ORIGINAL ARTICLE

Postural stability of children undergoing training in karate

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A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Physical activity develops motor skills. Muscular strength and suppleness development improve coordination ability. There are numerous reports on the beneficial impact of karate kyokushin on body posture and postural stability. It may be difficult to assess the effect of karate training on the postural stability of young schoolchildren, as body posture in children is naturally unstable and undergoes constant changes. The aim of the study was static balance in a group of karate training children and peers who did not train in martial arts.

Materials & Method: The study was conducted on 100 children. The study group consisted of 50 children who had been training karate for at least two years. There were 29 boys and 21 girls in the group. The control group consisted of 50 children of the same age. To achieve greater reliability of research, the clinical control group members were chosen on a 1:1 basis. The children from both groups did not differ significantly in terms of body mass, height or BMI, which allowed for a highly reliable comparison of the studied parameters.

Results: The compilation of the Mann-Whitney U-test results for the compared groups. The analysis of results revealed a statistically significant difference between the mean values of the MAML parameter (eyes open) and the MaxML parameter (eyes open) in measurements for the two groups of children. The analysis of results revealed a difference between the mean values of the LWML parameter – the number of sways on the x-axis (eyes open) in measurements for the two groups of children. Also the statistically significant differences has been observed between the mean values of the RQSA parameters (the Romberg quotient for the path length) and the mean RQSPA parameter values (the Romberg quotient for the COP field quotient with eyes open and with eyes closed) in measurements for the two groups of children.

Conclusions: Karate developed balance in children aged 7-10 years, in that it had a beneficial effect on their motor skills. Regular karate training developed increased medio-lateral postural stability and greater sensitivity of the postural system to the distorting stimuli. The dependence of postural stability on the corrective function of the visual system was lower in karate-training children due to the better-developed sensory integration.

Key words: comparatistic, karate kyokushin, martial arts, non-active children

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Postural control – a complex process to maintain equilibrium and orientation of the human body; it relies on multisensory processing and motor responses that seem to be automatic and occur without conscious awareness.

Introduction

Physical activity develops motor skills. Muscular strength and suppleness development improve coordination ability [1-4]. Eastern martial arts are a common form of recreation, and kyokushin karate is one of the most popular martial arts in Poland and around the world.

There are numerous reports on the beneficial impact of karate kyokushin on body posture and postural stability [5, 6]. The beneficial impact is related to the required correct starting position during training. Motor skills development, including coordination development, are the core of karate training, as they constitute the basis on which other abilities of karate contestants are formed, i.e. the combat techniques.

It may be difficult to assess the effect of karate training on the postural stability of young schoolchildren, as body posture in children is naturally unstable and undergoes constant changes. Many authors state that karate training develops motor skills in children to a lesser degree than in adults, and that this is probably related to the not yet stabilised postural stability of children [7-11]. No anthropometric reports on the impact of systematic karate training on body posture and postural stability in children have been found in the literature.

The aim of the study was static balance in a group of karate training children and peers who did not train in martial arts.

Materials and methods

After obtaining family consent and child assent to participate the study was conducted on 100 children. The study population (GROUP I) consisted of 50 children aged 7-10 years, with a mean age of 8.1±1.5 years. The children had been training karate for at least two years. There were 29 boys and 21 girls in the group. The control group (GROUP II) consisted of 50 children of the same age. The criteria for excluding children were: distinctive divergence from the norm in terms of development, and uncompensated postural disorders of distinctive intensity. Inclusion criteria met 68 children: 19 boys, and 15 girls from group I, 19 boys, and 15 girls from the control group. To achieve greater reliability of research, the control group members were chosen on a 1:1 basis, which means that, – for example, each 7-year old boy from the study population had a 7-year old boy counterpart in the control group. The children from both groups did not differ significantly in terms of body mass, height or BMI, which allowed for a highly reliable comparison of the studied parameters. The tests were conducted at the Kyokushin Karate Club in the Bielany, district of Warsaw (Poland). The karate practitioners trained there twice a week for 1.5 hours. The children from the control group were not involved in any physical activity on a regular basis.

