
MUSCULOSKELETAL BIOMECHANICS

SPINAL CURVES OF SELECTED SWIMMERS ACCORDING TO THE STROKE

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The developed "Radius Method with Intersection Point" permitted the evaluation of the evolution of curves of the spine in human beings and an example of the study of athletes participating in different sports was reported at Umea (Wielki, 1985) and at Aquatic Sports at Dunedin (Wielki, 1985).

Methodology

The present investigation focused on the study of the spinal curves of 20 selected Belgian swimmers according to the major stroke practice. Measurement and recording of the spinal curves was done during the "training activities" 1982 - 1985 by means of the "Wielki's Electronic Spherosomatograph" (Nagoya, 1981).

Interpretation was done employing ten indexes to establish the "normative typology" 1986 Halifax (Wielki et al) based on the study of 476 students of physical education from the University of Louvain-La-Neuve.

Subject in free standing position
Stabilization of the body at three levels (feet-hips-head)
Heels at the same height either touching or open
Arms along the body
Head in "Frankfurt" position
Recording during controlled breathing from C₇ until L₅ + 4cm



Figure 1. Recording of the Rachis using "Wielki's Electronic Spherosomatograph"

The Normative Typology was based on 286 Male 190 Female and characterized by :

4 indexes for both parts of the rachii :

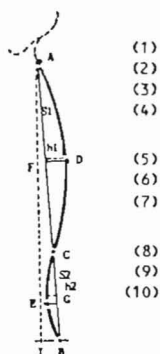
- Dorso-Lumbar Index: $DLI = (AC : CB) \times 100$; (1)
- Curve Relative Index: $CRI = (h1 : h2) \times 100$; (2)
- Relative Summation Index: $RSI = (h1+h2) : AB/x 100$; (3)
- Inclination Index: $II = (BI : AI) \times 100$; (4)

3 indexes for the dorsal part :

- Dorsal Top Index: $DTI = (AF : FC) \times 100$; (5)
- Dorsal Curve Index: $DCI = (h1 : AC) \times 100$; (6)
- Radius Dorsal Curve: $RDC = (h1^2 + s1^2) : 2h1$; (7)

3 indexes for the lumbar part :

- Lumbar Top Index: $LTI = (CG : GB) \times 100$; (8)
- Lumbar Curve Index: $LCI = (h2 : CB) \times 100$; (9)
- Radius Lumbar Curve: $RLC = (h2^2 + s2^2) : 2h2$; (10)



Previously the Main-Type was defined by taking into consideration only the relation between the length of the Dorsal curve to the length of the Lumbar. Current developed methodology showed that the relationship of the height of the dorsal to the lumbar curve is very important in characterization of the three morphological types of spine, (Type A-Normal, B-Lordotic, C-Kyphotic) and to follow the evolution and changes of spinal curves.

This classification was named "Normative Typology" and must be considered only as a statement, allowing to follow individual changes of the spinal curve.

Results

Figure 2 illustrates the profiles of Spinal Curve of the swimmers of four selected Indexes according to the major stroke practice and the Means (X).

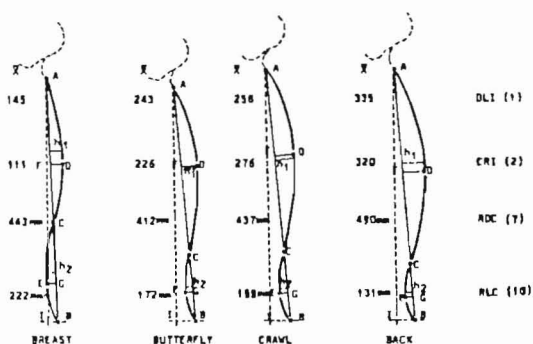


Fig.2. Profile and Means of Spinal Curves of Swimmers according to major stroke.

The difference in functional adaptation of the curve on the Vertebra Column was apparent.

The table shows means of all ten indexes, the SD and the V-Coefficient of variation of the swimmers according to their preferential stroke and permits you to follow closely and analyze differences in adaptation of the spinal curve between the various stroke-groups, and the All Average Type.

MEANS (\bar{x}), SD AND V [$V=(SD \times 100) : \bar{x}$] OF INDEXES OF SWIMMER'S ANATOMICAL SPINAL CURVES, NORMATIVE TYPOLOGY AND ALL AVERAGE TYPE OF 286 ♂ M. and 190 ♀ F. (L.L.N.)

