Risk-taking in contests with heterogeneous players and intermediate Information—Evidence from handball

Lena Neuberg1 and Stefan Thiem1

Abstract
This paper analyzes the risk-taking behavior of heterogeneous players in dynamic contests with intermediate information. Using data from the first German Handball league, we measure risk-taking by substituting the goalkeeper for an additional field player. By differentiating between ex-ante and in-game heterogeneity, we show that underdogs and trailing teams are willing to take more risks and that favourites and underdogs react differently to interim information. Trailing underdogs choose riskier strategies than trailing favorites during a match. The increased overall risk-taking is indeed beneficial for underdogs, whereas favourites lose significantly more games as a result of increased risk-taking.

Introduction
Be it bonus schemes in companies, political campaigns or even sporting competitions, the pay of participants frequently depends on their performance relative to other competitors, rather than on absolute performance. Above all, when monitoring productivity is costly or difficult, rank-order tournaments create a unique opportunity to assess the ability of workers, all while inducing incentives to elicit effort (see Lazear & Rosen, 1981; Green & Stokey, 1983; Nalebuff & Stiglitz, 1983;
Nevertheless, as agents do not decide only how much effort to provide, but also how much risk they are willing to take, they can jeopardize the efficiency of the contest (Hvide & Kristiansen, 2003).

In fact, whenever agents are heterogeneous, and thus have different win probabilities — either caused by differences in ability (ex-ante heterogeneity) or by differences in score (in-game heterogeneity) — less able and trailing agents might feel compelled to partake in riskier choices in order to have an increased chance of winning the tournament (see Rosen, 1988, referring to Bronars, 1986; Knoeber & Thurman, 1994; Kräkel & Sliwka, 2004). This possibility to offset ability or score differences with risky strategies introduces considerable noise into the tournament, resulting in a growing interest in literature in the risk-taking behaviour of agents in tournaments and their associated efficiency.

The bulk of previous literature on risk-taking in tournaments concentrates on one type of heterogeneity — either ex-ante or in-game heterogeneity. The majority confirms that indeed, either less able (underdogs) or trailing agents seem to increase risk in order still to have a chance of winning the tournament, while more able (favourites) and leading agents prefer safer strategies to secure their lead, and rely on their surplus in ability or their lead (Rosen, 1988; Becker & Huselid, 1992; Knoeber & Thurman, 1994; Chevalier & Ellison, 1997; Brown et al., 1996; Nieken & Sliwka, 2010).

In the real world, however, agents are rarely homogeneous and with performance feedback over the course of the tournament, additional asymmetries are unavoidable. Thus, in most contests, agents are confronted with both types of heterogeneity — ex-ante and in-game. This poses the question of whether favourites and underdogs react differently to interim information. In particular when agents face a score deficit, the behaviour of agents could diverge substantially. On the one hand, as favourites surpass their competitor in ability, they might rely on their surplus in ability to win, even when facing a deficit, instead of opting for a risk gamble (Schneemann, 2017). On the other hand, as expectations about performance and loss aversion play a crucial role in individual risk decisions, favourites may increase risk-taking in order to avoid an unexpected loss (Kahneman & Tversky, 1979; Lehman & Hahn, 2013; Bartling et al., 2015). Therefore, the aim of this paper is to examine how risk-taking behaviour is affected when agents are confronted with both types of heterogeneity, and whether increased risk-taking is beneficial for heterogeneous agents.

In order to investigate the difference in risk-taking strategies of heterogeneous agents over the course of a contest, we use a data set from two seasons of the German Handball-Bundesliga. Coaches in this sport have the unique opportunity to replace the goalkeeper with an additional field player at any time and as often as they like over the course of the match. This replacement option serves as an excellent proxy for risk-taking as an additional field player not only increases the number of field players, and thus the probability of a successful attack, but also leaves the attacking team vulnerable to a fastbreak and an easy goal for the opponent. As our
data set includes all attacks during a match and the respective score during the attack, we are able to allocate risk decisions to a specific time during the game, and show that timing in the contest is pivotal for the agent’s risk decision. Additionally, by using the goal differential to control for leading and trailing teams and the rank differential to control for underdogs and favourites, we can observe whether or not risk-taking behaviour differs for the respective parties.

Our study contributes to existing literature in several respects. First, we confirm previous results that both underdogs and trailing teams indeed chose riskier strategies than underdogs or leading teams. Second, we expand previous literature by observing risk-taking behaviour of agents facing both types of heterogeneity. Compared to trailing favourites, we show that trailing underdogs increase risk-taking to a larger extent, as favourites seem to rely on their ability surplus. However, this behaviour changes towards the end of the match when the influence of in-game heterogeneity exceeds the influence of ex-ante heterogeneity on risk-taking. Contrary to earlier in the match, trailing favourites now opt for riskier strategies than trailing underdogs. Third, our investigation offers new insights into the effectiveness of increased risk-taking. Our data indicates that the increased overall risk-taking does indeed pay off, albeit only for underdogs. Towards the end of the match, however, the beneficiary of increased risk-taking switches and only trailing favourites benefit from increased risk-taking.

Our result regarding the payoff of risk-taking is surprising, as previous research has questioned the effectiveness of this behaviour, finding that neither trailing teams nor underdogs benefit from increased risk-taking (Bartling et al., 2015; Grund & Gürtler, 2005; Grund et al., 2013; Schneemann, 2017). Using substitutions as a proxy for risk-taking, Grund and Gürtler (2005) find that increased risk-taking for trailing teams impacts score and point advancement negatively. Schneemann (2017) arrives at a similar conclusion. In addition to substitution strategies, Bartling et al. (2015) extend their risk analysis to yellow and red cards, as this implies a more aggressive and thus riskier form of play.2 If agents perform below their expectation, Bartling et al. (2015) find that both substitutions and cards affect match outcome negatively. Grund et al. (2013) check whether an increased fraction of three-point attempts in the last period of NBA matches compared to previous periods has a significant effect on win probability. They confirm that in close settings, trailing agents do not benefit from increased risk-taking. This holds for both trailing favourites and trailing underdogs. There is, however, some indication that teams with very high deficits might gain from an increase in three point attempts (Grund et al., 2013). Using professional handball penalty data, Bühren and Gabriel (2021) find that the overall tendency of players to take risks does not influence shot success during the game. There is, nevertheless, some evidence that higher risk-taking when leading has a detrimental effect on shot success during the last minutes of the match.

The remainder of this paper is structured as follows: Sections 2 and 3 derive hypothesis regarding the risk-taking behavior of heterogeneous agents in tournaments and examine risk-taking in handball. In Section 4, we present the data and
descriptive statistics, before the empirical results are presented in Section 5. Section 6 then examines the effectiveness of risk-taking actions in handball. The paper concludes with Section 7.

**Risk-taking of heterogeneous agents in tournaments**

Previous research on ex-ante heterogeneity assumes that agents base their risk decisions on their opponent’s ability. Due to a higher win probability, the more able agent relies on its ability and chooses a less risky strategy. The less able agent, however, is compelled to decide on a riskier strategy to increase win-probability (see Rosen, 1988, referring to Bronars, 1986; Knoeber & Thurman, 1994; Kräkel & Sliwka, 2004). The respective behaviour has been confirmed by various empirical studies. For instance, Knoeber and Thurman (1994) investigate the performance variability of contracted producers of broiler chickens. They find that more able producers have a lower variance in performance, implying the use of a less risky strategy. The opposite holds for producers with a lower mean performance. Ozbeklik and Smith (2017) observe similar behaviour amongst golfers in match-play tournaments. Using the variation of relative-to-par scores and the percent of holes conceded as risk measurements, they also find that less able agents indeed opt for riskier strategies. Based on previous literature, we thus formulate the following hypothesis:

**Hypothesis 1:** With an increasing difference in ability, underdogs use a more risky strategy than favourites in order to increase their winning chances.

