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Abstract

This study examines whether pre-competition uncertainty contributes to gender differences in competitive performance. Many workplace evaluations and promotions involve uncertainty regarding others' potential strategic actions prior to formal competition. Leveraging institutional variation in Japanese professional speedboat racing, we compare “quasi fixed-lane” races—where lane changes before the start are permitted by rule but not executed—with fixed-lane races, in which repositioning is strictly prohibited. This setting allows us to examine exposure to rule-based pre-competition uncertainty in the absence of realized strategic interaction. Gender performance gaps are observed only in environments characterized by such uncertainty. In mixed-sex quasi fixed-lane races, female performance declines while male performance improves; in contrast, these differences are substantially reduced in fixed-lane races, where such uncertainty is absent. The results are consistent with the interpretation that performance disparities partly reflect anticipatory psychological responses to the mere possibility of strategic interaction rather than realized strategic actions. These findings highlight the role of institutional design in shaping gender differences in competitive outcomes.

Keywords: Pre-competition uncertainty; gender differences; competitive performance; institutional design; strategic behavior

1. Introduction

Media reports describe how Kamala Harris and Donald Trump’s campaigns negotiated debate microphone rules prior to a debate—specifically, whether a candidate’s microphone would be muted while the opponent was speaking (Looker 2024). Such rules affect whether candidates can interrupt, respond immediately, or remain silent, thereby shaping expectations about control, exposure, and vulnerability during the debate. More broadly, this example illustrates a common feature of competitive environments: even before formal competition begins, individuals may face uncertainty about others’ potential strategic actions, which can generate psychological pressure and influence preparation and subsequent performance¹.

Many important career outcomes, such as promotions, evaluations, interviews, and salary or role negotiations, are shaped not only by task performance but also by uncertainty about others’ potential strategic actions prior to formal evaluation or competition. For example, candidates for promotion or leadership roles often face uncertainty regarding how others may strategically position themselves before any formal assessment occurs. If individuals respond differently to such uncertainty, these differences may translate into systematic disparities in subsequent performance and career outcomes. A growing body of literature suggests that men and women respond differently to competitive pressure (e.g., Ors et al. 2013; Booth and Lee 2021), raising the possibility that psychological pressure arising from uncertainty about others’ strategic actions before competition contributes to gender gaps in workplace performance and career outcomes.

Accumulating evidence demonstrates that gender differences in competitive behavior and performance are highly context-dependent rather than fixed traits, suggesting that features of the competitive environment play a central role. Prior studies show that institutional rules, competitive pressure, and the scope for strategic considerations substantially shape gender gaps in outcomes across workplaces, sports settings, and controlled laboratory experiments (for reviews, see Kugler et al. 2018; García-Segarra et al. 2025). However, the literature has largely focused on behavior and performance *during* competitions. Much less is known about how uncertainty about others’ potential strategic actions *prior* to competition shapes subsequent performance.

This study addresses this gap by examining how exposure to *pre-competition uncertainty* affects subsequent performance differently for men and women. Pre-competition uncertainty refers to uncertainty about competitors’ potential strategic actions before formal competition begins. Such uncertainty may induce anticipatory psychological responses that influence performance during competition. This study focuses on a form of pre-competition uncertainty that arises from institutional rules governing the scope of strategic behavior, allowing us to distinguish the role of pre-competition uncertainty from that of realized strategic actions.

¹ Historical examples of pre-competition psychological pressure include Bobby Fischer’s pre-match demands and delays in championship chess matches, as well as Muhammad Ali’s use of verbal intimidation before boxing bouts to unsettle opponents.

A key reason for focusing on the pre-competition stage is that it may shape performance beyond what can be explained by observable behavior during competition. Before competition begins, individuals may adjust attention, effort allocation, or risk-taking in anticipation of potential strategic actions. These anticipatory responses may generate psychological pressure that influences subsequent performance. If such responses differ by gender, then observed performance differences may partly reflect psychological processes that unfold before competition, rather than behaviors during it alone.

To understand the origins and consequences of pre-competition uncertainty, it is useful to consider how competitive environments differ in the extent to which performance depends on individual technical skills versus uncertainty about others' strategic actions. For instance, in track and field, pure physical ability largely determines outcomes in short-distance events such as the 100-meter sprint or hurdles. In middle- and long-distance races, however, performance depends more heavily on strategic elements and the associated uncertainty about others' actions, including pacing, positioning, and the timing of a final sprint (Renfree and Hanley 2021). A similar distinction arises in workplace settings. While some competitive situations, such as standardized exams or routine evaluations, are largely performance-based, others—such as promotion processes, leadership selection, and internal negotiations—involve substantial pre-competition uncertainty about how others will behave strategically. This distinction highlights the value of empirical settings in which the effects of pre-competition uncertainty can be separated from those of technical skill.

To examine how exposure to pre-competition uncertainty shapes gender differences in subsequent performance, this study focuses on professional speedboat racing in Japan. The sport includes mixed-sex, all-male, and all-female races. Because race assignments are determined randomly, this setting provides a suitable empirical context in which gender composition is plausibly exogenous to individual ability and other characteristics (Booth and Yamamura 2018; Booth et al. 2022).

In *standard races*, competitors are allowed to change lanes during the pre-start positioning stage to secure a more advantageous starting position, whereas in *fixed-lane races* such lane changes are strictly prohibited. We define races in which lane changes are permitted but do not actually occur as *quasi fixed-lane races*. The primary strength of this study lies in comparing quasi fixed-lane races with fixed-lane races. Although these settings share the same physical and technical starting conditions, they differ in whether participants are exposed to uncertainty about competitors' potential strategic actions—and the associated psychological pressure—during the pre-start positioning stage. This comparison allows us to assess whether exposure to potential strategic interaction is associated with the observed gender performance gap even when no lane changes actually occur.

Using detailed racer-race level data, we find that gender differences in performance vary systematically with the level of pre-competition uncertainty. In mixed-sex quasi fixed-lane races, where racers are exposed to uncertainty about competitors' strategic actions before the start, female performance declines while male performance improves. Conversely, these disparities are substantially weaker in fixed-lane races, where such uncertainty is absent. These findings are consistent with the

interpretation that the observed gender performance gap is associated with psychological responses to pre-competition uncertainty rather than realized obstruction.

This study makes two main contributions to the literature. First, it provides novel empirical evidence that rule design governing the preparation period immediately prior to competition affects performance. By leveraging the institutional features of speedboat racing—where exposure to pre-competition uncertainty during the pre-start positioning stage is rule-dependent—this study sheds light on the pre-competition phase, which is often acknowledged but rarely measured in empirical research. Second, it offers a new perspective on gender differences in performance by highlighting the potential role of anticipatory psychological responses associated with pre-competition uncertainty, even in the absence of realized strategic actions. Rather than focusing solely on observed strategic behavior, our analysis shows that exposure to pre-competition uncertainty embedded in institutional design is associated with systematic gender differences in competitive performance.