STROKES NORM. TYP. ALL AV. TYPE	Characteristics of both parts of Rachii				Dorsal Parts			Lumbar Parts		
	Dorso Lumbar	Curve Relative	Relative Summation	Inclination Index	Dorsal Top	Dorsal Curve	Radius Dorsal	Lumbar Top	Lumbar Curve	Radius Lumbar
	Index(1)	Index(2)	Index(3)	(4)	Index(5)	Index(6)	Curve(7)	Index(8)	Index(9)	Curve(10)
BREAST	\bar{x} 145	111	9.9	3.9	136	7.8	443mm	146	11.7	222mm
	SD 48.1	86.1	1.6	1.7	46.3	3.2	55.5	17.1	1.3	32.0
	V 33	77	16	44	21	41	12	12	11	14
BUTTERFLY	\bar{x} 243	226	11.1	8.6	97	10.2	412mm	155	12.4	172mm
	SD 91	135	2.5	2.0	32	2.4	73	34	3.8	84
	V 37	60	22	23	33	23	18	22	31	49
CRAWL	\bar{x} 258	276	11.3	8.0	96	11.1	437mm	120	11.9	155mm
	SD 88	107	2.3	3.1	18	1.7	102	41	3.7	30.5
	V 34	38	20	39	19	15	23	34	31	20
BACK	\bar{x} 335	320	11.2	7.3	117	10.8	490mm	123	12.3	131mm
	SD 101	189	2.2	3.1	24.7	2.6	180	41	3.0	28
	V 30	59	20	42	21	24	37	33	24	21
" B " 33 M	123	105	9.9	7.7	133	9.2	398mm	145	10.9	279mm
LORDOTIC 15 F	113	68	8.8	5.8	106	6.7	485mm	160	11.2	259mm
" A " 225 M	211	240	10.1	7.6	103	10.4	442mm	130	9.2	234mm
NORMAL 157 F	202	160	10.0	6.6	108	9.2	452mm	156	11.5	180mm
" C " 28 M	463	803	9.3	7.3	89	10.1	559mm	77	5.7	209mm
KYPHOTIC 18 F	391	360	9.7	5.8	97	9.6	515mm	148	10.1	126mm
All Av. 286 M	222	239	9.9	7.6	102	10.4	459mm	123	9.4	223mm
Type 190 F	209	168	9.8	6.4	105	9.1	462mm	156	11.4	181mm

Table 3

Discussion

Breaststroke swimmers with a DLI (1) of 145 showed strong prevalence toward Type B-Lordotic (DLI M. = 123, F. = 113). This indicates that the lumbar curve became longer and the dorsal part shorter as compared to Type A - Normal. Taking into consideration the mechanics of the arm-stroke and breathing out of the water, this adaptation of the spinal profile allows less frontal resistance, especially when the CRI (2) = 111 shows that the height of the dorsal curve to the lumbar is less than in the Type A - Normal, (M. = 240, F. = 160) and belongs to the Type B (CRI (2) M. = 105, F. = 68).

Backstroke swimmers with DLI (1) of 335, Type C - Kyphotic (M. = 463, F = 391) showed their profile to be opposite of that of the Breaststroke swimmers. The dorsal curve is longer and lumbar curve is shorter than the Type A - Normal (M. = 211, F. = 202). The report of the height of the curve also changed according to statements of Curve Relative Index (CRI (2) = 320); wherein Type C has M. = 803 and F. = 360 and Type Normal M. = 240, F. = 160. This curve profile of the spine is adapted to for a better slide of the body on the surface.

Butterfly and Crawl stroke swimmers had spinal curves close to the type A - Normal, but slightly Kyphotic. This DLI (1) is 243 BU and 258 CR, whereas the Type A - Normal had DLI (1) M. = 211, F. = 202. The report of heights shows the same tendency CRI (2) BU = 226, CR = 276 whereas Type Normal A = 240 for M. and 160 for F. and Type Kyphotic C, CRI of M. = 803, F. = 360.

Study of a large number of subjects showed that the anatomical spinal curves are closely dependent on each another in Length - Dorso - Lumbar Index DLI (1) as well as in the height - Curve Relative Index CRI (2). Even if only consideration of relation of the lengths of the curve (Dorsal to the Lumbar curve) are taken, these three Types of Rachii (A, B, C) permit to compare the curve evolution of the spine of each subjects, if compared with the "Normative Typology" with its ten Indexes.

The average comparison of the Radius Dorsal Curve - RDC (7) X, of the four strokes showed no practical difference (412mm to 490mm), but the coefficient of variation (V) was very different and progressively increased: the smallest was BR (V=12), and the greatest was BA (V=37); whereas BU group and CR group were 18 and 23, respectively.

With regard to the average Radius Lumbar Curves RLLC (10), the size of the Radius was greatest in BR (222mm), the shortest in BA (131mm) whereas BU group was 172mm and CR 155 mm. The coefficient of variation was smallest in BR (V=14) the greatest was by BU (V=49) whereas CR and BA swimmers were 20 and 21 respectively.

