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ORIGINAL ARTICLE

Assessment of body posture with the Moire's photogrammetric method in boys practising judo versus their non-sports-practising peers

Évaluation de la posture par la méthode photogrammétrique de Moire de garçons suivant un entraînement en judo, comparativement à des garçons du même âge ne le suivant pas

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Summary

Objective. – Regular judo training may induce favourable developmental changes in body posture of boys. The purpose of this work was to assess changes in body posture of 8-year-old boys training judo versus a control group in two repeated assessments.

Methods. – The study included 73 boys aged 8. Thirty-six of them started judo training in sports clubs at the beginning of the school year (JU). The control group included 37 boys attending first and second classes of primary schools, selected at random (NT). Body posture was assessed

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with the Moire's method, two times, at a 6-month's interval between the two assessments. Distributions of the values of the obtained variables were assessed with the W Shapiro–Wilk test. Non-parametric tests were used for their analysis. The median, mean and SD were calculated. To evaluate the differences between the T1 and T2 results, the Wilcoxon matched-pairs test was used, and to evaluate the intergroup differences both for the first and for the second measurement – the Mann–Whitney U test, adjusted for continuity.

Results. – In group JU, the time factor (T1–T2) had a significant effect ($P \leq 0.05$) on changes of 6 body posture indices. In the first assessment, there was a significant difference between the JU and NT groups with respect to 5 body posture indices; in the second assessment, there were only two differences.

Conclusion. – Regular 6-month's judo training in the examined boys resulted in deepening of physiological spinal curvatures, progressing symmetrisation of shoulder blades and spine alignment to the C7–S1 line.

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Résumé

Objectif. – L'entraînement régulier en judo chez des garçons peut engendrer des modifications favorables de la posture. L'objectif du travail était d'évaluer les modifications de la posture chez des garçons de 8 ans, suivant un entraînement en judo, comparativement à un groupe témoin.

Méthodes. – L'étude a été menée chez 73 garçons âgés de 8 ans ; 36 d'entre eux ont commencé à suivre un entraînement en judo dans des clubs sportifs au début de l'année scolaire (JU). Le groupe témoin ne s'entraînant pas, était composé de 37 garçons tirés au sort parmi des élèves de CE1 et CE2 (NT). L'évaluation de la posture par la méthode de Moire a été réalisée en respectant une durée de six mois entre les deux mesures (T1 et T2). L'évaluation de la distribution des valeurs des variables obtenues a été faite par le test W de Shapiro–Wilk. Des tests non paramétriques ont été utilisés pour leur analyse. On a calculé la médiane ainsi que la moyenne arithmétique et l'écart-type. Les différences entre les mesures réalisées à T1 et T2 ont été évaluées par le test de Wilcoxon pour observations appariées, alors que les différences entre les groupes à T1 et T2, ont été évaluées par le test U de Mann–Whitney avec une correction de continuité.

Résultats. – Le facteur temps (différences entre T1 et T2) a significativement modifié 6 paramètres de posture du corps dans le groupe JU ($p \leq 0,05$). À T1, le groupe JU s'est fortement différencié du groupe NT par les valeurs de 5 paramètres de posture ; à T2, seuls deux paramètres de posture diffèrent entre les groupes JU et NT.

Conclusion. – L'effet d'un entraînement en judo de 6 mois a induit une accentuation des courbures naturelles de la colonne vertébrale, une amélioration de la symétrie des omoplates ainsi qu'un alignement de la colonne vertébrale jusqu'à la ligne C7–S1.

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1. Introduction

Body posture defects have been a very serious problem among children and adolescents for many years [1]. The fact that they may affect even 15% of the population raises particular concerns here [2,3]. Uncorrected body posture defects may lead to many unfavourable changes in the body and physical fitness of young people [4,5]. The highest susceptibility to the development of body posture defects occurs in the periods of progressive development of boys, i.e. around the 7th year of life and then at the age of 11–14. These periods are associated with rapid growth of the skeletal system that is not paralleled by soft tissue development [6,7].

