ISSN: 2618 – 5911
Türkiye Spor Bilimleri Dergisi
2024; 8(2);21-33
DOI: 10.32706/tusbid.1497255

Research Article

Factors Affecting Shooting Skill in Turkish Archery The Relation between Final Pull Distance and Logarithmic Dimensionless Jerk

Uğur ÖDEK[1]

Abstract

The acceleration-derived jerk is negatively correlated with the performance of fine motor skills. Increased jerk significantly impairs the performance of the aiming phase in archery. The aim of this study was to investigate hand and bow jerk during shooting from different final draw distances. The study was conducted with the participation of 10 (age: 32.42±4.3 years; gender: 6 males, 4 females) experienced (6.23±2.35 years) traditional archers. The participants shot short-range shots at distances corresponding to the maximum draw distance and certain percentages of the maximum draw distance (98%, 96%, 94%, and 92%). Logarithmic dimensionless jerks of the hands and bow were calculated for the aiming phase. RM-ANOVAs and multiple linear regression analyses were used to explain the effect of final pull distance on jerk and the relationship between bow jerk and hand jerk. It was found that the jerks of the hands and bow varied significantly as a function of final pull distance, with the lowest jerks occurring at 98% and 96% of the maximum draw distance. It was also found that the bow jerk could be significantly explained by the collective effect of both hands in all trials. In conclusion, it is believed that the performance of traditional archery can be improved by implementing the results of this research in the field.

Keywords: Traditional Archery, Final Pull, Jerk

Türk Okçuluğunda Atış Becerisini Etkileyen Faktörler Son Çekiş Mesafesi ile Logaritmik Boyutsuz Sarsım Arasındaki İlişki

Öz

İvmenin türevi sarsım ince motor becerilerin başarısı ile negatif ilişkilidir. Sarsımın artması okçlukta hedefleme fazının performansını önemli ölçüde olumsuz etkiler. Bu çalışmanın amacı, farklı son çekiş mesafelerinden yapılan atışlarda ellerde ve yayda oluşan sarsımı incelemektir. Çalışma 10 (yaş: 32.42±4.3 yıl; cinsiyet: 6 erkek, 4 kadın) deneyimli (6.23±2.35 yıl) geleneksel okçunun katılımı ile gerçekleştirilmiştir. Katılımcılar maksimum çekiş mesafesi ve maksimum çekiş mesafesinin belirli yüzdelerine karşılık gelen mesafelerden (%98, %96, %94 ve %92) kısa menzilli atışlar gerçekleştirmişlerdir. Nişan alma fazı için ellerde ve yayda oluşan logaritmik boyutsuz sarsımlar hesaplanmıştır. Son çekiş mesafesinin sarsım üzerindeki etkisini ve yay ile ellerin sarsımı arasındaki ilişkiyi açıklamak için RM-ANOVA'lar ve çoklu doğrusal regresyon analizleri kullanılmıştır. Eller ve yayın sarsımlarının son çekiş mesafesine bağlı olarak anlamlı ölçüde değiştiğini, sarsımın en az olduğu çekiş mesafelerinin maksimum çekiş mesafesinin %98'i ve %96'sı olduğu bulunmuştur. Bununla birlikte yayın sarsımının tüm denemelerde iki elin kolektif etkisi ile anlamlı ölçüde açıklanabildiği bulunmuştur. Sonuç olarak, sahadaki çalışmaların araştırmanın bulguları dikkate alınarak yapılmasının geleneksel okçulukta performansı arttıracağı düşünülmektedir.

Anahtar Kelimeler: Geleneksel Okçuluk, Son Çekiş, Sarsım

[1] Sorumlu Yazar: Nevşehir Hacı Bektaş Veli Üniversitesi, Spor Bilimleri Fakültesi, Nevşehir-Türkiye. https://orcid.org/0000-0003-0335-7956, ugurodek@gmail.com

Atıf/Citation: Ödek, U. (2024). Factors Affecting Shooting Skill in Turkish Archery The Relation between Final Pull Distance and Logarithmic Dimensionless Jerk. *Türkiye Spor Bilimleri Dergisi*, 8 (1), 21-33. DOI: 10.32706/tusbid.1497255

Geliş Tarihi: 06.06.2024

Kabul Tarihi:28.06.2024

INTRODUCTION

The ultimate goal in competitive archery is to achieve the highest possible score by consistently hitting the target as close to the center as possible. This requires the execution of the shooting skill, a task of significant complexity, with remarkable accuracy and precision (Ertan et al., 2005; Leroyer et al., 1993). To facilitate a deeper understanding and enable detailed evaluations, this skill is analyzed by segmenting it into distinct phases. Despite the various definitions and numbers found in the literature, there are specific sequential phases that archers consistently follow for each shot (Shinohara et al., 2023; Vendrame et al., 2022). These phases include preparation, drawing, aiming, releasing, and follow-through (Baifa et al., 2023). Throughout these phases, archers diligently apply the necessary skills to ensure the arrow's trajectory aligns with the intended target.

