Trend projections of body deformities occurrence between the ages of 5 and 12, Metrically objectified and estimated by 3D postural status screening

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Trend Projections of Body Deformities Occurrence between the ages of 5 and 12, Metrically Objectified and Estimated by 3D Postural Status Screening

Kovač, S.*; Kajmović,H.*; Rađo,I.*; Manić, G**

*University of Sarajevo – Faculty of Sport and Physical Education

** University of Sarajevo – Faculty of Health Studies

Key words: Scoliosis screening, Prevalence rate, Spinal screening, Changing trend, Awareness, Human pose estimation

Abstract

The aim of this paper is comparative analysis of different posture status, recorded for 3D evaluation, in regards to a relatively heterogeneous group of children, with the trend projection of physical deformity development, estimated for n=699 children between the ages of 5 and 12, during the implementation of IPA SpineLab project, financed by European Commission. The samples of 17 variables are " Contemplas 3D posture compact" variables recorded following a precise protocol. According to the increasing deviation trend in correlation to vertical zero, an increase in the occurrence of the mean values for most variables is noticeable, which is making the situation in a researched groups much worse, except for the thoracic part of the spine in sagital plane, which according to the physiological curve in this part indicates that from the fifth to the twelfth year of age number of children with kyphotic deviation is increasing. In addition to the status of the spine there is a significant increase in the shape deviation of legs in correlation to the zero value, which is a noticeable increase in children with compromised leg angle, thigh and lower part of leg with a noticeable incline towards valgus position, as well as the knee joint hyperextension.

Introduction

Current civilisation is characterised by a specific lifestyle. From ecological and kinesiological perspective, living in cities is not a favourable circumstance. Deformities and the present illnesses- overweight and nervous tension are frequent occurrence among the children and youth, who use their free time for the activities which require little or no muscular effort (Prskalo and co-authors, 2010.). It is a generally known fact that young people still at an early adolescent age start accepting contemporary lifestyle imposed upon them. Computerisation and the growing impact of internet have taken their toll on the health status of every individual. Childhood and adolescence has been recognised as the critical age for adopting and maintaining the habits of performing physical exercise (Huddleston and co-authors, 2002.). Present generations live their lives in a virtual world which affects their health (mental and physical) negatively. Imagination and Virtual Reality is formulated so as to respond to the needs of mass application, it decreases the possibilities of personal creativity and separates an individual from real life and personal initiative by developing unified mentality stereotypes (Andrijašević, 2009.).

Contemporary life styles result in an increase of irregular body posture in children and youth. The problem of today is hypokinesia (decreased bodily movement) which leads to unbalanced development of certain muscle groups (Paušić, 2007.).

Posture is a descriptive term for the relative position of the body segments during rest or activity. The maintenance of good posture is a compromise between minimizing the load on the spine and minimizing the muscle work required. (Standring, 2007.). Muscles of the leg, pelvis, abdomen and back along with bones, ankles and ligaments participate in maintaining proper posture. If the muscles are strong enough to overcome Earth's gravitational force than the body will remain in the upright position, however if the muscles are not strong enough one would experience fatigue and the body would relax (Avdić and co-authors 2007.). In regards to the aforementioned, positive impact of any physical activity along with other healthy life habits, first and foremost adequate nutrition should be promoted through the physical and health education classes in schools.

If one wants to significantly affect the anthropological dimensions of younger school-aged children it is necessary to select physical exercising modes characterised as general, and their application should run with optimum intensity (Aleksić, 2009.). The results of annual medical examinations indicate the unsatisfactory status, especially regarding the data attesting to the status of feet, spine, frequent bad posture and increasing percentage of overweight children. At the same time, expert analysis and the results of numerous numbers of research papers demonstrate growing preferences in children practicing sedentary way of life and lacking the habit of performing regular physical exercise. Skeletal system in this age, especially spine and feet demand special attention during education: straightening of the spine, insufficiently developed musculature, irregular sitting position in school benches, easily lead to premature deformations which should be treated on time (Ilić, 2009; Bogdanović and co-authors, 2008.).

