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THE EVOLUTION OF THE CENTRE OF CORPORAL MASS (CCM) RELATED TO BODY HEIGHT - POSSIBLE CRITERION OF ORIENTATION OF BEGINNER AND ADVANCED ATHLETES TOWARDS THE HURDLES EVENT

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Abstract
The current study is mostly addressed to athletics teachers/ coaches who deal with the selection and training of athletes for hurdle events. The research aims to develop a certain aspect of beginner and advanced athletes training for professional athletics, particularising on permanent selection, within the orientation stage to short distance hurdles. Our brief presentation intends to develop particular aspects, less approached in the literature of this field, that of sportive selection for hurdles in children and juniors. Some of them may describe aspects of a narrow field of investigation, consisting in supportive arguments based on good practice experiences of athletics teachers/coaches, expectantly useful in professional athletics.
Key words: centre of corporal mass, constitutional morphotype, selection screening

Introduction

One of the most important issues in the process of screening future athletes is to anticipate physical constitution of tomorrow's teenager by looking at today's child. Yet, this anticipative image has no precise instruments of prediction. We often speak about the "eye" of the coach that mentally accelerates the evolution of the child in front of him. Some of the trainers are really able to predict that, based on a heavy professional experience, as well as on a specialised documentation within this field.

Large numbers of studies reveal the fact that there are no correlations that could demonstrate that an athlete with remarkable results at an early age will definitely perform as a senior athlete. As a trainer, I have often come up against situations when young athletes, mostly girls of 10-12 years old had won national championships at *children level I and II* categories. As they grew older, those tiny girls, powerful, very fast, robust, resistant and coordinated, became more and more heavy and massive, no longer able to catch up with the training exigencies. So called athletic "champions-to be" were disappearing from the running tracks, without even reaching the *junior II level* of age category (15-16 years old).

"Why is that happening?"- was the question we have asked ourselves over many years. Often, we thought training was not appropriate. The answer came out finally from the way of setting out <u>screening criteria</u> in the process of initial selection.

Content

Each branch of sport has its own ideal constitutional morphotype which is strongly related to a particular sportive field requirement. Athletics, for example requires motric criteria within the initial selection (screening stage). The most posturographists related the relationship between the position of the center of pressure and the position of the center of gravity, Gagey, Pierre-Marie, Bizzo Guy (2001). Bejan, A., Jones, E., Charles, J. (2010) pointed out that the position of the center of mass of the body makes the difference in speed records (e.g. athletes with longer legs and a higher center of mass are advantaged). These criteria point out the current motric qualities through a series of control tests of individuals, with the result of an individual score that enables ranking. The following motric qualities are assessed:

- <u>Speed</u>, i.e., running speed measured over 50 metres starting from standing position;
- <u>High jump</u> (explosive force) of the lower limbs, measured with la long jump without impetus;
- <u>Arm strength</u> and coordination elements of this level, measured with a shot put, without impetus; also, another test would be that of maintaining a suspended position with arms bent over at 90 degrees;
- <u>Abdominal strength:</u> timed pull-ups (30 seconds);
- <u>General skill:</u> a timed relay race;
- <u>General endurance</u>, measured by a 600 metres running test.

Up to a point, everything seems to work out well. But only up to a point which then becomes a "critical point", from which the assessment of the constitutional morphotype starts, as well as of the psycho type, then of the somatic type, physiotype, etc. For this new set of criteria, called "complex-factor" (with a determinative significant power, up to that of contributing factor), there is no "control testing" or standardised marks of ranking. We must underline that girls are mostly discussed here. Most of them, apparently thin, get higher results than boys of the same age group. This is the so called "trap" in which most of the coaches usually fall. Because of their short experience, they tend not to consider much of the important evidence, such as the following ones, called by us "screening tips", Neagu, N. (2010):

