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Simplified analysis of spine thermovision picture in diagnostics of scolioses

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In the study, the outline of ethiopathogenesis and epidemiology of the lateral spinal curvature is presented. We proposed a simplified verification of the radiography and spirometry factors detected by thermovision investigation conducted on patients of the Outpatient Clinic for Faculty Posture of Cieszyn. The binary, take-off board thermo-pictures were taken using different temperature thresholds, visualised asymmetry of infrared radiation emitted by paravertebral muscles in some kinds of scolioses and symmetric images in normal condition. The different levels of correlation between thermovision picture asymmetry factor (WAT), the value of Cobb's angle and the normal breathing capacity index were obtained, depending on the type of scoliosis.

Key words: spinal curvature, thermovision, thermo-pictures, paravertebral muscles, scoliosis

1. Introduction

The scoliosis is a multi-plane and multietiological defect, in which side curvature in a frontal plane, changes of physiological curvature in the sagittal plane and rotation about its long axle occur and result in the second curvature of vertebral body as a symptom of pathological structural adaptation to the modified biomechanics of the system [15], [18], [19], [21], [23], [32]. Examination of large groups of schoolchildren in Poland and in the world revealed scoliosis in 4 up to 14% of children aged between 10 to 14. In the group of pupils aged from 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 are known, but the remaining 80 to 90% contribute to the so-called idiopathic scoliosis, which is being explained by many theories [33]. We distinguish functional and structural scolioses [33].

Functional scolioses are mainly characterized by non-consolidated side curvature which can be easily altered in a resting position. These are curvatures of small degree (10 to 20 degrees) lacking fixed asymmetry of the trunk. The vertebrae are not permanently changed in their structure in a wedge-shaped form, rotation or second curvature. The yield after casual factor, e.g. difference in length between lower limbs, and the pain accompanying scoliosis is removed. Functional scoliosis resulting from the difference in the length between lower limbs can fix, leading to structural changes in vertebrae when not treated for a long time [32], [35].

The structural scolioses reveal changes in the structure or shape of separate vertebrae, whole of the spine and the trunk. These changes can be confirmed by clinical and radiological examinations, whose results are obtained in the form of wedge-shaped, rotated and second curvature with ensuing deformation of the chest and the pelvis [15], [19].

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

1. Bone-derivative innate scoliosis caused by disturbances in ossification processes.

2. Bone-derivative acquired scoliosis caused by the system of bacterial diseases, or by injury during organogenesis or development.

3. Nerve-derivative scoliosis caused by lesion of nervous system during organogenesis or development, e.g. Recklinghausen's disease or the Heine–Medina disease.

4. Muscle-derivative scoliosis, e.g. in the course of muscular dystrophy.

5. Idiopathic scolioses (80–90%), whose etiology is being explained by the following theories:

• The theory of innate changes in nervous system.

• The theory of rachitic changes (Gruc).

• The theory of physiological curvatures (Abbott, Lovett) postulates transformation of minor functional curvatures (asymmetry of internal organs) into structural changes.

• The anatomical and functional theory which postulates co-existence of three factors indispensable for the development of changes: diseases weakening the immunity of bones, growth distortion and faulty posture (Farkas).

• The osteoplastic theory – increase in plasticity (Doleg).

• The mechanical-static and dynamic theory (ligamentous) postulates tension asymmetry of intertransverse and costovertebral ligaments and muscles (Pusch, Meyer).

• The theory of growth distortion (Heuer, Cotrel).

• The theory of disturbance in proteoglycans' conversion (Farkas, Skwarcz, Ponseti).

• The theory of hereditary changes (Miodoński, Mitroszewska).

• The theory of distortion in muscle tension (Andry, Miles).

The most useful method in diagnosing scolioses, together with interview and clinical examination, is their radiological evaluation, which allows us to estimate the level and degree of curvature. Sometimes we can establish the cause, e.g. an innate vertebrae defect. Apart from that we can see the primary and secondary curvatures, degree of vertebra deformation, estimation of the progression of changes and child's skeletal age. Such data enable us to establish a correct therapeutic treatment [23], [32], [33].

Nowadays in diagnosing scolioses, 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 done as a resting examination of provocative tests [15], [19], [32].

