagram, we describe a process, step by step, with all conditions necessary for the next step, all the way to the end point. The Use Case Diagram makes it possible to define the primary elements of a system (participants, user) and the functions performed. In this way, it is possible to form a global picture of a system, which may serve as a basis for realising some further steps in the future. The main advantage of such an application to the drawing board is the possibility to save certain actions, print reports with notes during the presentation to the players, as well as saving actions in a video format allowing to watch them back with various speeds.

Basketball actions are composed of different stages, the drawing and animation of which have their own special methods. While solving animation problems and animate stages, it was necessary to learn how to handle lists of graphic objects, lists of distinct dots, as well as moving objects: speed and delay. Producing better algorithms for checking the lists or establishing new data structures, which could speed up object manipulation, could be potential improvements in this segment. In conclusion, we may say that the application of this modelling programme may be broadened in order to fulfil demands of other team sports, such as soccer, water polo or handball. The Use Case Model, the Class Diagram and the State Diagram, with some changes, may become a pattern for creating specialized modelling programme for these sports.

4. THE STUDY OF THE EFFECT OF PHYSICAL EXERCISE ON THE PARAMETERS CHARACTERISING CARDIOVASCULAR REACTIVITY IN BASKETBALL PLAYERS

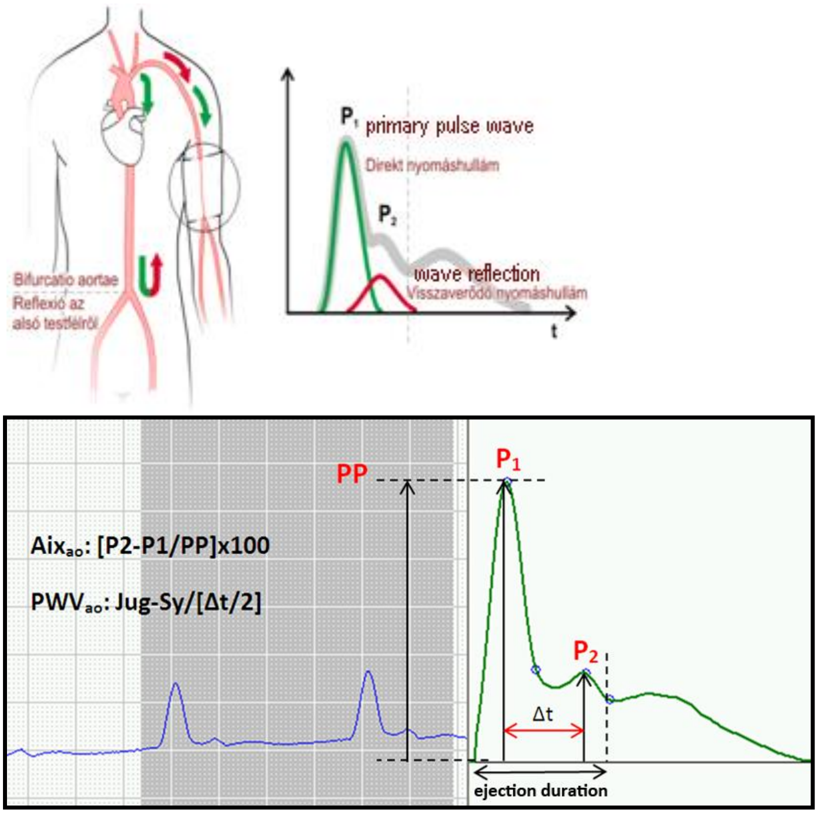
It is well-known that atherosclerosis may develop not only in adulthood but also in a relatively young age. One of the most remarkable studies describing atherosclerosis appearing in an early age is the so-called P-Day Study (Pathological Determinants of Atherosclerosis in Youth). In a prospective study carried out in the past century, in the 80's and in the 90's in the USA, the aorta and the right coronary artery of patients aged 15-34 were investigated and the morphological phenomena of atherosclerosis were recorded. In the order of frequency, the following unexpected disorders were found: fatty streak, fibrous plaque, complicated plaque and calcified plaque. The aortic pulse wave velocity (PWVao) measured invasively in young healthy adults was between -3.9-6.5 m/s depending on which section of the aorta was measured (ascendant, thoracic, abdominal).

