

# Choking Under Pressure in Front of a Supportive Audience: Evidence from Professional Biathlon

Ken Harb-Wu and Alex Krumer\*



This version: November 2017

*Date this version has been printed: 29 November 2017*

**Abstract:** Performing in front of a supportive audience increases motivation. However, it also creates a psychological pressure, which may impair performance, especially in precision tasks. In this paper, we exploit a unique setting in which professionals compete in a real-life contest with high monetary rewards in order to assess how they respond to the presence of a supportive audience. Using the task of shooting in sprint competitions of professional biathlon events over the period of sixteen years, our fixed effects estimations show that high-profile biathletes miss significantly more shots when competing in front of a supportive audience. Our results are in line with the hypothesis that a friendly environment induces individuals to choke when performing skill-based tasks.

**Keywords:** Choking under pressure; Paradoxical performance effects on incentives; Social pressure; Biathlon; Home advantage.

**JEL classification:** M54, Z13, Z20.

**Address for correspondence:**

Ken Harb-Wu, Swiss Institute for Empirical Economic Research (SEW), University of St. Gallen, Varnbuelstrasse 14, CH-9000 St. Gallen, Switzerland, ken.harb-wu@outlook.com.

Alex Krumer (corresponding author), Swiss Institute for Empirical Economic Research (SEW), University of St. Gallen, Varnbuelstrasse 14, CH-9000 St. Gallen, Switzerland, alexander.krumer@unisg.ch.

---

\* We would like to thank Anthony Strittmatter, Christoph Bühren, Daniel Goller, Danny Cohen-Zada, Florian Lindner, Igor Sherman, Martin Lakie, Michael Jetter, Michael Knaus, Michael Lechner, Milan Augustin and Rudy Shurman for their helpful comments. The usual disclaimer applies.

# 1 Introduction

There are many professions in which individuals perform their task in front of an audience. These include lecturers at university, presenters in marketing companies, researchers at conferences, politicians during public speeches, athletes in sports competitions, etc. Successful execution of these tasks may generate large monetary rewards. For example, a strong performance of a marketing person may result in a large contract for his/her firm or a convincing presentation in a job talk may have a very influential impact on the person's career. In this paper, we ask a simple question: Does the presence of a supportive crowd enhance or impair performance?

It is intuitive that performing in front of a supportive crowd increases motivation, since succeeding in front of familiar people might be more satisfying. However, it can also be much more disappointing when the people closest to you witness your failure. Therefore, from an economic perspective, the difference between the utility in the case of a strong performance versus that of a poor performance is much more pronounced when performing in front of a supportive crowd in comparison to when performing in front of a neutral one. Incentives to perform well are therefore higher when supported. Thus, according to standard economic assumptions this increased return is supposed to enhance performance (Stiglitz, 1976; Lazear and Rosen, 1981; Rosen, 1986; among many others). Although in most cases, this fundamental relationship holds true (O'Reilly, Main, and Crystal, 1988; Ehrenberg and Bognanno, 1990; Lazear, 2000; DeVaro, 2006),<sup>1</sup> an increased motivation beyond an optimal level may harm performance. This phenomenon was described by Baumeister (1984) and is known as "choking under pressure".

---

<sup>1</sup> For additional references on the linkage between incentives and performance, see the comprehensive review of Dechenaux, Kovenock and Sheremeta (2015).

For many decades economists assumed that performance neither depended on the social context of the task environment nor the psychological states. Therefore, for a long time, most evidence on the hypothesis of social facilitation, according to which individuals perform differently when in the presence of others, was based on experimental studies executed by sociologists and psychologists. For example, Butler and Baumeister (1998) showed that participants performed worse in front of a supportive audience. In a later work, Wallace, Baumeister and Vohs (2005) discussed how a supportive audience improved effort-based performance, but worsened skill-based tasks that involve automatic processes.

In recent decades, however, experimental and field economic studies have also shown the importance of psychological effects and that these effects can break the fundamental relationship between incentives and performance.<sup>2</sup> The economic literature on the effect of social interaction is mostly based on experimental studies.<sup>3</sup> The main reason thereof is that investigating the effect of an audience in general, let alone the effect of a supportive audience on performance in real-life settings, is quite challenging. This is because in most cases reality is too complex to allow for the disentanglement of the different effects. In addition, the outcome of any specific action is usually ambiguous and mostly unobserved.

A notable exception to the above-noted obstacles is Dohmen's (2008) study in which he investigated soccer penalty kicks in the German Bundesliga seasons from 1963 to 2004. The author

---

<sup>2</sup> See Ariely et al. (2009), who in experimental settings showed that high monetary rewards can impair performance. Non-experimental papers on choking mainly use data from sports competitions. For example, Paserman (2010) and Cohen-Zada et al. (2017) showed that professional tennis players choke more in the most important junctures of the match. Hickman and Metz (2015) found that higher stakes increase the likelihood to miss a shot on the final hole in professional golf. Cao, Price and Stone (2011) and Toma (2017) presented evidence on choking under pressure in professional basketball. For additional examples on different effects of incentives see Gneezy, Meier and Rey-Biel (2011).

<sup>3</sup> For example, Falk and Ichino (2006) showed a positive peer effect on productivity. In a more recent study, Georganas, Tonin and Vlassopoulos (2015) found some evidence that subjects increase their productivity when being observed.

found that soccer players are more likely to choke on a penalty kick when playing in front of their home audience. Despite an intriguing result, the author noticed several important caveats concerning choking. For example, a penalty kick is not a very prevalent action in a soccer match. Dohmen (2008) reports that out of 12,488 matches observed over the span of 41 years, only 3,619 penalties were awarded, meaning less than one penalty per every three games. Therefore, as only one player out of a team of eleven takes the penalty, self-selection into the task is very likely.<sup>4</sup> In addition, Dohmen's (2008) study does not control for players' time-invariant characteristics, which may play a role in stressful situations. Finally, although the common belief is that the outcome of a penalty kick primarily depends on the kicker and not on the goalkeeper, and despite that the definition of choking in Dohmen (2008) was "[m]issing the goal without the goalkeeper's interference" (pp. 638-639), it is still theoretically possible that in a two-person interactive game, the outcome does not depend on the kicker's performance alone. All these caveats call for more evidence in different environments that may serve as a test of the external validity of previous studies.

