scoliosis etiopathology,
thorax asymmetry coefficients,
body's activity computer measurement

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THE COMPUTER ANALYSIS OF PHOTOGRAPHS THERMOVISION AND RTG PICTURES IN CORRELATION WITH SPIROMETRY IN SCOLIOSIS DIAGNOSTICS

In the study, the outline of etiopatogenesis and epidemiology of the lateral spinal curvature is presented. We proposed multiparameter verification of the radiography and spirometry factors detected by thermovision investigation conducted on the patients of The Outpatient Clinic for Rehabilitation. The binary, take-off board thermo-pictures carried out using different temperature thresholds, visualised asymmetry of infrared radiation emitted by paravertebral muscles in kinds of scoliosis and symmetric images in normal condition. The different level of the correlation between thermovision picture asymmetry factor (TAF), the value of the Cobb's angle and the normal breathing capacity index (VS, DS) were obtained depending on the type of scoliosis. The aim of the work was to answer the following questions: (1) In what type of scoliosis the correlation between curvature angle and the respiratory capacity and spine asymmetry factor SAF is the highest. (2) Does the noticeable asymmetry of para-vertebral muscles in the thermographic image exist among the groups of scoliosis examined? (3) Does the simple type of plan-metric image processing guarantee sufficient level of expression in infrared emission differences between para-vertebral muscles? (4) In which type of scoliosis the correlation between curvature angle, respiratory factors (VS, SD) and the thermoemission asymmetry index (TAF) is the highest.The research group consisted of 60 persons: 20 boys (33,3% of the group) and 40 girls (66,6%). The average age for girls was 13,5 (± 3,65), for boys – 12,7 (± 2,85). The control group consisted of 30 healthy children from The Second Primary School of Cieszyn of which 10 were boys aged on average 11,7 (± 1,25) and 20 were girls aged on average 12,8 (± 2,4).Conclusions: (1) asymmetry of termovision picture in correlation with respiratory factors and the Cobb's angle exists in long-arched curvatures mainly in mirror type. (2) thermovision asymmetry factor (TAF) and spine asymmetry factor (SAF) of light photographs had better correlations with Cobb's angle than respiratory parameters VC, DC, (3) simplified procedure for measuring asymmetry factors in photographs recommended this methods to screen scoliosis diagnostic because it is less expensive comparing to infrared camera diagnistics.

1. INTRODUCTION

The scoliosis is multi-plane and multi-ethiology spine defect, in which side curvature in frontal plane, changes of physiological curvature in the sagittal plane and rotation along its long axle occur and result in second curvature of vertebral body as a symptom of

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pathological structural adaptation to the modified biomechanics of the system [15,18,19,21,23,32]. Examination of large schoolchildren groups in Poland and in the world has revealed existence of scoliosis in 4 up to 14% of children aged between 10 to 14. In the group of pupils aged 10 to 11 scoliosis occurred with the same frequency in boys and girls, on the contrary progressive scoliosis occurs 5 times more often in girls aged 14 than in boys. Etiological agents in 10 to 20% cases of spine curvature were known but the remaining 80 to 90% are so called idiopathic scoliosis, which are being explained by many theories [33]. We distinguish functional and structural scoliosis [33].

Main characteristics of functional scoliosis is non-consolidated side curvature, which can be easily altered in a resting position. These are curvatures of a small degree (10 to 20 degrees) lacking fixed asymmetry of the trunk. The vertebra are not permanently changed in their structure in a wedge-shaped form, rotation or second curvature. The structural scoliosis reveal changes in structure or shape of separate vertebrae, whole of the spine and the trunk. These changes can be confirmed by clinical and radiological means, in the form of wedge–shaped, rotated and second curvature with ensuing deformation of the chest and the pelvis [15,19].

Depending on aetiology we can distinguish the following types of scoliosis:

- Bone-derivative innate scoliosis caused by disturbances in ossification processes.
- Bone-derivative acquired scoliosis caused by system or bacterial diseases, or by an injury during organogenesis or development.
- Nerve-derivative scoliosis caused by lesion of nervous system during organogenesis or development e.g. the Recklinghausen's disease or the Heine Medina's disease.
- Muscle-derivative scoliosis e.g. in the course of muscular dystrophy.
- Idiopathic scoliosis (80-90%), which aetiology is explained by many theories:
    1) The theory of innate changes in nervous system.
    2) The theory of rachitic changes (Gruca).
    3) The theory of physiological curvatures (Abbot, Lovett) postulates transformation of minor functional curvatures (asymmetry of internal organs) into structural changes
    4) The anatomical and functional theory which postulates co-existence of 3 factors indispensable for the development of changes: diseases weakening immunity of bones, growth distortion and faulty posture (Farkas)
    5) The osteoplastic theory – increase in plasticity (Doleg)
    6) The mechanical-static and dynamic theory /ligamentous/ postulates tension asymmetry of intertransverse ligaments, cost-vertebral and muscles (Pusch, Meyer)
    7) The theory of growth distortion (Heuer, Cotrel)
    8) The theory of disturbance in proteoglycans conversion (Farkas, Skwarcz, Ponseti)
    9) The theory of hereditary changes (Miodoński, Mitroszewska)The theory of distortion in muscle tension (Andry, Miles)