The following balance parameters were analysed:
SP – total length of COP path [mm]
SPAP – length of COP path in the anterior-posterior plane, i.e., in the y-axis [mm]
SPML – length of COP path in the medial-lateral plane, i.e., in the x-axis [mm]
MA – mean amplitude of the COP projection [mm]
MAAP – mean amplitude of COP projection in the anterior-posterior plane, i.e., in the y-axis [mm]
MAML – mean amplitude of the COP projection in the medial-lateral plane, i.e., in the x-axis [mm]
MaxAP – maximal amplitude between the two most distant points in the anterior-posterior plane, i.e., in the y-axis [mm]
MaxML – maximal amplitude between the two most distant points in the medial-lateral plane, i.e., in the x-axis [mm]
MV – mean COP velocity [mm/s]
MVAP – mean COP velocity in the anterior-posterior plane, i.e., in the y-axis [mm/s]
MVML – mean COP velocity in the medial-lateral plane, i.e., in the x-axis [mm/s]
SA – sway area marked by the moving COP [mm^2]
SPSA – quotient of total length of COP path to the sway area marked by moving COP path [mm/mm^2].
LWAP-EO – number of antero-posterior COP amplitudes.
LWML-EO – number of medio-lateral COP amplitudes.
MNDB-EO – Mean (arythmetic) Difference Balans
RQSP – Romberg quotient for the length of path of statokinesiogram, which depicts the COP movement during the test in a two-dimensional coordinate system
RQSA – Romberg quotient for COP field marked by the movement of COP in a two-dimensional coordinate system
RQMV – Romberg quotient for the COP means velocity in a two-dimensional coordinate system
RQSPA – Romberg quotient for the COP field quotient to the COP path length

Results

The compilation of the Mann-Whitney U-test results for the compared groups is presented in table 1. Statistically significant differences were observed ($p<0.05$). Detailed analyses of the observed correlations are presented in figures 1-4.

Table 1. Compilation of the descriptive statistics of the analysed parameters, and of the Mann-Whitney U-test results for the parameters in the studied population (GROUP I) and the clinical control group (GROUP II).

VARIABLE	GROUP I					GROUP II					U MANNA-WHITNEY'A	
	x̄	Me	Min.	Max.	s	x̄	Me	Min.	Max.	S	Z	P
SP-EO [mm]	336.9	323.0	171.0	697.0	128.0	345.4	312.5	162.0	1045.0	167.4	0.09	0.9316
SPAP-EO [mm]	220.4	206.5	114.0	467.0	85.1	209.2	197.5	111.0	393.0	65.4	0.34	0.7359
SPML-EO [mm]	203.5	202.5	92.0	528.0	82.9	222.4	188.5	93.0	863.0	146.7	0.15	0.8830
MA-EO [mm]	3.4	2.8	1.0	11.0	2.3	3.8	3.3	1.2	9.6	2.2	−1.07	0.2831
MAAP-EO [mm]	2.6	2.4	0.8	6.9	1.5	3.0	2.4	1.0	15.2	2.6	−0.44	0.6631
MAML-EO [mm]	**1.5**	**0.9**	**0.4**	**9.5**	**1.9**	**2.4**	**1.5**	**0.3**	**15.7**	**2.9**	**−2.57**	**0.0103**
MaxAP-EO [mm]	10.2	7.5	2.3	37.0	7.0	12.2	8.8	3.1	33.9	7.6	−1.47	0.1410
MaxML-EO [mm]	**6.9**	**3.6**	**1.6**	**70.1**	**11.6**	**16.9**	**6.7**	**1.7**	**139.3**	**31.6**	**−2.59**	**0.0095**
MV-EO [mm/s]	11.2	10.8	5.7	23.2	4.3	11.5	10.4	5.4	34.8	5.6	0.06	0.9511
MVAP-EO [mm/s]	7.3	6.9	3.8	15.6	2.8	7.0	6.6	3.7	13.1	2.2	0.35	0.7266
MVML-EO [mm/s]	6.8	6.8	3.1	17.6	2.8	7.4	6.3	3.1	28.8	4.9	0.13	0.8926
SA-EO [mm^2]	432.3	243.0	63.0	2443.0	477.2	687.6	310.5	112.0	6280.0	1221.1	−1.28	0.2021
LWAP-EO	16.9	15.5	3.0	44.0	9.2	14.0	12.5	1.0	34.0	8.6	1.39	0.1650
LWML-EO	**24.9**	**23.5**	**3.0**	**57.0**	**12.0**	**18.4**	**18.0**	**1.0**	**44.0**	**12.8**	**2.24**	**0.0251**
MNDB-EO	1.4	2.0	−14.0	16.0	6.6	2.2	0.5	−14.0	23.0	9.1	−0.04	0.9657
RQSP	1.1	1.1	0.0	1.9	0.3	1.1	1.1	0.3	2.3	0.3	0.92	0.3575
RQSA	**1.5**	**1.4**	**0.0**	**4.3**	**1.1**	**0.9**	**0.9**	**0.1**	**2.1**	**0.5**	**2.58**	**0.0100**
RQMV	1.1	1.1	0.0	1.9	0.3	1.1	1.1	0.3	2.3	0.3	0.92	0.3575
RQSPA	**1.0**	**0.9**	**0.0**	**2.8**	**0.6**	**1.5**	**1.3**	**0.1**	**6.2**	**1.1**	**−2.69**	**0.0072**

The analysis of results revealed a statistically significant difference (p=0.0103) between the mean values of the MAML parameter (eyes open) in measurements for the two groups of children. The graphical representation is a figure showing the distribution of results in both groups. It is important to note the curve vertex shift – it can be seen that the red vertex is shifted further than the blue vertex. Children from the control group had higher mean results for the centre of foot pressure amplitude on the x-axis.

