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ABSTRACT

This study analyzes how psychological pressure affects performance. It refers to the discussion on differences between *choking*, i.e., an *acute* performance decline under pressure and *under-performance* under pressure. When performance outcomes are not defined binary even slight performance decrements can have huge consequences for future career. To study the consequences of psychological pressure on performance, we employ data on the serving performance of 213 professional volleyball athletes in 226 matches. We do not find any evidence for the existence of severe performance decrements under pressure (i.e. choking). However, athletes serve less effectively under pressure, i.e., they serve less direct points and less good serves. In consequence, we find that these subtler performance changes of serving players negatively affect overall team performance. Thus, we show that even if choking in the sense of an acute failure does not occur, performance decrements harming team production exist. This might be explained by single team members trying to avoid being held responsible for failure. Strengthening group cohesion to reduce psychological pressure on single group members might be a fruitful strategy to cope with similar problems in other working environments.

Keywords: performance; psychological pressure; choking; underperformance; volleyball

JEL codes: D91, J24, L830

1 Introduction

Pressure-packed situations are part of everyday life: Students grasp for points in exams, businessmen present new products to investors and athletes compete for medals and prizes. All these situations have in common that stakes are high and failure implies loss of rewards: Students fail to graduate, businessmen fail to attract (new) investors and athletes miss medals and prize money. Contrary to (standard-economic) expectation that performance should exceed when stakes are high (Lazear 2000), many examples exist of people who strive for success and fail to achieve it. The most well-known examples for this phenomenon, which is often referred to as *choking under pressure* by journalists come from sports: Greg Norman's failure to win the U.S. Masters after being 6 shots in lead. Jana Novotna's match versus Steffi Graf in Wimbledon 1993 where the latter surprisingly won after lagging behind for the longest time in the match. Michelle Kwan was the best figure skater in the early 2000s but failed to win Olympic gold twice. Both times she underperformed in the final round –she choked when it mattered most. These examples illustrate that even professionals sometimes fail to retrieve their potential when stakes are high.

In literature the *choking under pressure* phenomenon is controversial. In his seminal study, Baumeister argued that "[c]hoking refers to performance decrements under pressure circumstances." (1984, p. 610). However, this definition has been challenged by later studies because it defines *any* inferior performance under pressure as choking (e.g., Clark et al. 2005; Beilock and Gray 2007; Hill et al. 2009; Hill et al. 2010). Therefore, scholars moved to definitions which tried to emphasize the uniqueness of *choking* compared to any inferior performance changes. For example, Clark et al. defined choking as "colloquial pejorative term used to convey the phenomenon of *acute* performance failure under perceived stress." (2005, p. 361). Beilock and Gray stated that choking is more than poor performance, it "is *suboptimal* performance–worse than expected given what a performer is capable of doing" (2007, p. 426). Thus, latter definitions of choking refer to choking as something different than any inferior performance under pressure circumstances (Hill et al. 2010). In consequence, a universal definition of choking separating choking from any inferior performance is missing (Mesagno and Hill 2013a).[1] To avoid confusion, in what follows we refer to the term *choking* as an *acute* performance decrement, i.e., a complete failure, in contrast to *underperformance* which manifests in a significant but moderate performance decrement.

[1] See Mesagno and Hill (2013a; 2013b), Buszard et al. (2013), and Jackson (2013) for a debate on the choking versus under-performance definition in the *International Journal of Sport Psychology*.

Whether people choke under pressure or simply underperform is not only of theoretical importance but also of practical relevance. A complete failure under pressure implies the loss of rewards. For example, having a blackout in an exam implies the worst possible outcome, e.g., failure. However, performance decrements which are not acute but nevertheless prevalent are also of interest. Underperforming in an exam, e.g., being nervous and therefore solving less exercises relative to one's capability, leads to a suboptimal outcome, i.e., a bad grade, which might also have consequences for one's future. To be more precise, when performance outcomes are not defined binary, even underperformance can have huge consequences for future career.

Empirical research on the link between performance and pressure flourished since Baumeister's seminal work. On the one hand, scholars focused on the investigation of different channels causing performance decrements in laboratory settings (see Beilock and Gray (2007) for an overview). To test the validity of these results outside laboratories, many scientists employed data from sports. In comparison to datasets from typical working environment (e.g. offices) sports data has the advantage that it contains very detailed and accurate information on individuals' behavior and performance. Hence, it allows analyzing precisely the effect of pressure on performance (see Kahn 2000). In consequence, scholars turned to the question under which circumstances choking and/or underperformance occurs in sports (e.g., Dohmen 2008; Jordet 2009; Toma 2015; Cohen-Zada et al. 2017; Hickman et al. 2018). Many of these studies focus on the analysis of performance under pressure in penalty shootouts in soccer and do not paint a consistent picture on the pressure-performance relationship (e.g., Dohmen 2008; Jordet 2009; Apesteguia and Palacois-Huerta 2010; Arroundel et al. 2019). In contrast, studies employing basketball data confirm a negative effect of time-induced pressure on free-throw performance (Cao et al. 2011; Toma 2015). This result is also supported by studies using data from professional golf (Hickman and Metz 2015; Hickman et al. 2018) and weight lifting (Genakos and Pagliero 2012). Furthermore, scholars employing data from professional tennis find indication for gender differences in the effect of pressure on performance (Paserman 2010; De Paola and Scoppa 2017; Cohen-Zada et al. 2017). Most of these studies investigate whether performance changes drastically under pressure and hence, look at whether an *acute* performance decrease under pressure, i.e., complete failure, occurs. This is reasonable since failing to score in penalty shootouts, failing to score at the free throw line, failing to lift announced weights, or failing to put in golf implies complete failure with all its negative consequences.[2]

[2] Paserman (2010) observes small performance changes and concludes that at important stages of a tennis match players adjust the playing strategy leading them to make less unforced errors but also to hit less winning shots.

Our study aims to enhance the understanding of the link between individual performance and pressure. We refer to the debate on the difference between *choking* under pressure in the sense of an *acute* performance decrease (e.g., Clark et al. 2005) and Baumeister's (1984) seminal definition according to which *any* performance decrease is classified as choking (which we refer here to as *underperformance*). We make use of data on professional volleyball athletes at the serve that allows to study the difference between *choking* under pressure and *underperformance* under pressure and what the consequences for team performance are. To identify the effect of pressure on performance in the sense of *choking* as well as *underperformance*, we distinguish between three different performance outcomes. First, we estimate the probability of an athlete to serve an error. Since the individuals we observe are professionals, we expect them to be able to serve the ball into the other side of the court at any time. Therefore, any drop in performance according to this measure is *acute*, i.e., can be classified as *choking*. Second, we estimate the effect of psychological pressure on the probability of serving a direct point, i.e., an ace. Third, we estimate the effect of psychological pressure on the probability of serving a good serve, i.e., a serve which does not allow the opposite team to exploit all attack possibilities. These two outcomes refer to *any* performance decrements under pressure. Consequently, we refer to performance drops in these measures as *underperformance*. Since empirical literature gives some indication on the existence of gender differences in performance under pressure (e.g., Cohen-Zada et al. 2017), we study the effect of pressure on performance (also) separately for both sexes. To identify how these performance measures fluctuate under pressure, we exploit variation in the conjuncture of the game to operationalize pressure: We estimate performance changes when the game is in crunch time. Crunch time is defined as the decisive phase of a set. This is straightforward due to the increasing importance of each additional point for the course of the game, which implies increased pressure in crunch time (e.g., González-Díaz et al. 2012). Finally, our study analyses whether the consequences of individual pressure-induced performance changes the team's overall performance. More precisely, we estimate whether the probability of the serving team to win the rally (i.e., to score a point) is affected by crunch time.

