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Choking under pressure in archery

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ABSTRACT

In high pressure situations, individuals may perform well below expectations. This is called "choking under pressure" and we study it in the context of a competitive sports environment. We construct a unique dataset on archery to study whether performance deteriorates at the end of a match, when two players compete in a tiebreak. Our results suggest that pressure plays a key role: overall performance deteriorates in the tiebreak. This effect is even more pronounced in the tiebreak of the most important tournaments, but only for women.

1. Introduction

Performance pressure can arise when individuals take actions whose outcome is important or perceived to be important, for themselves or for others. For example, financial traders may have to make time-constrained decisions when markets are volatile; physicians may need to perform emergency surgeries to patients who have been affected by mass-casualty incidents; or, job candidates may rely on a single interview to determine their employability. In these situations, pressure can be detrimental to performance, and individuals may eventually perform more poorly than usual. This phenomenon has been labeled "choking under pressure" and in general it can apply to many situations, from failing a key exam to blowing an important presentation, or looking foolish during the first date. It is therefore of crucial relevance to understand whether individuals' performance declines in situations where pressure is the highest.

Choking under pressure is common in highly-competitive sports environment too. In fact, professional athletes frequently face high pressure episodes in their working environment. Choking in these instances may mean losing a point, a match, or even a tournament. There are many anecdotal examples of choking under pressure. For instance: the NovotnÃ!‘-Graf 1993 Wimbledon final, where NovotnÃ!‘ first went down a set, then took control winning 10 of 12 games and being up 4-1 (40-15) on serve, but eventually losing the match; or the 1994 FIFA World Cup final between Brazil and Italy, where the Italian soccer player Roberto Baggio, arguably the stand-out player of the competition, blazed his penalty, the fifth and final one, over the bar.

It does not come as a surprise, then, that the academic literature usually focuses on sports data to study choking under pressure (see, for instance, Apesteguia & Palacios-Huerta, 2010; Cohen-Zada, Krumer, Rosenboim, & Shapir, 2017a; Hickman & Metz, 2015). Sports are relevant for the study of choking not only because there are many game play situations in which pressure is extremely high, but also because they allow the researcher to analyze a clean environment. In sports there are plenty of data, the rules of the game are clear, the basket of available actions is well-defined, and moments in which the athletes face high pressure can be identified. From these analyses it is then possible to gain insights that can be used to understand behavior in real-life non-sport environments facing high performance pressure.

We undertake an empirical investigation of choking under pressure at key instances of game play using sports data. In contrast to previous studies, however, we are the first to look at archery. We believe archery is an ideal setting to study choking under pressure for several reasons. First, it is an individual sport where performance is not directly affected by the opponent's actions. In contrast, in sports where the payoffs are jointly determined by simultaneous interactions (such as in football or tennis), it is unclear whether the outcome is due to one athlete performing below expectation or because of the opponent's improved performance. Second, archery follows a simple rule: players' dominant strategy is to aim for the center of the target. This holds irrespective of players' risk preferences. In other words, athletes' actions are not driven by strategic considerations or individual risk preferences that may affect how the game is played. Finally, in archery the situations in which pressure is highest are easy to identify. This allows us to perform a tight test for choking under pressure and, in doing so, we can also enrich our analyses to study relevant factors that may promote it.

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Our first goal is to analyze choking under pressure in archery. Specifically, we want to establish whether performance deteriorates in the tiebreak (shoot-off) — the final arrow athletes shoot whenever the match ends in a tie. Subsequently, and more importantly, we aim to study if the extent of choking varies across key features of the tiebreak: the competitiveness of the tournament in which the tiebreak takes place, and the match's importance in the tournament. In particular, we hypothesize that choking is greatest in the most competitive tournaments and whenever the tiebreak takes place in the last stages of a tournament (i.e., in the final, semi-final, or quarter-final). Finally, we want to study whether these effects vary by the athletes' gender. Archery is an ideal setting to analyze performance deterioration by gender due to pressure. This is because in archery the same action is performed regardless of the gender of the athlete and, most importantly, it is an individual sport where one's own performance is not affected by the opponent's actions.

In order to answer our three research questions, we construct a unique panel dataset, at the athlete level, on archery matches over seven years (2013–2019). Our results indicate that players' performance indeed deteriorates in the tiebreak. Moreover, we find that choking under pressure is highest in the most competitive tournaments: tiebreak scores are significantly reduced whenever the athlete is shooting a tiebreak arrow in more competitive tournaments compared to the case where he or she is shooting that same arrow in less prestigious tournaments. In contrast, we do not find evidence of choking in the final stages of the tournament. Interestingly, when we look at heterogeneous effects of choking by gender, we find that the effect of higher levels of choking in the most prestigious tournaments is driven by women athletes only.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature; Section 3 presents the key features of archery and describes the dataset; Section 4 describes our econometric specifications and shows the main results. Section 5 discusses the results and concludes. The Appendix reports further analyses.

2. Literature review

The impact of pressure on performance has received considerable attention in the psychological literature. As early as the beginning of the 20th century, Yerkes and Dodson (1908) advanced what is now called the YerkesâDodson law, according to which performance increases with (mental) arousal, but only up to a point. Beyond this threshold, performance declines. More recently, Baumeister (1984) defined the performance decrements under circumstances that increase the importance of good or improved performance as "choking under pressure". Since then, several empirical papers used both laboratory experiments and observational data to assess the extent of choking.

Choking under pressure may arise for different reasons. In sports, in particular, the levels of pressure athletes face may increase due to several factors. For example, the order of play: moving first can put pressure on the opponent. The evidence on the first-mover advantage is mixed. While some studies have found evidence consistent with this psychological effect (Apesteguia & Palacios-Huerta, 2010; Kolev, Pina, & Todeschini, 2015), others have failed to find it (Kocher, Lenz, & Sutter, 2012; Feri, Innocenti, & Pin, 2013; Cohen-Zada, Krumer, & Shapir, 2018).

Several papers analyze performance deterioration linked to higher pressure due to the stage of the game. For instance, Cao, Price, and Stone (2011) find that basketball players shoot 5–10% worse than normal in the final seconds of very close games and players of lower ability are affected more by pressure. Hickman and Metz (2015) go further by establishing a link between performance and monetary rewards in the PGA (Professional Golfersâ Association) TOUR. Specifically, they study performance in the final hole of the tournament's final round, and quantify the pressure generated in this instance by linking it to the monetary prizes of the tournament. Their results show that as the amount of the expected prize increases, the likelihood that the shot is successful is significantly reduced. Similar to these studies, we also find reduced performance at key moments of game play. We further complement these studies by looking at choking that depends on key features of the tiebreak (stage and competitiveness of the tournament in which it takes place).

The effect on performance of higher pressure due to decisive moments in precision sports is also studied in two recent papers: Lindner (2017) and Teeselink, van Loon, van den Assem, and van Dolder (2020). The former paper defines choking under pressure as missing the final shot in biathlon and presents two main findings. First, being higher up in the ranking before the last shooting leads to a higher probability of missing the last shot. Second, the longer the athlete takes to shoot, the higher the probability of missing the final shot. We depart from this work in three main directions: i) we focus on archery that, as opposed to biathlon, minimizes the role of alternative explanations of performance deterioration (e.g., being tired); ii) we account for the prestige of the competition, as it may be consequential for pressure levels and performance; iii) we control for time-invariant characteristics by means of athlete fixed effects. Moreover, another important difference is that in our environment the time an athlete takes to make a shot does not matter for the final outcome in the game â unless he or she exceeds the time limit. Teeselink et al. (2020) examine how the importance of a single dart-throw for the probability of winning the match affects performance. Results show that performance of amateur and youth players deteriorates at decisive match moments, while it is much less pronounced or even nonexistent for professional players. We depart from this work in three key dimensions: i) we consider a different type of event that arguably causes a higher level of psychological pressure (i.e., the tiebreak); ii) we consider within-individual variation across tournaments; iii) we consider a different sport, archery, where — as opposed to darts — risk preferences do not affect play and thus performance in the tiebreak. With a dartboard the strategy that maximizes the number of points achieved is associated with a higher variance.