In general, it can be said that in the practice of the breaststroke the Dorsal curvature Kyphosis diminished, the Lumbar Curvature Lordosis increased as in Type B - Lordotic.

In the case of Backstroke practice, our findings are the contrary, the Dorsal Curve Kyphosis increased, and the Lumbar Curve Lordosis decreased as in Type C - Kyphotic.

The spinal curves of the Butterfly and Crawl swimmers was very close to Type Normal - 1, DLI (1) M. = 211, F. = 202.

The comparative average index of the height of the spinal curves (CRI₂) of the swimmers increases from BR = 111 to BA = 320 in the same way as the length whereas in the All Average Type is M. = 239; F. = 168.

Example for selected swimmers in four strokes practice.

Taking into consideration the difference in means of every group of swimmers these give us the general idea, now a further step can be made. For this purpose the spheromatogram of anatomical curves of Rachii of every stroke swimmers was selected and presented in Figure 3.

The swimmers are identified as follows:

- 1 BR F. - Breaststroke specialist Female,
- 1 CR F. - Crawl specialist Female,
- 3 BU M. - Butterfly specialist Male,
- 4 BA M. - Back specialist Male.

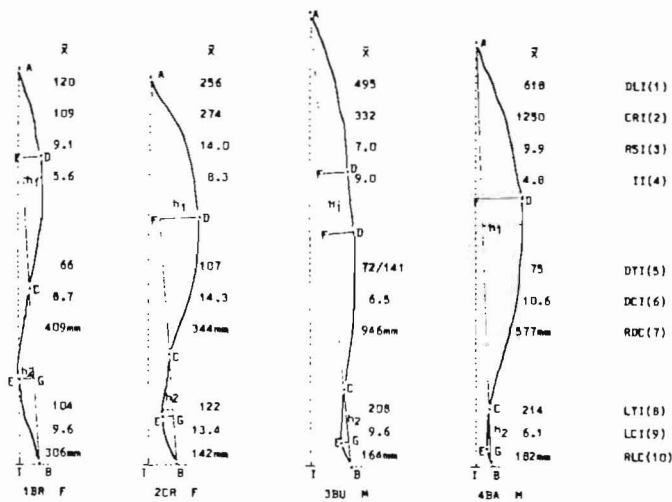


Fig.3. Spinal Curves of selected Swimmers according to the Stroke practice.

Case of 1 BR f.

1 BR F. 18.5 years old, height 168 cm, and weight 57.5 kg, after practice of recreational swimming in childhood chose Breaststroke for

competition at 12 years of age.

The relation of the length of the dorsal curve to the lumbar DLI (1) -120, and the relation of the heights of the curves CRI (2) = 109, belonged to the Normative Type B - Lordotic F. with X 113 and 68, as well as the X of BR group specialist with DLI = 145 and CRI = 111.

Taking into consideration the relation of the sum of the heights of curves to the total length of the spine ($C_7 L_5 + 4m$) RSI (3) = 9.1 was close to the Type Lordotic with X RSI = 8.8.

Inclination Index II (4) = 5.6 was very close to the Type B of F. with X = 5.8, while the X of BR group was only 3.9, the smallest of all the strokes. It seems that technique of propulsion and breathing, inhaling by extension of the dorsal curve in water without gravitation, influences the posture in standing position.

The value of the Top of Dorsal Curve DTI (5) = 66 was very small in comparison with the Lordotic Type (106), and the value of the Top of Lumbar Curve LTI (8) = 104 was also small in comparison with the Lordotic Type (180) F., and of X of BR group stroke (146).

The relation of the height of Dorsal Curve to the length DCI (6) = 7.8 is greater than in the Type Lordotic (6.7), and the relation for the Lumbar Curve LCI (9) = 11.7 was a little greater than in the Type Lordotic 11.2. It must be noted that the value of these two Indexes by Breaststrokes group was smallest in comparison with the other strokes.

RDC (7) = 409mm was shorter than in Lordotic Type F. (485mm), and was the shortest of all X of the other strokes, whereas the RLC (10) = 306mm was greatest than X of Lordotic Type F. (259mm) and also of X of the other strokes group (222mm, 172mm, and 155mm).

Case of 2 CR F.

2 CR F. 19 years old, height 173 cm, and weight 62 kg, practiced recreational swimming from early age without Breaststroke, with the predominance of the crawl in competition.

With value of DLI (1) = 256 belongs to the Type Normal A (202 F.), the value of CRI (2) = 140 was the greatest of all other strokes group and greater than Type Normal F. (160).

Inclination Index of the subject was II = 8.3, very close to the X of CR group swimmers (8.0) and greater than X of Type Normal (6.6 F.).