Human upright position is conditioned by maintaining constant balance between paravertebal muscles and gravity's centripetal force. This game in maintaining the upright position during the human evolution has contributed to the following physiological characteristics: lordosis of the cervical and lumbar region of the spine and kyphosis in thoracic spine section. If these curvatures appear within physiological norms, they are considered regular feature, however if their increase or decrease is noticed, that is regarded to be abnormal (Gajić, 2009.). Postural deformities are frequent in children and adolescents. In preschool and early school-aged children functional postural disorders are most common, while in adolescent age structural deformities of spinal column are a characteristic feature (Adzar, 2004; Demeši, 2007.). Under the influence of internal and external factors the musculoskeletal system of children in development is susceptible to deformities. The most common deformities during children's development are: kyphosis, scoliosis, lordosis, protuberant and sunken chest, flat feet, winged scapula, "x" (genua valga) and "o" (genua vara) legs.

During one's lifetime there are three significant stages when different samples may lead to posture deformities: Pre-school stage – during the first year a child gradually takes the upright posture and forms physiological spinal curves. If this phase occurs earlier, postural deformity might occur. School stage – starting school a child undergoes great changes, spending a lot of time sitting, carrying heavy school bags may lead to posture deformities. Some of the factors which can contribute to postural disorders are: school bag which weights more than 10 % of child's body weight, carrying school bags over one shoulder, irregularly placed schools bag, etc. Puberty stage – discordance between skeletal growth and muscle strengthening often leads to bad posture (Avdić and co-authors 2007.).

Connection between growth and progression of the spinal curve is the most common starting point when describing the occurrence and development of spinal abnormality. Between the ages of 5 and 10 when the growth slows down there is a less occurrence of postural problems, but when they enter the puberty stage, a rapid deterioration of existing postural characteristics is to be expected, along with the detection of new cases. Therefore, it is very important to detect postural problems and keep them under control in early years (Kosinac, Banović, 2007.).

The aim of this work is to compare different posture status, recorded for 3D analysis, in regards to a relatively heterogeneous group of children with trend projection of physical deformities development between the ages of five and twelve.

Methods

Sample

Sample consisted of children from 5 to 12 years of age selected from kindergartens and primary schools located in Sarajevo Canton and Zvornik. The sample group comprised of n=699 boys and girls divided into three age groups (first group: 5-7 years; second group: 8-9 years; third group: 10-12 years).

Variable sample

Variables used for the purposes of this research provide information regarding the posture status, Contemplas 3D posture compact mode. Variable sample consists of 17 variables acquired by "3D posture compact" testing protocol. The parameters indicate possible offsets from the zero posture value for all three levels, in which case the deviations of the neutral axis are expressed in centimetres and degrees. Higher values of provided displacements, whether negative or positive, represent the higher level of deformities in subjects.

Description of variables:

Shoulder displacement	Variable expressed in centimetres indicates elevation/depression of the left/right frontal plane. Results with the positive values are in regard to the right shoulder elevation, while the negative values indicate a left shoulder elevation.
Pelvic obliquity	Variable expressed in centimetres displays elevated/lowered left/right pelvic side in frontal plane. Results with positive values indicate the elevation of right pelvic side, and results with negative value indicate the elevation of left pelvic side.
Shoulder rotation	Variable expressed in degrees indicates the rotation in longitudinal axis (transversal plane) of the left/right shoulder. If the results are positive it indicates a rotation of the upper body in which case the right shoulder is placed forward, while negative results indicate a rotation of the upper body in which case the left shoulder is placed forward.
Pelvic rotation	Variable expressed in degrees indicates rotation in longitudinal axis (transversal plane) of the left/right pelvic side. If the results are positive it indicates the rotation in which case the right side of the pelvis is placed forward, while in negative results the rotation of the left side of the pelvis is placed forward.
Trochanter rotation	Variable expressed in degrees indicates rotation of the left/right tronchanter in longitudinal axis (transversal plane). If the result is positive it indicates the rotation of the lower body in which case the right side of pelvis is rotated towards front, while the negative results indicate the front rotation of the left side of pelvis.
Condylus rotation	Variable expressed in degrees indicates the knee rotation in longitudinal axis (transversal plane). If the results are positive, it indicates the front rotation of lateral condylus of the right leg, while the negative results indicate the front rotation of the left lateral condylus.
Malleolus rotation	Variable expressed in degrees indicates the rotation of the axis which runs through malleolus of ankle joint. If the result is positive it indicates the front rotation of the lateral malleoulus of the right foot, while the negative result indicates the opposite rotation.
Sag. Distance cervical spine – sacrum*	Variable expressed in centimetres indicates the distance of the most protruded cervical (neck) vertebra in regards to the vertical line projection of the sacrum (bone at the bottom of the spine) in the sagittal plane. Positive result indicates the increased flexion of the cervical spine, while the negative results indicate the increased extension of the cervical spine.
Sag. Distance thoracic spine – sacrum*	Variable expressed in centimetres indicates the distance of the thoracic spine in regards to vertical line projections of the sacrum (bone at the bottom of the spine) in sagittal plane. Positive results indicate an increase of flexion in thoracic spine, while the negative results indicate an increase in other extension of the thoracic spine . *Higher values in the positive and negative offset do not apply for the variables "Sag. distance cervical,