A friendly environment can also lead to performing worse than average because of the pressure associated with disappointing a supportive audience. Indeed, evidence that playing at home induces individuals to choke exists for different sports: noticeably, penalty kicks in football (Dohmen, 2008), free throws in basketball (Goldman & Rao, 2012), and shooting in biathlon (Harb-Wu & Krumer, 2019).[1] However, other papers have either found no evidence of choking or even a positive advantage at home. In fact, Cao et al. (2011) do not find evidence of performance under pressure in basketball being affected by home status, while Krumer (2017) finds that in judo home advantage increases the probability of winning a single fight. We too find that playing at home improves performance, although only for women athletes. The possible reasons for these contradicting results deserve further investigation as differences in the structures of these sports or in the level of sport attendance are not fully convincing in explaining the differential results.

Our paper also contributes to the literature that studies gender differences in choking under pressure. Toma (2017) finds that men and women do not differ significantly in their propensity to choke. Using tennis data, both Paserman (2010) and Cohen-Zada et al. (2017a) find that men's performance deteriorates as least as much as women's on more important tennis points. These findings are thus in line with our results on poorer performance in the tiebreak compared to performance in previous sets. Most interestingly, our results also show that there are gender differences in choking that are not only due to performance deterioration in crucial stages of the game. This highlights the need for more work that studies if and how choking varies by gender.

[1] Additionally, Butler and Baumeister (1998) find similar results in an experiment.

3. Archery

3.1. The sport

Modern competitive archery is managed by the World Archery Federation (WA). There are different disciplines depending on the characteristics of the shoot (e.g., standing, running, skying, etc.). Among these the most popular is target archery, in which athletes shoot at stationary circular targets at varying distances. The standard WA target is divided into 10 evenly spaced-concentric rings, which have score values from 1 through 10 assigned to them. In addition, there is an inner 10 ring, called the X ring.[2] The most common types of bow are Recurve and Compound. Athletes are grouped in classes according to their gender and their division (e.g., junior, adult, senior). The combination of a class and bow used is defined as a “Category”. Athletes compete against each other within their category.

Most tournaments are divided in two stages. In the first stage, called the “Qualifying Round”, athletes usually shoot 72 arrows. This round is shot to seed competitors. These seedings are then sorted into head-to-head matches in the second stage, called the “Elimination Rounds” stage. The first seeded is matched with the last seeded, the second seeded with the second to last one, and so on. In each match, the loser leaves the competition, while the winner advances to the next phase. The process continues until only two athletes remain to contest the final. The athletes that lost in the semi-final play off for third place.

Matches are divided into five sets. In each set, competitors shoot 3 arrows, alternating shooting. They have 20 seconds to shoot each arrow. In Recurve, the competitor with the highest score out of the three arrows, wins the set and is assigned 2 points. If their scores are tied, each competitor gets 1 point. The first competitor to reach 6 points wins the match. In Compound all (15) arrows are summed up and the competitor with the highest sum wins the match. If after the five sets competitors are tied, there is a tiebreak (shoot-off). In this stage, each competitor shoots one arrow. The competitor with the highest score wins the match.

3.2. Data

We collected our data from the World Archery Federation website (https://worldarchery.org/). We downloaded all available data from archery competitions that took place in the period 2013–2019.[3] The dataset includes 120 competitions and comprises both the main tournaments (i.e., the 2016 Olympics, world championships and world cup competitions) as well as less prestigious continental and national competitions. For each competition we focus on individual matches. Our dataset is at the athlete-match level. In particular, we have a panel dataset of the athletes' matches within the same competition and across competitions.

For each match, we have data on each player's score at the arrow or set level. If the match was tied after the 5 sets, we also have the tiebreak score. Moreover, we know the tournament where the match was, its date and location. We also have a variable identifying the type of tournament (i.e., world championship, world cup or other (inter)national events). For each athlete, we know his/her name, age and country.[4] Moreover, we have his/her seeding (rank) that determined his/her positioning at the start of the Elimination Rounds stage. Within our dataset, we construct two variables capturing an athlete's level of experience. First, we define a variable that takes into account the number of matches played. Second, we create a variable that incorporates the athlete's experience in the tiebreak stage (i.e., the number of matches that the athlete resolved in the tiebreak). Both variables are running, in the sense that they consider as a reference the period starting at the beginning of our dataset and concluding the day before the observed match.

Our final dataset is obtained after imposing several restrictions. First, we focus on the sole adult divisions, this way excluding all other divisions (junior, senior and para-archery) from our dataset (around 8900 matches). Second, we study performance in the competitions that use either Recurve or Compound bows. Thus, our dataset includes the following categories: Recurve Men, Recurve Women, Compound Men, and Compound Women (around 19,000 matches). Third, and unless stated otherwise, we only include data from matches that ended with a tiebreak (2,210 matches, corresponding to 4420 individual tiebreak observations). Finally, to exploit the panel dimension of our data, we keep track of athletes for which we have observations on at least two matches. Our final dataset consists of 3645 individual tiebreak observations. Fourth, we drop 38 observations for which data are missing (e.g., demographic variables).[5,6]

3.3. Summary statistics

Table 1 reports summary statistics on our dataset. *Tiebreak Score* and *Average Set Score* are two variables indicating the athlete's mean score (slightly more than 9 out of 10 on average) in the tiebreak and in a given set, respectively. Fig. 1 displays the distribution in the dataset of the tiebreak score (panel a) and the average set score (panel b). Both distributions are clearly skewed and mostly concentrated around the highest values. There are few cases, however, in which the score is exceptionally low. This happens especially on the tiebreak score; this evidence may explain the moderately lower performance observed in the tiebreak.

Higher Ranking is a dummy variable equal to one if the athlete starts the match with a lower seeding than the competitor, i.e., he/she is higher in the ranking. *Rank Difference* is the difference in seedings between the athlete and his or her competitor in the match; the higher this number, the larger the difference in ranking between the athlete and the competitor.[7] *Recurve* is a dummy variable equal to one if the category is Recurve and zero if it is Compound. On average in the sample there are around 74% matches belonging to the Recurve category.

Our key variables of interest inform on pressure. *World* is a dummy variable that takes the value of one if the tournament is either a world cup (including the 2016 Olympics) or world championship tournament (which happens in 53% of the cases), and zero if it is a less prestigious international tournament or a national competition.[8] The world tournaments are the most important tournaments in world archery. Other

[2] In WA, targets are coloured as follows. White: 1 ring & 2 ring; Black: 3 ring & 4 ring; Blue: 5 ring & 6 ring; Red: 7 ring & 8 ring; Gold: 9 ring, 10 ring, & inner 10 ring. Different distances use different size target faces. Common sizes are: 40, 60, 80, and 122 cm.

[3] Before year 2013, data on arrows and/or set scores are missing at the individual level. The dataset is not comprehensive of all competitions in this time interval. Some of the competitions listed in the World Archery website are dropped since match-level information is not available online. The dataset was downloaded in December, 2019.

[4] Country corresponds to the athlete's country of flag the country he or she is competing for. Unfortunately we do not have information on the athlete's country of birth.

[5] All the results throughout the paper hold in the extended dataset, that includes both observations with missing variables and the athletes for whom we only have one observation.

[6] In the few cases a match presents more than one tiebreak shot (because the scores are tied), we include the first tiebreak score only.

[7] The average of this variable is not zero as in the final dataset we do not always have one observation for the athlete and one observation for the competitor in the match.

[8] In a separate analysis, available upon request, we split the dummy in two, making a distinction between world cup tournaments and world championship tournaments. Our main results for *World* are confirmed in both cases, and with similar effects.

Table 1
Summary statistics (3645 observations) .

