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ORIGINAL ARTICLE

Assessment of the impact of regular judo practice on body posture, balance, and lower limbs mechanical output in six-year-old boys

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ABSTRACT

BACKGROUND: Physical activity is beneficial for young children. The aim of this study was to monitor the changes in body posture and balance, as well as in the level of lower limbs mechanical output in six-year-old boys practicing judo (JU) and in a group not practicing that sport (NT).
METHODS: In 12 matched pairs of boys (JU+NT) body mass and height were measured and Body Mass Index (BMI) was calculated at three time points (baseline, three months, six months). Body posture was evaluated with the use of Moiré method (TT, DTK, MR, LALBC-F, DALBS). The balance was examined by means of the UPST Test with the eyes open (EOA) and closed (ECA). Ground reaction and relative power were assessed in standing vertical jump on the dynamometric platform. In the subsequent calculations, the MANOVA with the GLM procedure using 10 dependent above variables (excluding BMI and Pr indices), and next Factorial Repeated Measures ANOVA were used.
RESULTS: In MANOVA a significant interaction of the time, and group, factor was ascertained. Next, the series of univariate ANOVAs yielded following results: for MR the difference between groups was significant after three months (with JU having better results than NT group), but not at the baseline or after six months. For UPST EOA, JU group had higher results after three months than those of NT group. For impulse (J), the interaction and time positive trend were significant.
CONCLUSIONS: A six-month practice of judo results in a significant improvement in the quality of body posture, balance, and lower limbs muscle strength impulse.

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World Health Organization [1] guidelines recommend that children and adolescents between ages 5 and 17 accumulate a minimum of 60 min of moderate to vigorous physical activity per day to achieve health benefits. The proportion of preorganized sporting activities for children is increasing in some European countries.[2] At the ages from 4 to 6, more than 60% of both boys and girls were able to perform at specific developmental levels for several motor skills like catching, running, jumping, throwing, kicking, striking and hopping.[3] In Spain, children start practicing judo quite early, namely between the ages 4 and 6.[4] Combat sports are recommended even for the youngest children, provided their practice is limited to formal exercises and pre-arranged sparring, which are deemed less risky for the children's health.[5, 6] Therefore, as a result of judo practice, one can expect a beneficial influence of such an additional motor activity on the children; in particular, an improvement in their body composition, adaptation to physical exercise, strength, endurance, cognitive functions, and feeling of life satisfaction.[7]

It is evident from additional inquiries that the children's parents noticed the beneficial influence of judo practice on the socially accepted conduct of their children at both school and home. They also perceived the impact of the training on various spheres of their children's personalities, that is the physical (improved health and fitness), emotional (improved self-discipline), intellectual (they show more courage and solve problems with more ease), motivational (pursuing an end in spite of impediments), and socio-moral (for instance, helping the weak).[8]

In the face of the commonly found body posture defects and obesity in children, additional motor activity can become a factor exerting a beneficial influence upon their general health and motor fitness.[9-11] Researchers claim that from 50 to 80 percent of children show at least one deviation in body posture.[12, 13] Apart from faulty posture, individual faults occur such as protruding head or shoulder blades and various trunk asymmetries. The asymmetries prelude scoliosis — various disadvantageous alterations of the spinal cord shape.[14, 15] Individual body posture is influenced by factors such as genetics, age, particular period of the motor system development, and general psychical and physical condition.[16, 17] Lack of exercise and sedentary lifestyle are factors conducive to the emergence of new, and intensification of the already existing, trunk deformities.[18, 19] Studies of body posture and balance, lower limbs muscle strength and power are rather scarce in youngest children who participate in judo training.

Research on the physical and motor development of younger children practicing judo has been quite rare.[20] International experts suggest making a new proposal for a methodology of teaching with the aim of encouraging learning and bringing the environment closer to the sport of judo. Progress should be based on actions and techniques that facilitate the throwing of the companion, based on safety in the performance and the balance of the judoists.[21] Studies of body posture and balance, lower limbs muscle force and power are unique in youngest children who participate in judo training.

Therefore the aim of the present research was to demonstrate the possible changes occurring in the body stature and posture, balance, strength, and power of six-year-old boys practicing judo in comparison with their non-training peers.