- Somatometric and anthropometric screening – somatometric assessment (height, weight, length of the limbs, length of the bust, perimeters, diameters, dynamometrics, centre of the corporal mass position, etc, as well as the correlations between them);
- Somatoscopic screening – somatoscopic assessment (vicious spine positions or lower limbs – *valgum* or *varrus* knee, flat foot, etc);
- Genotypic screening – constitutional genotypic assessment (morphotype) of the genitors;
- Puberty / sexual screening – the level of sexual development: evolution tendency of the secondary sexual characteristics at the pre-puberty and puberty age (the ratio between biological and chronological age);
- Anamnetic screening – investigation and assessment of clinical anamnesis;
- Functional screening – investigation of certain body functions, followed by minor medical evaluations (an ECG is compulsory), allergy tests, etc;
- Muscular screening – evaluation of the muscular fibres typology;
- Psychological screening – standardised tests are used here, such as for:
    - The level of attention (concentrated, distributed, discriminatory, etc)
    - The level of multiple intelligences – mostly those with a certain significance on high performance sports: spatial-visual intelligence, musical-rhythmic intelligence, corporal-kinaesthetic intelligence, interpersonal and intrapersonal intelligence;
    - The level of emotional intelligence;
    - A certain temperamental typology;
    - The affective-emotional typology;
    - The moral-volitional typology.
- Psychomotric screening such as for:
    - The level of psychomotric development (corporal scheme, laterality, coordinative capacity);
    - The sensorial perceptive and motric level;
    - The corporal and its segments kinaesthesia.
- Suggestional screening – investigation of the level of motric suggestibility.

We have therefore found that underlining the complexity of all aspects connected to the high performance sports selection is well based on facts. Obviously, there are certain steps to be followed, depending then on the trainer, who has to set priorities in a right chronological order. We also emphasise here the importance of this set of criteria, compulsory to be fully or partially assessed by the professional athletes-to be.

Related to the above mentioned criteria, we refer now to a personal longitudinal research study that I have elaborated and experimented during my professional activity. The starting point was the idea that hurdles runners should have an optimal constitutional shape, connected to the technical requirements of this certain athletic event.

Briefly, it is about designing somatic evaluation grids, so called somatic patterns, in which the hurdles runner should fit perfectly. We have experimented this study for over 15 years. As a result of this research, Table 1 shows the evaluation grids on certain stages. In relation to the hurdles techniques assimilation, we have considered the following parameters as suitable for the designed patterns:

- Body height (BH);
- Body weight (W);
- Length of the lower limb (LLL)
- Position and evolution of the height of the centre of corporal mass (CCM)

Within the permanent selection, approximately 200 girls were investigated. Based on individual somatometric files we have observed them over 5-6 years.

We have chosen the above parameters, due to the fact that the first signs of puberty lowered the sportive efficiency of the girls. Very few of them moved on without negative influences on their achievements.

Because, at present, the possibilities of a biomechanical study are utterly limited, oftentimes the appreciation of a technical execution has a deep objective characteristic, but obviously a limited one. In the case of hurdles, the constitutional particularities of the sportsperson, in correlation with the space and time particularities and the technicality of their movements, will constitute an assembly of factors that influence performance.

Among these particularities can be found those connected to the height of the centre of corporal mass (CCM), the point where the sum of all moments equals zero, Ackland, R. T., Elliot, C. B., Bloomfield, J.(2009). A part of the relationships that can be established between CCM and the other elements which take part in the achievement of high level performance:

- the position of CCM in connection with the height of the sportsperson;
- the position of CCM opposed to the height of the hurdle;
- the length of the lower limb (LLL) and its ratio with the height of the body;
- the amplitude of the trajectory of the vertical oscillations of CCM while jumping over the hurdle in relation to their amplitude while running in between the hurdles;

- their interrelationship in the context of dynamic features of the execution: speed and acceleration, rhythm and tempo, technicality.

The study of the segmentary lengths of the body and the relationships between them, correlated with the interactions that arise during the hurdles run, becomes a necessity if we intend to shape authentic performers for this sport event. If we only focus on partial guide marks (for example: focusing on the evolution of the height and weight), we will only obtain partial results throughout the training process. That is why an objective approach of the distribution of segmentary partial weights is utterly important (hindquarters/ backquarters) through the evolution of the position of the CCM (over the process of growth and ontogenetic development of the sportswomen). If we ignore the interdependence between these factors in the somato-functional development of the body, some early promising results will not necessarily have the expected results and we will have to realise where we failed with the training process, whereas the cause lies in the ignorance of some aspects of somatic evolution.

Gravity acts upon the body in the way of cumulated forces, on a vertical plane, having the running track as direction. The vector resulting from their cumulation acts upon a point of the body, called the centre of corporal mass, which is generally found at the intersection of medio-frontal, medio-sagittal and medio-transversal planes.

