GENDER EFFECTS ON POSTURAL SWAY DURING RIFLE AIMING

Rafal Zajac[1], Jan Basiaga[1], Kajetan Slomka[1], Grzegorz Juras[1]

[1] Academy of Physical Education in Katowice, Poland

Eight male and eight female subjects without prior shooting experience took part in the experiment. The aim of this study was to determine gender effects on postural sway characteristics and rambling and trembling components during rifle aiming. Subjects were tested with the use of force platform in quiet standing, in shooting position, and in shooting position with additional visual feedback, three times in each condition. Rambling (RM) –Trembling (TM) signal decomposition was used to process the data. Center of the pressure sway range (COP_{ra}), mean velocity (COP_{vel}), COP root mean square (RMS), and the rambling and trembling displacement length (RM_{len}, TR_{len}) in the anterior-posterior (AP) and medial-lateral (ML) directions were analyzed variables. The results showed significant changes in behaviour due to increased levels of task difficulty effect of gender.

KEY WORDS: postural sway, center of pressure, rambling and trembling, aiming

INTRODUCTION: In most of the sports, maintaining a stable posture is essential. It is particularly important in rifle shooting where even the slightest move of a weapon's muzzle can influence the accuracy of the shot. Unfortunately postural sway is an essential feature of the postural control system. Though many researchers tried to explain this phenomenon, the final answer is still unknown. Recent studies refer to it as a function of exploratory behavior of the postural control system (Carpenter et al. 2010; Murnaghan et al. 2011). Minimizing sway and learning to use them effectively should be the main goal for the shooter. A more important problem seems to be that of identifying the origin of increased body sway in varied groups with regard to subjects age, gender or experience.
One of the easiest ways to assess postural stability is to measure movement of the center of pressure (COP), which is the point location of the vertical ground reaction force vector. In order to understand the mechanisms underlying postural sway decomposition of COP signal is reasonable (Collins & De Luca, 1993, 1994; Levin & Mizrahi 1996; Caron et al. 1997; King & Zatsiorsky 1997; Zatsiorsky & King 1998; Peterka 2000). Zatsiorsky and Duarte (1999, 2000) proposed the method of decomposing the COP trajectory based on theory that a moving reference point with respect to which the body's equilibrium is maintained. This motion is termed "rambling" and during quiet stance is located very close to the gravity line trajectory. Dynamic component called trembling is defined by oscillations of COP around the reference point trajectory. These deviations appear to restore forces acting to return the body to equilibrium and their magnitude is proportional to the deflection range.
Lack of research concerning the use of rambling and trembling in the rifle shooting is an additional reason to conduct this research. It was hypothesized that in beginners group COP, rambling and trembling variables will be influenced by experimental condition. Also that results will differ by gender effects, especially in the medial-lateral direction.

METHODS: Twenty PE students took part in the experiment (10 male, 10 female). None of them had any shooting experience. All subjects were informed about the execution of the experiment and signed written consent, according to procedures approved by an 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.
Ground reaction forces were recorded with a force platform (AMTI BP 600900) at sampling frequency set to 50 Hz. Collected data were computed using a code written in Matlab software. At the beginning all instances where horizontal forces (F_{hor}) equals zero (F_{hor}= 0) are identified. The instances when F_{hor} changes its sign are determined using a local linear interpolation of the F_{hor} time-series. The next step is the identification of the instant equilibrium points (IEP, i.e., the COP locations in the instances when the horizontal forces are zero). To estimate rambling trajectory the COP positions at all these instances are determined and interpolated using the cubic spline function. The resultant rambling represents the migration of the reference point to the supporting surface with respect to that in which the body's equilibrium is maintained The trembling represents the deviation of the COP from the equilibrium position and is determined by subtracting the rambling trajectory from the COP trajectory.
The dependent variables analyzed in this study were the centre of the pressure sway range (COP_{ra}), mean velocity (COP_{vel}), and root mean square (RMS), and the rambling and trembling displacement length (RM_{len}, TR_{len}) in the anterior-posterior (AP) and medial-lateral (ML) directions. To examine the effects of gender in the consecutive trials repeated measures ANOVA with sigma-restricted model parameterization, and post hoc tests with Bonferroni correction were carried out.