Materials and methods

The research project gained the approval of the Bioethics Committee of the District Chamber of Physicians in Kraków (Opinion No. 75/KBL/OIL/2014 of October 1st, 2014). The parents of 88 boys aged from 3.8 to 8.0 expressed their written consent to their children's participation in the research, being interested in the continuous observation of their physical, and motor, development. Recruitment for the study and the first measurements (T1) were conducted in the beginning of the 2014/15 school year in a sports club running judo training sessions, in nearby kindergartens, and one primary school. A regular practice of judo was taken up by 51 boys (JU group), while the control group of the non-training boys (NT group) numbered 37 boys. Any spontaneous motor activity of the all examined boys was not inspected.

In the first measurement, there was no age difference between the examined boys from the groups NT and JU (5.77±0.17 *vs.* 5.70±0.29 years, t=0.415, P=0.680), although those belonging to group NT weighed significantly more (23.64±1.26 *vs.* 21.65±0.91kg, t=2.649, P=0.010) and were significantly taller than JU group (1.18±0.02 *vs.* 1.15±0.02, t=2.352, P=0.021). Therefore the results of the first measurement (T1) of the participants' age, body weight and height constituted a criterion to form pairs of representatives from the groups NT and JU in the planned repeated examinations. To obtain two groups equaled as much as possible as regards age, body mass, and body height, cluster analysis was applied. We selected 24 clusters joined at first stage as 12 closest pairs consisting of one boy from the study group and one from the control group. The city-block metric distance between the members of those 12 pairs was from 0.18 to 0.89. Thus the differences in age and basic physical development indices between groups NT (N.=12) and JU (N.=12) were reduced.

During the T1 measurements, there were no significant inter-group differences in age (NT= 6.12±0.50 *vs.* JU= 6.03±0.51 years, t=0.403, P=0.691), body weight (NT=22.69±2.99 *vs.* JU=22.44±2.90 kg, t=0.208, P=0.837), body height (NT=1.17±0.05 *vs.* JU=1.17±0.05 m, t=0.403, P=0.691), and Body Mass Index (NT=16.55±1.27 *vs.* JU= 16.40±1.17 kg/m^2, t=0.301, P=0.666). The boys were characterized by normal stature, since the cut-off point for overweight in this age group is 17.55 kg/m^2.[10] All the examined boys were right-handed and right-footed.

Anthropometric examinations

The participants' body weight was measured (in kilograms) with the use of electronic scales (Radwag, WPT 100/200 OW), while their height (in centimeters) was measured with anthropometer (American Martin type device, to be precise). On the basis of the results thus obtained, the participants' Body Mass Index was calculated (kg/m^2).[10]

Body posture assessment

Body posture was evaluated with the use of the projection Moiré method. The study was conducted in compliance with the general methodology of Moiré technique examinations, which resulted in setting fourteen parameters defining the body posture (six in the sagittal plane, one in the transverse plane, and seven in the frontal plane).[22-24] The examination was carried out with the use of the set for photogrammetric assessment of body posture produced by the CQ Elektronik System company.[25] 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. 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 of 1mm. 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 than 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%.[25]

Balance Test

Researchers used the deviceless Unipedal Stance Test (UPST). Following its directions, they measured the time of maintaining body position in one-leg stand with the upper extremities clasped on the chest (the measurement was conducted in seconds, with the use of a stop-watch). The foot of the raised leg was to be kept in contact with the supporting leg, touching it just over the inside of the ankle. Each of the participants performed the test three times in two different conditions, that is, with his eyes open (EO) and closed (EC).[26] For both the conditions, the average from three attempts was calculated.

Lower limbs mechanical output

In the examination of ground reaction force (GRF) during the two legged standing vertical jump with arm swing, the PJS-2D (JBA Zb. Staniak, control-measurement systems) measuring system was used (with the maximum force measurement error of less than 2%), designed to measure and record the mechanical characteristics of human lower extremities in the vertical jump. The system was composed of the PLA5-_2D dynamometric platform with a measurement range of 7kN and natural frequency of over 120Hz, the WWU001-2T amplifier and MVJ software. The participant performed tree maximum-effort countermovement jumps (CMJ), while standing on a force platform. The impulse-momentum method was used to calculate jump variables.[27] Shear forces are ignored. During the trial the participant stood on the force plate for 3 seconds before executing the jump. In the subsequent analysis, the following variables were used: impulse, recorded in the take-off phase (impulse J is the integral of a force, F, over the time interval, t [Ns]); relative power developed by the lower limbs muscles in the take-off phase (relative power is the rate of doing work per time and mass unit [W/kg]). During each examination, three trials of the maximum vertical jump were performed.[27] Because the maximum value of mechanical output of the muscles of the lower limbs was analyzed, therefore the tested data for the attempt which achieved the best result was selected.

