Int. J. Sport Psychol., 2024; 55: 334-353
doi: 10.7352/IJSP.2024.55.334

# Choking under pressure in Elite Recurve Archery

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*We examine how athletes react to competitive pressure using a special scenario in which two elite archers engage in a real-world competition. We show that pressure can substantially reduce an athlete's performance in the final arrow they shoot in each set by comparing their performance in low-stakes (first two shots) and high-stakes scenarios (final shot). Our research indicates that choking under pressure occurs when someone who is expected to perform well does not complete a task or skill in crucial circumstances where high performance is needed. We also note that female or less experienced archers are more vulnerable to pressure than their male or more experienced counterparts. Furthermore, we suggest that numerous variables, including competitors' skill level, gender, the tournament's set, the set point differential, and whether the player is competing in an Olympic sport, can influence the choking process and its effects.*

KEY WORDS: Choking Under pressure; Paradoxical performance, Psychological stress, Recurent, heterogeneity.

## 1. Introduction

The phenomenon of choking, which refers to failure under pressure in sports, can have significant negative psychological consequences for players. Choking refers to the inability of an individual or group to perform at their best, despite possessing extensive knowledge and experience, particularly in critical situations. Hill et al. (2009) define choking as a notable and abrupt deterioration in performance. Nevertheless, Baumeister (1984) and Baumeister & Showers (1986) have provided a more comprehensive definition of choking, encompassing any decline in performance that arises when individuals are under pressure.

Funding: This work was supported by the China Zhejiang Provincial Philosophy and Social Sciences Leading Talent Cultivation Project General Project under Grant [23YJRC12ZD-2YB].

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Pressure affects performance in, for example, penalty shootouts in soccer (Apesteguia & Palacios-Huerta, 2010; Dohmen, 2008), free throws in basketball (Böheim et al., 2019; Cao et al., 2011; Deutscher et al., 2013; Goldman & Rao, 2012; Toma, 2017), hockey (Depken II et al., 2012; Kolev et al., 2015), golf (Clark, 2007; Hickman & Metz, 2015; Hill et al., 2010; Wells & Skowronski, 2012), darts (Klein Teeselink et al., 2020), shooting in biathlon (Harb-Wu & Krumer, 2019; Lindner, 2017; Vickers & Williams, 2007), and tennis (Cohen-Zada et al., 2017; Paserman, 2007).

Choking can occur when athletes struggle to achieve their performance goals, especially during high-pressure situations. This is often due to heightened anxiety experienced by the athlete during these pressure situations, as noted by Mesagno and Beckmann (2017). There are various causes that can lead to choking, especially in sports where athletes are often subjected to high levels of pressure. This pressure can be attributed to several factors.

1. Efficacy expectancies: Efficacy expectancies refer to a performer's belief in his or her ability to achieve a desired outcome under pressure. These expectancies can be influenced by their prior experience and the range of possibilities for success or failure. If a performer is doubtful of their ability, the pressure to perform well may be severe. Success expectancies can harm performance. For example, players tend to shoot 5-10% below their regular shooting performance in the final seconds of tightly contested basketball games (Cao et al., 2011), and the overall performance of archers deteriorates in the tiebreak (Bucciol & Castagnetti, 2020). Similarly, an audience's expectancy of success tends to produce poor performance. An amicable setting may actually lead to subpar performance due to the pressure of not wanting to let down a supportive audience. Studies have shown that individuals are prone to choking when playing on their home field in various sports, such as penalty kicks in football (Dohmen, 2008), free throws in basketball (Goldman & Rao, 2012), shootouts in hockey (Kolev et al., 2015), and shooting in biathlon (Harb-Wu & Krumer, 2019).

2. Individual differences: Research suggests that some individuals are more prone to choke under pressure, and some athletes seem to improve under pressure. Two variables that may predict individual differences in choking are gender and level of skill. Regarding gender differences, based on the performance of tiebreaks in archery, the effect seems to be more prominent among females than males (Bucciol & Castagnetti, 2020). However, according to tennis data analysed by Paserman (2007) and Cohen-Zada et al. (2017), it has been found that men experience a similar level of performance decline as women do on crucial tennis points, indicating no significant gender difference in choking under pressure. The level of skill is another

variable that interacts with other factors in determining how much pressure is perceived in a given situation. Players with higher rankings tend to miss the final shot in biathlon (Lindner, 2017), and amateur and youth players experience a decline in performance during crucial moments in dart (Klein Teeselink et al., 2020).

3. Tournament's importance: According to Hickman and Metz (2015), as the expected prize amount increases, the probability of a successful shot decreases significantly.

