THE ESTIMATION OF THE EFFECT OF EXPERTISE ON POSTURAL CONTROL IN SHOOTING TASK WITH SAMPLE ENTROPY

Grzegorz Juras[1], Rafał Zając[1], Grzegorz Bril[1], Kajetan Słomka[1], Grzegorz Sobota[1], Bogdan Bacik[1]

The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland[1]

We aimed to determine the interdependence between functional and dynamic stability of young basketball players. Eight elite biathlon experts, 15 moderate experienced subjects and 15 novices took part in the experiment. The postural sway and complexity of CoP signal and its decomposed trajectories were measured using force plate. Results indicate that highly trained group of elite biathlon athletes was characterized by decreased values describing body sway and increased value of Sample Entropy during quiet stance. However, that situation was changed during maintaining a shooting position and during aiming at the target. These results lead to the conclusion that Sample Entropy could be used to estimate the attentional involvement in postural control according to skill development in sport performance.

KEY WORDS: balance, attention, sport performance, rifle shooting

INTRODUCTION: The importance of balance in daily activities is hard to overestimate. An opinion that in 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 (Paillard et all. 2011, Hrysomalis 2011). 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 quiet 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. However, the postural control requires the integration of a variety of sensory signals and the proper coordinated contraction of numerous muscles. The problem arises when someone tries to interpret the results of posturographic parameters. Following intuitive way of that interpretation, it leads to the statement that increasing sway correlates with pathology, aging and – in general – some deficits. And that is not true. It is more complicated because of the dynamic system of control. Based on that conviction, various measures of regularity and complexity are trying to be implemented and verify. One of a measures is entropy, which could be interpreted as a sign of disorder and noise. The symbol equation could be stated: entropy = automatic + noise – attention (Borg and Laxaback 2010). The interpretation is ambiguous. Usually, high values of entropy are associated with smaller and irregular CoP displacement, but also with high automatization of the process of control. That may be interpreted as a sign of vigilant system. That is desired in sport performance. On the other hand, high entropy was observed in stroke patients (Roerdink et al. 2006). In this case, high entropy may be taken as a sign that the system is loosing its structure and becoming less sustainable (Borg and Laxaback 2010). To our best knowledge, there are a few studies on the entropy in sport. Some measurements of noise and regularity of CoP signal were provided for dancers and athletes (Schmit et al. 2005). It was proved that dancers are more focus on attentional constraints and their stance is less automatical but more regular in the aspect of CoP displacement and a nature of control. However, increasing entropy could also be interpreted as a sign of "greater flexibility" (Schmit et al. 2005). The main objective of the study was to show the effect of expertise in shooting on the noise and complexity of postural control.

METHODS: 38 subjects voluntarily participated in the experiment. They were divided into three groups: eight highly trained biathlon athletes (mean ± SD: 58.9 ± 11.5 kg, 170,6 ± 9.5 cm, 20.1 ± 1.9 years) with at least 7 years of shooting training, fifteen PE students (73.9 ± 8.8 kg, 179.6 ± 6.5 cm, 22.3 ± 0.6 years) after an intense 3-months long training program in rifle shooting and 15 PE students (74.8 ± 9.5 kg, 180.5 ± 7.8 cm, 21.2 ± 0.8 years) after short instructions in maintaining a proper aiming position were enrolled this investigation. All participants completed a self-report health history questionnaire before testing. Any participant reporting the presence of physical injury and neural disease at time of screening and/or within the last three months was excluded from the study. All participants received a written invitation to participate and were thoroughly informed of the purpose, nature, practical details and possible risks associated with the experiment, as well as the right to terminate participation at will. The study conformed to the recommendations of the Declaration of Helsinki, and participants or their guardians in the case of underage players, gave their voluntary written consent to participate in this experiment, which was approved by the institutional review board. Participants received proper instruction about shooting position, i.e. standing sidewise to the target. Feet about shoulder width apart, knees straight and body weight spread equally on both feet. Rifle butt should be placed high on the shoulder distal to the target. They were asked to perform three trials. Each lasted 30 seconds and was repeated three times. First subject was asked to stand quietly on the force platform. Next, subject stood in shooting position with the air rifle (Narconia Prestige 4.5 mm with the red laser pointer attached to the weapon's barrel) and was instructed to hold this position during the trial. In the last test subjects task was to aim the laser beam on the target placed 5 meters from the firing lane marked on the force plate at the eye level. Target size was defined appropriately to the distance. Trial sequence was randomly assigned to each subject. A/P and M/L CoP trajectories were registered with the use of AMTI force plate (*Accugait*, USA), at 50 Hz sampling frequency. The offline raw data were low-pass filtered at 6 Hz using a dual-pass second-order Butterworth digital filter using MATLAB. Subjects performed 3 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 focused in front of the subjects 2 m away (round target marked on the wall of 2 cm diameter). The duration of each trial was 30 s with 60 s rest between trials during which the subjects were asked to step off the platform and relax. The data were further processed with the use of stabilogram decomposition, proposed by Zatsiorsky and Duarte (1999, 2000). 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. Sequence of operations used for stabilogram decomposition is described below (Zatsiorsky and Duarte 1999). 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 posturograhic parameters were calculated. The following variables were further analyzed: amplitude (mm) and velocity (mm/s) of CoP, Rb and Tr signals. The influence of noise and an effect of expertise on postural control were observed using entropy measures. The Sample Entropy (SampEn) was quantified from the normalized posturogram by using the polar coordinate time series, which was first normalized to unit variance for this purpose. The negative natural logarithm was calculated in MatLab for CoP signal using the algorithms published by Richman and Moorman (2000). In human quiet standing the majority of CoP displacement occurs in the anterior-posterior (A/P) directions. However, it is reasonable also to analyze media-lateral (M/L) direction during typical rifle aiming position. Thus, all calculations were made in both directions: anterior-posterior (A/P) and media-lateral (M/L). 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 was 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: We analyzed the differences of mean values obtained in the posturographic measures characterizing sway amplitude between groups under the same conditions, and within each group with respect to the three conditions for the implementation of the test: quiet stance (1), shooting position (2) and aiming at the target (3). In the frontal plane in terms of the amplitude of sway there was a significant main effect in the second attempt ($X2 = 16.99$, $p < 0.001$), third ($X2 = 17.27$, $p < 0.001$). Significantly lower CoP range of displacement observed in biathlon experts compared to the other two groups in the second and third conditions. ANOVA also revealed a significant interaction between the extent of displacement of the CoP and the experimental group ($F (4,70) = 7.14$, $p < 0.001$) in the sagittal plane. Post hoc analysis showed no significant differences between groups in quiet stance. There was a significant difference between athletes and the other two in the shooting position and during aiming at the target ($p < 0.05$). In the frontal plane there was a significant main effect for the Sample Entropy ($F (2,70) = 3.51$, $p < 0.05$) and a significant interaction effect ($F (2,70) = 4.56$, $p < 0.05$). Also in the sagittal plane there was a significant main effect for the SampEn ($F (2,70) = 3.51$, $p < 0.05$) and a significant interaction effect ($F (2,70) = 4.56$, $p < 0.05$). In the group of biathlon experts entropy value it was significantly lower in an attempt of quiet stance and increased in the following two conditions, but would only significantly compared to the aiming conditions. There were no significant differences between the other conditions. In the other two experimental groups there was no significant change observed variable (SampEn) subsequent task conditions.

