ORIGINAL ARTICLE

The influence of training on static and functional balance in adolescent karateka

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

Background and Study Aim: Almost every voluntary movement involves maintenance of balance in a static or dynamic form. The use of the functional balance test and rambling-trembling COP (centre of foot pressure) decomposition should allow to distinguish subtle alterations in the postural control of karate practitioners. The aim of this study was the knowledge about the static and functional balance in adolescent karate practitioners. We hypothesise that karate training elicit significant changes in postural control characteristics despite turbulent adolescence.

Material and Methods: Twenty-eight healthy male adolescents took part in the study, 13 of them were involved in karate training with at least 7 years of training experience. Their average age was 16.7 ±0.5 and 16.5 ±0.5 for the karate and control group respectively. Three testing procedures were used – anthropometric foot measurement, quiet standing and LOS test. A force platform was used in the static and functional balance examination. The range, root mean square (rms) and velocity of COP, rambling and trembling were analysed.

Results: The Mann-Whitney U test showed significant differences in all analysed variables in antero-posterior (AP) plane and only for rms in medio-lateral (ML) plane. The velocity of trembling in ML was the only variable differentiating the examined groups. The karate group presented superior functional stability in the LOS test and exceeded the presumed 100% of the functional stability region.

Conclusions: The existence of significant changes in the postural characteristics after a longitudinal karate training in adolescence confirmed our hypothesis. These changes positively support the athlete's competitive activity and the turbulent adolescence period do not negatively influence postural performance. The rambling-trembling analysis can be used in discrimination of the specificity of the discipline. The adolescent karate practitioners present superior functional balance with respect to their non-training peers. It seems that moderate karate/kata training would be a good alternative in rehabilitation programs. Furthermore, research concerning the role of the feet muscle would contribute to explanation of the reason for the registered differences in functional balance.

Key words: body balance • functional stability limit • martial arts • rambling/trembling decomposition of COP

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INTRODUCTION

FFSI – forward functional stability index, percentage of the use of forward functional stability region expressed in percent.

Forward functional stability region – the area between the medial malleolus and fist metatarsophalangeal joints.

AP/ML – antero-posterior/ medio-lateral.

LOS test – limits of stability test.

Dan (dan'i) – a term used to denote one's technical level or grade. In *jūdō*, the "*dan*" ranks start at shodan (1- *dan*) and go up to the highest grade of *jūdan* (10- *dan*) [23].

Kyū – the series of grades that precede *dan* ranks. *Ikkyū* is the grade immediately below *shodan* [23].

Karate is one of the most popular sports worldwide. In 2018 in Poland karate was trained by almost 50.000 of people, most of them were under 18 years old. Worldwide estimates of its popularity reach more than 50 million practitioners. It involves techniques of punching and kicking engaging the whole body for maximum effect. Nowadays competitors may specialize in two competitions – *kata* (forms – sequences of techniques) or *kumite* (free fight). Karate practice requires high-level of motor and functional abilities involving speed, strength and coordination [1]. The specificity of karate training also requires participants to perform precise control of movements and involves, as in other combat sports, a high level of balance [2-4]. While different aspects of balance and their impact on athletic performance have been studied in a wide range of sports [5], given the popularity of the karate discipline, the results are still limited.

Almost every voluntary movement involves maintenance of balance in a static or dynamic form. The current availability of sophisticated balance assessment methods makes it a focal point of many research centers. The most common laboratory tests for balance assessment incorporate monitoring center of pressure (COP) migration using force platforms (e.g. 6-8). This method allows one to assess the balance in static conditions (during quiet standing) as well as in dynamic conditions (while changing position). The latter brings many research problems because it is fraught with the burden of high variability and low repeatability. This problem is sometimes solved with the use of functional tests in static conditions, which involve some aspect of goal oriented voluntary movements. An example of such measurement is the limits of stability (LOS) test, which depicts balance performance in the conditions for high mobilization of the control system. It represents a valid and reliable measure of balance [9] and is ecologically close to sport performance.

Another problem arises when analyzing standard COP data from quiet standing. Many times the conclusion of these studies is that the method of analysis used was not sufficiently sensitive to detect differences between the groups examined or phenomena [10]. Therefore the need for different methods of COP data analysis, which are sensitive enough to show subtle changes in balance performance due to training or specific experience. The method that has not been commonly used in data analysis in sport postural stability studies seems to perfectly reflect subtle postural control mechanism in sportsman. It was introduced in by Zatsiorsky and Duarte [11] termed rambling, was developed. The rambling component reveals the motion of a moving reference point with respect to which the body's equilibrium is instantly maintained. The trembling component reflects body oscillation around the reference point trajectory. The concepts of instant equilibrium point (IEP and is called the rambling-trembling COP decomposition.