The centre of the corporal mass (CCM) can be defined as the point upon which a resultant of the lines of gravity acts. This is a conducted and oriented force, so it is a vector and can be described mathematically. Since gravity is defined according to acceleration "g" (9.81 m/s^2) and results from the action of the gravitational forces "F" on the mass of the body "M", it means that

$$g = \frac{F}{M} \quad \text{thus } M = \frac{F}{G} \text{ and } F = Mg.$$

For symmetrical bodies that have a uniform density, the gravitational centre superposes upon its geometrical centre. Since the human body is asymmetrical and the different segments have various densities, CCM will not coincide with the geometrical centre.

The different positions the human body can take, in our case the one of the hurdles runner, supposes the continuous modification of the position of the point in which the resultant of the lines of gravitational forces is applied. Thus, the CCM of the body does not have a fixed position, but it varies from person to person, from one body posture to another, from one sequence of movement to another. CCM moves in the same direction as the movements of the body. It can go upwards, whenever we lift the upper or lower limbs, and it goes down whenever the limbs come back to the normal position. Due to these multiple variations of CCM its localisation cannot be established but for one determined position of the body: orthostatism, sitting, hanging, clinostatism, etc.

In the case of hurdles, when the body of the athlete is in motion, the trajectory of CCM defines or does not define the efficiency of the movements the athlete performs. The totality of these movements leads to a movement of the CCM on the optimal trajectory which facilitates the obtaining of the best sporting achievements. The trajectory of CCM gives us data on particularities of the body (implicitly and the technicality of the movements) as a whole, as well as on the movement of its segments (lower limbs, upper limbs, etc).

Meanwhile, the vertical oscillations of CCM while running hurdles are more accentuated in the moment of the jump across the hurdle, and are higher, respectively. One of the objectives that has to be followed in the process of motric learning of the jump across the hurdle, is that, through its technical execution of this motric structure, the vertical oscillation is as low and precise as possible, it is close to the oscillations of the CCM while running in between the hurdles.

The lone interior forces cannot modify the position and movement in space of the CCM, but only the centres of weight of the segments of the body (limbs, trunk). The movement of the CCM is possible only when external forces act upon it, for instance the forces of reaction to the completion of impulsive movements of the legs while running or while jumping across the hurdle.

If the resultant vector of these forces is directed towards the centre of corporal mass, it will imprint on the whole body a movement of translation towards a direction and way, opposed to the action of the impulse of the legs, towards the finishing line, respectively. If the resultant force does not go precisely through the centre of weight, but through its vicinity (higher or lower), it imprints the body (the entire morphodynamic system) a movements of rotation or overturning.

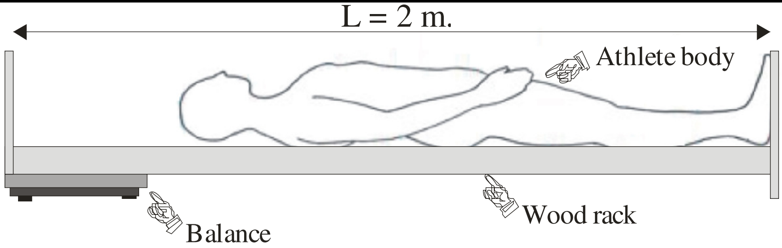
The direction or sense of overturning will be ahead and downwards, if the resultant acts above the CCM, and ahead and upwards if it acts under the CCM, respectively. There can be other situations, especially during bodily dexation during the jump over the hurdle, when the cumulated external forces act laterally from the point of CCM, imprinting over the body of the runner movements of torsion towards the right or the left, or in directions combined with those described above. All these will have negative effects on the final result. This matter will be closely examined later. But our aim was to describe the importance of biomechanical approaches in the analysis of the technicality of the hurdles event, with reference to the ideal constitutional morphotype for this complex event,

starting from the premise that a higher position of the CCM constitutes a favouring factor in the hurdles event.
Consequently, we measured the position of the CCM in different moments, over several years. The technique of measurement was the indirect method, using the following equipment (Figure 1):

- balance; wooden rack with a length of 2 metres and a weight of 10 kilograms; centimetric measuring tape.

