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Original article

A comparison of the stability of standing shooting stance in expert and novice mountain infantry shooters

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ABSTRACT

This study compares balance control in standing shooting stance in expert and novice military shooters among mountain infantry soldiers. Balance control was assessed using AccuSway (AMTI, USA) force platforms in terms of the range of the centre of pressure (COP) displacements in the mediolateral (RANGE(ML)) and anteroposterior direction (RANGE(AP)), the standard deviation of COP displacements in the mediolateral (SD(ML)) and anteroposterior direction (SD(AP)), the sway area of COP displacements (ELLIPSE), the average velocity of COP displacements (AVG VEL) and the COP path length (LENGTH). The participants (expert shooters, N=10; novice shooters, N=15) adopted tactical standing shooting stance wearing the field uniform, with a rifle on force platforms (one for each lower limb), over a period of 10 seconds, with sampling frequency of 100Hz. The statistical analysis using the Mann-Whitney U test revealed a significant difference between the studied groups, taking into account the ELLIPSE and the AVG VEL variables values for the dominant leg only. It was concluded that the expert shooters showed better stability than novice shooters. This study presents implications regarding biomechanical aspects of standing shooting stance stability.

KEYWORDS

military, shooting, balance control

Introduction

Maintaining a standing stance is subject to constant body sways that disturb the state of balance of the body, thus corrective actions to regain a balanced stance must be taken [1; 2]. One's ability to regain a state of equilibrium is called stability, and it depends on the efficient operation of specialised systems (visual, vestibular, proprioceptive and skin mechanoreceptors) constantly monitoring any deviation from the body's vertical alignment [3]. Body sways, i.e. deviations from the vertical alignment, are related to the displacement of the vertical projection of the centre of mass (COM) in relation to the base of support (BOS) [4]. In order to ensure the stability of the maintained position, the motor apparatus executes corrective actions in relation to body sways, which are represented in the displacements of the centre of pressure (COP) [5]. Based on the COP displacements as a function of time, the balance control variables can be calculated and the stability of the shooting stance can be assessed.

The shooting stance, along with the rifle hold, creates a binder that allows to align with the target and precisely perform all activities related to the process of shooting [6]. The stability of the shooting stance and the magnitude of the shooter's body sways are among the biomechanical factors determining shooting effectiveness [7; 8]. However, assessing the influence of body balance on shooting efficiency is difficult in light of the scientific evidence, the reasons include complex, direct and indirect, factors influencing postural balance and its impact on shooting performance [7; 9; 10].

The level of balance control and thus the shooter's body sways is significantly related to the rifle shooting effectiveness [11; 12]. In one of the studies, the magnitude of body sways is the most important factor in vertical shot distribution [8]; however, in turn, another study indicates a very low direct influence of postural balance on shooting performance [13]. Although the direct influence of the body balance level on shooting performance seems to be limited, balance control has a significant impact on the stability of the rifle [10; 13; 14]. The confirmed correlation between the body sways and the rifle sways indicates, that the stability of the rifle results from the stability of the maintained shooting stance [10; 13; 15]. Due to the aforementioned limitations, the mere reduction of the body sway does not guarantee the improvement of shooting performance, unless the amount of the rifle's muzzle displacement is also reduced [16]. Consequently, a rifle shooter must create an intersegmental interlocked block containing the body segments and the firearm to limit the movements of the rifle and to obtain the best possible shooting performance [7; 17].

In general, researchers agree that higher levels of balance control lead to higher shooting performance [18-20]. Shooters show less cognitive effort invested in balance control during positions that are more specific to their training, i.e. standing shooting stance [21]. Studies also indicate that shooters, while maintaining a standing stance rely less on visual control and more on vestibular and proprioceptive control [18; 22]. Higher proprioceptive control over shooting stance enables shooters to dedicate more attention to the other elements of the process of shooting (i.e. aligning the sights, aligning with the target, trigger and recoil control etc.) [16; 18]. As shooting training progresses, factors determining shooting efficiency improve, including the stability of the shooting stance [10]. Experienced rifle shooters are more stable than novice shooters, hence it is thought that postural performance would reflect the sport performance level [23]. The shooting stance of novice shooters is characterised by greater variability, while expert shooters present significantly lower values of COP displacements, especially in the mediolateral and anteroposterior directions [24-27].