4. Order of play: Initiating the first move can create a sense of pressure on the opposing party. However, the impact of the first-mover advantage is ambiguous, as studies on this psychological phenomenon have yielded mixed results. Some studies, such as those conducted by Apesteguia & Palacios-Huerta (2010) and Kolev et al. (2015), have discovered evidence that supports this notion. On the other hand, other studies, including those conducted by Cohen-Zada et al. (2018), Feri et al. (2013), and Kocher et al. (2012), have failed to identify this effect.

To accurately assess the impact of pressure, several considerations must be accounted for. First, it is essential to isolate performance metrics that are not influenced by external factors (Baumeister & Steinhilber, 1984). Second, given that the response to pressure can vary depending on expertise, it is advisable to limit the study group to elite athletes. Third, tasks performed under pressure (penalty kicks or free throws) may not reflect the entirety of an athlete's skills and may only constitute a small fraction of their typical performance, resulting in a low number of observations per subject and potentially leading to imprecise estimations (Gelman, 2018). Last, pressure situations often arise late in a game when athletes are fatigued, making it unclear whether athletes who falter under these circumstances would do so under normal conditions in soccer and basketball.

In professional recursive archery, there is minimal player-to-player interaction and a substantial number of observations per subject, making it a nearly optimal setting. Utilizing a comprehensive recursive archery dataset, we have advanced previous research in two significant aspects. First, we study the impact of pressure in a certain situation, such as comparing the performance of a player in the 3rd (final) shooting of a set with performance in a lower pressure situation (first two shooting of a set). Earlier research in this field commonly depends on simple distinctions between high-pressure and low-pressure conditions, such as the final hole or shot in a tournament. Their focus is on situations where psychological pressure is expected to play a notable role, specifically in high-stress scenarios. However, the last attempt from sequences of three shots per set is more normal. Since it is one of the

basic competition rules and archers encounter pressure situations frequently, they acquire expertise in handling such circumstances. Given the substantial degree of standardization involved in the task and the exceptional skill level of the players, we anticipate that archers will not succumb to pressure during the final shot of each set. Notably, the "alignment gauge" effect, which indicates the calibration effect from the previous two shots, contributes to the improved performance of the third shot. A phenomenon, archers choking in the last arrow, is exactly the opposite of the "calibration effect", which reveals cognitive biases and undoubtedly increases the importance of research. Second, we have suggested that individual competitive ability and gender differences play a moderating role in the choking process and its associated outcomes. We verify and explain the extent of this influence.

Recursive archery offers an ideal environment to investigate the phenomenon of choking under pressure for various reasons. First, it is an individual sport in which the opponent's actions do not directly impact the player's performance. Second, the sport of archery operates on a straightforward principle: the optimal strategy for players is to aim for the centre of the target, regardless of their risk preferences. This implies that athletes' behaviour is not influenced by strategic considerations or personal risk preferences that may impact the game's dynamics.

To investigate the occurrence of performance deterioration under pressure. We will examine the impact of pressure in specific scenarios. For instance, we will compare a player's performance in the final shooting of a set (which carries more pressure) to their performance in the first two shootings of the same set (which carry less pressure). Our goal is to determine whether the degree of choking differs based on factors such as the competitiveness of the tournament, the skill level of the athletes, and the importance of the match in the tournament. Additionally, we will explore whether these effects differ based on the gender of the athletes.

The paper is structured as follows: The Methods section outlines the key features of archery and provides details about our dataset. The Results section will present the primary findings of our study. The Discussion section will delve into the implications of our results, and in the final section, we will offer concluding remarks.

## Method

To investigate how experts perform under pressure, several conditions need to be met. First, the activity being studied must be clearly defined with outcomes that directly correspond to individual performance. Second, a precise measure of the importance or pressure

of the situation faced by the athlete must be established. Finally, a substantial amount of data must be available for both high- and low-pressure situations. Recurve archery games fulfil all of these requirements. Individual shooting attempts can be isolated in detailed arrow-by-arrow logs, and it can be assumed that the archer's objective is to hit the centre of the target.

### Database

During a recurrent archery competition, participants stand 70 metres away from a target and shoot arrows. Hitting the centre of the target results in a perfect score of 10 points, while scores ranging from 9 points to 0 points are awarded based on the arrow's distance from the centre of the target. The target is divided into 10 coloured rings, including white (1 ring and 2 ring), black (3 ring and 4 ring), blue (5 ring and 6 ring), red (7 ring and 8 ring), and gold (9 ring, 10 ring, and inner 10 ring).

The archery individual events consist of several stages. In the initial ranking-round match, each archer shoots a specified number of arrows (such as 72 in the Olympics) and is ranked based on their total score within their gender category. These rankings determine the archers' subsequent elimination match opponents, with the highest-ranked archer (ranked first) matched against the lowest-ranked archer (ranked 64th), the second-highest-ranked archer matched against the 63rd ranked archer, and so on.