Using data from professional volleyball to study performance fluctuations under pressure has two advantages. First, by having three different performance measures, we are able to disentangle *choking* from *underperformance*. Furthermore, we can show that even when *choking* under pressure is not present, negative consequences for team performance might occur due to *underperformance* under pressure. This stresses the importance to focus on the differences between *choking* and *underperforming*. Second, measuring performance using the outcome of a serve avoids self-selection, which is a serious caveat of the majority of prior literature (e.g., Jordet 2009; Dohmen 2008; Apesteguia and Palacois-Huerta 2010; Arroundel et al. 2019).[3] Due to the volleyball-specific rotating system, every player on the field must serve and therefore self-selection as driving force for our results is ruled out.[4]

Our results are summarized as follows: First, we find that athletes in pressure-packed situations commit –independently of gender– less serve errors. In consequence we cannot establish any support for *choking* under pressure, i.e., complete failure. Second, we establish strong evidence that this does not imply that athletes' performance increases under pressure since they are also found to serve less effectively. In consequence, we establish evidence for *underperformance* under pressure. By digging deeper into our data, we show that the consequences for overall team performance are negative. More precisely, the serving team's probability to score decreases under pressure which can be partly attributed to less effective serving under pressure. In consequence, we show that even when *choking* in the sense of an acute failure does not occur, performance decrements harming team production are present.

Succeeding under pressure is important for several reasons which go far beyond sports. According to findings in sport psychology, the potential negative effect of psychological pressure on performance is rooted in distraction which leads to an overload of the working memory, i.e., an overload of the part of the brain responsible for the execution of cognitive tasks. Albeit most tasks in sports are rooted in the procedural memory, the process leading to performance changes in sports are comparable to those processes which cause performance changes in cognitive tasks, i.e., in typical working environments which require high working memory capacity. Under pressure, increased anxiety and self-consciousness lead to self-monitoring. This means that automatized movements do not run in the procedural memory anymore but are retrieved back into the working memory which leads to its overload (Beilock and Gray 2007; Beilock 2010). Consequently, the processes leading to performance decrements in sports are correlated with those processes which decrease performance under pressure in typical working environments. Therefore, performance decrements in sports are comparable to performance decrements in an exam or failing to perform in an important presentation by not being able to answer questions on the spot. Since it has been shown that the ability to perform under pressure affects an individual's wage (Deutscher et al. 2013), the effect of psychological pressure is of crucial importance for individual economic success.

[3] Soccer teams usually select those players to shoot a penalty who have a reputation for being effective on the spot and exhibit high levels of self-efficacy at that moment. Self-efficacy in turn, is found to positively influence performance (Feltz and Lirgg 2001).

[4] Possibilities to substitute players are limited to three pair-wise substitutions in each set.

The remainder of the paper is structured as follows. Section 2 gives a brief overview about the structure of a volleyball match. In Section 3 the data and the empirical specification are discussed. Results are presented in Section 4. Section 5 concludes.

2 Setting the scene: Basic rules of volleyball

A volleyball match is played in three winning sets (best-of-five). To win a single set of the match, a team must be in lead with at least two points and score at least 25 points. Set number five (the tie-breaking set) is an exception since it ends if a team scores 15 points and is ahead by at least two points. A set is interrupted at most six times by *technical* timeouts or *team* timeouts. Technical timeouts occur when the leading team scores the eighth and the sixteenth point. In addition to the technical timeouts, each head coach can call at most two team timeouts in each set.

Each set consists of a sequence of rallies. A single rally starts with one team serving the ball into the opponent's field. A serve can lead to different situations: If the ball hits the net or lands outside the field, the receiving team scores. If the ball is grounded into the opponent's field, the serving team scores directly (ace). If the opponent team receives the ball properly, the rally continues and the receiving team prepares an attack. A rally ends when one of the teams grounds the ball successfully within the opponent's field or when the ball is grounded outside the field or hits the net (i.e., commits an error). In the first case, the team which grounds the ball scores. In the second case, the team which is not responsible for the error scores the point.

Volleyball matches start with each team fielding six athletes on six different positions on its half of the court. The player at position one carries out the serve as long as the serving team (Team A) scores. If the receiving team (Team B) scores, the teams change roles, i.e., Team B becomes the serving team and Team A becomes the receiving team. Then all players of Team B rotate clockwise. After rotating, the player at position number one of Team B serves the ball. This rotation system is carried out by the receiving team every time after it has scored.

3 Data and empirical specification

3.1 Sample

The basic sample of our analysis consists of all 288 matches from the German first division volleyball league (*Volleyball Bundesliga*) in the season 2014/2015. 154 matches of these matches stem from the women's league and 134 from the men's league[5]. This sample reduces

[5] The number of matches between the women's league and the men's league varies due to two reasons. First, whereas the women's league consists of 11 teams, only 10 teams constitute the men's league. Second, the number of play-off matches varies depending on the

to 226 matches due to non-availability of some official scouting files, which are the source of information for our analysis. Out of the remaining 226 matches, 152 matches stem from the women's league[6] and 74 matches stem from the male's league. We miss the full set of match information for some match days in the men's league, which implies that we do not have a selection bias towards specific teams or even players. The remaining sample contains 37,089 serves of 268 athletes. To avoid that occasionally fielded athletes bias our results, we exclude all athletes who served less than 50 times within the season. Thus, our final sample consists of information on 36,053 serves of 213 different athletes.

3.2 Variable definition and summary statistics

The official scouting files classify each serve according to its effectiveness. Failing to serve the ball legally into the opponent's court is coded as an error. Successfully grounding the ball into the opponent's court at the service is coded as an ace. Further, a serve is rated as average when the opposing team can easily receive the ball and prepare an attack. If the receiving team is not able to prepare a proper attack, the serve is classified as good. We exploit this information to define three performance variables. The first variable we define is *Serve error*. *Serve error* equals one if the serving athlete produces a serve error and zero otherwise. According to Table 1, in 13 percent of the cases a serve error occurs. A closer examination reveals significant gender differences: While women conduct an error in 11 percent of the cases, the share for men is about 17 percent and thus significantly higher ($p=0.000$). We interpret changes in performance induced by psychological pressure regarding the serve error rate as *choking* in the sense of an *acute* failure to perform (e.g., Clark et al. 2005; Beilock and Gray 2007; Hill et al. 2009; Hill et al. 2010). We justify this operationalization by the fact that the athletes in our sample are professionals who we expect to be able to serve the ball into the other side of the court at any time.

Our second performance measure is the variable *Serve ace*. *Serve ace* equals one if the server scores a direct point, i.e., when the ball is grounded into the opponent's side of the court directly and zero otherwise. We observe in total 8 percent aces in our samples (total, women's, and men's sample). The third performance variable we define is *Good serve*. *Good serve* equals one if the outcome of the serve is classified as good or ace in the official scouting file. We observe 28 percent (at least) good serves in the total sample. While this figure is slightly higher in the women's sample (29 percent), 26 percent of the serves are classified as being (at least) a

course of the competition. The pre-playoffs, quarter finals and the semifinals are played in the best-of-three mode. The finals are played in the best-of-five mode.

[6] Data on two women's league matches are not available due to recording problems.

good serve in the men's sample. These measures allow us to measure more subtle performance changes. Thus, we use these measures to study whether *underperformance* under psychological pressure occurs.[7]

INSERT TABLE 1 HERE

To study how psychological pressure affects our performance measures, we define the variable *Crunch Time*. The dummy variable *Crunch Time* equals one if the serve occurs in a situation where both teams scored at least 20 points and the difference is at most two points in a set. During crunch time the opportunities for compensating the loss of a point due to a serve error are limited. Therefore, the perceived importance of these serves increases. Thus, psychological pressure to perform a proper serve is increased in crunch time. Our definition is consistent with views of professionals.[8] However, due to lack of a sophisticated definition of crunch time, we re-estimate the main results with a set of modifications of this definition.[9] Following the reference definition for crunch time roughly 6 percent of all serves are carried out under psychological pressure (Table 1). The share of serves under psychological pressure is slightly higher in the men's league (7 percent).