The most useful method in scoliosis diagnostics, together with interview and clinical examination, is the radiological evaluation, which allows to estimate level and degree of curvature. Sometimes we can state the cause e.g. innate vertebrae defect. Apart from that, we can see primary and secondary curvatures, degree of vertebra deformation, estimation of the progression of changes and child's skeletal age. Such data helps to establish correct therapeutic treatment [23,32,33]. Nowadays in scoliosis diagnostics spirometric tests are being routinely used, and they allow evaluation of breathing distortion caused by deformation of the chest. Electromyographic examination of paravertebral muscles is also used, as a resting examination or provocative tests [15,19,32].

The tests that applies thermovision examination to evaluate the functional state of organism [1,2,3,6,7,8,9,11,12,13,14,17,20,22,25,26,27,28] in therapy monitoring [5,30,31,34,35] and in particular paravertebral muscles in scoliosis are very interesting [35]. Taking into account the phenomenon of heat emission during contraction of a muscle, the amount of heat is proportional to the strength of contraction and its duration. This method allows to evaluate visually and simultaneously the intensity of metabolic processes on the surface of all spine muscles. Modern methods of vision processing are very important in this case [4,5,16,29,34]. Starting the research programme a few questions were asked. They were meant to specify the purpose of using the method in different types of curvatures.

2. THE AIM OF THE WORK

The aim of the presented work was to answer the following questions:

1) In what type of scoliosis the correlation between curvature angle, spine asymmetry factor (SAF) and the respiratory capacity is the highest?
2) Does the noticeable asymmetry of para-vertebral muscles in the thermographic image exist among the groups of scoliosis examined?
3) Does the simple type of plan-metric image processing guarantee sufficient level of expression in infrared emission differences between para-vertebral muscles ?
4) In which type of scoliosis the correlation between curvature angle, respiratory factors (VS, SD) and the thermoemission asymmetry index (TAF) is the highest?

3. THE MATERIAL AND THE METHOD

3.1. GROUPS

Including criteria:

The research was conducted among a group of patients (A) of The Outpatient Clinic for Rehabilitation SNZOZ “VIS” of Cieszyn treated for lateral spinal curvature > 10°. Generally excluding criteria:

The following subjects were excluded from the study: those who smoked cigarettes had a positive history for arterial hypertension, epilepsy, collagen disease, those who had suffered any knee, hip, shoulder, spine or neck injury or operation.

The research group (A) consisted of 60 persons of which 20 were boys (33,3% of the group) and 40 were girls (66,6%). The average age for a girl was 13,5 (± 3,65), for a boy – 12,7 (± 2,85). The group A divided on a three subgroups:

A1 – thoracic homoarcual scoliosis

A2 – thoraco-lumbar even with primary arch on LS section

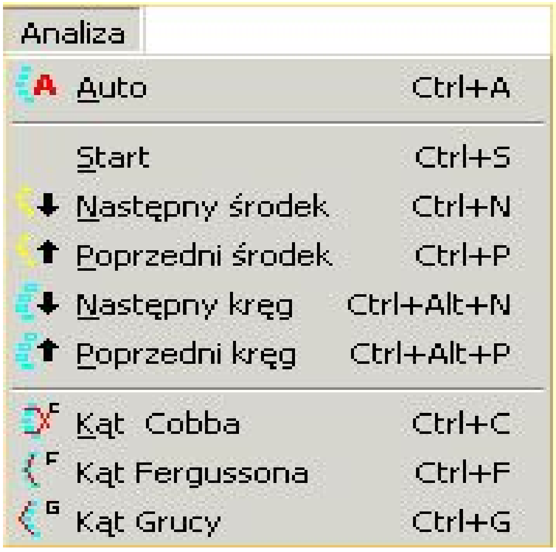
A3 – thoracolumbar homoarcual scoliosis, in most cases mirror-like