The aiming phase in archery is initiated when the archer's draw hand reaches the anchor point and finishes with the onset of finger movement for the release (Baifa et al., 2023; Ogasawara et al., 2021). This phase is dedicated to the critical task of finalizing the alignment of the arrow towards the target. Among all the phases, the aiming is notably the most static, predominantly characterized by isometric contractions due to its inherent nature (Kuch et al., 2020). These isometric contractions, distributed throughout the body, are primarily aimed at achieving and maintaining stability (Serrien et al., 2018; Spratford & Campbell, 2017). However, this phase also encompasses minute movements that are virtually undetectable to the naked eye. These subtle movements, performed with isotonic contractions, are effective in aligning the arrow before the string is released (Baifa et al., 2023; Simsek et al., 2018).

What distinctly sets archery apart from other shooting sports is that the movements during the aiming phase are executed under the forces produced by the tension of the bowstring and the bow (Ariffin et al., 2020; Shinohara et al., 2023). These forces introduce a challenge in managing fine motor skills. The first issue that emerges is maintaining intramuscular and intermuscular coordination in the face of this force (Scarzella, 2022). Research indicates that archers cultivate various synergies and activation strategies to attain the necessary coordination (Clarys et al., 1990; Ertan et al., 2003). While these aspects will not be highlighted here as they fall outside the scope of this research, a comprehensive review by Vendrame et al. (2022) serves as a valuable resource for detailed information on the studies and their results that address these issues. The second issue pertains to the escalating tremor that manifests towards the end of the aiming phase, despite the archers' correct the force that the muscle can generate to perform a specific motor task, resulting in an increase in jerkiness in the movement. This is due to the effort to recruit more muscle fibers to generate the required force. In this process, the alternating activation and deactivation of motor units increase the signal-induced noise, thereby negatively affecting stability (Boonstra et al., 2008; Takahashi et al., 2006). Archers are aware that tremors are likely to occur soon when the bow and bowstring are under maximum tension. To mitigate this, some archers momentarily pause the drawback of the bowstring upon reaching a certain tension, allowing time to make alignments along the vertical and horizontal axes. In modern archery, this pause typically occurs as the arrowhead nears the clicker. In traditional archery, the pause is usually made when the arrowhead is close to the grip, even though there is no specific reference point. Once all the necessary adjustments have been made, the archer pulls the bowstring back slightly further to increase the initial speed and flight distance of the arrow, before releasing it. This subsequent movement is referred to as the final draw or pull (Edelmann-Nusser et al., 2006; Moritz et al., 2006). The purpose of this pause before the final pull is to finalize the alignments on the horizontal and vertical axes prior to the onset of tremors. It's important to note that deviations are most commonly observed along these axes when fatigue increases (Squadrone et al., 1994). Ensuring an optimal distance for final tensioning is crucial. If the distance of the final pull increases, indicated by an expanding movement, the alignments made on the horizontal and vertical axes may be disrupted.

Leroyer et al., (1993) observed that the final pull varies in accordance with the archer's level of expertise, typically occurring over the last 5 seconds of the 7-second pulling motion. Additionally, during this period, the draw hand advances in the direction of the pull by approximately 5mm. In a study conducted by Edelmann-Nusser et al., (2006) with a cohort of expert archers, it was suggested that a smooth and consistent final pull motion could positively influence the score. Although the final pull is common in traditional archery, a thorough literature review revealed a lack of research on this particular subject. The studies on the final pull in archery that can be found in the literature consist of the ones mentioned above.

Accelerometers, integral to today's motion-tracking wearable technologies, are highly effective for measuring tremors and jerks (Mamorita et al., 2009; Veluvolu & Ang, 2011). They offer numerous advantages over other measurement tools such as cameras and force transducers. Not only are they cost-effective and easily accessible, but they also boast high data collection rates. Simple small-size data allows for easy storage and transfer of data via wired or wireless methods. Depending on the device's features, it's possible to collect data across three axes. When paired with other devices like gyroscopes and magnetometers, they can provide 3D position and orientation information. Their lightweight and small size allow for easy placement on the body or equipment without causing discomfort to the participant.