Taking into account the caveats highlighted in Dohmen (2008) we investigate the effect of a supportive crowd in a completely different setting. In this setting professionals compete for large monetary rewards in real-life competitions in front of supportive and neutral crowds. More specifically, we study shooting accuracy in the sport of biathlon, which is defined by the International Biathlon Union (IBU) as "[a] sport that combines the endurance of free-technique cross-country skiing with precision small-bore rifle marksmanship" (IBU, 2016b, p.13). Each

---

<sup>4</sup> A similar concern of self-election appears in basketball, where the opposite team may strategically foul players with bad free throw accuracy. In addition, in certain situations during the last seconds of a basketball game, players from the team lagging behind may choose to miss their last shot on purpose in order to increase their chances of winning by taking a rebound.

missed shot implies an immediate penalty, namely a 150 m penalty loop, which is imposed right after the task. Such penalties, obviously reduce the biathlete's chances of winning the competition, since the winner is a biathlete with the best time.<sup>5</sup>

Studying the effect of a supportive crowd in biathlon is feasible, since, unlike in other sports that involve precision tasks like soccer (penalty kicks) or basketball (free throws), every biathlete in every competition must perform the exact same non-interactive task of shooting the exact same number of times. In addition, unlike in many other sports, the home crowd cheers for the home athletes, but is not hostile toward other athletes. This allows us to compare the performance of athletes in front of supportive versus neutral crowds in a real-life situation. Finally, the multistage nature of a biathlon season enables the use of different fixed effects specifications (biathlete within several months or even biathlete within several weeks). This allows us to control for multiple sources of unobserved heterogeneity and estimate a biathlete's performance when he/she competes in front of a supportive audience (in his/her home country) and compare it to the same biathlete's performance when he/she competes in front of a neutral crowd (abroad).<sup>6</sup>

Our analysis is based on the performance of 220 professional male and 217 professional female biathletes that is composed of 8,262 male and 6,540 female distinct entries in the seasons from 2001-02 to 2016-17 that include 155 sprint competitions from all the World Cups, World Championships and the Olympic Games.<sup>7</sup> In these competitions biathletes start one after another in intervals of 30 seconds and shoot twice at five targets, first prone then standing. Such interval

---

<sup>5</sup> See Section 2 for additional details on biathlon rules.

<sup>6</sup> See Genakos and Pagliero (2012) and Genakos, Pagliero and Garbi (2015) for discussion on fixed effects estimations in multi-stage sports competitions.

<sup>7</sup> See Section 3 for our justification on why we only use the sprint competitions.

starts allow biathletes to be alone (or at most be with a few other biathletes) at the shooting range. Therefore, the home crowd, primarily located near the shooting range (see Figure 1), is able to concentrate on their preferred biathlete and is able to cheer only for him/her at the time of his/her shooting task.

Our fixed effects estimations reveal that both men and women miss more shots when competing in their home country compared to competing abroad. The estimated effect is about 0.15 misses on average among men and 0.23 among women. It is quite a large effect if we take into account that the average time it takes to ski a penalty loop is about 25 seconds, meaning that when competing at home, a biathlete loses on average 3.75 to 5.75 seconds.<sup>8</sup> To put this number into perspective, in the 2014 Sochi Olympic Games, the home biathlete Anton Shipulin was only 0.7 seconds away from a bronze medal after missing one shot.

We also find that biathletes ski faster in their home country, which is in line with Wallace, Baumeister and Vohs (2005) who discussed the positive effect of a supportive audience on the effort-based task. One possible inference may be that since biathletes perform the skiing task faster at home, it may result in a higher heart rate and harm their shooting performance. However, the literature on the relationship between heart rate and shooting accuracy is mixed, where some studies find a negative correlation (Kayihan et al., 2013) and others find no such relationship (Kruse et al., 1986; Konttinen, Lyytinen and Viitasalo, 1998). Moreover, Lakie (2010) suggested that an increased heart rate may even enhance the shooting performance in biathlon by decreasing the pulsatile input to the rifle.

---

<sup>8</sup> See, for example: <http://biathloncanada.ca/wp-content/uploads/2015/08/Description-of-Biathlon.pdf>. Last accessed on 15/09/2017.

Finally, our findings also shed a new light on a large share of literature on home advantage, which is a well-documented phenomenon in team (Dohmen and Sauer mann, 2016) and individual sports (Koning, 2011; Ferreira Julio et al., 2013; Krumer, 2017). This home advantage phenomenon can be attributed to crowd noise (Pettersson-Lidbom and Priks, 2010) and referee bias (Garicano, Palacios-Huerta and Prendergast, 2005).<sup>9</sup> To the best of our knowledge, only Balmer, Nevil and Williams (2001) examined the home advantage in biathlon as part of a study on the Winter Olympics. The authors concluded that the magnitude of the home advantage in this sport is little to none. This is not surprising, since professional biathlon is an objectively judged sport as performance is directly measured by the finishing time and indirectly by the targets missed. In addition, further studies that found no home advantage only showed it for specific parts of the week (Krumer and Lechner, 2017) or specific tasks (Dohmen, 2008). However, as far as we are aware of, our paper is the first to show a significant home disadvantage in the main task of a competition in professional sports.

The remainder of the paper is organized as follows: Section 2 describes the biathlon settings. The data and descriptive results are presented in Section 3. Section 4 explains the estimation strategy. In Section 5 we present the empirical evidence. Finally, in Section 6 we offer concluding remarks.

## 2 Description of biathlon competitions

Professional biathlon is a sport that combines cross-country skiing with shooting skills. Successful biathletes must master the quick switch between a sport that is intense and physically

---

<sup>9</sup> See the comprehensive review of Dohmen and Sauer mann (2016) for additional details on referee bias in different sports.

exerting and a sport that requires stability and extensive control. To reflect the combination of the two contradictory disciplines the term competition is preferred over the term race. In a nutshell, a biathlon competition can be described as follows: “[T]he athlete starts at the start line, skis one course loop ..., comes to the range and shoots, skis another loop, shoots, and so on, and then finishes by skiing to the finish line after the last bout of shooting.” (IBU, 2016b, p. 484).

The most prestigious events are: The World Cup, the World Championships and the Winter Olympic Games. The World Cup is an annual circuit of approximately ten events in various configurations for men and women that usually take place between December to March.<sup>10</sup> These events are organised in several cycles. Each cycle includes several events that take place week after week, usually two-three weeks in a row. Then there is a break of one-two weeks between the cycles. The athletes use this break to both rest and train.