The control group B consisted of 30 healthy children from The Second Primary School of Cieszyn of which 10 were boys aged on average 11,7 (± 1,25) and 20 were girls aged on average 12,8 (± 2,4). Among the persons examined the following groups were distinguished:

Methods

Among the groups mentioned above the following research was conducted:

1) Radiogram pictures of lumbar and thoracic vertebrae and the Cobb's angle (CA) were delineated by computer plan metric program (based on neuronal network) (fig.1)
2) Thermovision pictures were conducted by means of thermovision camera ("Agema 450") made available by The Institute of Iron Metallurgy of Gliwice. The data (pictures) were collected by Irwin Image Viewer 1.01 and calculated to Thermovision Asymmetry Factor (TAF) by author's software (fig.2).
3) Standard light photography (spine) was conducted to computer by digital camera "Canon 5.0" and calculated to Spine Asymmetry Factor (SAF) by author's software (fig.3).
4) Respiratory examination by means of "Ascard 4" apparatus with respiratory accessory "Spiro 31" made by Aspel company to determine breathing capacity (VS – Volume Spirometry) and the percentage of total lung capacity (SD – spirometry % due) (fig. 4).



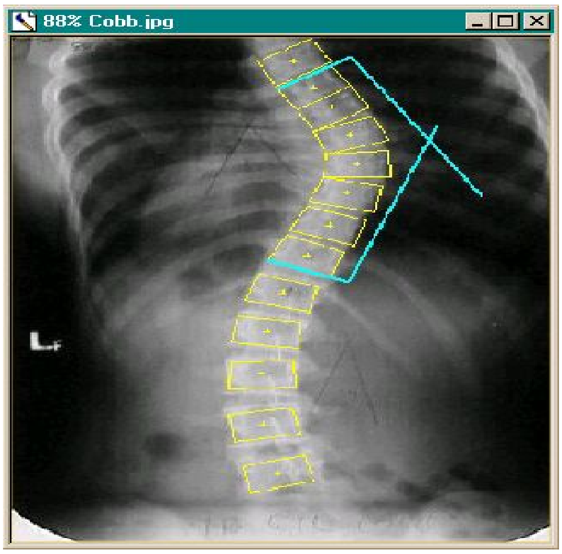
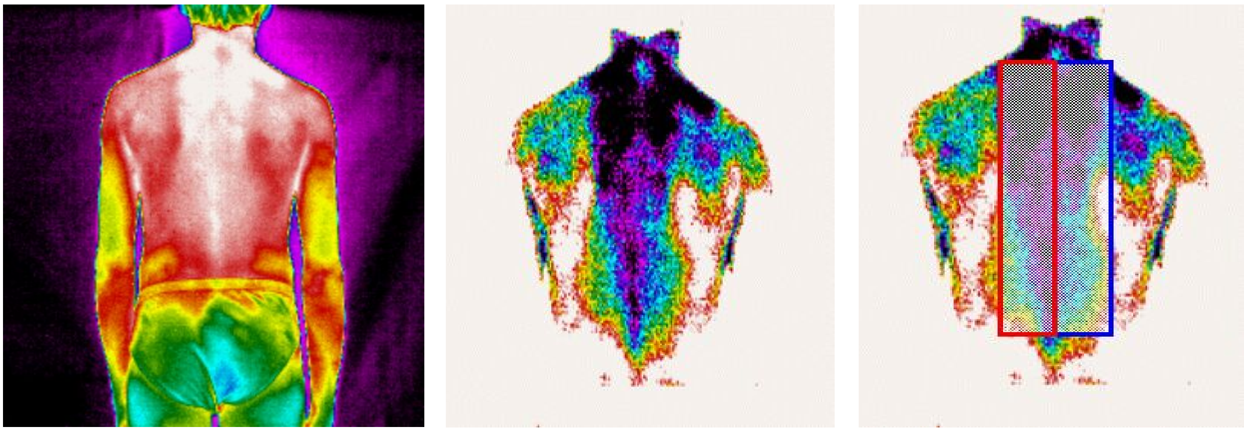


Fig.1. Plan-metric software, based on a neuron net: (a) dialogue window, (b) measuring window (parameters of Cobb's angle (CA))



a b c

Fig.2. Thermovision method (a) picture of a patient (PA projection), (b) the picture after binarisation and inversion (PA projection), (c) measuring template for the regions of the right and left side of the spine muscles (data for TAF estimate)