Nonetheless, asymmetry in tournaments does not arise solely due to ex-ante heterogeneity. In fact, feedback about previous performance in the tournament affects the risk decisions of individuals similarly, since it reveals in-game heterogeneity (Grund et al., 2013). While the trailing agents increase their risk to maintain a chance of winning the tournament, leading agents—having no desire to jeopardize their lead—choose less risky strategies (see Rosen, 1988, referring to Bronars, 1986; Chevalier & Ellison, 1997; Grund et al., 2013; Nieken & Sliwka, 2010). For instance, fund managers adjust their portfolio decisions when their fund performance is below average and increase their fund volatility (Brown et al., 1996; Chevalier & Ellison, 1997). Similarly, coaches substitute more offensively when trailing behind (see Grund & Gürttler, 2005). Hence, the literature suggests a negative relationship between performance feedback and risk-taking. Nevertheless, leading and trailing in itself are not the only factors influencing risk decisions. Similar to rank difference, the scale of the lead or deficit might have a substantial effect on risk choices. Indeed, Bothner et al. (2007) use NASCAR races to investigate how crowding effects risk-taking decisions in tournaments. Using car crashes as proxy for risk-taking, they find that agents are more concerned with losing their current standing in the
ranking and increase risk to avoid a loss in position. Hence, agents are not incentivized only by their position in the ranking, but also by how close their opponents are located in the ranking. Genakos and Pagliero (2012) confirm this result when investigating the behaviour of agents, based on interim rank information in weightlifting competitions. Using the announcement of weight prior to the lift as a measure of risk, they find an inverted U-shaped relationship between rank and risk-taking. Thus, athletes decide on higher risk strategies when in immediate reach of the top. Nonetheless, with decreasing rank, riskier decisions decrease, as winning becomes unlikely. This argumentation leads to the following hypotheses:

**Hypothesis 2a:** Trailing agents chose riskier strategies than leading agents.

**Hypothesis 2b:** The relationship between the difference in score and risk-taking behaviour of trailing agents follows an inverted u-shape.

To the best of our knowledge only two studies have tackled the effect of both heterogeneities on risk-taking behaviour. Schneemann (2017) stresses the importance of ability in risk-taking decisions when it comes to interim information. As favourites usually also have a higher level of ability, they do not require increased risk-taking when trailing behind. Instead they rely on their ability surplus to even out the score. The underdog, however, does not have the same privilege and continues to rely on riskier strategies. In order to investigate the risk strategies of soccer coaches over the course of a match, Schneemann (2017) uses the substitutions from the knockout stages of the UEFA Champions League. By measuring the offensive strength for different positions based on average goals and assists, she compares the offensive strength of incoming and outgoing players for each substitution. As the substitution of a more offensive player not only increases the probability of scoring, but also of conceding a goal, it indicates a riskier strategy. By investigating substitution strategies over the course of the match, she confirms that coaches of trailing underdogs substitute more offensively than those of trailing favourites when trailing by one goal. In cases of a larger deficit, however, risk strategies change and trailing favourites are more risk-friendly than trailing underdogs. Unfortunately, coaches in Champions League matches are limited to a certain amount of substitution, and thus somewhat restricted in their decision making.

Using shot data from NBA matches, Grund et al. (2013) offer an alternative and more continuous approach to assessing risk strategies. Depending on the distance, NBA players can score either two or three points for a successful shot, with shots from a larger distance earning more points. Although data shows that the expected points for both attempts are similar, three-point attempts have a significantly higher variance, thus indicating a riskier strategy. Comparing the fraction of three point attempts in the last minutes of the match to its use in previous periods, they find that trailing favourites tend to be more risk-friendly in the last minutes of the match than trailing underdogs. They argue that this observation might be caused
by different utility functions. While a loss by a small margin of an underdog might still be perceived as a win, this, is not the case for favourites. Thus, favourites benefit more from catching up than underdogs and tend to opt for riskier strategies. Increased risk-taking by trailing favourites, however, might additionally be explained by loss aversion and expectations. According to the theory, agents suffer a greater disutility from a loss than the utility from an equally high gain (see Kahneman & Tversky, 1979). Thus, individuals risk more to avoid a loss than to secure an equally large gain, leading individuals to be risk-friendly in losses and risk averse in gains. As gains and losses are defined not only with reference to the status quo, but also previous performance and expectations, changes in risk-taking might be more sensitive than otherwise if performance is below the aspiration level (Abeler, 2011; Ericson & Fuster, 2011; Kahneman & Tversky, 1979; Koszegi & Rabin, 2006, 2007; Samuelson & Zeckhauser, 1988). Indeed, using substitutions and betting odds in soccer games as reference points, Bartling et al. (2015) confirm that coaches substitute more offensively when lagging behind in expectations. Based on this observation, trailing favourites—performing below their expectation—increase risk-taking to avoid losing the match.

The seemingly contradictory results of Schneemann (2017) and Grund et al. (2013) of trailing favourites either decreasing or increasing risk-taking compared to underdogs are not necessarily at odds with one another. In fact, we are convinced that both attitudes towards risk-taking can be observed during a tournament, which, however, depends crucially on the timing of the decision in the contest. While Schneemann (2017) uses substitution data of the entire game, Grund et al. (2013) focus purely on the last minutes of the match. Nevertheless, since tournaments often consist of various stages, agents consistently obtain feedback about their relative position in the tournament and their productivity compared to their opponent (see Ederer, 2010). With constant feedback, agents can adjust their strategies more than once over the course of the tournament. This holds for the adjustment of effort (see e.g. Bach et al., 2009; Berger & Pope, 2011; Berger & Nieken, 2016; Iqbal & Krumr, 2019; Schneemann & Deutscher, 2017), as well as for the adjustment of risk-taking (see e.g. Bothner et al., 2007; Chevalier & Ellison, 1997; Grund & Gürtler, 2005; Genakos & Pagliero, 2012). At the beginning of the game, trailing favourites have the option to equalize the score with ability alone, and thus might revert to less risky strategies than trailing underdogs. Particularly in the last minutes of the game, however, expectations about relative performance might change the risk behaviour of agents, as the relationship between performance and risk-taking is stronger for performance below the aspiration level than for performance above it (see Bartling et al., 2015; Kahneman & Tversky, 1979; Lehman & Hahn, 2013). Thus, agents such as trailing favourites performing below their expectation, might eventually opt for riskier strategies to avoid an unexpected loss. As we expect a shift in risk strategies over the course of the tournament, we formulate the following hypotheses:
**Hypothesis 3a:** Overall, trailing favourites choose a less risky strategy than trailing underdogs, as they believe they can offset a temporary deficit with their ability.

**Hypothesis 3b:** Towards the end of a contest, trailing favourites will adopt a more risk-seeking strategy than trailing underdogs due to loss aversion.

**Risk-taking in handball**

Handball is a team sport in which two teams of seven compete against one another. In a ‘standard’ play of handball, six attackers face six defenders of the opposing team, both teams having a goalkeeper. This situation is usually referred to as six versus six (6 vs 6). Over the course of the match, coaches can substitute their players for one another at any time and do not have to inform the referee about their changes. This also applies to the substitution of the goalkeeper with an additional field player. In 2016, the rules of this substitution were expanded to create more tactical opportunities and make the sport more attractive to viewers. Since the rule change, coaches can substitute the goalkeeper with any field player during an attack, allowing for an additional field player. Unlike previously, this substituted field player has not to be marked as the goalkeeper’s replacement and is allowed to act like any other field player. This implies, that he is not allowed to enter the goal perimeter to defend a goal. After a turnover—due to a goal, loss in possession or unsuccessful attack—the goalkeeper can only re-enter the play in exchange for one of the current players on the field. Thus, before a sending the goalkeeper with another substitution back on the pitch, the goal is empty and the opponent can simply throw the ball into the empty goal and score.

Irrespective of the risk of leaving the goal empty, coaches mainly opt for the new substitution strategy to achieve two things: First, to offset the numerical imbalance caused by a two-minute suspension and second, to use the additional field player to outnumber the opponent and obtain a numerical advantage. In the first case, the attacking team is short-handed as at least one player has to leave the pitch for two minutes due to a rough foul. With the option of substituting the goalkeeper, the attacking team has the option of offsetting the imbalance caused by the suspension. Most frequently, the additional field player comes into play when the attacking team is one player down. In this case, the team can still maintain the ‘standard’ handball attack with six attackers and six defenders (6* vs 6). This behavior has been widely adapted in the handball community. Indeed, almost all teams have adopted this technique if facing a suspension (Montoya, 2016).

