ASPECTS OF SPINAL CURVE MEASUREMENT OF ATHLETES

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The curves of the spine, have not been researched extensively with respect to occupation or sports. Evaluation of the spine is complex. Methods of measurement and evaluation based on measuring 4 points of the rachis (spine) developed by (Wolanski, 1957) and the recording of the profile by evaluating the 3 angles of function in the vertical (Minski, 1972; Iwanowski, 1975) were indispensable steps in establishing the basis for more objective and precise methods and for identifying the importance of the spinal curves.

The "Radius Method with Intersection Point" was subsequently developed as an objective method to measure spinal curves. It is the result of 12 years of experimentation with an apparatus conceived to function electronically. The apparatus "Electronic Spherosomatograph" was developed at the Laboratory JECO of the Faculty of Medicine of the U.C.L. at Louvain-la-Neuve. Precise and quick measurement of the curves in space with a simultaneous recording of these curves of the rachis in the sagittal plane (lordosis and kyphosis) and in the frontal plane (scoliosis) are possible. The utilization of this measurement apparatus to develop normative rachis profiles, as well as lordotic and kyphotic profiles, are described. In addition, the rachis curvatures of 7 male volleyball players and 6 female gymnasts are compared.

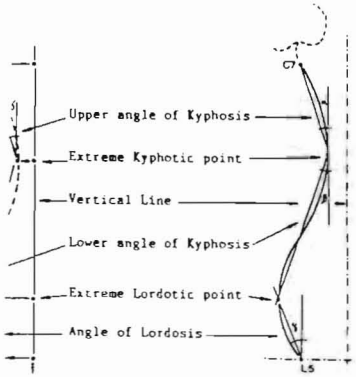
PROCEDURE AND MEASUREMENT

Based upon experiments between 1974 and 1977, the principles for measurement of the rachis were established with respect to stabilization, breathing, recording, and number of measurements. These have been described previously by Wielke (1983).

Figure 1 depicts the recording of the physiological curves of the spine. The recording begins at the anterior apophysis of the 7th Cervical vertebra and proceeds to the anterior apophysis of the 5th lumbar vertebra + 4 cm lower in order to include the top part of the sacrum whose curve and position influence the whole spinal curvature. The electronic spherosomatograph displays an exact outline of the profile of the curves of the spine and not only the position of selected points. It is upon an exact outline that a reliable system of reference must be based.

Figure 1. Using the electronic spherosomatograph to record the physiological curves of the spine.

In this research on the anatomical curves of the spine only two curves have been considered: 1) the dorsal (thoracic) curve, and 2) the lumbar curve. Wolanski (1957) and Minski (1972) and Iwanowski (1975) utilized the angular method of measurement of these spinal areas (See Fig. 2). Their method was based upon the concept that the two curves were independent. The radius method with intersection point is based upon the concept that the two curves are interdependent and inclined forward.



1957) (Minski 1972-Iwanonski 1975)

Figure 2. Scheme of angular method of measurement of the spinal curve.

The dorsal and lumbar curves thus are perceived as a function of their cords and not of the perpendicular. Since the two curves are dependant upon each other, they share the same system of reference. The line joining the top of the measured spine to its bottom passes through the actual point where the dorsal and lumbar curves meet, if 4 cm of the sacrum is taken into account in the measurement of adults. This is why all the measurements of the rachis are taken from C7 upper point to L5 +

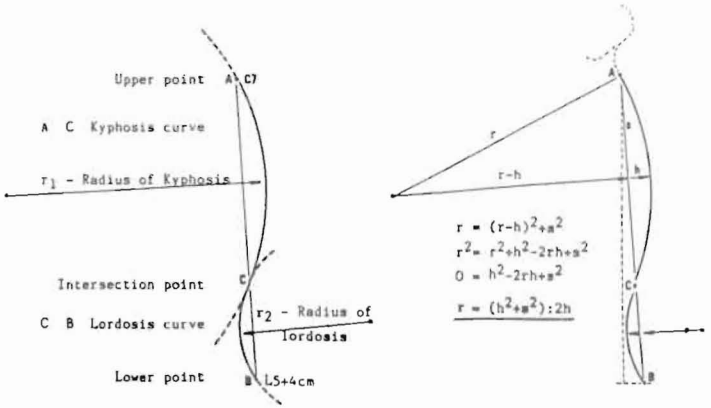


Figure 3. Radius method with intersection point.