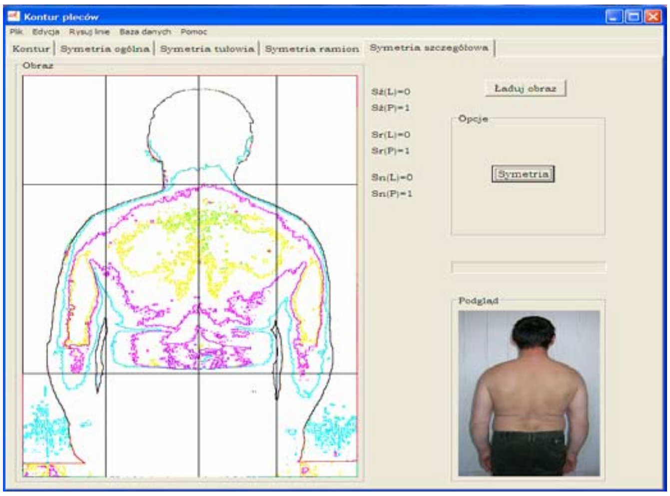


Fig.3. Photo-picture binary transformation (calculate data for Spine Asymmetry Factor (SAF)

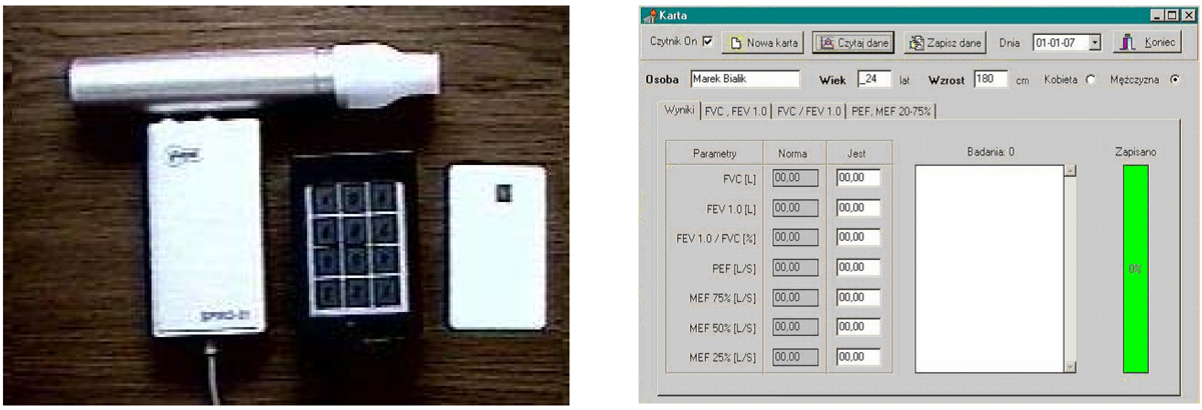


Fig.4. Respiratory examination system (Ascard 4): (a) spirometric accessory Spiro 31; (b) author's software for data acquisition "Spiro 1.0"

Initial condition

Temperature of the measurement room was 20°C. Patients included to measurement had acclimatization for 15 minutes. They were not smoking and drinking any caffeine drinks prohibited since the day before measurement (till measurement time). Before respiratory test patients had blood tension examination (by automatic system “OMRON” – exported data to EXCEL table). Only patients with tension lower than 140/90 been allowed to take the respiratory test.

The thermovision picture (fig. 2) of the patient received by the camera was decoded by means of the “Irwin Image Viewer 1.01” programme, and after binarisation according to the fixed temperature threshold, was a subject to measurement by means of the templates put against paravertebral muscles on the right and left side of the spine in standard location. On the measurement locations mentioned the pixels were counted and the histogram was made. The output of the measurement was defined by TAF rate (rate of thermal (infrared) emission asymmetry) describing proportions between the thermal emission activity on the bowstring side of the scoliosis to the activity on the arch side. We resigned from using the picture processing specialist software “Matlab” on purpose to increase chances of the simplified method to be used in medical environment.

Spirometer was connected with an AC processor and a PC computer. This signal was sampled with ca. 500 Hz trough an 10-bite analogue and digital processor DAC 18 and then transmitted to a PC computer. The curve of one pulse evolution consists of 825 points. The files were then processed by means of „Spiro 1.0” software, which enables to visualise the breath wave and to perform parametric analysis of any chosen fragments that are then averaged (from three waveforms of patient’s record). This procedure decreased standard deviation of plan metric parameters VC, DC.

4. RESULTS

Study results are shown in tab. 1-3 and in fig. 9-10. In A1 and A2 groups insignificant correlation between the Cobb’s angle and respiratory factors (SD) occurred. In A3 group the correlation value was noticeably lower, A1(0,504)>A2(0,47)>A3(0,33). Correlation between (CA) and (VS) was poor A2(0,55)>A1(0,53)>A3(0,43).