We gathered data on every athlete who participated in the most renowned recurve archery competitions, including the Olympics, World Championships, and European Championships, spanning from 2012 to 2021. The World Archery Federation Database provided us with detailed arrow-by-arrow information, resulting in a dataset of 19,122 individual observations across 598 athletes. For each observation, we have information on competition (shooting sequence, order, scores, set number, interim set point differential and game type), together with the player information, such as performance of the athlete in the ranking-round match and gender.

Table I provides summary statistics on the athlete's score on one shot and player heterogeneity. The athlete's score per shot had practised for an average of 8.71 points (range 0 to 10 points). Player heterogeneity ranged from 0.648–1.543, with a mean of 1.001.

## Variables

### *Dependent Variables*

The dependent variable, Score, records the points of each arrow.

### *Independent Variables*

*Shooting sequence:* The shooting sequence is separated into three categories: "1st shot, "2nd shot," and "3rd shot" (the reference category).

### *Control Variables*

*Intermediate information*. The match details are influenced by the game state, which is determined by the current set point difference between the players. The game state is categorized as "draw," (the reference category) "two points behind," "four points behind," "two points lead," or "four points lead."

TABLE I
*Definition And Descriptive Statistics Of Dependent And Independent Variables (N=19122)*

| | Factors | Type | Classification | Mean | Median | Std | Min | Max |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | Arrow | Count | The athlete's score on one shot. | 8.71 | 9 | 1 | 0 | 10 |
| Independent variable | Sequence | Categorical | An indicator of which arrow was shot in a set (ranging from 1 to 3)<br>1st (First arrow, n=6374)<br>2nd (Second arrow, n=634)<br>3th (third arrow, n=6374) | | | | | |
| | Game state | Categorical | Level (drawn, n=8088)<br>Lead2(lead by 2 points, n=4140)<br>Lead4 (lead by 4points, n=1377)<br>Behind2(lagging by 2points, n=4140)<br>Behind4(lagging by 4 points, n=1377) | | | | | |
| | Heterogeneity | Continuous | =one archer's ranking score / opponent's ranking score | 1.001 | 1 | 0.037 | 0.648 | 1.543 |
| | Gender | Dummy | 0= Female (n=8982, 1=Male(n=10140); | | | | | |
| | Set | Categorical | Set1(first set, n=4524),<br>Set2(second set, n=4524),<br>Set3(third set, n=4524),<br>Set4(fourth set, n=3528), Set5(fifth set, n=2022); | | | | | |
| | Game Type | Dummy | 0= Olympic(n=9708),<br>1=Champion(n=9414); | | | | | |
| | Order | Dummy | 0=First(n=9561),<br>1=Second(n=9561); | | | | | |

*Heterogeneity effect*. When analysing the performance of players in international recurve archery competitions, it is important to account for their overall ability. In this sport, comparisons can be made between players by controlling for their general competence. This is done by using the scores from the qualification round to estimate the strength ratio between the two players in a match (score ratio=player's qualification round score/opponent's qualification round score).

*Tournament type*. To investigate the existence of an Olympic advantage in recurve archery, we noted whether the match was a part of the Olympic games or world championship games. We then created a dummy variable called "Game Type," which takes a value of one when the match is an Olympic game and zero otherwise.

*Order*. To enhance our analysis, we have accounted for the shooting order. In each event, the archers take turns shooting, with the higher ranked archer shooting first in the first set and the archer with lower set points shooting first in the following set. As a result, we have included a dummy variable called "Order," which takes a value of one when an archer shoots first and zero otherwise.

*Set*. The set in which the match takes place is also categorized as "1st set," "2nd set," "3rd set," "4th set," or "5th set," with the first set being the reference category.

*Gender*. Gender is a dummy variable that is equal to zero if the athlete is a woman and one if a man.

### Model specification

Since the dependent variable is a count of integers, a linear model is not the best approach for estimation, as it assumes a continuous dependent variable with both homoscedasticity and normality. Instead, we opted for a Poisson GLM that detected underdispersion(Zuur et al., 2009). To correct for this, we used a quasi-GLM with the variance given by $\phi \times \mu$, where $\mu$ is the mean and $\phi$ is the dispersion parameter estimated at 0.16. This adjustment means that all standard errors were multiplied by 0.4 (the square root of 0.16). It should be mentioned that underdispersed count data can be handled using the quasi-Poisson approach(Hostetler et al., 2012; Otterbeck et al., 2019).