Figure 1 gives first descriptive evidence on the performance and psychological pressure link. It shows the distribution of our outcome variables and the reference category (average serves) separately for serves which are not performed in crunch time and serves performed in crunch time. We observe less serve errors in crunch time. Further, we observe slightly less good serves and less aces which is consistent with underperformance under pressure. This argument is strengthened by the increase in average serves.

INSERT FIGURE 1 HERE

When studying the relationship between performance and psychological pressure one has to consider risk-taking as an important intervening factor (see Genakos and Pagliero 2012; Hickman et al. 2018). One approximation for the level of risk-taking is the serve type, i.e.,

[7] We cannot disentangle unequivocally whether pressure does not also induce changes in the performance of the receiving player. However, we argue that an asymmetric performance change is unlikely since in crunch time stakes are equally high for both teams.

[8] A German national player answered our question: "When does crunch time start?" with 21:21. A professional volleyball coach defines crunch time as the moment when both teams reach 20 points in his blog (see https://markleb1.wordpress.com/2014/05/25/practicing-crunch-time/).

[9] A robustness check excluding observations just before crunch time, i.e., when both teams have at least 15 points and the difference is at most two points in a set, does not change our results qualitatively.

whether the serve is performed as a jump serve or another serve type.[10] Therefore, we consider the dummy variable *Jump Serve* as a measure for the level of risk-taking. *Jump Serve* equals one if the serve technique applied was a jump serve and zero otherwise.[11] Athletes and coaches agree that a jump serve is the riskiest type of serve. This is confirmed by the data: The error rate increases from 10.5 percent to 24.9 percent, when a jump serve is carried out.

In spite of the fact that *Jump serve* seems to be a very good proxy for the level of risk, we do not consider including it into our model for a specific reason. Whether a player performs a jump serve is usually her own choice. Accordingly, it is very likely that players adjust their serving technique to the current situation. More precisely, the level of risk-taking is at the discretion of the serving athlete and very likely to be a function of psychological pressure itself. In this sense, including *Jump serve* into our main model would imply running into the problem of including a *bad control* which would bias our results (Angrist and Pischke 2008). Empirical studies support that mechanisms causing performance fluctuations under pressure affect also biomechanical processes. For example, empirical evidence supports the occurrence of *freezing degrees of freedom* under psychological stress (e.g., Higuchi et al. 2002; Pijpers et al. 2003).[12] Therefore, it is plausible to believe that volleyball athletes avoid higher risk-taking which is connected to higher complexity in task execution and a higher probability to fail due to the occurrence of freezing degrees of freedom. Regression analyses employing *Jump serve* as dependent variable and *Crunch time* as independent variable (among other controls) confirm that the level of risk-taking is indeed a function of psychological pressure (see Table A.1 in the Appendix). Therefore, we do not include *Jump serve* in our model.

The main question of interest is whether psychological pressure affects an athlete's serving performance and to which extent, i.e., whether athletes experience *choking* and/or *underperformance*. However, at the end of the day, it is of inevitable interest whether team performance is affected too.[13] To asses this question, we define the variable *Break point*. *Break point* equals one if the serving team scores and zero otherwise. *Break point* is supposed to measure team

[10] Another suitable proxy for risk-taking would be the speed of the serve. Unfortunately, our data do not contain this kind of information.

[11] The procedure of a jump serve can be described as following. The player tosses the ball in the air, then she performs an attack jump and hits the ball. Volleyball professionals agree with our view that a jump serve is the most risk-taking serving technique, far riskier than a float or jump float.

[12] Freezing degrees of freedom is a phenomenon describing coordination problems which arise during the acquisition process of new movement skills.

[13] If a serve error occurs, this is clearly the case since the opposing teams scores automatically.

performance according to following reasoning. Generally, the serving team has a disadvantage to score because the receiving team is the first to prepare an attack given a proper reception of the serve. When psychological pressure has a negative effect on serving performance, then we would expect the receiving team to receive the ball more easily and hence, to score more easily, or to score directly when the serving player chokes (i.e. commits and error). Thus, we expect a negative effect on serving performance to translate into a higher probability of the receiving team to score. Therefore, our second question –whether individual performance under pressure affects team performance– is tested by employing *Break point* as a dependent variable. The likelihood to score a point after serving amounts to 35 percent (men's league) and 42 percent (women's league) which emphasizes that the serving team generally has a disadvantage to score.

We account for additional factors which have been shown to influence performance under pressure in all models. First, evidence from soccer supports the importance of the home turf for performance (e.g., Baumeister and Steinhilber 1984; Dohmen 2008). Therefore, we include the dummy variable *Home team* which equals one if the athlete at serve is a member of the home team and zero otherwise. Slightly more than half of the serves in the sample are carried out by the home team. Second, according to prior research, being the interim leader might influence performance (see Genakos and Pagliero 2012). We include the variable *Lag behind* which equals one if the serving team is trailing behind and zero otherwise. About one third of the serves are performed by players of the team trailing behind. Third, we account for serves just after team timeouts and technical timeouts. According to a common belief of volleyball coaches, taking team timeouts is a strategic choice, which increases the probability of producing serve errors. The variables *Team timeout* and *Technical timeout* equal one if the serve is carried out after a timeout and zero otherwise. About 6 percent of the serves are carried out after team timeouts and about 4 percent take place after technical timeouts. Fourth, performance at the beginning of a set might be influenced by increased excitement or, on the contrary, by decreased excitement due to maximum unimportance for the outcome of the set. Thus, the dummy variable *First serve of set* is included. It equals one if the serve is the first serve of the set and zero otherwise.

3.3 Empirical specification

To test for the relationship between performance and psychological pressure, we estimate equation (1). $Performance_{itsm}$ is the serving performance observed for player *i* at time *t* in team *s* and match *m.* More precisely, it is one of the four performance measures we defined in Section 3.2, i.e., *Serve Error*, *Serve Ace*, *Good serve*, or *Break point*. α is the effect of being in a crunch time on the corresponding performance variable given the control variables we discuss in Section 3.2 which are included in X_{itsm}.

Although self-selection does not play a role in our setting due to the volleyball specific rotation rules, observed performance differences might arise due to factors such as player specialization, experience, or physical capacity. By including player fixed effects (γ_i), we rule out all these potential sources of endogeneity. In a similar vein, match fixed effects (δ_m) capture performance differences arising from the performance differences between teams, fixture of the match, course of the season, and local conditions of the gym.

$$Performance_{itsm} = \alpha\, Crunch\ Time_{itsm} + \beta X_{itsm} + \gamma_i + \delta_m + \theta_s + \varepsilon_{itsm} \quad (1)$$

In what follows, we employ standard Linear Probability Models (LPM) to estimate the effect of crunch time on performance. Using LPM potentially causes problems. First, the predicted probabilities do not always lie within the interval of zero and one. Moreover, the nature of the LPM does not allow the estimation of non-linear effects of the independent variables. Nevertheless, in its basic assumptions it is less restrictive compared to Maximum Likelihood Estimators (MLE) where the underlying distribution must be correctly defined to yield consistent estimates. Furthermore, using fixed effects in a probit model might also lead to the well-established incidental parameter problem (Greene 2004). Since we use player and match fixed effects for good reasons in our preferred specification, we choose a linear probability model over MLE.[14] Finally, we allow for serial correlation in the error term by clustering the standard errors on player level.

4 Results

Table 2 reports the results of the regressions employing our performance measures as dependent variables and *Crunch time* as main independent variable given the full set of controls in models (1) to (3). In models (4) to (6) we additionally interact *Crunch time* and *Lag behind* to test whether the effect of psychological pressure depends on the relative rank of the team at the time the serve was carried out as proposed by prior literature (e.g., Genakos and Pagliero 2012).