	Mean	Std. Dev.	Minimum	Maximum
Tiebreak Score	9.088	1.011	1	10
Average Set Score	9.148	0.488	6.667	10
Higher Ranking	0.522	0.500	0	1
Rank Difference	−1.161	24.954	−95	95
Recurve	0.737	0.441	0	1
Pressure				
World	0.571	0.495	0	1
Final	0.028	0.165	0	1
Semi-final	0.061	0.240	0	1
Quarter-final	0.125	0.331	0	1
Athlete				
Age	25.929	6.549	13	65
Woman	0.425	0.494	0	1
Home Playing	0.064	0.245	0	1
Country Points	944.864	555.096	0	2327
N.Matches	28.568	26.824	1	200
N.Shoot-offs	4.331	3.853	1	30
Location				
America	0.226	0.418	0	1
Asia	0.394	0.489	0	1
Europe	0.369	0.483	0	1
Africa	0.011	0.105	0	1

variables inform on the stage of the match within the competition: *Final, Semi-final* and *Quarter-final* are dummy variables taking the value of one if the match is respectively the final, the semi-final or the quarter-final of the tournament. These are the most relevant stages in a competition; explicitly referring to further stages would not change our findings in Section 4 (results available upon request). Table 2 reports, for each combination of stage and competition, the average tiebreak score, the average set score, and the number of observations. We generally find a lower average score in the tiebreak than in the regular sets; this difference is more pronounced in the world competitions.

We also have variables for athlete characteristics. *Age* informs on the age of the athlete, which on average is close to 26 years. *Woman* is a gender dummy variable that is equal to one if the athlete is a woman and zero if a man; on average in the sample there are 43% women. *Home Playing* is a dummy variable equal to one if the athlete is competing at home; this happens in 6.4% of the cases. *Country Points* is a variable informing on the world ranking in archery of the athlete's country; the higher this variable, the better the ranking.[9] The remaining two athlete variables take into account the athlete's experience. First, *N.Matches* is the number of matches (in our dataset) that the athlete has played before the current match. Second, *N.Shootoffs* is the number of tiebreaks (in the dataset) that the athlete has played before the current match. Finally, the location variables yield information about the tournament's (or, similarly, the match's) location at the continent level. In our analysis we also account for time effects by incorporating a quadratic time trend.

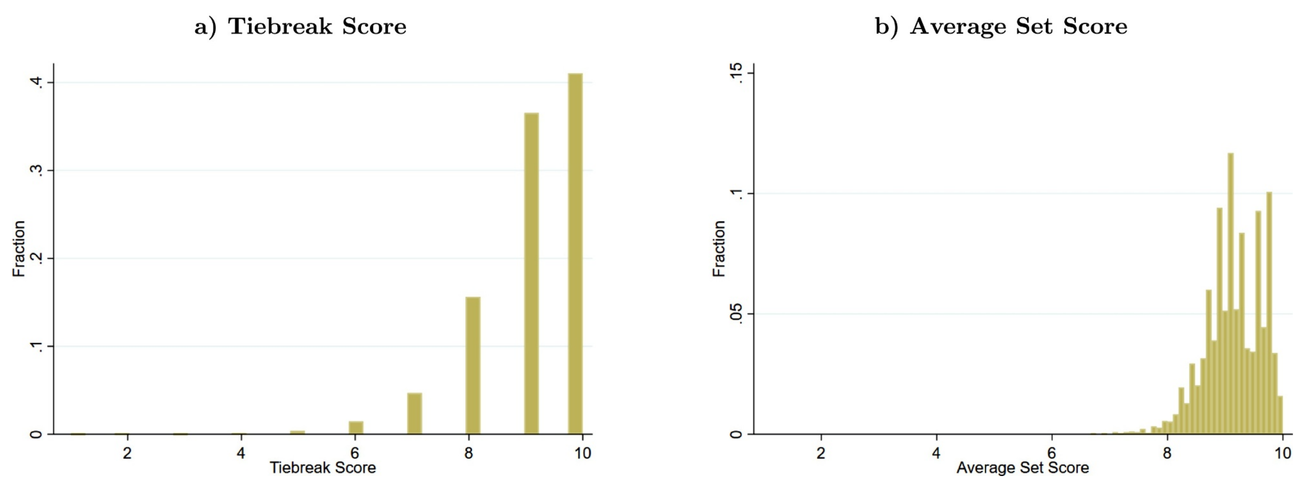

Fig. 1. Distribution of Tiebreak and Average Set Scores.

Table 2
Tiebreak and average set scores by stage and competition .

Stage	Competition		Total
	World	Other	
Final	9.413	9.125	9.255
	9.565	*9.155*	*9.340*
	(46)	(56)	(102)
Semi-final	9.463	9.164	9.291
	9.549	*9.145*	*9.317*
	(95)	(128)	(223)
Quarter-final	9.454	9.221	9.331
	9.462	*9.263*	*9.357*
	(216)	(240)	(456)
Other	9.063	8.975	9.028
	9.154	*9.005*	*9.095*
	(1,723)	(1,141)	(2,864)
All	9.129	9.034	9.088
	9.214	*9.061*	*9.148*
	(2080)	(1565)	(3645)

Notes: The table reports the average tiebreak score, the average set score (in italics) and the number of observations (within parentheses) by stage and competition.

3.4. Research questions

We analyze choking under pressure as follows. First, we study whether performance in the tiebreak deteriorates compared to performance at other points in the same match. Second, we study how tiebreak performance varies across tournament and match types. Third, we investigate if there are gender differences.

Our first goal is to analyze the extent of performance deterioration

[9] The variable measures the number of points earned by the country in the past competitions. For each year, we take the ranking as of July 1, of the following year. For instance for year 2013, we use the ranking as of July 1, 2014. Due to time constraints, for year 2019 we use the ranking as of April 1, 2020. The ranking is split in six categories (recurve men, recurve women, recurve mixed, compound men, compound women, compound mixed); our variable is the sum of the ranking in the six categories. Source: https://worldarchery.org/world-ranking.

in the tiebreak. If this occurs, we interpret this negative change as choking under pressure due to the tiebreak stage. The tiebreak is arguably the most important shot in a game: it determines with a single arrow whether the athlete wins or loses the match.

Not all tiebreaks are equally important. A tiebreak might allow the competitor to proceed to the next stage of a national competition or a much more prestigious one (such as the Olympics). Similarly, a tiebreak could make the athlete win the "round of32″ phase or the whole tournament. In other words, we have two dimensions that might affect pressure and performance: the competition type and the phase of the tournament. Thus, we will analyze whether tiebreak performance deteriorates (even more) in more prestigious tournaments and in the final phase of the tournament. If so, we will interpret this as choking under pressure related to the tournament's and match's importance.

Finally, although archery is played in separate categories by gender, there is no variation in the task performed by gender and the lack of interaction with other players (of the same gender) allows us to analyze whether there are gender differences in choking under pressure.

4. Results

4.1. Performance in the tiebreak and performance in the match

We now run parametric analyses to study choking under pressure in the tiebreak within the match. In particular, we estimate parameters β from the following log-linear equation, for athlete i in match j:

$$ln(Score_{ij}) = \beta_0 + \beta_1 MS_j + \epsilon_{ij} \quad (1)$$

The dependent variable, the logarithm of $Score_{ij}$, measures the athlete's mean score in a given set or the tiebreak; MS_j is a categorical variable indicating the stage of match (i.e., a specific set or the tiebreak) and ϵ_{ij} is the error term. Notice that the unit of analysis here is the single stage of each match; since each match in our dataset contains five sets and one tiebreak, the total sample size in this case is six times 3,645, or 21,870 observations. Column (1) of Table 3 reports the results from this regression, that we estimate using an OLS model with fixed effects taken at the athlete and match levels. Column (2) is the same as Column (1) with the inclusion of information on the ranking of the athlete and the competitor (rank difference, and whether the athlete ranks higher) and the athlete characteristics (age, home playing, country points, number of matches and number of shoot-offs) as control variables. The effect of the other variables listed in Table 1 is absorbed in the fixed effects.

Table 3
Regression results for mean scores by stage of the match .