Steadily improving and more and more accurate diagnostic methods used in the evaluation of posture defects are the only tools that allow to assess the current status of the subject's posture and to monitor any possible changes in this aspect. Apart from targeted corrective methods, regular general physical activity plays a very important prophylactic role and is particularly important in children [8]. According to the guidelines of the World Health Organisation, the appropriate time of daily physical activity for children and adolescents aged 5–17 is 60 minutes, at the minimum [9]. Sports particularly recommended for children are the ones, which promote formation of the correct body posture, i.e. which support harmonious development of many motor skills. Judo is for certain one of these sports.

Fukuda and La Monica [10], in their most recent publication (a review of up-to-date knowledge on the effect of fighting sports training on talent development and physical development), have described a possible relationship between the indices of general physical fitness in children and the result (index value) of the Special Judo Fitness Test in their adolescence [11,12]. However there are no publications, which would prove that judo training may lead to correction of body posture defects or prevent them.

According to the opinion of professor Kano, judo is not only a fighting sport whose main aim is a good competition result but also it is a form of activity with a strong accent on educational and health-promoting aspects. Typical time of single judo training for children aged 8 is 45 minutes. Preferred forms of exercises are these that develop basic motor abilities, such as running, climbing, crawling or jumping. Additionally, children are taught basic technical and tactical judo skills interwoven with physical games and activities. At this stage of training, there are no fights or sparring matches between the participants that might have a negative effect on the delicate skeletal system where formation processes are still ongoing. The following basic elements typical of judo are taught: rolling in the lying position, somersaults, falls, grips, deflection from balance or basic throws [13]. Pupils' attention is also drawn to how to correctly wear the uniform and tie the belt. The children get acquainted with the greeting and farewell ceremony and with the training discipline. The training programme for 8-year-old children is composed in such a way that all motor skills of children are being developed [14–17].

There are not many reports in the literature concerning the effect of additional physical activity (judo) on such an important health aspect as body posture of boys in the periods of dynamic development. Therefore, the purpose of this work was to assess changes in body posture of 8-year-old boys training judo versus a control group in two repeated assessments. The following research question was asked: what is the effect of regular 6-month judo training on changes of particular body posture indices measured with the Moire's photogrammetric method?

A hypothesis was formulated that regular judo training would cause positive changes of body posture of the examined boys.

2. Methods

2.1. Subjects and study design

The project of the study obtained approval of the Bioethics Committee at the Regional Medical Chamber in Kraków (Opinion No. 75/KBL/OIL/2014 dated 1 October 2014). The parents of all the boys gave their consent for their children to participate in the study, and after the study was completed they were informed about its results.

The study was performed in a group of 73 boys aged 8 living in Kraków. Thirty-six of them started judo training in sports clubs at the beginning of the school year (JU). The control group included 37 boys attending year 1 and 2 classes of primary schools, selected at random (NT). Body posture was assessed two times, at a six-months' interval between the two assessments. The assessments were performed at

the turn of September and October 2014 (T1) and March and April 2015 (T2). The boys from the NT group did not declare any organised physical activity similar to that undertaken by the boys from the JU group.

At the beginning of the study, body height and weight of the examined boys were measured. An anthropometer (Martin's type, USA) was used for the measurement of body height. It was measured with 0.01 m precision. Body weight was measured with 0.1 kg precision with use of electronic scales (Radwag, WPT 100/200 OW) (Table 1).