During these events, competitors can score up to 60 World Cup points (WC points) in each competition based on their performance.<sup>11</sup> At the end of each season, the highest (monetary and non-monetary) honours go to the man and the woman placed first in the World Cup total score. This ranking is compiled based on the sum of points earned in the individual, sprint, pursuit and mass start competitions minus the two lowest scores.<sup>12</sup> Additional World Cup trophies are awarded to the most successful athletes based on their cumulative scores in each competition type (IBU, 2016a).<sup>13</sup> The World Championship is also an annual event, except in the years of Winter Olympic

---

<sup>10</sup> In some cases, the season starts in the last week of November.

<sup>11</sup> Up to and including season 2007/08 competitors could score up to 50 WC points per competition.

<sup>12</sup> Up to and including season 2009/10 the lowest three scores were subtracted. In addition, no scores were subtracted in season 2010/11.

<sup>13</sup> Up to and including season 2009/10 the lowest score from the respective competition was subtracted.

Games, that counts towards the World Cup season. The Winter Olympic Games also counted towards the World Cup season up to and including the Winter Olympics 2010 in Vancouver (IBU, 2008; 2016a; 2016b).

In total, six different competition types – sprint, pursuit, individual, mass start, relay and mixed relay – are recognized by the IBU (IBU, 2016a). The last two are team competitions and do not count towards the individual World Cup score. An overview of the four individual competition types is depicted in Table 1. In general, depending on gender and competition type, biathletes ski up to 20 km spread over three or five loops and stop to shoot two or four times with five bullets at five targets. Shots are fired from a 50 m distance in either a prone or standing position. The targets are 45 mm and 115 mm in diameter, respectively. For each missed target a penalty minute or a 150 m penalty loop is imposed immediately after each bout. As the clock never stops, competitors must shoot as fast as and as accurate as they can.

The sprint competition, which is the competition of our interest, is 10 km for male and 7.5 km for female competitors and is skied over three loops. Competitors start one after the other in intervals of 30 seconds. Athletes shoot twice at five targets, first prone then standing. For each missed shot a 150 m penalty loop must be skied. The final ski time is the time elapsed between start and finish. The winner is the biathlete with the best time.<sup>14</sup>

---

<sup>14</sup> See Appendix A for description on pursuit, individual and mass start competitions, which are not included in our analysis.

## 3 Data and variables

### 3.1 Data

The data on seasons from 2001-02 to 2016-17 was downloaded from the official IBU website (<http://biathlonresults.com/>) and is based on the IBU rules.<sup>15</sup> The sixteen seasons amount to 144 World Cup events, twelve World Championships and four Winter Olympic Games (Salt Lake City, Torino, Vancouver and Sochi). The observed period has primarily been selected due to the accessibility and consistency of data. In total, 155 sprint competitions took place for each gender. For each competition, information was available regarding the season, the cycle, the event, the location (country and city), the competition type, whether it was a World Cup event, a World Championship or a Winter Olympic Game as well as the biathletes' name, starting number, competition ranking, nationality, missed shots at each bout and in total, finishing time, earned World Cup points and seasonal cumulative World Cup points prior to the competition.

To access the effect of the home crowd on shooting accuracy, we will only use the sprint competitions due to the following reasons. We do not use the pursuit competitions, because in these competitions the start time is based on the number of seconds a competitor lagged behind the winner of the sprint competition. Such ahead-behind asymmetry may jeopardise our identification strategy. The reason we do not use the mass start competitions is because it is a contact competition, where all the athletes start and arrive to the shooting point together (mostly in the first bout of shooting, but also in the following ones). Therefore, the element of peloton race, where the crowd is not concentrated on one athlete alone, like in the sprint competitions, makes it less feasible to study the effect of a supportive crowd on shooting accuracy. Finally, we disregard

---

<sup>15</sup> E.g. the data reflects ex-post disqualification of athletes due to the infringement of IBU anti-doping rules.

the individual competitions, because of the low number of competitions. The individual competitions took place in only 54 out of 160 possible events in our dataset (33.7%), compared to 155 sprint competitions during the same period of time (96.9%).<sup>16</sup>

The data set consists of 16,177 male and 14,360 female entries in sprint competitions. Unfortunately, not all entries meet the requirements for this analysis. First, after removing invalid entries – due to a biathlete not starting, not finishing, being disqualified – 15,833 male and 13,999 female entries remain. Second, in accordance with Balmer, Nevil and Williams (2003) and Ferreira Julio et al. (2013), entries of athletes who throughout their entire career have not experienced a competition both at home and away are excluded to ensure comparability. Therefore, we analyse the performance of 220 male and 217 female biathletes that are composed of 8,262 male (832 at home) and 6,540 female (736 at home) entries in different competitions.<sup>17</sup>

## 3.2 Variables and descriptive statistics

To estimate the possible effects of a supportive crowd on shooting accuracy we used the number of missed shots as the outcome variable. Table 2 shows that on average both men and women miss more shots when competing in their home country. We also have information on additional performance-related measures such as skiing time before the first bout of shooting, winning a medal and ranking points. In addition, we calculated the athletes' standardized ranking points prior to the respective race.<sup>18</sup> We can see that on average biathletes that compete in their

---

<sup>16</sup> This low number of competitions does not allow to use an athlete per month fixed effects, which is our preferred estimation method as will be explained in Section 4.

<sup>17</sup> Our results are robust to including all the data. The results are available upon request.

<sup>18</sup> This variable is defined as  $\frac{\text{cumulative WC Points prior comp. } r \text{ of biathlete } i - \text{avg. cumulative WC Points prior comp. } r \text{ of all biathletes}}{\text{std.dev. of cumulative WC Points prior comp. } r \text{ of all biathletes}}$ .  
For the first competition of the season we used the final table of the previous season.

home country have a better previous performance as represented by the higher measure of standardized ranking points.

## 4 Estimation strategy

We estimate the impact of competing in one's home country on the number of missed shots in a professional biathlon competition. Obviously, a naïve approach of correlating a dummy variable of competing at home with the performance measure will yield biased and inconsistent estimates, because the unobserved individual ability is likely to affect biathletes' shooting accuracy. This individual ability may also vary over time, as the ability of each biathlete may vary across years due to different preparations between seasons, for example. Moreover, this ability may also differ within the same season due to injuries, illness, etc. Hence, one needs to take the different sources of unobserved heterogeneity into account.