RESULTS: Measured parameters significantly changed between trials, and in some cases gender effects were observed in the AP direction. There was a significant main effect on COP_{ra}, $F(2,28)=83.48$, $p<0.001$. Post hoc comparisons with Bonferroni correction indicated that the mean range of sway during quiet standing (M=0.987 cm, S=0.235 cm) was significantly different than in position with a rifle condition (M=3.106 cm, S=0.834 cm) and aiming position condition (M=2.750 cm, S=0.706 cm) in the male group. However position with a rifle did not significantly differ with and without aiming (feedback from the laser). Similar results can be observed in the female group.
Significant main effect, $F(2,28)=6.223$, $p<0.05$, and gender effect, $F(1,14)=7.024$, $p<0.05$ on COP_{vel} was observed in the mean values of COP_{vel} across the trials. However, there was no interaction between gender and trial condition. In male group COP_{vel} remained almost constant across the trials. In the female group mean velocity was decreasing across the trails and was significantly lower in aiming condition (M=1. 790 cm/s, S=0. 238 cm/s) than in quite stance (M=2.158 cm/s, S=0.177 cm/s). COP_{vel} was also significantly higher in female group but only in quite stance condition (M=1.794 cm/s, S=0.201 cm/s in male group, M=2.158 cm/s, S=0.177 cm/s in female group).
RMS of the COP did not significantly differ neither across the trials, $F(2,28)=0.836$, $p>0.05$, nor between groups, $F(1,14)=5.223$, $p>0.05$. Also in RM_{len} there was no significant main effect, $F(2,28)=1.498$, $p>0.05$, but the significant gender effect was observed, $F(1,14)=12.180$, $p<0.05$. Post hoc comparisons with Bonferroni correction indicated that RM_{len} was significantly different in quite stance condition in male group (M=16.761 cm, S=2.221 cm) than in the female group (M=21.778 cm, S=4.342 cm).
Significant main effect , $F(2,28)=4.865$, $p<0.05$, and gender effects, $F(1,14)=13.203$, $p<0.05$, was also observed for mean values of TR_{len}. Post hoc comparisons indicated that TR_{len} was significantly (p=0.574) different in aiming condition (M=58.564 cm, S=7.755 cm) than in quite stance condition (M=66.118 cm, S=6.790 cm), while in male group it did not change significantly across the trials. TR_{len} was also significantly different in male and female group in quite stance condition (M=53.757 cm, S=4.991cm in male group and M=66.118 cm, S=6.790 cm in female group) and in position with a rifle condition (M=50.489 cm, S=5.827 cm in male group and M=61.664 cm, S=9.686 cm in female group).
Similarly to anterior-posterior direction, there was a significant main effect on COP_{ra} , $F(2,28)=11.452$, $p<0.001$ in ML direction. Though in both groups range of sway decreases across the trials only in male group difference is significant. COP_{ra} in quite stance condition

