Postural Sway Distinguishes Shooting Accuracy among Skilled Recurve Archers

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ABSTRACT

Postural movements affect aiming stability in archery, thus contributing to performance inconsistencies. A critical variable distinguishing highly skilled athletes from the novices is the former's ability to manipulate minute changes in their performance. Hence, the present study seeks to examine potential relationship that underlies postural sway and shooting performance amongst Malaysian skilled recurve archers. Twenty one archers participated in this study. Postural sway was assessed in terms of anterior and posterior deviation during motion. Sway analyses involved setup, aiming, and release phases. Participants were required to shoot 12 arrows to a 30-meter target. Data yielded significant relationship between postural sway and shooting accuracy. Correlation coefficients between shooting performance and postural sway ranged between r = -0.021 to 0.248; with highest correlation during release, and lowest during aiming phases. Setup phase showed the only anterior deviation throughout the test. During setup and release phases, correlation between postural sway with shooting performance was significant. Postural sway during setup and release phases is a significant indicator for shooting performance, accounting 17% and 24% of variances respectively. Findings indicated postural sway reduction during release phase improves shooting accuracy, thus establishing a significant relationship between postural sway values with shooting performance of skilled archers.

Keywords: *Aiming stability, postural sway, skilled archers, shooting performance.*

INTRODUCTION

Major performance variables in archery include muscular strength, upper body endurance and overall body stability. These performance variables are crucial specifically at the trunk region, shoulder girdle, and for both arms to ensure shooting accuracy (Ertan, 2009; Soylu, Ertan & Korkusuz, 2006). Besides strength and endurance, postural stability is another critical aspect in influencing the outcome of every shot. Assessment of an archer's skill is centred on the ability to shoot the arrow to a specific target within a designated time frame. Here, archers need to minimize their movements in each action phase in order to avoid unnecessary motion during the shooting action. Such movements reduce stability, thus minimizing chances of hitting the centre target. Movements in archery must be as precise as possible, coping fast with postural instability (Kuo, Chi, Yu, & Tsung., 2005; Ertan, 2009; Ertan. Kentel, Tumer, & Korkusuz, 2003; Kuo & Chi, 2005).

One of the crucial subcomponent in maintaining shooting stability is aiming stability. Attaining high level of postural stability during aiming increases the aiming stability of an archer. Aiming stability, defined as the locus pattern of aiming, ensures uninterrupted flight trajectory to the target. This particular situation gives impact to the performance outcome (Kuo *et al.,* 2005). It is noted that the expert archer's aiming locus is much smaller in contrast to the novice archers (Ertan *et al.*, 2003; Ertan, 2009; Kuo *et al.*, 2005). Archers, regardless of their performance level, are affected by postural sway (Era, Konttinen, Mehto, Saarela, & Lyytinen, 1996; Ball, Best. Wrigley, 2003; Mononen, Konttinen, Viitasalo, & Era, 2007). The most important phase in determining the success of every shot in archery is the aim and release phase, followed by the follow-through phase. Once an archer draws the bow and aim at the target, he or she tends to maintain the posture of the arms and trunk, keeping it fixated to ensure proper alignment of the arrow to the intended target. Hence, when postural sway are minimized, the archer may focus purely on the target, thereby enhancing shooting stability (Balasubramaniam, Riley, & Turvey., 2000). During performance, shooting stability needs to be maintained at the highest level in order to obtain a good and small score deviation.

Postural Sway and Aiming Stability

Posture can be defined as the geometric relationship that exists between different body segments (Balasubramaniam & Wing, 2002). In other words, posture encompasses body joints angles. For example, the right arm wrist and elbow angles describe the posture of string arm for right handed archers. Body posture serves two functions. Firstly, it serves as a standing position point of reference wherein posture works as antigravity and plays a major role in keeping body balance. The balancing function is affected by preventing falls through maintaining the centre of gravity within an individual (Fisher, 2010). As such, in normal standing positions, the postural control system's main function is to integrate the antigravity and balance functions of the body. Secondly, body posture functions as a reference framework for movements. It provides a framework for the head, torso, hip, legs and other body segments to move towards any specific target, or performing any movement (Fisher, 2010).