In the second case, the substitution can be used to outnumber the defending team and give the attacking team a numerical advantage. Most commonly, this is the case when the attacking team does not face a suspension and the coach deliberately decides to use an additional field player to outnumber the opposing team and thus increase their probability of scoring a goal (7* vs 6). Another option for substitutions
results in \((6^* \text{ vs } 5)\) (instead of \((5 \text{ vs } 5)\)) when both teams face a two-minute suspension or \((7^* \text{ vs } 5)\) when the attacking team uses two more players by substituting their goalkeeper, and the opposing team suffers a two-minute suspension.\(^7\)

In both cases, the possibility to substitute the goalkeeper with an additional field player increases the team’s chances of scoring a goal, while leaving the team vulnerable to a fastbreak and a counterattack. Thus, we argue that the use of an additional field player serves as an excellent proxy for risk-taking behavior. Nevertheless, in order to analyze the effect of heterogeneity on risk-taking, we will focus on the remainder of the paper on the case of the attacking team substituting their goalkeeper when none of the team faces a time penalty \((7^* \text{ vs } 6)\). The main reason for said restriction is that in the other situations, either the attacking or opposing (or both) teams faces a two-minute suspension. Having less players on the field, however, might bias decision making substantially.

Regarding our previously stated hypotheses, we expect both less able and trailing teams to opt for riskier strategies. Thus, when facing an ability or score deficit, coaches increasingly opt for an additional field player. In contrast to soccer, handball is a high-scoring game and has—particularly in close games—many turnarounds. Thus, we expect the previously mentioned behaviour only occurs when the score is close. Regarding the combination of both asymmetries, we expect a shift in behaviour. While, over the course of the match, trailing favourites opt for less risk than trailing underdogs, they surpass trailing underdogs in their risk-taking towards the end of the match.

**Data and Descriptive Statistics**

In our study, we use data from the major handball league in Germany for the first two seasons after the rule change. Thus, our data entails 306 games of the 2016/17 season and 305 games of the 2017/18 season of the first handball league in Germany.\(^8\) The first league consists of 18 teams competing for the title. The league is played as a round-robin tournament with each team playing one another twice (one home and one away game), resulting in 34 game days. The highest ranked teams have the chance to play internationally, whereas the three lowest ranked teams face relegation.\(^9\) Teams obtain two points for each win and one point for a draw. At the end of the season the teams are ranked by points. In case of a tie, the difference in goals is decisive for the ranking in the table.

The data was recorded by the coaching software ‘XPS Sideline’ in order to collect data for a central database that can be used by coaches and teams to obtain information about game plays and their effectiveness. It contains detailed information about all plays by the teams (including the use of the 7th field player), the intermediate score and the result of the respective play. Not all plays result in an immediate change in possession, as a member of the defending team might commit a foul or deflect the ball out of play, leading either to a free throw or to a throw-in. Indeed,
an attack may include many offensive plays. Hence, a possible result of a play may be a goal, a miss, a (standard) foul committed by the opponent (resulting in a free throw) or a technical fault. A possession can also result in a penalty, if the opponent commits a hard foul or steps into the goal perimeter. The penalty throw itself, however, is considered a new play. Thus, similar to Bauer (2019), we limit our data to plays, which lead to a change in possession (goal, penalty, miss or technical fault) to avoid a doubling of observations. Furthermore, we classify a play as a success, if the result is either a goal or a penalty. In addition, we restrict the data set to set plays (no fastbreaks) and to possessions when neither team faces any time penalties, as being shorthanded might affect decision making. Additionally, we extended the data set with match results, the standing of both teams at the end of the season and the rank difference between the two teams. Similar to Thiem (2021) we have chosen standings at the end of the season instead of current positions in the league, as they reflect the strength of the team more accurately. In fact, the current standing might be severely biased due to the amount of matches and the strength of teams played before. Table 1 presents the descriptive statistics of the variables used in this paper.

**Empirical Investigation**

7th field player as a risky-strategy

To analyze the risk-taking behaviour of teams in handball matches, we need to prove first and foremost that the use of an additional seventh field player indeed serves as an adequate proxy for risk-taking. For this assumption to hold, the strategy needs to be rewarded with a higher success rate. At the same time, an additional field player has to increase the risk of conceding a goal in case of a turnover.

| Statistic                        | N    | Mean | St. Dev. | Min | Max |
|----------------------------------|------|------|----------|-----|-----|
| 7*vs6                            | 37,061 | 0.055 | 0.227    | 0   | 1   |
| Success of a possession          | 37,061 | 0.527 | 0.499    | 0   | 1   |
| Rank Difference                  | 37,061 | 0.310 | 7.581    | -17 | 17  |
| Standing Attacking Team          | 37,061 | 9.583 | 5.186    | 1   | 18  |
| Standing Defensive Team          | 37,061 | 9.274 | 5.190    | 1   | 18  |
| Favourite                        | 37,061 | 0.485 | 0.500    | 0   | 1   |
| Home                             | 37,061 | 0.488 | 0.500    | 0   | 1   |
| Goal Differential                | 37,061 | 0.079 | 4.284    | -24 | 23  |
| Trailing                         | 37,061 | 0.422 | 0.494    | 0   | 1   |

Notes: Goal differential measures the current difference between the team’s goals scored and the opponent’s goals at the beginning of a possession.
The following Table 2 shows the success of a possession in a linear probability model, dependent on the use of the 7th player together with several variables controlling for the heterogeneity of the two competing teams. Similar to Haas and Nüesch 2012 and Schneemann (2017), we use a linear probability model instead of a non-linear model to avoid the incidental parameter problem in panel data sets or in regression models with fixed effects, and to include all data, since some teams or matches would be removed in a non-linear model, as some teams did not use the 7th field player in matches.11 As control variables, we employ the location of the match, the rank difference between the two teams at the end of the season, the standing of the attacking teams (model (1)) as well as team-season (model (2)), and solely team-game fixed effects (model (3)).

The results of an ordinary least squares (OLS) regression from Table 2 show that using the 7th field player undeniably increases the probability of a successful possession significantly.12 This is not surprising, as the attacking team has the numerical advantage.

In the next regression, we measure the effect on the success of a possession, if the opponent had used the 7th field player in its last possession (measured by the variable Before 7*vs6), to check whether there are also negative consequences for teams using this strategy. As can be seen in Table 3, the likelihood of success of the opponent in its next possession indeed increases, particularly if the team had used the strategy of

| Table 2. Impact of the 7th field player on success of a possession. |
|---------------------------------------------------------------|
| Depend*ent variable:                                         |
| Success of a possession                                     |
| (1)              (2)              (3)                               |
| 7*vs6           0.032***       0.029**       0.052***             |
|                 (0.012)        (0.012)       (0.015)                 |
| Standing Attacking Team                                    -0.045          |
|                                                             (0.068)        |
| Rank Difference                                            -0.492***      -0.490***     |
|                                                             (0.048)        (0.047)    |
| Home                                                       0.020***       0.020***     |
|                                                             (0.005)        (0.005)    |
| Season Fixed Effects                                       Yes             No             No          |
| Team-Season Fixed Effects                                  No              Yes            No          |
| Team-Game Fixed Effects                                    No              No             Yes         |
| Observations                                               37,061          37,061         37,061     |
| R²                                                         0.006            0.003          0.001      |

Notes: Values in parentheses are robust standard errors, clustered by team-game. The variables Rank Difference and Standing Attacking Team are scaled with the factor 100.

*p<0.1; **p<0.05; ***p<0.01.
the 7th field player unsuccessfully (Before 7*vs6 · Before Miss), as there is no goalkeeper protecting the goal in counterattacks.

It can be noted that the positive effect of using the 7th player is almost the same as the negative effect in the next opponent’s possession. Thus, the expected net value of this strategy is almost identical to not using the 7th field player, which one would expect and is line with observations of Grund et al. (2013) on three-point attempts in the NBA. However, the larger variance of the expected net value of this strategy indicates that using the 7th player is indeed a risky strategy.