Research objective

The aim of this study is to compare the balance control over standing shooting stance in experienced and novice shooters of mountain infantry. The following research question was posed: To what extent do balance control variables differ in the examined groups of soldiers?

Material and research method

Participants

Overall 25 healthy soldiers were recruited for this research, divided into separate groups: expert shooters (N=10, firearms experience of 5 years and more) and novice shooters (N=15, firearms experience of 1 year and less). Standing shooting stance was characterised by a slight lean towards the target area, legs apart and knees slightly bent, feet shoulder-width apart with the non-dominant foot ahead of the dominant one. Table 1 presents basic characteristics of the tested groups. The soldiers undertook the test in field uniforms with a Beryl wz. 96 rifle.

Table 1. Basic characteristics of the tested groups

No.	Group	Age range [years]	Firearms experience [years]	Height [m]	Weight [kg]
1.	Expert shooters (N=10)	26-31	5≤	1.80±0.06	82.70±8.09
2.	Novice shooters (N=15)	19-25	≤1	1.81±0.07	83.11±11.11

Source: Own study.

Testing device

The study was conducted using two AccuSway (Advanced Mechanical Technology, Inc) force platforms compatible with the NetForce data collection software version 2.3.0 (AMTI, Watertown MA, USA) and BioAnalysis app version 2.3.0 (Biosoft, Cambridge, UK). AccuSway platforms are calibrated with factory-supplied drivers and controlled via the NetForce application. The testing devices are connected to the analogue-to-digital converter and the entire assembly is turned on simultaneously. The force platforms enabled the measurement of the acting forces (Fx, Fy, Fz) and the moments of forces (Mx, My, Mz) of the centre of the pressure parameter and its derivatives. The high-precision, multiaxial, AccuSway platforms have 3 built-in strain gauges in each corner, which enable reliable measurement regardless of the location of the support point on the surface of the platform [28]. Sampling frequency was set to 100 Hz. The balance control variables were calculated on the basis of the COP displacements.

Balance control variables

For the purposes of this study, the following balance control variables were selected for the assessment of the stability of the standing shooting stance:

1. Range of the COP displacements in the mediolateral direction (RANGE (ML)), measured in [cm], defined as the maximal distance over two points of the stabilogram along the transverse axis.

2. Range of the COP displacements in the anteroposterior direction (RANGE (AP)), measured in [cm], defined as the maximal distance over two points of the stabilogram along the sagittal axis.
3. Standard deviation of the COP displacements in the mediolateral direction (SD (ML)), measured in [cm], defined as the amount of dispersion of a set of values along the transverse axis.
4. Standard deviation of the COP displacements in the anteroposterior direction (SD (AP)), measured in [cm], defined as the amount of dispersion of a set of values along the sagittal axis.
5. Sway area of COP excursion in all directions (ELLIPSE), measured in [cm^2], defined as the area of the ellipse with 95% confidence in results.
6. Average velocity of COP displacements (AVG VEL), measured in [cm/sec], calculated by the COP excursion by the trial time.
7. Path length (LENGTH), measured in [cm], defined as the quantification of the two-dimensional COP displacement based on the total distance of COP excursion.

Testing procedure

The individuals involved in the study were instructed about the testing procedure. None of the soldiers had previous experience with measuring body balance using force platforms, so it was a new task for everyone. The testing procedure started by collecting from each soldier the feet contours of their standing shooting stance before proceeding to a separate room with the testing device. Next, a sheet of A0 paper with the contours was placed on the testing device and, after taring the equipment, a soldier placed his feet exactly in their contours. After entering the force platforms, one for each lower limb, the soldier adopted a low ready standing shooting stance. After the "start!" command, the soldier aligned sights on the target area, which was a sheet of A4 paper hung 1.7 m high on a wall 7 m away. In order to exclude test artefacts caused by the auditory stimulus, the actual record of the COP displacements started 3 seconds after the "start!" command. Over a period of 10 seconds (counted from the actual start of the recording), the soldiers maintained the standing shooting stance with sights aligned on the target area. No trigger action was allowed, the participants were clearly instructed not to dry fire. The participants were to focus on the stable shooting stance and maintain sights aligned on the target only. With the end of the recording period, the "stop!" command informed the soldier to switch back to low ready shooting stance, and after securing the rifle, step down from the force platforms. Each soldier performed the testing procedure only once.

