ORIGINAL ARTICLE

The effect of expertise in karate on postural control in quiet standing

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Abstract

Background & Study Aim: Balance ability plays and important role in daily activities. A general opinion that in the sports performance high level of balance is even more desirable is common. However, there are limited data on the influence of balance training on sport performance in elite athletes. We aimed to investigate the effect of expertise on the static balance in elite karate practitioners and determination of the value of COP trajectory decomposition as a useful tool in describing quiet standing in karate experts.

Material & Methods: Nine elite karate athletes (24.6 years ± 4.8) and eleven PE students participated voluntarily in the experiment. A force platform (AMTI, Accugait, USA), with a sampling frequency set at 50 Hz was used to measure the static balance. Subjects performed 2 trials of quiet standing with eyes open and eyes closed. Subjects were instructed to stand barefoot in a comfortable foot position with their arms along their sides and with their gaze pointed straight ahead. The duration of each trial was 30 s, during which subject was asked not to shift their body weight. Stabilographic signal was processed with the use of standard and a relatively new method of stabilogram decomposition, proposed by Zatsiorsky and Duarte (1999).

Results: There was a significant main effect of expertise in both directions A/P and M/L (Wilks' Lambda = 0.0958; F = 44.8479; $p < 0.0001$ in A/P and Wilks' Lambda = 0.0256; F = 34.2630; $p < 0.0001$ in M/L) (ANOVA). Post hoc comparisons using the Tukey HSD test indicated that the mean score for path length of COP, rambling and trembling displacement differs in karate and the control group (increased mean values of basic parameter which was a COP path length). Highly trained group of elite karate athletes was characterized by increased values of path length of COP and rambling / trembling trajectories. Results of Mann-Whiney U test shows that there were NOT significant differences in the group of elite athletes during trials conducted with eyes closed ($p>0.05$).

Conclusions: Practicing karate results in long term changes in postural control. The effect of expertise on the static balance in examined elite karate practitioners was observed in increasing of the body sway. We assumed that it was caused by the redundancy of the sensorimotor system.

Key words: body balance • rambling/trembling decomposition of COP • elite athletes • martial arts

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BACKGROUND

Balance is the process of maintaining the position of the body's centre of gravity vertically over the base of support and relies on rapid, continuous feedback from visual, vestibular and somatosensory structures and then executing smooth and coordinated neuromuscular actions [1]. The importance of balance in daily activities is hard to overestimate. An opinion that in the sports performance high level of balance is even more desirable is common. However, there are limited data on the influence of balance training on motor skills of elite athletes [2-7]. The relationship between balance and sport activity is still ambiguous.

Static balance, understood as the ability to maintain a center of mass (COM) within the base of support with minimal movement, is the most examined aspect of human balance performance. The most prevalent laboratory test for static balance is measuring the displacement of the center of pressure (COP) during quite standing (or as many prefer during normal stance). That measure is conducted on a force plate and is considered as the gold standard measure of balance [8].

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

Stabilographic parameters – the variables such as range or velocity of COP displacement in AP / ML or total path length of COP trajectory, which characterized the body sway during maintaing balance in quiet stance

There is no doubt that force platforms are efficient tools used for postural control investigation. Measured stabilographic parameters as e.g. COP mean velocity, root mean square (RMS), COP range and path length of COP displacement are commonly used. These measures show differences with age [9], sensory conditions [10] and pathology [11]. There are reports documenting relations of these measures to the risk of falls [12].

Static balance was extensively studied in various sport disciplines with the use of force plates. Gymnasts and rifle shooters are among most commonly examined athletes. There are some studies of static balance in martial arts as well. Perrin et al. [13] showed that judoists has a superior static balance. Rynkiewicz et al. [14] examined the elite sumo wrestlers and found that they had lower values of an area of COP displacement, what they interpreted as better stability. The similar results were recently obtained by Pop et al. [15]. At the same time, Negahban et al. [16] showed lower sway of the COP in shooters but higher in taekwondo practitioners.

With summary statistics-based measures, one cannot correctly interpret the underlying neuromuscular mechanisms of balance control [17]. Therefore, researchers look for methods that more explicitly address the dynamic nature of COP motion. One of such methods is rambling-trembling decomposition of COP trajectory proposed by Duarte and Zatsiorksy [18]. Despite its high informative value, so far this method has not been used in the data analysis of postural stability measurements in sports.