Teaching program (experimental factor)

The training schedule consisted of judo training sessions organized by professional coaches at the local school of *tatami*. Two judo sessions per week were proposed to the participants, with an average time ranging from 35 to 45 minutes. The teaching program for children aims at an improvement of basic motor abilities (endurance, speed and dynamic balance) and motor skills (running, climbing, throwing, holding, jumping). Strong emphasis is laid on development of general fitness and gymnastics (stretching, doing bridges, somersaults, hand springs using mats, mattresses, balls, benches, bars, or gymnastic rings). The teaching focuses on basic elements of judo, such as bowing in standing position and kneeling (*seiza*), natural stances (*shizen hontai*, *migi shizentai*, *hidari shizentai*), defensive stances in standing and lying position, moving on the mat using various judo steps, moving on the mat while kneeling and lying, and the skill that might be the most useful for maintaining health, *i.e.* falls such as, *ushiro ukemi*, *yoko ukemi*, *mae ukemi* and *zempo ukemi*, *kumi kata*, entrance to throws *uchikomi*, etc. Children who train judo for a longer period of time should also be familiarized with basic holds (*hon kesagatame*, *yokoshiho gatame*, and *kamishiho gatame*), body shifting (*tai sabaki*) and some elementary technical throws (*o-goshi* and *osotogari*). The program takes into consideration the difficulty in children's learning judo techniques. All elements are taught in educational form or by means of learning games in order to motivate the children to participate in the program. The drills are most often performed in pairs. The aim was to arouse the children's imagination as much as possible through various task solution forms. Sometimes, when introducing a new gymnastic or judo element, the main emphasis was put on imitative methods, including direct imitation, the child's task being to mimic the movement demonstrated by a coach.[8, 28]

Statistical analysis

The dependent variables were provided by the results of the anthropometric examination and body posture, balance, force, and power in the vertical jump measurements. The statistical elaboration included the distribution normality test in the successive time points (T1 baseline, T2 three months later; and T3 six months later) and calculation of descriptive statistics (the average and SD). The experimental plan was a mixed 2×3 design; it included one between group factor: the group (boys training *vs.* non-training judo), and one repeated-measures factor: three moments of measure (baseline, three months, and six months). As there were ten dependent variables, therefore ten analyses, which could increase the probability of type I error, a multivariate analysis of variance was performed first (MANOVA), for the main effects of time and the group, as well as for the interaction between the factors, and the series of univariate ANOVAs was performed only after the MANOVA was significant. With the factorial repeated measures ANOVA procedure, the Mauchly's test was performed to test the assumption of sphericity. If sphericity was not present, the Greenhouse-Geisser correction was applied when epsilon was less than 0.75.

On the basis of the Wilk's λ value in the MANOVA, the multivariate effect size index η^2_{multiv} was calculated.[29] The value of the globalized eta-squared η^2_G effect was calculated.[30]

In the case of a significant interaction, differences between groups separately at the three moments of measures were calculated, by means of the 95% confidence intervals with Bonferroni correction and comparison of group means at same time.

Results

The GLM MANOVA procedure results for the ten dependent variables (*i.e.*, weight, height, UPST EOA [balance test with eyes open average], UPST ECA [balance test with eyes closed average], TT [tilt of the trunk], DTK [depth of thoracic kyphosis], MR [maximum rotation], LALB C-F [lower angle of left blade: closer-further], DDALBS [difference in deflection angles of the lower blade of the spine], and J impulse) have demonstrated that the time factor had a significant impact on the level of this set ($F=5.82$, $P<0.001$, Wilk's $\lambda=0.152$, $\eta^2_{multiv}=0.848$). The influence of the group factor was

TABLE I.—*Means and standard deviations for physical development indices, body stature and posture, balance, and force and power in boys practicing judo across experimental conditions.*