For all GLM analyses conducted in this paper, pairwise comparisons of means were conducted using the multicomp package. The statistical software package R (R development core team 2018) was utilized for statistical analyses and graphing. All tests were two-tailed, and a P value of less than 0.05 was deemed statistically significant.

The entire quasi-Poisson GLM is now given by:

$$\begin{aligned}
&\text{Point}_i \sim \text{Possion}(\mu_i) \text{ and } E(Y_i)=\mu_i \text{ and } \text{var}(Y_i)=\phi \times \mu_i \\
&\log(\mu_i)==\alpha+\beta_0\text{Sequence}_i+\beta_1\text{GameState}_i+\beta_2\text{Heterogeneity}_i \\
&\qquad +\beta_3\text{GameType}_i+\beta_4\ \text{Order}_i \\
&\qquad +\beta_5\text{Set}_i+\beta_6\text{Gender}_i+\beta_7\text{GameType}_i\times\text{Gender}_i \\
&\qquad +\beta_8\text{Sequence}_i\times\text{Heterogeneity}_i \\
&\qquad +\beta_9\ \text{GameState}_i\times\text{Heterogeneity}_i+\beta_{10}\text{Gender}_i\times\text{Sequence}_i+\varepsilon_i
\end{aligned}$$

$\text{Point}_i$, with the number of points in arrow i, is Poisson distributed with mean $\mu_i$.

## Results

Table I shows the definition and descriptive statistics of the dependent and independent variables. The single arrow scores ranged from 0 to 10, and the heterogeneity value ranged from 0.648 to 1.543. Table II presents the comprehensive results for all variables, encompassing the following observations:

TABLE II
*Parameter Estimates With 95% Cis (N=19122).*

| Parameters | β(95%CI) | SE | t |
|---|---|---|---|
| Intercept | 1.643(1.548,1.738) | 0.049 | 33.812*** |
| Gender: Female# | | | |
| Gender: Male | 0.053(0.046,0.061) | 0.004 | 13.277*** |
| Sequence:3rd# | | | |
| Sequence:1st | 0.31(0.227,0.393) | 0.042 | 7.302*** |
| Sequence:2nd | 0.224(0.14,0.307) | 0.043 | 5.229*** |
| State: Level# | | | |
| State: Behind2 | -0.182(-0.295,-0.07) | 0.057 | -3.172** |
| State: Behind4 | -0.362(-0.515,-0.21) | 0.078 | -4.648*** |
| State: Lead2 | 0.04(-0.063,0.143) | 0.052 | 0.761 |
| State: Lead4 | 0.196(0.064,0.327) | 0.067 | 2.912** |
| Player heterogeneity | 0.423(0.336,0.511) | 0.045 | 9.488*** |
| Type: Champion# | | | |
| Type: Olympic | 0.035(0.03,0.041) | 0.003 | 12.235*** |
| Order | -0.005(-0.013,0.003) | 0.004 | -1.229 |
| Set: Set1# | | | |
| Set: Set2 | 0.014(0.007,0.022) | 0.004 | 3.792*** |
| Set: Set3 | 0.015(0.008,0.022) | 0.003 | 4.42*** |
| Set: Set4 | 0.014(0.007,0.021) | 0.004 | 3.798*** |
| Set: Set5 | 0.017(0.009,0.025) | 0.004 | 4.209*** |
| Male×1st | -0.011(-0.021,-0.002) | 0.005 | -2.365* |
| Male×2nd | -0.008(-0.017,0.002) | 0.005 | -1.64 |
| Male×Olympic | -0.019(-0.026,-0.011) | 0.004 | -4.745*** |
| 1st×Player heterogeneity | -0.204(-0.287,-0.122) | 0.042 | -4.854*** |
| 2nd×Player heterogeneity | -0.156(-0.24,-0.073) | 0.042 | -3.682*** |
| Behind2×Player heterogeneity | 0.172(0.061,0.284) | 0.057 | 3.037** |
| Behind4×Player heterogeneity | 0.354(0.2,0.509) | 0.079 | 4.49*** |
| Lead2×Player heterogeneity | -0.035(-0.138,0.069) | 0.053 | -0.659 |
| Lead4×Player heterogeneity | -0.188(-0.318,-0.059) | 0.066 | -2.846** |
| ϕ | 1.061 | | |
| pseudo-$R^2$ | 0.128 | | |

Notes: ***, **, and * denotes statistical significance at the 0.1%, 1%, and 5% levels, respectively. β denotes estimated coefficients. # denotes Reference categories. ϕ.