There was a statistically significant difference (p=0.0095) between the mean values of the MaxML parameter (eyes open) in measurements for the two groups of children. The figure depicts the distribution of results in both groups. The curve vertex shift shows that the higher mean results for the maximal amplitude of centre of foot pressure on the x-axis were found in the control group children.

The analysis of results revealed a difference (p=0.0251) between the mean values of the LWML parameter – the number of sways on the x-axis (eyes open) in measurements for the two groups of children. A curve vertex shift was noted – the blue vertex was shifted further than the red vertex. The karate-training children had higher mean results, which means they had a mean of more sways.

The figure shows the statistically significant differences (p=0.0100) between the mean values of the RQSA parameters (the Romberg quotient for the path length) in measurements for the two groups of children. The curve vertex shift is worthy of note – the blue vertex was shifted further than the red vertex. The karate-training children had higher mean results.

Statistically significant differences (p=0.0072) were found between the mean RQSPA parameter values (the Romberg quotient for the COP field quotient with eyes open and with eyes closed) in measurements for the two groups of children. The figure analysis reveals a curve vertex shift – the red vertex is shifted further than the blue vertex. The control group children had higher results.

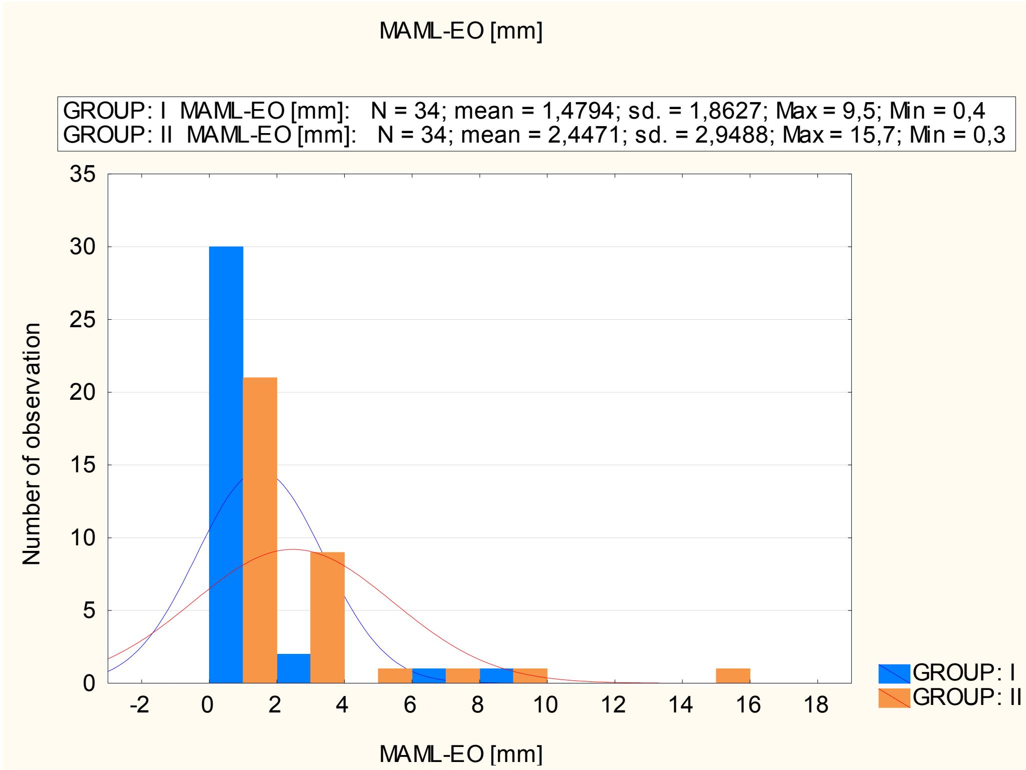

Figure 1. Value distribution of the parameter denoting the mean amplitude of the centre of foot pressure in the medio-lateral plane – on the x-axis (MAML-EO).