The tests to apply thermovision examination to evaluate the functional state of organism [1]–[3], [6]–[9], [11]–[14], [17], [20], [22], [25]–[28] in therapy monitoring [5], [30], [31], [34], [35] and in particular paravertebral muscles in scolioses 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 us to evaluate visually metabolic processes on the surface of all spine muscles and simultaneously the intensity of these processes. Modern methods of vision processing are very important in that 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 research

The aim of the research was to answer the following questions:

1. In what type of scoliosis, the correlation between a primary curvature angle (calculated according to Cobb's method) and the percentage of normal inspiratory capacity of the patients examined is the highest?
2. Does the noticeable asymmetry of paravertebral muscles in the thermographic image exist in the groups of scolioses examined?
3. Does the simple type of morphometric image processing guarantee a sufficient level of differences between paravertebral muscles during thermionic emission?
4. In which type of scoliosis, the correlation between primary curvature angle, the normal breathing capacity factor and the thermoemission asymmetry index (WAT) is the highest?

3. The material and the method

The research was conducted on a group of patients of the Outpatient Clinic for Faulty Posture (ZZOZ of Cieszyn) treated for lateral spinal curvature. The group being tested consisted of 50 persons: 10 boys (20% of the group) and 40 girls (80%). The average age of a girl was 13.5 (±3.65) and that of a boy – 12.7 (±2.85). The control group consisted of 30 healthy children from the Second Primary School of Cieszyn: 10 boys aged on average 11.7 (±1.25) and 20 girls aged on average 12.8 (±2.4).

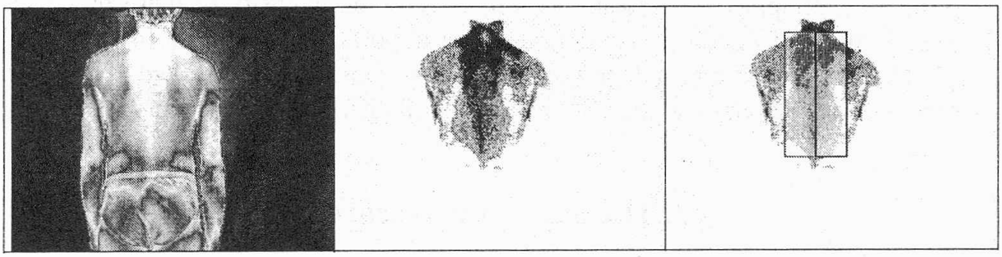
The research conducted on the groups mentioned above comprises:

1. Radiogram pictures of lumbar and thoracic vertebrae and delineation of Cobb's angle.

2. Spirometric examination by means of "Ascard 4" apparatus with spirometric accessory "Spiro 31" made by Aspel company to determine breathing capacity and the percentage of total lung capacity.

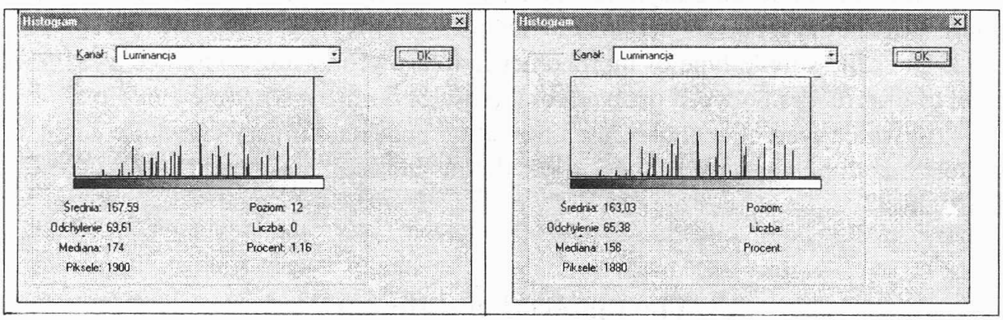
The research was conducted by means of thermovision camera ("Agema") made available by the Institute of Iron Metallurgy of Gliwice. Among the persons examined the following groups were distinguished:

- A1 – thoracic homoarcual scoliosis,
- A2 – thoracolumbar scoliosis even with primary arch on LS section,
- A3 – thoracolumbar homoarcual scoliosis, in most cases mirror-like,
- B – control group.



a b c

Fig. 1. Simplified algorithm for thermovision image analyses: a) the thermovision picture of a patient (PA projection), b) the picture after binarisation and inversion (PA projection), c) measuring template for the muscle regions of the right and left sides of the spine



a b

Fig. 2. Histograms of the measurement regions: a) the left measuring template; diameter: 167.59, deviation: 69.61, median: 174, pixels: 1900, level: 12, number: 0, percent 1.16, b) the right measuring template; diameter: 163.03, deviation: 65.38, median: 158, pixels: 1880

The thermovision picture of a patient obtained 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 of measurement by means of the templates for paravertebral muscles on the right and left sides 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 the WAT rate (the rate of thermionic emission asymmetry) describing the proportion of the thermionic emission activity on the bowstring side subjected to scoliosis to the activity on the arch side. We resigned from using the picture processing specialist software "Matlab" on purpose, to increase the chances of the simplified method to be used in medical environment.