We used the following formula for determining the position of the CCM: $\mathbf{H_{(CMC)}} = \dfrac{\mathbf{GP–GT}}{\mathbf{G}} \mathbf{\ x\ 2}$, where:
H $_{(CCM)}$ **=** the height of the centre of corporal mass, $\mathbf{G_P}$ = the partial weight of the body of the sportsperson, lying on the rack with the soles placed on the distal end of the stretcher, **G** = the weight of the sportsperson, $\mathbf{C_T}$ = the weight of the rack.

Figure 1. The indirect determining of the position of CCM



We used this method because according to Palmer (2005), the level of CCM is positioned invariably at approximately 56.5% of the height, regardless of the constitutional particularities of the sportsperson, which introduces an invariable coefficient (0.057) in the formula, thus:

CMC = height x 0.057 + 1.4 (measurement in centimetres)

This seems to be a limited interpretation, because it does not take into account the distribution partial weights and the relationship between the lengths of the segments. Each athlete constitutes an individuality, that is why a global approach is inefficient, if not mistaken.
Thus, we started from some premises – hypotheses:

a) we have no objective reason to state that the curve of the evolution of body height is necessarily parallel to the CCM, during the growth and development of the body.
b) the development of the body does not necessarily happen on the basis of proportional evolution of the partial weights and the length of its segments;
c) the distribution of muscular mass and of the adipose tissue is not uniform and identical for several individuals.

These premises allowed us to reason that there can be at least three different situations of the evolution of these ratios:

a) an evolution proportional to the parameters involved;
b) a stagnation or regress of the position of the centre of corporal mass (CCM), paralleled with the growth of body height (BH) and the length of the lower limb (LLL) on the basis of accentuated accumulation of muscular and adipose mass (especially in girls), on the level of the pelvis and hips;
c) an accentuated growth of the height of CCM, on the basis of the growth of body height (BH), due to the growth in length of the hindquarters or to accentuated accumulation of muscular or adipose mass in the area of backquarters.

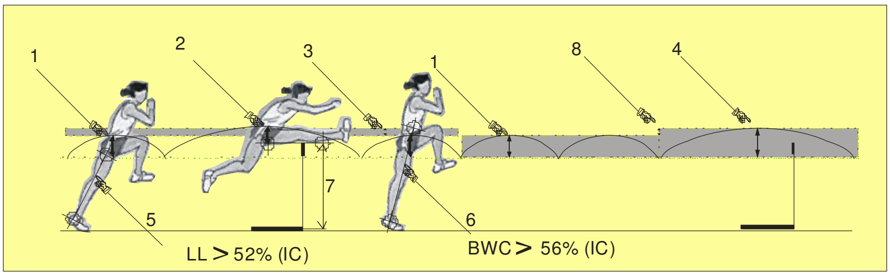
During the research, new elements have come to light, elements that had not been in our focus initially. By this we mean the surveillance of the percentage ratio between weight and height, recorded at different moments:

a) before the beginning of the menstrual cycle;
b) at the beginning of the menstrual cycle;
c) after approximately one year from the beginning of the menstrual cycle;
d) after two years;
e) after more than two years from the beginning of the menstrual cycle.

The measurements and the correlations between the parameters allowed us to establish some approximate (constitutional morphotypes) stadial somatic models, that we considered optimal for the hurdles event, with the aid of which we can thus compare the comprising (or not) into a chart, of a future hurdles athlete, starting from prepuberty or puberty age. Thus we can foresee the constitutional profile of the future hurdles runner, adequately directing the selection and training, having a reliable reference and more consistent elements regarding the evolution of the athlete. Knowing in due time the differences in regard to these models, we are able to predict the age of maximum efficiency or the age of risk.
The chart in Figure 1 resulted from the analysis of the results. We applied it and noticed that it is a useful tool in the selection process, but also in the prevention of some unreal predictions in the constitutional evolution of the hurdles runner. We started from the hypothesis that a higher position of the CCM constitutes a favouring element in the hurdles event, because it determines a diminution