Statistical methods

The following numbers of observations were taken into account in the statistical analysis: for the expert shooters group n=10, for the novice shooters group n=15. Due to numerically unequal groups and the distribution of the data set not fulfilling the conditions of normality, statistical tests were performed based on nonparametric techniques. In order to determine the significance of the difference between examined groups, the Mann-Whitney U test was used for the left and right lower limb respectively. The level of significance of the difference was set at $p<0.05$.

Research approval

This research was approved by the Commander of the Mountain Infantry Military Unit and by the Director of the Ministry of National Defence Operational Centre.

Informed consent

Informed consent has been obtained from all individuals included in this study. Each individual was advised about the possibility of discontinuing their participation in this study, without giving a reason, at any stage of the experiment.

Results

Table 2 presents the median values of results of balance control variables for the left and right lower limb respectively. Noteworthy is the fact that the range of the COP displacements in the mediolateral directions for both feet and the length of the COP path for the left foot are similar in both groups. However, the differences in the median values of the remaining balance control variables are more noticeable, especially for the right (dominant) leg.

Table 3 presents the value of significance of the difference (*p*) between the studied groups for each balance control variable for the left and right leg respectively. A statistically significant difference was noted only for two balance control variables of the dominant leg. The expert shooters group showed significantly lower values in the COP sway area and the average velocity of COP displacements compared to the novice shooters group. Other balance control variables did not reach the required threshold of significance of the difference.

Discussion

The results of this study show that more experienced military shooters are characterised by lower body sway, i.e. more stable shooting stance than novice shooters. The authors presume

Table 2. Median values of balance control variables in the expert and novice shooters for the left and right leg respectively

No.	Balance control variable	Median value			
		Expert shooters		Novice shooters	
		left leg	right leg	left leg	right leg
1.	RANGE (ML) [cm]	0.544	0.883	0.554	0.802
2.	RANGE (AP) [cm]	2.798	2.485	3.192	2.971
3.	SD (ML) [cm]	0.096	0.174	0.101	0.164
4.	SD (AP) [cm]	0.630	0.520	0.763	0.661
5.	ELLIPSE [cm^2]	0.468	0.395	0.774	0.853
6.	AVG VEL [cm/sec]	3.672	3.376	3.794	3.908
7.	LENGTH [cm]	37.332	36.002	37.939	39.080

Source: Own study.

Table 3. The values of the difference significance (p) of balance control variables between the studied groups for the left and right leg respectively

No.	Balance control variable	*p* value	
		left leg	right leg
1.	RANGE (ML)	0.48	0.67
2.	RANGE (AP)	0.76	0.25
3.	SD (ML)	0.36	0.42
4.	SD (AP)	0.50	0.11
5.	ELLIPSE	0.06	**0.03***
6.	AVG VEL	0.23	**0.004***
7.	LENGTH	0.93	0.19

* significant at level of $p<0.05$

Source: Own study.

that it is due to a higher degree of training in shooting and more experience. A number of studies show that expert athletes exhibit high motor abilities strictly related to the specificity of a given sport, in this case maintaining balance in the standing shooting stance [29]. High-level athletes sway less compared to lower-level athletes due to training that leads to specific adaptations in relation to the task being trained [30; 31]. In fact, expert athletes and non-expert athletes use different posture strategies [2].

The current study seems to confirm the conclusions of other researchers, that more experienced rifle shooters have better balance control over shooting stance than lower-level shooters [11; 12; 23]. These correlations also seem to apply to other shooting disciplines as well, since more experienced pistol shooters show less COP displacement and less involuntary gun movement compared to novices [26]. Postural adjustment is better coordinated with arm movements to minimise gun movement in experienced shooters [25].

However, direct reference to the results of other researchers is limited due to the different research groups and also because the shooting stance adopted by sports shooters differs significantly from the shooting stance of military shooters. The posture characteristics of sports shooters allowed other researchers to use one force platform [27], while the shooting stance of military shooters requires the use of two force platforms. The authors presume that the use of two force platform allows for a more accurate assessment of the stability of the standing shooting stance.

This study showed a significant difference in the stability of the standing shooting stance only for the hind leg in the adopted shooting stance. The analysis of the balance control variables showed that the expert shooters differed in a statistically significant manner only in the case of the dominant leg in terms of the sway area (ELLIPSE) and the average velocity of COP displacements (AVG VEL).