Considering the information provided above, the hypotheses for this study are:

1. The final pulls from different draw lengths will yield a significant difference in jerk.

2. The jerk in the bow is explained by the collective jerk in the draw and bow hands.

METHODS

Participants

This study involved the voluntary participation of 10 traditional archery athletes (age: 32.42±4.3 years; gender: 6 male and 4 female) who use the final pull technique in the competition and training bases, each with national and international competition experience and an average of 6.23 years (*sd* = 2.35) of archery training. During the measurement period, the participants maintained a training regimen of three days per week, dedicating 1.5 to 2 hours each day. Participants included in this study were individuals who had no disability, were not diagnosed with any health problem related to tremors, had not experienced any injury or surgical intervention in the past six months, were not under the influence of any medication, had maintained a minimum attendance rate of 90% during the last six months of training, and were not engaged in any other physical activity program. Participants were also requested to abstain from consuming certain food items, such as stimulants and sedatives which were presumed to hand tremors, for up to 12 hours prior to the measurements. Participants were free to leave the study at any time of their own volition. Other exclusion criteria were pain and injury during the measurement process and inability to complete the desired number of shots. Before their participation, all individuals were provided with comprehensive written and verbal information about the research study. These included details of ethical considerations and measurement methodologies. Informed consent was obtained from all participants after the briefing. The study was conducted under the ethical approval granted by the Nevşehir Hacı Bektaş Veli University Ethics Committee (Document No. 26.12.2022-2023/02)

Data Collection

Acceleration data was collected using 3-axis accelerometers integrated into activity monitors (Actigraph, GT9X Link, USA) at a sampling rate of 100 Hz. Prior to the measurements, three monitors were placed on the front upper part of the bow grip (B), and on the dorsal surfaces of the 3rd and 4th metacarpal bones of the draw hand (DH) and bow hand (BH; Figure 1). The trials were recorded with a high-speed camera (Sony, FDR-X1000V, Japan) at 100 frames per second and 1920x1080 pixels resolution. The camera was mounted on a tripod at a height of 160 cm from the ground, positioned at the DH side of the participants, and angled at 90 degrees to the arrow flight plane to capture the entire shooting. All devices were synchronized before the trials. For synchronization, all monitors were placed and fixed in a box in a way that they couldn't move on any axis. While the cameras were shooting close to the box and the ground, the box was released from a height of approximately 30 cm. The moment of impact in the recording and the peak resulting from the impact in the acceleration data were used as synchronization points.

Figure 1. Plain and wrapped monitor placements with orientations.

The maximum draw lengths (No Final Pull: NFP) of the participants were measured. This was achieved by performing three shots without the final pull, after which a mark was placed on the shaft of the arrow, aligned with the back of the grip. The distances of these marks to the bottom of the bowstring nock were then measured, with the average of the distances measured in three shots accepted as the NFP. Thereafter, on the same arrow shaft, marks were placed at distances corresponding to 98 (FP-2), 96 (FP-4), 94 (FP-6), and 92 (FP-8) percent of the NFP, respectively, in close proximity to the arrowhead (Figure 2). A circular rubber ring with a thickness and width of 1 mm was fixed on the mark representing the NFP. Another ring with the same dimensions was placed at the aforementioned distances, respectively, and used in the measurements. The two rings placed on the arrow served as a reference for the participants to make the final pull from the desired distance to the NFP. It was observed that the participants were unable to see the marked distances on the arrow in the trials without the auxiliary rings, which resulted in deviations from the determined distances and significant measurement errors affecting the calculations.

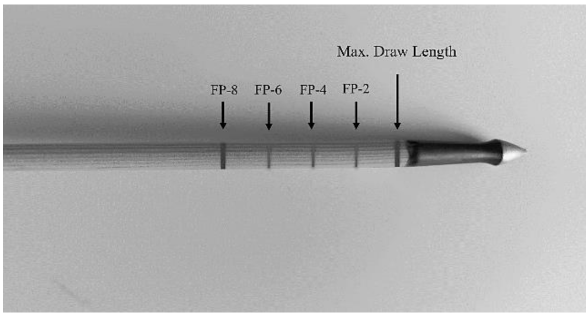

Figure 2. Final pull draw marks.

Before data collection, participants performed five warm-up shots. Participants used their archery equipment for the trials, and the draw weights of the recurve bows (Figure 3) ranged between 38 and 55 lb, with an average of 42.25±2.09 lb. Participants performed a total of 15 shots in 5 categories from a short distance (approximately 1.5 m) during the measurements. Three of these shots were performed from the NFP, and the remaining 12 shots were performed three times each from the remaining final pull distances, in order from short to long. Before the trials began, each participant was provided with the instructions given below.

Figure 3. An example of a traditional Central-Asian composite recurve bow used by participants.

The instructions given to the participants for the trials in which the final pull was not performed were as follows.