	thoracic, lumbar – sacrum”
Sag. Distance lumbar spine – sacrum*	Variable expressed in centimetres indicates the distance of the lumbar (lower) spine in regards to the vertical line projection of sacrum (bone at the bottom of the spine) in sagittal plane. Positive result indicates an increase in lumbar spine flexion, while negative results indicate increase in the lumbar spine extension.
Varus/Valgus left	Variable expressed in degrees indicates the Varus-Valgus alignment angle of the left leg (medial/lateral) at the knee joint.
Varus/Valgus right	Variable expressed in degrees indicates the Varus/Valgus alignment angle of the right leg (medial/lateral) at the knee joint.
Flexion/Extension left	Variable expressed in degrees indicates the hyperextension and flexion of the left leg at the knee joint (sagittal plane). Positive result indicates the left leg flexion, while negative result indicates hyperextension of the left leg.
Flexion/Extension right	Variable expressed in degrees indicates the hyperextension or the flexion of the right leg at knee joint (sagittal plane). Positive result indicates the right leg flexion, while the negative result indicates the hyperextension of the right leg.
Frontal Cervical spine	Variable expressed in centimetres indicates the distance of the cervical spine in frontal plane in relation to the vertical line projection of the sacrum. If the result is positive it indicates the right displacement of the cervical spine, and the negative result indicates the left side displacement.
Frontal Thoracic spine	Variable expressed in centimetres indicates the distance of the thoracic spine in frontal plane in relations to vertical line projection of the sacrum. If the result is positive it indicates the right displacement of the thoracic spine, while the negative result indicates the left side displacement.
Frontal Lumbar spine	Variable expressed in centimetres indicates the distance of the lumbar spine in frontal plane in relation to vertical line projection of sacrum. If the result is positive it indicates the right displacement of the lumbar spine, but if the result is negative it indicates the left side displacement.

Testing protocol

Mobile laboratory was assembled in those primary schools and kindergartens whose children were tested. In regards to the testing protocol the Contemplas testing equipment required and ideally flat surface. After acquiring an adequate surface Contemplas testing instrument was position on top of it (image 1) and fixed to the surface so as to avoid displacement during children positioning and to avoid additional space calibration.

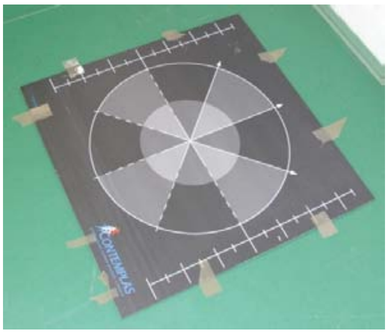


Image 1. Screening surface

3D calibrator was placed on the surface with fluorescent markers attached to it. 3D Calibrator must be exactly placed in the centre of the measuring board (image 2.) and its upper and lower beams along with the vertical beam must be ideally aligned and levelled by the spirit level. The next step is to position a “V” frame supporting three cameras enabling 3D analysis. The camera’s distance from the centre of the measuring board must be at least 2 metres and 15 centimetres (image 3.). The images taken by the camera needs to be sharpen in the software programming in order to start the space calibration. After the calibration has been concluded, the 3D Calibrator is packed away and the testing can be initiated.