We aimed to determine (i) the effect of expertise on the static balance in elite karate practitioners and (ii) the COP trajectory decomposition method as a useful tool in describing quiet standing in karate experts. We expected differences in stabilographic parameters which could be possible to identify using decomposition of COP signals. Based on the mentioned studies, we also hypothesized that the values of path length will be decreased in elite athletes.

MATERIAL AND METHODS

Nine healthy male karate athletes (24.6 years ± 4.8) participated voluntarily in the experiment. The mean body mass and height were respectively: 78.8 kg ± 8.2 and 178.81 cm ± 6.7 (mean±SD). They had more than 8 years' of experience in karate competition and were ranked at least in 6th place of European or World Championships.

Eleven young healthy adults (PE students) that were not professional athletes were recruited to the control group. They were selected from a group of 40 volunteers according to similarity of basic somatic parameters. None of the subjects reported any balance disorders and neuroimpairments in the past 2 years.

All participants gave their written informed consent to participate in this study, which was approved by the local ethics commission and was in accordance with the Helsinki Declaration.

Stabilographic measurement

We used a force platform (AMTI, *Accugait*, USA), with a sampling frequency set at 50 Hz. The offline raw data were low-pass filtered at 6 Hz using a dual-pass second-order Butterworth digital filter using MATLAB. Subjects performed 2 trials of quiet standing with eyes open and eyes closed. We zeroed the device each time before the subjects stepped on the platform. Subjects were instructed to stand barefoot in a comfortable foot position with their arms along their sides and with their gaze pointed straight ahead. The duration of each trial was 30 s, during which subject was asked not to shift their body weight. There was a 60 s break between consecutive trials during which the subjects were asked to step off the platform and relax. No effect of fatigue was observed.

Stabilographic signal was processed with the use of a relatively new method of stabilogram decomposition, proposed by Zatsiorsky and Duarte [18,19]. Two components: rambling (the motion of an instant equilibrium point with respect to which the body's equilibrium is instantly maintained) and trembling (the oscillation of COP around the reference point trajectory) were calculated. By the means of the LABVIEW signal processing, the values of sway ranges of COP and path length of rambling and trembling were obtained.

Sequence of operations used for stabilogram decomposition is described below. At the instances when the horizontal force (Fhor) is zero the body is instantaneously in an equilibrium state. The instances of zero horizontal force (IEP – instant equilibrium point, i.e., the COP locations in the instances when the horizontal forces were zero) were identified in the Fhor time-history data; in the COP displacement data, the COP positions at the instants Fhor=0 (IEP) were located and interpolated by cubic spline functions to obtain an estimate of the rambling trajectory. The COP trajectory is compared with the interpolated rambling trajectory. To obtain the trembling trajectory, the deviation of the COP from the rambling trajectory was determined.

Next standard posturographic parameters were calculated. The following variables were further analyzed: path length of COP (lenCOP), path length of RAMB (lenRAMB) and path length of TREMB (lenTREMB) (all in mm). All calculations were made in both directions: anterior-posterior (A/P) and media-lateral (M/L).

Statistical Analysis

The Shapiro-Wilk and Lilliefors tests were used to check the data for normal distribution, while variance homogeneity was investigated with the Levene's test. The significance of differences between the means of particular variables in the groups were evaluated by using analysis of variance (ANOVA). When some parameters failed to meet the assumption about the normal distribution of variables and variance homogeneity, the Mann-Whitney U test was employed. All data were expressed as mean ± SD. The significance level was set at $p<0.05$.

RESULTS

First, a one-way ANOVA was conducted to compare the effect of expertise (karate / control group) on posture control during quiet stance on a force plate. There was a significant main effect of expertise in both directions A/P and M/L (Wilks' Lambda = 0.0958; $F = 44.8479$; $p < 0.0001$ in A/P and Wilks' Lambda = 0.0256; $F = 34.2630$; $p < 0.0001$ in M/L).

Post hoc comparisons using the Tukey HSD test indicated that the mean score for path length of COP, rambling and trembling displacement differs in karate and the control group. Significant differences were observed in all three basic parameters in the A/P plane (lenCOP: $F(1.18) = 24.6967$; $p < 0.0001$; lenRAMB: $F(1.18) = 22.2201$; $p<0.001$; lenTREMB: $F(1.18) = 41.3599$; $p<0.0001$) and only in one of them in the M/L direction (lenRAMB: $F(1.18) = 6.0786$; $p<0.05$). Effect of expertise has been much more significant in the A/P plane yet the strong tendency to increase the path length could be observed across both directions (Fig. 1. and 2).