**Risk-taking with ex-ante heterogeneous players**

After confirming that replacing the goalkeeper indeed serves as a suitable proxy for risk-taking, we investigate whether ability differences between the two teams (ex-ante heterogeneity) has an effect on risk-taking decisions. In particular, we consider whether lower ability handball teams use the strategy of the 7th player more often to increase their winning chances. At this point, we measure inequality by the rank difference of the two competing teams at the end of the season. To avoid any bias from using risky strategies towards the current score, we focus on

|                | (1)       | (2)       | (3)       | (4)       |
|----------------|-----------|-----------|-----------|-----------|
| Before 7*vs6   | 0.030**   | 0.018     |           |           |
|                | (0.013)   | (0.016)   |           |           |
| Before 7*vs6 · Before Miss | 0.066*** | 0.054*** |           |           |
|                | (0.016) | (0.018)   |           |           |
| Before 7*vs6 · Before Success | -0.006 | -0.018    |           |           |
|                | (0.019) | (0.021)   |           |           |
| Before Success | -0.032***| -0.035*** |           |           |
|                | (0.005) | (0.005)   |           |           |
| Rank Difference| -0.414***| -0.395*** |           |           |
|                | (0.045) | (0.045)   |           |           |
| Home           | 0.021*** | 0.020***  |           |           |
|                | (0.005) | (0.005)   |           |           |
| Team-Season Fixed Effects | Yes | Yes | No | No |
| Team-Game Fixed Effects | No | No | Yes | Yes |
| Observations  | 37,326   | 37,326    | 37,326    | 37,326    |
| R²             | 0.003    | 0.004     | 0.001     | 0.002     |

Notes: Values in parentheses are robust standard errors, clustered by team-game. Possessions with a fastbreak are included. The variable Rank Difference is scaled with the factor 100.

*p<0.1; **p<0.05; ***p<0.01.
possessions at the beginning of a match, when the score is usually still tied or very close. We therefore create two dummy variables \textit{First} 6 and \textit{First} 12 that equal one if a team choose to use the 7th field player at least once in their first 6 or respectively 12 possessions of a match. At this point, we prefer these clustered variables to an analysis of each possession, as we want to use these variables in the remainder of the paper to evaluate the effectiveness of this strategy. However, our results are also robust if we study the probability of using the 7th field player in each possession at the beginning of a match, instead of clustering the data to these new two variables (see Table A2 in the appendix).

The results from Table 4 show that risk-taking does not depend only on a team’s own ability in general, as the estimators of the variable \textit{Standing Attacking Team} in columns (1) and (3) of Table 4 are insignificant, but rather on the opposing team’s strength as well. Teams adjust their risk-taking behaviour to the relative strength of their opponent, because the estimator of the variable \textit{Rank Difference} is significantly positive. Thus, underdogs are willing to take more risks in order to increase their winning chances. In addition, this effect becomes stronger with increasing heterogeneity between the two teams. As we only investigate possessions at the

\begin{table}
\centering
\caption{Impact of ex-ante heterogeneity on risk-taking.}
\begin{tabular}{lcccc}
\hline
 & \multicolumn{2}{c}{At least once} & \multicolumn{2}{c}{At least once} \\
 & \text{in first 6 Possessions} & \text{in first 12 Possessions} \\
\hline
\text{Constant} & 0.014 & 0.067*** & (0.014) & (0.029) \\
\text{Rank Difference} & 0.144* & 0.144* & 0.358*** & 0.361*** \\
 & (0.078) & (0.078) & (0.168) & (0.169) \\
\text{Standing Attacking Team} & -0.007 & -0.248 & (0.139) & (0.264) \\
Home & -0.007 & -0.007 & -0.005 & -0.005 \\
 & (0.007) & (0.007) & (0.013) & (0.013) \\
\text{Season Fixed Effects} & Yes & No & Yes & No \\
\text{Team-Season Fixed Effects} & No & Yes & No & Yes \\
\text{Observations} & 1,222 & 1,222 & 1,222 & 1,222 \\
\text{\textnumero}^2 & 0.015 & 0.003 & 0.015 & 0.007 \\
\hline
\end{tabular}
\end{table}

Notes: Values in parentheses are robust standard errors, clustered by team-season. The variables \textit{Rank Difference} and \textit{Standing Attacking Team} are scaled with the factor 100.
*p<0.1; **p<0.05; ***p<0.01.
beginning of a match in this regression, one can assume that this strategy is part of the game plan developed by coaches of underdog teams prior to the match. These findings confirm Hypothesis 1.14

### Risk-taking with in-game heterogeneity

Next, we investigate teams’ risk-taking choices on intermediate scores during a match. In particular, we study whether risk-taking behaviour changes if teams are trailing, and whether or not this potential reaction is additionally dependent on the current deficit. Therefore, we analyse team risk-taking choices in different circumstances (teams leading and tailing) in each possession, while controlling for heterogeneity in playing abilities of the two teams, home-field advantage, crowd-effects and general team risk-taking strategies with team-game fixed effects. Furthermore, we add the variables Goal Differential and Goal Differential^2 as additional explanatory variables to our model in order to test for non-linear effects of the current score (Columns (2) and (3) in Table 5).

As can be seen in Column (1) of Table 5, teams choose to use the 7th field player more often, when they are trailing. Hence, teams indeed adjust their risk-taking

### Table 5. Impact of in-game heterogeneity on risk-taking.

|                | (1)     | (2)     | (3)     |
|----------------|---------|---------|---------|
| Dependent variable: | 7^*vs6  |         |         |
| Behind         | 0.054***| 0.045***| −0.008  |
| (0.006)        | (0.007) | (0.008) |         |
| Goal Differential | −0.225**|         |         |
| (0.112)        |         |         |         |
| Goal Differential^2 | 2.116*   |         |         |
| (1.253)        |         |         |         |
| Goal Differential · Leading | 1.666    |         |         |
| (1.344)        |         |         |         |
| Goal Differential^2 · Leading | 0.102    |         |         |
| (0.135)        |         |         |         |
| Goal Differential · Behind | −3.559*** |         |         |
| (0.459)        |         |         |         |
| Goal Differential^2 · Behind | −23.922*** |         |         |
| (3.383)        |         |         |         |
| Team-Game Fixed Effects | Yes     | Yes     | Yes     |
| Observations   | 37,061  | 37,061  | 37,061  |
| R²             | 0.009   | 0.010   | 0.023   |

**Notes:** Values in parentheses are robust standard errors, clustered by team-game. The variable Goal Differential is scaled with the factor 100. *p<0.1; **p<0.05; ***p<0.01.
strategy to the circumstance of leading or trailing. Following this result, we subse-
quently check whether the intermediate goal differential also influences the usage
of risky strategies.

In addition, according to the results in Column (3) of Table 5, leading teams stick
to their game plan and do not change their risk-strategies regarding the current score.
However, as the estimators for the variables Goal Differential and Goal Differential
to trailing teams, teams lagging behind in score adjust to
the goal differential by taking more risk until they believe that they cannot overcome
the current deficit (at around 9 goals), as they opt for less risky strategies upon reach-
ing said point. The results from Table 5 strongly support the theoretical consider-
ations of Hypothesis 2.

### Risk-taking with in-game heterogeneity and heterogeneous teams

As the main focal point of our study, we investigate whether teams with heteroge-
eous playing abilities (namely favourites and underdogs) react differently in risk-
taking to intermediate information. Following the results from Table 5, we only
check whether there is an effect on trailing teams, as there seems to be no risk-taking
effect on leading teams regarding the current score.

| Table 6. Impact of in-game heterogeneity on risk-taking with heterogeneous teams. |
|-----------------------------------------------|
| **Dependent variable:**                      |
|                                               |
| 7∗vs6                                         |
| (1) (2)                                       |
| Trailing · Underdog                          |
| 0.064*** (0.008)                             |
| −0.005 (0.011)                               |
| Trailing · Favourite                         |
| 0.040*** (0.008)                             |
| −0.014 (0.015)                               |
| Goal Differential · Trailing · Underdog       |
| −3.502*** (0.514)                            |
| Goal Differential · Trailing · Favourite      |
| −3.326*** (1.180)                            |
| Goal Differential² · Trailing · Underdog      |
| −23.883*** (3.680)                           |
| Goal Differential² · Trailing · Favourite     |
| −17.615 (13.984)                             |
| Team-Game Fixed Effects                      |
| Yes                                          |
| Yes                                          |
| Observations                                 |
| 37,061                                       |
| 37,061                                       |
| R²                                           |
| 0.009                                        |
| 0.022                                        |

Notes: Values in parentheses are robust standard errors, clustered by team-game. The variable Goal
Differential is scaled with the factor 100.