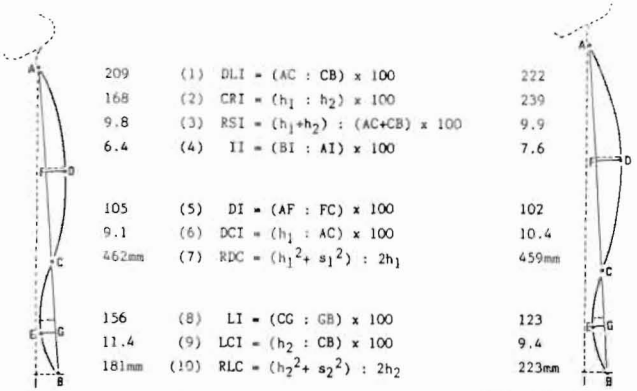


Figure 4. Profile of the Anatomical spinal curve and their indexes. (♀ = 190♀, ♀ = 286♂)

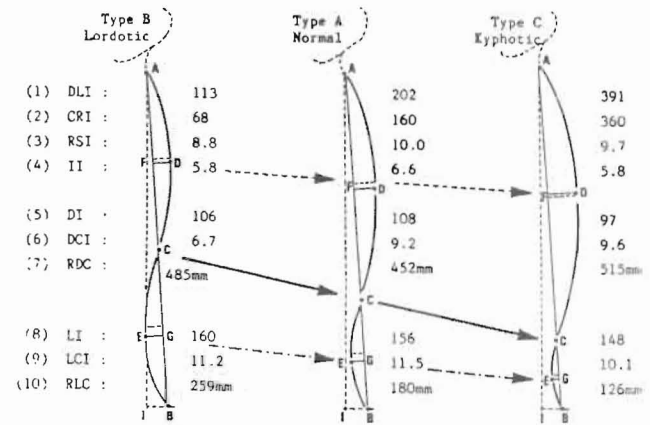


Figure 5. Profile of normative types anatomical rachis curves and their indexes. (♀ = 190♀)

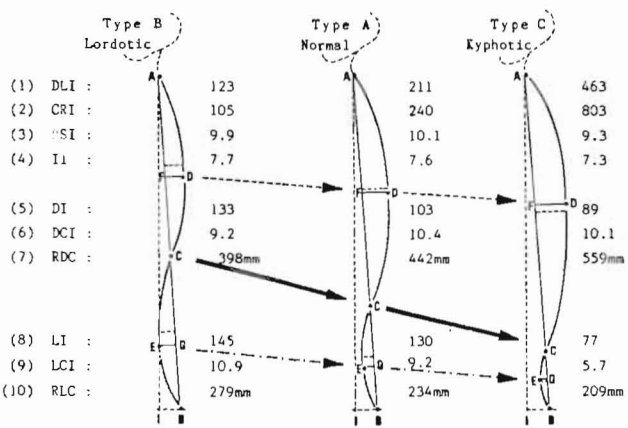


Figure 6. Profile of normative types anatomical rachis curves and their indexes. (♀ = 286♂)

4cm lower point. The straight line joining the upper and lower points passes at the intersection point of the dorsal and lumbar curves and two arcs are drawn. The measurement of the cord and the depth of each arc supplies the data to calculate the radius of the arcs by the use of the theorem of Pythagoras. See Fig. 3.

To determine normative typology the electronic spherosomatograph was used to measure a group of 190 female subjects and 286 male subjects in good health and normally developed. Three basic types of the spinal curve of healthy subjects were identified and 10 indexes calculated from the spinal curve recordings. The athletes were selected from this population.

RESULTS

Calculation of the ratio between the length of the dorsal curve and the length of the lumbar curve gives a result of about 2 to 1 (2.1 to 1 for the women; 2.2 to 1 for the men). See Fig. 4. The size of the dorsal curve is about 460 mm for the men and women. Statistical analysis indicates that the above relation accounts for 82.6% of the women and 80.3% of men in this sample. They constitute the Type A - Normal, spinal curve.

Indexes

In order to compare the profiles of the rachis curves of men and women of different ages the different parameters have been converted into 10 comparative indexes.

(1) Dorso-Lumbar Index (DLI) - The relation of the size of the Dorsal Cord to the Lumbar Cord multiplied by 100.

(2) Curve Relative Index (CRI) - The relation of the height of the Dorsal Curve to the height of the Lumbar Curve multiplied by 100.