Body posture was assessed according to the general methodology of Moire's technique and 15 body posture indices were obtained as a result: tilt of the trunk (TT), lumbar lordosis angle (LLA), thoracic kyphosis angle (TKA), depth of thoracic kyphosis (DTK), depth of lumbar lordosis (DLL), maximum rotation (MR), inclination of the trunk (IT), set of shoulders (SS), set of blades: below – above (SB: b-a), set of blades: closer – further (SB: c-f), difference deflection angles of the lower blade of the spine (DDALBS), setting the waist triangles: below – above (SWT: b-a), setting the waist triangles: narrowly – wider (SWT: n-w), difference of the height anterior superior iliac spine (DHASIS), maximum deviation from the straight line of the spine C7–S1 (MDFSLS C7–S1) [18–21]. To enable photogrammetric examination, points and measurement lines with characteristic distribution pattern were marked. The system for photogrammetric body posture assessment of CQ Elektronik System was used in this study [22].

The set included:

- projector for obtaining a three-dimensional picture, consisting of a screen, a low-power halogen bulb (50–100 watt), a lens, and video camera to observe the examined part of the body surface area;
- graphics card for connecting the projector with the computer and for direct observation of the examined subject on the monitor screen;
- portable computer with software for recording and analyzing the location of the marked bone points.

In order to conduct the examination, anatomical topographic points were marked on each subject's back following the set producer's manual. The test took place in a purposefully arranged dark room. 2.6 m from the set there was a parallel line, which marked the measurement spot for each of the subjects. The subjects were in standing position with their backs towards the set. Their heads were in the standard anatomical position (Frankfurt plane), with upper limbs hanging loosely beside the trunk and heels at the edge of the line marking the measurement spot, while the plane of lines emitted by the camera at the level of their pelvises was parallel to the picture. Obtaining a spatial image was possible thanks to a raster built into the projector, emitting a light bulb on the back of the examined person, which, while falling on the back became deformed depending on the configuration of its surface. The computer software measured the examined parameters in steps of 1 mm. The resolution resulting from the density of isolines was not lower than 1 cm; as a result of this, the rigor of calculations between any selected points was not lower than 2 cm. Thanks to the approximating functions of the software, it was possible to raise the rigor of calculations to the level

Table 1 The results of the Wilcoxon matched-pair test for somatic parameters of judo training boys (JU) and of their peers not practising any sports (NT).

Parameters	T1 (mean \pm SD, median)	T2 (mean \pm SD, median)
Height (m)	1.17 \pm 0.05; 1.18	1.20 \pm 0.05; 1.21 ^a
NT	1.18 \pm 0.04; 1.18	1.21 \pm 0.04; 1.21 ^a
JU	1.16 \pm 0.05; 1.16	1.19 \pm 0.06; 1.20 ^a
Weight (kg)	22.90 \pm 3.37; 22.70	24.38 \pm 3.44; 23.90 ^a
NT	23.60 \pm 3.79; 22.80	25.10 \pm 3.74; 24.10 ^a
JU	22.10 \pm 2.71; 22.40	23.65 \pm 2.97; 23.30 ^a

^a Difference between T1 and T2, $P < 0.001$.

of 1 mm. The time taken to perform a single measurement was 0.03 seconds. In the course of 1 s, about 3 full measurements were repeated, and the average time of one test was 1 minute. From among several scores of pictures saved by default in the set's memory, a frame was selected reflecting the correct body posture of a given subject. The underlying assumption was always to assess the habitual posture as a comparatively constant individual feature of a human being. The picture thus recorded was then analyzed without the subject's participation. The parameters calculation and printing only took place after the full examination had been completed. Approximation error of the measurements, as indicated by the Moire device producer, is about 2% [22].

2.2. Statistical analysis

To verify similarity of the JU and NT groups, distribution of the age, somatic features and body posture index variables were evaluated first with the W Shapiro–Wilk test. It was assumed that the distribution of the analysed variables would be different from the normal one at calculated P -value ≤ 0.05 . Non-parametric tests were used for the analysis of the obtained variables because the distributions of the examined variables differed significantly from the Gaussian curve. The median, mean and SD were calculated. To evaluate the differences between the T1 and T2 results, the Wilcoxon matched-pair test was used, and to evaluate intergroup differences both in the first and in the second measurement – the Mann–Whitney U test, adjusted for continuity.