The average velocity of COP displacements illustrates the efficiency of the balance control system [32]. Lower values of the average velocity of COP displacements indicate better stability, which seems to be due to faster discrepancy recognition between the actual and the desired position of the body segments, which in turn allows for faster corrective postural adjustments and thus a smaller overall COP displacements size [33; 34]. Thereby, it seems that expert shooters are characterised by greater sensitivity of sensory receptors or better integration of postural information [31; 34]. This conclusion is consistent with the results of other researchers, indicating that lower values of the average velocity of COP displacements are correlated with better shooting performance and less advanced shooters show higher values of this variable [16; 36].

Lower values of the COP sway area seem to be in line with the conclusion that top athletes could apply local postural corrections before the situation requires the use of more global postural strategies [2]. The theorem that the lower values of the COP sway ellipse area the better the postural performance seems to be due to more automatic postural adjustments among more experienced athletes [37-39].

Contrary to previous study results, this study showed no difference between expert and novice military shooters in terms of the COP displacement range and the standard deviation of the COP displacements, both in the mediolateral and anteroposterior direction [13; 24]. The authors speculate that the reason may be the adopted research methodology, namely the analysis of balance control variables in a 10-second perspective with firearm no-shoot condition, while other researchers studied the variables mainly in the period of 0.5-0.2 seconds preceding the shot with actual live fire. This period is considered crucial in the context of the relationship between posture control and shooting performance [14; 15].

Conclusions

1. In the studied group of soldiers, the balance control of the standing shooting stance is different in the expert and the novice shooters groups. The expert shooters present a more stable shooting stance compared to the novices.
2. A statistically significant difference was found in two balance control variables for the dominant lower limb, meaning the sway area (ELLIPSE) and the average velocity of COP displacements (AVG VEL).

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Conflict of interests

All authors declared no conflict of interests.

Author contributions

All authors contributed to the interpretation of results and writing of the paper. All authors read and approved the final manuscript.

Ethical statement

The research with the participation of humans complies with all the relevant national regulations and institutional policies, follows the tenets of the Declaration of Helsinki, and is approved by the Ethics Committee for Research at the University School of Physical Education in Wroclaw.

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Porównanie stabilności postawy strzeleckiej stojąc doświadczonych i początkujących strzelców piechoty górskiej

STRESZCZENIE Celem pracy jest porównanie jakości procesu kontroli równowagi w postawie strzeleckiej stojąc doświadczonych i początkujących strzelców piechoty górskiej. Kontrolę równowagi oceniono za pomocą platform sił AccuSway (AMTI, USA) pod względem wartości miar stabilności obliczonych na podstawie przebiegu punktu przyłożenia wypadkowej siły reakcji na podłoże – COP (ang. Center of Pressure), w tym: zakresu przemieszczeń w kierunku przyśrodkowo-bocznym (RANGE(ML)) i przednio-tylnym (RANGE(AP)), odchylenia standardowego przemieszczeń COP w kierunku przyśrodkowo-bocznym (SD(ML)) i przednio-tylnym (SD(AP)), pola elipsy przemieszczeń COP (ELLIPSE), średniej prędkości przemieszczeń COP (AVG VEL) oraz długości ścieżki COP (LENGTH). Uczestnicy (doświadczeni strzelcy, N=10, początkujący strzelcy, N=15) przyjęli taktyczną postawę strzelecką stojąc w umundurowaniu polowym z karabinkiem Beryl wz. 96 na platformach sił (po jednej dla każdej kończyny dolnej) przez okres 10 sekund, z częstotliwością próbkowania ustawioną na 100Hz. Analiza statystyczna przeprowadzona za pomocą testu U Manna-Whitneya wykazała istotną różnicę pomiędzy badanymi grupami w wartościach wskaźnika pola elipsy (ELLIPSE) oraz średniej prędkości przemieszczeń COP (AVG VEL) jedynie dla dominującej kończyny dolnej. Stwierdzono, że doświadczeni strzelcy charakteryzują się większą stabilnością przyjętej postawy strzeleckiej niż początkujący strzelcy. W pracy przedstawiono implikacje dotyczące biomechanicznych aspektów stabilności postawy strzeleckiej stojąc.

SŁOWA KLUCZOWE wojsko, strzelectwo, kontrola równowagi

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