Our panel data follows the same athletes over time, which allows us to use a fixed effects model that controls for all time-invariant differences between the individuals. Therefore, we can use biathlon-season fixed effects. Moreover, owing to the multistage nature of the biathlon season that is organised over the period of four months (December-March) we also include biathlete-month fixed effects, which has less restrictive assumptions about time-invariant characteristics, such as ability or athlete's shape than the biathlete-season specification.<sup>19</sup> This means that our most general specification allows us to test the effect of competing at home by exploiting the variability of the home status across different events of the same month/season for a given biathlete.

Using a fixed effects model, our specification takes the following form:

---

<sup>19</sup> Usually there are 2-3 events per month. At the earliest, a season may start in the last week of November. For our analysis we denote this competition as one that took place in December.

$$(1) \text{ Missed Shots}_{itr} = \alpha_1 \cdot \text{Home}_{itr} + \alpha_2 \cdot X_{itr} + \mu_{it} + \delta_r + \varepsilon_{itr}$$

Where  $\text{Missed Shots}_{itr}$  is the number of missed shots of biathlete  $i$ , in period (season or month)  $t$  and competition  $r$ .  $\text{Home}_{itr}$  is a dummy variable that gets the value of one if a biathlete competes at home and zero otherwise,  $X_{itr}$  is our set of basic controls that includes the starting number of biathlete in a competition and its squared term. Finally,  $\mu_{it}$  is a biathlete's per period (season or month) fixed effects, and  $\delta_r$  is the competition fixed effects.

## 5 Results

### 5.1 Main results

Column 1 of Table 3 presents the results from estimating equation (1) without a list of basic controls and by using biathlete-season fixed effects, where standard errors clustered at the biathlete per season level are in the parentheses. The results show that the coefficients of  $\text{Home}_{itr}$  are positive and significant at the 2.9% level for men (Panel A) and at the 1.9% level for women (Panel B), which implies that biathletes perform the shooting task worse when competing at home. One may claim that competitions vary in their levels of difficulty, their climate conditions or their importance (for example Olympic Games), and that this may affect the performance of athletes. Therefore, failing to control for this unobserved heterogeneity between the competitions may bias the results. Consequently, in Column 2 we also use specific competition fixed effects. This allows us to control for all the features of the specific competition that were common for all participants. We can see that the results are robust when including these fixed effects. In Column 3, when additionally controlling for starting number and its squared value, the results are kept almost the

same. The findings suggest that a biathlete misses on average 0.10 (men) to 0.14 (women) shots more when competing at home compared to when competing abroad.

As already stated, 0.10 misses are equivalent to on average 2.5 seconds in a competition, which is not a negligible amount of time in professional biathlon. In addition to the example of Anton Shipulin that was discussed in the introduction, it is worth to mention the German biathlete, Rico Gross who was only 0.2 seconds away from the Olympic medal in the 2002 Salt Lake City Olympic Games. Similar examples are found also among women, where in the 2006 Turin Olympic Games, a Swedish silver medallist, Anna Carin Olofsson-Zidek was only 2.4 seconds behind the winner and in the 2010 Vancouver Olympic Games, the Russian biathlete, Anna Froolina missed the bronze medal by only 1.2 seconds.

In columns 4-6 we present the results of the specification where we use biathlete-month fixed effects. We can see that the results are basically the same with regard to sign and significance level as in the biathlete-season specification. In addition, it is important to note that we do not include the standardized ranking points prior to a competition in our fixed effects model. This is because the past performance is very likely to be a function of missed shots in previous competitions and therefore is function of  $Missed\ Shots_{it,r-1}$ ,  $Missed\ Shots_{it,r-2}$ , ... Thus, once we include the previous performance on the right hand side of equation (1) and conduct a fixed effects estimation, we will have a bias because the error term includes  $\mathcal{E}_{it,r-1}$ ,  $\mathcal{E}_{it,r-2}$ , ....., which is obviously correlated with the past performance of biathlete  $i$ .<sup>20</sup> Moreover, it was shown that the size of the bias is larger when the time horizon is rather short (Nickell 1981; Hsiao 2003). Thus,

---

<sup>20</sup> Nevertheless, all the results are robust to inclusion of the standardized ranking points prior to competition. In addition, the results of a Poisson regression analysis are very similar to the results of the linear model in regard to size and significance level. These results are available upon request.

as in our panel dataset we have on average only 2 observations per biathlete per month for both men and women, the inclusion of a past performance variable is very questionable.<sup>21</sup>

Taken together, all the estimation strategies above yield the same finding: Professional biathletes from both genders choke in the shooting task, which is considered as a precision activity, when competing in front of a supportive audience.

## 5.2 Skiing performance

According to Wallace, Baumeister and Vohs (2005), apart from a negative effect of a supportive audience in skilled-based tasks, there is also a positive effect of a supportive audience on the effort-based performance. The aim of this sub-section is to study the effect of competing in one's home country on skiing performance, which is an effort-based task. To this end we use the course time before the first bout of shooting, which is, in our opinion, the cleanest possible way. This is because the skiing time after the first shooting may be affected by shooting performance. For example, athletes who missed may be discouraged because of a poor shooting performance or may be more tired because of additional penalty loops compared to athletes who did not miss.

Columns 1 and 4 of Table 4 show that there is no significant effect of competing in one's home country on skiing time.<sup>22</sup> However, when we use specific competition fixed effects the standard errors are much lower and we find that athletes ski significantly faster at home. The estimated effect is between 1.25 (athlete-season) to 2.03 (athlete-month) seconds among men and

---

<sup>21</sup> The corresponding numbers for biathlete-season specification are 6.1 for men and 5.9 for women.