2. Literature Review

This study examines gender differences in performance in mixed-sex competitive environments, with a particular focus on how pre-competition uncertainty shapes behavior and outcomes. Accordingly, we review prior research on gender differences in competition, as well as studies on how uncertainty and psychological pressure in competitive settings affect performance.

2.1. Gender Differences in Competition: Preference-Based Explanations

A substantial body of research examines gender differences in competitive behavior and performance, often attributing these differences to variation in preferences—particularly competitiveness, risk-taking, and overconfidence (e.g., Gneezy et al. 2003; Niederle and Vesterlund 2007; Croson and Gneezy 2009; Datta Gupta et al. 2013; Saccardo et al. 2018). For example, in a widely cited study, Niederle and Vesterlund (2007) show that although men and women perform equally well on calculation tasks, women are significantly less likely to enter competitive tournaments. They argue that this gap is partly driven by differences in overconfidence and preferences for competition.

However, accumulating evidence suggests that preference-based explanations alone cannot fully account for gender differences in competition. For instance, Mago and Razzolini (2019), who focus on behavior during competition rather than entry decisions, find no gender difference in competitive behavior in mixed-sex settings. Notably, when competing against other women, women’s effort levels surpass those of men. Similarly, several studies report that women are more likely to enter competitions when they compete only against other women, and that their performance is less adversely affected in same-sex than in mixed-sex competitions (Gneezy et al. 2003; Datta Gupta et al. 2013; Niederle et al. 2013).

Moreover, gender differences in competitive behavior tend to emerge in math-related tasks—typically male-stereotyped—but not in verbal tasks, which are often female-stereotyped (Dreber et al.

2014; Boschini et al. 2019). Gender differences in bargaining behavior, a form of strategic interaction, also vary across cultural contexts (e.g., patriarchal versus matrilineal societies; Gneezy et al. 2009), educational environments (e.g., single-sex versus co-educational schools; Booth and Nolen 2012), and roles (e.g., employees versus employers; Dittrich et al. 2014; Andersen et al. 2018; Hernandez-Arenaz and Iriberry 2018). Taken together, these findings suggest that women are not consistently more averse to competition than men; rather, competitive behavior is highly sensitive to contextual features of the environment.

2.2. Context Dependence and Strategic Interaction in Mixed-Sex Competition

Building on these insights, we examine how competitive environments with and without strategic elements influence gender-specific behavioral responses in mixed-sex settings. Closely related to our empirical context, Booth and Yamamura (2018) show that male racers behave more aggressively in standard mixed-sex races, whereas women adopt less aggressive strategies. These differences in strategic behavior help explain why men perform better when competing against women, while women perform better in same-sex settings.

More broadly, the literature on gender differences in strategic interaction in controlled laboratory settings provides mixed evidence (see García-Segarra et al. 2025, for a review). In an ultimatum bargaining game, Eckel and Grossman (2001) find that women are more likely to accept offers from women, while men are more likely to accept offers from men. Conversely, Solnick (2001) reports that women tend to accept offers from males rather than female proposers. Sutter et al. (2009) show that same-sex bargaining pairs exhibit more competition and retaliation, resulting in lower efficiency. In another strategic setting—the battle-of-the-sexes game—Holm (2000) demonstrates that when paired with a female partner, both men and women are more likely to choose aggressive actions, systematically disadvantaging women in mixed-sex pairings. However, Huang and Low (2022) demonstrate that explicit verbal communication can significantly alter these gender differences.

The present study departs from this literature by shifting attention from realized strategic behavior to pre-competition uncertainty embedded in institutional rules. Specifically, we examine whether the mere possibility of strategic interference shapes performance outcomes.

2.3. Strategic Ambiguity and Gendered Performance

Recent research suggests that ambiguity in institutional rules plays a central role in shaping gender outcomes in competitive settings. Gender differences tend to diminish when rules are clearly specified and strategic discretion is limited. For example, Hernandez-Arenaz and Iriberry (2023) show that introducing a clear sharing rule eliminates gender differences in bargaining outcomes. Similarly, Dato and Nieken (2020) find that gender gaps in sabotage behavior emerge under uncertainty but disappear once uncertainty is removed. Field and meta-analytic evidence further indicates that clearly defined

bargaining ranges and institutional constraints reduce gender disparities (Bowles et al. 2005; Leibbrandt and List 2015; Kugler et al. 2018).

In this context, our empirical setting can be interpreted as contrasting environments with high versus low ambiguity. Standard races, which allow discretionary strategic actions, involve ambiguity regarding the possibility of opponents' aggressive behavior (e.g., lane changes or obstruction). By contrast, fixed-lane races substantially restrict such discretion and thus minimize ambiguity. Taken together, existing evidence suggests that ambiguity in institutional environments may generate differential behavioral responses between men and women by increasing exposure to pre-competition uncertainty. Rather than merely altering strategic choices, ambiguous rules may generate psychological pressure even before competition begins.

A growing body of research identifies psychological pressure as a key factor underlying gender differences in performance. Studies show that women experience larger declines in performance than men under competitive pressure (Ors et al. 2013; Booth and Lee 2021). Laboratory evidence further demonstrates that acute psychosocial stress reduces women's tournament performance while leaving men's performance largely unchanged (Cahlíková et al. 2020). Notably, in many of these studies, psychological pressure arises from anticipated evaluation or potential interaction rather than from realized interference.

Taken together, these studies suggest a possible mechanism: pre-competition uncertainty arising from institutional rules generates psychological pressure that affects men and women asymmetrically. When rules permit discretionary strategic maneuvering—even if it is not ultimately exercised—competitors may anticipate potential interference or disadvantage. This anticipatory process may generate psychological pressure that, in turn, affects subsequent performance. If such pressure differs by gender, ambiguity embedded in rule design may translate into systematic performance gaps.

3. Institutional Setting and Hypotheses

This section introduces the institutional features of Japanese speedboat racing that create exogenous variation in pre-competition uncertainty. The sport has a two-stage structure consisting of a pre-start positioning stage and a racing stage, and race formats differ in whether lane changes are permitted during the pre-start period. Comparing quasi fixed-lane races with fixed-lane races allows us to assess the effect of exposure to potential strategic interaction before the start while holding physical starting conditions constant. These institutional features underpin our identification strategy and motivate the hypotheses developed below.

3.1. Institutional Features of Speedboat Racing in Japan

Japanese speedboat racing operates under a highly standardized institutional framework administered by the Japan Motor Boat Racing Association. Each race consists of six racers, who are randomly assigned to races that may be either mixed-sex or single-sex. Boats and motors are also randomly

allocated at the beginning of each race meeting, preventing racers from systematically selecting higher-performance equipment.