* p<0.1; ** p<0.05; *** p<0.01.
The results in Column (1) of Table 6 show that both underdogs and favourites increase their risk-taking behavior when trailing, and that this effect is larger for underdogs than for favorites, as favourite teams might believe they can still win the match without taking risky actions.16

Furthermore, trailing underdogs and trailing favourites react differently to intermediate scores, since the estimator for the variable Goal Differential2 is not significant for favourites. Hence, favourites (in contrast to underdogs) still increase their risk-taking behavior with an increased goal differential (regardless of the amount of the deficit). These findings are in line with Schneemann (2017). Favourite teams might believe that they still have a shot at winning the match despite a large deficit. Furthermore, coaches of favourite teams with large deficits teams might send a message to their players, not to give up the match and still demanding full effort by increasing the risk-taking behaviour (see Column (2) in Table 6).

Next, we investigate the risk-taking behavior of favorites and underdogs towards the end of matches, and determine whether trailing teams choose riskier actions close to the end, compared to during the match. To do so, we limit our data to possessions with teams trailing.

In contrast to previous regressions, the estimator of the interaction term Last 12 Possessions · Favourite measures the additional effect on risk-taking in the last 12 possession of favourites compared to underdogs. With this in mind, the results show that favourites increase their risk-taking behavior towards the end of matches in which they are trailing more than trailing underdogs, as the interaction terms for the last 6 and last 3 possessions are significantly positive (see Table 7). However, this does not state that the fraction of possessions, in which a favourite used the 7th field player, is higher for trailing favourites towards the end of matches (and as a consequence, the risk-taking), as we use team-game fixed effects and the overall risk-taking during the course of a match is lower for favourites while trailing.

To determine whether trailing favorites indeed choose riskier strategies towards the end of matches than trailing underdogs, as they are below their own expectations, we use an exact matching model with the favourites being in the treatment group and underdogs in the control group (Ho et al., 2007). As matching covariates, we utilize the current score, the location of the game and the season. Basically, we match a game of a trailing favourite to all games with a trailing underdog that have the exact goal differential played in the same season and location (home or away) as the trailing favourite. Subsequently, we determine whether the likelihood of using the 7th field player in the last three possessions is different between favourites and underdogs by comparing the weighted means in the treatment and control group (average treatment effect).

The results from Table 8 regarding the average treatment effect show that favorite teams indeed use riskier strategies more frequently when trailing towards the end of the match. However, this effect disappears if we only take a look at matches which are still close and not yet decided, as there is then no difference in risk-taking between underdogs and favourites (Column (2) in Table 8). Interestingly, the difference in
### Table 7. Risk-taking with trailing and heterogeneous teams towards the end of matches.

|                      | (1)             | (2)             | (3)             |
|----------------------|-----------------|-----------------|-----------------|
|                      | Last 12 Possessions | 0.027**      | 0.032           |
|                      | (0.012)         | (0.027)        | (0.027)        |
|                      | Last 6 Possessions · Favourite | 0.041***     | 0.054*         |
|                      | (0.012)         | (0.030)        | (0.030)        |
|                      | Last 3 Possessions | 0.036***     | 0.094***        |
|                      | (0.013)         | (0.033)        | (0.033)        |
| Control Variables for Goal Differential | Yes | Yes | Yes |
| Team-Game Fixed Effects | Yes | Yes | Yes |
| Observations | 15,647 | 15,647 | 15,647 |
| R²                  | 0.024           | 0.026           | 0.025           |

Notes: Values in parentheses are robust standard errors, clustered by team-game. Data is limited to possessions with the attacking team trailing. We control for the current score with the variables Goal Differential and Goal Differential² for both underdogs and favourites. 

*p<0.1; **p<0.05; ***p<0.01.

### Table 8. Risk-taking behaviour of trailing favourites towards the end of a match.

|                      | (1)                   | (2)                   | (3)                   |
|----------------------|-----------------------|-----------------------|-----------------------|
|                      | All matches           | Only close matches    | Only decided matches  |
| Favourite            | 0.120**               | 0.051                 | 0.285***               |
|                      | (0.050)               | (0.062)               | (0.087)               |
| Constant             | 0.324***              | 0.342***              | 0.282***              |
|                      | (0.027)               | (0.035)               | (0.041)               |

Notes: Average treatment effects. Standard errors are in brackets. Data is limited to games at which the attacking team is behind with three possessions remaining. In estimation (1), 126 games out of 127 treated games were matched to 313 matches in the control group. In estimation (2), 89 games out of 89 treated ones were matched to 188 matches in the control group. In estimation (3), 37 games out of 38 treated games were matched to 125 games in the control group. Close matches are defined as those with a goal differential of a maximum of four goals. Already decided matches are those with a goal differential of at least five, with three possessions remaining. 

*p<0.1; **p<0.05; ***p<0.01.
risk-taking between favorites and underdogs is quite substantial in already decided matches (goal differential of at least five goals with only three possessions remaining). Furthermore, favourite teams even choose riskier strategies in already decided matches compared to close matches. In our estimation, 56.7% of the favourite teams used the 7th field player at least once when trailing by at least five goals, but only 39.3% favourite teams did so in matches which were not yet decided. We can think of several explanations for this peculiar observation. Although coaches of trailing favourites towards the end of a match might know that their risk-taking actions are of no avail for their teams, they might want to signal their players and their boss that they are not satisfied with the situation by choosing proactive behaviour. This behaviour is labeled “commission bias” in the literature and also studied empirically in several articles (e.g. Grund et al., 2013). Another possible explanation could be a training effect, as coaches might want to practice possessions with the 7th field player for upcoming matches. To test the training hypothesis, we ran another estimation similar to the one above, but this time investigating only leading teams. As the results of this estimation indicate no increased risk-taking behaviour for leading teams in already decided matches (see Table A3 in the appendix), the training hypothesis is not supported in the data and seems rather unlikely.

Impact of risk-taking on success

The primary goal of handball teams is winning matches and gaining points in order to secure a good classification in the round-robin tournament. The strategic use of the 7th field player might be a helpful method for increasing the winning probability during a match. This begs the question whether or not increased risk-taking behaviour is indeed beneficial for handball teams. Thus, we investigate whether teams that have used the 7th field player—especially towards the end of matches—have a higher chance of winning.

When stakes are high and teams face the last minutes of a match, the increased pressure might cause agent’s performance to deteriorate—often referred to as choking under pressure (see e.g. Ariely et al., 2009; Baumeister, 1984). Thus, in our analysis of the effectiveness of risk-taking we control for a possible bias of choking under pressure by comparing the effectiveness of teams playing in the usual six field player formation with teams using an additional 7th field player.

First, we investigate whether or not trailing teams can overcome a possible loss by increasing their risk-taking towards the end of matches. For this purpose, we limit our data to matches at which the attacking team is trailing, with twelve possessions remaining. In addition, we restrict the data to close matches (maximum goal differential of four goals) to ensure that teams have a realistic chance of overcoming the deficit. Furthermore, we construct a binary variable $7^*\text{vs6}_{\text{Last12}}$ that equals one if the trailing team used the 7th field player at least once in its last twelve possessions, to test whether the effect of increased risk-taking has an effect on certain outcome
variables. At this point, we use three different outcome variables: a binary variable \textit{Win/Draw} which equals one if the match is won or drawn, the points gained in the match (\textit{Points}) and the change in goal differential between the end of the match and twelve possessions remaining (\textit{Goals caught up}).

In order to identify any effect of increased risk-taking towards the end of a match on the outcome variables (treatment effect), we use a coarsened exact matching model to decrease ex-ante and in-game heterogeneity between teams in the treatment group (teams that used the 7th player in their last twelve possessions) and control group (no use of the 7th field player). This method allows us to coarsen the data of the covariates (e.g. clustering the data into groups) and to identify exact matches afterwards (see Iacus et al., 2012).