3. Results

The results are presented in [Tables 2 and 3](#).

Both the body height and the body weight of boys in both groups were significantly higher in the second examination ($P < 0.001$). In group JU, the time factor (T1–T2) had an effect on 6 body posture indices describing body posture. There was significant decrease in the values of the following indices: LLA ($P < 0.05$), TKA ($P < 0.01$), MR ($P < 0.01$); DDALBS ($P < 0.05$) and MDFSLC C7–S1 ($P < 0.01$). Only for the SWT: n-w index there was an increase of the value after a 6-month judo training ($P < 0.05$). In the NT group, the time factor (T1–T2) had a significant effect on 5 body posture indices (there was a change of 3 of them also in the JU group). A decrease of the values of three indices was noted: LLA ($P < 0.01$), DDALBS ($P < 0.05$) and DHAIS ($P < 0.05$), as well

as a minor increase of the values of the other two indices: DTK ($P < 0.001$) and MR ($P < 0.05$). In the first assessment, the JU group presented significantly higher values of 5 body posture indices, as compared to the NT group, as follows: TKA ($P < 0.05$), DTK ($P < 0.001$), DLL ($P < 0.01$), MR ($P < 0.001$) and SB: c-f ($P < 0.05$). In the second assessment, there was a significant difference between groups JU and NT only for 2 body posture indices, and in both cases the judokas had higher values: DLL ($P < 0.05$) and SB: b-a ($P < 0.01$).

4. Discussion

The results of our study have confirmed hypothetical improvement of body posture of boys starting judo education. Probably this is the reason why the parents justified their decision to enrol their children into organised sports activities by willingness to improve their child's health condition and in particular their child's body posture. Both motor abilities and body posture may improve as a result of additional physical activity [23]. According to the studies by Bieć and Demczuk-Włodarczyk, individuals who train fighting sports have better body posture than the general population of people of the same age [24]. These studies included athletes representing various styles and their average training experience was 5 years. In our study, a 6-months' period of regular judo training resulted in favourable significant changes of 5 body posture indices of the examined boys. The largest changes were noted for the MR parameter – there was a 2-fold decrease of trunk rotation in the axial plane in the second assessment, as compared to the first one (14.5°–29°). It is worth noting that there was a decrease of the TKA and LLA index values, by 6.3° (4%) and 4.3° (3%), respectively, which means deepening of physiological spinal curvatures in the sagittal plane, i.e. enhancement of the thoracic kyphosis and of the lumbar lordosis. In the context of the corrective effect of a regular physical activity, changes of the other two indices: MDFSLC C7–S1 and DDALBS seem very important. Lower values of these indices in the second examination, by 25 and 24%, respectively, reflect a reduction of lateral spine deviation, as well as improved symmetry of shoulder blades' position with respect to the spine.

After the examined 6-month period, similarly to the judo training group, there were favourable and significant changes of the indices defining spine curvatures in the sagittal plane in the NT group, where we have observed an increase of the DTK value, i.e. thoracic kyphosis

Table 2 The results of the Wilcoxon matched-pair test and of the Mann–Whitney U test for body posture indices measured in mm of judo training boys (JU) and of their peers not practising any sports (NT).

