INFLUENCE OF MUSCLE ACTIVITY ON SHOOTING PERFORMANCE IN ARCHERY: PRELIMINARY FINDINGS

Edin Suwarganda, Ruhil Razali, Barry Wilson and Ahmad Pharmy

Centre for Biomechanics, National Sports Institute, Kuala Lumpur, Malaysia

The use of proximal muscle is advocated for consistent archery shooting due to higher tolerance for fatigue. Muscle activity was subject of investigation in several archery studies. But thus far variation in muscle activity has been ignored. This study presents the preliminary findings of the influence of proximal muscle activity and variation on score and arrow release speed in Archery. Subjects were three Malaysian National archers shooting 29-36 arrows from 70 meter distance. Surface electromyography (EMG) was recorded for triceps (bilateral), left deltoid and right trapezius muscles. Arrow release speed was recorded with a speed radar gun. Linear and curvilinear associations of muscle activation and variation with score and speed are presented. Findings show each archer has different muscle determinants influencing score and speed.

KEY WORDS: EMG, variation, score, speed, regression.

INTRODUCTION: Consistency in archery shooting depends on adopting a posture in which forces between the archer and bow are correctly aligned. Muscles play an important role maintaining the correct posture and releasing the arrow. The utilization of bigger proximal muscles is thought to promote consistency due to the higher tolerance for fatigue than the smaller distal muscles (Larven, 2007). In archery the proximal muscles may include muscles in the neck, shoulder and upper arm. Several researchers have used EMG in archery to study the timing, magnitude and fatigue of muscles in the arm and shoulder muscles (Yiming & Nan, 2006; Ertan, 2009; Lin, Hung, Yang, Chen, Chou & Lu, 2010). A few researchers have further associated EMG activity (indirectly) with the level of scoring performance (Ertan, Soylu & Korkusuz, 2005; Soylu, Ertan & Korkusuz, 2006). However what seems to have been ignored thus far is how the variability of muscle activity relates to consistent shooting and or arrow release speed.
The aim of this study is to investigate any association between proximal muscle activation and variability on shooting scores and arrow speed. The purpose is to find which proximal muscles are determinants of archery performance.

METHODS: Subjects included in this study were three Malaysian National archers (2 male, 1 female) with minimal 4 years experience in the international competition circuit, the two males having competed at Olympic level. Data was collected individually on non-consecutive days at the National training centre (outdoors) during regular training sessions. After a warm up, archers were fitted with EMG electrodes and shot 29-36 arrows at a distance of 70 meters under calm and warm (approx 28 C^{o}) weather conditions.
Twin electrodes were placed on the skin above the muscle belly and parallel to the muscle fibers of the triceps (bilateral), left deltoid and right trapezius. EMG was collected using TeleMyo 2400T G2 (Noraxon) and analysed with MyoResearch XP software. Signals were rectified and filtered using the RMS function over 100ms intervals. Standardized EMG activation and variation were calculated for the period between the anchoring of the hand at the chin and the arrow release. The standardized activation of each shot was calculated by dividing the average EMG activity of each shot by the total average EMG of all shots. Therefore a standardized activation of 1.0 means the average EMG activity during that shot has the same value as the average activity of all shots. The standardized variation was calculated as the standard deviation of EMG activity of each shot divided by the total average EMG of all shots. Additionally, a speed radar gun (Stalker Radar) was set up directly behind the archer to measure the arrow release speed. Lastly, the score was manually tracked after each shot via monocular by a former elite archer.

The R-squared associations between scores and proximal muscle activation/variation, and speed and proximal muscle activation/variation were investigated in Microsoft Office Excel. Associations were characterized as linear or curvilinear (by 2nd order polynomial trend lines). Individual multiple linear regressions were performed in SPSS version 17 over all shots with score or speed as dependent variables ($p<0.05$). For curvilinear associations additional hierarchical linear regression analyses were done which included the linearised variable X^2 e.g. L.Triceps^2 (Hopkins, 1997).

RESULTS: The overall scoring performance is tabulated in Table 1. The average score per arrow for the three archers ranged from 8.93 to 9.14. The average arrow release speed ranged from 198 to 220 km/hr. The low release speed of Archer 1 was mainly caused by the lower string tension used. Interference of concurrent shooting team members resulted in a number of speeds that were not reliably measured. Speed data was discarded for Archer 1, 2 and 3 on respectively 4, 6 and 5 occasions.