Model	(1) OLS	(2) OLS
Set (Baseline: Set I)		
Set II	0.003**	0.003**
	(0.001)	(0.001)
Set III	0.003*	0.003*
	(0.001)	(0.001)
Set IV	−0.002	−0.002
	(0.002)	(0.002)
Set V	-0.001	−0.001
	(0.002)	(0.002)
Tiebreak	−0.011***	−0.011***
	(0.002)	(0.002)
Constant	2.181***	2.193***
	(0.011)	(0.053)
Athlete FE	YES	YES
Match FE	YES	YES
Control variables	NO	YES
R-Squared	0.001	0.008
Fraction ind. spec. variance	0.447	0.465
Observations	21,870	21,870

Notes: Robust standard errors in parentheses. Control variables are the ranking of the athlete and the competitor (rank difference, and whether the athlete ranks higher) and the athlete's characteristics (age, home playing, country points, N. matches, N. shoot-offs). ** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

This table shows that, while performance slightly but significantly improves from the first to the second set, it remains stable or slightly decreases in the following sets, although not significantly so. However, the decline in the tiebreak compared to the mean score in the first set (-1.1%) is highly significant (p-value < 0.001). In sum, it is clear that performance deteriorates in the tiebreak compared to other stages of the same match.

In Appendix A.1 we perform similar analyses but by replacing mean scores with median scores per set. Of course, the tiebreak score remains the same as it is based on just one arrow. Our results are robust to this alternative test for choking under pressure. In Appendix A.3, we look at average performance per set of those matches that did not reach the tiebreak. We find no significant differences in the score dynamics, suggesting that matches that reached the tiebreak are not, in essence, (that) different from matches that did not reach it.

4.2. Performance in the tiebreak across matches

Having established that performance drops in the tiebreak, we now study whether performance in the tiebreak deteriorates even more depending on the tournament's characteristics (i.e., prestigious vs. less prestigious tournaments) and match's characteristics (i.e., final phase of the tournament or not). To do so, we aim to estimate the following equation, describing the expected value of the athlete's score in the tiebreak, SO_{ij}, as a function $f(.)$ of several explanatory variables:

$$E[SO_{ij}] = f\begin{pmatrix} \beta_0 + \beta_1 World_j + \beta_2 Stage_j + \beta_3 World_j \times Stage_j \\ +\beta_4 AScore_{ij} + \beta_5 HigherRanking_{ijk} + \beta_6 ihs(\Delta Rank_{ijk}) \\ +\beta_7 Recurve_j + \beta_8 Athlete_{ij} + \beta_9 Loc_j + \beta_{10} time_{ij} \end{pmatrix} \quad (2)$$

Here the unit of analysis is the single match j played by an athlete i. Our key variables on pressure are $World_j$ and $Stage_j$. The former is a dummy equal to one if the tournament is a world cup or world championship the most important tournaments in world archery. The latter is a categorical variable that we split in three dummies equal to one if the tiebreak takes place respectively in the final, semi-final or quarter-final stage. Pressure is presumably higher in the most important tournaments and at the final stages of the tournament.

We enrich the specification to include further variables. $AScore_{ij}$ is the average score of the athlete in the match (excluding the tiebreak score). $HigherRanking_{ijk}$ is a dummy equal to one if athlete i has lower seedings than opponent k in match j. $\Delta Rank_{ijk}$ is the difference in seedings across the two competitors, i and k, in match j. We take this variable in its inverse hyperbolic sine (ihs) transformation to account for potential non-linearities, and to reduce its variability.[10]

We then control for a number of variables. First, $Recurve_j$ is a dummy variable taking the value of one if the category of play is Recurve. Further controls are at the athlete level: age, a dummy variable equal to 1 if athlete's country corresponds to the tournament's location, and the year-specific number of points earned by the country of the athlete in official archery matches (in ihs transformation). This variable is added to proxy for popularity of the sport in the country. We also control for athlete's experience: the number of matches (in our dataset) the athlete has played up to the current match, and the number of tiebreaks (in the dataset) that the athlete has played up to the current match. Finally, Loc_j is a categorical variable that we split in three dummies (for Asia, Europe and Africa. Excluded category: America) to identify the continent on which the match is played. $time_{ij}$ includes a quadratic polynomial on time to control for time effects.

[10] We prefer the ihs transformation to the similar, but more common, logarithmic transformation because the variable can take negative and null values.

The dependent variable in Eq. (2) is an integer count variable, and this makes the OLS model — like the one we used for Eq. (1) — a suboptimal estimation method because it assumes a continuous dependent variable.[11] Preferable models are the Poisson and Negative Binomial models for count data, which create a log-link between the expected count and the explanatory variables. Such models, however, rely on strong distributional assumptions that may not hold. Santos-Silva and Tenreyro (2006) show that in these cases it is advisable to use an extension of the Poisson model, the Poisson Pseudo Maximum Likelihood (PPML) model first introduced in Gourieroux, Monfort, and Trognon (1984), which makes the distributional assumption less stringent as it is based on the pseudo-maximum likelihood estimation method. In our analysis we then implement this estimation method, which provides consistent estimates under the only requirement that the specification of the conditional mean is correct.

Specifically, we run a PPML model with fixed effects to take advantage of the panel structure of our dataset:[12] indeed, athletes play in different matches and tournaments of our sample (on average we have 4.76 observations per athlete), which allows us to control for individual observable and unobservables time-invariant individual characteristics (such as gender or country). In this way, we take into account shoot-off performance with varying levels of pressure at the individual level. Because the PPML model describes the log of the expected count as a linear function of the explanatory variables, the coefficient estimates can be interpreted as semi-elasticities. In particular, we are interested in a test of choking under pressure; for this reason we study the significance of the coefficients β_1, β_2 and β_3 capturing whether there are differences in performance in the tiebreak when pressure is the highest, compared to when the individual faced shoot-offs with lower levels of pressure. All our specifications use robust standard errors. Below we adopt the convention of only commenting on coefficients that are significant at the 5% or lower level.

Our results are shown in Table 4. Columns (1)-(3) report the output from Equation (2), with different details on the pressure dimension. Column (1) considers two variables only: a dummy equal to one if the match belongs to a world competition and a dummy equal to one if the match is the final stage of a competition. Column (2) adds the interaction between the two dummy variables, to test if the effect on the tiebreak score is higher for final matches played in world competitions. Finally, Column (3) considers the most general specification, also including dummies equal to one for semi-final and quarter-final stages of the competition, and their interactions with the dummy for world competitions. Our findings are qualitatively the same in all the cases, as the variables added in Columns (2)-(3) are not significantly different from zero. Below we refer to the most general specification of Column (3).

We learn that the tournament type matters: playing in a world cup or a world championship tournament significantly reduces the tiebreak score by 0.9%. In other words, tiebreak scores are significantly reduced whenever the athlete is shooting a tiebreak arrow in a world tournament compared to shooting the same arrow in a less prestigious tournament. In contrast, we see no significant performance deterioration in the tiebreak of a final, semi-final or quarter-final stage compared to shoot-offs that take place at other stages in the tournament. Similarly, we observe no significantly different effect when the match is in an advanced stage of a world competition.

Concerning the other variables, the tiebreak score is, not surprisingly, strongly related to the average set score (one more point in the sets is related to a 7.3% increase in the shoot-off). Our results show evidence of an average lower tiebreak score in Europe than in America, and a quadratic time trend (which, however, remains positive throughout our sample period). Interestingly, we also find that experience is associated with lower tiebreak scores: a 100% increase in the number of previous matches played is associated with a 1.4% reduction in the tiebreak score. This seems counterintuitive, as one might

Table 4
Main regression results .