As covariates in this model, we utilise the rank difference towards the end of the season (to control for playing abilities), the goal differential with twelve possessions remaining (to control for in-game heterogeneity), the location and the season. We only coarsen the data for the variable \textit{Rank Difference}, so that we only allow matches with the exact covariates for the other three variables. In Table A4 in the appendix, we present the summary of the balance of the matched games, which shows a good improvement after the matching.

Table 9 presents the average treatment effects of risk-taking on the three outcome variables (divided into underdogs and favourites) and it can be seen that only favourites significantly win or draw more games and gain more points after increasing risk-taking. However, there is no effect on the outcome variable \textit{Goals caught up}. Risk-taking increases the probability of extreme results and hence, the variance of the goal differential (see Grund et al., 2013). This implies that there will be teams

\begin{table}[h]
\centering
\caption{Average treatment effects of risk-taking on the success of trailing and heterogeneous teams.}
\begin{tabular}{lccc}
\hline
 & \textbf{Win/Draw} & \textbf{Points} & \textbf{Goals caught up} \\
 & \textbf{(1)} & \textbf{(2)} & \textbf{(3)} \\
\hline
\textit{Favourite} & 0.024 & 0.078 & 0.537 \\
 & (0.078) & (0.125) & (0.526) \\
7\textit*vs6\textit{Last12} & 0.008 & 0.011 & 0.088 \\
 & (0.076) & (0.122) & (0.513) \\
\textit{Favourite} & 0.253** & 0.375** & 0.976 \\
 & (0.116) & (0.186) & (0.781) \\
\textit{Constant} & 0.197*** & 0.284*** & -0.565* \\
 & (0.043) & (0.069) & (0.289) \\
\hline
\end{tabular}
\end{table}

\textit{Notes:} Average treatment effects. Standard errors are in brackets. Data is limited to games at which the attacking team is behind with twelve possessions remaining and with a maximum goal differential of four goals (close matches). 63 out of 70 treated games were matched to 136 games in the control group. There are 19 favourite teams and 44 underdog teams in the treatment group.

\(\ast p<0.1; \ast\ast p<0.05; \ast\ast\ast p<0.01.\)
that benefit from risk-taking, but also those that increase their deficit or respectively worsen their goal differential. Therefore, it is not surprising that despite the fact that favourite teams gain more points due to the use of 7th field player, teams do not improve their goal differential on average, as teams that lose their game, suffer an even greater loss\textsuperscript{18}.

In addition to the previous estimation, we want to explore the effect of risk-taking on leading teams. Therefore, we take a look at teams that are ahead in score with twelve possessions remaining. We limit the data to games with a maximum goal differential of three goals, so that teams which are three goals ahead, need to have a deficit of at least four goals in the last twelve possessions to lose the match, which is similar to the previous estimation.

The results from Table 10 show that leading teams do not benefit from risk-taking, as it lowers the probability of winning or of drawing the game. This is true for both leading favourites and leading underdogs. Furthermore, the results are only significant for the variable Win/Draw, which indicates a relatively high fraction of draws in the treatment group. Following these results, coaches of leading teams should consider lowering their risky actions, as risk-taking seems to decrease the winning probability if a team is leading towards the end of a match\textsuperscript{19}.

Lastly, we want to estimate the overall effect of risk-taking on the outcome of a match. Therefore, we use the variable 7$^\star$vs6\textsubscript{First9} (a binary variable which equals one if the 7th field player has been used in the first nine possessions) as a proxy for overall risk-taking in a game, as it reflects the tactical and strategic direction for the full match by the coach prior to the match. In Table A5, we show that this

\begin{table}[h]
\centering
\caption{Average treatment effects of risk-taking on the success of leading and heterogeneous teams.}
\begin{tabular}{lccc}
\hline
 & \textbf{Dependent variable:}\ & \textbf{Win/Draw}\ & \textbf{Points}\ & \textbf{Goals caught up}\ \\
 & & \textbf{(1)}\ & \textbf{(2)}\ & \textbf{(3)}\ \\
\hline
Favourite & 0.149\textsuperscript{**} & 0.319\textsuperscript{**} & 1.583\textsuperscript{***} \\
 & (0.073) & (0.143) & (0.452) \\
7$^\star$vs6\textsubscript{Last12} • Underdog & -0.243\textsuperscript{**} & -0.306 & -0.066 \\
 & (0.111) & (0.218) & (0.691) \\
7$^\star$vs6\textsubscript{Last12} • Favourite & -0.199\textsuperscript{**} & -0.312 & -0.639 \\
 & (0.099) & (0.194) & (0.614) \\
Constant & 0.716\textsuperscript{***} & 1.201\textsuperscript{***} & -0.986\textsuperscript{***} \\
 & (0.054) & (0.107) & (0.338) \\
\hline
\end{tabular}
\begin{flushleft}
\textit{Notes:} Average treatment effects. Standard errors are in brackets. Data is limited to games at which the attacking team is ahead in score with twelve possessions remaining and with a maximum goal differential of three goals (close matches). 43 out of 46 treated games were matched to 137 games in the control group. There are 24 favourite teams and 19 underdog teams in the treatment group. *p<0.1; **p<0.05; ***p<0.01.
\end{flushleft}
\end{table}
variable is indeed suited as such a proxy, as teams which used the 7th players in the first nine possessions, also use it more frequently in the remainder of the game. In addition, the variable 7*vs6First9 should be unbiased regarding the current score.

Similar to the previous two estimations, we use an exact matching model with 7*vs6First9 being the treatment variable and Rank Difference, Home and Season being covariates. The average treatment effects of risk-taking are presented in Table 11, which are again divided into underdogs and favourites. It is evident that underdogs benefit from increased risk-taking (a higher chance of winning or drawing the match), whereas favourites have a lower probability of winning or drawing the match and gain significantly fewer points.20

However, the results might be distorted by selection bias, if favourite teams which are currently on a losing streak increase their risk-taking ex-ante. Surprisingly though, more than 66% of the favourite teams that decided to use the 7th field player at the beginning of a match, had won their previous match. The high risk-taking might then reflect bad coaching strategies or a commission bias. Furthermore, players might have reduced their effort level due to an increased level of risk, as the input factors of talent and effort are substituted by luck to a certain extent in this case. They also might have not supported the coach’s decision of higher risk-taking in a match, in which they are the favourite, resulting in poorer performances.

The results of this section also show that timing and intermediate information is crucial for risk-taking and its success. According to the results of our estimations, favourite teams should rely on their superior playing ability and not increase risk-taking, unless they are trailing near the end of the match. Then these teams benefit

| Dependent variable: | (1) | (2) | (3) |
|---------------------|-----|-----|-----|
| Favourite           | 0.648*** | 1.257*** | 8.899*** |
|                     | (0.042) | (0.080) | (1.122) |
| 7*vs6First9 - Underdog | 0.145*  | 0.229  | 2.028  |
|                     | (0.079) | (0.150) | (2.105) |
| 7*vs6First9 - Favourite | −0.193** | −0.353* | −2.021 |
|                     | (0.096) | (0.182) | (2.555) |
| Constant            | 0.177*** | 0.307*** | −5.457*** |
|                     | (0.027) | (0.051) | (0.714) |

Notes: Average treatment effects. Standard errors are in brackets. This estimation measures the effect of having used the 7th field player in the first nine possessions on three different variables. 47 out of 47 treated games were matched to 362 games in the control group. There are 19 favourite teams and 28 underdog teams in the treatment group.

*p<0.1; **p<0.05; ***p<0.01.
from risk-taking, as it increases the probability of overcoming the deficit. Underdogs, on the other hand, should choose a moderate risk-taking strategy for the entire game. However, we did not find any evidence for trailing underdogs that higher risk-taking near the end of a game helps these teams to overcome a deficit.