1. Complete the preparation phase (placement, knocking the arrow on the bow) according to your preference behind the line drawn in front of the target.
2. Start the drawing phase with the voice command of the researcher.
3. Reach the maximum drawing distance within three seconds.
4. Make horizontal and vertical alignments within six seconds, but not shorter than three seconds, release the bowstring and complete the shot.
5. Prepare for the next shot with the command of the researcher.

The instructions given to the participants for the trials in which the final pull was performed were as follows.

1. Complete the preparation phase (placement, knocking the arrow on the bow) according to your preference behind the line drawn in front of the target.
2. Start the drawing phase with the voice command of the researcher.
3. Reach the specified draw distance within three seconds.
4. Make horizontal and vertical alignments within three seconds.
5. Reach the maximum draw length within two seconds by using the final pull.
6. Complete the shot by releasing the bowstring after one second waiting at the maximum draw length.
7. Prepare for the next shot with the command of the researcher.

The duration(s) mentioned in the instructions were monitored by the researcher with a handheld stopwatch, and the time read on the stopwatch was verbally reported to the participants. Passive, sitting rest breaks of 1 minute were given between the shots to prevent the repetitions from causing fatigue. During the rest breaks, the last shot was reviewed on the computer display and if the shot was not performed under the desired criteria, the participant was asked to repeat the shot. This situation was encountered a total of 4 times during all trials. Although the scores that the participants gained from their performances were not taken into account in this study, it was requested that all shots be made as close as possible to the self-selected spot on the target.

Data Analysis

All video recordings and acceleration data from the trials were digitally imported into a computer environment for further scrutiny. The images were meticulously examined to ensure that the archers adhered to the necessary conditions during their shots. The Tracker video analysis software (O.S.P, Ver. 6.0.1) was utilized to establish the cut-off points for the sequences to be included in the analysis. The data obtained from the accelerometers were extracted to MS Excel (Microsoft, Ver.2307, USA) using Actilife (ActiGraph, Ver.6.1.3, USA), and then trimmed following determined cut-off points. In the trials where the final pull was not executed, the analysis incorporated data from the moment the participants reached the NFP. For the remaining trials, the analysis included data from the moment the predetermined draw distance was achieved, up until the release of the arrow. Although there were certain time limits in the instructions given to the participants, these were ignored for the analyses. The limitations were only intended to be applied in order to allow the shots to be made within particular standards. The acceleration data served as the basis for calculating the translational jerk values along the x, y, and z axes for each shot. To eliminate high-frequency noise originating from the accelerometers and low-frequency signals from the gravitational acceleration that could potentially skew the interpretation of the analysis results, the data was processed through a bandpass filter with a bandwidth of 2-15Hz. The upper cut-off frequency of the filter was determined based on research findings that suggest the normal physiological tremor, which is also responsible for the jerks in the hands, is typically observed within the 8-12Hz band (Novak & Newell, 2017). This filtering procedure was consistently applied to the data from all measurements conducted in the study. To ensure the calculated jerk values were independent of both time and movement intensity, the values underwent logarithmic transformations (LDJ). This transformation process was guided by the equation presented in the study by Melendez-Calderon et al., (2021). With this approach, the jerkiness decreases as the LDJ value approaches zero. By taking the average of the three LDJs in each trial, it was ensured that each region was represented by a single LDJ.

In the statistical analysis of the LDJ, a repeated measures analysis of variance (RM-ANOVA) was utilized to discern the differences between the trials. Concurrently, a multivariate regression analysis was employed to identify the variables that exert influence on the LDJ in the bow. This comprehensive analytical approach allows for a robust examination of the factors impacting the jerk values in trials. Before the main tests were conducted, all necessary assumptions indicated by Tabacknick et al., (2013). were rigorously tested to ensure the appropriateness of the tests. Post-hoc comparisons were adjusted with the Bonferroni correction to increase the test power in repeated measures (The corrected α using the Bonferroni correction method is 0.005). All statistical analyses were conducted using the Statistical Package for the Social Sciences (IBM, Ver.27, USA) program.

RESULTS

RM-ANOVAs

Descriptive statistics of the trials and LDJs categorized by regions and trials are depicted in Table 1 and Figure 7. Furthermore, the results of the main RM-ANOVAs are provided in Table 2. The outcomes of the post-hoc pairwise comparisons are also detailed in Table 3. In addition, two example figures representing the shots without (Figure 4) and with (Figure 5) the final pull were given below. In order to enhance the clarity of the acceleration curves, 0.1 was added to the entire x-axis acceleration values and 0.1 was subtracted from the entire z-axis acceleration values in the time series graphs. The y-axis acceleration values were not intervened. This intervention was made solely for the purpose of increasing visibility.