Model (1) employs *Serve error* as dependent variable and tests the proposition that psychological pressure induces an *acute* performance decrease, i.e., choking (e.g., Clark et al. 2005; Beilock and Gray 2007; Hill et al. 2009; Hill et al. 2010). According to model (1), the probability of committing a serve error in crunch time decreases by 2.8 percentage points given all

[14] As a robustness check we estimate our main model employing a probit model. Our results do not differ qualitatively and are available upon request.

control variables. Thus, in contrast to prior studies on performance under pressure in basketball (Cao et al. 2013; Toma 2015) we do not find any indication for an *acute* performance decrement under psychological pressure. In models (2) and (3), we employ *Serve ace* and *Good serve* as dependent variables. The results of both models indicate that psychological pressure induces some performance decrements: The probability to serve a direct point –an ace– decreases on average by 1.8 percentage points and the corresponding effect on the probability to serve a *Good serve* equals 2 percentage points. These decrements are about one percentage point smaller in absolute value compared to the effect of pressure on the likelihood to commit a serve error. In total, we find support that pressure in general does affect individual performance negatively when employing *Serve ace* or *Good serve* as performance measures. Thus, it seems that pressure is a double edged-sword, i.e., it has an effect conditional on the outcome under scrutiny.

The established effects are also of economic significance. The probability of committing a serve error is reduced by 2.8 percentage points in model (1). Compared to the unconditional probability of serve errors which equals 13 percent (Table 1), this is a reduction of more than 20 percent. Thus, the effect is comparably large for an *acute* performance decrease and therefore economically significant. The relative effect is about the same for *Serve ace* as outcome variable. The corresponding effect for committing a good serve is about 7 percent, i.e., significantly smaller.[15]

Models (4) to (6) in Table 2 test whether the established effects depend on the relative rank of the serving athlete's team. After including the interaction of *Crunch time* and *Lag behind* the established effect of *Crunch time*, i.e., the effect of pressure on performance is slightly more pronounced. More precisely, the probability to commit an error at service is 3.2 percentage points lower in crunch time when the athlete is not serving for the team lagging behind. The corresponding probabilities to serve an ace or a good serve are larger in absolute values too. However, we do not find significant evidence for a performance increase of athletes whose team is lagging behind. Albeit positive, none of the interaction terms is significant at conventional levels. Therefore, we conclude that the interim rank of the team hast no (additional) significant effect on individual performance under pressure. This result contradicts the finding of a better performance when lagging behind which has been established in literature (Hickman et al. 2018) and mainly attributed to more risky-strategies (Genakos and Pagliero 2012).[16]

[15] Our results are robust to the definition of crunch time (see Figure A.1 in the Appendix).
[16] We do find evidence that athletes choose less risky strategies under pressure. However, again this does not depend on the team's relative rank (see Table A.1 in the Appendix).

The results of the remaining control variables reveal further insights into the determinants of serving performance. Serving for the team trailing behind has a small and negative effect of 0.6 percentage points when aces are considered as performance outcome. We do not find any evidence for the *home choke* (see Schlenker et al. 1995). All coefficients of the *Home* dummy are insignificant at conventional levels. The results do not support the proposition that team timeouts cause acute performance decrements. However, we establish support that team timeouts decrease the probability of serving direct points or good serves, i.e., *effective* serves. The size of the latter effect is even comparable to the effect size of psychological pressure. In contrast to team timeouts, technical timeouts do not seem to affect the server's performance. This might be due to the fact that technical timeouts can be anticipated by athletes while team timeouts are at the discretion of the coaches.[17] Being the first server in a set significantly decreases the probability of serving effectively by 2.6 percentage points. Finally, athletes produce significantly less serve errors in tie-breaks (*Set 5*) compared to the reference set (*Set 2*).

INSERT TABLE 2 HERE

In Table 3 we report the results separately for the women's and the men's sample. We do so because some indication for gender differences in performance under pressure has been detected in prior studies (e.g., Paserman 2010; Cohen-Zada et al. 2017). The main result regarding the question whether psychological pressure induces an acute performance decrease holds in both subsamples, i.e., we find further support for a performance increase under psychological pressure (models (1) and (4)). Women and men produce significantly less errors in crunch time. However, while the effect for men is about 2.3 percentage points, the corresponding point estimate in the men's sample is 3.6 percentage points and thus about one third larger. Interestingly, while both sexes produce significantly less aces in crunch time (models (2) and (5)), this is not the case when we consider *Good serve* as dependent variable. Here, we find a significant drop in probability in the women's sample (model (3)) but none in the men's sample (model (6)). However, this is very likely to be a product of the smaller size in the latter sample which increases the imprecision of the estimation.[18] In conclusion, the results from the pooled sample find further support when splitting the sample by gender. Thus, in spite of an acute performance decrease, we observe that athletes reduce the likelihood of serve errors, but at the same time they serve less effectively, i.e., they score less direct points (aces) at the service and

[17] Coaches usually call team time outs when the opposing team scores a series of points. The idea behind this strategy is to break the flow of the opponent through interruption.
[18] The coefficient in men's sample is about 1.8 percentage points, thus far away from being zero and equals exactly the standard error.

serve more easily receivable balls (less good serves). We find that both, men and women, underperform under pressure which is in line with findings in professional tennis (Paserman 2010).[19]

The results of the remaining control variables reveal further insights. First, while trailing behind had almost no effect on serving performance considering the full sample, this is not the case anymore when focusing on female athletes. Trailing behind reduces the probability of an ace (good serve) by 1 (1.6) percentage points. The result indicates that female athletes serve less effectively when trailing behind. This is in line with findings in professional tennis emphasizing that women tend to play poorly when lagging behind (see De Paola and Scoppa 2017). [20] Interestingly, we find some evidence that serving at the home court has an effect on performance. While the likelihood to commit an error is slightly lower for women (0.9 percentage points), it is slightly higher for men to score directly (1.1 percentage points) at home. Making use of team timeouts is more effectively in the women's league since female athletes score less aces and serve less often effectively after team timeouts. Women commit less errors and men commit less good serves after technical timeouts. Finally, women serve significantly less errors in the tie-breaking fifth set compared to the second set.

INSERT TABLE 3 HERE

Our main results until here can be summarized as follows. First, we find that athletes commit less serve errors. In consequence we cannot find any support for acute performance decrements under pressure, i.e., choking. Rather our results support that athletes commit significantly less serve errors. Second, we establish strong evidence that this does not translate into a performance increase since athletes are also found to serve less effectively (less aces and less good serves occur under pressure). Naturally, the question arises what the consequences of these findings are for overall team performance. On the one hand, one would expect that serving less errors, i.e., not being subject to choking in the sense of an *acute* performance decrement, might be beneficial for overall team performance since the team secures the chance to win the rally. On the other hand, it is more easily for the opponent to prepare a proper attack and score when serves are less effective. This might harm the serving team's chances to score. Therefore, the consequences of our findings for overall team performance are *a priori* unclear. In what follows

[19] Including an interaction term of a gender dummy and *Crunch time* in the full sample does not yield significant gender differences in performance under pressure.

[20] Table A.2 in the Appendix shows the corresponding models where *Crunch time* is interacted with *Lag behind*. The results established in Table 2 do not change when splitting the sample by gender.

we estimate the effect of psychological pressure on the probability of the serving team to score a point, i.e., a *break point*. This allows us to assess the effect of the established results on overall team performance.

Table 4 reports the estimates of regressions employing *Break point* as dependent variable for the full sample and separately by gender. The likelihood to score a break point under psychological pressure is significantly lower for the full sample and also in both subsamples. The effect ranges between 5.5 percentage points (men's sample) and 5.9 percentage points (women's sample) and is of economic significance. Given an unconditional probability of 40 percent to score a break point (see Table 1), this effect implies about a 14 percent decrease in the probability to score a break point in crunch time for the serving team. This finding is robust to different definitions of crunch time, i.e., psychological pressure, in all samples (see Appendix Figure A.2). Consistent with the prior finding of errors at the home court in the women's league, we also establish a higher probability to score break points at the home court.

INSERT TABLE 4 HERE

5 Discussion and conclusion

The aim of the present study is to analyze how psychological pressure affects performance. More precisely, we refer to the discussion on the difference between choking, i.e., an *acute* performance decline under pressure and underperformance under pressure. The question is relevant when performance is measured continuously, e.g., exam grades. Then, even underperformance under pressure can have huge consequences for future career. To answer this question, we employ data on the serving performance of 213 professional volleyball athletes in 226 matches. To distinguish between choking and underperformance, we define three binary performance measures. Finally, to study the consequences of performance changes under pressure on overall team performance, we estimate the effect of pressure on the probability of the serving team to score.