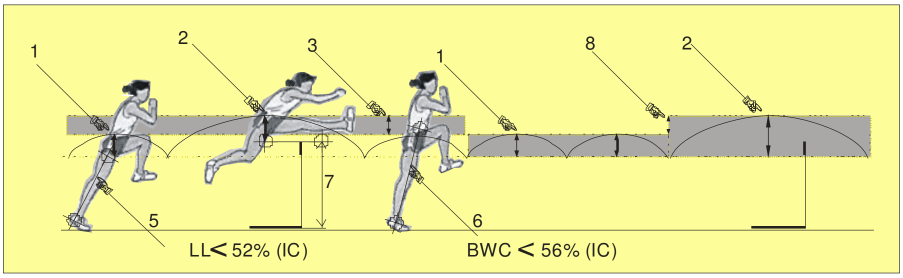
of the amplitude of the vertical oscillations of the CCM while jumping across the hurdle and its bringing closer to the level of vertical oscillations of the CCM during a sprint event on a plane level, and also of the running in between the hurdles. The positioning of the CCM at an optimal level of 56-57%, or even at 57-58% from the body height determines the above mentioned details (see Figures 2 and 3)

Figure 2. The low level of vertical oscillations of the CCM, morphotype included in the chart



1. vertical oscillations of the CCM while running between the hurdles; **2.** vertical oscillations of the CCM while jumping across the hurdle; **3.** the difference in amplitude between the two moments; **4.** the amplitude of the oscillation of CCM over the hurdle; **5.** the length of the lower limb (LLL); **6**. the height of the position of the CCM; **7.** the height of the hurdle (HH); **8.** the difference between the amplitudes of the oscillations of CCM during the running between the hurdles and the jump over the hurdle.

Figure 3. The high level of vertical oscillations of the CCM – morphotype which cannot be included in the graph



1. vertical oscillations of the CCM while running between the hurdles; **2.** vertical oscillations of the CCM while jumping across the hurdle; **3.** the difference in amplitude between the two moments; **4.** the amplitude of the oscillation of CCM over the hurdle; **5.** the length of the lower limb (LLL); **6**. the height of the position of the CCM; **7.** the height of the hurdle (HH); **8.** the high difference between the amplitudes of the oscillations of CCM during the running between the hurdles and the jump over the hurdle.

Below is the description of a tool, still in the stage of prototype, which will allow precise measurements of the CCM in clinostatism which is in its final stage of development. We intend to register this tool with OSIM, being an invention in the field. See Figure 4.

Figure 4. Tool for the measurement of CCM in clinostatism (prototype)

Table 1. Correlative stadial somatic morphotypes – girls trained for short distance hurdles, Neagu, N. (2010).

BODY HEIGHT (BH) (cm)	STAGES														
	I			II			III			IV			V		
	PREPUBERTY MORPHOTYPE W/BH=24% CCM/BH =58% LLL/BH=53% (tolerance ≈ ± 1-1,5%)			**MORPHOTYPE AT THE BEGINNING OF THE MENSTRUAL CYCLE** W/BH=26% CCM/BH =58% LLL/BH=53% (tolerance ≈ ± 1-1,5%)			**MORPHOTYPE AFTER ONE YEAR FROM THE BEGINNING OF THE MENSTRUAL CYCLE** W/BH =28%±1% MENSTRUAL CCM / BH =57% LLL/BH=52% (tolerance ≈ ± 1-1,5%)			**MORPHOTYPE AFTER TWO YEARS FROM THE BEGINNING OF THE MENSTRUAL CYCLE** W/BH =31%±1% MENSTRUAL CCM / BH =57% LLL/ BH =53% (tolerance ≈ ± 1-1,5%)			**MORPHOTYPE AFTER MORE THAN TWO YEARS FROM THE BEGINNING OF THE MENSTRUAL** W/BH =34%±1% MENSTRUAL CCM / BH =56,5% LLL/ BH =53% (tolerance ≈ ± 1-1,5%)		
	W (kg)	(CCM) (cm)	LLL (cm)	W (kg)	(CCM) (cm)	LLL (cm)	W (kg)	(CCM) (cm)	LLL (cm)	W (kg)	(CCM) (cm)	LLL (cm)	W (kg)	(CCM) (cm)	LLL (cm)
140	33.60	81.20	74.20	36.40	81.20	74.20									
142	34.08	82.36	75.26	36.92	82.36	75.26									
144	34.56	83.52	76.32	37.44	83.52	76.32									
146	35.04	84.68	77.38	37.96	84.68	77.38									
148	35.52	85.84	78.44	38.48	85.84	78.44									
150	36.00	87.00	79.50	39.00	87.00	79.50	42.00	86.25	77.40						
152	36.48	88.16	80.56	39.52	88.16	80.56	42.56	87.40	78.43						
154	36.96	89.32	81.62	40.04	89.32	81.62	43.12	88.55	79.46						
156	37.44	90.48	82.68	40.56	90.48	82.68	43.68	89.70	80.50	48.36	88.92	82.68			
158	37.92	91.64	83.74	41.08	91.64	83.74	44.24	90.85	81.53	48.98	90.06	83.74			
160	38.40	92.80	84.80	41.60	92.80	84.80	44.80	92.00	82.56	49.60	91.20	84.80	54.40	90.40	84.80
162	38.88	93.96	85.86	42.12	93.96	85.86	45.36	93.15	83.59	50.22	92.34	85.86	55.08	91.53	85.86
164	39.36	95.12	86.92	42.64	95.12	86.92	45.92	94.30	84.62	50.84	93.48	86.92	55.76	92.66	86.92
166	39.84	96.28	87.98	43.16	96.28	87.98	46.48	95.45	85.66	51.46	94.62	87.98	56.44	93.79	87.98
168	40.32	97.44	89.04	43.68	97.44	89.04	47.04	96.60	86.69	52.08	95.76	89.04	57.12	94.92	89.04
170	40.80	98.60	90.10	44.20	98.60	90.10	47.60	97.75	87.72	52.70	96.90	90.10	57.80	96.05	90.10
172							48.16	98.90	88.75	53.32	98.04	91.16	58.48	97.18	91.16
174							48.72	100.05	89.78	53.94	99.18	92.22	59.16	98.31	92.22
176							49.28	101.20	90.82	54.56	100.32	93.28	59.84	99.44	93.28
178										55.18	101.46	94.34	60.52	100.57	94.34
180										55.80	102.60	95.40	61.20	101.70	95.40