**Shooting sequence effect**

As illustrated in Table II, the t-statistic test for differences between fields showed that when all other predictors were kept constant, the expected points of the first arrow were 1.363 ($e^{0.31}$) times the third arrow scores. This outcome represents a highly significant 36% increase ($p$<0.001). Similarly, the mean points of the second arrow were 1.251 ($e^{0.224}$) times that of the third arrow, a significant 22.4% increase ($p$<0.001).

CONTROL VARIABLES

As shown in Figure 1. G, a positive correlation was found between player heterogeneity and shooting performance. As the data in Table II show, archers' competitive ability had a significant impact on their performance, and one unit extra on player heterogeneity led to a 52.7% score increase. This is by far the most important control variable in this research.

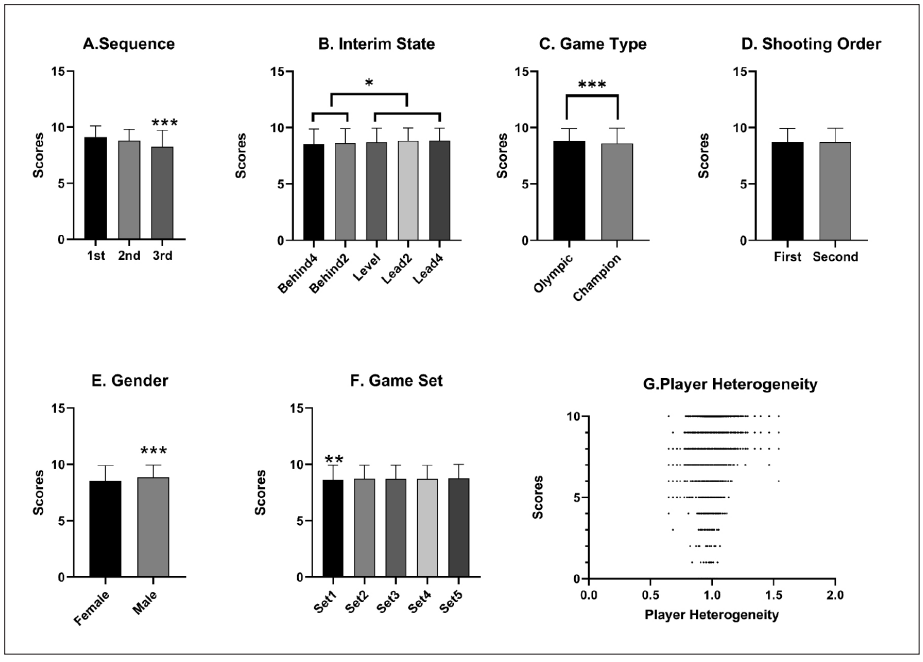


Fig. 1. - Simple Main Effects.

As shown in Figure 1. C, we found better performance in the Olympic games than in the championship games (t = 12.235, $e^{\beta}$= 1.036 [1.03–1.041], $p < 0.001$), and the average score per arrow in the Olympic games was 1.036 (e0.035) times the average score per arrow in the championship games, representing a significant increase of 3.6%.

Gender factors had a marked effect on performance (t = 2.299, $e^{\beta}$= 1.055[1.047–1.063], $p < 0.001$), and the average score per arrow of male archers was 1.055 (e0.053) times that of female archers, representing a significant increase of 5.5% (Figure 1.E).

Table II shows that, on average, archers scored significantly fewer points per arrow in the first set than in the other four sets ($p < 0.001$). This amounted to an ~1.4–1.6% difference between the first set and the other four sets (Figure 1.F).

Finally, game state was an important factor associated with shooting performance (Table II). The mean points per arrow were 16.7% lower in the group of caregivers with a two-set points-lagging level compared to drawing caregivers ($t$ = -3.172, $e^{\beta}$= 0.833 [0.745–0.933], $p$ = 0.002). The mean points per arrow in the group of caregivers with a four-set points-lagging level were 46% lower compared to the drawing caregivers ($t$ = -4.648, $e^{\beta}$= 0.696 [0.597–0.811], $p < 0.001$). The mean points per arrow in the group of caregivers with a four-set point-leading level were 21.6% higher than those in the drawing caregivers ($t$ = 2.912, $e^{\beta}$= 1.216 [1.066–1.387], $p$ =0.004). Additionally, post hoc comparisons using Tukey's HSD test indicated that archers leading by two and four set points received significantly more points per arrow than those lagging by four set points ($p$<0.001; Figure 1.B). Archers leading by four set points received significantly more points per arrow than those lagging by two set points ($p$<0.001). Archers leading by two set points received significantly more points per arrow than those lagging by two set points ($p$<0.01). In short, archers performed poorly when trailing behind.

Controlling for these variables makes our results more robust and reinforces the existence of choking.