Our results can be summarized as follows. First, we do not find any evidence for the existence of *choking* under pressure in our data –overall and for both sexes. We even observe a lower probability for an acute performance decline, i.e., less serve errors under pressure. Second, we establish strong evidence that this should not be set equal with exceling under pressure since athletes are also found to serve less effectively, i.e., they serve less direct points (aces) and less good serves. These findings affect team performance negatively. In consequence, we show that even if *choking* in the sense of an acute failure does not occur, performance decrements harming team production are present. Therefore, our findings emphasize that it is important to focus not only on choking under pressure but more general pressure-induced performance decrements.

Comparing our results to existing literature on choking under pressure gives further insights. When focusing solely on our finding referring to *choking* under pressure, our results are partly in line with established evidence. On the one hand, similar to studies using data from professional soccer (e.g., Dohmen 2008; Braga and Gullíen 2012; Kocher et al. 2012), we cannot establish any evidence for the existence of choking under pressure. On the other hand, our results contradict findings employing basketball and golf data which establish the existence of choking under pressure (e.g., Hickman and Metz 2015; Toma 2015). However, when taking into account that we establish also evidence for *underperformance* under pressure, our results paint a nuanced picture of the performance and pressure relationship. We show that in pressure-packed situations athletes seem to change their serving behavior since they serve less aggressively, i.e., they produce less serve errors but also less direct points. Thus, we observe a shift in the performance distribution to less extreme performances. On the one hand, this might be evaluated positively since they produce fewer errors which is in general positive from a team's perspective. On the other hand, less effective serves might enable the opposite team to attack more powerfully which has negative consequences for the server's team. Overall, we show that the latter channel is stronger, i.e., team performance is harmed.

Our findings are comparable to evidence from tennis which shows that at important stages of a match players adjust their playing strategy which leads them to make less unforced errors but also to hit less winning shots (Paserman 2010). Paserman (2010) offers a potential explanation for this finding. He argues that players anticipate performance deterioration under pressure and optimize their strategy by adjusting their behavior. This might also be one valid explanation for our findings. However, since volleyball is a team sport, we argue that one other channel might also explain our results. More precisely, we refer to literature on social responsibility to explain our results. According to this literature, individuals try to shift responsibility away by acting more conservatively towards risk decisions in the case of group decisions to avoid being blamed by group members (Bartling and Fischbacher 2012; Bolton et al. 2015; Charness and Jackson 2009). Our results fit this argument: Serving players choose to serve less aggressively in order to avoid producing a serve error, i.e., to avoid being held responsible for helping the opponent team to score, or to put it differently, to have failed to save the opportunity for the own team to score. This is in line with results of auxiliary regressions showing that athletes tend to choose a less aggressive serving technique in crunch time (see Table A.1 in the

Appendix). More generally said, our results support the argument that players try to shift responsibility away by serving more conservatively. However, this strategic behavior harms overall team performance. Referring to the *choking* versus *underperformance* debate, our result indicates that in team sport settings pressure-induced *choking* is less relevant than *underperformance* induced by strategic choices of players in order to avoid being held responsible for complete failure.

Our results have limitations which are at the same time avenues for future research. First, since our data does not allow to study the behavioral change which take place at the service in detail, we encourage future research to focus on the measurement of the aggressiveness in task execution. More precisely, it would be interesting to study the exact physiological and psychological changes that take place under pressure. One first attempt would be to collect data on the speed of the serve. That will strengthen our results. Second, our findings are based on data from professionals which means that we deal with particularly trained people who are carrying out a routine task. This raises the question whether our results can be generalized to other competitive environments. Thus, future research might study the question of interest in other settings.

Our findings are crucial for the design of working environments, where the team's overall performance is dependent on the success of a single team member. Our results indicate that, when psychological pressure is at work, a team member might try to avoid being responsible for failure and reduces the riskiness and aggressiveness of her actions which in turn might harm the team's overall performance. This result has at least two implications. First, performance-based compensation schemes should consider not solely the output of workers, but also incentivize intermediate performance outcomes. Second, individual underperformance under pressure might be avoided by strengthening group cohesion. This reduces psychological pressure on single group members which might be induced by the anxiety to fail. Thus, our results emphasize the importance of team building as a tool optimizing team production.

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TABLES AND FIGURES

Table 1 Summary statistics. Means reported.

	All (N = 36,053)	Women (N = 24,678)	Men (N = 11,375)
Serve error	0.13	0.11	0.17
Serve ace	0.08	0.08	0.08
Good serve	0.28	0.29	0.26
Crunch time	0.06	0.06	0.07
Break point	0.40	0.42	0.35
Lag behind	0.31	0.32	0.31
Female	0.68	1.00	0.00
Home team	0.51	0.51	0.51
Technical timeout	0.04	0.04	0.04
Team timeout	0.06	0.06	0.07
First serve in set	0.02	0.02	0.02
Set 1	0.27	0.28	0.27
Set 2	0.27	0.28	0.27
Set 3	0.27	0.27	0.27
Set 4	0.15	0.14	0.15
Set 5	0.04	0.04	0.04

The variable *Serve error* equals 1 when the serving player commits a serve error and zero otherwise. The variable *Serve ace* equals 1 when the serving player scores a direct point (ace) and zero otherwise. The variable *Good serve* equals one when the player's serve is rated as good, very good or an ace and zero otherwise. *Crunch time* equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. The variable *Break point* equals 1 when the serving team scores. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. The variable *Female* equals one if the player is a woman and zero otherwise. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 2, Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set.

Table 2 Effect of psychological pressure (*Crunch time*) on serving performance of professional volleyball athletes (*Serve error, Serve ace, Good serve*).

Dependent variable	Serve error	Serve ace	Good serve	Serve error	Serve ace	Good serve
	(1)	(2)	(3)	(4)	(5)	(6)
Crunch time	-0.028*** (0.0070)	-0.018*** (0.0059)	-0.020** (0.0099)	-0.032*** (0.0077)	-0.022*** (0.0066)	-0.026** (0.0121)
Lag behind	-0.000 (0.0043)	-0.006** (0.0031)	-0.008 (0.0053)	-0.001 (0.0044)	-0.007** (0.0032)	-0.009* (0.0054)
Lag behind x crunch time				0.013 (0.0146)	0.014 (0.0116)	0.022 (0.0198)
Home team	-0.003 (0.0036)	0.004 (0.0029)	0.005 (0.0049)	-0.003 (0.0036)	0.004 (0.0029)	0.005 (0.0049)
Team timeout	0.007 (0.0083)	-0.010* (0.0055)	-0.024** (0.0100)	0.007 (0.0083)	-0.011* (0.0055)	-0.024** (0.0100)
Technical timeout	-0.012 (0.0071)	-0.003 (0.0069)	-0.016 (0.0104)	-0.012* (0.0071)	-0.003 (0.0070)	-0.016 (0.0104)
First serve of set	-0.003 (0.0115)	0.003 (0.0103)	-0.026* (0.0153)	-0.003 (0.0115)	0.003 (0.0104)	-0.027* (0.0153)
Set 1	0.007 (0.0047)	-0.002 (0.0035)	-0.001 (0.0061)	0.007 (0.0047)	-0.002 (0.0035)	-0.000 (0.0061)
Set 2			Reference category			
Set 3	-0.000 (0.0047)	-0.002 (0.0038)	-0.007 (0.0065)	-0.000 (0.0047)	-0.002 (0.0038)	-0.007 (0.0065)
Set 4	-0.006 (0.0056)	-0.006 (0.0041)	-0.001 (0.0080)	-0.006 (0.0056)	-0.006 (0.0041)	-0.001 (0.0080)
Set 5	-0.025*** (0.0090)	-0.003 (0.0079)	-0.010 (0.0126)	-0.025*** (0.0091)	-0.003 (0.0079)	-0.010 (0.0126)
Player FE	yes	yes	yes	yes	yes	yes
Match FE	yes	yes	yes	yes	yes	yes
Observations	36053	36053	36053	36053	36053	36053
Adjusted R^2	0.033	0.008	0.033	0.033	0.008	0.033

Notes: * p<0.10, ** p<0.05, *** p<0.01; Coefficient estimates from ordinary least squares estimations. Standard errors clustered on team-player level. The dependent variable is a dummy variable equals 1 when the serving player commits a serve error in columns (1) and (4), when the serving player scores a direct point (ace) in columns (2) and (5) and when the player's serve is rated as good, very good or an ace in columns (3) and (6). The explanatory variable of main interest is the variable *Crunch time*. It equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. The interaction variable *Lag behind x Crunch time* is a dummy variable that equals 1 if a player serves the ball in the crunch time and her team is lagging behind. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set. *Set 2* omitted. Constant not reported.