Highest score in archery is achieved by hitting the centre or within range of the centre of target. Archers need to control their movements at every action phase for precise aims and release arrows at accurate sighting points. Accurate sighting points can be achieved by maintaining or maximizing aiming stability. To sustain aiming stability at the highest level, archers need to maximise postural stability whilst controlling every other aspect in their aiming prior to shooting. Earlier research illustrated that increased aiming (and equipment) stability corresponded with increased in shooting scores. Besides equipment stability, postural stability also plays a major role in determining performance. Archers or shooters who are able to control their postural stability have a more stable platform in aiming, and this increases performance as compared to those who cannot control excessive postural sway (Mononen *et al.*, 2007).

Level of expertise plays a major role in determining whether archers are able to cope with postural sway. Era *et al.*, (1996) found that expert archers were able to rapidly stabilize postural stability compared to the novices. In the same study, highly skilled archers also demonstrated ability to maintain postural stability throughout the major action phases. This condition appears to be acquired through training and competitive experiences, thus enabling skilled archers to manipulate their posture in order to achieve positive outcomes. The present study seeks to examine possible causal relationship between postural sway and shooting performance among skilled archers.

METHOD

Participants

A total of 21 skilled archers from Peninsular Malaysia participated voluntarily in this study. The skilled archers comprised of both genders, and were aged between 13 to 25 years. However, gender and age were not treated as variables in this present study. All participants are considered skilled archers due to their qualification scores of 1150 upon 1440 full FITA score in either national or international rank competitions.

Instrumentation

Quantification of postural sway value was obtained using the Zephyr Bio-Harness device (model PSM Research version 1.5, single transmitter and receiver), with reported reliability of 0.758. The transmitter allowed transmission of live data feed. Subsequently, live data were transformed into graphs and figures in 10-second lengths per draw with 15 frames per second drawing feed. A laptop (model Toshiba Satellite L510, 3Gb ram capacity, 4.60Ghz processing capabilities) was used to compute all equations with software from Zephyr (version 2.3.0.5) that enabled comparison of multiple data and capturing real time data transmission. A digital video recorder (model Sony Handy cam DCR-SR68E) was used for video recording purposes. Every participant's shooting performance was recorded for further analyses.

Procedures

A shooting area was constructed at the respective testing sites. The shooting area prepared included two target butts and target stands that were situated 30 meters from the shooting line for official target practice and official data collection. Multiple 10-metre targets were set up for warming up prior to target practice and the official data collection period.

