Stance Stability in Shooters

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Abstract

In many sports events, the role of balance is obvious. In shooting even small changes in posture may lead to significant changes in performance. Balance is the result of interactions between many physiological and functional systems, including cerebellum, vestibular organs, visual system, and proprioceptive system. In this study, the stance stability was quantified by three forceplate measures: the maximum sway velocity, the mean sway velocity and the dispersion index. Posture control during standing on a force plate over a period of 15 seconds was studied for talented shooters trained for the Olympic games and controls. Furthermore, the accuracy of each parameter was detected and all factors for the stability of shooters and non-shooters were weighted. Subjects were tested under four sensory conditions: comfortable stance with eyes open, comfortable stance with eyes closed, narrow stance with eyes open, and narrow stance with eyes closed. It was concluded that the shooters had better stability than untrained control subjects. The maximal velocity and the mean velocity were both valid measures of stance stability during all sensory conditions. However, the dispersion index was poor in distinguishing the differences of stance stability between shooters and controls. The results also indicated that the shooters relied less on visual control and more on proprioceptive and vestibular control than the control subjects did, but the foot position also played an important role on stability control for both the shooters and control subjects.

Keywords: Sway velocity, Sensory conditions, Dispersion index

Introduction

Maintenance of an up-right standing posture during bipedal standing is a demanding task. The base of support is narrow, and the center of mass is located high above the supporting surface. Sensory information about posture is important for balance control. The main sources for this information are the vestibular organs, visual system, proprioceptive system, and exteroceptive pressoreceptors. Depending on the actual situation, the contribution of each of these systems may vary. Balance is the result of interactions between many physiological and functional systems (Diener et al. 1984; Dietz et al. 1987; Dorman et al. 1978; Era & Heikkinen 1985; Hasselkus & Shambes 1975; Lehmann et al. 1990; Norre & Forrez 1986; Sahlstrand et al. 1978; Shumway-Cook & Horak; 1986). The contribution of each sensory modality may also be changed with the help of specific balance training. For shooters, Era et al. (1996) investigated if there were any differences in scores between different ability levels. They analyzed the postural control of rifle shooters of different ability levels during the last seconds preceding the shot. The trained athletes have systematically better control of the posture and are able to improve their stability during the last seconds preceding the shot. They suggested that at least the lower level athletes could benefit from specific training aimed at improving these abilities. In the study of Aalto et al. (1990), ten competition shooters (8 rifle, 2 pistol) were tested during simulated race using the force platform technique to investigate the effect of training on postural stability. The postural stability was evaluated with and without competition clothing. The results show that the shooters have significantly better stability than untrained control subjects, when tested without supportive clothing. The competition clothing reduces the sway velocity further both in the visual and non-visual conditions. The results also indicate that the shooters used to an increased amount proprioceptive and vestibular cues to stabilize their posture. In many sports events the role of balance is obvious. In shooting, the importance of stability is much higher than other sport events. In Olympic games, the β-blocker was included as illegal medicine in shooters, even though the medicine can improve body stability induced by decreasing heart rate. The top-level shooters can stabilize their posture further during the last seconds just before shooting to increase the accuracy of shot. Thus the ability of good instant posture control is necessary for shooters.

The purpose of this study was to compare the balance control in stance between shooters and inexperienced controls from the perspectives of sensory integration, sensory system efficiency and the motor strategy involved. The sway velocities including maximum, minimal and mean sway velocities were used to evaluate...
posture stability in shooters. In addition, the abilities and usefulness of three measures, maximum sway velocity ($V_{\text{max}}$), mean sway velocity ($V_{\text{mean}}$), and dispersion index, in distinguishing changes in posture stability were studied.

**Methods**

Eleven talented competition shooters, six male and five female being trained for Olympic game, were recruited. Twenty-two normal college students, eleven male and eleven female, were served as control group. The age, height and shooting practice period were 17-30 (mean 21.2) years, 167-182 (173.3) cm, and 2-8 (mean 4.8) years for male shooters and 16-18 (mean 16.8) years, 155-169 (161.8) cm, and 1-4 (mean 1.6) years for female shooters. For controls, the age and height were 24-28 (mean 25.3) years and 168-183 (173.8) cm for male and 21-23 (mean 22) years and 162-167 (163.4) cm for female. All of the subjects were excluded from any orthopedic, neurologic diseases or disorders, and they were also excluded from any impairment of somatosensory, hearing, vestibular and uncorrectable visual functions.

The test consisted of four sensory conditions: (1) comfortable stance, eyes open; (2) comfortable stance, eyes closed; (3) narrow stance, eyes open; and (4) narrow stance, eyes closed. Comfortable stance means standing in subject's comfortable status and narrow stance is to stand with two feet closed touched and parallel.

Standing balance was measured with a Kistler 9281-B force platform system (Kistler 9281, Kistler, Amhurst, NY). The system was composed of a forceplate with 4 force transducers under each corner of the forceplate. Signals were amplified and converted into digits using A/D converter card. Signals were sampled at frequency 100Hz with a low pass filter at 10 HZ using the Bioware software (Kistler, Amhurst, NY). Three orthogonal components of ground reaction forces, a torsional component of moment, and locations of center of pressure (COP) could be obtained.