(3) Relative Summation Index (RSI) - The relation of the sum of heights (h1+h2) Lumbar and Dorsal, to the sum of the two Cords (AC+BC) multiplied by 100.

(4) Inclination Index (II) - The relation between the lengths of the horizontal passing through the lower point B (L5+4cm) to the vertical passing through the upper point A (C7) multiplied by 100.

(5) Dorsal Index (DI) - The position of the top (D) of the Dorsal part of the rachis. It is the relation of distances between the projection of the top the dorsal curve (D) to the upper point A on one hand (AF) and to the intersection point (C) on the other hand (FC) multiplied by 100.

(6) Dorsal Curve Index (DCI) - The relation between the height of the Dorsal Curve (h1) to the cord (AC) multiplied by 100.

(7) Radius Dorsal Curve (RDC) - The Radius of the circle closest to the curve of Dorsal parts of the rachis.

(8) Lumbar Index (LI) - The position of the top (E) of the Lumbar part of the rachis. It is the relation of distances between the projection of the top the lumbar curve (E) to the intersection point C on one hand (CG) and to the lower point C on the other hand (GB) multiplied by 100.

(9) Lumbar Curve Index (LCI) - The relation between the height of the Lumbar Cruve (h2) to its cord (BC) multiplied by 100.

(10) Radius Lumbar Curve (RLC) - the length of the Radius of the circle closest to the curve of Lumbar parts of the rachis;

Indexes 1, 2, 3, and 4 characterize the whole profile of the rachis, taking into consideration the parameters of Dorsal and Lumbar Curves.

Indexes 5, 6 and 7 characterize the profile of the Drosal parts of the rachis.

Indexes 8, 9, and 10 characterize the profile of the Lumbar part of the Rachis.

With respect to the Radius Dorsal Indexes and Radius Lumbar Indexes, the size of the radius is in relation to the height of the curve, that is, the smaller the radius, the higher the curve. The value of these indexes for men and women are presented in Figure 4.

Comparison of Indexes by Gender

The observation of the average curves obtained from the study of 190 women and 286 men shows how very similar the average profiles are. The indexes concerning the length of the curves RSI (3) are quite close: 9.8 for the women and 9.9 for the men. DI (5) is 105 for the women and 102 for the men. RDC (7) is 462 mm for the women and 459 for the men, practically identical.

But important difference appear in the heights of the curve. The relations of the heights of curves CRI (2) is 168 for the women against 239 for the men. This is the consequence of differences in the DCI (6), smaller for the women (9.1) than for the men (10.4) and of the difference in the LCI (9), the women reach 11.4 against 9.4 for the men. This difference is confirmed by the length of the radius of the lumbar curves. RLI (10) is 181 mm for the women and 223 mm for the men.
On the other hand for 7.9% of the women and 11.5% of the men the ratio between the curves is 1.1 to 1 for women and 1.2 to 1 for the men meaning that the lumbar curve is longer and the dorsal curve shorter than those of Type A curve. The curve with this characteristic has been called Type B-Lordotic.

Moreover for 9.5% of the women and 9.6% of the men the ratio between the curves is approximately 4 to 1 (3.9 to 1 for the women and 4.6 to 1 for the men). This indicates a type curve in which the dorsal part shows an important increase and the lumbar part shows a decrease compared with the normal (Type A). This type of curve has been called Type C-Kyphotic.

The diffeent typologies Type A - Normal, Type B - Lordotic, Type C - Kyphotic, and thus the classification systems are based on relationships between the sizes of the dorsal and lumbar curves. They are only a statement of facts and not an appreciation of any other value.

When the subjects are grouped by typology, the indexes reveal significant differences between women and men i the normative types of the rachis. Figures 5 and 6 depict the differences and similarities of the two sexes with respect to the 10 indices.

Dorsal-Lumbar Index (DLI) - This value is higher for the male subjects in all three normative types. Men-Type B-Lordotic 123; Type A-Normal 211; Type C-Kyphotic 463, Women-Type B 113; Type A 202; Type C 391. It means that the men have a longer dorsal curve and a shorter lumbar curve than the women.

The Inclination Index II(4) - This index is smaller for the women than for the men. Type A-Normal men 7.6, women 6.6, Type B-Lordotic men 7.7, women 5.8, Type C Kyphotic men 7.3, women 5.8. This could be explained by the different statures of men and women.