Image 3. Calibration frame

Next is the preparation and placement of fluorescent markers on the subjects. Markers are placed on specific points of the subject's body which only need to wear their underwear. Considering that this testing protocol was the one specified by the „3D Posture Compact“, it was necessary to apply 14 markers for each subject (image 3). The following represent the body points of marker placement: acromion (left and right), cervical spine, thoracic spine (kyphosis), lumbar spine (lordosis), crista iliaca posterior superior (left and right), sacrum, trochanter major (left and right), condylus laterallis (left and right), malleolus laterallis (left and right). The subject is placed on the measurement board so as to have his/her back to the cameras, with feet placed parallel and in hip width apart, where the axis along the centre of the malleoulus must be paralleled with the horizontal line at the measuring board (frontal plane). The subject is then instructed to take an upright position, look straight, relax his/her arms along his/her body and then the screening takes place for 12 seconds but not after the 18^{th} second of positioning. The comfort criterion adopts assumptions in terms of pose equilibrium, while the shading criterion eliminates the ambiguities of postures taken into account the image illumination. One can emphasise that the removal of ambiguous 3D poses related to a single image is the main focus of posture analyses (Dihl,L.; Raupp Musse,S. 2014). After screening the markers are removed from the subjects and placed on the following subject to be tested. The process of assembly and testing instrument calibration is repeated every time the location is changed, specifically with each new schools and kindergarten where the testing is to take place.

Image. „V“ Camera Frame

Data analysis method

Results were processed in „SPSS 22“software package. Descriptive indicators were calculated for the entire group and for the special age groups. Projection trends of physical deformity occurrence were established for all three age group subjects. In order to determine the significant difference of each variable for the observed children groups, ANOVA test was applied.

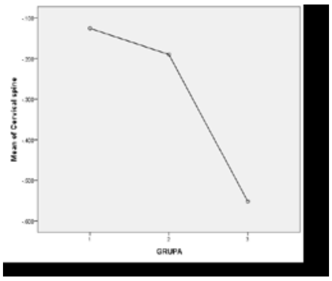
Results

Entire group of subjects was divided into three smaller groups. Each assigned with an individual mean value of results. The parameters indicate a posture image offset from zero value for which purposes the horizontal, vertical and rotational offsets represented in centimetres were valorised and illustrated in degrees as offsets from the neutral axes in the observed plane. Considering frontal plane only, analysis reveals no differences between groups but ‘3D deformity’. On the contrary, transversal plane analysis, which combines sagittal and frontal information, delivers more relevant information than only an analysis of sagittal plane (Steffen et al. 2010). Higher negative and positive offset values assume a higher degree of deformities in subjects. Three variables which offer data on spinal column from a sagittal point of view are following I group mean=2.1093; II group mean=2.5161; III group mean=3.2131 and for cervical spine I group mean -0.9522; II group mean -0.5871; III group mean -0.3426 for thoracic spine I group mean 1.9232; II group mean 2.5354; III group mean 2.9714, and for the lumbar spine the data observed are assumed to have “normal” offset values. The values are conditioned by the physiological curves of the cervical, thoracic and lumbar spine in regards to the distance from the most protruded part of the sacrum. Results for this posture are observed separately along with the designated criteria attesting to the spinal status in sagittal plane. According to the statistical result analysis, a trend of physical deformities development was projected for children between the ages of five and twelve. Concerning the identifiable indicators (table 1., graph. 1.) „0“offsets for all segments in regards to the frontal plane are I group mean -0.1261; II group mean -0.1905; III group mean -0.5521 for the cervical spine; I group mean -0.3294; II group mean -0.4104; III group mean -0.6198; for thoracic spine; I group mean -0.1417; II group mean -0.1707; III group mean -0.2428 for lumbar spine.