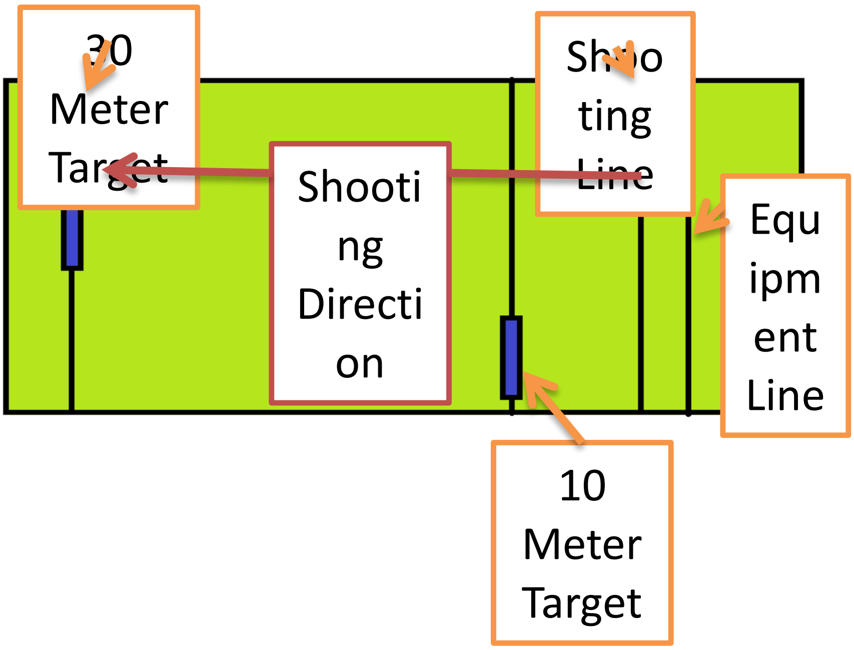

Figure 1: Shooting Area for Data Collection

Participants were briefed on the purpose of the study and the procedures involved. Letters of consent were signed a week before to waive any accidental occurrences during the test that are not related with the test protocols. The study was also approved by the UiTM research ethical committee (reference no: 600-RMI [5/16]). Prior to data collection, ample warming up time was given to the participants for short distance targets. This warming up session lasted 15 minutes. Participants were required to adhere to the shooting regulations, which limit long end shooting in a four-minute time period. Within the provided time frame, archers need to shoot a minimum of six arrows. Shooting speed usually correlates with the expertise level. Expert or skilled archers are usually able to shoot 10 to 12 arrows in the time limit provided.

After thorough familiarization with the test conditions, participants were given 12 arrows for target practice. They were required to shoot at the 30-meter target, with no score and postural sway value recorded. Twelve arrows were shot in two ends within a four-minute time period for each respective end. Participants paced their own shooting time according to their expertise level. Arrows that were shot after the time limit ended were considered as misses with zero (0) marks awarded.

Participants were then asked to complete 12 shots at the 30-meter target. Shooting cue was given by researchers. The target face used was the official FITA 80 cm 30-meter target. This target face consists of five colours and 11-point rings that reflect the score ranging from one to ten with the center ring marked as “X”. This ring brings a score of ten and is considered as highly accurate compared to the actual outer ten rings.

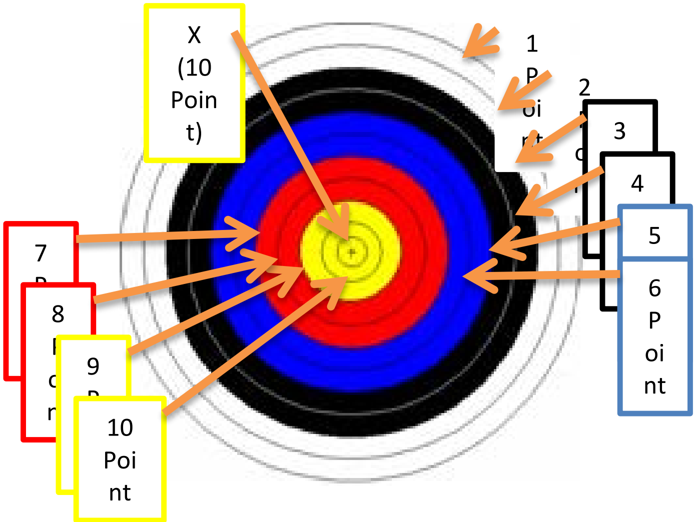

Figure 2: Target Face Diagram (Score Ring)

Since the use of equipment in archery at competitive level is personalized, participants were required to use their own bow and arrows for performance measurement purposes. Standardized prepared equipments by the researcher would inhibit participant's own shooting style and shooting performance would be affected due to the difference in ergonomics and equipment characteristics.

During testing, each participant was equipped with a Zephyr Bio-Harness device, worn on the xyphoid process under the sternum. The device belt is placed under the participant's shirt. Pilot study carried out showed that the device would not interfere with the bow string path, and would therefore not affect the shooting characteristics. All participants were allowed to shoot with their preferred position but stance techniques were limited as they were required to use the straight stance. After putting on the Bio-Harness, the participants were asked to stand still with full equipment on the shooting line for 10 seconds to obtain a standing-upright posture value. Subsequently, the participants shot an arrow each time they were given a start cue until they finished shooting all the 12 arrows. Whenever the participants were in the stance phase, they were given a "start" command and the data was collected by starting the recording of the live data transmitted by the device. The transmitting of the real-time data was stopped after the participants finished the release and follow-through phases of the six arrows or end. All of the phases took about four to ten seconds depending on the expertise and level of performance. In this study, performance was individually observed and was digitally recorded.