Dorsal Curve DI(5) - This index has a decreasing value with the men Type B-Lordotic 133, Type A-Normal 103, and Type C-Kyphotic 89, but less so with the women, respectively 106, 108, and 97. DI is below the height of the dorsal curve in Type Lordotic and Normal for men and women but in Type C-Kyphotic it is the opposite for the men than for the women.

Comparison of the Dorsal Curve Index DCI(6) with the Lumbar Curve Index LCI (9) shows that the Dorsal Curve Index (6) of men is, in every normative typology, greater for the men than for the women 9.2, 10.4, 10.1 against 6.7, 9.2, 9.6. On the other hand the Lumbar Curve Index (9) is lower by the men than the women in every normative typology men 10.9, 9.2, 5.7 against women 11.2, 11.5 and 10.1. It confirms the difference between men and women in the Curves Relative Index CRI (2) of every normative Typology.
Radius Dorsal Curves RDC(7) for Type A-Normal men and women is practically similar, men 442mm, women 452mm. In the Type B-Lordotic and Type C-Kyphotic, the values for the men and women are very different. Type Lordotic men 398 mm, women 485 mm, Type Kyphotic men 559 mm, women 515 mm.

The top of the Lumbar Curve LI(8) has a higher value for the women than for the men. Type Lordotic 160, Type Normal 156 and the Type Kyphotic 148 for the women, and for the men respectively 145, 130, and 77, for both sexes. The top e in Type C-Kyphotic is above the height of the lumbar curve only for the men.

The length of the Radius of the Lumbar Curve (10) is longer with the men (209 mm for Type C, 234 mm for Type A and 279 mm for Type B) than with the women (126 mm for Type C, 180 mm for Type A and 259 mm for Type B). These values like those of DLI(1) and RDC(2) are characteristic of the difference between men and women and confirm the normative Typology.

During the registration of the spinal curves it was noticed that the profiles of the curves of the best athletes in this group appeared to diverge from the normative typology. These athletes showed characteristics of hyperlordosis (Type B) or hyperkyphosis (Type C). The data from the elite athletes were identified and the registration of the curves and calculation of the 10 indexes specific to the "Radius Method with Intersection Point" was applied to selected athletes: foreigners competing in Belgium and one Belgian.

Comparison of Volleyball Players

The characteristics (10 indexes) of the three main type of rachis curves of 286 male adult subjects and of 7 male volleyball players from the Junior National Team (Cuba) taking part in the 1985 World Championships in Europe are listed in Table 1. All measurements were taken three times and the mean of these measurements appear in the table.

The players are identified as follows:
1VB(B), 2VB(B), 3VB(B) are spikers;
4VB(A), 5VB(A) are set-ups;
6VB(B), 7VB(C) are major spikers. The letter in brackets identifies the typology of the rachis to which the subject is closest: A-Normal, B-Lordotic, C-Kyphotic.

TABLE 1.

INDEXES OF THREE TYPES OF ANATOMICAL CURVES (286 men)
AND SELECTED MALE VOLLEYBALL PLAYERS

Type Subject	Characteristic of both parts of Rachii				Dorsal parts			Lumbar parts		
	Dorso Lumbar Index(1)	Curve Relative Index(2)	Relative Summation Index(3)	Incli-nation (4)	Dorsal Index(5)	Dorsal Curve Index(6	Radius Dorsal Curve (7)	Lumbar Index(8)	Lumbar Curve Index(9)	Radius Lumbar Curve(10)
B-Lord.	123	105	9.9	7.7	133	9.2	398mm	145	10.9	279mm
A-Normal	211	240	10.1	7.6	103	10.4	442mm	130	9.2	234mm
C-Kyph.	463	803	9.3	7.3	89	10.1	559mm	77	5.7	209mm
1VB/B-Lord.	106	80	5.6	4.4	20	4.9	733mm	264	6.4	527mm
2VB/B-Lord.	126	90	7.3	13.4	129	6.1	595mm	128	8.7	340mm
3VB/B-Lord.	124	123	8.8	1.2	190	8.3	469mm	129	9.6	376mm
4VB/A-Norm.	187	290	7.7	9.0	93	8.8	521mm	122	5.7	424mm
5VB/A-Norm.	262	352	10.1	8.9	126	11.2	289mm	83	8.4	227mm
6VB/B-Lord.	157	109	11.2	8.8	151	9.4	473mm	114	13.6	197mm
7VB/C-Kyph.	570	830	6.6	7.7	68	6.3	993mm	146	4.3	251mm

TABLE 2.