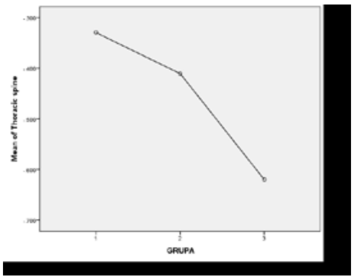
Table 1. descriptive data 3D variables

Descriptives						
		N	Mean	Std. Devia.	Minimum	Maximum
Shoulder displacement	1	235	.29190	.9731	-3.915	3.171
	2	277	.38039	.8581	-2.109	2.825
	3	187	.26484	.9035	-3.306	2.649
	Total	699	.31973	.9103	-3.915	3.171
Trochanter rotation	1	235	-1.41462	6.5834	-22.127	18.108
	2	277	-2.07751	6.4147	-26.224	15.489
	3	187	-.57616	6.7412	-30.703	24.468
	Total	699	-1.45300	6.5781	-30.703	24.468
Condylus rotation	1	235	-1.85237	4.7641	-17.489	8.865
	2	277	-2.74005	4.6818	-19.671	11.308
	3	187	-1.51936	6.7448	-17.829	28.474
	Total	699	-2.11505	5.3546	-19.671	28.474
Distance cervical spine - sacrum	1	235	2.10928	1.9780	-2.798	13.243
	2	277	2.51610	2.1175	-2.535	10.284
	3	187	3.21313	2.713076	-2.510	10.657
	Total	699	2.56580	2.2868	-2.798	13.243
Distance thoracic spine - sacrum	1	235	-.95225	1.6727	-6.227	7.263
	2	277	-.58713	1.702029	-5.322	4.617
	3	187	-.34262	2.145789	-5.114	5.129
	Total	699	-.64447	1.835247	-6.227	7.263
Distance lumbar spine - sacrum	1	235	1.92322	.956412	-.440	4.640
	2	277	2.53542	1.025566	-.176	5.964
	3	187	2.97144	1.254706	-.497	7.065
	Total	699	2.44625	1.145082	-.497	7.065
Varus/Valgus left	1	235	.70543	2.943345	-10.347	8.060
	2	277	1.04376	3.047525	-6.639	19.527
	3	187	1.31965	2.764389	-8.098	8.921
	Total	699	1.00382	2.944553	-10.347	19.527
Varus/Valgus right	1	235	.37001	2.936426	-7.805	8.091
	2	277	.44627	2.927892	-9.062	6.555
	3	187	1.73250	2.958429	-6.339	8.865
	Total	699	.76473	2.992705	-9.062	8.865
Flexion/Ext left	1	235	-2.97121	7.679945	-26.507	18.198
	2	277	-1.25083	8.120360	-60.962	23.080
	3	187	.12198	7.047340	-16.098	27.388
	Total	699	-1.46195	7.780631	-60.962	27.388

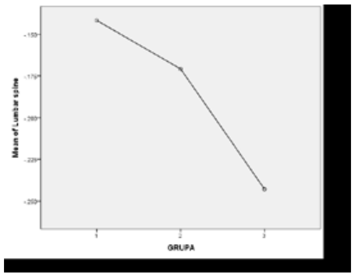
Flexion/Ext right	1	235	1.03502	8.526294	-25.502	28.874
	2	277	-1.60483	7.065437	-26.096	21.824
	3	187	-1.97567	7.837679	-21.062	27.122
	Total	699	-.81654	7.889290	-26.096	28.874
Cervical spine	1	235	-.12606	.980288	-2.268	3.203
	2	277	-.19052	.989148	-3.233	2.659
	3	187	-.55213	1.036711	-3.524	3.174
	Total	699	-.26559	1.013028	-3.524	3.203
Thoracic spine	1	235	-.32937	.840363	-2.356	2.165
	2	277	-.41037	.698497	-2.222	1.675
	3	187	-.61979	.830848	-2.888	2.763
	Total	699	-.43916	.791677	-2.888	2.763
Lumbar spine	1	235	-.14171	.370090	-1.160	1.299
	2	277	-.17076	.366967	-1.721	1.098
	3	187	-.24284	.441628	-1.666	1.882
	Total	699	-.18028	.390798	-1.721	1.882