Speedboat racing takes place across 24 stadiums in Japan, on artificial ponds or sectioned-off bodies of water measuring 600 meters in length. A standard race consists of three laps (1,800 meters in total), although races may be shortened to two laps (1,200 meters) under adverse weather conditions. While environmental conditions vary across locations, rules and race formats are standardized nationwide. Race meetings last up to seven consecutive days, during which racers typically compete in approximately three races per day.

Male and female racers undergo identical training at a single national training school before entering professional competition. Applicants must be aged 15 to 29, complete a one-year training program, and pass a final examination. Thus, men and women enter the profession under the identical qualification requirements and compete under the same institutional conditions.

Of approximately 1,600 active racers, about 240 are women. Racers range in age from their teens to their seventies. In single-sex races, all six participants are of the same gender, whereas mixed-sex races typically include one or two female racers alongside male competitors. Despite differences in participant composition, rules, race conditions, and prize structures do not vary by gender. The only exception is the minimum weight requirement: men must weigh at least 50 kg, whereas women must weigh at least 47.5 kg. Additional institutional details are provided in **Appendix A**.

3.2. Two-stage Structure and Pre-Start Positioning

Speedboat racing follows a two-stage structure, consisting of a *pre-start positioning* stage (**Figure 1**, panels (1) and (2)), followed by a *racing stage* that determines final standings. The racing stage begins when racers accelerate toward the starting line from their starting lanes (**Figure 1**, panels (3) and (4)) and continues through the timed race.

In the standard race format, the lane initially assigned to a racer (the lane at Pit Out) may differ from the actual starting lane (the lane at Acceleration). During the pre-start positioning stage, racers maneuver at relatively low speeds and adjust their positions before the start. Because inside lanes are generally more advantageous, racers may attempt to secure them during this stage; however, they face disqualification and severe penalties if they interfere with another racer's course. Once starting lanes are finalized, racers make brief positional adjustments before accelerating toward the starting line.

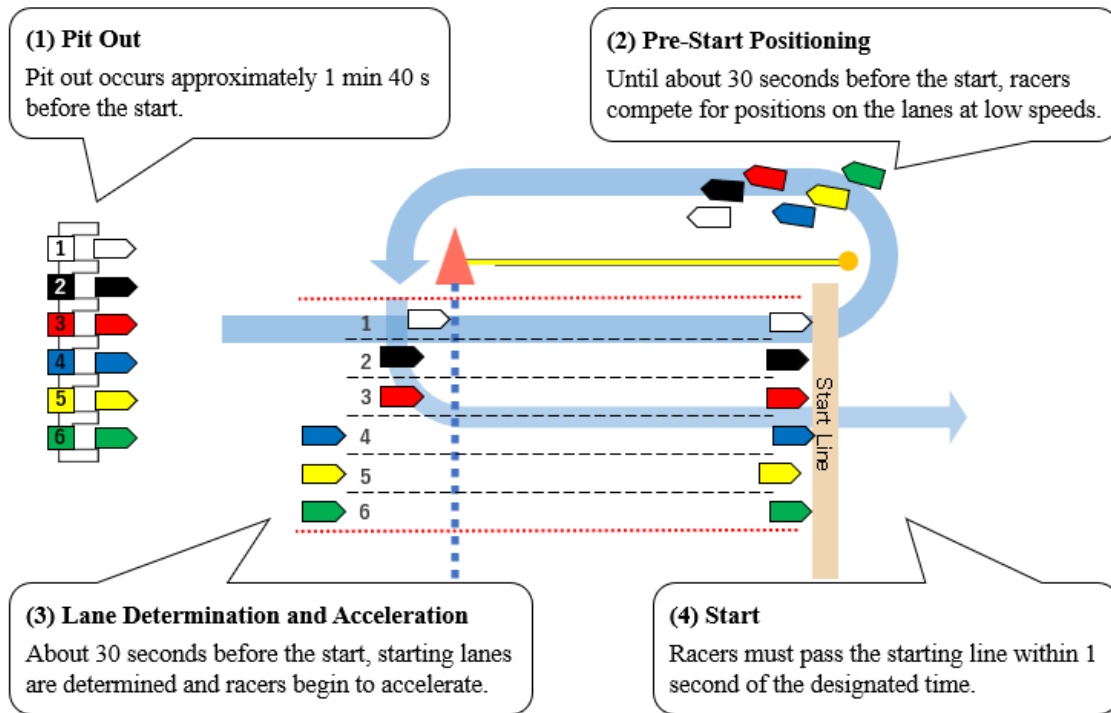


Figure 1. Pre-Start Positioning Stage in a Standard Race

Source: Japan Motor Boat Racing Association, <https://www.boatrace.jp/owpc/pc/extra/en/index.html> (accessed on September 11, 2023).

This two-stage structure makes speedboat racing particularly well suited to analyzing how differences in competitive environments shape performance outcomes, as it separates strategic interaction during the pre-start positioning stage from technical performance during the racing stage. Because final standings are determined during the racing stage, the pre-start positioning phase can be interpreted as the source of pre-competition uncertainty.

3.3. Flying Start System and Timing Constraints

Speedboat racing employs a *flying start system* that shapes racers' strategic behavior by creating a trade-off between potential advantages and the risk of penalties. Racers must ensure that their boats cross the starting line within a narrow time window relative to the official race clock. **Figure 2** illustrates the flying start system used in Japan. In official race records, start time is measured as the number of seconds at which a racer crosses the starting line after the race clock reaches zero.

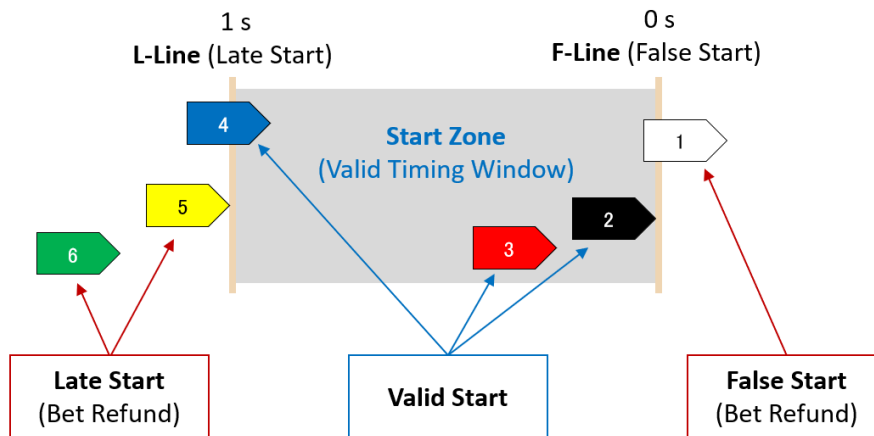


Figure 2. Flying Start System and Timing Rules

In this system, crossing the starting line earlier than other boats provides a positional advantage. However, if a boat crosses the line before the race clock reaches zero, the start is classified as a false start (F). Conversely, if a boat crosses the line more than one second after zero, the start is classified as a late start (L). Both outcomes constitute starting violations, resulting in disqualification and the refund of bets placed on the boat.