RESULTS

Participants' shooting performance was measured by their shooting scores from the twelve shots to the 30-meter target. The shooting scores ranged from zero to bulls eye (X, or ten points, the highest mark). Zero point was awarded if the participants missed the target face or the target, while the highest score was given to the participant that hits bulls-eye. Figure 3 depicted the score distribution between skilled and unskilled participants.

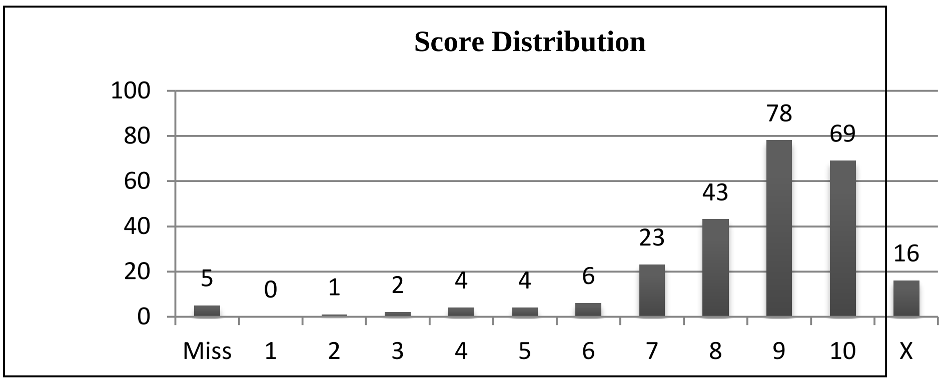

Figure 3: Score distribution of skilled archers

The mean score for the skilled group was 8.58 points. For this group, the highest score was nine points (31.0%) followed by 10 points (27.4%) and eight points (17.1%). Two percent from a total of five arrows that missed the target constitutes the lowest score for this group. The lowest percentage score obtained by the skilled participant group was four and five (1.6%). Data obtained from the study illustrates variances in postural sway characteristics throughout shooting performance. As shown in Table 1, the least sway recorded was during the setup phase and the highest was during the aiming phase. During the setup phase, the sway was positive which indicates the occurrence of swaying to the anterior while for the aiming and release phase, negative reading was recorded indicating posterior sway.

Table 1: Postural Sway Value (Mean ± SD)

Phase	Postural Sway (^{0})
Phase 1 (Setup)	**0.01 ± 7.532**
Phase 2 (Aiming)	**-1.56 ± 4.129**
Phase 3 (Release)	**-0.71 ± 4.675**