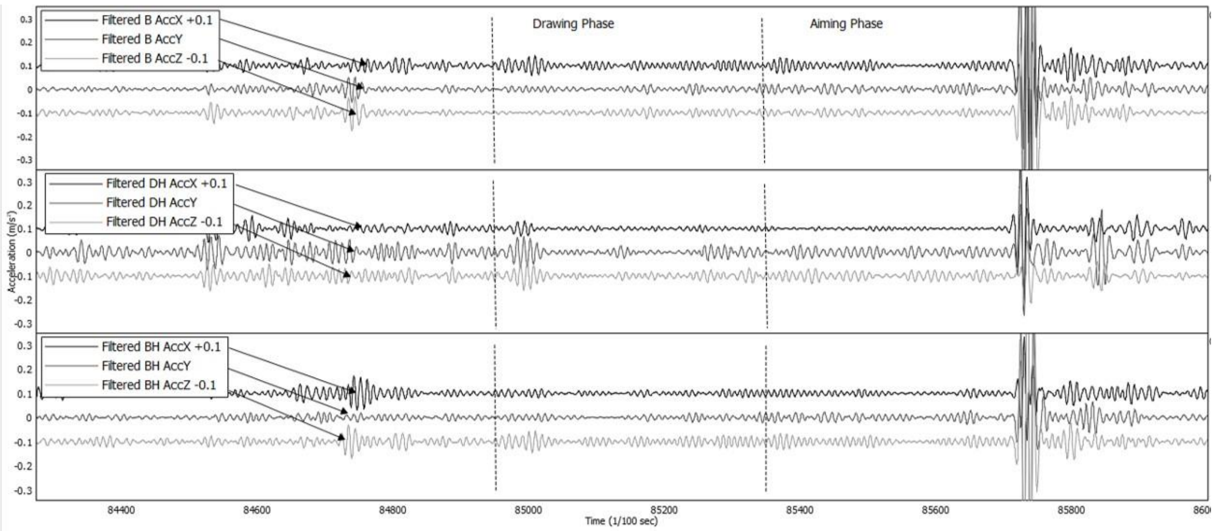

Figure 4. Filtered acceleration data of a shooting trial without a final pull.

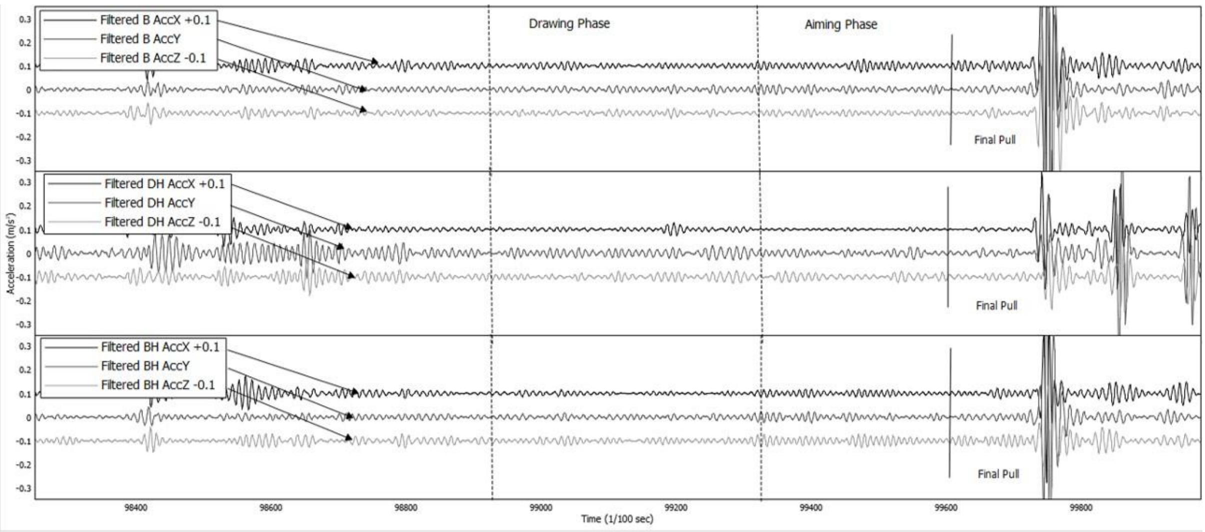

Figure 5. Raw and filtered acceleration data of a shooting trial with a final pull (FP-4).

Table 1. Descriptive statistics of the trials.