Unfortunately, the relationship between balance ability and athletic performance is still unclear [5]. Influence of karate training on balance is not clear-cut either – there are some research indicating an improvement in balance after short karate training (intensive, one-week camp, or 5-6 month course) [12]while the CG performed only, but also some research proving that elite karateka's balance is worse than non-training individuals. Unfortunately, this is the result of an ambiguous interpretation COP characteristics, which still arouses a lot of discussion and disagreement between scientists. For example, it is assumed that in sports shooting or in archery, less body sway is more desirable. However, similar characteristics in combat sports could negatively affect fighting performance, where rapid response and adaptation to changing conditions are required. Thus, greater postural sway, which promote more variability and plasticity of movements in able-bodied individuals, will be more appropriate.

Most studies describing the impact of karate training on balance focused on adult groups [3, 13]. Studies conducted in children's are much rarer [12, 14]. The same situation is observed in terms of adolescents. This group seems to be especially interesting from the developmental point of view, where the intensive period of growth and maturation may disturb coordination.

It is of interest, whether the changes observed in children are persistent through adolescence and can be transferred to senior performance.

The aim of this study was the knowledge about the static and functional balance in adolescent karate practitioners. We hypothesise that karate training elicit significant changes in postural control characteristics despite turbulent adolescence. The proposed methodology has rarely been used in karate so far, however, we believe that it has strong potential in the process of sport selection and training control.

MATERIAL AND METHODS

Participants

Twenty-eight healthy male adolescents took part in the study, 13 of them were involved in karate training with at least 7 years of training experience. The group characteristics were presented in Table 1. Every athlete was a member of the national team and ranked minimum 1 kyu (11 athletes was ranked 1 dan). The control group consisted of 15 non-athlete peers with no prior karate experience. The exclusion criteria were the presence of vestibular or visual disorder, musculoskeletal or neurological disease, history of injury in the past 12 months requiring medical attention and regular training in sports other than karate. All participants have given written consent to participate in the study or obtained them from a legal guardian if necessary.

The study was carried out in accordance with the Helsinki Declaration and approved by the Ethics Committee of the Academy of Physical Education Jerzy Kukuczka in Katowice (Poland).

Study design

We have assumed that the use of the functional balance test and rambling-trembling COP decomposition should allow to distinguish subtle alterations in the postural control of karate practitioners.

The study comprised three testing procedures – anthropometric foot measurement, quiet standing and LOS test [9]. The anthropometric foot measurements were done according to the method presented by Słomka et al. [15]. A force platform (AMTI, Accugait, Watertown, MA, USA) was used in the experiment to register forces (Fx, FY, Fz) and moments (Mx, My Mz) which were further processed to obtain a calculated center of foot pressure (COP) displacements in quiet standing and LOS test. The sampling frequency of the platform was set to 100 Hz. A low-pass 4-order Butterworth filter with a sampling frequency of 7 Hz was used for the raw platform data. The COP data were subject to further analysis using the Matlab (Mathworks, Natick, MA, USA).

During the quiet standing test subjects were instructed to stand still on a force plate, with arms along their sides and eyes fixed on a target (point) placed 3 m away from the subject. Additionally, balance performance in quiet standing was registered with eyes closed. Next, subjects performed maximal voluntary forward leaning (LOS test) with eyes opened. After each trial the subjects were instructed to step off the platform. In order to secure high reliability of measurements, the trials were repeated three times for each test and condition.

The LOS test procedure last 30 seconds and is divided into 3 phases:

- Phase 1 – quiet standing – the subjects are standing still for 10 seconds on the platform with arms along sides, looking straight ahead,

- Phase 2 – the subject after an auditory signal lean forward as fast and as far as they can, while keeping their heels on the ground, primarily the movement occurs in the ankle joint with stiffening of the hip joint in the erect position, the arms remain along the body,

- Phase 3 – the subjects maintain inclined position for the remaining time of the trial.

Table 1. Basic group characteristics.

