A SHOOTER'S POSTURE IN HANDLING A RIFLE WHILE AIMING AT A TARGET IN STANDING POSITION

Wan Din[1] and Azmin Rambely[2]

Centre of Foundation Studies and Applied Sciences, Universiti Pertahanan Nasional Malaysia, 57000 Kem Sg Besi, Kuala Lumpur, Malaysia[1]
School of Mathematical Sciences, Faculty of Science & Technology, Universiti Kebangsaan Malaysia, 46300 Bangi, Malaysia [2]

The purpose of the study is to determine a good posture of an upper limb segment in handling a rifle while aiming at a target in standing position. Ten male subjects participated in the study. The experiment was done using Vicon 1.5.2 motion analysis system and seven infra-red cameras. Data were filtered using Functional Data Analysis (FDA) technique. Results showed that mean flexion angle for all the subjects are 52 ±7 deg and 32 ±9 deg for right and left shoulder, respectively. Mean elbow angle is 118 ±8 deg on the right and 103 ±10 deg on the left. Ulnar deviation for wrist angle is the smallest with 21 ±9 deg for the right hand side and 47 ±11 deg for the left hand side. It is concluded that the shooting posture of the upper limb segment of a shooter is consistent within all the subjects.

KEY WORDS: joint angle, functional data analysis (FDA), shooting accuracy.

INTRODUCTION: Accuracy in shooting is very important for sports shooters, police and army personnel as well as hunters. Shooting accuracy depends on several factors such as postural balance (Era, Konttinen, Mehta, Saarela & Lyytinen, 1996; Ball, Best & Wrigley, 2003; Mononen et al. 2007; Hrysomallis 2011), breathing techniques (Plaster, 2006), ammunition dimensions (Anderson, Boneh & Grevstad, 2009), novice and expert shooters (Doppelmayr, Finkenzeller & Sauseng , 2008; Ravindra, Errol & Wing, 2009), length and weight of the rifle (Yuan & Lee, 1997) and biomechanical interactions in human-rifle system (Grebot & Burtheret, 2008). None discusses on the shooter's posture of handling a rifle in target accuracy.

In Malaysia, army and police personnel are required to attend shooting training to improve their shooting skill technique. The normal shooting training procedure is done by trial and error practice. The fact that the number of practice does not necessarily give the better outcome in shooting accuracy is long known (Platte & Powers, 2008). Thus live shooting exercises which involved a combination of expert and novice shooters has been carried out to obtain the level of shooting accuracy among Malaysian military staff and soldiers. It is found out that the mean score was 55 (SD = 10) (Din, Rambely, & Jemain, 2011). Thus the objective of this paper is to determine a correct posture of handling a rifle while aiming a target during standing shooting activity.

METHODS: Ten healthy male military trainers free from any injuries, age 31 ±6.2 years old, weigh 71.6 ±10.4 kg with height of 166.3 ±5.9 cm were chosen as subjects. Consent was obtained prior to the experiment. All of the subjects are soldiers with more than ten years shooting experience using M16 rifle. The subject wore tight outfit carrying a 4 kg rifle. An M16 rifle without bullets was used in the experiment. Standing shooting positions was performed with three repetitions by each subject.

Thirty-nine reflected markers were placed on the bony landmarks of the subject's body (Figure 1). Tracking of gait kinematics data of the subject's body motion while ambushing and aiming the target prior to shooting were recorded and digitized using Vicon 1.5.2 Motion Analysis Systems with seven infra-red cameras attached to the walls. There were 45 trials digitized and data was sampled at 50 Hz.

Figure 1: Subject holding a rifle with infrared body markers attached before experiment (left) and while aiming the target in prone shooting positon (right).