Methods

The investigation of the aortic pulse wave velocity (PWVao) and the aortic augmentation index (Aix_{ao}) was performed by using the occlusive-oscillometric method. Practically, the measurement done by an oscillometric device does not differ too much from a standard digital blood pressure measure. The device, following blood pressure measurement, blows up the cuff put on the upper arm to a value, which is at least 35 Hgmm higher than the systolic blood pressure, so the condition of occluding the brachial artery is met. A specific method, the so-called stop-flow, excludes that the pressure curves get distorted. The blood flow seizes only after 8-20 sec.

Statistical methods and analysis

The data were given in the form of average ± SD. The statistical analysis was performed by the Student's paired or unpaired two-sample *t*-tests, a difference was considered significant when $p<0.05$. The percentile values of PWVao were determined by the LMS method assisted by the “LMS Chartmaker” computer programme.



PWV_{ao}= jugulum-symphysis distance /RT/2

Figure 2. Determining the aortic pulse wave velocity (PWVao) and the aortic augmentation index (Aix_{ao}) by the occlusive-oscillometric method

Studying the literature in this field, it can be observed that there are only few PWVao reference data available on youngsters aged 0.2-20. On the one hand, the “healthy population” investigated in these studies was composed of few individuals (hardly 140 people altogether), on the other, it was mainly used as controls. It may also be noted that PWVao values in these studies were partially determined by Doppler-Ultrasound and partially by the applanation tonometry technique. It is well-known that these examination methods demand rather sophisticated laboratory circumstances, they last for a long time and may cause some inconveniences, so they can only be applied in the children population with significant limitations.

One of the main aims of the present study was to determine the PWVao reference values in a remarkably large, healthy population being well balanced regarding age distribution by applying a newly developed non-invasive, easy-to-be-used method operating on the occlusive-oscillometric hypothesis and also validated by an invasive method. 1802 boys were included in the study (average age: 3-18 years). The data resulted from their investigation could be used as reference data in later studies and could be compared to data gained from the investigation of basketball player boys at rest regarding age and anthropometric phenomena.

RESULTS, DISCUSSION

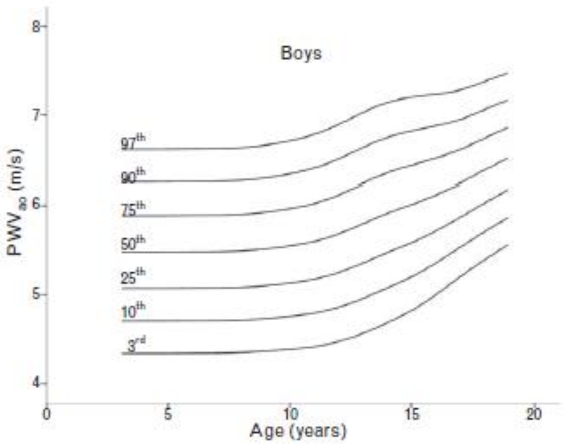


Figure 3.The percentile curves of PWVao (3-97%) regarding age in boys 3-18 years of age

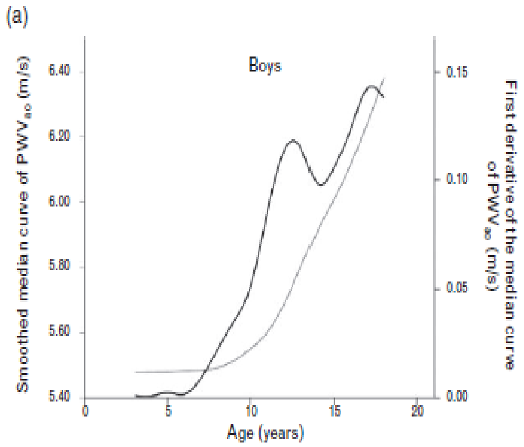


Figure 4. The 50 percentile curve of PWVao (grey line) and its first derivative (black line) regarding age

In the age group 3-18 years, the average PWVao increase was approximately 1 m/s. This value significantly grew in the boys population from 5.5±0.3 m/s to 6.5±0.3 m/s ($p<0.05$). The median (50 percentile) PWVao curve of the boys shows that the PWVao increase by ageing is not stagnant, its dynamics is more complex (Figure 4). The PWVao values do not change considerably between 3-8 years of age, while, after this, there is a remarkably steep climb up in boys.