<sup>22</sup> The number of observations differ between Tables 3 and 4 because the data on course time was missing for the men's competitions that took place on 16/12/2016 in Austria (51 obs.), 13/03/2014 in Finland (49 obs.) and 15/03/2007 in Russia (58 obs.) as well as for one observation in the 2009 World Championships that took place on 14/02/2009. For women, the data on course time was missing for one biathlete in competitions that took place on 16/01/2004, 05/03/2005 and 10/12/2010.

between 1.90 (athlete-season) to 2.06 (athlete-month) seconds among women. Table 4 shows that failing to control for competition fixed effects (difficulty of a track, for example) may result in biased and inconsistent estimates. In addition, it is important to note that it is not possible to add the skiing time to equation (1) and use it as a control variable together with  $Home_{it}$ . This is because the skiing time is an outcome variable and therefore according to Angrist and Pischke (2008) is a “bad control”, which should not be included in a regression. Therefore, it is not possible to identify the separate causal effects of competing in one’s home country and of the skiing speed on shooting performance.<sup>23</sup>

### 5.3 Possible sources of choking in shooting task

One possible explanation is that since biathletes perform the skiing task faster at home, it may result in a higher heart rate and thus, harm their shooting performance. However, the evidence on the association between heart rate and shooting performance is mixed. On one hand, Kayihan et al. (2013) showed a negative correlation between heart rate and pistol shooting performance from 10 m distance. On the other hand, Kruse et al. (1986) found no relationship between heart rate and shooting performance with a standard pistol from 25 m distance. The authors attributed a better shooting performance to reduced hand tremor. Similarly, Konttinen, Lyytinen and Viitasalo (1998) failed to establish a relationship between heart rate patterns and shooting performance. Moreover, according to Lakie (2010), “[h]igh heart rate shooting is not a big problem in biathlon” (p.449); the increased heart rate in biathlon may even be an advantage, because it decreases the pulsatile input to the rifle and as a consequence reduces the chance of error.

---

<sup>23</sup> If we, nevertheless, add the skiing time as an additional control variable in equation (1), then the  $Home_{it}$  variable remains positive and significant for both genders and all the specifications. The skiing time remains significant only for men and only in athlete-year specification. The results of these regressions are available upon request.

There are several additional possible psychological and physiological explanations to our findings on poor shooting performance in front of a supportive audience. One possible mechanism is based on the so-called explicit monitoring theory which links performance decline to home crowd support through undesired cognitive processes. In other words, athletes choke in critical situations because pressure affects their attentional focus. For example, Beilock and Carr (2001) presented evidence on the explicit monitoring theory based on putting in golf that represents a complex sensorimotor task, which is best performed when executed as an automated action. Therefore, it is likely that individuals choke when a high-pressure situation provokes them to monitor their action more closely instead of executing it in an automated manner. In our case, it is plausible to assume that when the audience, primarily located near the shooting range (see Figure 1), cheers (the loudest for local favorites), the biathletes competing at home overthink instead of shoot as practiced. Another possible explanation to such choking may be related to a simple physiological tremor that biathletes may experience when performing in front of the supportive crowd. This tremor may be caused by the increased level of adrenaline, which is detrimental for precision tasks and may occur in stressful situations.<sup>24</sup>

#### 5.4 Additional performance-related variables

Since in the previous sub-sections we found that home athletes ski faster, but shoot worse, it is interesting to study the effect of competing at home on additional performance measures. First,

---

<sup>24</sup> For example, in the 2008 Beijing Olympic Games, the North Korean shooter Kim Jong Su won silver and bronze medals, however was disqualified after testing positive for propranolol, the drug that blocks the action of adrenaline. From: <https://www.scientificamerican.com/article/olympics-shooter-doping-propranolol/>. Last accessed on 15/09/2017. See also Lakie (2010) who discusses the possible inverse correlation between tremor and shooting performance in biathlon. For additional neuropsychological mechanisms of choking, see the recent review of Yu (2015).

we investigate the effect of competing in one's home country on the probability of winning a medal, namely finishing in one of the first three places.

The results of the fixed effects linear probability model (LPM) are presented in Table 5. We can see that for men (Panel A), all the specifications yield a negative coefficient of  $Home_{it}$ . However, the results are not significant at conventional levels. Therefore, our findings suggest that men do not have any home advantage in terms of winning a medal. If at all, there is some (not significant) evidence of a home disadvantage. The results from the women competitions yield highly insignificant results, suggesting that competing at home does not provide any positive or negative effect in terms of winning a medal. These findings are in line with the analysis in the previous sub-sections, since despite the fact that home biathletes miss more shots at home, they compensate by skiing faster.

In addition, it is important to note that the LPM has the disadvantage that it produces predicted probabilities outside the range 0-1. However, as Wooldridge (2002) argues, "[i]f the main purpose is to estimate the partial effect of [the independent variable] on the response probability, averaged across the distribution of [the independent variable], then the fact that some predicted values are outside the unit interval may not be very important" (p. 455). In Table 5, we show that the number of observations with predicted values outside the range 0-1 is negligible, which negates this possible problem of using a linear probability model.

Finally, in Table 6, we test the effect of competing in one's home country on the number of the World Cup ranking points obtained in the respective competition. As in the case with medals and for the same reason, in men's competitions we find a negative coefficient of the  $Home_{it}$  variable, which, however, is not significant at conventional levels.

The results for women, presented in Panel A show that when using biathlete-season fixed effects (columns 1-3), the effect is negative, although not significant at conventional levels. However, when using the biathlete-month specification (columns 4-6), which has less restrictive assumptions about time-invariant characteristics than the biathlete-season specification, we find that women obtain a significantly lower number of ranking points when competing in their home country compared to when competing abroad. The average negative estimated effect is 1.6 points. This gender difference in the athlete-month specification may stem from the fact that women's race is shorter and therefore they have less skiing time to compensate for the mistakes in the shooting task.

## 6 Conclusion

Studying the effect of a supportive audience on performance in real-life settings is not a trivial task, since nature rarely creates situations that make it possible. The natural experiment we have studied provides an opportunity to clearly observe the effect of a supportive audience on performance of high profile agents in real-life contests with large monetary rewards.

Taking the caveats highlighted by Dohmen (2008) into consideration, our results support the hypothesis of a social facilitation pattern in social psychology according to which individuals perform differently when in the presence of others. More specifically, using within-biathlete variation, our findings suggest that professional biathletes, who are used to perform under high physical pressure, choke under psychological pressure when performing the shooting task in front of a supportive audience. Our findings, obtained in a completely different environment are in line with previous results obtained in the laboratory (Butler and Baumeister, 1998) and in the field

(Dohmen, 2008). As such, it provides a test of the external validity of previous results regarding the negative effect of a supportive audience on skill-based activities for both genders.