**Sequence × Heterogeneity**

Table II and Figure 2 introduce the interaction terms between the heterogeneity effect variables and the shooting sequence variable. There are significant interactions between the shooting sequence and archer heterogeneity of the mean points per arrow. Hence, for every one-unit increase in heterogeneity, the mean points per first arrow changed by 1.245 ($e^{0.423\text{-}0.204}$) compared to 1.527 ($e^{0.423}$) in the mean points per third arrow. When heterogeneity

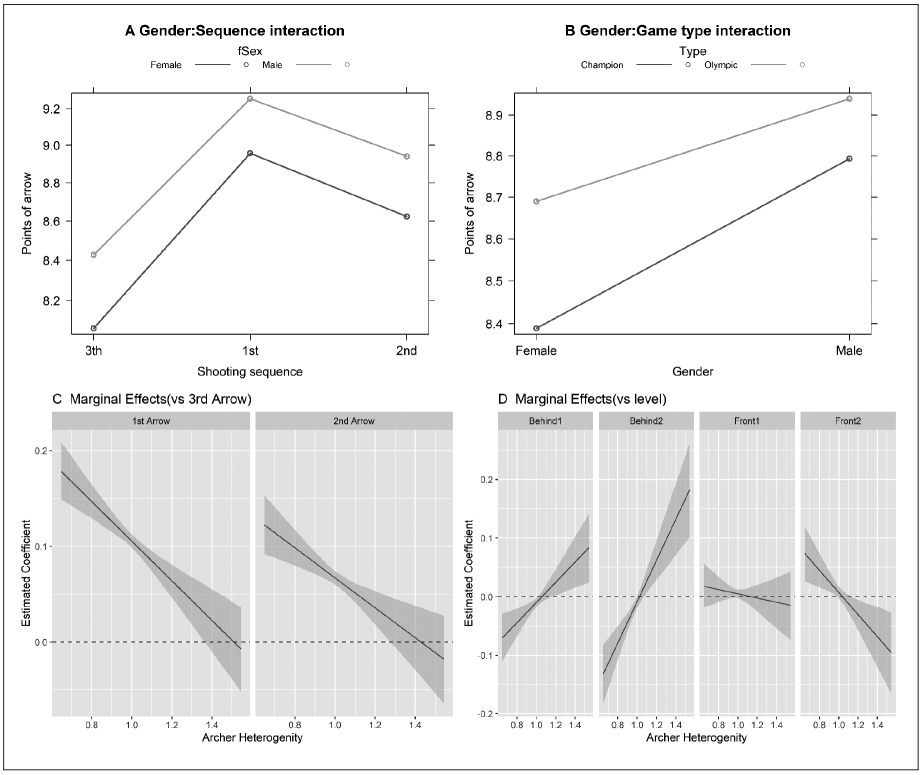


Fig. 2. - Interaction effects.

increased by one unit (indicating a better competitive ability), the growth rate of the average points of the first arrow relative to the last arrow declined from 1.527 to 1.245 ($p<0.001$, Figure 2.C). Similarly, the growth rate of the average points of the second arrow relative to the last arrow declined from 1.527 to 1.306, an increment of one heterogeneity unit ($p<0.001$, Figure 2.C).

## Sequence × Gender

As Table II shows, there is a significant interaction between gender and shooting sequence ($t$ = -2.365, $e^{\beta}$= 0.989 [0.979–0.998], $p$ = 0.018). Female archers experienced a greater performance decline (3.6%) from the first arrow to the third arrow than male archers (3.4%). It seems that female archers perform more erratically than their male counterparts (Figure 2. A).

### Game state × Heterogeneity

There are significant interactions between the game state and player heterogeneity of the mean points per arrow (see Table II). Hence, for every one-unit increase in player heterogeneity, the mean points per arrow changed by 2.176 ($e^{0.423+0.354}$) for the player lagging by four set points compared to only 1.527 ($e^{0.423}$) for the drawing player. When heterogeneity increased by one unit, the increase in the average points per arrow for the player lagging by four set points was 1.43 times that for the drawing player ($p<0.001$; Figure 2.D). In the same way, the growth rate of the average per arrow score for the player lagging by two set points relative to the drawing player increased from 1.527 to 1.814 ($p<0.01$; Figure 2.D).

On the other hand, when heterogeneity increased by one unit, the mean points per arrow changed by 1.265 ($e^{0.423-0.188}$) for the player leading by four set points compared to 1.527 ($e^{0.423}$) for the drawing player ($p<0.01$; Figure 2.D).

As shown (Figure 2. D), the relationship between shooting performance and athlete strength changes direction based on the game state. For trailing, there is a positive relationship between shooting performance and athlete strength, while for leading, there is a negative relationship.