BH body height; **W** body weight; **CCM** the height of the centre of corporal mass; **LLL** the length of the lower limb.

For a better understanding, the usage method of this table will be explained below.

Cased study 1: Let us take for example the case of a 10 year-old girl, B.D. She has a height of 1.50 metres. Following the table we will notice that she should have a weight of 36 kilograms in order to have an ideal ratio between height and weight, that is 24% (with a tolerance of ± 1%) at this stage. Also, she should have the CCM situated at 87 cm from the ground and a length of the lower limb (LLL) of 79.5 centimetres. The girl, after the anthropometric measurements had 35.5 kilograms (with a ratio of 23.66% W/BH), but her CCM was 24.8%. In conclusion B.D. corresponds, from a constitutional point of view, to the hurdles event. If these values had been higher, she would have encountered problems that would have perturbed the training process, regardless of some acceptable motric qualities. See figure 9 and Figure 2 with the personal somatometric file.

Case study 2: Let us take the example of T.R. a 9 year-old girl. During the initial selection process, she has a height of 1.42 metres. The girl, after the anthropometric measurements had 31 kilograms (with a ratio of 21.8% W/BH), the level of CCM was 57.7%. Three years later of evolution according to the table, after approximately one and a half year from the beginning of the menstrual cycle, on the basis of a relatively balanced growth of the other parameters, the level of CCM drops to 58.5% at the age of 12 until 56.9 % at the age of 13.5. In conclusion T.R. does not constitutionally correspond to the hurdles event. At the age of 15 she abandons professional athletics, not being able to cope with the demands of the training. See figure 3 with the personal somatometric file.

Conclusion

Based on the recorded result and their analysis we can notice the following:

a) the evolution of the height of CCM shows particular differences for each individual, exemplifications in two different typical cases, presented in Figures 5 and 6;
b) the middle level we found for CCM is of approximately 57% of the height;
c) the middle level of the LLL/H ratio is about 53-54%;
d) the middle level of the W/H percentage is:
   I. prepuberty stage, 24% 1-1.5%
   II. puberty stage, 26% ± 1-1.5%

III. stage at the beginning of the menstrual cycle, 28 %±1-1.5%

IV. stage after 1 year from the beginning of the menstrual cycle 31 % ± 1-1.5%

V. stage after two years and after more than two years from the beginning of the menstrual cycle + 34 % ± 1-1.5%

According to the results we can come to a number of conclusions and recommendations:

a) the hypothesis is confirmed also through the point of view of the results of the athletes in time;
b) a distorted evolution of the recorded parameters is correlates with the lowering of the sporting efficiency and vice-versa;
c) the non-framing in stadial models leads, in time, to a stagnation of the results and even to their regress;
d) the keeping and training of the girls who fit into these models, even if the initial results are not very satisfactory;
e) the individual somatometric file is useful in predicting the somatic evolution;
f) even within exceptional results in the categories children I or juniors III, the girls who overcome these models, in time become overweight, regressing in time;
g) the guide mark for the appreciation of biological age is the beginning of the menstrual cycle and not the chronological age and the level of manifestation of secondary sexual characteristics.