Parameters	T1 (mean ± SD, median)	T2 (mean ± SD, median)
DTK (mm)	10.50 ± 7.34; 8.00	16.47 ± 10.11; 14.00 ^e
NT	7.10 ± 4.40; 7.00 ^c	15.65 ± 10.18; 13.00 ^f
JU	14.10 ± 8.05; 14.00	17.31 ± 10.10; 17.00
DLL (mm)	14.20 ± 12.06; 12.00	16.89 ± 12.28; 13.00
NT	10.10 ± 8.74; 6.00 ^b	14.57 ± 12.15; 10.00 ^a
JU	18.50 ± 13.55; 16.50	19.28 ± 12.12; 16.50
MR (mm)	21.00 ± 17.86; 14.00	18.73 ± 15.33; 13.00
NT	10.70 ± 6.17; 10.00 ^c	17.46 ± 14.10; 11.00 ^d
JU	31.70 ± 19.70; 29.00	20.03 ± 16.59; 14.50 ^e
SS (mm)	4.80 ± 4.45; 4.00	4.01 ± 4.18; 2.00
NT	4.60 ± 3.85; 4.00	3.38 ± 3.73; 2.00
JU	5.00 ± 5.05; 4.00	4.67 ± 4.56; 3.00
SB: b-a (mm)	6.50 ± 4.72; 6.00	6.59 ± 5.8; 5.00
NT	6.10 ± 4.89; 5.00	4.43 ± 4.11; 3.00 ^b
JU	6.90 ± 4.58; 6.50	8.81 ± 6.47; 8.00
SB: c-f (mm)	12.70 ± 10.21; 11.00	9.95 ± 8.81; 8.00
NT	9.80 ± 7.25; 8.00 ^a	8.76 ± 7.58; 6.00
JU	15.70 ± 11.91; 14.00	11.17 ± 9.86; 8.00
DDALBS (mm)	10.30 ± 7.41; 9.00	7.01 ± 5.17; 6.00 ^d
NT	10.30 ± 6.97; 10.00	7.30 ± 5.69; 6.00 ^d
JU	10.20 ± 8.02; 8.50	6.72 ± 4.65; 6.50 ^d
SWT: b-a (mm)	11.90 ± 9.86; 11.00	9.70 ± 7.44; 9.00
NT	11.00 ± 8.07; 11.00	8.16 ± 6.19; 7.00
JU	12.90 ± 11.46; 11.00	11.28 ± 8.33; 12.00
SWT: n-w (mm)	10.20 ± 9.26; 6.00	13.08 ± 9.29; 12.00 ^d
NT	11.40 ± 9.64; 8.00	12.22 ± 8.77; 13.00
JU	9.10 ± 8.84; 6.00	13.97 ± 9.85; 11.50 ^d
DHASIS (mm)	2.70 ± 2.36; 2.00	1.99 ± 2.41; 1.00
NT	2.50 ± 2.06; 2.00	1.68 ± 2.20; 1.00 ^d
JU	2.90 ± 2.63; 2.00	2.31 ± 2.61; 2.00
MDFSLS C7–S1 (mm)	6.60 ± 3.01; 6.00	5.58 ± 2.89; 5.00 ^d
NT	6.50 ± 3.45; 5.00	6.22 ± 3.07; 7.00
JU	6.80 ± 2.52; 6.00	4.92 ± 2.58; 4.50 ^e

DTK: depth of thoracic kyphosis; DLL: depth of lumbar lordosis; MR: maximum rotation; SS: set of shoulders; SB: b-a: set of blades: below – above; SB: c-f: set of blades: closer – further; DDALBS: difference deflection angles of the lower blade of the spine; SWT: b-a: setting the waist triangles: below: above; SWT: n-w: setting the waist triangles: narrowly: wider; DHASIS: difference of the height anterior superior iliac spine; MDFSLS C7–S1: maximum deviation from the straight line of the spine C7–S1.

^a Difference between NT and JU, $P < 0.05$.

^b Difference between NT and JU, $P < 0.01$.

^c Difference between NT and JU, $P < 0.001$.

^d Difference between T1 and T2, $P < 0.05$.

^e Difference between T1 and T2, $P < 0.01$.