In measurement the subject stood on the platform with barefoot. The testing sequence was random. Each trial lasted for 15 seconds. The system recorded the sway path, which is the trajectory of the COP. Then, the maximum and mean sway velocities and dispersion index could be calculated from the sway path. These three parameters were used to describe the postural stability and defined as follows:

**Sway velocity**: The sway path was differentiated using a generalized cross-validation spline smoothing routine (Woltring, 1986) to get the sway velocity of the COP in the unit, cm/sec.

**Dispersion Index**: The standard deviation of the COP dispersion.

$$\text{Dispersion Index} = \text{STD}\{\sqrt{(x_i-\text{mean}(x))^2+(y_i-\text{mean}(y))^2}\}$$

where $x_i$ and $y_i$ are the components of the location of the COP in force platform coordinate system. STD means standard deviation function.

An SPSS for windows software package was used for statistical analysis. 2-sample t-test was used to evaluate the statistical significance of the differences between the shooter and control groups. Paired t-test was used to compare the means between different sensory conditions within each group.

**Results and Discussion**

Three parameters, maximum sway velocity, mean sway velocity and dispersion index, were used for analysis. The differences between shooters and controls and between different sensory conditions within each group were studied, respectively.

**Group Difference**: Previous studies have shown that there exists the gender effect on postural control. Gender effect would not be included in this study. We compared the differences in stance balance control between control group and shooters for male and female, respectively, using maximum sway velocity, mean sway velocity and dispersion index (Figures 1-6). Both $V_{\text{max}}$ and $V_{\text{mean}}$ measures demonstrated that shooters had significantly better stance stability than untrained controls for four sensory conditions (Figures 3-6). This was in agreement with Aalto et al. study (1990).

![Figure 1: Dispersion index of male subjects. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.](image1)

![Figure 2: Dispersion index of female subjects. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.](image2)

However, dispersion index only showed that shooter had smaller dispersion value than untrained controls under two eyes closed conditions, not eyes open conditions. And, the difference is significant only for the narrow stance, eye closed condition in female ($p<.01$). Therefore, results
V_{max} and V_{mean} in distinguishing changes in posture stability between groups were high (p<.01) for all sensory conditions except V_{mean} for the comfortable stance, eye closed condition in male (p>.05). In contrast, the sensitivity of the dispersion index measure was poor (p>.05).

Sensory Conditions: By using V_{max}, V_{mean}, and dispersion index measures, two sensory conditions, visual input (eye open vs. eye closed) and altered support (comfortable foot stance vs. narrow foot stance), were tested using paired t-test in female control group, male control group, female shooter group, and male shooter group, respectively (Nashner et al. 1982). Figures 7-10 only showed the bar charts with significant differences. Results revealed that visual input and foot position could contribute to the stance stability in controls. However, the stability of shooters might be only contributed by foot position.

Figure 3: Maximal sway velocity of male subject. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.

Figure 4: Maximal sway velocity of female subject. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.

Figure 5: Mean sway velocity of male subjects. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.

Figure 6: Mean sway velocity of female subjects. A: comfortable stance, eyes open; B: comfortable stance, eyes closed; C: narrow stance, eyes open; D: narrow stance, eyes closed.

Explicitly revealed that the sensitivities of two measures,
The relationship between stability control and shooting score in Aalto et al. (1990). They reported that the relationship between stability control and shooting score in untrained controls and middle-experiment shooters, but none in highly trained shooters. This could partly be due to the fact that the variation between the trials was considerable small in the experienced shooters. Furthermore, the shooters on this study were classified as middle-experiment shooters (training time below 10 years) based on the classification of Era et al. 1996. Thus the postural testing presented in this study could give valuable information for each individual shooter and might be used in training to improve the shooters’ capabilities by using vestibulospinal pathways. That is, the postural testing could give valuable information on the individual features of shooters, such as high posture stability (either natural or acquired by training) or visually oriented postural control. It also could be used for selecting high potential of shooters.

In this study, the COPs acquired by force plate were used for analysis. The interaction response between the body’s center of mass and COP would be interesting and important to realize the postural control mechanism. Partial body stabilization on specific shooters, for example, the upper arm stabilization of pistol shooters, would be also worth for further investigation. Of course, the number of subjects was suggested to increase, and then the results and conclusion would be more reliable.

Conclusion

This study showed that the shooters had significantly better stance stability than untrained controls. Both the maximum sway velocity and mean sway velocity had good concurrent validity for stability test, but not the dispersion index. It is also concluded that the visual cues in shooting could be compensated by the other sensory organs. On the other hand, the standing positions played an important role on postural control both in shooters and controls.

General speaking, the postural testing presented in this study could give valuable information for each individual shooter and might be used in training to improve the shooters’ capabilities. It also could be used for choosing shooters with high potential.

References