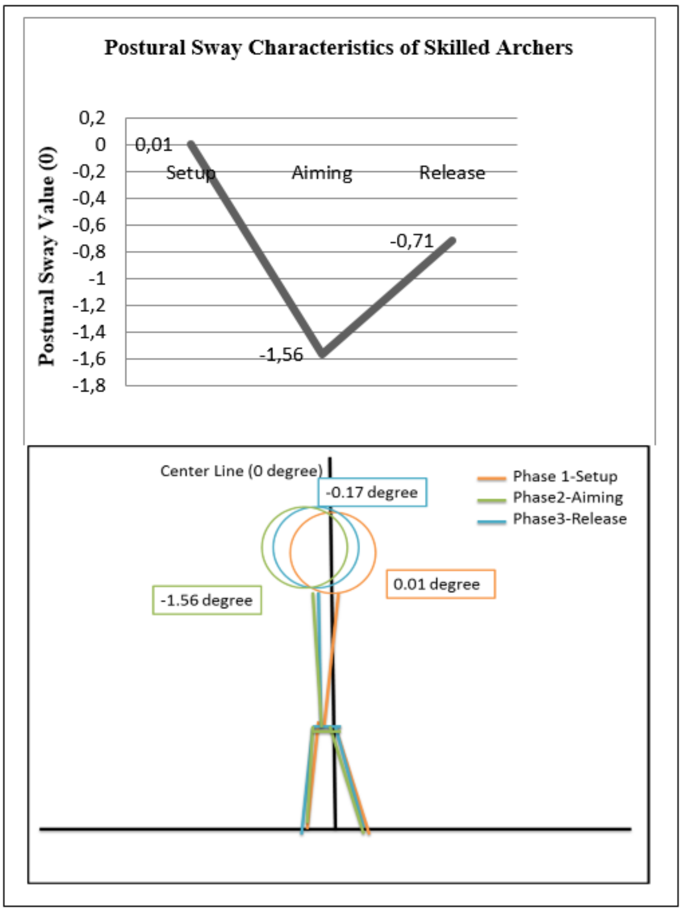

Figure 4: Diagram of Postural Sway Characteristics through Phases

Correlation analysis was applied to determine the relationship between postural sway during shooting phases and shooting performance. Results indicated that when body sway increases, shooting performance will decrease. Table 2 shows the correlations and significant value of variables which contributed to shooting score performance of Malaysian skilled archers. The highest correlations are exhibited by postural sway characteristics during the release phase with r value of 0.248 and reached a statistically significant state at (*p*<.001). The second highest relationship was documented by postural sway characteristics during the setup phase (r = -0.221) with a significant value of (*p*<.001).

Table 2: Correlations between Variables with Shooting Score

Variables	Pearson Correlation	p value
Posture 1 (Setup)	-.221*	.001
Posture 2 (Aiming)	-.021	.367
Posture 3 (Release)	.248*	.001

** Significant level (p < .05)*

zAccording to Table 3, postural sway during the release phase contributes the most towards the model with standardized coefficients value of 0.262 (p<.001) with 23.8 percent partial correlation of overall model correlation. This variable provided a unique contribution to explain the shooting performance of the skilled group compared to other variables, when the variance explained by all other variables in the model was controlled. The second highest contributor towards the model was postural sway during the setup phase with standardized coefficients of -0.174 (p = .008) with 16.7 percent partial correlation value. Regression analysis indicated a significant result for the relationship between the model with shooting performance (p<.001). These data suggest that the model contributes towards shooting performance characteristics, thus indicating that there exists a significant relationship between postural sway across shooting phases with the performance of arrow shoots of the skilled Malaysian recurve archers.

Table 3: Coefficients between Variables with Score for Skilled Group

Model	Standardized Coefficients Beta	p value
Posture 1 (Setup)	-.174*	.008
Posture 2 (Aiming)	-.072	.309
Posture 3 (Release)	.262*	.001

** Significant level (p < .05)*

Table 4 displayed the R Squared and adjusted R square value. For this model, the R square value was 0.105 which expresses a percentage of 10.5 per cent. This means that this model explains the 10.5 per cent of the variance in skilled group shooting performance. A coefficient test was conducted afterwards in order to seek the variable that contributes the most towards the relationship between the model and shooting performance.

Table 4: Model Summary for Skilled Group

Model	R Square	Adjusted R Square
Posture 1, Posture 2, Posture 3	.105	.094

DISCUSSION

The goal of this study was to determine whether postural sway affects shooting performance whilst examining the phase which directly affects shooting performance. Stuart and Atha's (1990) study which compared archers from different skilled levels and also examined those within the same level of performance revealed that the differences between skilled levels were smaller compared to differences between each respective shooting ends within each group. However, their research focused on movements of certain body parts such as the head, string arm elbow and bow handle. Prior studies also focused on the whole shooting process, while the current study examines the movements at three different phases of shooting.

The current study maintains ecological validity via measures of actual postural sway characteristics in an outdoor shooting setting, with performances totally subjected to the surrounding ambience, wind and weather conditions. Prior studies were all lab-based in an enclosed environment which did not resemble the actual environment. In addition, the present study analysed multiple phases of the shooting process. Past studies mostly focused on one phase wherein overall data was compared between groups. Here, overall performance was broken down into three phases; i.e. the setup, aiming and release phase. Such process allows determining of which action phase that impact shooting performance, rather than a general observation of the shooting performance (Balasubramaniam *et al.*, 2000; Era *et al.*, 1996; Gautier *et al.*, 2008; Keast & Elliot, 1990; Miyamoto, 1994; Mononen *et al.*, 2007; Stuart & Atha, 1990).