Trials	Total aiming time (s)		Time to reach specified draw length (s)		Final alignment time (s)		Final pull time (s)		Final pull distance (cm)	
	Ave.	*SD*	*Ave.*	*SD*	*Ave.*	*SD*	*Ave.*	*SD*	*Ave.*	*SD*
NFP	6.80	1.90	3.91	0.93	2.89	0.86	N/A	N/A	N/A	N/A
FP-2	7.17	2.30	2.61	0.62	2.46	0.47	2.10	0.45	1.57	0.91
FP-4	7.09	1.98	2.73	0.57	2.36	0.56	2.01	0.38	3.21	1.08
FP-6	7.36	1.87	2.42	0.71	2.43	0.65	2.51	0.63	4.70	1.07
FP-8	7.01	1.36	2.39	0.67	2.46	0.58	2.02	0.72	6.27	1.09

NFP: No Final Pull, FP-2: 98% of NFP, FP-4: 96% of NFP, FP-6: 94% of NFP, FP-8: 92% of NFP

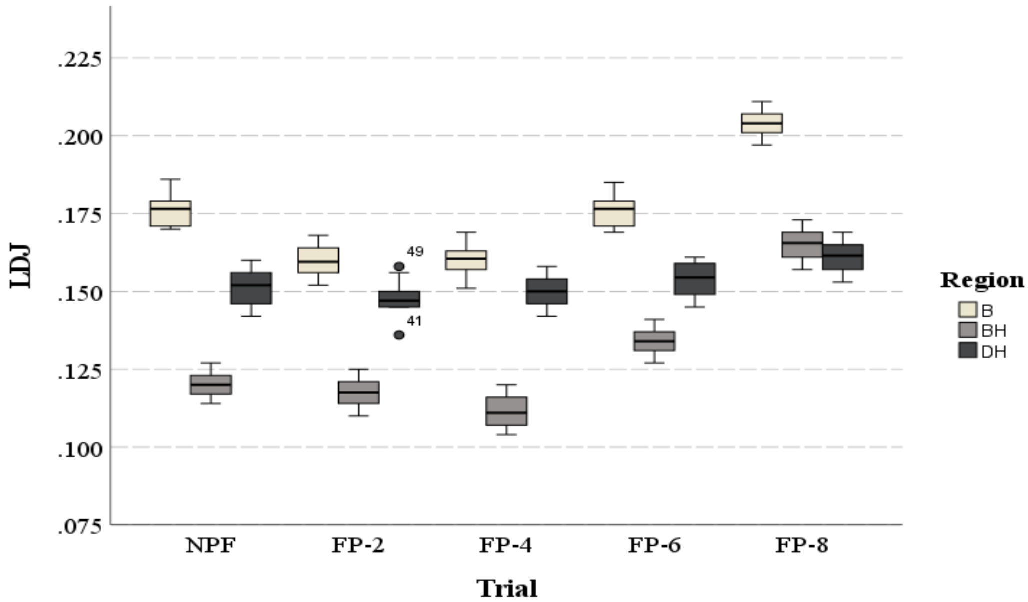

Figure 6. LDJs of archers are categorized by trials and regions.

Table 2. Results of RM-ANOVAs by regions.

Region	*n*	*df*	*F*	*p*	η_p^2	Observed Power
B			424.11	<0.001*	0.98	
BH	10	4	613.53	<0.001*	0.99	0.761
DH			110.45	<0.001*	0.92	

B: Bow, BH: Bow Hand, DH: Draw Hand, *: Statistically Significant Difference ($p < 0.05$)

Table 3. Results of pairwise post-hoc comparisons.

	B			BH			DH		
Pairs	*Diff.*	*F*	*p*	*Diff.*	*F*	*p*	*Diff.*	*F*	*p*
NFP & FP-2	0.02	154.77	<0.001*	0.00	72.43	<0.001*	0.00	12.63	0.006
NFP & FP-4	0.02	118.34	<0.001*	0.01	37.73	<0.001*	0.00	6.31	0.033
NFP & FP-6	0.01	18.24	0.003*	0.02	204.82	<0.001*	0.00	13.64	0.004*
NFP & FP-8	0.03	290.03	<0.001*	0.05	799.34	<0.001*	0.01	491.11	<0.001*
FP-2 & FP-4	0.00	0.31	0.591	0.01	12.86	0.006	0.00	5.44	0.04
FP-2 & FP-6	0.02	143.96	<0.001*	0.02	167.25	<0.001*	0.01	43.55	<0.001*
FP-2 & FP-8	0.04	3898.28	<0.001*	0.05	636.45	<0.001*	0.01	225.31	<0.001*
FP-4 & FP-6	0.02	131.64	<0.001*	0.02	902.23	<0.001*	0.00	90.00	<0.001*
FP-4 & FP-8	0.04	2153.18	<0.001*	0.05	7980.44	<0.001*	0.01	12321.00	<0.001*
FP-6 & FP-8	0.03	267.93	<0.001*	0.03	1645.54	<0.001*	0.01	268.46	<0.001*