Consequently, starting as early as possible may improve race outcomes but also entails substantial risk. Racers must therefore balance the potential gains from an aggressive start against the possibility of severe penalties. Additionally, disruptive behavior during the pre-start positioning stage may delay acceleration, potentially worsening start timing.

3.4. Race Formats and Strategic Interaction

Japanese speedboat racing features two institutional race formats: standard and fixed-lane. For analytical purposes, we define a subset of standard races without lane changes as *quasi fixed-lane* races.

In standard races, competitors may change lanes during the pre-start positioning stage, introducing strategic interaction in addition to technical skill. After the start, the race becomes a timed competition, and technical ability plays a dominant role in determining outcomes. In fixed-lane races, lane changes are prohibited during the pre-start stage, and racers must approach the starting line in their assigned lanes from pit-out. Apart from this restriction, all other race rules are identical across formats.

Quasi fixed-lane races—standard races in which no lane changes occur—raise a potential concern about selection bias, as lane changes reflect racers’ strategic choices. If the propensity to change lanes is systematically related to unobserved characteristics such as ability, aggressiveness, or risk preferences, conditioning on races without lane changes could introduce bias.

Several pieces of evidence suggest that this concern is limited in practice. First, quasi fixed-lane races account for approximately 85% of standard races, indicating that the absence of lane changes is

typical rather than exceptional. Lane changes require coordination among multiple racers and involve a substantial risk of penalties if interference occurs; consequently, they do not occur in many races despite being permitted. Second, lane changes occur in 13.7% and 15.0% of single-sex and mixed-sex standard races, respectively. Although this difference is statistically significant given the large sample size, it is economically small, suggesting that the likelihood of lane changes does not differ meaningfully by gender composition. Third, observable race and racer characteristics are broadly comparable across formats (**Table A1**), providing no evidence of systematic sorting on observables.

More generally, the quasi fixed-lane classification introduces a potential endogeneity concern. Because the absence of lane changes is an equilibrium outcome of racers’ strategic decisions, such races may arise in environments with lower expected strategic intensity—for example, races involving less aggressive competitors or lower anticipated benefits from repositioning. If such unobserved factors are correlated with performance, conditioning on quasi fixed-lane races could bias the estimates.

Importantly, our identification strategy does not rely solely on the quasi fixed-lane classification. Instead, it is based on comparing quasi fixed-lane and fixed-lane races, which share the same physical starting conditions but differ in whether rule-based pre-competition uncertainty is present. Because both formats share the same physical starting conditions, differences in performance between quasi fixed-lane and fixed-lane races are more plausibly associated with institutional exposure to potential strategic interaction rather than with realized positioning or technical factors. Although quasi fixed-lane races may still reflect equilibrium selection, the comparison substantially narrows the set of alternative explanations.

To further address potential selection concerns, we employ several complementary approaches. First, we show that observable characteristics are balanced across race formats. Second, we exploit within-racer variation using racer fixed effects, which absorb time-invariant individual heterogeneity. Third, we conduct additional robustness checks (Section 5.3), including inverse probability weighting (IPW) to correct for selection on observables, alternative interaction specifications, and expanded samples; all approaches yield consistent results.

3.5. Race Formats, Competitive Environments, and Pre-Competition Uncertainty

Building on the institutional features described above, we classify races into three competitive environments: standard races, quasi fixed-lane races, and fixed-lane races. These environments differ along two key dimensions: whether lane changes before the start are institutionally permitted and whether they actually occur. **Table 1** summarizes these differences and highlights the variation underlying our identification strategy.

Table 1. Comparison of Race Formats and Strategic Conditions

Race Format	Lane Changes Permitted by Rules	Lane Changes Occur	Pre-Competition Uncertainty
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Standard Race	Yes	Yes	Yes
Quasi Fixed-Lane Race	Yes	No	Yes
Fixed-Lane Race	No	No	No

Note: Pre-competition uncertainty refers to uncertainty prior to the start about whether competitors will engage in strategic lane positioning. In quasi fixed-lane races, lane changes are permitted institutionally but do not occur.

As shown in **Table 1**, quasi fixed-lane races occupy an intermediate position: although lane changes are permitted by rule, they do not actually occur. This feature makes them a useful benchmark for distinguishing the role of pre-competition uncertainty from the direct effects of realized lane repositioning. If outcomes differ between quasi fixed-lane and fixed-lane races, such differences are consistent with the interpretation that exposure to rule-based pre-competition uncertainty is associated with gender differences in competitive performance.

3.6. Hypothesis Development

Booth and Yamamura (2018) show that male racers perform better in mixed-sex races than in single-sex races, whereas female racers perform worse in mixed-sex settings. They attribute this gender difference to strategic aggressiveness during the pre-start positioning stage, as male racers are more likely than female racers to attempt aggressive lane changes without incurring higher penalty rates.

While this explanation focuses on realized strategic behavior, racers must also anticipate potential actions by their competitors before the race begins. Building on this mechanism, we argue that gender differences in mixed-sex races may be shaped not only by the execution of strategic behavior but also by pre-competition uncertainty regarding whether such behavior will occur.

From this perspective, competitive environments differ along two dimensions: whether strategic interaction is institutionally permitted and whether it actually occurs. Crucially, even in the absence of observed strategic actions, the mere possibility of such actions may affect performance differently for men and women. Accordingly, we propose the following hypotheses:

Hypothesis 1 (H1). *In quasi fixed-lane races, where racers face pre-competition uncertainty:*

(A) *Female racers perform worse in mixed-sex races than in same-sex races; and*

(B) *Male racers perform better in mixed-sex races than in same-sex races.*

This may occur because uncertainty regarding competitors' potential strategic actions (e.g., lane changes) may generate psychological responses prior to competition and thereby affect performance differently by gender.

In fixed-lane races, pre-competition uncertainty is absent. Therefore, no gender differences in performance are expected across mixed- and same-sex races.

Hypothesis 2 (H2). *In fixed-lane races, where no pre-competition uncertainty exists:*

(A) *Female racers perform similarly in mixed-sex and same-sex races; and*

(B) *Male racers perform similarly in mixed-sex and same-sex races.*

4. Data and Sample Construction

This study uses a dataset combining race performance records with racer attributes for races conducted between January 1, 2018, and April 30, 2020. Race performance data were obtained from the “Race Results” section of the official BOAT RACE website, while racer attributes were collected from the “Racer Term Records” section of the same source².

Following Booth and Yamamura (2018), we construct a panel dataset using data from seven of the 24 boat-race stadiums in Japan that publicly disclose complete race and racer records. These stadiums were selected based on data completeness and consistency. In line with their approach, the analysis is restricted to observations with valid race outcomes.