Even though our finding is consistent with the hypothesis that a friendly environment induces individuals to choke, it is important to note that the finding was obtained from the sport of biathlon, where the precision tasks of shooting follows intensive physical effort, which is also affected by the presence of a supportive audience. It is possible that the results would differ in other environments. For example, in the labor market, individuals may only concentrate on cognitive tasks during interactions with familiar co-workers, who may serve as a supportive audience. In addition, the results may be different with supportive audiences that are not quite as enthusiastic as crowds in sports competition. Nevertheless, such a consistent finding on a negative effect of a supportive audience in a skilled-based task, calls for extra-attention among individuals who have to perform different, audience related tasks.

## 7 References

- Angrist, J.D. and Pischke, J.S., 2008. Mostly harmless econometrics: An empiricist's companion. Princeton university press.
- Ariely, D., Gneezy, U., Loewenstein, G. and Mazar, N., 2009. Large stakes and big mistakes. *The Review of Economic Studies*, 76(2), pp.451-469.
- Balmer, N.J., Nevill, A.M. and Williams, A.M., 2001. Home advantage in the Winter Olympics (1908-1998). *Journal of Sports Sciences*, 19(2), pp.129-139.
- Balmer, N.J., Nevill, A.M. and Williams, A.M., 2003. Modelling home advantage in the Summer Olympic Games. *Journal of Sports Sciences*, 21(6), pp.469-478.
- Baumeister, R.F., 1984. Choking under pressure: self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology*, 46(3), pp.610-620.

- Beilock, S.L. and Carr, T.H., 2001. On the fragility of skilled performance: What governs choking under pressure?. *Journal of Experimental Psychology: General*, 130(4), pp.701-725.
- Butler, J.L. and Baumeister, R.F., 1998. The trouble with friendly faces: skilled performance with a supportive audience. *Journal of Personality and Social Psychology*, 75(5), p.1213.
- Cao, Z., Price, J. and Stone, D.F., 2011. Performance under pressure in the NBA. *Journal of Sports Economics*, 12(3), pp.231-252.
- Cohen-Zada, D., Krumer, A., Rosenboim, M. and Shapir, O.M., 2017. Choking under pressure and gender: Evidence from professional tennis. *Journal of Economic Psychology*, 61, pp. 176-190.
- Dechenaux, E., Kovenock, D. and Sheremeta, R.M., 2015. A survey of experimental research on contests, all-pay auctions and tournaments. *Experimental Economics*, 18(4), pp.609-669.
- DeVaro, J., 2006. Internal promotion competitions in firms. *The Rand Journal of Economics*, 37(3), pp.521-542.
- Dohmen, T.J., 2008. Do professionals choke under pressure?. *Journal of Economic Behavior & Organization*, 65(3), pp.636-653.
- Dohmen, T. and Saueremann, J., 2016. Referee bias. *Journal of Economic Surveys*, 30(4), pp.679-695.
- Ehrenberg, R.G. and Bognanno, M.L., 1990. Do tournaments have incentive effects?. *Journal of Political Economy*, 98(6), pp.1307-1324.
- Falk, A. and Ichino, A., 2006. Clean evidence on peer effects. *Journal of Labor Economics*, 24(1), pp.39-57.
- Ferreira Julio, U., Panissa, V.L.G., Miarka, B., Takito, M.Y. and Franchini, E., 2013. Home advantage in judo: a study of the world ranking list. *Journal of Sports Sciences*, 31(2), pp.212-218.
- Garicano, L., Palacios-Huerta, I. and Prendergast, C., 2005. Favoritism under social pressure. *The Review of Economics and Statistics*, 87(2), pp.208-216.
- Georganas, S., Tonin, M. and Vlassopoulos, M., 2015. Peer pressure and productivity: The role of observing and being observed. *Journal of Economic Behavior & Organization*, 117, pp.223-232.

- Genakos, C. and Pagliero, M., 2012. Interim rank, risk taking, and performance in dynamic tournaments. *Journal of Political Economy*, 120(4), pp.782-813.
- Genakos, C., Pagliero, M. and Garbi, E., 2015. When pressure sinks performance: Evidence from diving competitions. *Economics Letters*, 132, pp.5-8.
- Gneezy, U., Meier, S. and Rey-Biel, P., 2011. When and why incentives (don't) work to modify behavior. *The Journal of Economic Perspectives*, 25(4), pp.191-209.
- Hickman, D.C. and Metz, N.E., 2015. The impact of pressure on performance: Evidence from the PGA TOUR. *Journal of Economic Behavior & Organization*, 116, pp.319-330.
- Hsiao, Cheng. 2003. *Analysis of Panel Data*. Cambridge Books, Cambridge University Press.
- IBU, 2008. 3 IBU Event and Competition Rules (IBU Rules). Retrieved from:  
[http://www5.biathlonworld.com/media/download/Handbook\\_event\\_and\\_competition\\_rules.pdf](http://www5.biathlonworld.com/media/download/Handbook_event_and_competition_rules.pdf)
- IBU, 2016a. 03 Competition Rules (IBU Rules). Retrieved from:  
<http://www.biathlonworld.com/downloads/>
- IBU, 2016b. IBU Biathlon Guide 2016/2017 (IBU Guide). Retrieved from:  
<http://www.biathlonworld.com/downloads/>
- Kayihan, G., Ersöz, G., Özkan, A. and Koz, M., 2013. Relationship between efficiency of pistol shooting and selected physical-physiological parameters of police. *Policing: an international journal of police strategies & management*, 36(4), pp.819-832.
- Krumer, A., 2017. On winning probabilities, weight categories, and home advantage in professional judo. *Journal of Sports Economics*, 18(1), pp.77-96.
- Krumer, A. and Lechner, M., 2017. Midweek effect on soccer performance: Evidence from the German Bundesliga. *Economic Inquiry*, forthcoming.
- Kruse, P., Ladefoged, J., Nielsen, U., Paulev, P.E. and Sorensen, J.P., 1986. Beta-blockade used in precision sports: effect on pistol shooting performance. *Journal of Applied Physiology*, 61(2), pp.417-420.
- Koning, R.H., 2011. Home advantage in professional tennis. *Journal of Sports Sciences*, 29(1), pp. 19-27.