DISCUSSION: The results of the present study were in line with our expectations. Our results indicate that highly trained group of elite biathlon athletes was characterized by decreased values describing body sway and increased value of Sample Entropy during quiet stance. That situation was changed during maintaining a shooting position and during aiming at the target. Results are in agreement with other studies suggesting the existence of a positive correlation between the amount of attention invested in postural control and regularity center of pressure trajectory. Withdrawing attention from postural control by creating external focus leads to smaller variability (Donker et al. 2007). Also the difficulty of cognitive task could be main factor influencing body sway in dual task condition. More difficult cognitive task leads to higher decrease in body sway than simple task (Swan et al. 2007, Vuillerme & Nafati 2007). Another possible explanation is that postural sway reflects exploratory behavior of the postural control system (Carpenter et al. 2010; Murnaghan et al. 2011) referring postural sway to perceptual-action strategy, providing essential information's about subjects interaction with the environment (Riccio 1993). Some limitations of our study should be noticed. Probably specific adaptations due to the training cycle, fatigue, stage of technical development and other factors also should be considered. Therefore, it is essential to obtain reliable results concerning the relationship between the effect of expertise and postural stability in other sport disciplines.

CONCLUSIONS: The presented results should be useful in the interpretation of the effect of expertise on body balance. Sample Entropy could be used to estimate the attentional involvement in postural control, according to skill development in sport performance. However, in the case of establishing certain limits for less experienced athletes further research is desired.

REFERENCES:

Borg F.C., Laxaback G. (2010). Entropy of balance – some recent results. *Journal of NeuroEngineering and Rehabilitation*, 7:38.

Carpenter, M. G., Murnaghan, C. D., Inglis, J. T. (2010). Shifting the balance: evidence of an exploratory role for postural sway. *Neuroscience*, 171, 196-204.

Donker, S. F., Roerdink, M., Greven, A. J., & Beek, P. J. (2007). Regularity of center-of-pressure trajectories depends on the amount of attention invested in postural control. *Experimental Brain Research,* 181, 1-11.

Hrysomallis C. (2011). Balance ability and athletic performance. *Sports Medicine*, 41(3), 221–32.

Murnaghan, C. D., Horslen, B. C., Inglis, J. T., & Carpenter, M. G. (2011). Exploratory behavior during stance persists with visual feedback. *Neuroscience*, 195, 54-59.

Paillard T., Margnes E., Portet M., Breucq A. (2011). Postural ability reflects the athletic skill level of surfers. *European Journal of Apllied Physiology*, 111(8), 1619–23.

Riccio, G. E. (1993). *Information in movement variability about the qualitative dynamics of posture and orientation.* Variability and Motor Control. Champagne, IL, USA, Human Kinetics Publishers, 317-357.

Roerdink M., De Haart M., Daffertshofer A., Donker S.F., Geurts A.C., Beek P.J. (2006). Dynamical structure of center-of-pressure trajectories in patients recovering from stroke. Experimental Brain Research, 174, 256-69.

Schmit J.M., Regis D.I., Riley M.A. (2005). Dynamic patterns of postural sway in ballet dancers. Experimental Brain Research, 163, 370-8.

Swan, L., Otani, H., Loubert, P. V. (2007). Reducing postural sway by manipulating the difficulty levels of a cognitive task and balance task. Gait and Posture 26, 470-474.

Vuillerme, N., Nafati, G. (2007). How attentional focus on body sway affects postural control during quiet standing. Psychological Research, 71, 192-200.

Zatsiorsky V.M., Duarte M. (1999). Instant equilibrium point and its migration in standing tasks: rambling and trembling components of the stabilogram. Motor Control, 3, 28–38.

Zatsiorsky V.M., Duarte M. (2000). Rambling and trembling in quiet standing. Motor Control, 4, 185–200.