Correlation between the spirometry volume (VS) and the TAF factor was the highest in A3 group. Also correlation between the Cobb’s angle and the TAF factor was the highest in A3 group. Correlation between the Cobb’s angle (CA) and the (SAF) was good in group A1 (0,63), better in A2 (0,71) and best in A3 (0,83). Correlation with (CA) and the (TAF) was poor in group A1(0,27)<A2(0,38) and good in group A3(0,78).

Table 1. Data of Cobbs's angle (CA), spine asymmetry factor (SAF), volume spirometry (VS), spirometry % due (SD), thermovision asymmetry factor (TAF) in a group A1, A2, A3, B

Group	The Cobb's angle (CA)	Spine asymmetry factor (SAF)	Volume Spirometry (VS)	Spirometry % due (SD)	Thermovision Asymmetry factor (TAF)
A1	18,8 ± 5,68	0,79 ± 0,093	2,71 ± 0,93	63,4 ± 15,18	0,921 ± 0,085
A2	22,43 ± 14,17	0,71 ± 0,11	2,46 ± 0,59	61,87 ± 11,35	0,87 ± 0,08
A3	19,94 ± 8,18	0,84 ± 0,12	2,53 ± 0,58	64,47 ± 11,11	0,78 ± 0,09
B	–	0,93 ± 0,099	3,24 ± 0,51	71,2 ± 13,2	0,94 ± 0,11
p	(CA) A1-A2 p < 0,05	(PAF) A1-A2 p < 0,1	(VS) A1-A2 p < 0,1	(SD) A1-A2 p < 0,5	(TAF) A1-A2 p < 0,1
	(CA) A1 – A3 p < 0,5	(PAF) A1 – A3 p < 0,1	(VS) A1 – A3 p < 0,1	(SD) A1 – A3 p < 0,5	(TAF) A1 – A3 p < 0,05
	(CA) A2 – A3 p < 0,05	(PAF) A2 – A3 p < 0,05	(VS) A2 – A3 p < 0,5	(SD) A2 – A3 p < 0,5	A2 – A3 p < 0,1
	(CA) A1 – B –	(PAF) A1 – B p < 0,05	(VS) A1 – B p < 0,05	(SD) A1 – B p < 0,05	(TAF) A1 – B p < 0,5
	(CA) A2 – B –	(PAF) A2 – B p < 0,01	(VS) A2 – B p < 0,05	(SD) A2 – B p < 0,01	(TAF) A2 – B p < 0,1
	(CA) A3 – B –	(PAF) A3 – B p < 0,05	(VS) A3 – B p < 0,05	(SD) A3 – B p < 0,05	(TAF) A3 – B p < 0,05

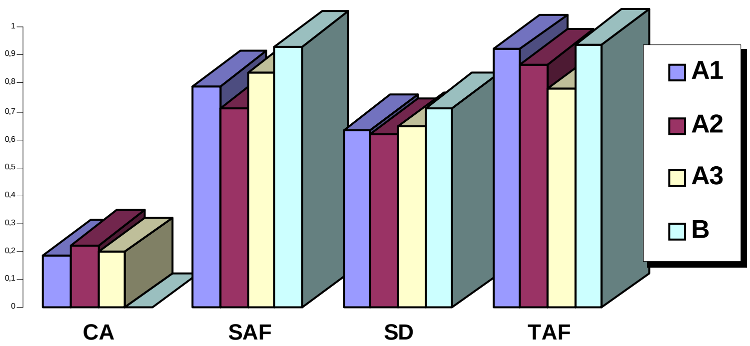


Fig.5. Graph of parameters CA, SAF, SD, TAF in groups A1, A2, A3, B

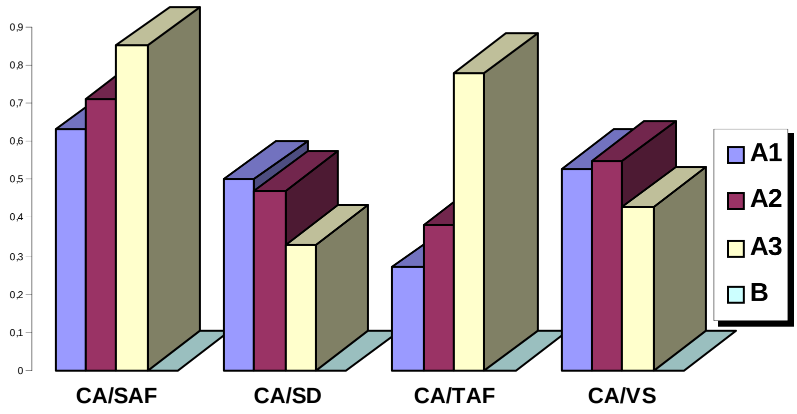


Fig.6. Graph of correlations between CA/SAF, CA/SD, CA/TAF, CA/VS

Table 2. Correlation between the Cobb's angle and the (PAF), (SD), (TAF), (VS) coefficients