The first derivative of the 50 percentile curve of PWVao, which shows the speed of dynamic changes, is the first remarkable rising point in the boys population at the age of 12.1 years (Figure 3). We believe that this increase cannot be explained either by the elevation of the periferal arterial blood pressure or the central blood pressure or the pulse rate. We are convinced that this newly recognised phenomenon can mainly be reasoned by the physiological changes characterising the onset of puberty. This hypothesis is supported by the findings presented in the literature, which demonstrated that the structure as well as the biochemical composition of the aorta change even at an early age, which causes that, by aging, the wall of the aorta gradually looses its elasticity, a characteristic feature at birth (61-68).This explains that, between 3-8 years, the constantly rising blood pressure causes a lateral stiffness in the aorta wall, while the pulse wave velocity responsible for the elasticity of the aorta wall does not change. In contrast to this, at the age of 10-12 years or later,the aorta wall is not able to compensate this stiffness in a way as earlier, so the stiffness in the aorta wall will be unavoidable leading to the increase of PWVao values.

The effect of physical exercise on arterial stiffness parameters in healthy young sportsmen

A total of 108 young male subjects (boys) (mean age 14.2 y ±3.4) were enrolled into the study. First, the cardiovascular and aortic stiffness parameters of healthy individuals not having different weight, height and other somatometric parameters were contrasted at rest to the parameters of 58 young sportsmen. Acute exertion investigation was performed on 58 young basketball players of different years of age, Group 1: 11-12 years, Group 2: 13-14 years and Group 3: 15-16 years). Each player was chosen from the “RátgéberAkadémia”. Stiffness parameters were measured at rest and after following isometric (20 sit-ups and 20 push-ups) and dynamic (400 m sprint) exertion.

RESULTS, DISCUSSION

There were no significant differences between the two groups regarding PWV (5.82 ± 0.14 m/s vs. 5.83± 0.12 m/s) and AIXao. During the investigation, the peripheral systolic blood pressure remarkably increased due to dynamic physical exertion, while the diastolic blood pressure decreased or did not change, which is considered as a physiological blood pressure change in sportsmen. The pulse rate change calculated this way is characteristic in individuals doing regular exercises.

	Group 1. (age 11-12)			Group 2. (age 13-14)			Group 3. (age 15-16)		
	Rest	Isometric	Dynamic	Rest	Isometric	Dynamic	**Rest**	**Isometric**	**Dynamic**
Heart rate beat / min	75.3±3.4	72.2±4.1	108.0±4.0*	70.8±2.2	72.7±2.8	97.0±4.5*	56.6±2.2	67.8±3.9	117.4±4.9*
Systolic BP (mmHg)	112.2±3.3	117.0±6.3	141.3±6.3*	121.9±3.5	131.7±3.0	144.1±5.5*	122.9±4.1	127.8±5.8	163.0±4.8*
Diastolic BP (mmHg)	60.7±2.0	59.0±4.2	66.8±3.3	61.9±1.3	63.8±1.7	67.4±2.9	70.2±8.1	58.0±2.3	69.4±2.9

Table 4. Change of sysstolic blood pressure, diastolic blood pressure and heart rate during isometric, dynamic exercise and at rest.

BP: blood pressure. data are presented as mean ± SD

Compared to resting condition and isometric exertion, higher PWVao values were measured following dynamic exertion (Figure 5), which was even more expressed in the elderly group (15-16 years of age group).

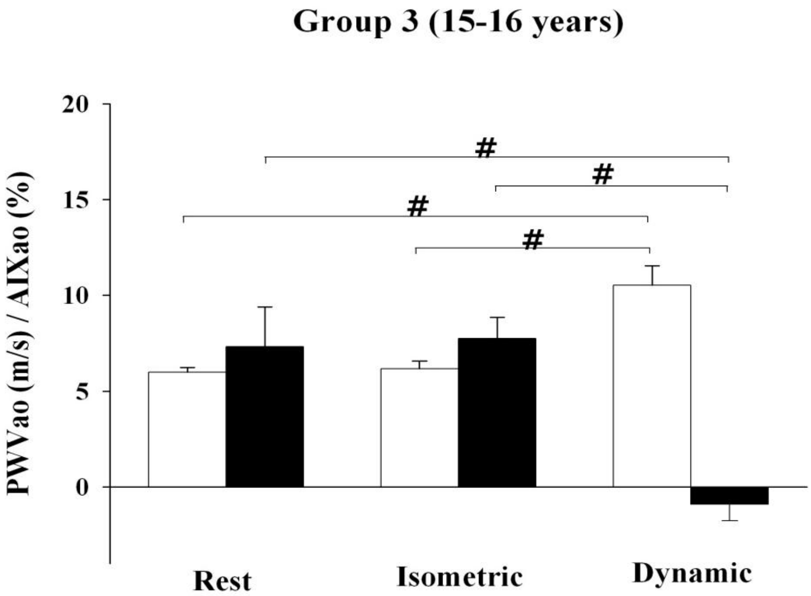


Figure 5. Change of aortic pulse wave velocity (PWVao) and aortic augmentation index (AIXao) at rest as well as following isometric and dynamic exertion in young basketball players (15-16 years of age group) (average + SD. ; # = p< 0.005)