- Konttinen, N., Lyytinen, H. and Viitasalo, J., 1998. Preparatory heart rate patterns in competitive rifle shooting. *Journal of Sports Sciences*, 16(3), pp.235-242.
- Lakie, M., 2010. The influence of muscle tremor on shooting performance. *Experimental Physiology*, 95(3), pp.441-450.
- Lazear, E.P., 2000. The power of incentives. *The American Economic Review*, 90(2), pp.410-414.
- Lazear, E.P. and Rosen, S., 1981. Rank-order tournaments as optimum labor contracts. *Journal of Political Economy*, 89(5), pp.841-864.
- Nickell, S., 1981. Biases in dynamic models with fixed effects. *Econometrica: Journal of the Econometric Society*, pp.1417-1426.
- O'Reilly III, C.A., Main, B.G. and Crystal, G.S., 1988. CEO compensation as tournament and social comparison: A tale of two theories. *Administrative Science Quarterly*, pp.257-274.
- Paserman, M.D., 2010. Gender Differences in Performance in Competitive Environments? Evidence from Professional Tennis Players, mimeo.
- Pettersson-Lidbom, P. and Priks, M., 2010. Behavior under social pressure: Empty Italian stadiums and referee bias. *Economics Letters*, 108(2), pp.212-214.
- Rosen, S., 1986. Prizes and incentives in elimination tournaments. *The American Economic Review*, 76(4), pp. 701-715.
- Stiglitz, J.E., 1976. The efficiency wage hypothesis, surplus labour, and the distribution of income in LDCs. *Oxford Economic Papers*, 28(2), pp.185-207.
- Toma, M., 2017. Missed shots at the free-throw line: Analyzing the determinants of choking under pressure. *Journal of Sports Economics*, 18(6), pp. 539-559.
- Wallace, H.M., Baumeister, R.F. and Vohs, K.D., 2005. Audience support and choking under pressure: A home disadvantage?. *Journal of Sports Sciences*, 23(4), pp.429-438.
- Wooldridge, J., 2002. *Econometric analysis of cross section and panel data*. The MIT Press. Cambridge, Massachusetts, London, England.
- Yu, R., 2015. Choking under pressure: the neuropsychological mechanisms of incentive-induced performance decrements. *Frontiers in Behavioral Neuroscience*, 9(19), pp.1-8.

Figure 1 – Biathlon Stadium Overview (Own Depiction)

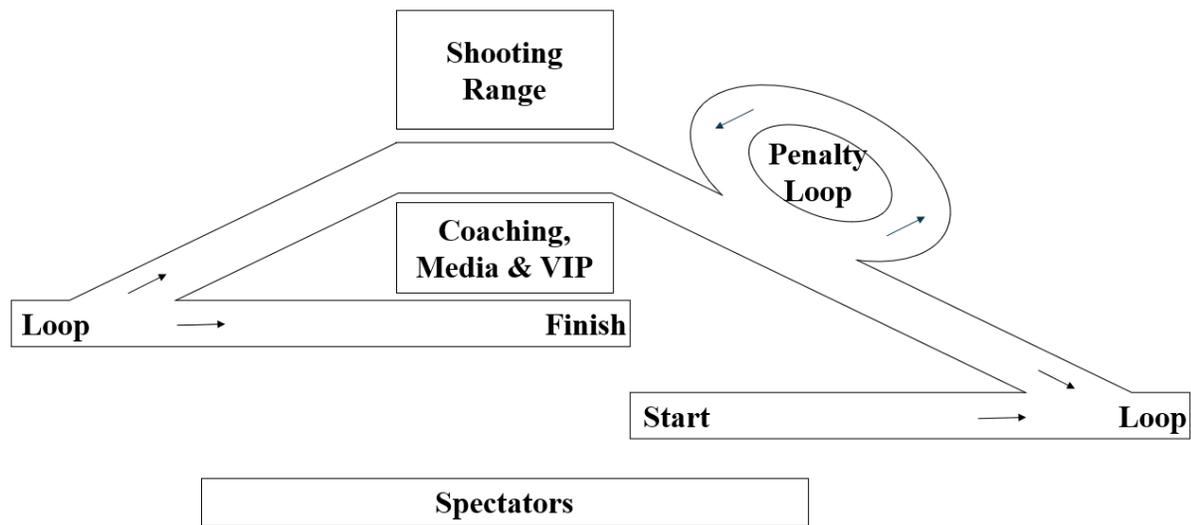


Table 1 – Competition Types

Competition Type and Course Length	Standard Start Types and Intervals	Ski Loops	Shooting Bouts (5 Shots per Bout)	Shot Penalty
<b>Sprint</b> ♂: 10 km, ♀: 7.5 km	Single 30 sec	3	Prone, Standing	150 m
<b>Pursuit</b> ♂: 12.5 km, ♀: 10 km	Pursuit based on results in sprint	5	Prone, Prone, Standing, Standing	150 m
<b>Individual</b> ♂: 20 km, ♀: 15 km	Single 30 sec	5	Prone, Standing, Prone, Standing	1 min
<b>Mass Start</b> ♂: 15 km, ♀: 12.5 km	Simultaneous	5	Prone, Prone, Standing, Standing	150 m

Table 2: Descriptive statistics

Variable Name	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
	Not home country				Home country			
	Men's competitions (220 biathletes)							
Number of missed shots	2.050	1.438	0	9	2.120	1.455	0	8
Course time before the first bout of shooting (seconds)	466.1	44.5	295.2	703.0	466.9	43.5	303.9	660.8
Winning a medal dummy (top 3 rank)	0.051	0.219	0	1	0.049	0.217	0	1
Ranking points	11.341	15.372	0	60	12.029	15.327	0	60
Starting number	48.610	30.986	1	136	49.268	31.664	1	136
Standardized ranking points prior to competition	0.357	1.132	-0.990	4.870	0.406	1.175	-0.990	5.350
Number of observations	7,430				832			
	Women's competitions (217 biathletes)							
Number of missed shots	2.023	1.458	0	9	2.136	1.472	0	7
Course time before the first bout of shooting (seconds)	411.1	40.7	312.8	860.3	413.4	36.8	338.0	520.3
Winning a medal dummy (top 3 rank)	0.053	0.223	0	1	0.064	0.245	0	1
Ranking points	11.676	15.400	0	60	11.591	15.925	0	60
Starting number	44.522	27.733	1	118	43.308	27.527	1	112
Standardized ranking points prior to competition	0.286	1.143	-1.180	4.61	0.345	1.206	-1.180	4.280
Number of observations	5,804				736			

*Table 3: FE estimates of the effect of competing at home on the number of missed shots*