The dataset contains racer–race observations, including race outcomes and performance measures, lane assignments, race grade³, gender composition, and racer characteristics such as age and body weight (measured on the day of each race). To ensure comparability across races, we restrict the analysis to races conducted over a distance of 1,800 meters. Shorter races (1,200 meters) are excluded because goal times are not directly comparable across distances. These races account for only a small fraction of the sample (1,128 observations, approximately 0.5%), indicating that this restriction is unlikely to affect representativeness. During the sample period, 1,444 male and 227 female racers participated in 32,615 races. Because each race involves six racers, the final estimation sample consists of 195,690 racer–race observations, yielding an unbalanced panel.

We use two outcome measures: finishing position and goal time. Finishing position is observed only for officially completed races, whereas goal time is available only for racers who finish. These restrictions reflect institutional rules governing race completion. Although such exclusions may raise concerns about sample selection, races with incomplete results account for only a small fraction of observations.

Race grades are included as key control variables, as their distribution differs systematically by gender. Female racers are more likely to participate in lower-grade races, consistent with differences in experience and ranking⁴. Controlling for race-grade fixed effects helps ensure that estimated gender differences are not driven by variation in competitive intensity.

A key institutional feature of speedboat racing is the random assignment of racers to races. We assess this by examining whether racer characteristics differ across mixed- and single-sex races.

² The data are publicly available at <https://www.boatrace.jp> (accessed in September 2023).

³ Race grades reflect the competitive level and money prize of races, with higher-grade races typically involve more experienced and higher-ranked racers (See **Appendix A.1**).

⁴ Racers are ranked based on past performance records, and eligibility for races of different grades is determined by these rankings. Rankings are updated twice a year (in May and November), defining discrete ranking periods, at which time racers’ performance records are reset and their official rankings and weights are announced (see **Appendix A.1**).

Balance tests reported in **Appendix B** show that key observable characteristics—including age, body weight, and racer rank—are similar across race types, with economically small differences in means. These results support the assumption that race gender composition is conditionally exogenous to individual ability and physical characteristics.

Fixed-lane races account for a relatively small proportion of the sample, reflecting institutional constraints: they are conducted in only a limited number of stadiums and are scheduled less frequently than standard races. In the analytical sample, fixed-lane observations represent approximately 2–3% of all racer–race observations. The limited share may raise concerns about statistical power when comparing race formats. To address this, **Section 5.3.2** presents robustness checks using expanded samples and alternative specifications, which suggest that the main findings are not driven by the small number of fixed-lane observations. **Appendix B** provides detailed descriptive statistics, balance checks, and additional figures illustrating gender differences in race performance.

5. Model and Results

5.1. Empirical Strategy and Model Specification

Our empirical strategy exploits a key institutional feature of Japanese speedboat racing: racers are randomly assigned to races, generating plausibly exogenous variation in race gender composition. We use racer fixed effects to compare performance across mixed- and single-sex races, thereby isolating the effect of mixed-sex competition from time-invariant individual characteristics.

We examine how mixed-sex races affect performance using two outcome measures: (i) finishing position and (ii) the natural logarithm of goal time (in seconds). We estimate the following racer fixed-effects model separately by gender and race format:

$$P_{irtk} = a_0 + a_1 \text{MixRace}_{irtk} + \mathbf{X}'_{irt} \boldsymbol{\beta} + \mathbf{Y}'_{irt} \boldsymbol{\gamma} + \mathbf{Z}'_{irtk} \boldsymbol{\delta} + m_{tk} + \theta_i + \varepsilon_{irtk}, \quad (1)$$

where P_{irtk} denotes the performance outcome of racer i in race r , on day t , at stadium k . The unit of observation is the racer–race pair. Because racers may participate in multiple races on the same day at the same stadium, races are explicitly indexed by r .

We divide the sample by race format (quasi fixed-lane and fixed-lane) and by racer gender. Equation (1) is therefore estimated separately for four subsamples: female racers in quasi fixed-lane races, female racers in fixed-lane races, male racers in quasi fixed-lane races, and male racers in fixed-lane races.

The key explanatory variable, MixRace_{irtk} , is a dummy equal to one if the race is mixed-sex and zero otherwise. In alternative specifications, we replace this indicator with the number of opposite-sex competitors to capture more granular variation in gender composition.

The vector \mathbf{X}_{irt} includes individual racer characteristics capturing ability and physical attributes. Specifically, it includes age and its square to allow for a nonlinear relationship with performance, as

well as body weight measured immediately before each race. Greater body weight increases water resistance and is therefore expected to be associated with slower goal times.

The vector \mathbf{Y}_{irt} controls for the characteristics of competitors in the same race that may affect individual performance. These variables capture the competitive environment and include the number of competitors with higher and lower ranks than the focal racer, as well as the number with more and fewer years of professional experience. To account for physical disparities among competitors, we also include the number of heavyweight racers (defined as those in the top 75th percentile of the male weight distribution within each ranking period) and lightweight racers (defined as those in the bottom 25th percentile of the female weight distribution).

The vector \mathbf{Z}_{irtk} captures race-level conditions. It includes race-grade dummy variables to account for differences in prize money and psychological pressure, as well as lane-assignment dummies, since inner lanes are generally more advantageous than outer lanes.

We include stadium \times day fixed effects (m_{tk}) to control for race conditions that vary across locations and race days. Racer fixed effects (θ_i) absorb all time-invariant individual characteristics, such as innate ability and long-term skill. The error term ε_{irtk} captures unobserved shocks to performance. Standard errors are clustered at the race level to account for within-race correlation across racers.

5.2. Results for Hypotheses 1 and 2

5.2.1 Results for Quasi Fixed-Lane Races (Hypothesis 1)

Figure 3 reports the estimated effects of mixed-sex races and exposure to opposite-sex competitors in quasi fixed-lane races. Two clear patterns emerge. First, female racers perform significantly worse in mixed-sex races than in single-sex races: finishing positions worsen (higher values indicate poorer performance), and goal times increase. The magnitude of these effects rises with the number of male competitors. On average, women's finishing position worsens by approximately 0.52 places, and goal time increases by about 0.34 seconds. Second, male racers exhibit the opposite pattern. In mixed-sex races, they perform significantly better than in single-sex races: finishing positions improve and goal times decrease. The magnitude of these effects increases with the number of female competitors. On average, men's finishing position improves by approximately 0.11 places. These findings provide strong support for Hypothesis 1.