INDEXES OF THREE TYPES OF ANATOMICAL CURVES (190 women)
AND OF SELECTED FEMALE GYMNASTS.

Type Subject	Characteristic of both parts of Rachii				Dorsal parts			Lumbar parts		
	Dorso Lumbar Index(1)	Curve Relative Index(2)	Relative Summation Index(3)	Incli-nation Index(4)	Dorsal Index(5)	Dorsal Curve Index(6)	Radius Dorsal Curve(7)	Lumbar Index(8)	Lumbar Curve Index(9)	Radius Lumbar Curve(10)
B-Lord.	113	68	8.8	5.8	106	6.7	485mm	160	11.2	259mm
A-Normal	202	160	10.0	6.6	108	9.2	452mm	156	11.5	180mm
C-Kyph.	391	360	9.7	5.8	97	9.6	515mm	148	10.1	126mm
1KG/B-Lord.	107	26	9.2	-4.7	272	3.7	715mm	116	15.1	178mm
2KG/B-Lord.	137	58	15.4	-1.5	225	10.5	319mm	124	21.2	115mm
3KG/B-Lord.	117	80	12.2	6.8	96	10.0	312mm	175	14.7	189mm
4KG/A-Norm.	192	178	6.4	5.4	107	6.2	668mm	123	6.7	323mm
5KG/A-Norm.	274	300	10.4	3.8	116	10.7	412mm	232	9.8	164mm
6OG/C-Kyph.	561	600	14.7	1.1	127	14.8	370mm	157	13.9	70mm

Curve Relative Index (CRI) - The relation between the heights of the dorsal and lumbar curves (for the three typologies as follows: Type C greatest, Type B next largest, Type A Smallest).

The Relative Summation Index RSI (3) - This is more stable for the men divided in normative typologies (9.9, 10.1, 9.3) than for the women (8.8, 10.0, 9.7).

The top (D) of the curves values 20, 129, 190 for the spikers are more widely dispersed than in the typology, with a range of 89 for Type C-Kyphotic and 133 for Type B-Lordotic. Both the Dorsal Curve Index (DCI(6)) and the Radius Dorsal Curves (RDS(4)) are different than the Type B-Lordotic. The Dorsal Curve of the players is less marked than the subjects of Type B-Lordotic. This may be related to the fact that spikers must be able to attack the ball at a height of more than 3.20 m.

The top of lumbar curve Lumbar Index (LI(8)) is respectively 264, 128, 129 against 145 for the Type B-Lordotic. Thus for the lumbar curve, as with the dorsal curve wide differentiation, with strong individualization, exists. The Lumbar Curve Index (LCI(9)) values are also widespread. When we consider the Radius Lumbar Curve (RLC(10)) we find respectively 527 mm, 340 mm and 376 mm values for the spikers. This indicates that the lumbar curves of these spikers are less marked than in the typology. This seems logical if we take into account that a change in the dorsal curve must have an effect on the lumbar curve.

It should be noted that the profile of the curves of the spikers as revealed by the spherosomatograph electronic shows that part of the dorsal curve (concave forward) becomes convex in front like the cervical curve.

The set ups 4VB, 5VB.

These players belong to the Type A-Normal since the Dorso-Lumbar Index values (DLI(1)), The Relative Summation Index (RSI(3)) and the height of the curves (CRI(2)) are in Type A-Normal. The Inclination Index values, however, are 9.0 and 8.9, thus more than Type A-Normal (7.6).

The Dorsal Index (DI(5)) values are dissimilar for the subjects: 4VB is close to Type C-Kyphotic (89) and 5VB is close to Type B-Lordotic (133). The Radius Dorsal Curve (RDC(7)) value for 4VB is close to Type Kyphotic (559); 5VB with 289 is below Type Lordotic (398). Athlete 4VB has a lumbar curve as poorly marked as his dorsal curve. 5VB on the other hand has a Radius Lumbar Curve close to the Type A-Normal (234).

The Major Spikers 6VB, 7VB.

Spiker 6VB with a Dorso-Lumbar Index (DLI(1)) of 157 belongs to Type B-Lordotic (123) while 7VB spiker with 570 belongs to Type C-Kyphotic (463).