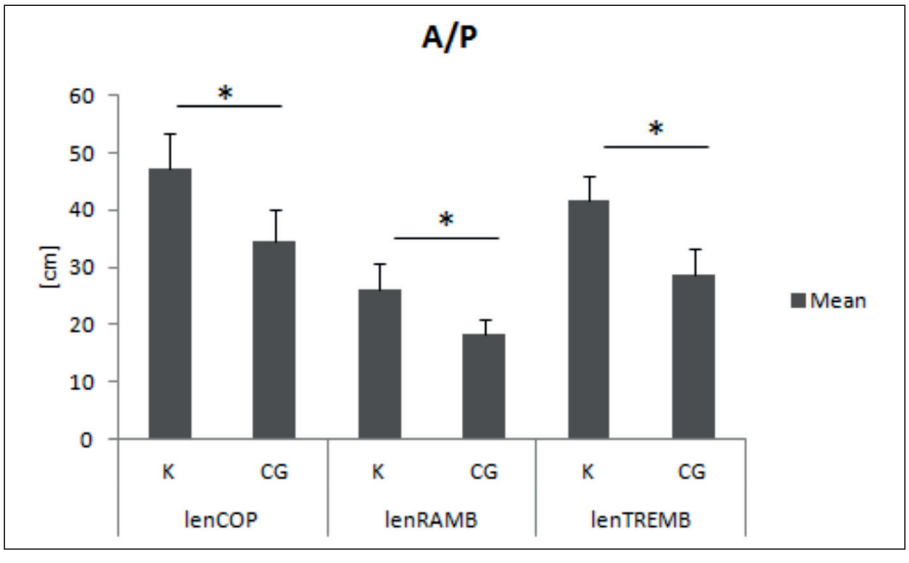

Figure 1. Mean path length of COP, rambling and trembling trajectories values in the anterior-posterior plane

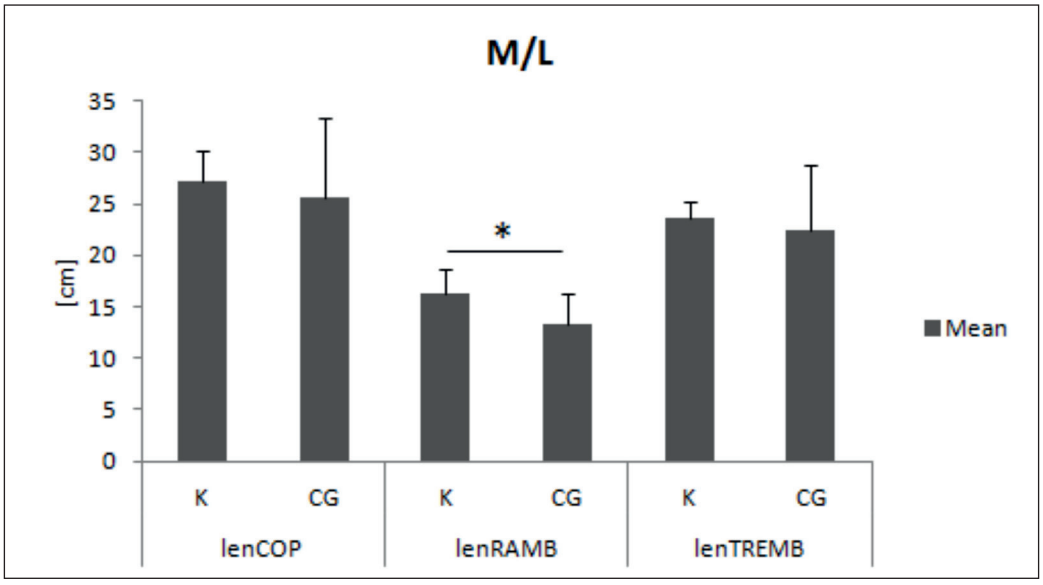

Figure 2. Mean path length of COP, rambling and trembling trajectories values in the media –lateral plane

Results of Mann-Whiney U test shows that there were NOT significant differences in the group of elite athletes during trials conducted with eyes closed ($p>0.05$). In case of path length of COP displacement mean value increased from 47.3158 ± 6.0757 to 48.3031 ± 9.2731 cm in A/P and from 27.2574 ± 3.0028 to 28.0534 ± 6.7010 cm in M/L plane. The path length of displacements of all trials conducted with eyes open and closed in control group significantly increased in both planes ($p<0.05$).