NFP: No Final Pull, FP-2: 98% of NFP, FP-4: 96% of NFP, FP-6: 94% of NFP, FP-8: 92% of NFP
B: Bow, BH: Bow Hand, DH: Draw Hand, *: Statistically Significant Difference ($p < 0.005$)

Multiple Regression Analyses

The results demonstrated that neither the LDJ of DH nor BH, when considered individually, showed a significant impact; however, their combined effect was significantly predictive of the LDJ of B. Consistently strong collective significant effects were observed across multiple trials. In the first trial, the combined effect was highly significant ($F(2,7) = 18.86$, $p = 0.002$, $R^2 = 0.84$, $R^2\_adj = 0.80$), despite the LDJ of DH ($t = 3.141$, $p = 0.196$) and BH ($t = -2.257$, $p = 0.059$) being non-significant individually. The second trial echoed these findings with a very strong collective effect ($F(2,7) = 24.17$, $p < 0.001$, $R^2 = 0.87$, $R^2\_adj = 0.84$), and again, the LDJ of DH ($t = 1.482$, $p = 0.182$) and BH ($t = 1.399$, $p = 0.205$) were not significant on their own.

Similarly, the third trial reported a robust collective significance ($F(2,7) = 35.86$, $p < 0.001$, $R^2 = 0.91$, $R^2\_adj = 0.89$), with the LDJ of DH ($t = 0.981$, $p = 0.359$) and BH ($t = 1.525$, $p = 0.171$) remaining non-significant predictors. In the fourth trial, the strong collective effect persisted ($F(2,7) = 19.83$, $p = 0.048$, $R^2 = 0.85$, $R^2\_adj = 0.83$), yet the LDJ of DH ($t = 1.992$, $p = 0.087$) and BH ($t = -0.983$, $p = 0.358$) did not show individual significance. Finally, the fifth trial also indicated a strong collective effect ($F(2, 7) = 13.03$, $p = 0.004$, $R^2 = 0.79$, $R^2\_adj = 0.73$), with the LDJ of DH ($t = 0.482$, $p = 0.645$) and BH ($t = 0.004$, $p = 0.997$) failing to reach individual significance. These findings suggest that while the combined effect of the LDJ of DH and BH is consistently significant in predicting the LDJ of B, their individual contributions vary and are generally not significant across different trials.

Discussion and Conclusion

In this study, the LDJs of five shots without a final pull and with final pulls at different distances were investigated by taking into consideration the location of 3 different accelerometers. The RM-ANOVAs highlighted significant variations in the LDJs across all locations where monitors were placed, corresponding to shots executed at different final pull distances. The eta squared values indicate that the final pull distance significantly impacts the differences among the LDJ. Upon examination of the LDJ of BH, pairwise comparisons reveal that the LDJ of NFP significantly deviates from all others. However, the LDJ of FP-2 and FP-4 trials are lower than those of the NFP trial, while the LDJ of FP-6 and FP-8 trials exceed those of the NFP trial. The NFP trial was conducted under the highest bow-bow string tension among all trials. As a result, it was expected that the tremor-induced jerk in the muscles on this side of the hand would increase following approximately 6 seconds of isometric contractions and this trial would not have the lowest LDJ. This finding of the study is similar to the studies showing that isometric tremor increases with elapsed time (Raethjen et al., 2000; Stone, 2007). The lower LDJ of FP-2 and FP-4 trials, compared to the NFP trial, suggest that the final pull at shorter distances may reduce jerk. The final pulls from this distance closely mirror the typical final pull distances of traditional archers. These results indicate that the archers adopted an effective strategy for reducing the jerk of this hand. On the other hand, the LDJ, which increased with the final pull distance and exceeded those in the NFP trial, may indicate a threshold related to the duration and amplitude of the movement. In the FP-6 and FP-8 trials, the final pull distances were lengthened up to approximately 6cm. From another point of view, this means that the archers pulled the bowstring through the first half of the targeting phase 6cm shorter than in the NFP trials. Thus, this may be expected to reduce the LDJ significantly, because the isometric tremor caused by the high tension would be much less evident in this case. However, the results showed us the contrary. During the last draw, the archer pulls the bowstring backward with the DH and tries to keep the bow as steady as possible with the BH in order not to distort the alignment. However, keeping the BH stationary which preserves the alignment is quite difficult for archers. The tension force generated when the DH draws the bowstring backward pulls the BH to the direction of force, but the BH and arm cannot counteract this force by transferring it vertically to the body. This is due to the archer's body configuration when holding the bow and bowstring. Archers cannot hold the bow with the shoulder joint in zero-degree horizontal adduction. When the shoulder angle approaches zero, the body intervenes between the bow and the bowstring, and the shot cannot be carried out. For this reason, archers must hold the bow with the shoulder horizontal adduction angle of about 10-15 degrees (Serrien et al., 2018). When this is the case, the tension force also acts to pull the BH towards the DH side. With the effort to keep the horizontal alignment intact, the whole final pull process enters into a disturbance-correction cycle that increases the jerk. Therefore, it is believed that the effect of the prolongation of the pulling time and the increase in the amplitude of DH’s movement in the FP-6 and FP-8 trials on this cycle is higher than in the trials with a short final pull or without a final pull.