■ = AIxao

□ = PWVao

We believe that pulse wave velocity is not exclusively influenced by physical exertion. This is supported by the findings that in young sportsmen the aorta wall is elastic. On the other hand, it is inevitable that increased systolic blood pressure and heart frequency may have a considerable influence on PWVao, which is indicated by the shorter retur time (RT) i.e. the accelerated velocity of the pulse waves measured on the thoracic and abdominal sections of the aorta.

Augmentation index (AIX) is a complex parameter, the value of which greatly depends on several dynamic parameters, such as pulse wave velocity, left chamber contractions and the resistance of small vessels, i.e. on the peripheral vascular resistance. In adult professional sportsmen, the value of AIXao exceeds the population average. In our study, the AIXao values measured in young sportsmen (5.34± 1.5%) did not show any considerable differences compared to the values measured in the volunteer group of the same average age. On physical exertion, NO released due to the intensifying transversal force decreases the peripheral resistance and the AIXao. In the sportsmen investigated in the present study, considerable decrease of AIXao was observed following dynamic exertion only in the elderly group (doing sports for a longer time) (group 3) (Figure 6).

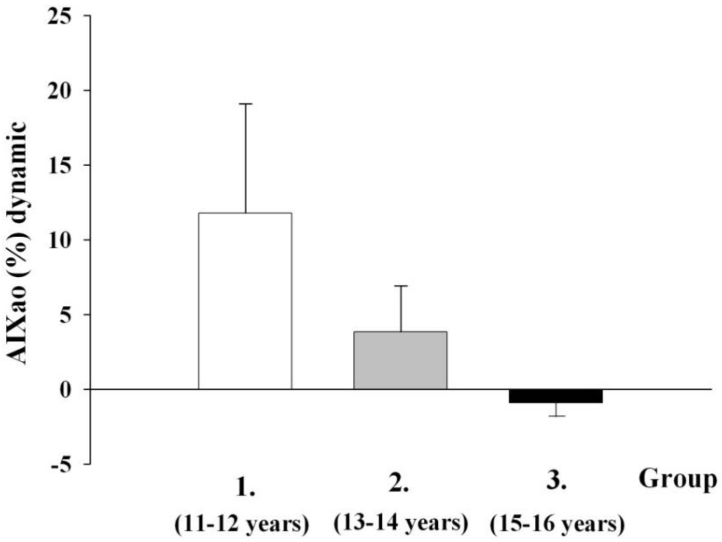


Figure 6. Change of aortic augmentation index (AIXao) due to physical exertion in different groups of young basketball players. Group 1 = 11-12 years; Group 2 = 13-14 yeras; Group 3 = 15-16 years. (average + SD)

In our study, the changes of the arterial stiffness parameters were investigated by an easy-to-be-used measurement technique operating on the oscillometric theory. The precise, simple and fast measurement procedure made it possible to perform the measurements at the court right after the different kinds of exertions. Further investigations are needed to determine the exact influence of short- and long-term trainings on the parameters characterising aortic vessel reactivity, and also to show what consequences can be drawn from these changes regarding the given individual's toughness condition.

NEW RESULTS AND CONCLUSIONS OF THE THESIS

1. Our model based on input parameters, involving the most relevant basketball parameters, has a relatively high prognostic exactitude regarding the outcome of the matches. More than 80% of the input data predicts the outcome of the matches correctly.
2. Certain basketball parameters determine the outcome of women and men matches differently, their measure is also different.
3. By the support of the graphic modelling programme, basketball actions can precisely be modelled making it possible to animate the activities analysed by the trainer.

Performing some changes specific to a given branch of sport, the programme can be extended to other ball games of teams.

4. We were the first to determine the normal PWVao values of a considerably large number of boys (1802) aged 3-20 years on a population screening by oscilometric measurement technique.
5. We compared the arterial stiffness and echocardiographic parameters of boys aged 12-16 years at rest. The boys were composed of healthy volunters and sportsmen with balanced weight, height and age.
6. We demonstrated the changes of the PWV and AIX stiffness parameters due to single, acute static and dynamic physical exertion.
7. We demonstrated that there are significant changes developing as a consequence of acute static and dynamic exertion in the arterial stiffness parameters in different age groups.