	(1) Benchmark	(2)	(3)	(4) Linear model	(5) No outliers
Model	PPML	PPML	PPML	OLS	PPML
Pressure					
World	−0.008**	−0.008**	−0.009**	−0.011**	−0.008**
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Final	0.000	0.008	0.009	0.012	0.004
	(0.008)	(0.012)	(0.012)	(0.015)	(0.011)
Semi-final			0.008	0.011	0.004
			(0.009)	(0.010)	(0.008)
Quarter-final			−0.002	−0.001	−0.005
			(0.006)	(0.008)	(0.006)
World × Final		−0.016	−0.013	−0.013	−0.009
		(0.015)	(0.015)	(0.017)	(0.015)
World × Semi-final			0.006	0.006	0.006
			(0.011)	(0.013)	(0.010)
World × Quarter-final			0.015*	0.017*	0.016*
			(0.009)	(0.009)	(0.008)
Average Set Score	0.074***	0.074***	0.073***	0.080***	0.057***
	(0.007)	(0.007)	(0.007)	(0.009)	(0.005)
Higher Ranking	0.006	0.006	0.006	0.007	0.003
	(0.010)	(0.010)	(0.010)	(0.014)	(0.008)
(ihs) Rank Difference	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Recurve	−0.081*	−0.081*	−0.083*	−0.080*	−0.090**
	(0.044)	(0.44)	(0.044)	(0.042)	(0.042)
Athlete					
Age	−0.004	−0.004	−0.004	−0.008	−0.002
	(0.007)	(0.007)	(0.007)	(0.009)	(0.006)
Home Playing	0.005	0.005	0.004	0.004	0.009
	(0.007)	(0.007)	(0.007)	(0.008)	(0.006)
(ihs) Country Points	−0.004	−0.004	−0.004	−0.005	−0.001
	(0.005)	(0.005)	(0.005)	(0.007)	(0.005)
(ln) N.Matches	−0.014**	−0.014**	−0.014**	−0.017**	−0.012**
	(0.006)	(0.006)	(0.006)	(0.008)	(0.005)
(ln) N.Shoot-offs	−0.004	−0.004	−0.004	−0.004	−0.003
	(0.006)	(0.006)	(0.006)	(0.008)	(0.005)
Location (Baseline: America)					
Asia	−0.025*	−0.025*	−0.022*	−0.022	−0.021*
	(0.013)	(0.013)	(0.013)	(0.017)	(0.012)
Europe	−0.029**	−0.030**	−0.026**	−0.028*	−0.021*
	(0.013)	(0.013)	(0.013)	(0.016)	(0.012)
Africa	−0.028**	−0.029**	−0.025*	−0.025	−0.023**
	(0.013)	(0.013)	(0.013)	(0.016)	(0.011)
Period					
Time	0.002***	0.002***	0.002***	0.003**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$Time^2$	−0.000**	−0.000**	−0.000**	−0.000*	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.703***	1.700***	1.714***	1.720***	1.807***
	(0.158)	(0.158)	(0.158)	(0.189)	(0.142)
Athlete FE	YES	YES	YES	YES	YES
Pseudo R-Squared	0.011	0.011	0.011		0.007
R-Squared				0.090	
Log pseudo-likelihood	-7533.0	−7533.0	−7532.8		−7314.9
Fraction ind. spec. variance				0.397	
Observations	3645	3645	3645	3645	3550

Notes: Robust standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[11] Notice that, in the model in Eq. (1), the dependent variable is a non-integer number (the mean score in a set) rather than a count.

[12] We use Stata v16 and the function "ppmlhdfe" developed in Correia, Guimar aes, and Zylkin (2020).

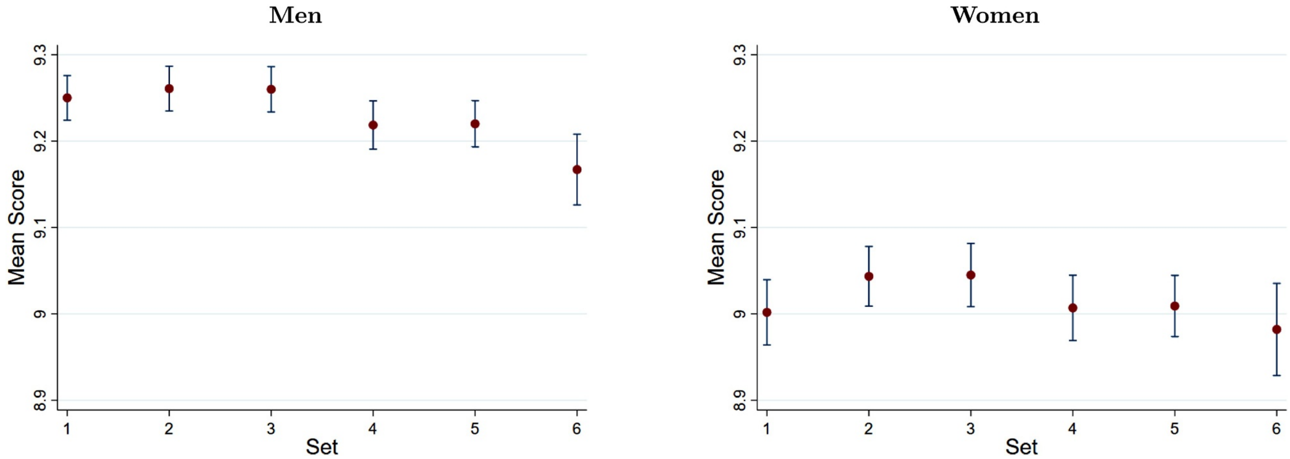

Fig. 2. Mean score by stage of the match and by gender. Notes: The plot shows the mean score per set. Set = 6 represents the mean score in the tiebreak. The whiskers represent 95% confidence intervals.

expect experience to reduce choking under pressure, and in general enhance performance. This is not what we find. While we cannot pin down the mechanism for the negative effect that we find, one possible interpretation is the following. A driver of choking under pressure is a downward shift in attention and executive control. Indeed, choking under pressure is more frequent when an individual is highly aware or knowledgeable about the skill at hand because this can distract the player (Lee, Acuña, Kording, & Grafton, 2019). Higher awareness and knowledge of the skill are likely to be, in turn, higher for more experienced athletes, thus leading to higher levels of choking under pressure.

In Appendix Table A.2, Columns (1) and (2), we repeat our analysis of Column (3) separately in two sub-samples of world and other competitions. In so doing, we allow all the coefficients in the equation to change by type of competition. Although this type of analysis makes it more difficult to isolate and interpret the overall effect of a world competition, we can run a Chow test comparing the size of the coefficients in the two columns. The test rejects the null hypothesis (Chi-squared test: 40.02; p-value < 0.01) suggesting a different behavior in world competitions than in other competitions. From the size of the constant, which is lower in Column (1) than in Column (2), we learn that the tiebreak score is on average lower in more prestigious tournaments.

Our models are drawn from the PPML estimation method. In Column (4) we replicate the analysis by means of an OLS regression with athlete fixed effects. For the sake of comparability with the other columns, and following common practice, in this case the dependent variable is taken in logarithms. Our benchmark results are qualitatively preserved, and quantitatively very similar. Table 4 shows one further column, Column (5), where we repeat the analysis of Column (3) on a sub-sample of observations, excluding the 5% lowest tiebreak scores. The motivation is that the tiebreak score has few exceptionally small outliers (see Fig. 1) that could affect our analysis. Our benchmark results, however, are preserved here as well.

4.3. Gender differences in choking under pressure

We now look at gender differences in choking under pressure. There are two steps to our analysis. First, as in Subsection 4.1, we look at performance deterioration in the tiebreak compared to overall performance in the same match by gender. Second, following our econometric specifications in Section 4.2, we run the same regressions separately by gender.

In Fig. 2 we show the mean score by set/tiebreak and separately by gender (men on the left panel and women on the right panel). From these panels, it is clear that performance deteriorates in the tiebreak for both men and women athletes. For men it decreases from 9.25 (s.d. 0.013) in the first set to 9.167 (s.d. 0.021) in the tiebreak,[13] whereas for women it falls from 9.002 (s.d. 0.019) in the first set to 8.982 (s.d. 0.027) in the tiebreak.[14] Interestingly, the drop in tiebreak scores is larger for men than women. A formal t-test, however, accepts the null hypothesis on the equality of the drop in shoot-off scores by gender at the 5% significance level (test: 1.851; p-value; 0.064).