### Gender × Tournament Type

There was a significant interaction between gender and game type ($t$ = -4.745, $e^{\beta}$= 0.982 [0.974–0.989], $p < 0.001$, see Table II). Tukey HSD comparisons revealed that in the Olympic Games, male archers had 3.6% more points than female archers. In championship games, male archers had 5.5% more points than female archers. The performance difference between male and female archers in the Olympic Games is significantly lower than that in the World Championships (Figure 2.B).

## Discussion

The aim of this study is to explore the choking phenomenon in professional archers and generate fresh evidence by analysing the impact of pressure from varying shooting sequences on their shooting performance.

To assess the pressure-related disadvantage in performance, we use a panel dataset containing arrow-by-arrow information from the Olympic Games and World Championships between 2012 and 2021. Our data re-

cords the shooting sequence, points, order, and interim set point differences of archers for every arrow, combined with tournament and athlete information, enabling us to generate a distinctive dataset for estimating how shooting performance varies depending on the shooting sequence in a set.

The key finding of this study is the occurrence of significant deterioration in shooting scores despite striving and incentives for superior performance in the last arrow of every set, which means professional recurve archers are impacted by (high) pressure situations. The contextual variables, such as the quality of opposition and gender of the performer, whether the archer participated in the Olympics, match status, and the information of the attempt, were considered before labelling the magnitude of performance decrease as choking.

Our research methodology contributes to the robustness of the conclusions. The improvement of the player's competitive ability helps to reduce the negative impact of the choking effect on the performance of the last arrow, but the average choking effect over all archers is statistically significant. Consequently, the choke observed in the final shot of each set cannot be attributed to a random fluctuation in skill level but rather to a distinct adverse reaction to psychological stress.(Beilock & Gray, 2007).

Additionally, in comparison to their male counterparts, female archers tend to have lower performance levels during the high-stakes final shot in a set, despite their performance being relatively better during the low-stakes first shot.

To summarize, there is evidence suggesting that professional recurve archers are prone to choking under pressure, which can lead to a decline in their performance as pressure increases. Archers performed far worse in the last arrow than what he (she) is capable in the previous two shots, low pressure circumstances, and should be indicated as a choking experience rather than normal performance fluctuations or random variation.

A previous study by Bucciol and Castagnetti (2020) showed a comparable result, which indicated a lower performance during tiebreaks as opposed to the performance in preceding sets. Furthermore, our study contributes to this literature by demonstrating a correlation between different arrow shots in a set, which can serve as an index of stress in elite athletes, and their performance in high-stakes competitions. These findings are consistent with previous research indicating that athletes often experience a significant decrease in performance in competitive and stressful situations (Mesagno & Beckmann, 2017), particularly in high-stakes conditions where individuals are randomly assigned to different levels of psychological stress (Apesteguia & Palacios-Huerta, 2010; Ariely et al., 2009; Dohmen, 2008; Gneezy et al., 2011).

However, this finding is contrary to previous studies that have suggested that professional darts players do not chock under high pressure(Klein Teeselink et al., 2020; Ötting et al., 2020). Although both archery and darts belong to the skill tasks that win with precision, the difference is that the former is a simple target and the latter is multiple targets. Archers' only target is bullseye (10 points), but a dart player's target changes as the game progresses. The above facts lead us to speculate that choking may arise for different competition characteristics.

The reason for the decrease in performance in the final shot per set could be due to physical fatigue experienced by athletes. As arrows in a set are shot in sequence, the third arrow shot may result in even higher levels of fatigue. To determine the impact of pressure on performance in a skill-based setting, it is crucial to distinguish between effort and skill tasks and investigate whether incentives that typically impact effort also influence performance.

Contest theory suggests that if shooting arrows was considered a task that requires effort, heterogeneity in ability between contestants would lower performance. This is because the outcome of the contest becomes more predictable in advance, and both contestants save on effort costs. This argument is supported by several studies, including Bach et al. (2009), Backes-Gellner & Pull (2013), Brown (2011), and Sunde (2009). Additionally, intermediate scores indicating an asymmetric contest would diminish the motivation to exert effort, resulting in decreased performance. However, our findings reveal the opposite. Specifically, we found that heterogeneity in ability between contestants increases performance and that archers tend to have lower scores when lagging and slightly higher scores when leading. Physical fatigue cannot account for the observed decrease in performance in the first set compared to the other four sets. Our results indicate that archers who are leading during close contests tend to exhibit lower performance towards the end, which supports the idea that shooting arrows requires effort. However, the significant decline in performance during the third shot of a set cannot be solely attributed to fatigue.