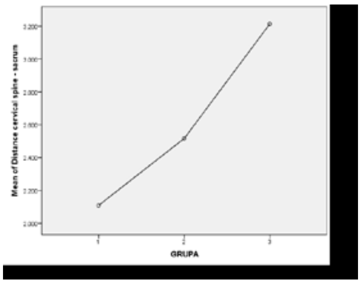
Spine, front. Cervical



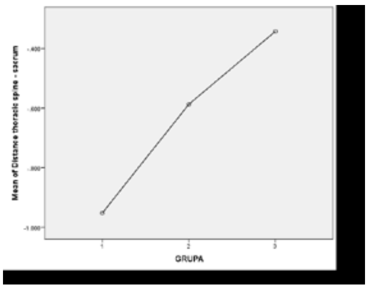
Spine, front. Thoracic



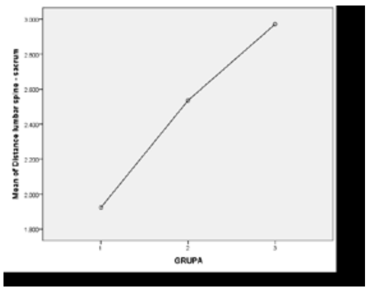
Spine, front. Lumbar



Spine, sag.. Cervical



Spine, sag. Thoracic



Spine, sag. Lumbar

Graph 1. –Graphical representation of mean value trends of spinal offsets for three age groups (group 1: 5-7y; group 2: 8-9y; group 3: 10-12y)

The application of ANOVA statistical method (table 2.) when different subject age groups are compared, indicates a significant difference from $p \leq 0.00$ to $p \leq 0.026$, in offset values in regards to the vertical position for the spinal column parameters and leg parameters. The result relates to the offsets of physiological curves in the sagittal plane.

Tab.2 ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Distance cervical spine - sacrum	Between Groups	128.021	2	64.010	12.649	.000
	Within Groups	3522.236	696	5.061		
	Total	3650.257	698			
Distance thoracic spine - sacrum	Between Groups	40.210	2	20.105	6.056	.002
	Within Groups	2310.747	696	3.320		
	Total	2350.957	698			
Distance lumbar spine - sacrum	Between Groups	118.070	2	59.035	51.544	.000
	Within Groups	797.156	696	1.145		
	Total	915.226	698			
Varus/Valgus left	Between Groups	40.018	2	20.009	2.316	.099
	Within Groups	6011.915	696	8.638		
	Total	6051.933	698			
Varus/Valgus right	Between Groups	239.846	2	119.923	13.884	.000
	Within Groups	6011.639	696	8.637		
	Total	6251.486	698			
Flexion/Ext left	Between Groups	1016.794	2	508.397	8.580	.000
	Within Groups	41238.883	696	59.251		
	Total	42255.677	698			
Flexion/Ext right	Between Groups	1229.023	2	614.512	10.131	.000
	Within Groups	42215.124	696	60.654		
	Total	43444.147	698			
Cervical spine	Between Groups	21.491	2	10.745	10.764	.000
	Within Groups	694.815	696	.998		
	Total	716.306	698			
Thoracic spine	Between Groups	9.163	2	4.582	7.445	.001
	Within Groups	428.310	696	.615		
	Total	437.473	698			
Lumbar spine	Between Groups	1.106	2	.553	3.650	.026
	Within Groups	105.494	696	.152		
	Total	106.601	698			

Discussion

Analyses of offsets and rotations which are expressed in centimetres for offsets and degrees for rotations, did not reveal high degree result if compared to the physical height of the subjects. In the screening records all the segments include offsets, indicating that all the three age groups have offsets in relation to the proper posture status.

Entire research was conducted focusing on the spinal column status of the subjects, for that reason the results emphasize the frontal and sagittal perception of the spine. If we follow the increase trend of zero vertical offset, the increase of mean values is noticeable for all the variables, apart from sagittal perspective of the thoracic spine, which according to physiological curve in that spinal section indicates that the number of children with kyphotic offset between the ages of five and twelve is increasing. The Scoliosis Research Society has recommended annual screening of all children age 10–14 years; the American Academy of Orthopaedic Surgeons has recommended screening girls at the ages of 11 and 13 years and boys age 13 or 14; and the American Academy of Paediatrics has recommended routine screening at ages 10, 12, 14, and 16 years. The Bright Futures guidelines recommend noting the presence of scoliosis during the physical examination of adolescents and children who are at least 8-years-old (Seung – Woo, at al. 2011). This research was conducted with children of younger age (5 – 12 years) since in their case it is possible to greatly affect the postural status corrections. The calculated trend projection of postural deformities development increases as the subjects are older, regardless of the growth of negative or positive offset values in regards to zero values. The analysis results regarding the scoliosis of the spinal column are particularly important. Scoliosis is a complex three-dimensional (3D) deformation of the spine and rib cage that produces cosmetic asymmetries of the trunk, which represent the main complaints of patients (Gignac at al. 2000).