We now run Equation (2) separately by gender to see if the result of performance deterioration in more competitive tournaments is driven by any specific gender. Table 5 reports the results: Columns (1), (3) and (5) concern men, while Columns (2), (4) and (6) concern women. Columns (1)-(2) are the equivalent in the subsamples of Column (3) in Table 4; Columns (3)-(4) report the fixed-effect OLS estimates and Columns (5)-(6) display the PPML results excluding the 5% lowest values. Also here, the different approaches show similar qualitative results and we base our comments on the benchmark estimates of Columns (1)-(2).

From this table it is clear that our previous result of performance deterioration in more competitive tournaments is driven by women. Indeed, only for women is the coefficient of world competitions significantly different from zero. This indicates that the tiebreak score is 2.3% lower in matches played in world competitions.

We find once more that there is no negative pressure effect of shooting in the tiebreak in the final of the tournament as compared to other tournament's stages. Indeed, the estimated coefficients are small and not statistically distinguishable from zero for both genders.

As for the other results, not surprisingly, the average performance in the match (i.e., Average Set Score) is strongly and significantly associated with a higher tiebreak score for both genders. Indeed, a 1-point rise in the mean set score, increases the tiebreak score by around 6.5% for men and by around 8.1% for women. Only women display a significant effect of facing a stronger opponent, although the evidence is not supported in the further regressions of Columns (4) and (6). We generally observe a negative effect of the recurve category, as already found in Table 4, that is more pronounced among women.

There are two further gender differences worth mentioning. Playing at home (i.e., in the athlete's country) increases tiebreak performance for women, while not for men. The effect is large as it increases the tiebreak score by about 2.7%. This result adds to the literature on the effects of a supporting audience on choking and is consistent with home advantage in judo (Krumer, 2017). The number of previous matches,

[13] The difference is significant. t-test: 3.364; p-value < 0.001.

[14] The difference is not significant. t-test: 0.594; p-value $= 0.553$.

Table 5
Regression results by gender .

	(1) Benchmark	(2)	(3) Linear model	(4)	(5) No outliers	(6)
Model	Men PPML	Women PPML	Men OLS	Women OLS	Men PPML	Women PPML
Pressure						
World	-0.000	−0.023***	−0.002	−0.025***	−0.001	−0.018***
	(0.005)	(0.007)	(0.006)	(0.009)	(0.005)	(0.006)
Final	-0.004	0.017	−0.002	0.020	−0.011	0.012
	(0.016)	(0.018)	(0.020)	(0.021)	(0.016)	(0.017)
Semi-final	0.008	0.007	0.010	0.010	0.005	0.001
	(0.012)	(0.013)	(0.015)	(0.015)	(0.010)	(0.012)
Quarter-final	-0.002	−0.003	−0.002	-0.001	−0.006	−0.004
	(0.009)	(0.009)	(0.010)	(0.011)	(0.008)	(0.008)
World × Final	0.008	−0.029	0.008	−0.031	0.014	−0.028
	(0.019)	(0.025)	(0.023)	(0.028)	(0.019)	(0.023)
World × Semi-final	0.003	0.013	0.003	−0.014	0.006	0.009
	(0.015)	(0.018)	(0.017)	(0.020)	(0.013)	(0.017)
World × Quarter-final	0.013	0.021	0.014	0.024	0.015	0.018
	(0.011)	(0.013)	(0.012)	(0.015)	(0.011)	(0.012)
Average Set Score	0.065***	0.081***	0.068***	0.093***	0.058***	0.056***
	(0.009)	(0.011)	(0.011)	(0.015)	(0.007)	(0.008)
Higher Ranking	0.023*	−0.020	0.028	−0.023	0.020*	−0.018
	(0.012)	(0.016)	(0.018)	(0.021)	(0.011)	(0.014)
(ihs) Rank Difference	0.002	−0.006**	0.003	−0.007*	0.001	−0.004*
	(0.002)	(0.003)	(0.003)	(0.004)	(0.002)	(0.002)
Recurve	−0.032**	−0.161**	−0.030*	−0.160***	−0.048***	−0.157**
	(0.013)	(0.070)	(0.016)	(0.019)	(0.011)	(0.074)
Athlete						
Age	−0.004	0.001	−0.006	−0.002	−0.004	0.003
	(0.009)	(0.010)	(0.012)	(0.012)	(0.008)	(0.009)
Home Playing	−0.012	0.027***	−0.015	0.030***	−0.001	0.024***
	(0.009)	(0.010)	(0.011)	(0.010)	(0.008)	(0.009)
(ihs) Country Points	0.000	−0.010	−0.002	−0.009	0.003	−0.008
	(0.006)	(0.011)	(0.007)	(0.014)	(0.005)	(0.009)
(ln) N.Matches	−0.007	−0.022**	−0.010	−0.026*	−0.004	−0.022***
	(0.007)	(0.009)	(0.009)	(0.014)	(0.006)	(0.007)
(ln) N.Shoot-offs	−0.010	0.002	−0.011	0.003	−0.012*	0.005
	(0.007)	(0.010)	(0.010)	(0.014)	(0.007)	(0.008)
Location (Baseline: America)						
Asia	−0.030	−0.016	−0.033	−0.013	−0.025	−0.016
	(0.019)	(0.019)	(0.025)	(0.021)	(0.016)	(0.019)
Europe	−0.039**	−0.011	−0.048**	−0.007	−0.028*	−0.009
	(0.019)	(0.018)	(0.024)	(0.022)	(0.016)	(0.019)
Africa	−0.040**	−0.007	−0.045*	−0.005	−0.034*	−0.005
	(0.019)	(0.018)	(0.025)	(0.020)	(0.016)	(0.018)
Period						
Time	0.002**	0.002	0.003*	0.003	0.002**	0.002
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
$Time^2$	−0.000*	0.000	−0.000	−0.000	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.701***	1.661***	1.738***	1.593***	1.769***	1.838***
	(0.209)	(0.243)	(0.251)	(0.292)	(0.185)	(0.221)
Athlete FE	YES	YES	YES	YES	YES	YES
Pseudo R-Squared	0.009	0.012			0.007	0.008
R-Squared			0.062	0.120		
Log pseudo-likelihood	−4330.4	−3201.1			−4235.3	−3078.6
Fraction ind. spec. variance			0.347	0.422		
Observations	2095	1550	2095	1550	2054	1496

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

our measure of experience, significantly reduces performance in the tiebreak. In Appendix A.4, we also look at whether there are differences in psychological momentum by gender. We define “momentum” as the condition of having won the fifth set and, thus, tied up the game to reach the tiebreak. As for choking under pressure across tournaments, we find that women benefit from momentum, but men do not.

In Appendix Table A.2, we run the equivalent of Columns (1) and (2) of Table 5 separately for the subsamples of world and other competitions. Columns (1) and (2), already discussed in Section 4.3, present the general case of both genders; Columns (3) and (4) refer to men, while Columns (5) and (6) refer to women. Interestingly, a Chow test finds no overall significant difference in the coefficients for men (Chi-squared test: 16.69; p-value: 0.475), while it does so for women (Chi-squared test: 34.03; p-value < 0.01). This confirms that world competitions play a role only among women, and in the same direction of Table 5 as we can notice from the lower constant of Column (5) compared to Column (6).

From the analyses in this section, we thus conclude that while both genders show a significant decrease in the tiebreak compared to their scores in the sets, there are heterogeneous effects as far as tournament types are concerned. Indeed, only women athletes’ performance in the tiebreak decreases even more if they are playing a world cup/

championship match.

5. Discussion and conclusion

5.1. Discussion

Our main results show that archery scores are lower in the tiebreak but even more so if the tiebreak takes place in a prestigious world tournament. The effect is mainly present in women athletes. Our empirical analyses allow us to study performance deterioration at different stages of the tournament and their interaction with the type of tournament. We do not find evidence that in the final phase(s) performance deteriorates relative to other stages of the tournament. Similarly, we do not find evidence that performance deteriorates in the final phases of the most important tournaments compared to the same phases of the other tournaments. A possible explanation for these null results is that pressure in a top competition is so high during any phase that any match carries similar psychological pressure for the athletes. This is possible since losing in the tiebreak, irrespective of the stage of the tournament, implies leaving the tournament. However, one limitation of our dataset is that once we start looking into performance deterioration by stage of the tournament and the interaction with the type of the tournament, our statistical power to detect small differences declines.