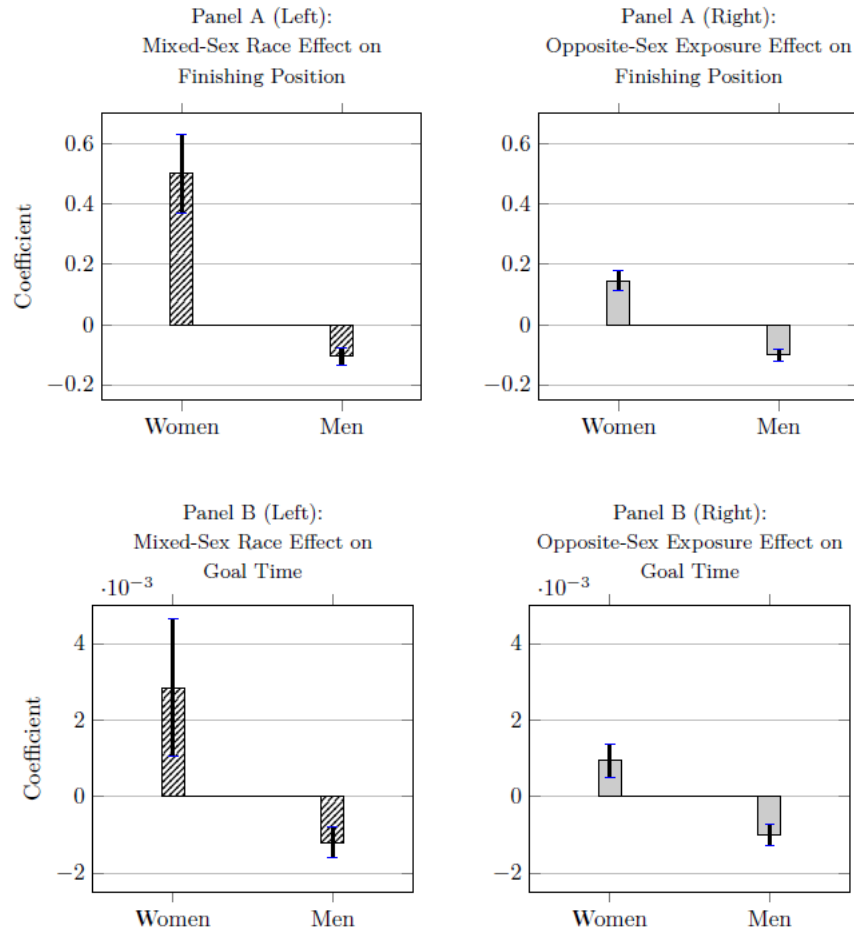


Figure 3. Effects of Mixed-Sex Races and Opposite-Sex Exposure in Quasi Fixed-Lane Races

Note: This figure reports coefficient estimates for quasi fixed-lane races (see **Appendix Table A4**). Panel A presents results for finishing position, and Panel B presents results for goal time. The left column shows estimates using the mixed-sex dummy, and the right column uses the number of opposite-sex competitors. Bars indicate point estimates, and error bars represent 95% confidence intervals. All specifications follow Equation (1). Standard errors are clustered at the race level. The sample includes 20,372 female racers and 148,849 male racers.

The estimated increase in women’s goal time is economically meaningful. In professional boat racing, outcomes are often determined by margins well below one second; a 0.34-second increase therefore represents a substantial disadvantage that can affect final rankings and prize eligibility. Detailed regression results are reported in **Appendix Table A4**.

The estimated effects are asymmetric across genders: the decline in female performance is larger than the improvement observed among male competitors. Consequently, pre-competition uncertainty may affect aggregate performance outcomes rather than simply reallocating performance across competitors. Although the present study does not directly evaluate overall efficiency, the results suggest that institutional rules may influence the aggregate level of competitive performance.

5.2.2 Results for Fixed-Lane Races (Hypothesis 2)

Figure 4 presents the estimated effects of mixed-sex races and exposure to opposite-sex competitors in fixed-lane races. In contrast to the quasi fixed-lane results in **Section 5.2.1**, we find no statistically significant performance effects in this setting. A formal test of whether these effects differ from those in quasi fixed-lane races is presented in **Section 5.3.2**. For female racers, both the mixed-sex indicator and the number of male competitors yield small and statistically insignificant estimates for both finishing position and goal time, and the corresponding confidence intervals consistently span zero. These findings provide little evidence that mixed-sex competition affects women’s performance in fixed-lane races. Similarly, there is little evidence that mixed-sex competition affects men’s performance in fixed-lane races, and the gender asymmetry observed in quasi fixed-lane races is no longer statistically detectable. Detailed regression results are reported in **Appendix Table A5**.

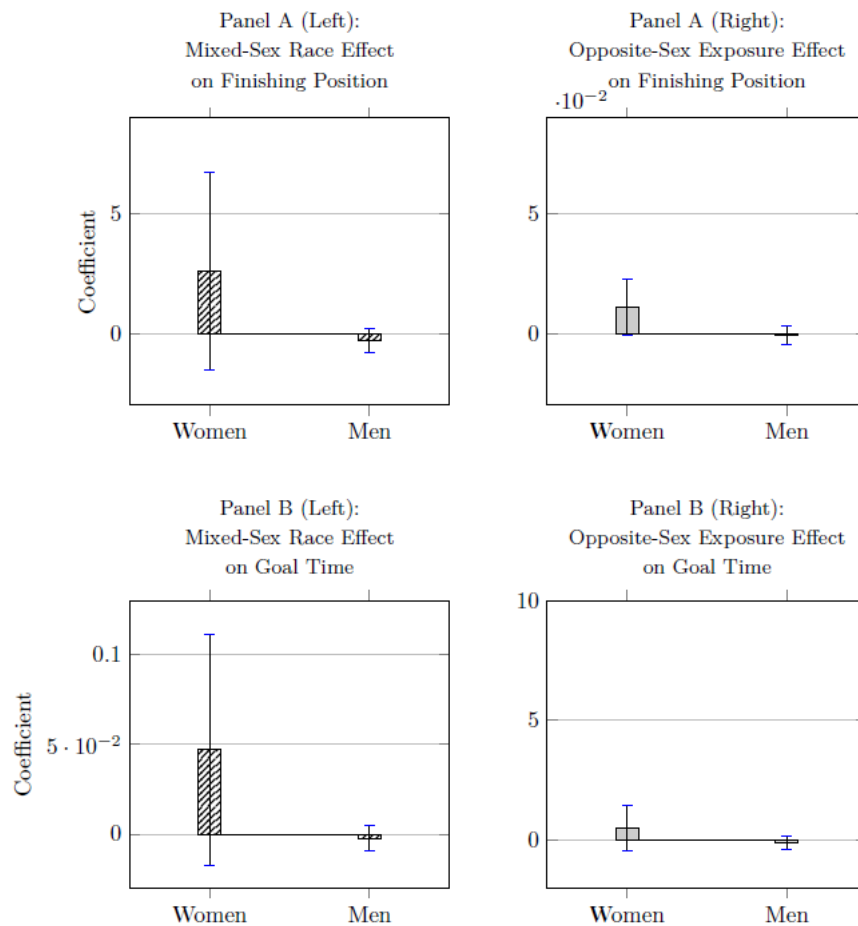


Figure 4. Effects of Mixed-Sex Races and Opposite-Sex Exposure in Fixed-Lane Races

Note: This figure reports coefficient estimates for fixed-lane races (see **Appendix Table A5**). Panel A presents results for finishing position, and Panel B presents results for goal time. The left column shows estimates using the mixed-sex dummy, and the right column uses the number of opposite-sex competitors. Bars indicate point estimates, and error bars indicate 95% confidence intervals. All specifications follow Equation (1). Standard errors are clustered at the race level. The sample includes 623 female racers and 3,895 male racers.