	Group			Baseline T1			3 months after T2		6 months after T3	
	Count	Average	SD	Count	Average	SD	Average	SD	Average	SD
Mass (kg)	72	23.32	2.90	24	22.57 [a]	2.89	23.26 [a, b]	2.79	24.14 [b]	2.93
NT	36	23.48	3.07	12	22.69	2.99	23.33	3.11	24.43	3.12
JU	36	23.16	2.76	12	22.44	2.90	23.19	2.57	23.86	2.84
Height (m)	72	1.19	0.05	24	1.17 [a]	0.05	1.19 [a, b]	0.05	1.20 [b]	0.05
NT	36	1.19	0.05	12	1.17	0.05	1.17	0.05	1.20	0.05
JU	36	1.18	0.05	12	1.17	0.05	1.18	0.05	1.20	0.06
BMI (kg/m^2)	72	16.56	1.24	24	16.48	1.20	16.51	1.30	16.71	1.26
NT	36	16.64	1.41	12	16.55	1.27	16.50	1.59	16.87	1.45
JU	36	16.49	1.05	12	16.40	1.17	16.52	1.00	16.55	1.08
TT (deg)	72	1.06	7.35	24	-0.25	8.37	2.21	6.11	1.21	7.48
NT	36	-0.94*	6.66	12	-5.08 *	3.58	2.08	6.79	0.17	7.23
JU	36	3.06	7.54	12	4.58	9.1	2.33	5.65	2.25	7.90
DTK (mm)	72	16.53	11.30	24	11.33 [c]	9.51	19.718 [b]	11.51	18.54	11.32
NT	36	14.39	11.82	12	5.92 [a, c] *	5.07	20.16 [b]	13.54	17.08 [b]	10.61
JU	36	18.67	10.48	12	16.75	9.97	19.25	9.65	20.00	12.27
MR (deg)	72	4.17	13.28	24	7.58	9.98	2.08	16.40	2.83	12.53
NT	36	-0.78*	11.95	12	3.75 [c]	5.07	-8.33 [b] *	13.38	2.25	12.45
JU	36	9.11	12.82	12	11.42	12.27	12.50	12.10	3.42	13.13
LALB C-F (mm)	72	-6.46	14.63	24	-9.13	11.67	-6.83	19.01	-3.42	12.08
NT	36	-0.31*	12.69	12	-4.67	7.57	3.58*	17.67	0.17	10.28
JU	36	-12.61	13.97	12	-13.58	13.56	-17.25	14.37	-7.00	13.10
DDALBS (mm)	72	-5.40	8.66	24	-8.67 [a]	6.73	-4.42	10.45	-3.125 [b]	7.73
NT	36	-6.72	7.83	12	-10.25	6.06	-4.17	9.87	-5.75	6.25
JU	36	-4.08	9.35	12	-7.08	7.24	-4.67	11.43	-0.50	8.42
UPST (EOA) (s)	72	13.62	8.86	24	10.56 [a, c]	6.97	14.39 [b]	8.89	15.92 [b]	9.94
NT	36	14.26	9.09	12	11.68 [c]	8.10	17.79 [b] *	10.43	13.33	8.17
JU	36	12.98	8.71	12	9.44 [a]	5.78	10.98 [a]	5.57	18.52 [b, c]	11.20
UPST (ECA) (s)	72	3.84	2.05	24	3.00 [a]	1.46	3.85	2.01	4.67 [b]	2.30
NT	36	3.33	1.74	12	2.47	1.04	3.69	1.96	3.83*	1.86
JU	36	4.35	2.22	12	3.54 [a, b]	1.66	4.02 [b]	2.14	5.50 [b]	2.46
J (Ns)	72	40.32	7.65	24	39.58 [a]	6.46	39.08 [a]	8.37	42.29 [b, c]	7.90
NT	36	40.05	8.00	12	40.67	6.72	37.58 [a]	9.53	41.92 [c]	7.52
JU	36	40.58	7.38	12	38.50 [a]	6.29	40.58	7.13	42.67 [b]	8.56
Pr (W/kg)	72	15.11	3.55	24	14.39	4.62	15.02	3.12	15.93	2.58
NT	36	14.60	3.99	12	14.37	5.55	14.20	3.57	15.23	2.47
JU	36	15.62	3.04	12	14.41	3.73	15.83	2.46	16.63	2.59

Comparison of time in the same group: [a] significantly different from T1 condition; [b] significantly different from T2 condition; [c] significantly different from T3 condition; comparison of group at the same time: * group JU is significantly different from NT.
JU: boys practicing judo; NT: non-training boys; TT: tilt of the trunk; DTK: depth of thoracic kyphosis; MR: maximum rotation; LALB C-F: lower angle of left blade: closer-further; DDALBS: difference in deflection angles of the lower blade of the spine; UPST EOA: balance test with eyes open average; UPST ECA: balance test with eyes closed average; J: impulse during the take-off phase; Pr: relative power.
The [a, b, c] indexes refer to the main effects of time (differences between three time points), or to the differences between three time points in particular groups. The index * refers to the difference between both groups in a given time points (when the index is present at one group, it means that both groups differ significantly.