An alternative explanation for the drop in performance we observe in the tiebreak is due to athletes' physical fatigue. Indeed, the tiebreak comes after the athletes have already shot fifteen arrows and thus the level of physical fatigue may be the highest at this stage of the match. However, this explanation is not convincing for several reasons. First, it is not clear that fatigue is the highest in the tiebreak. Fatigue may be even higher in the third arrow shot of any given set. This is because arrows in a set are shot in sequence, whereas in the tiebreak only one arrow is shot, and only after some time has passed from the last arrow shot in the fifth set. Second, the drop in performance in the tiebreak compared to other instances in the match is too large in magnitude to be fully explained by fatigue. Indeed, the convexity of fatigue due to the number of arrows shot would need to be really steep to account for such a drop in performance from the 15th to the 16th shots. Third, fatigue alone cannot account for the dynamic pattern of mean set scores, that is, the evidence that performance increases from the first to the second and third sets. Finally, and most importantly, physical fatigue cannot explain our results of poorer performance in the tiebreak of world tournaments compared to tiebreak performance in other tournaments. Physical fatigue should be the same in all the tournaments; in case, *psychical* fatigue should be higher in world tournaments. However, this relates to our previous pressure explanation.

One could think that our results are mainly driven by outliers. That is, poorer performance in the tiebreak is driven by few exceptional cases of lower scores in the tiebreak. We indeed find episodes of particularly low scores in the tiebreak, although they arise extremely rarely. Even though these episodes could be potentially driven by choking under pressure, the analysis excluding them (Column (5) of Table 4) preserved the main results.

5.2. Conclusion

We ran an empirical analysis on archery data to study the phenomenon of choking under pressure. Our results show strong evidence of performance deterioration in the tiebreak, are robust to alternative ways of assessing this drop in performance, and other explanations, such as fatigue, do not seem convincing. Moreover, our analysis of performance deterioration when pressure is presumably the highest reveals that, while pressure detrimentally affects performance in the most prestigious tournaments, it does not seem to negatively impact performance in the final match of the tournament.

Interestingly, while performance deterioration in the tiebreak affects both genders (men in particular), our results show that the type of tournament mainly affects women. This result reveals gender differences in choking under pressure. This is consistent with literature in psychology suggesting that women and men may perceive stressful events differently and may react to them in different ways too (e.g., Grossman & Wood, 1993; Mayor, 2015). Our findings confirm that gender disaggregated data are necessary in research on choking under pressure.

Our results reinforce the finding that choking under pressure is common. This underlines competitive advantage of being able to maintain performance under pressure. In fact, one can think of handling high levels of stress and pressure as a critical skill that is highly valuable. This ability is not relevant in sports settings only, as performing under pressure is common in several other professions (e.g., financial traders, surgeons, job candidates). In other words, coping with pressure is an important skill to manage and that may rightly lead to better professional career outcomes. Our results also show that the skill of handling pressure is difficult to master. Athletes at the highest levels of international competition are still susceptible to choking. This suggests that, unlike other athletic skills that can be acquired through training, athletes and coaches have not yet discovered how to overcome the effect of pressure on performance.

Future research should enrich the current analysis at least in two dimensions. First, the dataset considered a time-span and a set of competitions constrained by the availability of information in the world archery website. We would like to expand the dataset to a longer time-span and to include a richer set of competitions, to benefit from more heterogeneity of information. Second, the dataset should incorporate more socio-demographic characteristics of the athletes to understand if choking under pressure exhibits some regularities, and to learn if specific types of individuals may suffer from this problem more than others. It would also be interesting to dig deeper in the analysis of the momentum effect.

Acknowledgment

We thank the Head of Communications at World Archery Federation, Chris Wells, for his constant support. The usual disclaimers apply.

Appendix A. Appendix

A1. Median score in the set

In Section 4.1 we have analyzed performance in the tiebreak compared to mean set scores during the game. We now perform a similar analysis but replacing mean set scores with median set scores. We do this as a further test of choking under pressure that is robust to outlier arrow scores in each set.

In Fig. A.1, we show the mean scores by set (panel a) and the mean of the median scores by set (panel b). Median scores are generally higher, but they show a pattern similar to mean scores. They increase from the first set (9.249) to the second and third sets (9.273 and 9.280), and then they decrease in the last two sets (9.236 and 9.235). However, the drop is by far the largest in the tiebreak (9.106), and is much more pronounced than comparing the mean scores.

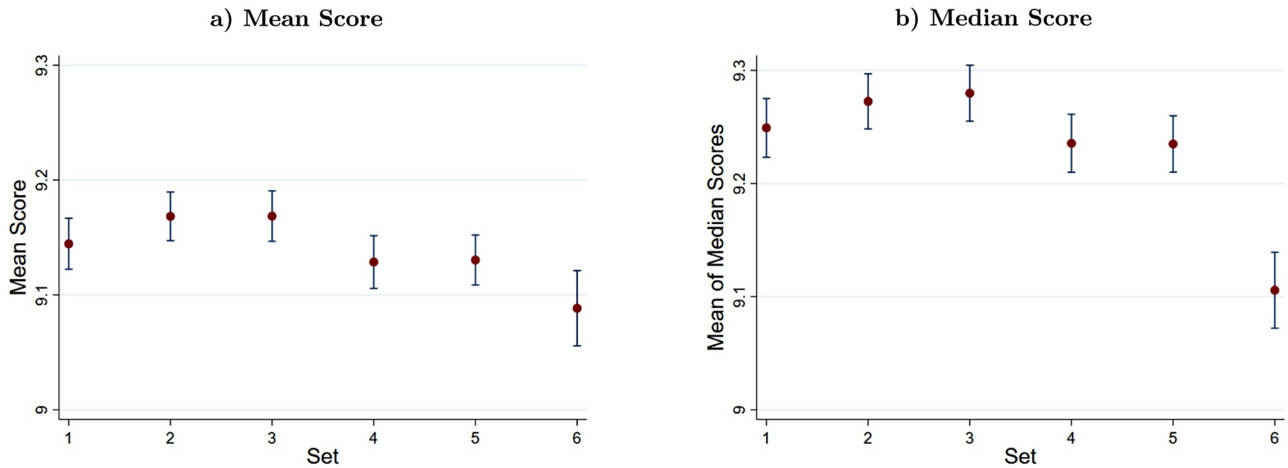

Fig. A1. Mean and median scores by stage of the match. Notes: Set = 6 indicates the mean score in the tiebreak. The whiskers represent 95% confidence intervals.

If we test for differences in means between the tiebreak score and the median score per set, we find that the tiebreak score is consistently and significantly lower than the score of any set (p-values < 0.001). Alternatively, we run Eq. (1) where we replace mean scores with median scores per set. Table A.1 displays the results and shows essentially the same information as Fig. A.1: the performance drop in the tiebreak as compared to the median value in set 1 (the reference category) is large and highly significant (coefficient= −0.019).

Table A1
Regression results for median scores by stage of the match .

Model	(1) OLS	(2) OLS
Set (Baseline: Set I)		
Set II	0.003*	0.003*
	(0.002)	(0.002)
Set III	0.004**	0.004**
	(0.002)	(0.002)
Set IV	−0.001	−0.001
	(0.002)	(0.002)
Set V	−0.001	−0.001
	(0.002)	(0.002)
Tiebreak	−0.019***	−0.019***
	(0.002)	(0.002)
Constant	2.200***	2.132***
	(0.010)	(0.064)
Athlete FE	YES	YES
Match FE	YES	YES
Control variables	NO	YES
R-Squared	0.009	0.001
Fraction ind. spec. variance	0.502	0.473
Observations	20,736	20,736

Notes: Robust standard errors in parentheses. Control variables are the ranking of the athlete and the competitor (rank difference, and whether the athlete ranks higher) and the athlete's characteristics (age, home playing, country points, N. matches, N. shoot-offs). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A2. Subsample analysis

Table A2
Analysis by world competition .