After analysing the results, the resulting conclusions, we suggest the following:

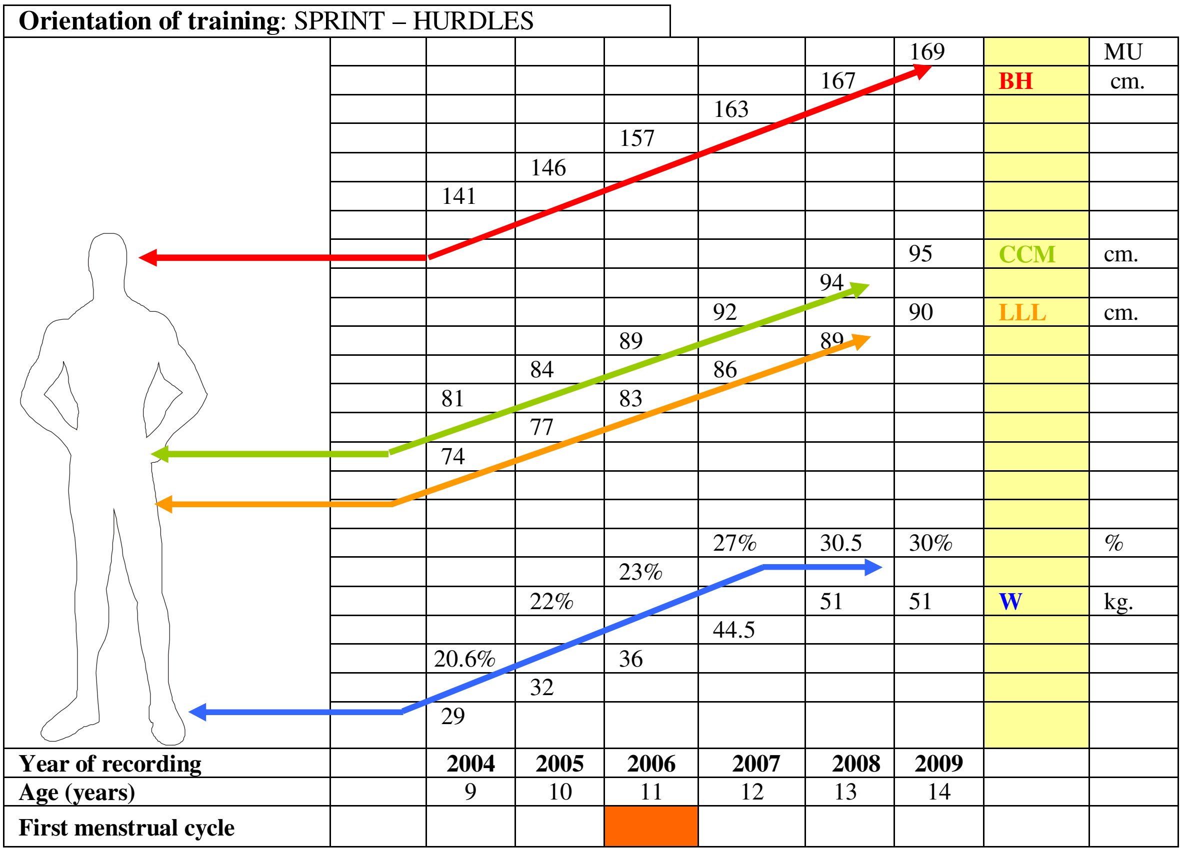
a) the usage of the stadial models as orientative reference values in the prediction and constitutional evolution of the selected athletes (see Table 1);
b) we suggest the using of these referential models, both in the initial selection process as well as during the training stage.

This is only a component of the factors that influence achievement, the framing in the above described models not being functional, isolated from the level of motric qualities or the necessary set of motric skills, a premise fulfilled by us through the selection of the most valuable athletes of our club.