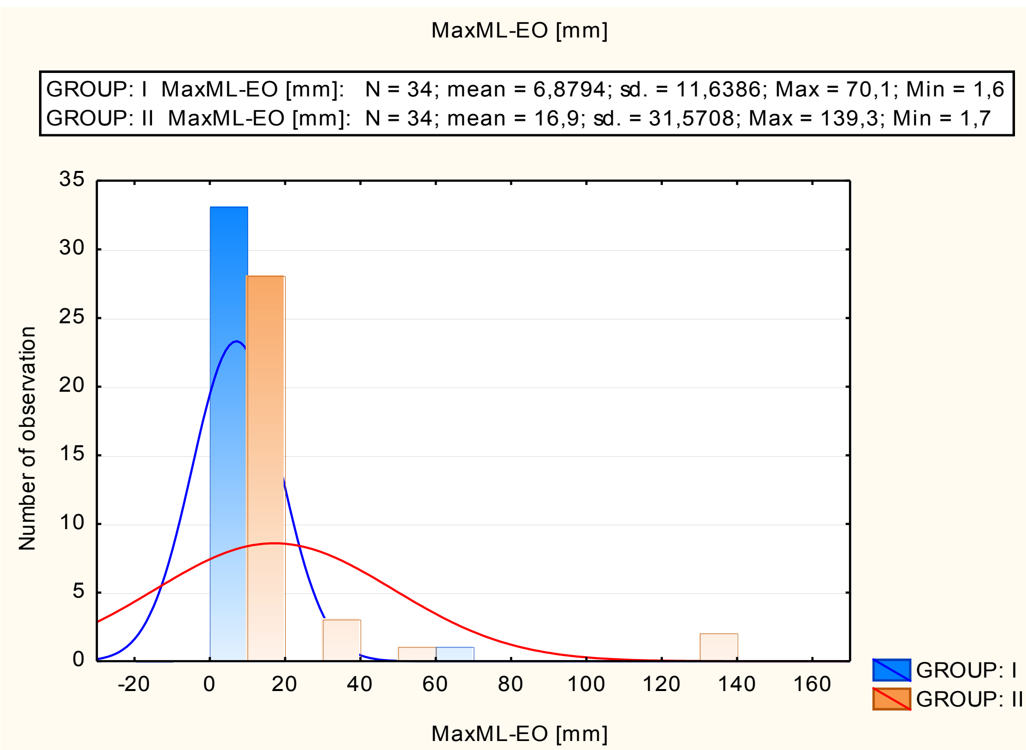

Figure 2. Value distribution of the parameter denoting the maximal amplitude of the centre of foot pressure projection from the O point, in the medio-lateral plane – on the x-axis (MaxML-EO).

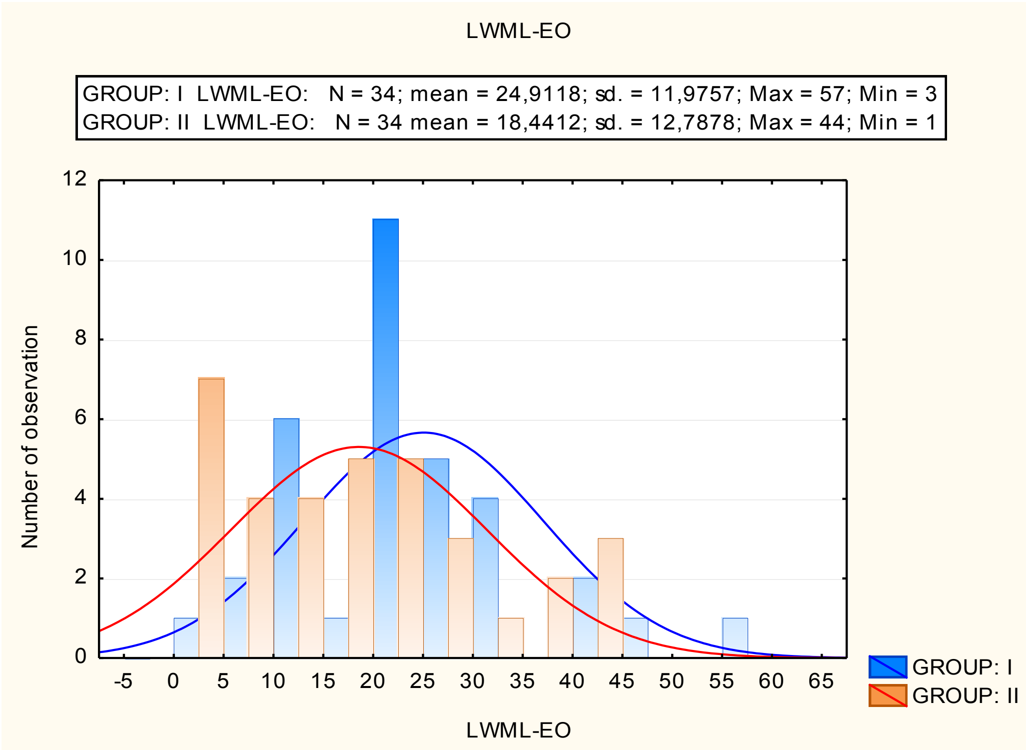

Figure 3. Value distribution of the parameter denoting the number of centre of foot pressure amplitudes in the medio-lateral plane – on the x-axis (LWML-EO)