(M=2.408 cm, S=0.670 cm) was significantly different than in stance with a rifle (M=1.348 cm, S=0.159 cm) and aiming (M=1.584 cm, S=0.351 cm) condition.
Decreased range of body sway was followed by increased velocity. Significant main effect, $F(2,28)=56.271$, $p<0.001$, marginally significant gender effects, $F(1,14)=4.165$, $p=0.06$, and effect of interaction, $F(2,28)=3.749$, $p<0.05$, on COP_{vel} was observed. In male group velocity in quite stance (M=1.542 cm/s, S=0.194 cm/s) was significantly different than in stance with a rifle (M=2.034 cm/s, S=0.322 cm/s) and in aiming condition (M=2.110 cm/s, S=0.247 cm/s). Similar effects were observed in female group, but values of velocity were higher than in male group and was significantly different in quite stance (M=1.626 cm/s, S=0.200 cm/s) than in stance with a weapon (M=2.490 cm/s, S=0.344 cm/s) and aiming condition (M=2.288 cm/s, S=0.359 cm/s).
Contrary to the results in anterior-posterior direction significant main effects, $F(2,28)=3.569$, $p<0.05$, gender effects, $F(1,14)=6.704$, $p<0.05$, and effects of interaction, $F(2,28)=8.893$, $p<0.05$ on RMS of the COP was observed. In the male group RMS did not change significantly. In female group values in quite stance (M=2.355 cm, S=1.501) was significantly different than in stance with a rifle condition (M=7.401 cm, S=1.710 cm). RMS in stance with a weapon condition was also significantly different in the corresponding trial in male group (M=2.711 cm, S=2.333 cm).
No main effect for RM_{len}, $F(2,28)=2.047$, $p>0.05$, but significant effect of interaction, $F(1,14)=20.850$, $p<0.001$, was observed. RM_{len} value in stance with a rifle condition in male group (M=17.571 cm, S=1.665 cm) was significantly different than in corresponding trial in the female group (M=22.578 cm, S=2.910 cm). Similarly RM_{len} in aiming condition in male group (M=16.689 cm, S=2.288 cm) was significantly different than in the female group (M=20.686 cm, S=2.407 cm).
Significant main effect, $F(2,28)=51.247$, $p<0.001$, gender effect, $F(1,14)=10.800$, $p<0.05$) and effect of interaction, $F(2,28)=4.331$, $p<0.05$, for TR_{len} were observed. In male group value of trembling length in quite stance (M=48.714 cm, S=5.534 cm) was significantly different than in stance with a rifle (M=60.983 cm, S=7.710 cm) and aiming condition (M=60.061 cm, S=5.858 cm). In female group TR_{len} during quiet standing (M=56.653 cm, S=4.964 cm) was significantly different than in stance with a weapon (M=76.435 cm, S=9.134 cm), and aiming condition (M=66.731 cm, S=8.597 cm). Also mean values in stance with a rifle were significantly higher than in stance with a rifle and during aiming in male group.

DISCUSSION: The aim of this study was to determine gender effects on postural sway characteristics and rambling and trembling components during rifle aiming but quiet standing was also taken under consideration. Postural sway range in the AP direction was lowest in quiet standing and was significantly increased in other trials. Contrary to AP direction sway range in ML during quiet standing was significantly higher than in other trials. These changes were followed by COP velocity. 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). During standing smaller ankle movements are perceived when calf muscles are contracted. While RMS of the COP in male group did not change across the trail for both directions in female group magnitude of RMS was significantly highest in shooting position in ML direction. Perhaps rifle was too heavy to fully stabilize and control the body position during the trial (Cheng-Kang & Yung-Hui 1997).
In this experiment rambling trajectory did not change for both directions but in trials including shooting position in ML direction rambling length was significantly higher in female group. Also trembling component did not change in the AP direction, but was significantly higher in

quiet standing and shooting position in female group. In ML direction TR_{len} was higher only instance with a weapon condition in the female group. In the male group trembling increased instance with a rifle condition yet remained almost unchanged in aiming condition while in female group significantly decreased.

CONCLUSIONS: This study has shown that additional visual information during aiming the target did not significantly influence measured parameters in studied group. Also that subject's gender significantly influences measured parameters.

REFERENCES:

Balasubramaniam, R., Riley, M. A., & Turvey, M. T. (2000). Specifity of postural sway to the demands of precision task. *Gait and Posture 11, 12-24*.

Caron, O., Faure, B., & Breniere, Y. (1997). Estimating the center of gravity of the body on the basis of the centre of pressure in standing posture. *Journal of Biomechanics 30, 1169-1171*.

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

Cheng-Kang, Y., & Yung-Hui, L. (1997). Effects of rifle weight and handling. *Applied Ergonomics* , Vol 28. No. 2, 121-127.

Collins, J. J., & De Luca, C. J. (1993). Open-loop and closed-loop control of posture: A random-walk analysis of center-of-pressure trajectories. *Experimental Brain Research*, 95, 308-318.

Collins, J. J., & De Luca, C. J. (1994). Random walking during quiet standing. *Physical review letters*, 73, 764-767.

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*.

King, D. L., & Zatsiorsky, V. M. (1997). Extracting gravity line displacement from stabilographic recordings. *Gait and Posture 6, 27-38*.

Levin, O., & Mizrahi, J. (1996). An iterative model for estimation of the trajectory of center of gravity from bilateral reactive force measurements in standing sway. *Gait and Posture 4, 89-99*.

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.

Peterka, R. J. (2000). Postural control model interpretation of stabilogram diffusion analysis. *Biological Cybernetics*, 82, 335-343.

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.

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*.