Table 2 shows the minimum and maximum range of standardized activation and variation of all muscles for each archer. With Archer 1 the right triceps show the highest range of activation (0.71-1.34) compared to the other muscles (Table 2). On the other hand the right trapezius has the highest range of variation (0.12-0.21). For Archer 2 both the right triceps and the left deltoid have higher range of activation compared to the other muscles. The right triceps show more range at the higher end (0.85-1.60) whereas the left deltoid show more range at the lower end (0.70-1.26). The right triceps also shows the highest range of variation (0.08-0.30) (Table 2). Archer 3 performed the best from all archers (Table 1). For Archer 3 the right trapezius muscle has the highest range of activation (0.79-1.22) as well as variation (0.09-0.56) compared to the other muscles. Thus both Archer 1 and 3 show the highest range of variation of muscle activity with the right trapezius.

Figures 1-6 show the scattergrams of all archers with trend line and highest R-squared value of score or speed and associated muscle activity or variation. The graphs show that the best fit trend line was either a linear or a quadratic function. Results from the individual multiple linear regressions for score and speed for each archer are tabulated in Table 3. The regression formula contains the significant variables from the SPSS output. Significance found with hierarchical linear regression for the curvilinear analysis is indicated by a * in the graph title.

Table 1. Number of arrows, average speed and score for each shot and frequency of scores.

Archer	Arrows	Speed [km/hr]	Avg Score	10's	9's	8's	7's
Arch1	29	197.9 ±1.0	8.93 ±0.96	9	12	5	3
Arch2	36	219.4 ±1.8	8.86 ±0.80	7	19	8	2
Arch3	36	220.3 ±0.9	9.14 ±0.80	12	19	3	2

Table 2. Minimum and maximum range of activation and variation of standardized EMG.

	Left Triceps		Left Deltoid		Right Triceps		Right Trapezius	
	activat.	variat.	activat.	variat.	activat.	variat.	activat.	variat.
Arch1	.85-1.15	.09-.17	.87-1.17	.11-.21	.71-1.34	.08-.18	.86-1.17	.12-.21
Arch2	.86-1.11	.09-.18	.70-1.26	.10-.21	.85-1.60	.08-.30	.88-1.11	.09-.19
Arch3	.90-1.18	.10-.19	.81-1.20	.11-.24	.79-1.19	.06-.23	.79-1.22	.09-.56

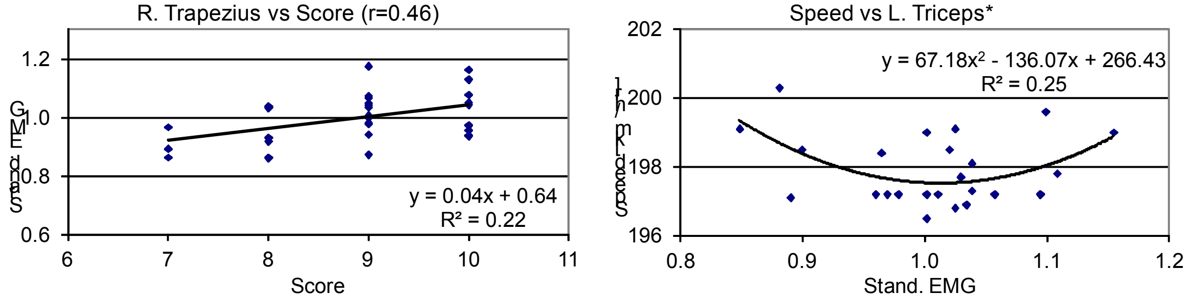

Figure 1 & 2. Linear regression line between score and right trapezius activation (left) and, significant non-linear association between speed and left triceps (right) for Archer 1.

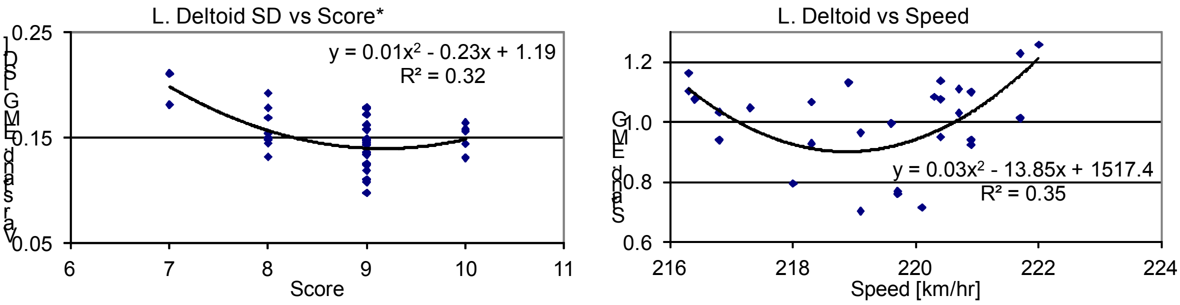

Figure 3 & 4. Significant non-linear association between score and the variation of left deltoid (left) and, non-linear association between speed and left deltoid (right) for Archer 2.