As exemplifications of the present study, we include below the somatometric files of the two cases described above. Based on the graphic representation of the recordings over several years, the differences of evolution between the two distinct situations becomes evident, framing in the model and non-framing in the model. See figures 5 and 6.

Figure 5. Individual constitutional morphotype which fits in the correlative somatometric chart

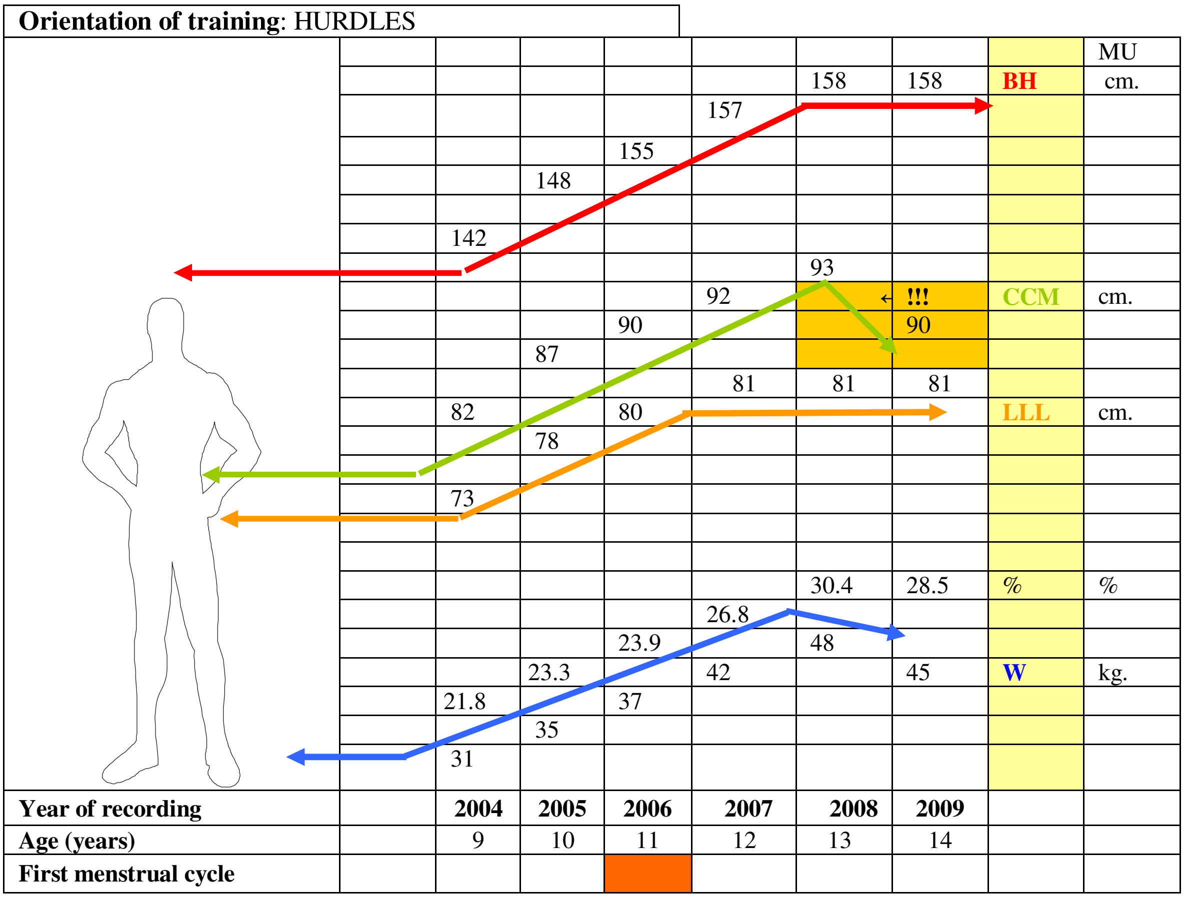
INDIVIDUAL SOMATOMETRIC FILE – THE EVOLUTION OF THE RECORDED PARAMETERS



BH, body height; W, body weight; CCM, height of centre of corporal mass; LLL, length of lower limb.

Figure 6. Individual morphotype which does not fit in the correlative somatometric chart

INDIVIDUAL SOMATOMETRIC FILE – THE EVOLUTION OF THE RECORDED PARAMETERS



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