Apart from the spinal column status, there is a significant offset increase in regards to zero value of leg shape, with an increase in the number of subjects with a disturbed relationship angle between upper leg and lower leg, in which case there is an incline towards the valgus position, as well as hyperextension in the knee joint. Children with such diagnosis have potential difficulties when walking and that segment is very important for the overall postural analysis. Scoliosis patients and patients with valgus legs deformities showed significant but slight modifications in gait, even in cases of mild scoliosis. With the naked eye, one could not see any difference from controls, but with powerful gait analysis technology, the pelvic frontal motion (right–left tilting) was reduced, as was the motion in the hips and shoulder. (Mahaudens at al.).

Once the matrix consisting of all research data was created, it became evident that the applied testing protocol consisting of computer outputs if reversed for the purposes of explaining someone's posture status excluding specific physical deformities by data valorisation, would not produce a precise insight in all the deformities from the sagittal perspective. For that reason 3D result outputs consisting of rotations and offsets were discussed along with necessary insight into the posture result imagery, clustered as numerical data.

Conclusion

It is evident that the trend projection of physical deformities occurrence is statistically significant for the parameters of the spinal column results in relations to scoliosis, kyphosis and lordosis with an increase in an offset from the "proper" posture for children of the two older age groups in relation to children of the youngest age group (5-6 years). In addition, such trend was recorded for the angle status of upper leg in relation to the lower leg, reflecting in a significant increase in number of children with "x" legs. When a child starts attending first to fifth grade primary school his/her posture status worsens.

Therefore, the scientific contribution of the research conducted in Sarajevo schools and kindergartens made possible due to European Commission funding, is reflected in the possibility of clear and concise physical deformity valorisation, assisted by modern kinematic procedures with the purpose of designing the total results matrix indicating the postural status of the assigned population. The possibility of predicting the deformity occurrence trend, represent the baseline for gaining direct benefits in a form of potential, individual programmes for treating or decreasing registered physical deformities. Application of technological solution for assessing the posture status ("Contemplas 3D posture compact"), for all three subject age groups is extremely adequate for obtaining the individual analysis results which will serve as a baseline for planning and programming corrective procedures for the purpose of treating and decreasing physical deformities.

Reference

1. Adar, B.Z. (2004). Risk Factors of Prolonged Sitting and Lack of Physical Activity in Relate to Postural Deformities, Muscles Tension and Backache Among Israeli Children. A clinical cross sectional research. Doctoral Thesis, Semmelweis University Budapest.
2. Aleksić, D. (2010). Efekti primene gimnastičkih sadržaja u nastavi fizičkog vaspitanja na transformaciju nekih antropoloških sposobnosti i karakteristika kod učenica mlađeg školskog uzrasta, Gazette of Anthropological society of Serbia.

(The Effects of Gymnastic Teaching Content Application in the Physical Education Class on Transformation of Certain Anthropological Abilities and Characteristics in Younger Female Students)

3. Andrijašević, M. (2009). Upravljanje slobodnim vremenom sadržajima sporta i rekreacije, Upravljanje slobodnim vremenom, sadržajima sporta i rekreacije /Andrijašević, M., (ur.). Zagreb: Kineziološki fakultet Sveučilišta u Zagrebu, 3-15. (Leisure Time Management with Sport and Recreational Content, Zagreb: Faculty of Kinesiology, University of Zagreb)
4. Avdić, D. And co-authors (2007). Loše držanje tijela-informacije za pacijente. Bosnalijek, Sarajevo, (Bad posture – information for the patients, Bosnalijek, Sarajevo)
5. Bogdanović, Z., Milenković, S. (2008). Prisustvo lošeg držanja tela kod mlađeg školskog uzrasta u zavisnosti od nivoa informisanosti o načinu sedenja. Glasnik Antropološkog društva Srbije, (43), 365-367. (Presence of Bad Posture in Young-School-Age Children Depending on Level of Information in Regards to Sitting Position, Gazette of Anthropological society of Serbia)
6. Demeši, Č. (2007). Antigravitaciona muskulatura kod posturalnog statusa dece uzrasta 7 i 13 godina. Magistarski rad, Medicinski fakultet Novi Sad. (Antigravity Musculature in Postural Status of Children 7 and 13 Years of Age, Master paper, Faculty of Medicine Novi Sad)
7. Dihl, L.; Raupp Musse, S. (2014). Recovering 3D human pose based on biomechanical constraints, postures comfort and image shading, Expert Systems with Applications 41 6305–6314
8. Gajić, D. (2009). Kineziterapija kod deformiteta kičmenog stuba. Specijalistički/diplomski rad, Fakultet zdravstvene njege Panevropskog univerziteta,