Data was smoothed using Functional Data Analysis (FDA) technique (Ramsay, Hooker & Graves, 2009). FDA was a relatively new method for analyzing data. It first transformed data to functional forms for further analysis. Besides normal statistical analysis and verification of data, information from derivatives of the data could also be used. Other important features available in FDA were the ability to smooth and interpolate data, to remove phase lag and to align curves according to specified peak and trough which were not possible by other methods. This study fully utilized FDA smoothing technique in order to remove noise and spike with prior testing done thoroughly before selecting the most suitable parameters. FDA smoothing parameters selected was penalizing fourth derivatives with the amount of smoothing, lambda 1e-12. Programming was done in an open access R programming language.

RESULTS AND DISCUSSION: Sixty frames from all trials during the aiming stage in sagittal plane are combined together. The first 30 frames is the getting ready position to perform the aiming. The real aiming point actually occurs at normalized time 0.69s. Figure 2 showed the angles recorded from all subjects. Table 1 showed mean angles for shoulder, elbow and wrist joints. Mean angles for right shoulder flexion and elbow are greater than that of left side mean angles as the rifle is always positioned on the right side of the body regardless of a dominance side of the subject. Elbow angles are almost flat lines with 110-120° (about 2.0 radian) and 100-110° for right and left sides, respectively. The result shows that every subject possesses almost identical and consistent elbow angle while aiming the target in a standing position. Left shoulder angles are almost flat while the right shoulder angles have more variations compare to that of the left hand shoulder. The difference in shoulder flexion may due to different length of subjects' hands as the length of rifle is fixed. Anyhow the gap is not that large from one subject to another with standard deviation of about 7° and 10° for left and right, respectively. The dotted lines at the bottom of the graph refer to wrist angles for all the subjects. Wrist deviation and flexion seems very small and consistent, with the contralateral wrist hyperextended at around 11° and ulnar deviation of ipsilateral wrist by 9°. Among the three angles, elbow flexion angles are the highest followed by shoulder flexion angles and wrist angles are the smallest of all. All subjects possess almost equivalent degree of angle movements. This may due to their many years experience in rifle shooting.

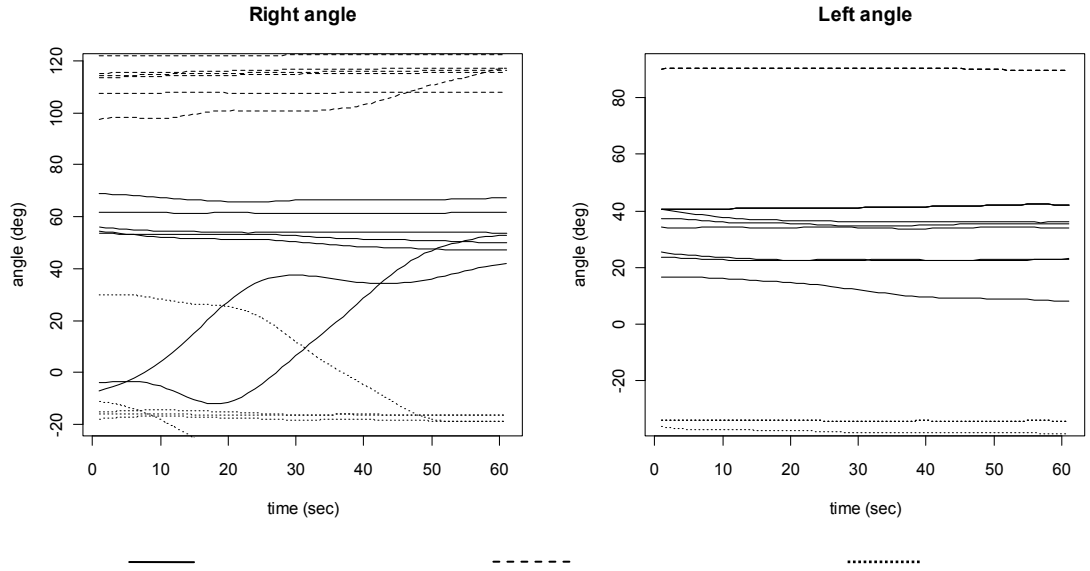

Figure 2: Right and left angles for all subjects during aiming phase. The top dotted lines refer to elbow angles, the middle straight lines are for shoulder angles and the bottom dotted lines are for wrist angles.