^f Difference between T1 and T2, $P < 0.001$.

enhancement (by 46%) and a decrease of the LLA value, i.e. enhancement of the lumbar lordosis (by 3.6%), and of the DDALBS value, reflecting a marked improvement of the symmetry of shoulder blades' position with respect to the spine axis (the value of this index has decreased by as much as 40%). A decrease of the DHASIS value appeared to be a positive change as well, meaning improvement of pelvis position in the coronal plane. The only negative change was found in the case of the MR index – there was a minor increase of trunk rotation (by 9%) in the axial plane.

During the first examination the boys from the NT group were found to have better body posture than the boys from

the JU group. They had better results in body posture assessments for 11 out of 15 indices. At the beginning of the study, there were statistically significant differences between the JU and NT group in the values of 5 body posture indices, as follows: TKA and DTK – judokas had less pronounced thoracic kyphosis, MR – judokas had as much as 3 times more rotated trunks in the axial plane than non-training boys, SB: c-f – judokas presented markedly more asymmetric shoulder blade position (the difference in winged shoulder blades incidence was as high as 43%). Only for the DLL index did the boys from the JU group have more pronounced lumbar lordosis – the difference measured linearly was 64%.

Table 3 The results of the Wilcoxon matched-pair test and of the Mann–Whitney U test for body posture indices measured in degrees of judo training boys (JU) and of their peers not practising any sports (NT).

Parameters	T1 (mean ± SD, median)	T2 (mean ± SD, median)
TT (deg)	5.50 ± 3.92; 4.70	5.95 ± 3.03; 5.70
NT	5.80 ± 2.99; 5.80	6.33 ± 3.04; 6.50
JU	5.20 ± 4.70; 4.30	5.55 ± 3.01; 5.00
LLA (deg)	162.90 ± 13.47; 162.10	156.83 ± 6.92; 157.90 ^c
NT	161.00 ± 7.15; 161.60	155.71 ± 7.93; 155.80 ^c
JU	164.90 ± 17.68; 162.50	157.98 ± 5.59; 158.25 ^b
TKA (deg)	162.50 ± 6.54; 161.70	159.54 ± 6.20; 158.60 ^b
NT	160.50 ± 4.07; 160.40 ^a	159.66 ± 5.89; 159.30
JU	164.50 ± 7.93; 164.20	159.43 ± 6.57; 157.95 ^c
IT (deg)	1.50 ± 1.30; 1.30	1.49 ± 1.21; 1.10
NT	1.40 ± 1.26; 1.00	1.32 ± 1.05; 1.00
JU	1.70 ± 1.33; 1.40	1.66 ± 1.35; 1.35

TT: tilt of the trunk; LLA: lumbar lordosis angle; TKA: thoracic kyphosis angle; IT: inclination of the trunk.

^a Difference between NT and JU, $P < 0.05$.

^b Difference between T1 and T2, $P < 0.05$.

^c Difference between T1 and T2, $P < 0.01$.

In the second assessment, the difference between the JU and NT groups with respect to the DLL index values was still present, but it was smaller (by 25%) than the difference found during the first assessment. Differences were also shown for the SB: b-a – values – the boys from the NT group had both shoulder blades positioned almost at the same level; the boys from the JU group still showed some asymmetry.

Positive changes in body posture in the JU group were visible in its most important segments. It seems that they may be attributed both to regular physical activity and to the developmental factor, naturally occurring in this period. Deepening of the physiological spinal curvatures in the examined judokas was found that is responsible for improvement of shock absorbing function of the spine for loads encountered by an adult individual. Similar favourable changes were observed by Drzał-Grabiec and Truszczyńska: two-year and longer regular training of kyokushin karate oriented towards general development contributed to correct spinal curvature formation (deepening of the curvatures) in the sagittal plane in children aged 7–10 years [25]. The mean value of the DTK parameter in the karate training group was 13.2 mm, as compared to only 5.5 mm in the control group. There were very similar changes of the DLL parameter: the mean value in the karate training group was 13.8 mm, and in the control group – 9.7 mm.