Group	Correlation level			
	(CA) / (SAF)	(CA) / (SD)	(CA) / (TAF)	(CA) / (VS)
A1	0,63	0,504	0,27	0,53
A2	0,71	0,47	0,38	0,55
A3	0,83	0,33	0,78	0,43
B	–	–	–	–
P	(CA/SAF) A1-A2 $p < 0,05$	(CA/SD) A1-A2 $p < 0,0$	(CA/TAF) A1-A2 $p < 0,1$	(CA/VS) A1- A2 $p < 0,5$
	(CA/SAF) A1 – A3 $p < 0,01$	(CA/SD) A1 – A3 $p < 0,1$	(CA/TAF) A1-A3 $p < 0,01$	(CA/VS) A1 – A3 $p < 0,1$
	CA/SAF) A2 – A3 $p < 0,05$	CA/SD) A1 – A3 $p < 0,01$	CA/TAF) A2– A3 $p < 0,05$	CA/PAF) A1– A3 $p < 0,1$
	(CA/SAF) A1 – B	(CA/SD) A1 – B –	(CA/TAF) A1– B –	(CA/PAF) A1– B –
	(CA/SAF) A2 – B –	(CA/SD) A2 – B –	(CA/TAF) A2– B –	(CA/VS) A2 – B –
	(CA/SAF) A3 – B –	(CA/SD) A3 – B –	(CA/TAF) A3– B –	(CA/VS) A3 – B –

Table 3. Correlation between VS, DS – SAF, TAF

Groups	Correlations			
	VS / SAF	DS / SAF	VS / TAF	SD / TAF
A1	0,53	0,52	0,28	0,25
A2	0,51	0,49	0,33	0,31
A3	0,69	0,65	0,64	0,61
B	0,88	0,78	0,83	0,71
p	(VS / SAF) A1-A2 $p < 0,5$	(DS / SAF) A1-A2 $p < 0,5$	(VS / TAF) A1-A2 $p < 0,1$	(VS / TAF) A1-A2 $p < 0,1$
	(VS / SAF) A1-A3 $p < 0,1$	(DS / SAF) A1-A3 $p < 0,1$	(VS / TAF) A1-A3 $p < 0,05$	(VS / TAF) A1-A3 $p < 0,05$
	(VS / SAF) A2-A3 $p < 0,05$	(DS / SAF) A2-A3 $p < 0,1$	(VS / TAF) A2-A3 $p < 0,05$	(VS / TAF) A2-A3 $p < 0,05$
	(VS / PAF) A1-B $p < 0,05$	(DS / SAF) A1-B $p < 0,05$	(VS / TAF) A1-B $p < 0,01$	(VS / TAF) A1-B $p < 0,01$
	(VS / SAF) A2 – B $p < 0,05$	(DS / SAF) A2 – B $p <$	(VS / TAF) A2 – B $p < 0,01$	(VS / TAF) A2 – B $p < 0,01$
	(VS / SAF) A3- B $p < 0,05$	(DS / SAF) A3- B $p < 0,05$	(VS / TAF) A3- B $p < 0,05$	(VS / TAF) A3- B $p < 0,01$

Correlation between the (VS) and the (SAF) is poor in groups A2(0,51)<A1(0,53), better in group A3(0,69) and good in B(0,88). Correlation between (DS) and (SAF) is similar. Correlation between (VS) and (TAF) is poor A1(0,28)<A2(0,33), better in A3(0,64) and very good in B(0,83). Correlation between (SD) and (TAF) is similar.