Position of the Top of Dorsal Curve DTI (5) = 107 was practically the same value as the Type A (DTI = 108 F.), but a little greater than the X of the CR group (96), and the value of LTI (8) = 122 was also a little greater than her stroke group (120), but less than Type

A (156 F.).

DCI (6) = 14.3 was greater than the X of all other strokes, (7.8, 10.2, 11.1, and 10.8) and Normative Types (6.7, 9.2, and 9.6). The LCI (9) = 13.4 was greater than her CR group with 11.9, and Normal type A with value of 11.5

RDC (7) = 344mm was shorter than the X of CR group (437mm) and of the Normal Type F. with 452mm, but RLC (10) = 142mm was shorter than CR group (155mm) but close to the Type Kyphotic F. with Value 126mm.

Case of 3 BU M.

3 BU M. 17.5 years old, height 191 cm, and weight 75 kg, practiced on the beginning competitive of Backstroke, after good performance changed and became Butterfly specialist.

With value of DLI (1) of 495, and CRI (2) = 332, belonged to the Type Kyphotic C, and not as the BU group with X of DLI = 243, and CRI = 226, who belonged to the Normative Type Normal with DLI = 211, and CRI = 240 for M.

Value of RSI (3) = 7.0 was the smallest of all X of the other strokes (9.9, 11.1, 11.3, and 11.2) as well of the normative Typology of M. (9.9, 10.1 and 9.3).

II (4) = 9.0 was greater than X of the BU group (8.6) and of Normative Types of M. (7.7, 7.6, and 7.3).

With regard to the position of the Top of Dorsal parts of the Spine, he presented exceptionally two values DTI (5) = 72, and 141, whereas the BA group had 117 and BU group = 97, and Typology of M. Lordotic = 133, and Kyphotic = 89; while his LTI (8) = 208, was the greatest of all X of Typology of M.

DCI (6) was smaller than the X of the other strokes (7.8, 10.2, 11.1 and 10.8) and of the Normative Typology (9.2, 10.4, and 10.1 for M.), and LCI (9) = 9.6 was smaller than BA group = 12.3 and BU group = 12.4, and the Normal Type M. had 9.2 and Type Kyphotic only 5.7.

RDC (7) = 946mm was the greatest of all the stroke groups 443mm, 412mm, 437mm, and 490mm, and of the Normative Types M. 398mm 442mm and 559mm, while RLC (10) = 164mm was smaller than BU group 172mm but greater than BA group 131mm, and shorter than Normal Type M. 234mm and Kyphotic 209mm.

Case of 4 BA M.

4 BA M. 19 years old, height 178 cm and weight 81 kg, practiced

from childhood for Backstroke competition.

With DLI (1) = 618 and CRI (2) 1250 belonged not only to BA group with X of DLI = 335 and CRI = 320 and to the Type Kyphotic DLI = 463, and CRI = 803, but we can consider that the value of these indexes are outside the limits of the Normative Typology, and are deformations due to early specialization in BA stroke.

RSI (3) = 9.9 is smaller than for BA group with X of 11.2, but greater than by Type Kyphotic with X = 9.3 for M.

II (4) = 4.8 is smaller than of Kyphotic Type C of M. = 7.3.

Position of the Top of Dorsal Curve DTI (5) was smaller than BA group 117, it was the opposite for the LTI (8) with value of 214 compared with 123 for BA group, it was also greater than for the Kyphotic Type with values of DTI = 89 and LTI = 77.

DCI (6) = 10.6 was between the values of X of BA group (10.8) and of Type Normal M. (10.4), while LCI (9) had a very small value 6.1 between the stroke groups (11.7, 12.4, 11.9, and 12.3).

RDC (7) = 577mm was typical of Type Kyphotic (559mm) and was the greatest compared with all strokes groups (BA = 490mm M.), while RLC (10) = 182mm was greater than BA group (131mm) but shorter than Type Kyphotic M. (209mm).

Conclusion

Spherosomatography of Spinal Curves with Interpretation by “Developed Radius Method with Intersection Point” shows the high complexity of the dynamic part of the body: the Spine. The study of changes in Spinal Curves of Selected Swimmers is one step to a better understanding of short and long range effects of training of young swimmers. These changes are very individual and proper characteristics of every one, according to the stroke pattern, will help realize better results. This is a “functional adaptation.” Too early specialization during biological maturation in breast or backstroke could cause deviation and not be profitable for long range results. These deviations could become “functional Deformation” within breaststrokes - Hyperlordotic, within Backstrokers - Hyperkyphotic.

To avoid or diminish this deviation or deformation we suggest for the teacher-trainer a “natural approach in aquatic education,” practice of both opposite strokes and medley. In this manner we can look for the optimal adaptation of the profile of the spinal curve, use the natural abilities of the swimmer, and help him to reach the highest level helping him to practice his favorite sport for “lifetime.”

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