As far as the MR parameter is concerned, the boys from the JU group significantly improved their results as compared to the NT group. Thus, it may be concluded that regular judo training had a corrective effect on the trunk rotation index. In the judo training group, the median value of the MR parameter decreased from 29° in the first assessment to 14.50° in the second assessment. The angular value achieved in the second examination approached the normative values – in the studies by Stoliński and Kotwicki in a population of children aged 7–10 values ranging from 1 to 3° were noted in as many as 735 out of 1000 subjects [26].

As a result of the 6-month training period, very important changes occurred in the values of the indices describing

the position of both shoulder blades. This is the asymmetry in the distance of the lower angles of the shoulder blades from the spine that is pointed out by many investigators in the context of the first alarming signals preceding development of scoliosis [27–29]. In our study, the distances of the lower angles of both shoulder blades from the spine were almost the same in the second assessment that reflected its more correct, almost axial position. Thus, these changes may be deemed as preventive with respect to possible scoliosis development (one of the most common body posture defects) in subsequent years of dynamic development of the examined judo training boys [30]. Also in the experiment by Drzał-Grabiec and Truszczyńska an improvement of shoulder girdle position of the examined karate training children was found that was expressed by more symmetric shoulder line in this group, as compared to the control group [25]. Both authors concluded that karate training is a perfect complement to the individual process of body posture defect correction, and that athletes who trained fighting sports regularly for a period longer than 2 years had better body posture than those from the control group. Important seems the fact that the karate training in the age range analysed by the authors (7–10 years) was very similar to “our” judo training in terms of its programme promoting general development and lack of sparring matches and fights. We obtained similar results in the group of 6-year-old boys selected for matched-pair comparisons [31]. At present, it is difficult to answer the question which children will be successful when they progress to an older division since judo stability of competitive success is not a high one, irrespective of the age range [32].

Unfortunately, the favourable trends in correct body posture formation listed above are not always reflected in the anatomy and body posture of older judokas, representing a high sport performance level. Castropil and Arnoni, after their study of body posture of judokas aged 16–33, both male and female, have found that there were many posture defects in this group. They found flat feet in 80% of the examined individuals, asymmetry of shoulder blades’

position – in 70%, winged scapulas – in 54%, and excessive forward protrusion of the head – in 58%. As the cause of these findings they indicated positions specific for judo and multiple repetitions of asymmetrical movements both during regular trainings and during official sports competitions [33]. Therefore researchers suggest that posture correcting exercises should be included in judo training, which would prevent both deformities of body anatomy and injuries [34]. In order to reduce the risk of injuries and minimise the body impact in judo training, it is recommended that constant monitoring and correction of the optimal body contents are done in proportion to the weight category of the specific judo athlete's weight, as well as to the symmetrical proportion of active mass in particular segments [35]. The judo athletes' prophylactic basic training might follow these general guidelines:

- appropriate strength-training workouts for the main muscle groups with three goals: achieve the eutony muscular tone, muscular symmetry, and the adaptation of tendons;
- muscular flexibility improvement;
- specific technical training to avoid noxious movements [36].

In this context, it seems necessary to regularly monitor the judo athletes' posture (at least once a year), by using the Moire's method among the others.

5. Conclusion

Regular 6-month judo training had statistically significant effect on the values of several body posture indices measured with the photogrammetric method. The largest favourable changes were observed for the maximum rotation index and slightly smaller changes were observed for the thoracic kyphosis angle, lumbar lordosis angle, maximum deviation from the straight line of the spine C7–S1 and difference deflection angles of the lower blade of the spine indices which is the evidence of comprehensive corrective effect of judo training. Deepening of spinal curvatures in the sagittal plane will create an effective mechanism of shock absorption for growing loads and will be an important element of prevention of overload syndromes of the spine in the next developmental period, and progressing symmetrisation of shoulder blades and spine alignment to the C7–S1 line will decrease the risk of scoliosis development.

Disclosure of interest

The authors declare that they have no competing interest.

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