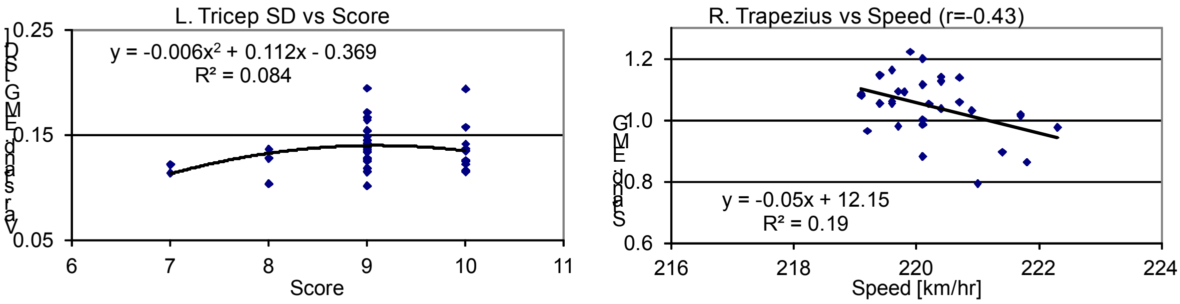

Figure 5 & 6. Curved association between score and the variation of left triceps (left) and, linear regression line between speed and right trapezius activation (right) for Archer 3.

Table 3. Linear regression formulas for score and speed.

	Score	Speed
Arch1	11.3(R.Trap) - 8.8(L.Triceps)+ 6.4	-7.8(L.Triceps)+ 205.3
Arch2	14.4(L.Triceps sd) -14.4(L.Deltoid sd)+ 9.2	11.7(R.Triceps sd)+ 217.6
Arch3	5.1(R.Triceps sd)+ 8.4	5.1(L.Triceps) - 5.1(R.Trap)+ 220.4

DISCUSSION: The purpose of this study is to find proximal muscles that are determinants of archery performance e.g. score and speed. For Archer 1 the right trapezius was moderately linearly related to score with higher EMG activity being associated with higher scores (Figure 1), accounting for 22% of the measured variance in score. Though the linear regression indicate that a combination of the right trapezius and the left triceps activation determine score (Table 3). Thus the activation of right trapezius and to lesser extent left triceps were determinants of score for Archer 1. For Archer 2 the variation of left deltoid was significantly associated with score as seen by the curved line in Figure 3. The regression analysis shows that not only the variation of left deltoid but equally so the variation of left triceps determined score (Table 3). Although not significant for Archer 3, the variation in the left triceps has a curvilinear association with score (Figure 5). Moreover the linear regression analysis (Table 3) shows that score was best associated with the variation in the right triceps not the left. Therefore the scores of the best performing archer were determined by the variation of right triceps.

With regards to speed; for Archer 1, the left triceps activation had a curvilinear association with speed (Figure 2) and was a significant predictor of speed in the regression analysis (Table 3). Thus the activity of left triceps was a determinant of speed for Archer 1. For Archer 2 the activation of left deltoid shows the highest R^2 value (0.35) with speed but this was not statistically significant (Figure 4). On the other hand, the linear regression outcome indicated that the variation of right triceps was related to arrow speed (Table 3). For Archer 3, Figure 6 displays a moderate correlation between the right trapezius activation and speed. The linear regression analyses (Table 3) showed that speed was associated with the right trapezius and left triceps activation. Thus for Archer 3 the activation of right trapezius and left triceps determined speed.

For the archers studied, the influence of muscle activity and or variability on score and speed differed with each individual. Also, the range in magnitude of the coefficients of the multiple linear analyses (Table 3) is smaller with Archer 3 (5.1) than Archer 1 (7.8-11.3) and Archer 2 (11.7-14.4). This suggests that the scores and arrow speeds by Archer 3 (the best performing archer) are less dependent on the muscle activity or variation than for the other archers.

The results of this study could be considered specific for these archers and the training condition at the time. It is not known how the influence of muscle activity may change in different stages of the training cycle periodization. Additional data collection is needed to test for reliability or as follow up test. Future studies should include more subjects and shooting at different distances could also be considered. A further limitation of this study is that due to the standardized calculations the EMG values are biased towards the activity for the average score (±9). The method of expressing activation and variation as a percentage of maximum voluntary contractions (MVC) is preferred. However this was not feasible due to practical implications and time constraints of the archery team.

CONCLUSION: There is not a single muscle that was determinant for score or speed for all archers. Rather, different proximal muscles or muscle combinations determined speed or score for different archers. Muscle activity levels determined score for the archer with lower arrow speed while variation in muscle activity determined score for the archers with higher speed. The varied muscle activity by the archers in this study shows that the archers have an individual manner of influencing score and speed.

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Acknowledgement: This study was not possible without the cooperation of the head coach, assistant coach and members of the Malaysian Archery team.