4. Results

Table 1. Correlation between Cobb's angle and normal inspiratory capacity

Group	Cobb's angle	Spirometry	Spiro. % due	Correlation angle /spiro. %
A1	18.8±5.68	2.71±0.93	63.4±15.18	0.27
A2	22.43±14.17	2.46±0.59	62.57±11.35	0.21
A3	19.94±8.18	2.53±0.58	64.47±11.11	0.62
B	–	3.24±0.51	71.2±13.2	–

Table 2. Correlation between normal inspiratory capacity factor and WAT

Group	Spiro. % due	WAT factor	Correlation spiro. %/WAT
A1	63.4±15.18	0.93±0.085	0.25
A2	62.57±11.35	0.87±0.08	0.31
A3	64.47±11.11	0.78±0.09	0.72
B	71.2±13.2	0.94±0.11	0.21

Table 3. Correlation between Cobb's angle, normal inspiratory capacity factor and WAT

Group	Correlation angle /spiro. %	Correlation spiro. %/WAT	Correlation angle/WAT
A1	0.27	0.25	0.27
A2	−0.21	0.31	0.38
A3	−0.62	0.72	0.68
B	–	0.21	–

In A1 and A2 groups, an insignificant correlation between Cobb's angle and the normal inspiratory capacity factor occurred. In A3 group, the correlation was noticeably higher. Correlation between the normal inspiratory capacity and the WAT factor was the highest in A3 group. Also correlation between Cobb's angle and the WAT factor was the highest in A3 group.

5. Discussion

Statistical analysis for the groups examined proved that the highest correlation occurred between normal inspiratory capacity factor and Cobb's angle in the A3 group. This phenomenon might have been caused by long-curve mirror scolioses in which the compensation for respiratory path changes in lung parenchyma in the group mentioned did not occur. Also the highest correlation between thermographic asymmetry factor and muscle activity asymmetry proves that muscles are active in the process of scoliosis formation only in the A3 group. That phenomenon did not occur in the A1 and A2 groups in which biomechanics of curved spine reached the level of osseous stabilisation. On the basis of the observations we can draw the following conclusions:

- Noticeable asymmetry of termovision picture is correlated with spirometric factors and Cobb's angle in long-arched curvatures, mainly of mirror type.
- Simplified procedure for measuring thermionic emission by means of easily available software is sufficient for screening description od asymmetry in the work of paravertebral muscles when scolioses occur.

Literature

[1] BENINGTON J., BIAGIONI P., CROSSEY P., *Temperature changes in bovine mandibular bone during implant site preparation; an assessment using infra-red thermography*, J. Dent., 1996, July 20, 263–267.

[2] BIANCHI S., GATTI G., MECOZZI B., *Circulation variations in the cutaneous thermal map in normal subjects*, Acta Thermogr., 1979, Vol. 4, 3, 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*, Hum Genet, 1990 Nov., 86 (1), 7–13.

[4] DOROSZEWSKI J., *Komputerowe wspomaganie diagnostyki medycznej*, [w:] Nałęcz M., *Problemy biocybernetyki i inżynierii biomedycznej*, WKŁ, Warszawa, 1990, 94–207.

[5] DYSZKIEWICZ A., BURCZYK J., *Próba zlogarytmizowania zasad diagnostyki i terapii systemu wodoleczniczego Żniniewicza z zastosowaniem komputerowej termowizji*, Post. Rehab., 1999.

[6] DYSZKIEWICZ A., WRÓBEL Z., *Możliwości zastosowania technik informatycznych w medycynie, biologii i ochronie środowiska*, Probl. Środ. Ochr., Katowice, 1999, 7, 233–255.

[7] ENGEL J., COSH J., RING E., *Thermographie bei erkrankungen des bewegungsapparates*, Anglo Dutch Thermographic Society, 1978, Rotterdam, 2–16.

[8] GOLDIE I., *Der heutige Stand der Thermographie in klinischer und experimentaller Anwendung*, Ein Symposium über Thermographie, 21–22 Mai, 1971, Kurstadt Baden, 2–10.

[9] HAJEK P., JAKOUBEK B., KYHOS K., *Increase of cutaneous temperature induced by hypnotic suggestion of pain*, Percept. Mot. Skills, 1992 June, 70 (3) 737–738.

[10] HARDLEY L., *Anatomico-roentgenographic study of the spine*, Springfield, 1964, 95–121.

[11] HUSSEY D., BIAGIONI P., LEMEY P., *Thermographic measurement of temperature change during resin composite polymerization in vivo*, J. Dent., 1990 October, 23, 267–271.