Table 3 Effect of psychological pressure (*Crunch time*) on serving performance of professional volleyball athletes (*Serve error, Serve ace, Good serve*). Separated effects by gender.

Dependent variable	Men's sample			Women's sample		
	Serve error	Serve ace	Good serve	Serve error	Serve ace	Good serve
	(1)	(2)	(3)	(4)	(5)	(6)
Crunch time	-0.023*** (0.0077)	-0.017** (0.0069)	-0.021* (0.0120)	-0.036** (0.0145)	-0.019* (0.0112)	-0.018 (0.0177)
Lag behind	-0.003 (0.0047)	-0.010*** (0.0037)	-0.016** (0.0063)	0.004 (0.0095)	0.002 (0.0056)	0.010 (0.0096)
Home team	-0.009** (0.0040)	0.001 (0.0034)	0.007 (0.0057)	0.010 (0.0079)	0.011** (0.0053)	-0.002 (0.0095)
Team timeout	0.013 (0.0100)	-0.013** (0.0064)	-0.027** (0.0113)	-0.008 (0.0152)	-0.003 (0.0109)	-0.018 (0.0209)
Technical timeout	-0.015* (0.0080)	0.003 (0.0089)	-0.005 (0.0128)	-0.004 (0.0142)	-0.014 (0.0106)	-0.039** (0.0174)
First serve of set	-0.007 (0.0112)	0.014 (0.0133)	-0.026 (0.0179)	0.006 (0.0268)	-0.020 (0.0141)	-0.025 (0.0289)
Set 1	0.004 (0.0051)	-0.004 (0.0043)	0.004 (0.0077)	0.012 (0.0100)	0.000 (0.0062)	-0.011 (0.0102)
Set 2	Reference category					
Set 3	0.007 (0.0052)	-0.002 (0.0048)	-0.007 (0.0076)	-0.017* (0.0096)	-0.002 (0.0059)	-0.006 (0.0121)
Set 4	-0.004 (0.0058)	-0.005 (0.0047)	-0.003 (0.0092)	-0.009 (0.0128)	-0.009 (0.0085)	0.005 (0.0160)
Set 5	-0.027*** (0.0093)	0.006 (0.0096)	0.002 (0.0141)	-0.021 (0.0207)	-0.022 (0.0140)	-0.037 (0.0257)
Player FE	yes	yes	yes	yes	yes	yes
Match FE	yes	yes	yes	yes	yes	yes
Observations	24678	24678	24678	11375	11375	11375
Adjusted R^2	0.021	0.005	0.030	0.037	0.014	0.038

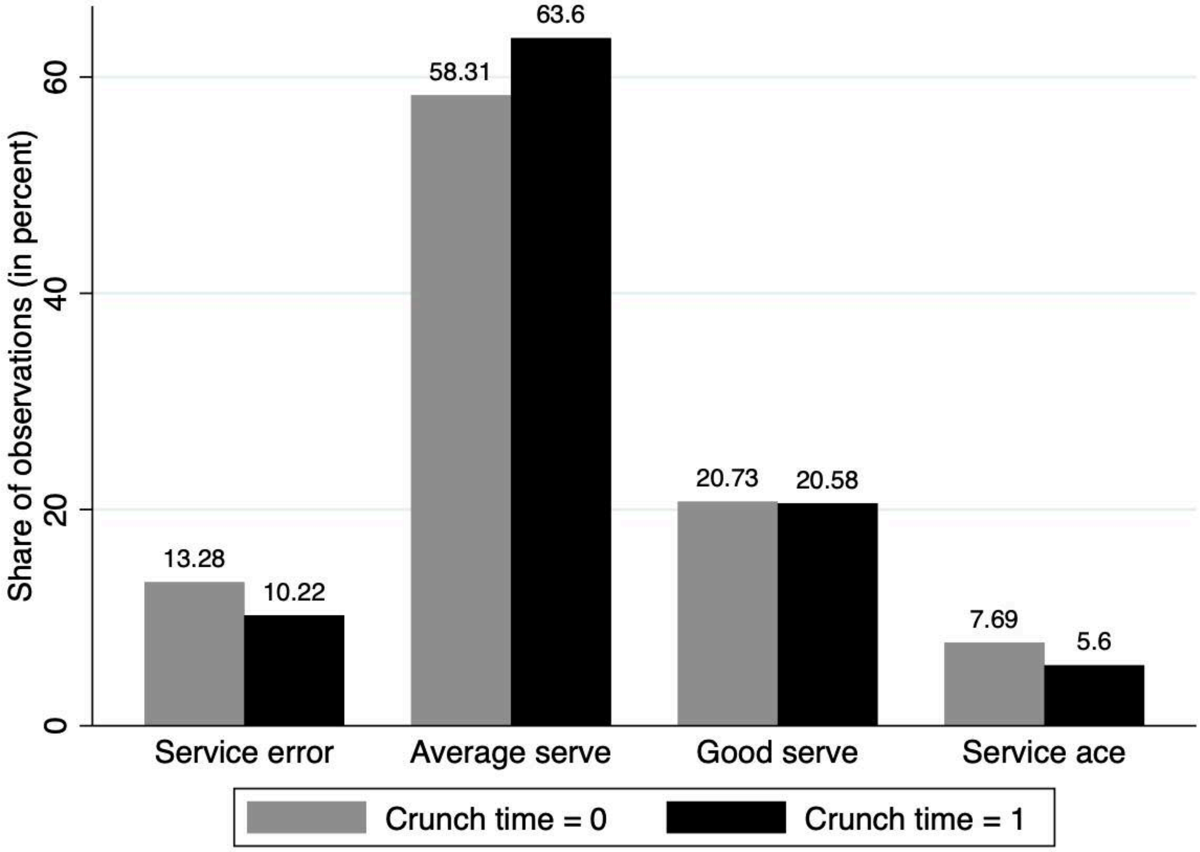
Notes: * p<0.10, ** p<0.05, *** p<0.01; Coefficient estimates from ordinary least squares estimations. Standard errors clustered on team-player level. The dependent variable is a dummy variable equals 1 when the serving player commits a serve error in columns (1) and (4), when the serving player scores a direct point (ace) in columns (2) and (5) and when the player's serve is rated as good, very good or an ace in columns (3) and (6). The explanatory variable of main interest is the variable *Crunch time*. It equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set. *Set 2* omitted. Constant not reported.

Table 4 Effect of psychological pressure (*Crunch time*) on the probability of the serving team to score (*Break point*).