Group	body height [cm]	body mass [kg]	age [years]	practice time [years]	practice frequency [per week]
Karate	177.4 ±5.5	68.3 ±11.1	16.7 ±0.5	9 ±1.8	3.6 ±1.2
Control	179.4 6.5	71.4 ±12.2	16.5 ±0.5	-	-

The functional measures of balance, maximal voluntary COP excursion and the forward functional stability index (FFSI) were calculated [15]. First, differences of canter of foot pressure (COP) were examined in anterior-posterior (AP) plane both with eyes opened and eyes closed in quiet standing. The next step in the analysis was to show the differences in the functional balance between karate practitioners and their non-training peers. For this purpose the LOS test was used.

Statistics analysis

Normal data distribution was tested with the Shapiro-Wilk test. To find significant differences between examining variables Student's T-test and Mann-Whitney U tests were used when applicable. The significance level for all statistical tests was set ($p<0.05$).

RESULTS

The Mann-Whitney U test showed significant differences ($p<0.05$) in almost all analysed variables between the karate and control group (Figure 1-3). The karate group exhibited a smaller range of COP, rambling and trembling, but significantly higher rms, both in eyes open and eyes closed. The control group had higher velocity of COP and rambling in the AP plane ($p<0.05$). In the ML plane the differences were mostly not significant, except for range of trembling both in eyes open and eyes closed ($p<0.05$). The statistical analysis also showed significant differences between karate and the control group with respect to the rms of COP and rambling in trials with closed eyes and for trembling both in eyes open and eyes closed ($p<0.05$). The differences in velocity were only significant in the AP plane for COP and rambling, both in eyes open and eyes closed ($p<0.05$) (Figure 3). The karate practitioners exhibited lower velocities. The trembling component of COP decomposition did not show a difference between the karate and control group with respect to velocity neither in AP nor ML plane.

As expected, the maximum voluntary COP excursion (MVE) and forward functional stability index (FFSI) was significantly higher in karate group ($p<0.05$). Note that the karate group exhibited much higher value by crossing their mechanical limit – over 100% of the forward anatomical stability limit (Figure 4).

DISCUSSION

The body posture of young karate competitors with respect to their non-training peers has not yet been investigated in this regard. It is known that the period of adolescence is extremely turbulent from a developmental point of view due to the intense growth and gradual maturation of the nervous system, in which inhibitory processes slowly begin to take control.

Our hypothesis was confirmed in the study as expected, the adolescent karateka presented significantly different characteristics of static and functional balance. The given characteristics of balance were chosen due to their most informative insight into the postural control processes and the relatively simple interpretation of the results in most cases. Unfortunately, as indicated in Michalska et al. [10], the interpretation of the balance results in experts is a problem because it concerns some kinds

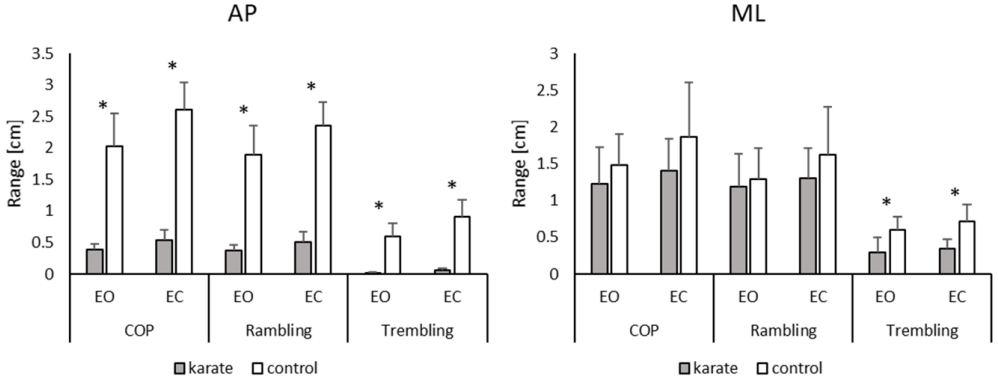

Figure 1. Mean values (±SD) of range of COP, RM and TR in antero-posterior (AP) and in medio-lateral (ML) plane with eyes open (EO) and eyes closed (EC) in quiet standing (*p<0.05).