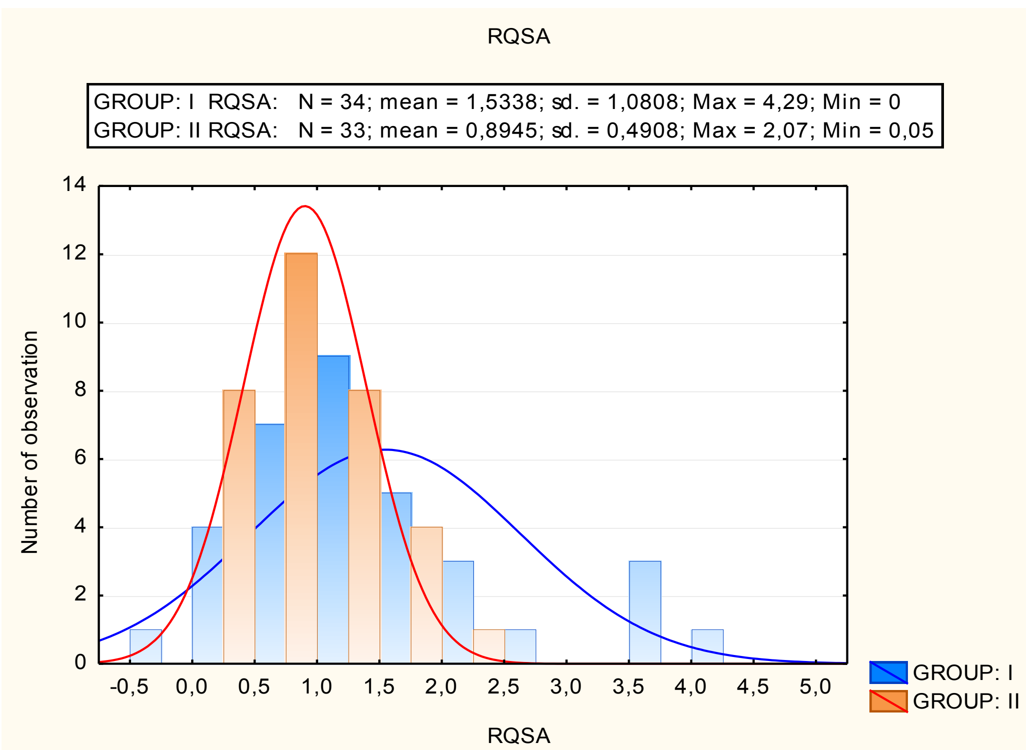

Figure 4. Value distribution of the parameter denoting the Romberg quotient for the COP field (RQSA)

Discussion

The conducted study revealed the effect of karate training on postural stability. The studied population of children was characterised by a considerable natural postural instability related to the young age and development [8-10]. However, the studied population had better static balance test results than the control group.

Numerous authors have observed the effect of various sports disciplines on the motor skills and balance control [12-15]. Karate training develops strength, endurance and coordination, which in turn improve the balance system [5,13,16-17]. Regular training improves sensomotoric organisation [18-20] and enhances reaction speed [20]. It helps improve motor ability test results, including balance control [12, 18, 21].

In their study, Conant et al. pointed out that regular karate training had a beneficial effect on the quality of life of epileptic children. This stems from the multidimensional impact of karate on a young system [22]. The increase of the muscular strength of lower limbs [13-14] has a beneficial effect on the ability to keep balance.

In their study, Fonga et al. noted an improvement of balance reactions quality in comparison to control group [13, 23]. Our study confirmed this findings.

Other studies proved the effect of doing sports on the changes in spinal curvature and spinal symmetry [24-26]. This is achieved through the required starting position assumed during training. Our own studies prove that such changes have an impact on postural stability, they stimulate the initial muscle tone responsible for the time and quality of the proprioceptive sensation reception, and stimulate muscle reply to the sensory input [27-31].