[12] IVANOV V., BEGAURI N., *The role of thermography in the diagnosis of the obliterating vascular disorders of the lower extremities*, Khirurg., Mosk., 1992 May–June, 6, 38.

[13] JONES C., XENOFOS S., *The influence of body contours on surface temperature distribution*, Acta Thermogr., 1979, Vol. 4, 3, 113–117.

[14] KELLNER G., *Voraussetzungen für die Reactionsprufung mit Infrarotgeraten*, Ein Symposium über Thermographie, 21–22 Mai, 1971, Kurstadt Baden, II/2–17.

[15] KRÓL J., PUCHER A., *Skoliozy*, [w:] *Rehabilitacja medyczna*, PZWL, Warszawa, 1993, 230–264.

[16] KULIKOWSKI J., *Komputerowe metody przetwarzania obrazów*, [w:] Nałęcz M., *Problemy biocybernetyki i inżynierii biomedycznej*, WKŁ, Warszawa, 1990, 254–317.

[17] LOBZIN V., ZHULEV N., KOSACHEV V., *Autonomic vascular disorders in neuropathies and the methods for their pathogenic therapy*, Zh. Nevropatol. Psikhiatr., 1992, Wint, 2, 77–80.

[18] MAJOCH S., *Kinezyterapia w bocznych skrzywieniach kręgosłupa*, [w:] Zembaty A., *Fizjoterapia*, PZWL, Warszawa, 1987, 209–244.

[19] MILANOWSKA K., *Wady postawy*, [w:] *Rehabilitacja medyczna*, PZWL, Warszawa, 1993, 274–288.

[20] MINITENTAG I., MARGUES E., RIBEIRO M., *Thermographic study of laser on arteries*, Laser Surg. Med., 1987, 7, 307–329.

[21] NAWOTNY J., *Neurofizjologiczne aspekty korekty odchyleń od prawidłowej postawy ciała*, [w:] Nawotny J., *Dysfunkcje kręgosłupa, diagnostyka, terapia*, Katowice, 1993, 21–37.

[22] NORMELLI H., SEVASTIK J., WALLBERG H., *The thermal emission from the skin and the vascularity of the brest in normal and scoliotic girls*, Spine, 1986 January, 3 (1), 92–97.

[23] OCIEPKA R., ŁĘCZYŃSKI R., *System aktywnej korekcji idiopatycznych skolioz oparty na patogenezie i patomechanice skrzywienia*, [w:] Nawotny J., *Dysfunkcje kręgosłupa, diagnostyka, terapia*, cz. II, Katowice, 1993, 157–167.

[24] RING E., *Objective measurement of arthritis by thermography*, Acta Therm., 1980, Vol. 5, 1, 14–18.

[25] SHAPIRA N., LEMOLE G., SPAGNA P., *Antegrade and retrograde infusion of cardioplegia assessment by thermovision*, Ann. Thorac., Surg., 1987 January, 3 (1), 92–97.

[26] SHEVELEV J., TSIACOLOV E., BUDKO K., *Dynamic infrared functional mapping of the cerebral cortex*, Biomed. Sci., 1990, 1 (16), 71–77.

[27] SHEVELEV J., TSICALOV E., GORBACH A., *Thermoimaging of the brain*, J. Neurosci. Meth., 1993 January, 6 (1), 7–9.

[28] SHEVELEV J., *Temperature topography of the brain cortex; thermoencephaloscopy*, Brain Topogr., 1992, 2, 77–80.

[29] SZAMOWSKA R., *Fizyczne podstawy termografii*, [w:] Stopczyk M., *Elektrodiagnostyka medyczna*, PZWL, Warszawa, 1984, 266–271.

[30] TAUCHMANNOVA H., TAUCHMANN M., MISTINA T., *Use of thermography for the evaluation of physical therapy*, Acta Thermograph., 1979, Vol. 4, 3, 129–131.

[31] TOGAWA T., SAITO H., *Non-contact imaging of thermal properties of the skin*, Physiol. Meas., 1990 August, 10 (3), 291–298.

[32] TYLMAN D., *Boczne skrzywienia kręgosłupa*, [w:] *Patomechanika bocznych skrzywień kręgosłupa*, Severus, Warszawa, 1995, 62–106.

[33] TYLMAN D., *Postawa i jej wady*, [w:] *Patomechanika bocznych skrzywień kręgosłupa*, Severus, Warszawa, 1995, s. 44–60.

[34] VOLKER D., *Thermographic heute*, Ein Symposium über Thermographie, 21–22 Mai 1971, Kurstadt Baden, III/1–7.

[35] WEXLERC., *Thermographic evaluation of trauma spine*, Acta Thermograph., 1980, Vol. 5, 1, 3–11.