Pairwise comparisons for the LDJ of DH showed no significant difference between the LDJs of the NFP, FP-2 and FP-4 trials. However, all of these trials were found to have significantly lower LDJs than FP-6 and FP-8 trials. The difference between the LDJs of FP-6 and FP-8 trials is also significant, with the LDJ of FP-8 trial being higher than that of FP-6. These findings show that the final pull distance in the DH affects the LDJ after a threshold, and as the pull distance increases, the LDJ increases in this hand. The situation in the DH is different from the BH. While the increase in the LDJ of BH is largely due to the isometric tremor that increases with the duration, two different tremors affect the

LDJ of DH in the trials where the final pull is performed. The first one is the isometric tremor like the one observed in the BH when the hand is stabilized. The other is the kinetic tremor observed when the hand is moving during the final pull. Finally, in the period when the hand is moving, there is also an increase in LDJ due to the jerk caused by the nature of the motion. Although the static and dynamic movements of the targeting phase were not analyzed separately, it may be inferred from the data that in trials where the dynamic movements of the stretching hand increased, the LDJ of this hand also increased.

Pairwise comparisons for the LDJ of B demonstrated the same significant differences as those for the LDJ of BH. This similarity is believed to be due to the proximity of the monitor placed on the BH and the B. As depicted in Figure 6, even though the LDJs differed from each other, the pattern they followed from the 1st to the 5th trial was consistent. As it is evident from the results of multiple regression analyses, in all trials, the LDJs of BH and DH alone were not sufficient to explain the LDJ of B. On the other hand, when the variables were entered into the model together, they explained the LDJ of B to a great extent. Based on these findings, it would not be reasonable to attribute only the jerk on one hand to the LDJ changes in the bow.

Regardless of its source, jerk is an important factor that negatively affects shooting performance in archery. The main reason for this is that it occurs out of control and makes aiming difficult by distorting the alignment both vertically and horizontally. The results of the previous and the present study demonstrated that the aiming phase, although it appears to be completely static, is quite complex and influenced by even the slightest movements of the archer. Furthermore, stabilizers and dumpers that minimize the impact of the archer's errors are not employed in traditional archery. This results in a greater transfer of the archer's skill to the bow and shooting performance than in other disciplines. The results of this study indicated that reducing jerk in both the hands and the bow during the aiming phase may be achieved by performing the final pull at 96% to 98% of the archer's maximum drawing distance. By taking these final pull distances into consideration, traditional archery coaches and athletes in the field may be able to enhance performance and score accordingly.

One of the most significant limitations of this study is the relatively small sample size. Due to the difficulty of forming a homogeneous group of traditional archers with similar experience levels using the final pull technique, the number of participants had to be limited to 10 individuals. Conducting future studies with a larger number of participants will increase the statistical power of the tests and will also provide advantages for generalizing the results. A further limitation of the study is that electromyography (EMG), which is one of the most important measurement methods for analyzing muscle activities that are the source of movement jerks, was not included. Including EMG in future studies would be beneficial in explaining the results of the study. Finally, a study examining the differences in scoring caused by different final pull distances would provide a better understanding of the link between jerks and performance.

Author's Statement of Contribution to the Article

Idea/Concept: Uğur Ödek; Article design: Uğur Ödek; Consulting: Uğur Ödek; Data Collection and Processing: Uğur Ödek; Analysis/Comment: Uğur Ödek; Literature review: Uğur Ödek; Article writing: Uğur Ödek; Critical Analysis: Uğur Ödek; Source/Material: Uğur Ödek; Article Submission Corresponding Author: Uğur Ödek

Conflict of Interest

The authors have no conflict of interest to declare.

Financial support

No financial support was received for the completion of this study.

Ethics Committee Approval

This study is in line with the Declaration of Helsinki. The study was conducted under the ethical approval granted by the Nevşehir Hacı

Bektaş Veli University Ethics Committee (Document No. 26.12.2022-2023/02)

Peer Review

After the blind review process, it was found suitable for publication and accepted.

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