In the studied population, in comparison to the control group, an increased medio-lateral stability was observed. Lower values were observed for the parameters of the mean COP amplitude on the x-axis and the maximal amplitude from the reference point for this direction. However, the number of the COP amplitudes for this direction increased. It was related to the correction signal and clearly points to the increased reactivity of the postural system controlled by the balance system, which proves the enhanced readiness to counteract the balance-disturbing stimuli [32-33]. These reactions become part of the phenomenon of postural stability as discussed by numerous authors, including Błaszczyk [34,36]. Postural stability is the ability of the postural system to regain the relative balance after an action from a balance-disturbing stimulus [36-38].

In the quantification of static balance in the studied population, 30-second measurements with eyes closed were taken. After comparing the results (the measurement with eyes open and the measurement with eyes closed), the Romberg quotient was determined. The quotient is calculated by the equipment, and relates to the values of the measured parameters with eyes open and eyes closed. On the basis of the quotient, one can determine the degree of dependence of postural stability on the visual system [39,40]. In the cases of the parameters of field COP, COP path length or COP velocity (a function of time represented in the stabilograms), the lower the value of the quotient, the more the quality of the balance reaction is dependent on visual control. The control has the value of correction and it allows for the finding of an external frame of reference [41]. It may also point at the considerable disorder of the functions of the proprioreceptors of joints and muscles, or disorders unrelated to the cerebellum, for example dorsal column-medial lemniscus tract disorders [42-43]. Such dysfunctions affect the quality of the balance system response to a much greater degree in measurements with eyes open. The diagnosis of considerable proprioceptive sense disorders can be made when the Romberg quotient value does not rise considerably for a generally bad result (considerable values of path length etc). A similar situation arises when the patient suffers from visual disorders (the visual system does not compensate for the information deficit from the proprioreceptors). On the other hand, the correlation of the Romberg quotient for the COP path length and COP field quotient is different. The result of the (mathematical) quotient itself has to be interpreted in the following way: the greater the value, the greater the postural stability. The Romberg quotient for the mathematical quotient, however, has to be interpreted otherwise: the lower the value, the lower the dependence of the postural stability on the visual system.

We found that in the karate-training children posture was less dependent from the corrective signal from the visual system than in the control group [44-45]. This may prove that the balance reaction quality intensified in the studied population, resulting from strong sensomotoric integration [20, 23, 46-47], and the following increase in balance system readiness and an enhanced sense of one's own body in space [41].

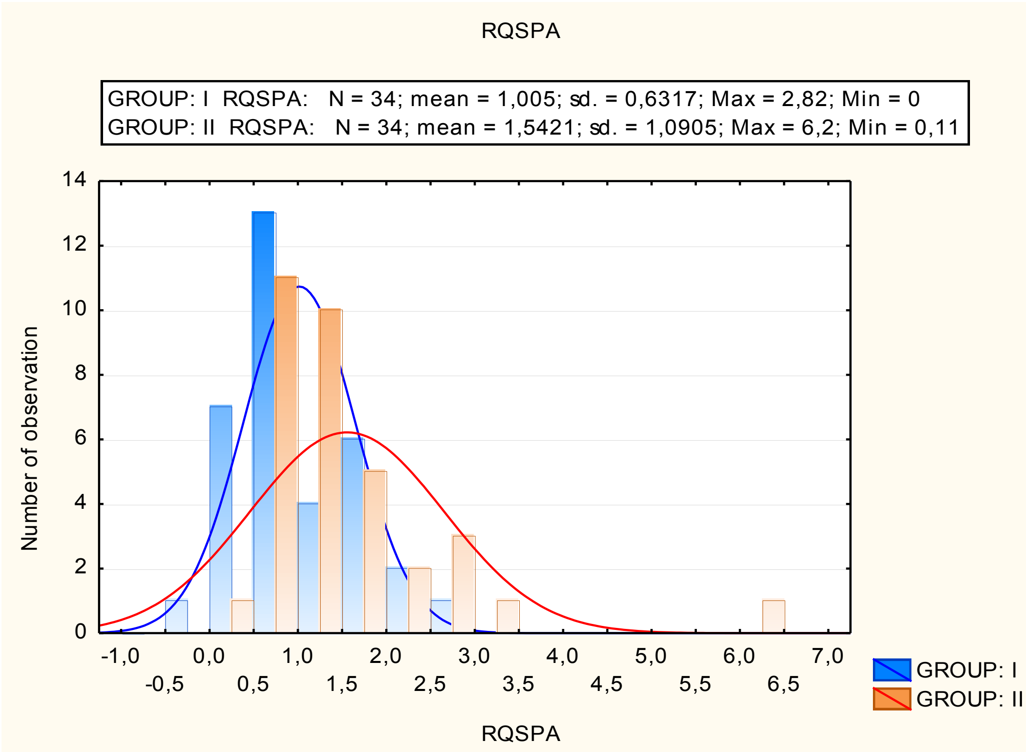

Figure 5. Value distribution of the parameter denoting the Romberg quotient for the COP path length and COP field quotient (RQSA).