also demonstrated (F=3.93, P=0.001, Wilk's λ =0.471, η^2_{multiv} =0.529). Besides, a significant interaction between the time factor and group factor was ascertained (F=2.04, P=0.015, Wilk's λ =0.399, η^2_{multiv} =0.601). Therefore, it was deemed useful and expedient to present inter-group changes to the individual independent variables in the different time points (Table I).

The results of the series of univariate ANOVAs performed for the dependent variables after the MANOVA yielded following results.

Body weight

There was no difference in body weight between the groups training judo and non-training ($F_{1, 22}$ =0.07; P=0.780; η^2_G=0.003). The impact of the time factor on the changes in body weight was significant ($F_{2, 44}$=70.75; P<0.001; η^2_G=0.632 [large effect]): the body mass was higher after 6 months than at the baseline. The influence of the interaction of time and the group was not significant ($F_{2,44}$=0.83, P=0.444,η^2_G=0.001).

Body height

The inter-group differences in body height were insignificant ($F_{1, 22}$ =0.02, P=0.898, η^2_G =0.001). The time factor proved significant for the body height ($F_{1,46, 44}$ =49.70, P=<0.001, η^2_G =0.687 [large effect]): after six months the boys were higher by about 4 cm. The interaction of time and the group was also not significant ($F_{1,46,44}$ =0.04, P=0.958, η^2_G <0.001).

Body Mass Index

The differences between groups training and not training judo were insignificant ($F_{1, 22}$ =0.09, P=0.768, η^2_G=0.004). No significant differences between the successive measurements were demonstrated for the body mass index (BMI; $F_{2, 44}$ =2.33, P=0.109, η^2_G =0.091). The time × group interaction effect was not significant ($F2_{2, 44}$=1.02, P=0.370, η^2_G =0.003).

TT

For the TT, group differences proved significant: the results were higher in the case of boys training judo than for their not training counterparts ($F_{1, 22}$ =6.54, P=0.018, η^2_G =0.083 [small effect]. The time factor effect was insignificant ($F_{2, 44}$ =0.73, P=0.486, η^2_G =0.029).

The interaction between the time and the group factor was barely significant ($F_{2, 44}$ =2.99, P=0.061, η^2_G =0.086 [small effect]): at the baseline, the TT was significantly higher for training than for nontraining boys, whereas the differences between groups were non-significant after three and six months.

DTK

No differences between training and non-training groups were observed ($F_{1, 22}$ =2.76, P=0.111, η^2_G =0.043). The time factor had a significant impact on the change in the DTK ($F_{2, 44}$ =4.64, P=0.015, η^2_G =0.164 [medium effect]): the results were higher after three months than at the baseline. The time × group interaction effect was not significant level ($F_{2, 44}$ =2.02, P=0.144, η^2_G =0.056.

MR

Boys training judo had higher results than non-training ($F_{1,22}$ =10.63, P=0,004, η^2_G =0.162 [medium effect]). The time factor did not cause significant changes of the MR average ($F_{2, 44}$ =1.71, P=0.192, η^2_G =0.056), but the interaction of time and the group factor was significant ($F_{2, 44}$ =4.84, P=0.013, η^2_G =0.117 [small effect]) (Figure 1): the difference between groups was significant after three months (with boys training judo having higher results than non-training), but not at the baseline or after six months.

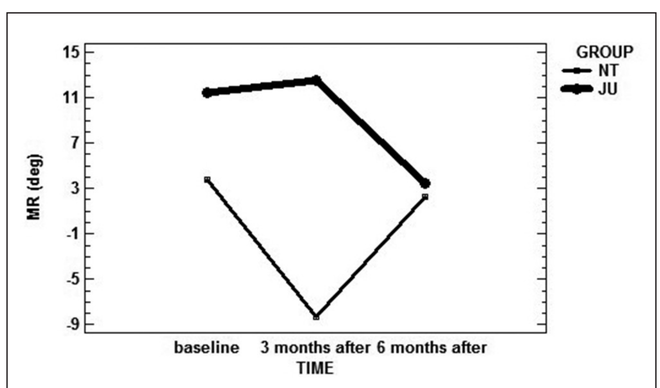

Figure 1.—Changes of maximum rotation (MR) values in successive tests in the boys practicing judo (JU) and of the non-training boys (NT).