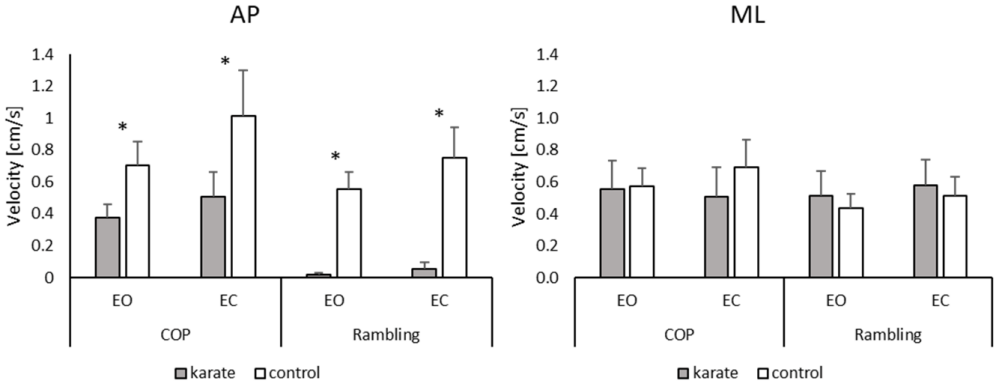

Figure 2. Mean values (±SD) of rms of COP, rambling and trembling in AP and ML plane with EO and EC in quiet standing (*p<0.05).

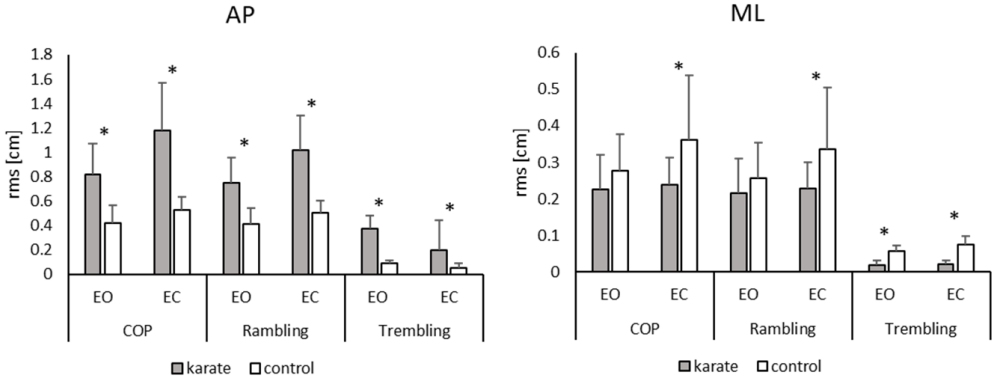

Figure 3. Mean values of COP and Rambling displacement velocity (±SD) in AP and ML plane with EO and EC in quiet standing (*p<0.05).

of extremes. At one end there are athletes experts and on the other clinical patients. It can be observed that COP characteristics of athletes often tend to become more like those achieved by patients. For example, in the study by Stegemöller et al. [16], patients are characterized by smaller COP displacements compared to their healthy peers. The results of the young karateka present the same trend, which are characterized essentially by a significantly smaller range of COP, rambling and trembling regarding the control group. Such characteristic with respect to the clinical patients is often interpreted as better stability [17]. We claim that it should be considered rather a misconception coming from the interpretation of the results of the well-known Romberg test which is used as a clinical measure of balance deficits, where the high postural sway is a sign of postural and neurological disorders. The smaller range of COP displacement in PD patients might be also associated with freezing of gait and fear of falling – which are interpreted rather as detrimental for balance control. Therefore, the interpretation of the results is not straightforward.

The significant differences between karate and the control group are dominant in the AP plane. This concern all characteristics of the COP registered in quiet standing (range, rms and velocity). Although, there are essentially no studies on adolescent karateka we can relate our results to taekwondo practice, a martial art that is similar to karate. Fong and colleagues studied the development of balance and sensory functions in adolescent taekwondo (TKD) competitors with respect to their non-training peers as well as adult [18]. They reported similarly to our study significantly smaller COG sway velocities in TKD practitioners with respect to their non-training peers. They also found that teenagers who practiced TKD improved their vestibular function, making them