Conclusion

The aim of this paper is to investigate risk-taking strategies used by handball teams in situations with ex-ante and in-game heterogeneity and to evaluate the success of this strategy. We show that teams are willing to take more risks when they have to overcome a deficit in ability (ex-ante heterogeneity) or in score (in-game heterogeneity). In addition, we provide evidence that heterogeneous teams react differently to current scores, as underdogs counter a current deficit by taking more risks than favourites, overall in the match. It seems that overall favourites rely more heavily on their superior ability than underdogs in order to overcome the current deficit. Interestingly, near the end of a match, this asymmetric behaviour changes, and trailing favourites choose riskier strategies, most notably if they no longer have any chance of winning the match. The commission bias may explain such behaviour, as coaches prefer to be proactive in hopeless situations, although this behaviour may not be effective.

Furthermore, we explore whether risk-taking is beneficial for teams. To do so, we investigate three different scenarios: teams with different (ex-ante) abilities at the beginning of a match, as well as teams trailing and leading near the end of a match. We show that underdogs who choose a riskier strategy overall, have a higher chance of winning the match. Favourites with overall increased risk-taking behaviour, on the other hand, have a significantly lower winning probability. Near the end of the match, however, the results indicate that trailing favourites benefit from increased risk-taking, whereas there is no such effect for underdogs adopting increased risk-taking. Leading teams on the other hand, both favourites and underdogs, suffer from riskier strategies close to the end of a match, as it decreases the probability of winning or drawing. Our results imply that the efficiency of using an additional field player depends crucially on timing and ability. Thus, particularly coaches of favourites need to be careful in their use of the 7th field player, as it may be counterproductive. The limited success of using an additional field player has not gone unnoticed by coaches. In fact, the share of attacks that use a 7th field player has decreased from 6.5% in the first year after the introduction of the new rule to 4.5% in the second year.

Our analysis has two clear advantages compared to what can be found in literature. First, the use of the 7th field player as a proxy for risk-taking is a very good reflection of a coach’s strategy implemented before and during the match. Second, the detailed data on every possession in a handball match provides an excellent opportunity to study the team’s changes in risk-taking in the context of the current score and whether this behaviour may depend on ex-ante heterogeneity as well.
Unfortunately, our data set only contains two seasons with 607 matches, and the fraction of possessions in which the 7th player has been used, is also comparatively low (about 5%), which makes it difficult to empirically evaluate the effectiveness of this risk-taking strategy, as the number of teams in the treatment group (teams which used the 7th field player) is small. Future research might delve deeper into this issue. In addition, it could be interesting to test whether risk-taking is dependent on the tournament format (league tournaments vs cup tournaments), and whether teams are willing to take more risks in cup tournaments, because they face elimination in this format.

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**ORCID iD**
Lena Neuberg [https://orcid.org/0000-0002-3957-6408](https://orcid.org/0000-0002-3957-6408)

**Supplemental Material**
Supplemental material for this article is available online.

**Notes**
1. With professionalised agents highly incentivized to win, as well as detailed information about performance and productivity, data from sporting competitions serves as a unique testing ground for testing fundamental economic theories and behavioural biases (see e.g. Bar-Eli et al., 2020; Kahn, 2000). To the best of our knowledge, we are not the first to utilize handball data. Berger and Nieken (2010), for instance, use data on two-minute suspension to study the influence of player heterogeneity on effort provision. Bühren and Träger (2022) investigate how the order of play during a penalty shootout and personality traits might affect performance of handball players. Bühren and Gabriel (2021) use professional handball penalty data during crunch time to examine how professional athletes perform under pressure.
2. Indicators such as fouls, however, need to be used with caution. Similar to increased risk-taking, less able and trailing agents are also prone to forfeit prematurely or sabotage their competitor (Dye, 1984; Lazear, 1989). Thus, instead of an indicator of increased risk-taking, crashes and fouls might also indicate increased sabotage activities of agents.
3. Nevertheless, it remains unclear which agent chooses the strategy—coach or player—and whether or not players might be forced to increased risk-taking due to the defensive
behaviour of the competitor. As the variance in expected points is higher for three-point attempts than for two-point attempts, the defence might try to elicit three-point attempts rather than safer two point shots from the attacking players.

4. Although the rule change offers a broad variety of new tactical opportunities and reduces logistical efforts, such as finding the sports bib, putting it on etc., it has been heavily criticized in the past. Critics argue that the additional field player reduces the harm of a two-minute suspension as teams can simply offset the imbalance with an additional field player, leading to a rougher play. Additionally, with an additional field player, handball loses one of its core components, the play one-against-one and attacking teams might advance slower fearing they might lose the ball and suffer an easy counterattack on the empty goal.

5. For more information on the rules of handball and the possible substitutions before and after the rule change see the appendix (A1).

6. The use of an additional field player is denoted with an asterisk.

7. $(6^* \text{ vs } 5)$ and $(7^* \text{ vs } 5)$ are very specific situations that rarely occur during play. For instance, $(7^* \text{ vs } 5)$ was not used at all during season 2016/2017 and 14 times during season 2017/2018.

8. Unfortunately, one game of the 2017/18 season is missing from the data set.

9. From 2011 until 2017 the three lowest ranked teams would be relegated. From 2017 onwards, only the two lowest ranked teams face relegation.

10. Handball has various rules on technical faults, e.g. on how the ball is supposed to be carried and how the attack should take place. If the attacking team breaks the rules—due to too many steps with the ball not being dribbled, passive play or a forward foul—the respective team loses the ball.

11. Our results are robust in non-linear models. Results of logit regressions, in which season or team-season fixed effects are employed, are provided in the online appendix.

12. We used R statistical program to run all regressions and matching, using the packages MatchIt (Ho et al., 2011) and stargazer (Hlavac, 2018).

13. As argued in the literature, there might be a dependency between risk-taking decisions between teams in a certain match. Therefore, we checked whether there is any correlation between teams using the 7th field player in a match, and could not find any evidence of this. Hence, we assume that risk-taking decisions are made independently of the opponent’s decisions.

14. In a robustness check of the result, we split all teams into three groups, based on their standings at the end of the season. Teams from the top third are in Group 1, teams from the middle third in Group 2 and accordingly, teams from the bottom third in Group 3. We then test, in three separate regressions for each group, if risk-taking at the beginning of matches is dependent on the group affiliation of the opposing team. Indeed, the results confirm the previous results, as teams from Group 2 and Group 3 increase their risk-taking significantly, when playing against teams from Group 1, which are the best of this league. The results are provided in the online appendix.

15. In our data set, the largest deficit a team could turn into a win amounted to eight goals. The same deficit was turned into a draw once, so it seems that it is hard for handball teams to overcome a deficit of more than eight goals. Interestingly, according to Column (3) of
Table 5, the goal differential that maximizes the risk-taking behavior of trailing teams, is between seven and eight goals.

16. Note that the difference in reaction to trailing between favourites and underdogs is also statistically significant.

17. Nevertheless, previous studies on this phenomenon have come to varying conclusions on whether or not the performance of professional agents decreases under pressure. Paserman (2007) finds that the performance of tennis players declines with increasing importance of the point. Wells and Skowronsiki (2012) observe a similar behaviour, as golf players perform with a lower average in the last round of the tournament. While Dohmen (2008) and Apesteguia and Palacios-Heurta (2010) find a higher percentage of successful penalty kicks when importance is greatest, Jordet et al. (2007) observes kickers to be less successful towards the end of the shootout. Investigating the success rate of handball penalties thrown during the last minutes of the match, Bühren and Gabriel (2021) find that handball players are more likely to hit penalties, indicating that the athletes perform best when it matters the most.

18. We also created a variable High Usage which stands for a team’s percentage usage of the 7th field player above the median (in this case at least three out of twelve possessions). The results indicate that only favourite teams which had a high usage of the 7th field player benefit from the increased risk-taking behavior. The full results are provided in the online appendix.

19. Similar to the previous estimation, the effect (in this case negative) is stronger for the team which used the 7th field player more frequently towards the end of the match. The results will be provided in the online appendix.

20. As only the estimator of the variable Win/Draw is significantly positive for underdogs, this indicates that many underdog teams drew in games in which they used the 7th field player in their first nine possessions. As expected and discussed above, both relevant estimators regarding risk-taking on the outcome variable Goal Differential are not significant, because risk-taking only has an influence on the variance, but not significantly on the mean.