Dependent variable: Break point	Full sample	Men's sample	Women's sample
	(1)	(2)	(3)
Crunch time	-0.056*** (0.0105)	-0.059*** (0.0186)	-0.055*** (0.0127)
Lag behind	0.010 (0.0061)	0.004 (0.0107)	0.013* (0.0074)
Home team	0.012** (0.0051)	-0.007 (0.0100)	0.019*** (0.0058)
Team timeout	-0.005 (0.0113)	0.012 (0.0177)	-0.012 (0.0142)
Technical timeout	-0.011 (0.0125)	-0.030 (0.0224)	-0.002 (0.0150)
First serve of set	0.018 (0.0176)	0.018 (0.0273)	0.019 (0.0226)
Set 1	-0.056*** (0.0105)	-0.059*** (0.0186)	-0.055*** (0.0127)
Set 2		Reference category	
Set 3	-0.005 (0.0070)	-0.005 (0.0113)	-0.005 (0.0088)
Set 4	-0.000 (0.0078)	0.008 (0.0130)	-0.004 (0.0097)
Set 5	0.022** (0.0093)	0.010 (0.0179)	0.027** (0.0109)
Player FE	yes	yes	yes
Match FE	yes	yes	yes
Observations	36053	11375	24678
Adjusted R^2	0.016	0.015	0.011

Notes: * p<0.10, ** p<0.05, *** p<0.01; Coefficient estimates from ordinary least squares estimations. Standard errors clustered on team-player level. The dependent variable is a dummy variable that equals 1 when the serving team scores (*Break point*). The explanatory variable of main interest is the variable *Crunch time*. It equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set. *Set 2* omitted. Constant not reported.

Figure 1 Serving performance separated by psychological pressure (*Crunch time*).



APPENDIX

Table A.1 Effect of psychological pressure (*Crunch time*) on risk-taking behavior (*Jump serve*).

Dependent variable: Jump serve	Full sample		Men's sample		Women's sample	
	(1)	(2)	(3)	(4)	(5)	(6)
Crunch time	-0.022*** (0.0056)	-0.021*** (0.0062)	-0.065*** (0.0148)	-0.059*** (0.0160)	-0.000 (0.0014)	-0.000 (0.0019)
Lag behind	0.002 (0.0031)	0.003 (0.0031)	0.005 (0.0096)	0.007 (0.0096)	-0.000 (0.0018)	-0.000 (0.0018)
Lag behind x crunch time		-0.004 (0.0104)		-0.022 (0.0304)		0.001 (0.0024)
Home team	0.009* (0.0049)	0.009* (0.0049)	0.033** (0.0159)	0.033** (0.0159)	-0.002 (0.0020)	-0.002 (0.0020)
Team timeout	-0.009** (0.0039)	-0.009** (0.0039)	-0.035*** (0.0125)	-0.035*** (0.0125)	0.002 (0.0012)	0.002 (0.0012)
Technical timeout	-0.009 (0.0058)	-0.009 (0.0058)	-0.035** (0.0174)	-0.034* (0.0173)	0.003* (0.0018)	0.003* (0.0018)
First serve of set	0.018* (0.0092)	0.018** (0.0092)	0.061** (0.0261)	0.062** (0.0261)	-0.003 (0.0020)	-0.003 (0.0020)
Set 1	0.017*** (0.0043)	0.017*** (0.0043)	0.049*** (0.0122)	0.048*** (0.0122)	0.002* (0.0010)	0.002* (0.0010)
Set 2	Reference category					
Set 3	-0.015*** (0.0036)	-0.015*** (0.0036)	-0.040*** (0.0103)	-0.040*** (0.0103)	-0.004*** (0.0016)	-0.004*** (0.0016)
Set 4	-0.017*** (0.0049)	-0.017*** (0.0049)	-0.052*** (0.0151)	-0.052*** (0.0151)	-0.003** (0.0015)	-0.003** (0.0015)
Set 5	-0.016** (0.0070)	-0.016** (0.0070)	-0.038* (0.0206)	-0.038* (0.0205)	-0.007* (0.0042)	-0.007* (0.0042)
Player FE	yes	yes	yes	yes	yes	yes
Match FE	yes	yes	yes	yes	yes	yes
Observations	36053	36053	11375	11375	24678	24678
Adjusted R^2	0.785	0.785	0.655	0.655	0.899	0.899

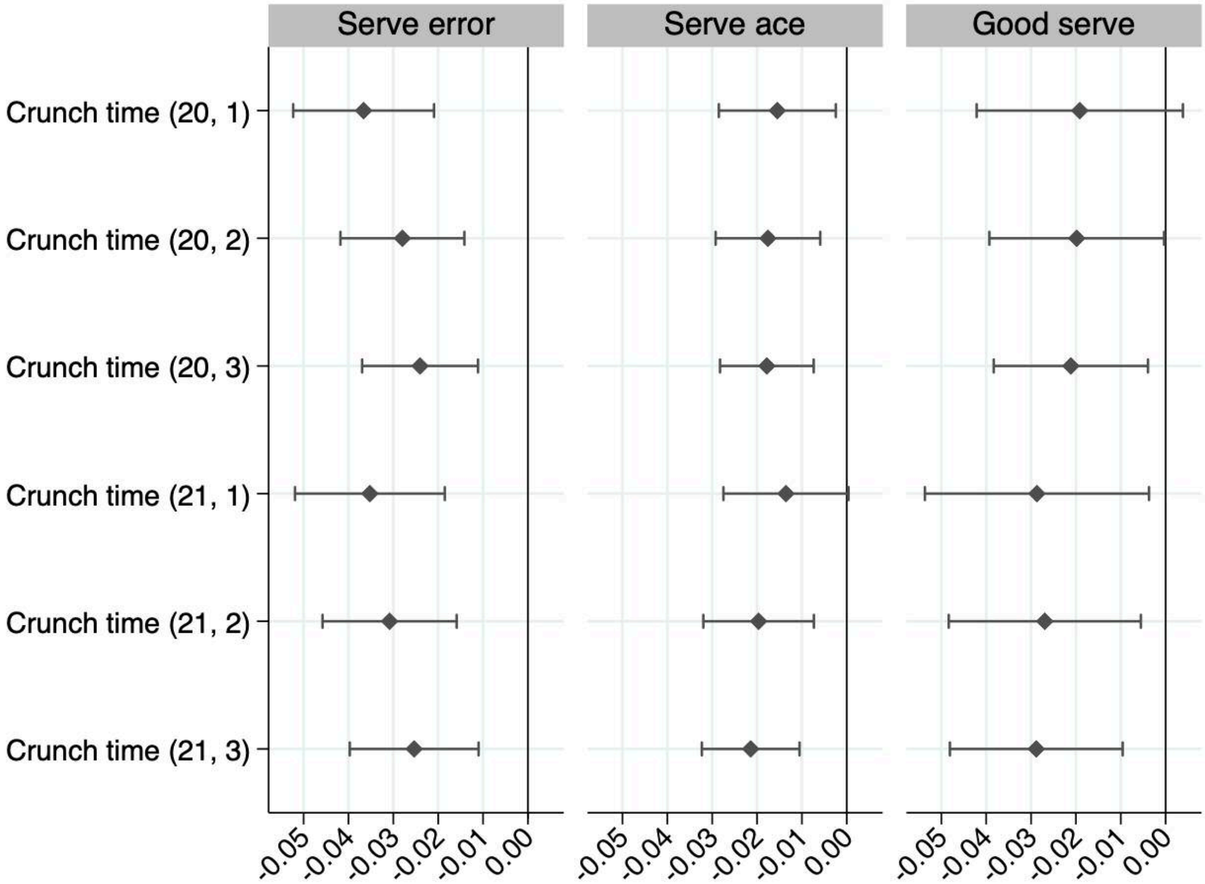
Notes: * p<0.10, ** p<0.05, *** p<0.01; Coefficient estimates from ordinary least squares estimations. Standard errors clustered on team-player level. The dependent variable is a dummy variable equals 1 when the player employs a jump serve and zero otherwise (*Jump serve*). The explanatory variable of main interest is the variable *Crunch time*. It equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. The interaction variable *Lag behind x Crunch time* is a dummy variable that equals 1 if a player serves the ball in the crunch time and her team is lagging behind. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set. *Set 2* omitted. Constant not reported.

Table A.2 Effect of psychological pressure (*Crunch time*) on serving performance of professional volleyball athletes (*Serve error, Serve ace, Good serve*). Crunch time and lag behind interacted. Separated effects by gender.