	(1) All	(2)	(3) Male	(4)	(5) Female	(6)
Model	World PPML	Other PPML	World PPML	Other PPML	World PPML	Other PPML
Final	−0.014	0.008	−0.004	−0.005	−0.026	0.025
	(0.010)	(0.013)	(0.013)	(0.018)	(0.017)	(0.018)
Semi-final	0.128	−0.003	0.013	−0.001	0.012	−0.006
	(0.009)	(0.009)	(0.010)	(0.012)	(0.015)	(0.014)
Quarter-final	0.013**	0.001	0.010	−0.002	0.018*	0.006
	(0.006)	(0.007)	(0.008)	(0.009)	(0.010)	(0.011)
Average Set Score	0.093***	0.046***	0.087***	0.039***	0.099***	0.052***
	(0.011)	(0.010)	(0.013)	(0.015)	(0.017)	(0.013)
Higher Ranking	−0.005	0.019	0.013	0.043**	−0.026	−0.023
	(0.014)	(0.015)	(0.016)	(0.019)	(0.023)	(0.027)
(ihs) Rank Difference	−0.003	0.001	−0.001	0.006*	−0.005	−0.009*
	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)
Athlete						
Age	0.008	−0.003	0.007	0.013	0.015	−0.026
	(0.010)	(0.011)	(0.015)	(0.014)	(0.014)	(0.018)
Home Playing	0.015*	−0.012	0.001	−0.033*	0.031**	0.022
	(0.009)	(0.013)	(0.011)	(0.018)	(0.014)	(0.017)
(ihs) Country Points	0.004	−0.002	0.009	−0.004	−0.007	−0.000
	(0.007)	(0.010)	(0.008)	(0.014)	(0.015)	(0.012)
(ln) N.Matches	−0.010	−0.003	0.001	0.011	−0.024**	−0.023
	(0.007)	(0.012)	(0.010)	(0.013)	(0.011)	(0.024)
(ln) N.Shoot-offs	0.004	−0.031***	−0.008	−0.038***	0.017	−0.019
	(0.008)	(0.011)	(0.010)	(0.013)	(0.012)	(0.020)
Location (Baseline: America)						
Asia	−0.020	-0.145	−0.021	−0.322*	−0.025	0.071
	(0.013)	(0.142)	(0.017)	(0.170)	(0.021)	(0.139)
Europe	−0.024*	−0.131	−0.032*	−0.314*	−0.014	0.084
	(0.013)	(0.141)	(0.017)	(0.168)	(0.020)	(0.136)
Africa	−0.017	−0.154	−0.030*	−0.329**	−0.004	0.059
	(0.013)	(0.141)	(0.017)	(0.167)	(0.020)	(0.137)
Period						
Time	0.001	0.001	0.001	0.000	0.001	0.003
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Time^2	−0.000*	0.000	−0.000	−0.000	−0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	1.164***	1.945***	1.168***	1.819***	1.050***	2.198***
	(0.225)	(0.292)	(0.311)	(0.366)	(0.342)	(0.403)
Athlete FE	YES	YES	YES	YES	YES	YES
Pseudo R-Squared	0.010	0.015	0.009	0.013	0.012	0.018
Log pseudo-likelihood	−3987.1	−2835.7	−2260.4	−1675.3	−1726.1	−1159.6
Observations	1927	1379	1092	815	835	564

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A3. Score by set (including all observations)

In the main analyses we focused our attention on archery matches that reached the tiebreak since we were mainly interested in performance at this stage of the game. Here, we now show that these matches are not so different from matches that do not reach it.

In Fig. A.2 we show the mean score per set including athlete-match observations on all matches that finished in 5 sets (N = 19,838). The mean score increases from the first set (9.138) to the second and third sets (9.151 and 9.155), and then decreases in the last two sets (9.145 and 9.122). In other words, we find a similar dynamic pattern compared to the scores of those matches that reached the tiebreak. The same pattern emerges if we look at matches that concluded in 3 or 4 sets (results available upon request).

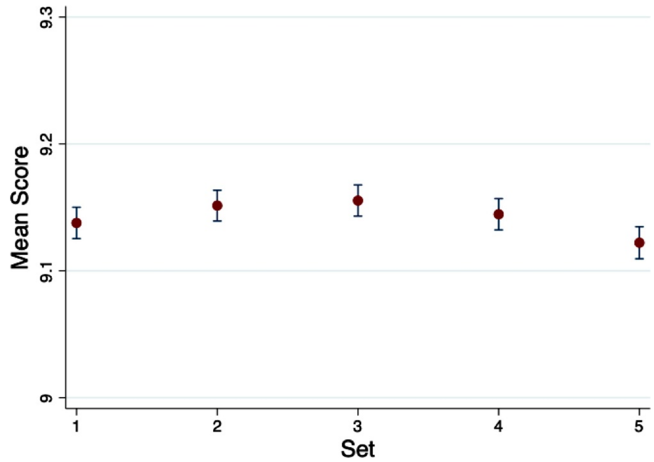

Fig. A2. Mean score by stage of the match. Notes: The whiskers represent 95% confidence intervals.

A4. Momentum effect

As an additional analysis, in the context of the tiebreak scores we can check if there is evidence of psychological momentum. Psychological momentum can be defined as improved performance that derives from previous high performance in the game. A form of momentum may arise when coming from behind and enhancing subsequent performance (Morgulev, Azar, & Bar-Eli, 2019). In archery, we can define momentum as the positive effect that coming from behind - that is, winning the fifth set of the match and, thus, tying up the game to reach the tiebreak - has on the subsequent tiebreak score.

In particular, to assess whether tiebreak scores are influenced by momentum, we run Eq. (2) and expand the set of regressors with two variables. First, we include the variable *Win Set* 5, which is a dummy that takes the value of 1 if the athlete has won set 5 and thus has tied up the game in the last set, taking the match to the tiebreak. Second, we add the variable *Avg Set* 5, that controls for the score in the fifth set of the match.[15] In this way, we are able to capture the effect of winning the last set on tiebreak performance net of the performance in the fifth set. Table A.3 shows the results. We find a positive and significant effect of winning the fifth set on tiebreak performance for women only. In other words, our results indicate that women athletes coming from behind improve their performance in the tiebreak by around 1.8%.

These results contribute to the empirical literature studying the impact of momentum on performance, that either finds support for psychological momentum (Arkes & Martinez, 2011; Page & Coates, 2017) or not (Malueg & Yates, 2010; Morgulev et al., 2019). In particular, we provide an additional piece of evidence using archery data and focusing on gender differences. The only paper, to our knowledge, that looks into gender differences is Cohen-Zada, Krumer, and Shtudiner (2017b); they find that in judo, while men's performance is affected by momentum, women's is not. Thus our findings provide new insights to this literature that deserve further investigation. In particular, momentum effects may arise differently by gender depending on the features of the task (e.g., whether it is a physical task such as in judo, or one requiring precision such as in archery).

Table A3
Regression results of tiebreak scores on momentum .

Model	(1) All PPML	(2) Male PPML	(3) Female PPML
Win Set 5	0.002	−0.010*	0.018***
	(0.004)	(0.005)	(0.006)
Avg Set 5	−0.003	−0.003	−0.003
	(0.005)	(0.006)	(0.008)
Pressure Control Variables	YES	YES	YES
Athlete Control Variables	YES	YES	YES
Location Control Variables	YES	YES	YES
Period Control Variables	YES	YES	YES
Athlete FE	YES	YES	YES
R-Squared	0.011	0.009	0.012
Log Pseudo-likelihood	−7532.8	−4330.2	−3200.8
Observations	3645	2095	1550

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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[15] The average set score variable, that we use as control variable, is therefore defined here as the mean score in the first four sets.

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