Table 1: Mean angles and standard deviation for right and left hand at shooting.

Position	Angle	Mean angle (deg)	Standard deviation
Right	Shoulder	52	6.95
	Elbow	118	8.63
	Wrist	-21	9.32
Left	Shoulder	32	9.28
	Elbow	103	10.62
	Wrist	-47	11.20

CONCLUSION: Shoulder, knee and wrist angles vary slightly from one shooter to the other as their height and posture are different. Somehow, angles for all the subjects for this experiment are not much in variation which may be due to the subject years of experience in rifle shooting. Therefore, we can conclude that a good standing posture for Malaysian military is about the same range as subjects experimented in this paper. Right shoulder, elbow and wrist angles are more consistent compare to that of the left side of the arm. Flexion angles of the right hand side of the shoulder and elbow are greater compare to that of the left hand side. It is observed that the arm motions produce greater mean angle values on the right hand side while handling the rifle to aim for a target.

REFERENCES:

Anderson, S.M., Boneh, S. & Nels Grevstad. (2009). Statistical Methods for Determining Optimal Rifle Cartridge Dimensions. *JSM Proceedings*. arXiv:0905.0727v1[stat.AP].

Ball, K., Best, R. & Wrigley, T. (2003). Inter and Intra individual analysis in elite sports: pistol shooting. *Journal of Applied Biomechanics*, 19, 28-38.

Din, W.R.W., Rambely, A.S. & Jemain, A.A. (2011). Load carriage analysis for Malaysian military using functional data analysis technique. In *Proceedings of 4th International Conference on Modelling, Simulation & Applied Optimization* (ICMSAO), IEEE Xplore, pp 1-8.

Doppelmayr, M., Finkenzeller, T. & Sauseng ,P. (2008). Frontal Midline theta in the pre-shot phase of rifle shooting: Differences between experts and novices. *Elsevier Neuropsychologia,* 46, 1463-1467.

Era, P., Konttinen, N., Mehta, P., Saarela, P. & Lyytinen, H. (1996). Postural stability and skilled performance – a study on top level and naïve rifle shooters. *Journal of Biometrics* 29, 301-306.

Grebot, C. & Burtheret, A. (2008). Pressure Applied by the Shoulder and Correlation with the Shooting in Biathlon. *Journal of Biomechanics* 41 (S1).

Hryomallis, C. (2011). Balance ability and athletic performance. *Sports Med.,* 41, 221-232.
Mononen, K., Konttinen, N., Viitasalo, J. & Era, P. (2007). Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. *Scand. J. Med Science Sports*, 17, 180-185.
Plaster, J. L. (2006). *The Ultimate Sniper*. Boulder, Colorado: Paladin Press.
Platte, W. L. & Powers J. J. (2008). *Storming Media Pentagon Reports: Using Motion Capture to Determine Markmanship Shooting Profiles: Teaching Soldiers to Shoot Better Faster*.http://www.stormingmedia.us/
Ramsay, J.O., Hooker & G. Graves, S. (2009). Functional data analysis with R and MATLAB, New York, Springer.
Ravindra, S. G, Errol, R. F. & Wing, C. L. (2009). Pistol shooting accuracy as dependent on experience, eyes being opened and available viewing time. *Applied Ergonomics*. 40, 500-508.
Yuan, C. K., Lee & Y. H. (1997). Effects of rifle weight and handling length on shooting performance. *Applied Ergonomics* . 28, 121-127.

Acknowledgement: This work was supported by funding from UKM-OUP-TKP-23-188/2011. We would like to thank University of Malaya, for providing the Motion Analysis Laboratory and meaningful discussion and suggestions. We also would like to thank PALAPES UKM for providing the military soldiers as the subject for this experiment and also valuable discussion regarding military procedure.