	Women's sample			Men's sample		
Dependent variable:	Serve error	Serve ace	Good serve	Serve error	Serve ace	Good serve
	(1)	(2)	(3)	(4)	(5)	(6)
Crunch time	-0.028*** (0.0083)	-0.023*** (0.0077)	-0.027* (0.0157)	-0.039** (0.0157)	-0.020 (0.0124)	-0.023 (0.0191)
Lag behind	-0.004 (0.0048)	-0.011*** (0.0039)	-0.017*** (0.0064)	0.004 (0.0097)	0.001 (0.0057)	0.009 (0.0099)
Lag behind x crunch time	0.014 (0.0173)	0.019 (0.0148)	0.023 (0.0257)	0.009 (0.0269)	0.004 (0.0178)	0.019 (0.0302)
Home team	-0.009** (0.0040)	0.001 (0.0034)	0.007 (0.0057)	0.010 (0.0078)	0.011** (0.0053)	-0.001 (0.0095)
Team timeout	0.013 (0.0100)	-0.014** (0.0064)	-0.027** (0.0113)	-0.008 (0.0151)	-0.003 (0.0108)	-0.018 (0.0208)
Technical timeout	-0.015* (0.0080)	0.002 (0.0089)	-0.006 (0.0129)	-0.005 (0.0142)	-0.014 (0.0106)	-0.040** (0.0173)
First serve of set	-0.007 (0.0112)	0.014 (0.0133)	-0.027 (0.0179)	0.006 (0.0268)	-0.021 (0.0142)	-0.026 (0.0287)
Set 1	0.004 (0.0051)	-0.003 (0.0043)	0.004 (0.0077)	0.012 (0.0100)	0.000 (0.0062)	-0.011 (0.0101)
Set 2	Reference category					
Set 3	0.007 (0.0052)	-0.002 (0.0048)	-0.007 (0.0076)	-0.017* (0.0096)	-0.002 (0.0059)	-0.006 (0.0121)
Set 4	-0.004 (0.0058)	-0.005 (0.0047)	-0.003 (0.0092)	-0.009 (0.0128)	-0.009 (0.0085)	0.005 (0.0160)
Set 5	-0.027*** (0.0093)	0.006 (0.0096)	0.002 (0.0141)	-0.021 (0.0207)	-0.022 (0.0140)	-0.037 (0.0257)
Player FE	yes	yes	yes	yes	yes	yes
Match FE	yes	yes	yes	yes	yes	yes
Observations	24678	24678	24678	11375	11375	11375
Adjusted R^2	0.021	0.005	0.030	0.037	0.013	0.038

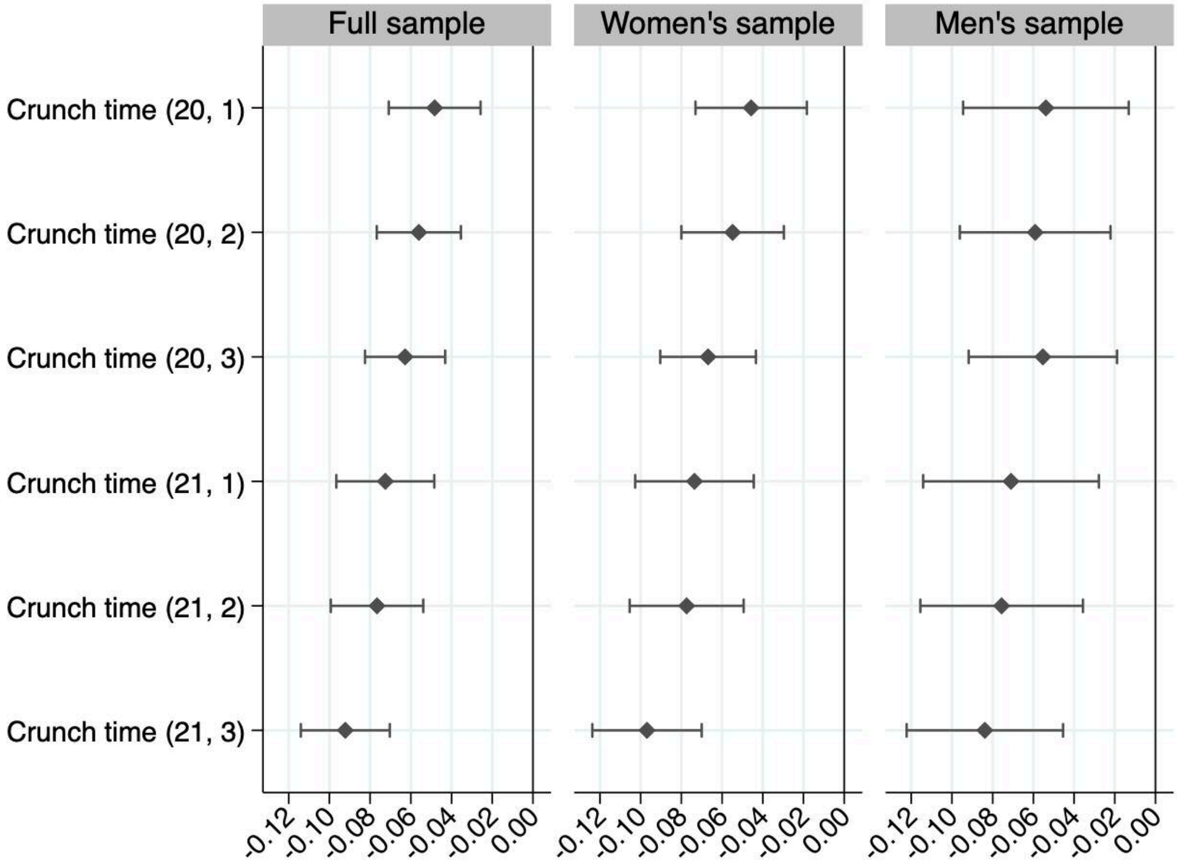
Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$; Coefficient estimates from ordinary least squares estimations. Standard errors clustered on team-player level. The dependent variable is a dummy variable equals 1 when the serving player commits a serve error in columns (1) and (4), when the serving player scores a direct point (ace) in columns (2) and (5) and when the player's serve is rated as good, very good or an ace in columns (3) and (6). The explanatory variable of main interest is the variable *Crunch time*. It equals 1 if the serve occurs in a situation where both teams have at least 20 points and the difference is at most two points. *Lag behind* is a dummy variable that equals 1 if the serving team is lagging behind and 0 otherwise. The interaction variable *Lag behind x Crunch time* is a dummy variable that equals 1 if a player serves the ball in the crunch time and her team is lagging behind. *Home team* is a dummy variable that equals 1 if the serving player belongs to the home team and 0 otherwise. *Team timeout* and *Technical timeout* are dummy variables that equal 1 if the serve was carried out after a team timeout or a technical timeout, respectively. *Set 1*, *Set 3*, *Set 4* and *Set 5* are dummy variables that equal 1 if the serve was carried out in the respective set. *Set 2* omitted. Constant not reported.

Figure A.1 Effect of different crunch time definitions on serving performance. OLS estimates and 95 percent confidence intervals displayed.



Displayed are the coefficients and 95 percent confidence intervals of the respective *Crunch time* variable. Estimates obtained from OLS regressions with the respective performance outcome as dependent variable and the full set of control variables. The variable *Crunch time (i, j)* equals one if both teams scored at least *i* points and the score difference is at most *j* point(s).

Figure A.2 Effect of different crunch time definitions on the probability of the serving team to score by sample. OLS estimates and 95 percent confidence intervals displayed.



Displayed are the coefficients and 95 percent confidence intervals of the respective *Crunch time* variable. Estimates obtained from OLS regressions with the variable *Break point* as dependent variable and the full set of control variables. *Break point* equals 1 when the serving team scores. The variable *Crunch time (i, j)* equals one if both teams scored at least *i* points and the score difference is at most *j* point(s).