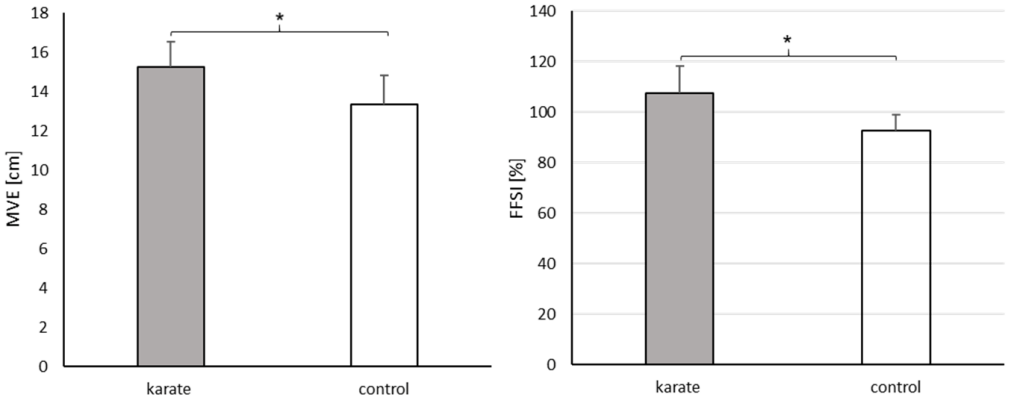

Figure 4. Mean values of MVE and FFSI (±SD) in the LOS test for the karate and the control group (*p<0.05).

more stable in a one-legged stance in comparison to their non-training counterparts. They suggest that the frequent jumps and spinning kicks in TKD training might stimulate the development of vestibular system which is much involved in the balance control. Although the two martial arts have many differences in details their training might elicit similar adjustments to the postural control system. Note that subjects in the current study were on average 2 years older which results in a more mature nervous system.

The introduction of the rambling-trembling decomposition analysis of COP merely confirmed the results obtained with the standard COP analysis. One significant difference was observed where standard COP analysis was not sensitive enough. Only the range of trembling occurred to be significantly smaller in the karate group in ML plane indicating less need for adjustments during the correction of the posture in response to sway. This is an interesting result which is worth investigating. In the study by Michalska et al. [10], where the authors examined static and functional balance of ballet experts, they showed that the range of trembling was significantly higher with respect to the control group in quiet standing. This indicates that there are different demands concerning postural control in these two disciplines and proves again that balance is task specific. Our results encourage to use the rambling-trembling analysis to show the specificity of the disciplines, nevertheless, more research is needed to see the bigger picture of the competitive sports. Finally, the test condition with eyes closed in quiet standing did not show any surprising results. The deprivation of vision stimulated, in all cases, a significant increase of the recorded indicators as in most previous research work.

Interesting is the result and the data of the LOS test. According to the assumption presented by Słomka et al. [15] healthy, efficient people should reach 100% of their maximum capabilities in this test. For this purpose of the FFSI was to show whether the subject can achieve a maximum of their functional capabilities. It is worth noting that those who did not train from the control group were able to approach the designated stability limit (FASL) but did not exceed it. This is a prerequisite for believing that karate training causes significant changes in this functional performance. The question arises, what way were the karateka able to cross the stability limit which should be impossible in the assumptions? First of all it has been already well established that ka rate training elicit significant changes in postural characteristics of the karateka [3, 19, 20]. The specificity of karate training mentioned before, apart from frequent kicks and punches, requires a very stable posture. The kata and *kumite* techniques are always performed barefoot, sometimes on a training mat that induce additional difficulty for the proprioceptive system. Although it was not examined, we are convinced that due to this kind of training and competition regimen, an effective karate technique requires “strong feet” or more specifically higher level of toe muscle strength. The role of the great to on dynamic balance was studied by Chou et al. [21] where they concluded that it has significant influence on rhythmic weight shifting. The basic behaviors in karate performance involved fast weight shifts and position changes. The role of great toe and its shape should be further studied with respect to different populations to explain its role in functional balance and show potential opportunities for programmed improvement. Another argument comes from gait biomechanics research reported and reproduced in Chan and Rudins [22] where the authors refer to an axis

represented by a line drawn obliquely across the metatarsal heads, around which dorsiflexion of the toes occurs. It is called the "metatarsal break". The orientation of this axis varies to the long axis of the foot (from 50° to 70°). The occurrence of the metatarsal break facilitates external rotation of the leg at toe-off, and this in turn facilitates supination and hence rigidity of the foot. We believe that the rotational tolerance of 20° of the metatarsal break reflects the performance of the karateka in LOS test.

CONCLUSIONS

The study hypothesis was confirmed that there are significant changes in the postural characteristics and that the postural adaptations in the longitudinal karate training are persistent through adolescence. These changes positively support the athlete's competitive activity and the turbulent adolescence period do not negatively influence postural performance. The rambling-trembling analysis can be useful in discrimination of the specificity of the discipline and is more sensitive to changes induced by sports training than the standard measures. The adolescent karate practitioners present superior functional balance with respect to their training peers. It seems that moderate karate/kata training would be a good alternative in rehabilitation programs. Further research concerning the role of the feet muscle would contribute to explain the reason for the registered differences in postural control.

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