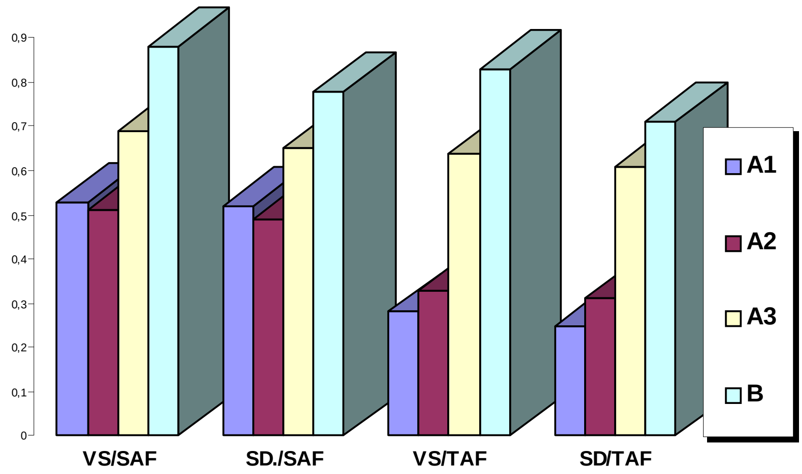


Fig.7. Graph of correlations between VS/SAF, SD/SD, VS/TAF, SD/VS

5. CONCLUSSIONS

1) Asymmetry of termovision picture in correlation with respiratory factors and the Cobb's angle exists in longarched curvatures mainly in mirror type.
2) Thermovision asymmetry factor (TAF) and spine asymmetry factor (SAF) of light photographs (detected paravertebral muscle status) had better correlations with Cobb's angle than respiratory parameters VC, DC.
3) Simplified procedure for measuring asymmetry factors in photographs recommended this methods to screening scoliosis diagnostic because it is less expensive in correlation with infrared camera.

6. DISCUSSION

Statistical analysis among the groups examined proved the highest correlation between respiratory factors (VC, DC) and the Cobb's angle in the group A3.

The phenomenon might have been caused by existence of long curve mirror scoliosis in which phenomena of respiratory path changes compensation in lungs parenchyma among the group mentioned did not occur. Also the highest correlation factor between thermography asymmetry factor which is manifestation of muscle activity asymmetry indicates size (SAF) and infra-red muscle activity (TAF) in the process of scoliosis formation - only in the group A3. That phenomenon did not occur in the groups A1 and A2 in which biomechanics of curved spine reached probably the level of osseous stabilisation.

BIBLIOGRAPHY

[1] BENINGTON J, BIAGIONI P, CROSSEY P. Temperature changes in bovine mandibular bone during implant site preparation; an assesment using infra red thermography. J Dent 1996 Jul, 20, pp. 263-267.
[2] BIANCHI S, GATTI G, MECOZZI B. Circadian variations in the cutaneous thermal map in normal subjects. Acta Thermographic 1979, Vol. 4, 3, pp. 95-98.
[3] CLARK R, GOFF M, MAC DERMOT K. Identification of functioning sweat pores and visualization of skin temperature patterns in X linked hypohidrotic ectodermal dysplasia by whole body thermography. Human Genetics 1990 Nov, 86(1), pp. 7-13.
[4] DOROSZEWSKI J. Komputerowe wspomaganie diagnostyki medycznej. W: Nałęcz M. Problemy biocybernetyki i inżynierii biomedycznej. WKŁ Warszawa 1990, pp. 94-207.
[5] DYSZKIEWICZ A, BURCZYK J. Próba zalgorytmizowania zasad diagnostyki i terapii systemu wodoleczniczego Żniniewicza z zastosowaniem komputerowej termowizji. Postępy Rehabilitacji, 1999.
[6] DYSZKIEWICZ A, WRÓBEL Z. Możliwości zastosowania technik informatycznych w medycynie, biologii i ochronie środowiska. Problemy Ochrony Środowiska, Katowice 1999, 7, pp. 233-255.
[7] ENGEL J, COSH J, RING E. Thermographie bei erkrankungen des bewegungsapparates. Anglo Dutch Thermographic Society, 1978 Rotterdam, pp. 2-16.
[8] GOLDIE I. Der heutige Stand der Thermographie in klinischer und experimentaller Anwendung. Ein Symposium uber Thermographie 21-22 Mai 1971, Kurstadt Baden, pp. 2-10.
[9] HAJEK P, JAKOUBEK B, KYHOS K. Increase of cutaneous temperature induced by hypnotic suggestion of pain. Percept Mot Skills 1992 Jun, 70(3), pp.737-738.
[10] HARDLEY L. Anatomico-Roentgenographic study of the spine. Springfield 1964, pp. 95-121
[11] HUSSEY D, BIAGIONI P, LEMEY P. Thermographic measurment of temperature change during resin composite polymeryzation in vivo. J Dent 1990 Oct, 23, pp. 267-271.