Vuillerme and Nougier (2004) have noted that experts from different sports do not differ in terms of postural sway during unperturbed stance and during raised difficulties. This is because experts tend to increase their ability to control postural sway autonomously. Prior studies suggested that cognitive mechanisms are dependent on levels of expertise. Expert athletes are able to perform autonomously and with less effort as compared to non-experts. As such, more effort can be channelled to process other movements (Era *et al.*, 1996; Gautier *et al.*, 2008; Vuillerme & Nougier, 2004).

The human body has an integrated system in order to maintain postural stability. The systems include visual, vestibular and somatosensory. Findings in this study logically showed that all participants demonstrated the same level of postural control. Crucially, it establishes a significant relationship between postural sway and shooting performance and proposes that postural sway during the release phase, rather than the setup and aiming phases, plays a major role in determining good shooting performance. According to practice-based automaticity theories, attentional demands are minimized when athletes are highly trained on postural tasks (Vuillerme & Nougier, 2004). Similarly, skilled archers are highly trained in order to achieve stable aiming and good shooting performance. Clearly, athletes who are highly tuned on activities are able to minimize their intentional demands on the performance itself because it has been automated by the body system. Since the overall movements of expert athletes are autonomous in nature, they are able to focus on perfecting the techniques of shooting in order to obtain stable aiming and attain consistent shooting performance (Era *et al.*, 1996; Gautier *et al.*, 2008; McKinney, 1996; Stuart & Atha, 1990; Vuillerme & Nougier, 2004; Wulf, 2008).

Data for Phase 1 and Phase 3 showed less than 1.0 degree in sway; hence denoting minute sway contributed significantly to the outcome of a shooting performance. Positive data in Phase 1 indicated that skilled archers tend to sway to the anterior side during the setup phase. During this phase, archers are in the preparation phase to draw the bow, and would have to adjust grip techniques, hooking and adjusting bow arm elbow height in order to get the best posture as possible for drawing. Negative data during Phase 2 and Phase 3 reflected the archers' sway towards the posterior aspect. Phases 2 and 3 were aiming and release phases respectively. During these phases, archers tend to compensate the force of drawing via swaying backwards in order to maintaining stability. During these phases, the muscles used are the back muscles, i.e. trapezuis, deltoids are used to pull the string instead of the biceps, triceps and the forearms muscles in order to maintain longer sustenance in the shooting (Ertan, 2009; Ertan *et al.*, 2003; Ertan *et al.*, 2004; Ertan *et al.*, 2005; Kuo & Chi, 2005; Kuo *et al.*, 2005; McKinney, 1996).

While the value of sway was small, it nevertheless impacts shooting performance. Current data revealed that during the setup and aiming phases, there was negative correlation. Such findings indicated that shooting performance decreases when postural sway increases. However, during the release phase, the correlation was linear indicating that an increase in postural sway corresponds with increase in shooting performance. In this context, with increased postural sway during release (-0.71), archers tend to sway back to the normal line. This account may be derived from the situation that during the release phase, the sway was towards the posterior side. Data trend suggested that the archers were in the process to move to the center line as evidenced from the decreasing value of postural sway from the aiming phase to the release phase. Hence, illustrating that minimizing postural sway, or by returning to the center line (or within the center) increases the consistency of the shooting performance of skilled recurve archers.

In summary, postural sway specifically at the release phase can produce inconsistency in shooting techniques thus preventing archers from obtaining a best possible score. Postural sway, in whichever respective phases, plays a role in the overall shooting outcomes, thus the need to control it. Uncontrolled sway clearly minimizes probability of winning by deteriorating aiming stability. Future studies on appropriate training programmes, or specialized apparels and apparatus for precision aiming task athletes should be conducted to minimize the effects caused by uncontrolled postural sways.

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