LALB C-F

The results differed among groups, with boys training judo having higher results than non-training ($F_{1, 22}$ =9.24, P=0.006, η^2_G =0.193 [medium effect]). The impact of the time factor upon the changes in LALB C-F proved insignificant ($F_{1.44, 44}$ =1.77, P=0.193, η^2_G =0.049), but the interaction of time and the group factor was close to the conventional significance level ($F_{1.44, 44}$ =2.97, P=0.076, η^2_G =0.081 [small effect]): boys training judo had lower results than non-training after three months, but not after six months or at the baseline level.

DDALBS

The differences between groups were insignificant ($F_{1, 22}$ =1.27, P=0.271, η^2_G =0.026). The results on DDALBS did not change across time ($F_{2, 44}$ =3.51, P=0.039, η^2_G =0.132 [medium effect]), as was the interaction between the factors of time and the group ($F_{2, 44}$ =0.88, P=0.420, η^2_G =0.021).

UPST (EOA)

The average UPST (EOA) result depended on the time factor ($F_{2, 44}$ =7.44, P=0.002, η^2_G =0.248 [medium effect]): results at the baseline were lower than both after three and six months. The main effect of the group factor on the UPST (EOA) average was not significant ($F_{1, 22}$ =0.18, P=0.678, η^2_G =0.006), but the interaction of both factors was ($F_{2, 44}$ =8.94, P=0.001, η^2_G =0.085 [small effect]; Figure 2): after three months, boys training judo had higher results than those not training.

UPST (ECA)

In the case of this variable, there was a tendency indicating better results of the UPST (ECA) Test in group E than in group C ($F_{1, 22}$ =3.48, P=0.076, η^2_G =0.072 [small effect]). Group difference was significant after six months. The time factor had a significant influence on the average results ($F_{2, 44}$ =6.05, P=0.005, η^2_G =0.192 [small effect]): there was a significant increase in the results between the baseline and after six months, but not between three months and baseline. The time group interaction was not significant ($F_{2, 44}$ =0.99, P=0.380, η^2_G =0.022).

Impulse (J)

The main effect of the group factor was insignificant ($F_{1, 22}$ =0.03, P=0.857, η^2_G =0.020), but the impact of the time factor on the change of impulse (J) in the vertical jump was significant ($F_{2, 44}$ =5.52, P=0.007, η^2_G =0.199 [medium effect]): the average result increased significantly between three and six months, but the interaction of time and the group was significant ($F_{2, 44}$ =3.11, P=0.055, η^2_G =0.020 [small effect]; Figure 3); however, it is difficult to interpret, as no group differences were significant at any of the time points.

Relative power

In the case of this variable, there was no significant impact of the group factor ($F_{1, 22}$ =0.83, P=0.369, η^2_G =0.022), of the time factor ($F_{2, 44}$ =1.83, P=0.183, η^2_G =0.010), and of the interaction ($F_{2, 44}$ =0.57, P=0.572, η^2_G= 0.079).

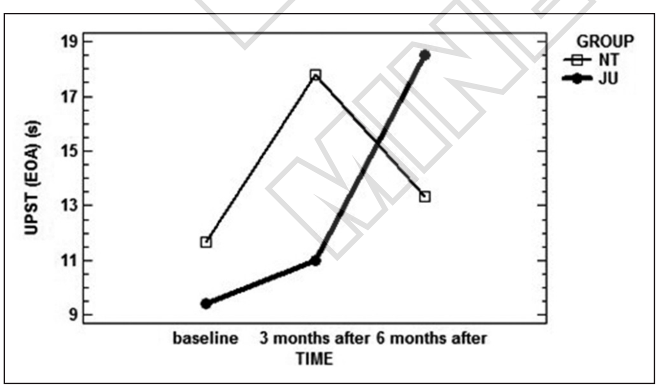

Figure 2.—Changes of balance test with eyes open UPST (EOA) results in successive examinations in the boys practicing judo (JU) and of the non-training boys (NT).