For 7VB the Dorsal Index (5) of 68 puts the dorsal top (D) in a very high place; he is the tallest of all subjects analyzed. For 7VB the RDC (7) index is far outside the norms, it is 993 mm against 559 mm for Type C-Kyphotic. The two major-spikers have dorsal characteristics which are of opposite types. They belong to opposite normative types. The characteristics of the lumbar part are also quite different.

In order to visualize the curves of the volleyball players, the different profiles are presented in Figure 7.

Results and Analysis of Women Gymnasts.

Table 2 presents th characteristics of the three normative types of rachis curves of women by 10 indexes for 190 female adult subjects and 6 female top gymnasts.

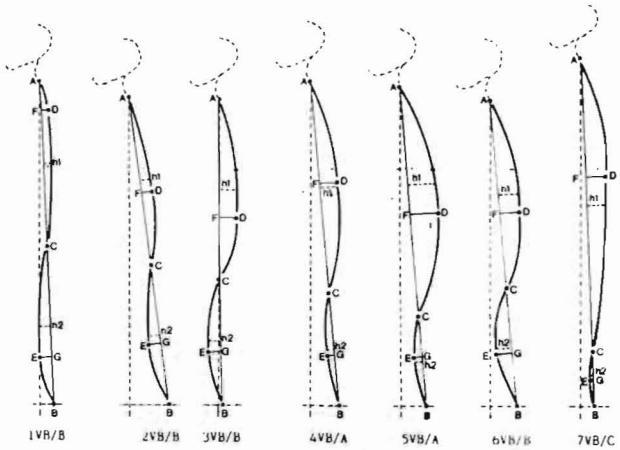


Figure 7.

Profiles of the Curves of Male Volleyball Players

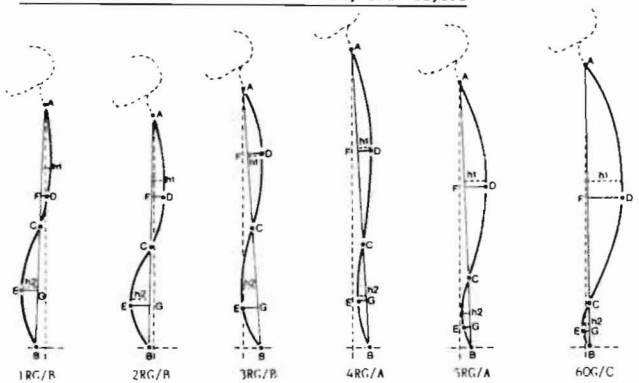


Figure 8.

Profiles of the Curves of Female Gymnasts

The group of tymnasts is composed as follows: 5 specialists in Sports Rhythmic Gymnastics investigated in 1984 when taking part in a pre-olympic tournament in Belgium. The two first are West-Germans, the three others are Polish and are identified as 1RG(B), 2RG(B), 3RG(B), 4RG(A), 5RG(A), and one Belgium Olympic Gymnast identified as 60G(C).

As the group contains subjects of different ages, and thus different stages of their morphological evolution we have mentioned the age, size and weight.

Cases 1RB(B) and 2RB(B)

Characteristics of both parts of rachis.

1RG is 15 years old, height 164 cm and weight 46 kg; 2RG is 13 years old, 160 cm in size and 42 kg in weight. Both belong to Type B-Lordotic.

The position of the top (D) of the dorsal part (DI(5)) is 272 for 1RG and 225 for 2RG. Both values are much higher than in all the types of the normative typology. These two gymnasts have the lowest and highest DCI(6) of all the cases presented in the two tables.

The Lumbar Indexes (LI(8)) of the two gymnasts show that for both, the top (E) is higher than in the normative typology. Likewise, the Lumbar Curve Indexes (LCI(9)) are very different from our typology in value and differentiation.

Case of 3RG(B)

Characteristics of both parts of rachis.

3RG is 17 years old, height 171 cm, and weight 57 kg belongs to the Type B-Lordotic. The Curve Relative Index (2) of 80 is greater than in the previous gymnasts and Type B(68).

The Dorsal Index (5) of 3RG is 96 which is the same as the normative Type C-Kyphotic (97) and the Dorsal Curve Index (6) is 10.0 a little more than Type C-Kyphotic (9.6).

3RG has a greater Lumbar Index (8) value (175) than either 1RG, 2RG and the three normative types, but it is close to the value of Type B-Lordotic (160).