Banja Luka, 5. (Kinesiotherapy in Spinal Column Deformities, Specialist/final paper, Faculty of Health Care Pan-European University, Banja Luka)

9. Gignac, D.; Aubin, C.-É.; Dansereau,J.; Labelle,H.(2000). Optimization method for 3D bracing correction of scoliosis using a finite element model. Eur Spine J (2000) 9 :185–190, Springer-Verlag
10. Huddleston, S., Mertersdorf, J., Araki, K. (2002). Physical Activity Behaviour and Attitudes towards Involvement Among Physical Education, Health, and Leisure Services Pre-Professionals. College Students Jurnal, 36 (4), 555.
11. Ilić, D., Drašković, V., Eminović, F., Višnjić, S. (2009). Uticaj sportske edukacije u formiranju posturalnog statusa dece mlađeg školskog uzrasta. Tuzla: Zbornik naučnih i stručnih radova „Sport i zdravlje". (Effect of Sport Education Classes in the Formation of Postural Status of Younger- School-Aged Children. Tuzla: Collection of Scientific Papers)
12. Kosinac, Z., Banović, I. (2007). Povezanost između nekih pokazatelja nepravilnoga tjelesnoga držanja i skolioze u djece juvenilne dobi. Život i škola 19, 9-10. (Correlation between Certain Indicators of Irregular Body Posture and Scoliosis in Juvenile Age Children. Life and School)
13. Mahaudens, P. X.; Banse, M.; Mousny, C.; Detrembleur, C. (2009) Gait in adolescent idiopathic scoliosis: kinematics and electromyographic analysis, Eur Spine J 18:512–521DOI 10.1007/s00586-009-0899-7.
14. Paušić, J. (2007). Konstrukcija i vrednovanje mjernih postupaka za procjenu tjelesnog držanja u dječaka od 10 do 13 godina. Doktorska disertacija, Kineziološki fakultet Sveučilišta u Zagrebu.(Construction and Value Determination of Measurement Procedures in Regards to Postural Status Assessment in Boys from 10 to 13 Years of Age. Doctor Dissertation, Faculty of Kinesiology, University of Zagreb.)
15. Prskalo, I., Barić, A., Badrić, M. (2010). Kineziološki sadržaji i slobodno vrijeme mladih, U: Andrijašević, M. (ur.): Kineziološki sadržaji i društveni život mladih, Zagreb, Kineziološki fakultet Sveučilišta u Zagrebu; 65-71. (Kinesiology Content and Youth Free Time , Faculty of Kinesiology, University of Zagreb)
16. Seung-Woo, S.; Hitesh N. M.; Yang J.-H.; Hong, J.Y. (2011). Idiopathic scoliosis in Korean schoolchildren: a prospective screening study of over 1 million children, Eur Spine J 0:1087–1094 DOI 10.1007/s00586-011-1695-8.

17. Standring, S. (2005). Gray΄s Anatomy-The Anatomical Basis of Clinical Practice. Elsevier Churchill Livingstone. U.K.

18. Steffen, J.-S.; Obeid, I.; et all. (2010). 3D postural balance with regard to gravity line: an evaluation in the transversal plane on 93 patients and 23 asymptomatic volunteers, Eur Spine J 19:760–767, DOI 10.1007/s00586-009-1249-5.

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Correspondence to:
Siniša Kovač, PhD
University of Sarajevo, Faculty of Sport and Physical Education
Patriotske lige 41, 71000 Sarajevo, BiH
e-mail: sinisadkovac@gmail.com