To further assess whether the null results in fixed-lane races reflect random variation, we conduct permutation tests based on 1,000 random reassignments of mixed-sex status at the race level. For goal time, the observed coefficients fall well within the permutation distributions for both male and female racers. Detailed results are reported in **Appendix B**.

5.3. Robustness Checks

We conduct four robustness checks. First, we restrict the sample to stadiums that host fixed-lane races to mitigate concerns about unobserved stadium heterogeneity. Second, we estimate alternative interaction specifications and use expanded samples to assess sensitivity to statistical power, estimation strategy, and sample coverage, thereby addressing concerns that the null effects in fixed-lane races may be driven by limited sample size. Third, we examine whether the estimated effects depend on the gender composition of adjacent lanes, providing a more localized measure of exposure than the race-level mixed-sex indicator. Fourth, we implement an IPW approach to address potential selection into quasi fixed-lane races.

5.3.1. Stadium Heterogeneity

Racer performance may vary with stadium characteristics, such as whether races are held in artificial pools or open water, as well as environmental conditions including wind, waves, and currents. Fixed-lane races are conducted in a limited subset of stadiums, whereas quasi fixed-lane races are held nationwide. Consequently, differences in performance across race formats may partly reflect stadium-specific conditions rather than the race format itself.

Stadium conditions may also differentially affect male and female racers. For example, rough water conditions could influence performance through physical or technical channels. If mixed-sex races or exposure to opposite-sex competitors are systematically more likely to occur at particular stadiums, the estimated effects may conflate gender composition with unobserved stadium heterogeneity.

To address this concern, we restrict the sample to stadiums that host fixed-lane races. This ensures that both quasi fixed-lane and fixed-lane races are observed within the same venues. Comparing race formats within the same stadiums reduces the likelihood that estimated mixed-sex effects capture systematic differences in stadium conditions rather than the institutional features of the race format.

Table 2, Panel A reports results for finishing position, using the same column structure as the main results tables (Appendix **Tables A4–A5**). In quasi fixed-lane races, the mixed-sex effect remains positive and statistically significant for female racers, indicating worse performance, while the corresponding coefficients for male racers are negative and statistically significant, indicating improved performance. In contrast, in fixed-lane races, the estimated coefficients are imprecise and statistically insignificant for both genders, providing no evidence of systematic performance differences.

Table 2. Robustness Check: Stadium Subsample**Panel A: Finishing Position**

	Finishing Position							
	Quasi Fixed-Lane Races				Fixed-Lane Races			
	(1) Women	(2) Men	(3) Women	(4) Men	(5) Women	(6) Men	(7) Women	(8) Men
Mixed-sex	0.533*** (0.0673)	-0.0956*** (0.0156)			2.594 (2.114)	-0.301 (0.244)		
Number of opposite-sex competitors			0.139*** (0.0163)	-0.0909*** (0.0112)			0.526 (0.438)	-0.128 (0.145)
Constant	13.47*** (3.294)	4.077*** (1.406)	13.17*** (3.305)	4.029*** (1.405)	29.80 (27.23)	9.457 (10.70)	29.97 (27.28)	9.366 (10.71)
Other Controls	Included	Included	Included	Included	Included	Included	Included	Included
Lane dummies (1–5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,504	127,498	17,504	127,498	623	3,895	623	3,895
R-squared	0.380	0.345	0.381	0.345	0.773	0.680	0.772	0.680

Note: Columns (1)–(4) correspond to quasi fixed-lane races, and columns (5)–(8) to fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Panel B: Goal Time

	Goal Time							
	Quasi Fixed-Lane Races				Fixed-Lane Race			
	(1) Women	(2) Men	(3) Women	(4) Men	(5) Women	(6) Men	(7) Women	(8) Men
Mixed-sex	0.0030*** (0.0009)	-0.0012*** (0.0002)			0.0471 (0.0328)	-0.0024 (0.0035)		
Number of opposite sex competitors	0.0010*** (0.0001)	0.0010*** (6.48e-05)	0.0008*** (0.0002)	-0.0010*** (0.0001)			0.0110* (0.0063)	-0.000547 (0.0022)
Constant	4.817*** (0.0480)	4.739*** (0.0197)	0.000*** (1.37e-05)	0.000*** (5.65e-06)	5.111*** (0.319)	4.846*** (0.146)	5.106*** (0.320)	4.846*** (0.147)
Other Controls	Included	Included	Included	Included	Included	Included	Included	Included
Lane dummies (1-5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,778	143,600	18,778	143,600	623	3,895	623	3,895
R-squared	0.455	0.394	0.455	0.394	0.821	0.698	0.822	0.698

Note: Columns (1)–(4) correspond to quasi fixed-lane races and columns (5)–(8) to fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Table 2, Panel B reports results using goal time as the outcome variable. Consistent with the main analysis, female racers experience a statistically significant increase in goal time in quasi fixed-lane races, while male racers exhibit a decrease. In fixed-lane races, however, no significant effects are observed for either gender. The estimates are imprecise, further supporting the conclusion that mixed-sex competition does not affect performance when pre-competition strategic interaction is absent.

Overall, results from both outcome measures indicate that mixed-sex effects are present in quasi fixed-lane races but are substantially weaker and no longer statistically detectable in fixed-lane races. Detailed regression results are reported in Appendix **Table A7**.

5.3.2. Statistical Power Concerns and Sample Coverage

The main analysis in **Section 5.2** estimates separate models by gender and race format to examine whether the effects of mixed-sex competition differ across these dimensions. However, estimating multiple subsamples may reduce statistical power, particularly for fixed-lane races, which have relatively few observations. Consequently, the absence of statistically significant effects in fixed-lane races could reflect limited statistical power rather than a genuine attenuation of mixed-sex effects.

This analysis complements the permutation-based evidence in **Section 5.2** by assessing whether the null results in fixed-lane races persist under alternative specifications with greater statistical power. To assess whether the fixed-lane null results are sensitive to sample size and model specification, we estimate two complementary specifications. First, following Booth et al. (2022), we estimate a pooled model using the full sample that includes all interaction terms among the mixed-sex, female, and fixed-lane indicators:

$$\begin{aligned}
P_{irtk} = & a_0 + a_1 \text{MixRace}_{irtk} + a_2 \text{FixedLane}_{irtk} + a_3 (\text{MixRace}_{irtk} \times \text{FixedLane}_k) \\
& + a_4 (\text{MixRace}_{irtk} \times \text{Woman}_i) + a_5 (\text{FixedLane}_k \times \text{Woman}_i) \\
& + a_6 (\text{MixRace}_{irtk} \times \text{Woman}_i \times \text{FixedLane}_k) \\
& + \mathbf{X}'_{irt} \boldsymbol{\beta} + \mathbf{Y}'_{irt} \boldsymbol{\gamma} + \mathbf{Z}'_{irtk} \boldsymbol{\delta} + m_{tk} + \theta_i + \varepsilon_{irtk}, \tag{2}
\end{aligned}$$

This specification allows us to test whether the effect of mixed-sex competition differs by gender across race formats. The triple interaction term captures whether the gender-specific mixed-sex effect differs between quasi fixed-lane and fixed-lane races. Pooling the data increases statistical power and enables a direct test of whether fixed-lane rules attenuate gender-specific mixed-sex effects.