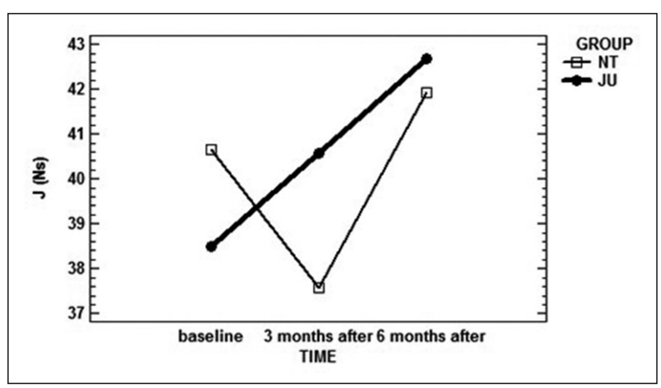

Figure 3.—Changes of the impulse (J) value in the take-off phase in successive tests in the boys practicing judo (JU) and of the non-training boys (NT).

Discussion

Considering the aim of the present study, the main time factor combined with the impact of the time x group factor was of particular interest to the researchers. The primary results of our study regarding the main time factor can be classified as follows: 1) substantial, natural change between all three time points in average body mass and body height; 2) the result of average balance test with eyes open (UPST EOA) increased substantially from baseline to time point three, but the changes from both the baseline to 3 months after and from 3 months after to 6 month after were minimal; 3) depth of thoracic kyphosis (DTK) average value increased substantially from baseline to time point two, but was followed by a minimal decrease from time points two to three; 4) minimal change in the successive time periods but, collectively, a substantial change in difference in deflection angles of the lower blade of the spine (DDALBS), and in the balance test with eyes closed performance (UPST ECA); 5) the average value of impulse (J) increased substantially from time point two to three, following a minimal decrease from time point one to two; 6) the average values of the BMI, TT, MR, LALB C-F and relative power (Pr) did not change during the six-month period of observation.

The findings of the above examinations confirm the expectations regarding the impact of taking up judo practice on the improvement and development of the youngest six-year-old training boys' physical fitness. This is one of the few prospective studies to analyze this phenomenon at early stage of ontogenesis. During another research in seven-year-old boys who participated in a nine-month judo training, it was demonstrated that the practice decreased their adiposity level and had a beneficial impact on their general physical fitness (results of the sit-and-reach test, shuttle run test, sit-ups, and flexed arm hang test).[20] Expert judo coaches agreed that training volume in this age category should not be larger than in our study (two to three 45-minute workouts per week).[31] Other writers warned against a too early sports specialization: "*Successful competitive performance in early judo competition was not associated with success later in adulthood.*"[32] The training program implemented in our previous study — as well as during the present research[8] — aimed at observing the changes in body stature and posture, balance, force and power - complied with the following argument of sports medicine physicians concerning children's physical activity: "Younger than 6 years — all disciplines based on natural forms of movements in a form of games and plays involving movement. Older than 6 years — the disciplines based on natural forms of movement, developing movement coordination that do not exert selective load on the skeletal system".[33]

The Factorial ANOVA procedure demonstrated the time x group interaction for the MR (Figure 1) and UPST (EOA) results (Figure 2). Furthermore, a tendency towards the time x group interaction was observed in the case of the following examinations: TT, DTK, LALB C-F, and impulse J (Figure 3). The six points on the interaction charts (Figures 1-3) represent the average values of dependent variables in the subjects in each combination of the time and group factor. For group JU, significant linear time trends were revealed for UPST EOA ($t=4.48$, $P=0.004$) and for impulse (J) in the take-off phase ($t=2.83$, $P=0.007$). For group NT, the significant but quadratic trends over time were observed in the changes of MR (degree; $t=2.87$, $P=0.006$), UPST EOA ($t=-3.02$, $P=0.004$) and for impulse (J) in the take-off phase ($t=2.91$, $P=0.006$). The changes in the judo-training boys in the three successive examinations are beneficial: a gradual improvement is recorded in both body posture (MR) and balance parameters (UPST EOA), as well as in the impulse (J). Characteristically, in the NT group boys the average results of the third examination were already similar to the average values scored in the first examination, with the time changes being of a definitely step nature (in the second examination a marked decrease or improvement is observed (in MR or J, and UPST EOA, respectively). It cannot be excluded that the phenomenon observed may have been due to the impact of some spontaneous physical activity taken up by the NT group boys in that period.