The current study's results do not support the "gauging effect" or "calibration effect" (Yaari & Eisenmann, 2011), which suggests that the archer uses short-term muscle memory to refine the arrow's direction after two previous trials. Based on the above facts, we attribute the choking phenomenon to psychological factors.

The occurrence of choking in our setting has been explained by the psychological literature for at least four reasons. The first reason is the fear of failure, which is a significant source of pressure for athletes. Athletes worry about the outcome and the potential embarrassment or letting down their

teammates in case of a set-ending mistake. This fear of failure can cause choking, as observed in the current study on archers.

The second reason is the level of motivation, which can be so high that it becomes detrimental to performance. Drive theories hold that a key determinant of performance is the performer's level of arousal. In applying these theories to performance under pressure, we interpret increased subjective motivation to do well as an increased level of arousal or 'drive'. One version of drive theory postulates an inverted-U relation between drive and performance, which means that performance is worst at lower and higher levels of drive. The inverted-U theory is a plausible explanation for poor performance in the first set and choking in the last arrow per set. According to Yerkes and Dodson's (1908) research, it has been suggested that there is an ideal level of arousal needed to perform a specific task, and exceeding this level by offering more incentives may result in decreased performance. For example, extreme motivation to win or achieve a perfect finish could cause athletes to choke.

Third, under heightened pressure, mental processes unconsciously shift from automatic to controlled, which is the third reason. Although automatic processes are typically more efficient for highly rehearsed tasks such as recursive archery, increased pressure can cause individuals to switch to controlled processes, which may result in poorer performance (Baumeister & Tice, 1985).

Last, research has shown that under stress, the brain's capacity to process information decreases, resulting in slower processing. Athletes' focus of attention is often on their performance worries rather than skill execution (Oudejans et al., 2011), which can lead to insufficient attention to the task at hand and consequently choking.

Furthermore, two factors that are believed to moderate performance failure have been identified, including skill level and gender effect.

Regarding the skill level, the improvement of the player's competitive ability helps to reduce the negative impact of the choking effect on the performance of the last arrow. Very highly skilled individuals are more likely to choke in the last arrow per set when facing a stronger opponent than when facing a weaker opponent.

Due to the gender-segregated nature of archery competitions in the Olympics and World Championships, examining a potential gender gap in performance directly is a challenging task. However, our observation of real-time psychological stress suggests that it has a similar detrimental effect on both male and female archers' performance. Nonetheless, studies have shown that women tend to perform worse than men in more competitive

settings (Azmat et al., 2016; Cai et al., 2019; Ors et al., 2013), which is in line with our findings. Some studies have also found evidence to the contrary, showing little difference in performance between men and women in competitive settings (Lavy, 2012; Paserman, 2007).

Moreover, our findings suggest that although both men and women exhibit a decline in performance during the critical stages of each set, women's drop is more significant than men's. These results are consistent across different specifications and estimation methods. Women's lower tolerance for pressure and weaker incentives to perform well in high-stakes situations may explain these findings (Cai et al., 2019).

Furthermore, the type of tournament played is also a significant factor affecting performance. Scores per arrow are significantly reduced when athletes are shooting in a world championship tournament compared to an Olympics game, which is a more prestigious tournament. Overall, these findings highlight the complex interplay of gender, psychological stress, and tournament type in determining archery performance.

### Limitations

These findings may be somewhat limited by the lack of physiological and biochemical data to reflect psychological stress. For example, Lu and Zhong (2023) present the initial concrete proof backing the adverse impact of stress, as quantified by a real-time biomarker (heart rate), in a fiercely competitive and high-pressure setting. According to the study, there is no notable decline in performance of the final shot per set when the heart rate is controlled. However, using their data (2022 Tokyo Olympics games), we observe no significant difference among the three shots without considering the heart rate factor. This may be partly due to different sample sizes but also highlights the importance of large sample sizes in research.

## Conclusion

Our study delves into the choking phenomenon, exploring the impact of pressure from various shooting sequences on the shooting performance of professional archers. By analysing arrow-by-arrow data from the Olympic Games and World Championships spanning from 2012 to 2021, we examine how shooting performance differs depending on the order of shots within a set.

The study's most apparent result is that archers performed far worse in the last shot than what they were capable of in the previous two shots. More-

over, we show that women appear to be more affected by competitive and high-stakes in the last shot than their male counterparts, and the improvement of the player's competitive ability helps to reduce the negative impact of the choking effect on the performance of the last arrow.

Our discovery supports the idea that psychological stress can have negative effects on elite athletes. Managing performance while experiencing psychological stress holds significant policy implications.

## Acknowledgements

This research was supported by the Institute for the Olympics and Good Governance of Global Sports at Wenzhou University.

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*Manuscript submitted August 2023. Accepted for publication January 2024.*