[12] IVANOV V, BEGAURI N. The role of thermography in the diagnosis of the obliterating vascular disorders of the lover extremities. Khirurg Mosk 1992 May-Jun, 6, pp. 38.
[13] JONES C, Xenofos S. The influence of body contours on surface temperature distribution. Acta Thermographic 1979 Vol 4, 3, pp. 113-117
[14] KELLNER G. Voraussetzungen fur die Reactionsprufung mit Infrarotgeraten. Ein Symposium uber Thermographie, 21-22 Mai 1971, Kurstadt Baden, II/pp. 2-17
[15] KRÓL J, PUCHER A. SKOLIOZY. W: MILANOWSKA K. Rehabilitacja medyczna. PZWL Warszawa 1993, pp.230-264.
[16] KULIKOWSKI J. Komputerowe metody przetwarzania obrazów. W: Nałęcz M. Problemy biocybernetyki i inżynierii biomedycznej. WKŁ Warszawa 1990, pp. 254-317.
[17] LOBZIN V, ZHULEV N, KOSACHEW V. Autonomic vascular disorders in neuropathies and the methods for their pathogenic therapy. Zh Nevropatol Psikhiatr 1992 Wint, 2, pp. 77-80.
[18] MAJOCH S. Kinezyterapia w bocznych skrzywieniach kręgosłupa. W: Zembaty A. Fizjoterapia. PZWL Warszawa 1987, pp. 209-244.
[19] MILANOWSKA K. Wady postawy. W: Rehabilitacja medyczna. PZWL Warszawa, 1993, pp. 274-288.
[20] MINITENTAG I, MARGUES E, RIBEIRO M. Thermographic study of laser on arteries. Laser Surg Med 1987, 7, pp. 307-329.
[21] NAWOTNY J. Neurofizjologiczne aspekty korekty odchyleń od prawidłowej postawy ciała. W: Nawotny J. Dysfunkcje kręgosłupa, diagnostyka, terapia. Katowice 1993, pp. 21-37.
[22] NORMELLI H, SEVASTIK J, WALLBERG H. The thermal emission from the skin and the and the vascularity of the brest in normal and scoliotic girls. Spine 1986 Jan, 3(1), pp. 92-97.
[23] OCIEPKA R, ŁĘCZYŃSKI R. System aktywnej korekcji idiopatycznych skolioz oparty na patogenezie i patomechanice skrzywienia. W: Nawotny J. Dysfunkcje kręgosłupa, diadnostyka, terapia cz. II. Katowice 1993, pp. 157-167.
[24] RING E. Objective measurment of arthritis by thermography. Acta Thermographic 1980, Vol 5, 1, pp. 14-18.
[25] SHAPIRA N, LEMOLE G, SPAGNA P. Antegrade and retrograde infusion of cardioplegia assesment by thermovision. Ann Thorac Surg 1987 Jan, 3(1), pp. 92-97.
[26] SHEVELEV J, TSIACOLOV E, BUDKO K. Dynamic infrared functional mapping of the cerebral cortex. 1990, 1(6), pp. 71-77.
[27] SHEVELEV J, TSICALOV E, GORBACH A. Termoimaging of the brain. J Neurosci Meth 1993 Jan, 6(1),pp. 7-9.
[28] SHEVELEV I. Temperature topography of the brain cortex; thermoencephaloscopy. Brain Topography 1992 Wint, 2, pp. 77-80.
[29] SZAMOWSKA R. Fizyczne podstawy termografii. W: Stopczyk M. Elektrodiagnostyka medyczna. PZWL Warszawa 1984, pp. 266-271.
[30] TAUCHMANNOVA H, TAUCHMANN M, MISTINA T. Use of thermography for the evaluation of physical therapy. Acta Thermographic 1979 Vol 4, 3, pp.129-131.
[31] TOGAWA T, Saito H. Non contact imaging of thermal properities of the skin. Physiol Meas 1990 Aug, 10(3), pp.291-298.
[32] TYLMAN D. Boczne skrzywienia kręgosłupa. W: Patomechanika bocznych skrzywień kręgosłupa. Severus Warszawa 1995, pp. 62-106.
[33] TYLMAN D. Postawa i jej wady. W: Patomechanika bocznych skrzywień kręgosłupa. Severus Warszawa 1995, pp.44-60.
[34] VOLKER D. Thermographie heute. Ein Symposium uber Thermographie, 21-22 Mai 1971, Kurstadt Baden, III/1-7.
[35] WEXLER C. Thermographic evaluation of trauma spine. Acta Thermographic 1980, Vol 5, 1, pp. 3-11.