The body posture changes observed in the judo-training boys in the three successive examinations were self-evidently beneficial. In the first examination, there was a statistically significant difference in the average TT values between the two groups, namely, the boys practicing judo tended to lean backward ($4.58\pm9.1°$), while their control group (NT) leaned forward ($-5.08\pm3.58°$). In the second examination, in both groups a gradual correction of body posture in the standing position occurred. In the third examination, the average value of the torso inclination angle was only 2.25±7.9° in group JU and 0.17±7.23° in the NT group.

In the first examination, there is a statistically significant difference between the average DTK values in the judokas group and in the control group (the difference being no less than 10.83mm). In the boys practicing judo, the depth of thoracic kyphosis increases in each successive examination. The same changes in young boys were noted in the research conducted by Giglio *et al.*,[34] or Willner *et al*;[35] with age, the angular and linear values of both the spinal curvatures (the thoracic and the lumbar) tend to increase. Correct formation of these curvatures guarantees a proper shock absorption of the child's spine, gradually allowing it to accept heavier loads — resulting, for instance, from continued practice of judo — and is an element of the preventive treatment of spinal pain syndromes at a later age.[36, 37]

In the boys who practiced judo, the trunk rotation in the transverse plane (MR) decreases in the successive examinations. In the last examination, the rotation value is only 3.42±13.13° (DDALBS). The angular value thus achieved seems almost standard, as in the research conducted by Stoliński and Kotwicki in the population of children aged from seven to ten, values within the range of 1-3° were noted in as many as 735 out of the thousand participants.[38]

In the sagittal plane, big differences between the examined groups were observed during each of the examinations with regard to the average parameters of LALB C-F (lower angle of left blade: closer-further); besides, during the six-month training period the asymmetry in deflection of shoulder-blades in frontal plane (DDALBS) is reduced in judo-training boys. In the third and final examination, the average difference of the distances of the lower blades to the spinal cord (DDALBS) is only 0.5±8.42 mm, which testifies their correct, *i.e.*, symmetrical, positioning in relation to the axis of the spine. In the control group, shoulder-blades asymmetry is observed in each of the examinations and it is nearly always bigger than in the boys from the judokas group. The bigger differences in the distance of the lower shoulder-blades to the spinal cord (DDALBS) in the judokas group in the early period of their practice can be accounted for by the diminished stability of the left shoulder blade due to the fact that the boys used the right upper limb more often and also more often employed the right-hand-side muscles of the pectoral girdle, as all of the examined judokas proved to be right-handed. Over time, regular sports training aimed at all-purpose physical development brings about a gradual symmetrization in the work of the pectoral girdle muscles and thus a correction in the positioning of both the shoulder-blades in relation to the spine. Such beneficial changes can decidedly reduce the risk of scoliosis.[39] Using the Moiré method, Bibrowicz specified those asymmetries that can be most helpful in early detection of scoliosis; as such, he recognized the asymmetries of waist triangles and of the distance of lower shoulder-blades from the spine.[40] In the present research, the latter asymmetry was reduced in the boys practicing judo.

Limitations of the study

The young judokas achieved better and better results in the successive stages of the impulse (J) value examinations, which indicates a beneficial increase in the force of their lower extremities muscles. However, they were unable to improve the efficiency of their muscles in the take-off phase (relative power Pr). This lack of improvement is a natural consequence of the applied training techniques directed to all-round development of the children's motor fitness, and not to achieving great sporting success. Undoubtedly, by including some elements of plyometric training in the judo practice, it would be possible to improve the values of the relative power indices (Pr) and increase the efficiency of the lower limbs muscles.[41] A weak spot of our investigation was that we did not collect exact data regarding any spontaneous physical activity in both the JU and NT groups.

Conclusions

Several months' cycle of regular judo practice is enough to achieve a distinct improvement in body balance; the biggest changes — by as much as 51% — were recorded between the first and last measurement in the UPST (EOA) test. Regular six-month practice of judo had a beneficial impact on the young judokas' body posture; its corrective influence was particularly evident in the deepening of the natural spinal curvatures, symmetrization of the shoulder-blades positioning, and in trunk derotation. In the judokas group, a significant increase of the impulse value (J) in the take-off phase was observed in the successive examinations. Other parameters of the vertical jump did not show significant differences. Significant linear trend concerning the increase of body balance in standing position and of the impulse value (J) in group JU can be of particular importance for the general improvement of the children's wholesomeness, especially in combination with pre-planned exercises in the skill of safe fall.

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