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**Appendix**

**Basic Information about Handball**

Handball is a team sport in which two teams compete against one another in two halves of thirty minutes. Similar to many other team sports, players aim to throw the ball past the goalkeeper into the goal. Each goal counts the same and the team with the highest score wins the match. Two semicircles with a radius of six meters around each goal, mark the goal area or the goal perimeter, which only the goalkeeper is allowed to enter. If a defending field player enters the goal perimeter—depending on whether or not the field player prevents a clear goal opportunity—the opposing team is awarded a free throw or a penalty. An offensive player entering the perimeter causes an immediate turnover. A game features seven players, six field players and a goalkeeper. In a ‘standard’ play of handball, six attackers face six defenders of the opposing team, often referred to as 6 vs 6. Since the goalkeeper is the only one to enter the goal perimeter, he has to be recognizable as such. Therefore, he wears a different jersey to the other players of the team. Over the course of the match, coaches can continuously substitute players for one another—even the goalkeeper for a field player. Before 2016, the substitution process of goalkeepers was much more rigid. The substituted field player took over the role of the goalkeeper.
and had to wear a sports bib, such that the player was recognizable in the new role as substituted goalkeeper. This substituted player was allowed to perform all tasks of the goalkeeper; most importantly, to enter the goal perimeter. Additionally, the goalkeeper could only re-enter the pitch when substituted for the player marked with the sports bib. Thus, fearing a fast turnover and the possibility of an empty goal, the substituted player often remained close to the substitution zone to allow the goalkeeper to re-enter the play. In 2016, the rules of this substitution were extended. Even though the ‘old’ substitution of a goalkeeper with a field player wearing a sports bib is still possible after the rule change, the substituted field player is no longer required to wear one. If not wearing a bib, however, the player loses the ‘power’ of a goalkeeper to enter the goal perimeter to defend the goal. Hence, if a defending field player enters this area without a bib, a free throw or a penalty follows. Thus, before sending the goalkeeper back in the pitch, the goal is empty and the opponent can simply throw the ball into the empty goal and score. Nevertheless, now any of the field players can swap with the goalkeeper to allow him to re-enter the match, allowing for faster and more flexible substitutions.

**Additional Tables**

**Table A1.** Impact of ex-ante heterogeneity on risk-taking.

|                                | Opponent’s success of a possession | Probability of a fastbreak |
|--------------------------------|-----------------------------------|---------------------------|
|                                | (1)                               | (2)                       | (3)                        | (4)                        |
| Before 7th Player              | 0.028***                          |                           | 0.025*                     |
|                                | (0.012)                           |                           | (0.014)                    |
| Before 7th Player · Before Miss| 0.06***                           | 0.067***                  |
|                                | (0.013)                           | (0.020)                   |
| Before 7th player · Before Success| −0.005                          | −0.016                    |
|                                | (0.021)                           | (0.017)                   |
| Before Success                 | −0.006                            | −0.383***                 |
|                                | (0.007)                           | (0.009)                   |
| Fastbreak                      | 0.076***                          | 0.075***                  |
|                                | (0.006)                           | (0.006)                   |
| Rank Difference                | −0.004***                         | −0.004***                 |
|                                | (0.0004)                          | (0.0004)                  |
| Home                           | 0.018***                          | 0.026***                  |
|                                | (0.005)                           | (0.006)                   |
| Team-Season Fixed Effects      | Yes                               | Yes                       |
| Observations                   | 37,326                            | 37,326                    | 37,326                     | 37,326                     |
| R²                             | 0.008                             | 0.008                     | 0.170                      | 0.170                      |

Notes: Values in parentheses are robust standard errors, clustered by team-game. 

*p<0.1; **p<0.05; ***p<0.01.
### Table A2. Impact of ex-ante heterogeneity on risk-taking.

|                  | First 6 Possessions | First 12 Possessions |
|------------------|----------------------|-----------------------|
|                  | (1) | (2) | (3) | (4) |
| Constant         | 0.006 | 0.019** | 0.006 | 0.019** |
| (0.007)          | (0.009) |       |      |
| Rank Difference  | 0.112** | 0.109** | 0.203*** | 0.208*** |
| (0.048)          | (0.046) | (0.054) | (0.053) |
| Standing Attacking Team | -0.009 | -0.009 | -0.076 | -0.006 |
| (0.060)          | (0.076) |       |      |
| Home             | -0.004 | -0.004 | -0.005 | -0.006 |
| (0.006)          | (0.005) | (0.006) | (0.006) |
| Season Fixed Effects | Yes | No | Yes | No |
| Team-Season Dummies | No | Yes | No | Yes |
| Observations     | 6,625 | 6,625 | 12,462 | 12,462 |
| \(R^2\)          | 0.012 | 0.095 | 0.014 | 0.090 |

*Notes: Values in parentheses are robust standard errors, clustered by team-season. The variable Rank Difference is scaled with the factor 100. *p<0.1; **p<0.05; ***p<0.01.*

### Table A3. Risk-taking behaviour of leading favourites near the end of a match.

|                  | 7*vs6 in last 3 possessions (at least once) |
|------------------|--------------------------------------------|
|                  | (1) | (2) | (3) |
| Favourite        | -0.009 | 0.084 | -0.065* |
| (0.030)          | (0.058) |       | (0.037) |
| Constant         | 0.136*** | 0.040 | 0.193*** |
| (0.024)          | (0.052) |       | (0.029) |

*Notes: Average treatment effects. Standard errors are in brackets. Data is limited to games, at which the attacking team is ahead in score with three possessions remaining. In estimation (1), 189 games out of 190 games in the control group were matched to 387 matches in the treatment group. In estimation (2), 35 games out of 36 games in the control group were matched to 145 matches in the treatment group. In estimation (3), 154 games out of 154 games in the control group were matched to 242 matches in the treatment group. Close matches are defined as those with a goal differential of a maximum of four goals. Already decided matches are those with a goal differential of at least five with three possessions remaining. *p<0.1; **p<0.05; ***p<0.01.*
### Table A4. Summary of selected variables of all data and matched data.

|                        | Summary of All Data | Summary of Matched Data |
|------------------------|---------------------|-------------------------|
|                        | Means Treated       | Means Control | Mean Diff | Means Treated | Means Control | Mean Diff |
| Rank Difference        | 2.943 (6.241)       | 2.353 (1.103) | 0.590     | 3.270 (6.489) | 3.087 (1.143) | 0.183     |
| Goal Differential$_{\text{Last12}}$ | −2.586 (1.103)     | −2.271 (0.497) | −0.315    | −2.530 (1.143) | −2.530 (0.487) | 0.000     |
| Home                   | 0.414 (0.497)       | 0.436 (0.47)  | −0.022    | 0.381 (0.487) | 0.381 (0.473) | 0.000     |
| Season                 | 0.671 (0.500)       | 0.474 (0.500) | 0.197     | 0.666 (0.473) | 0.666 (0.473) | 0.000     |

Notes: Standard deviations for means in the control group are in brackets. Data is limited to games at which the attacking team is behind with twelve possessions remaining and with a maximum goal differential of four goals (close matches). 63 out of 70 treated games were matched to 136 games in the control group.

### Table A5. 7∗vs6$_{\text{First9}}$ as a proxy for overall risk-taking in a match.

|                        | Dependent variable: |
|------------------------|---------------------|
|                        | 7∗vs6               |
| 7∗vs6$_{\text{First9}}$ | 0.221*** (0.039)    |
| Rank Difference        | 0.207*** (0.076)    |
| Home                   | −0.022*** (0.007)   |
| Control Variables for Goal Differential | Yes |
| Team-Season Fixed Effects | Yes |
| Observations           | 28,615              |

Notes: Values in parentheses are robust standard errors, clustered by team-game. Data is limited to possessions after the ninth attack by a team. The variable Rank Difference is scaled with the factor 100. We control for the current score with the variables Goal Differential and Goal Differential$^2$ for both underdogs and favourites. 7∗vs6$_{\text{First9}}$ is a dummy variable, which equals one, if the observed team has used the 7th field player in its first nine possessions. *p<0.1; **p<0.05; ***p<0.01.