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Men's competitions</i>						
Home country	0.113** (0.052)	0.099** (0.050)	0.099** (0.050)	0.180** (0.073)	0.147** (0.070)	0.152** (0.070)
Number of obs.	8,262	8,262	8,262	8,262	8,262	8,262
<i>Panel B: Women's competitions</i>						
Home country	0.133** (0.057)	0.139** (0.056)	0.138** (0.057)	0.263*** (0.084)	0.235*** (0.082)	0.237*** (0.082)
Number of obs.	6,540	6,540	6,540	6,540	6,540	6,540
Biathlete per season fixed effects	Yes	Yes	Yes	No	No	No
Biathlete per month fixed effects	No	No	No	Yes	Yes	Yes
Competition fixed effects	No	Yes	Yes	No	Yes	Yes
Starting number and its squared value	No	No	Yes	No	No	Yes

Note: The dependent variable is the number of missed shots of biathlete  $i$ , in competition  $r$ . Season includes all the events within the period between November to March. Month includes all the events within the same month. Standard errors clustered at the biathlete per season level (columns 1-3) and at the biathlete per month level (columns 4-6). \*, \*\*, \*\*\* denote significance at the 10%, 5%, 1% level respectively.

Table 4: FE estimates of the effect of competing at home on the course time before the first bout of shooting

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Men's competitions</i>						
Home country	1.491 (1.731)	-1.238*** (0.284)	-1.251*** (0.283)	2.688 (2.402)	-1.996*** (0.360)	-2.026*** (0.359)
Number of obs.	8,103	8,103	8,103	8,103	8,103	8,103
<i>Panel B: Women's competitions</i>						
Home country	2.378 (1.805)	-1.900*** (0.321)	-1.880*** (0.320)	1.351 (2.222)	-2.055*** (0.387)	-2.064*** (0.386)
Number of obs.	6,537	6,537	6,537	6,537	6,537	6,537
Biathlete per season fixed effects	Yes	Yes	Yes	No	No	No
Biathlete per month fixed effects	No	No	No	Yes	Yes	Yes
Competition fixed effects	No	Yes	Yes	No	Yes	Yes
Starting number and its squared value	No	No	Yes	No	No	Yes

Note: The dependent variable is the course time in seconds before the first bout of shooting of biathlete  $i$ , in competition  $r$ . Season includes all the events within the period between November to March. Month includes all the events within the same month. Standard errors clustered at the biathlete per season level (columns 1-3) and at the biathlete per month level (columns 4-6). \*, \*\*, \*\*\* denote significance at the 10%, 5%, 1% level respectively.

Table 5: FE estimates of the effect of competing at home on the probability to win a medal

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Men's competitions</i>						
Home country	-0.011 (0.008)	-0.011 (0.008)	-0.011 (0.008)	-0.017 (0.012)	-0.015 (0.011)	-0.015 (0.011)
Number of obs.	8,262	8,262	8,262	8,262	8,262	8,262
Number of obs. outside range 0-1	0	55	43	0	88	87
<i>Panel B: Women's competitions</i>						
Home country	0.003 (0.010)	0.003 (0.010)	0.003 (0.010)	-0.008 (0.014)	-0.009 (0.014)	-0.009 (0.014)
Number of obs.	6,540	6,540	6,540	6,540	6,540	6,540
Number of obs. outside range 0-1	0	82	100	0	258	258
Biathlete per season fixed effects	Yes	Yes	Yes	No	No	No
Biathlete per month fixed effects	No	No	No	Yes	Yes	Yes
Competition fixed effects	No	Yes	Yes	No	Yes	Yes
Starting number and its squared value	No	No	Yes	No	No	Yes

Note: The dependent variable is the event of winning a medal (gold, silver or bronze) by biathlete  $i$ , in competition  $r$ . Season includes all the events within the period between November to March. Month includes all the events within the same month. Standard errors clustered at the biathlete per season level (columns 1-3) and at the biathlete per month level (columns 4-6). \*, \*\*, \*\*\* denote significance at the 10%, 5%, 1% level respectively.

*Table 6: FE estimates of the effect of competing at home on the ranking points*

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Men's competitions</i>						
Home country	-0.474 (0.502)	-0.379 (0.502)	-0.376 (0.502)	-0.201 (0.698)	-0.008 (0.686)	-0.013 (0.686)
Number of obs.	8,262	8,262	8,262	8,262	8,262	8,262
<i>Panel B: Women's competitions</i>						
Home country	-0.696 (0.504)	-0.712 (0.497)	-0.726 (0.499)	-1.612** (0.693)	-1.647** (0.703)	-1.646** (0.703)
Number of obs.	6,540	6,540	6,540	6,540	6,540	6,540
Biathlete per season fixed effects	Yes	Yes	Yes	No	No	No
Biathlete per month fixed effects	No	No	No	Yes	Yes	Yes
Competition fixed effects	No	Yes	Yes	No	Yes	Yes
Starting number and its squared value	No	No	Yes	No	No	Yes

Note: The dependent variable is the number of ranking points won by biathlete  $i$ , in competition  $r$ . Season includes all the events within the period between November to March. Month includes all the events within the same month. Standard errors clustered at the biathlete per season level (columns 1-3) and at the biathlete per month level (columns 4-6). \*, \*\*, \*\*\* denote significance at the 10%, 5%, 1% level respectively.

## Appendix A: Description of additional biathlon competitions

The pursuit competition is held among the top 60 competitors of the sprint race. The start time is based on the number of seconds a competitor lagged behind the winner of the sprint competition. The distance of 12.5 km for men and 10 km for women is completed in five loops. Four rounds of five are shot in the order: prone, prone, standing, standing. The penalty of a missed target is a 150 m penalty loop. The first competitor to cross the finish line is declared the winner.

In individual race, the biathletes start individually in intervals of 30 seconds, over a five-loop course of 20 km for men and 15 km for women, athletes shoot four times at five targets in the order: prone, standing, prone, standing. Unlike other competition types, a penalty minute is added to the final ski time for each missed target. The final ski time is defined as the time elapsed between start and finish plus any penalty minutes imposed.

Finally, the mass start competition is limited to the top 30 competitors, which are selected based on their performance in the ongoing World Cup season, their performance in other competitions of the current event and the national franchise quotas. All competitors start simultaneously and ski five loops of totally 15 km for men and 12.5 km for women. Trying to avoid the 150 m penalty loop, they shoot four times at five targets in the order: prone, prone, standing, standing. As in the pursuit, the first competitor to cross the finish line wins.