Taken together, these results suggest that an expertise in karate caused significant changes in postural stability. It is important to notice that the values of analyzed stabilographic parameters (COP and its trajectory components displacement) were increased. Conditions (eyes open / eyes closed) disturb stability significantly in different way in athletes and non-athletes.

DISCUSSION

Postural strategies – stereotypical movement patterns to achieve or maintain the postural stability during an anterior / posterior sway; "ankle-" or "hip strategies" could be used in fixed stance position yet the most common regularity in the behavior is a combination of both of them

The results of this study do not support our hypothesis. We expected decreased values of analyzed parameters which characterized the body sway in quiet standing in elite karate fighters and we obtained the opposite results. Surprisingly, the best athletes had increased values of COP path length and rambling / trembling trajectories. We observed this phenomenon mainly in A/P plane but we have also noted a strong tendency in M/L direction (Figure 1 and 2). This is in congruence with results presented by Negahban et al. [16], which showed the similar data in taekwondo practitioners. Our data corresponds with the results of the experiment conducted by Vuillerme et al. [20]. They examined expert gymnasts and found that they were not more stable than other sport experts. As an explanation Henry's hypothesis under which the transfer of motor skills is not an automatic phenomenon was presented [20]. Interestingly, the same authors found that the gymnasts were less affected by the removal of vision during unipedal stance. The same adaptation was observed in examined elite karate fighters. Simultaneously, our results do not confirm recent data presented by Rynkiewicz et al. [14] and Pop et al. [15], what might be caused by the details of research procedures and a level of expertise of examined athletes.

Our results, however, could have a different explanation. As suggested first by Winter [21] perfect processing of the information from each of the three sensory systems may have a side-effect called redundancy. One can have all data concerning external and internal factors that determine motor action resulting in varieties of possible postural strategies. In other words, subject (well trained athlete or circus artist) could reach such specific neutral condition which might be expressed in increased body sway. Our results may be interpreted within the same scheme. The spontaneous nature of body sway gives an additional argument for such explanation.

This hypothesis could be supported by recent studies that showed the elite karate and fencing athletes showing greater "neural efficiency" than non-athletes, as a result of intensive sports training [22].

One limitation of our study should be noticed. It is especially important in sports practice to conduct an effective selection. Based on our results it is impossible

to estimate if there is such strong tendency of increasing body sway also in less experienced karate athletes. Probably specific adaptations due to kata or kumite practice also should be considered. Therefore, it is essential to obtain reliable results concerning postural stability in other sport disciplines.

Considering the second goal of that study, we should notice that rambling / trembling decomposition of a stabilogram is a relatively new method based on the equilibrium point hypothesis that addresses more explicitly the dynamic nature of COP and represents more subtle aspects of postural control. With this method, the COP trajectory can be decomposed into deviations resulting from supraspinal (i.e., RAMB) and spinal processes (i.e., TREMB). The results of Słomka et al. [17] indicate the high reliability of the measures of rambling / trembling. It seems to be extremely important while measurements are conducted during training or competition which should be not disturbed with many repetitions of any task. However much more could be expected to get from rambling / trembling analysis than just a strong confirmation of the COP displacement analysis. Although there is still scientific discussion as to how interpret information about postural control processes from this sophisticated analysis. There is also a lack of attempts to make use of this method in sport performance studies, and it is reasonable to use it in postural control studies.

The presented results should be useful in the interpretation of COP signals in sport performance. Our results indicate that highly trained group of elite karate athletes was characterized by increased values of path length of COP and rambling / trembling trajectories. Examined karate fighters were less affected by the removal of vision during quiet stance. These data should be taken under consideration in the selection and training processes. However, in the case of establishing certain limits for less experienced athletes further research is desired. This might be justified to include tests for dynamic balance (e.g. Star Excursion Balance Test (SEBT) described by Bressel et al. [23] or Rotational Test proposed by Kalina et al. [24]). Unfortunately, there are more studies needed to better understand the true nature of the processes underlying the postural stability.

Kata / kumite – two specialties of modern karate: a sequence of techniques simulating an imaginary fight / a real score-based fight between two athletes

Conclusion

Practicing karate results in long term changes in postural control. The effect of expertise on the static balance in examined elite karate practitioners was observed in increasing of the body sway. We assumed that it was caused by the redundancy of the sensorimotor system.

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