Our observations may be used in the therapy and training of people with motor and balance disorders. Through carefully chosen forms of karate training, subjects with a narrowed safety margin may develop their coordination skills in an attractive way. Karate should be treated as a supplementary form of balance training for fit subjects, including children. Karate influences balance indirectly, in that it develops motor skills and coordination.

Regular karate training developed increased mediolateral postural stability and greater sensitivity of the postural system to the distorting stimuli.

The dependence of postural stability on the corrective function of the visual system was lower in karate-training children due to the better-developed sensory integration.

Conclusions

Karate developed balance in children aged 7-10 years, in that it had a beneficial effect on their motor skills.

Competing interests

The authors declare that they have no competing interests.

References

1. Okely AD, Booth ML, Patterson JW. Relationship of physical activity to fundamental movement skills among adolescents. Med Sci Sports Exerc 2001; 33(11): 1899–1904
2. Strong WB, Malina RM, Blimkie CJ et al. Evidence based physical activity for school-age youth. J Pediatr 2005; 146(6): 732–737
3. Stodden DF, Goodway JD, Langendorfer SL et al. A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. Quest 2008; 60(2): 290–306
4. Koç H, Tekin A, Aykora E. Impact of Physical Education Classes on Selected Motor Skills of Children. Middle-East Journal of Scientific Research 2012; 11(3): 386–390
5. Woodward T. A review of the effects of martial arts practice on health. WMJ 2009; 108(1): 40–43
6. Bajorek W, Czarny W, Król P et al. Assessment of postural stability in traditional karate contestants. J Combat Sport Martial Arts 2011; 1(2): 23–29
7. Westcott SL, Lowes LP, Richardson PK. Evaluation of Postural Stability in Children: Current Theories and Assessment Tools. Phys Ther 1997; 77(6): 629-45
8. Schmid M, Conforto S, Lopez L et al. The development of postural strategies in children: a factorial design study. J Neuroengineering Rehabil 2005; 2(1): 29
9. Bucci MP, Lê TT, Wiener-Vacher S et al. Poor Postural Stability in Children with Vertigo and Vergence Abnormalities. Invest Ophthalmol Vis Sci 2009; 50(10): 4678-84
10. Paszko-Patej G, Terlikowski R, Kułak W et al. Factors affecting the process of balance development of child and the possibility of objective evaluation. Neurol Dziec 2011; 20(41): 121–127
11. Smith AW, Ulmer FF, Wong del P. Gender Differences in Postural Stability Among Children. J Hum Kinet 2012; 33: 25-32