Cases of 4RG(A) and 5RG(A).

4RG is 20 years old, height 180 cm and weight 62 kg, while 5RG is 17 years old, height 164 cm, and weight 56 kg. Both belong to the Type A-Normal, in spite of the differences between them. Dorsal-Lumbar Index (1) is 192 for 4RG, close to Type C-Kyphotic (391). The same judgment can be made for the Curve Relative Index (2).

The Dorsal Index (5) of 4RG (107) and 5RG (116) are not too distant from Type A-Normal (108). The Lumbar Index (8) of 4RG (123) is quite small even less than Type C-Kyphotic (148), but 5RG has the greatest Lumbar Index of all the subjects. The Lumbar Curve Index (9) of 4RG is 6.4 the smallest of all the subjects.

Case of 60G(C)

To give idea of differences between elite rhythmic gymnasts and olympic gymnasts, the rpofile of the curves of three female gymnasts are presented in Fig. 8. The case of 60G with typical characteristics of profile of athletes specialized in olympic tymnastics is presented.

60G is 19 years old, height 160 cm, and weight 60 kg, with DLI(1) of 561, the greatest of all gymnasts belongs to the normative Type C (391). The Curves Relative Index (2) of 600 is also the greatest of all. The Relative Summation Index (3) is 14.7, one a greatest, but her Inclination Index of spinal curves II(4) of only 1.1 is the smallest positive value. The lumbar part of rachis has the largest curvature compared to all the others. The characteristics of the profile of the rachis of 60G shows not only a great difference with the profiles of Rhythmic gymnasts but while belonging to Type C-Kyphotic she differs considerably from normative typology. This important deviation could be considered as a deformation.

The findings about the spikers show that volleyvall players even when they have the same speciality and belong to the same normative type (Type B Lordotic in this case) present important differences, these lead in the direction of the Kyphotic Type-C, thus opposite their normative type. The two set-ups belong to Type A-Normal and keep to the characteristics of their type even if they show personal differences. The major spikers who are over-specialized present the greatest difference to the normative type. The values in the dorsal and lumbar parts are abnormal if we compare them with the spikers. We should speak here not only of deviation but of deformation. As far as the set-up is concerned, the extreme difference in the lumbar curves must be considered as sign of deviation.

The findings about the women gymnasts show that they present individual characteristics in profile and signs of unique curves. They deviate not only from normative typology, but show also wide differences amo themselves.

It might be speculated that the method of training the gymnast, may influence the curves of rachis. It is interesting to note that the two German "children", of Type B-Lordotic, show common trends, such as a low value of the Curve Relative Index (2) an extraordinary negative Inclination Index (4), an abnormal change of the tops of the Dorsal and Lumbar Curves (DI(5); LI(8)) and a great depth of the lumbar curves (LCI(9)).

The Polish gymnasts (3GR) belongs to Type B-Lordotic and the two other to Type A-Normal but present Kyphotic characteristics in an individual way. One should note the height of 4RG Type A-Normal 1.89 cm. These two last women 4RG/A and 5RG/A reached the finals in 4 events and won respectively: 4RG 3 second places and 1 third place; 5RG with most characteristics of the normal profile of rachis - won 3 first places and 1 third place. It appears that the Kyphotic profile of the Rhythmic Gymnasts is anatomically profitable for the performance.

The Belgian Olympic Gymnast belongs to the kyphotic typology but presents abnormal characteristics within this type. This may be considered, not only deviation, but deformation.

CONCLUSION

The study presented here is only the first step in the application of normative typology to understand the problem of the spinal curves of athletes. Deviations from Type A-Normal have been noted in male volleyball players and female gymnasts. Courses are not identified. Women rhythmic gymnasts appear to have more kyphotic spines than other types. Male volleyball players show kyphotic and lordotic spines. The spikers present a merge of the cervical and lumbar curves and tendency to diminuation of the dorsal and lumbar curves. The inclination of the rachis is greater by set up players than by the spikers.

The results obtained by the "Radius Method with Intersection Point", characterized by indexes and the connection of the "Electronic Spherosomatograph" with computer, will allow the examination of a larger number of athletes and take into consideration more parameters. It will lay the basis for further study of a theoretical model of the spine in different sports in order to evaluate the optimal functional adaptation. Most importantly, it may provide the method to understand the role of the sport compared to that of functional activities of daily living including adaptation of the spine.

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