12. Asseman F, Caron O, Crémieux J. Is there a transfer of postural ability from specific to unspecific postures in elite gymnasts? Neurosci Lett 2004; 358(2): 83-6
13. Lion A, Gauchard GC, Deviterne D et al. Differentiated influence of off-road and on-road cycling practice on balance control and the related-neurosensory organization. J Electromyogr Kinesiol 2009;19(4): 623-30
14. Negahbana H, Aryanb N, Mazaheri M et al. Effect of expertise in shooting and Taekwondo on bipedal and unipedal postural control isolated or concurrent with a reaction-time task. Gait & Posture 2012; 38(2): 226-230
15. Fong SS, Chung JW, Chow LP et al. Differential effect of Taekwondo training on knee muscle strength and reactive and static balance control in children with developmental coordination disorder: a randomized controlled trial. Res Dev Disabil. 2013; 34(5): 1446-55
16. Fong SSM, Tsang WWN. Relationship between the duration of taekwondo training and lower limb muscle strength in adolescents. Hong Kong Physiotherapy Journal 2012; 30(1): 25–28
17. Pop T, Czarny W, Glista J et al. Influence of traditional karate training on the stability and symmetry of the load on lowerlimbs. Arch Budo 2013; 9(1): 39-49
18. Leong HT, Fu SN, Ng GY et al. Low-level Taekwondo practitioners have better somatosensory organisation in standing balance than sedentary people. Eur J Appl Physiol 2011; 111(8): 1787-93
19. Filingeri D, Bianco A, Zangla D et al. Is karate effective in improving postural control? Arch Budo 2012; 8(4): 203–206
20. Fong SS, Fu SN, Ng GY. Taekwondo training speeds up the development of balance and sensory functions in young adolescents. J Sci Med Sport 2012; 15(1): 64-8
21. Cesari P, Bertucco M. Coupling between punch efficacy and body stability for elite karate. J Sci Med Sport 2008; 11(3): 353-6
22. Conant KD, Morgan AK, Muzykewicz D et al. A karate program for improving self-concept and quality of life in childhood epilepsy: results of a pilot study. Epilepsy Behav 2008; 12(1): 61-5
23. Fong SS, Tsang WW, Ng GY. Taekwondo training improves sensory organization and balance control in children with developmental coordination disorder: A randomized controlled trial. Res Dev Disabil. 2012 Jan-Feb;33(1):85-95
24. Grabara M, Hadzik A. The Body posture in young athletes compared to their peers. Medycyna Sportowa 2009; 2(6): 115–124
25. Lopez-Minarro PA. Alacid F, Rodriguez-Garcia PL. Comparison of sagittal spinal curvatures and hamstring muscle extensibility among young elite paddlers and non-athletes. International Sport Med Journal 2010; 11(2): 301–312
26. Muyor JM, López-Miñarro PA, Casimiro A et al. Sagittal spinal curvatures and pelvic tilt in cyclists: A comparison between two master cyclist categories. International SportMed Journal 2012; 13(3): 122–132
27. Grillner S. The role of muscle stiffness in meeting the changing postural and locomotor requirements for force development by the ankle extensors. Acta Physiol Scand 1972; 86(1): 92-108
28. Chen PQ, Wang JL, Tsuang Y et al. The postural stability control and gait pattern of idiopathic scoliosis adolescents Clin Biomech 1998; 13(1 Suppl 1): s52-S58
29. Gauchard GC, Lascombes P, Kuhnast M et al. Influence of Different Types of Progressive Idiopathic Scoliosis on Static and Dynamic Postural Control. Spine 2001; 26(9): 1052-8
30. Riemann BL, Lephart SM. The Sensorimotor System, Part II: The Role of Proprioception in Motor Control and Functional Joint Stability. J Athl Train 2002; 37(1): 80–84
31. Marek SM, Cramer JT, Louise Fincher A et al. Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching on Muscle Strength and Power Output. J Athl Train 2005; 40(2): 94–103
32. Riley MA, Clark S. Recurrence analysis of human postural sway during the sensory organization test. Neurosci Lett 2003; 342(1-2): 45-8
33. Lamoth CJ, van Lummel RC, Beek PJ. Athletic skill level is reflected in body sway: a test case for accelometry in combination with stochastic dynamics. Gait Posture 2009; 29(4): 546-51
34. Blaszczyk JW. Sway ratio – a new measure for quantifying postural stability. Acta Neurobiol Exp 2008; 68(1): 51-7
35. Blaszczyk JW. Spontaneous body sway and postural stability. Reply to letter to the editor by Dr. Handrigan and colleagues "Balance control is altered in obese individual". Journal of Biomechanics 2010; 43(2): 385–386
36. Blaszczyk JW, Lowe DL, Hansen PD. Ranges of postural stability and their changes in the elderly. Gait and Posture. 1994; 2(1): 11–17
37. Kuczyński M. The second order autoregressive model in the evaluation of postural stability. Gait Posture 1999; 9(1): 50-6
38. Kelty-Stephen DG, Dixon JA. Temporal correlations in postural sway moderate effects of stochastic resonance on postural stability. Hum Mov Sci. 2013 Feb;32(1): 91-105
39. Cornilleau-Pérès V, Shabana N, Droulez J et al. Measurement of the visual contribution to postural steadiness from the COP movement: methodology and reliability. Gait Posture 2005; 22(2): 96-106
40. Lê TT, Kapoula Z. Role of ocular convergence in the Romberg quotient. Gait Posture 2008; 27(3): 493-500
41. Massion J. Movement, Posture And Equilibrium: Interaction And Coordination. Prog Neurobiol 1992; 38(1): 35-56
42. Ozdemir RA, Pourmoghaddam A, Paloski WH. Sensorimotor posture control in the blind: Superior ankle proprioceptive acuity does not compensate for vision loss. Gait Posture 2013; 38(4): 603-8
43. Konczak J, Timmann D. The effect of damage to the cerebellum on sensorimotor and cognitive function in children and adolescents. Neurosci Biobehav Rev 2007; 31(8): 1101-13
44. Redfern MS, Yardley L, Bronstein AM. Visual influences on balance. J Anxiety Disord 2001; 15(1-2): 81-94
45. Ray CT, Horvat M, Croce R et al. The impact of vision loss on postural stability and balance strategies in individuals with profound vision loss. Gait Posture 2008; 28(1): 58-61
46. Perrin P, Deviterne D, Hugel F et al. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture 2002; 15(2): 187-94
47. Mori S, Ohtani Y, Imanaka K. Reaction times and anticipatory skills of karate athletes. Hum Mov Sci 2002; 21(2): 213-30

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