Second, to facilitate comparison with the main results in **Section 5.2**, we estimate separate models for quasi fixed-lane and fixed-lane races following Booth and Yamamura (2018):

$$P_{irtk} = a_0 + a_1 (\text{MixRace}_{irtk} \times \text{Woman}_i) + \mathbf{X}'_{irt} \boldsymbol{\beta} + \mathbf{Y}'_{irt} \boldsymbol{\gamma} + \mathbf{Z}'_{irtk} \boldsymbol{\delta} + m_{tk} + \theta_i + \varepsilon_{irtk}, \tag{3}$$

Comparing the pooled and split-sample estimates allows us to assess whether the main conclusions are sensitive to sample partitioning and model specification. The vectors of control variables \mathbf{X}_{irt} , \mathbf{Y}_{irt} , and \mathbf{Z}_{irtk} , as well as the stadium \times day fixed effects (m_{tk}), racer fixed effects (θ_i), and error structure are identical to those in the baseline specification (Equation (1)).

Table 3 reports results from these alternative specifications. Columns (1)–(2) present pooled estimates using the full sample. The coefficient on the mixed-sex indicator captures the effect for male racers in quasi fixed-lane races and is negative and statistically significant, indicating improved performance. The interaction term *Mixed-sex* \times *Woman* captures the differential effect for female racers in quasi fixed-lane races and is positive and statistically significant, indicating worse performance under mixed-sex competition. The coefficient on *Mixed-sex* \times *Fixed-lane* reflects how the mixed-sex effect for male racers differs in fixed-lane races relative to quasi fixed-lane races; it is statistically insignificant, providing limited evidence of a differential mixed-sex effect for male racers across race formats. Most importantly, the triple interaction term *Mixed-sex* \times *Woman* \times *Fixed-lane* captures the additional differential effect for female racers in fixed-lane races. This coefficient is statistically insignificant for both outcome measures, indicating that the baseline sample provides limited evidence that the gender-specific mixed-sex effect differs across race formats.

Table 3. Robustness Check: Alternative Interaction Specifications

	Full Sample		Quasi Fixed-Lane		Fixed-Lane	
	(1) Goal Time	(2) Finishing Position	(3) Goal Time	(4) Finishing Position	(5) Goal Time	(6) Finishing Position
Mixed-sex	−0.001*** (0.0001)	−0.104*** (0.0142)	−0.0011*** (0.0001)	−0.103*** (0.0137)	−0.0025 (0.0028)	−0.215 (0.213)
Mixed-sex \times Woman	0.004*** (0.000)	0.564*** (0.041)	0.0040*** (0.0004)	0.562*** (0.0371)	0.0007 (0.0062)	1.027 (0.542)
Mixed-sex \times Fixed-lane	0.0001 (0.001)	0.024 (0.065)				
Mixed-sex \times Woman \times Fixed-lane	−0.002 (0.002)	−0.046 (0.127)				
Fixed-lane	0.000283 (0.000349)	−0.0661*** (0.0247)				
Fixed-lane \times Woman	0.0002 (0.001)	−0.001 (0.058)				
Constant	4.764*** (0.0174)	5.622*** (1.277)	4.761*** (0.0147)	5.523*** (1.097)	4.878*** (0.112)	10.77 (9.871)
Lane dummies (1–5)	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included
Stadium \times Day FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	169,221	169,221	164,703	164,703	4,518	4,518
R-squared	0.407	0.343	0.405	0.340	0.700	0.678

Note: Columns (1)–(2) report pooled estimates for the full sample based on a specification that includes the triple interaction among *Mixed-sex*, *Fixed-lane*, and *Woman*. Columns (3)–(6) report estimates separately for quasi fixed-lane and fixed-lane races. In these specifications, the coefficient of interest is *Mixed-sex* \times *Woman*. Columns (1), (3), and (5) use goal time as the dependent variable, while columns (2), (4), and (6) use finishing position. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium \times day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Columns (3)–(6) present results from separate estimations by race format. Consistent with the pooled results, the deterioration in female performance in mixed-sex races is evident in quasi fixed-lane races, whereas the estimated mixed-sex effects for female racers in fixed-lane races remain statistically insignificant.

The pooled and split-sample specifications yield qualitatively similar patterns. However, the triple interaction term is statistically insignificant in the baseline sample and therefore does not provide direct evidence that the mixed-sex effect differs across race formats. As discussed below, the expanded-sample analysis provides additional evidence on this question. Detailed regression results are reported in **Appendix Table A9**.

Beyond statistical power concerns, the baseline specification also restricts sample coverage. Following Booth and Yamamura (2018), we limit the sample to races with complete finishing information, which reduces the number of observations, particularly for fixed-lane races. This issue is especially important because the baseline sample contains only 623 female racer-race observations in fixed-lane races, limiting statistical power and the precision of interaction-effect estimates.

To assess this concern, we re-estimate the models using an expanded sample that includes races with incomplete finishing information (i.e., races reporting only the top three finishers). Expanding the sample substantially increases the number of fixed-lane observations and allows us to examine whether the attenuation of mixed-sex effects in fixed-lane races persists when sample coverage is broadened.

Table 4 reports the results. Columns (1)–(2) present the pooled interaction specification using the mixed-sex race dummy, while Columns (3)–(4) replace the mixed-sex indicator with the number of opposite-sex competitors in the race. Consistent with the baseline findings, the coefficient on *Mixed-sex* \times *Woman* remains positive and statistically significant, indicating that female racers perform worse in mixed-sex races under quasi fixed-lane conditions. Importantly, the coefficient on *Mixed-sex* \times *Fixed-lane* \times *Woman* is negative for goal time and becomes statistically significant in the expanded sample, suggesting that the female-specific mixed-sex effect is significantly weaker in fixed-lane races than in quasi fixed-lane races. This finding is consistent with the interpretation that the female-specific mixed-sex disadvantage is weaker when pre-competition uncertainty is removed.

Table 4. Robustness to Sample Coverage: Full Sample Including Races with Incomplete Results

	(1)	(2)	(3)	(4)
	Goal Time	Finishing Position	Goal Time	Finishing Position
Mixed-sex	-0.0005*** (0.0001)	-0.0983*** (0.007)		
Mixed-sex \times Woman	0.0032*** (0.0003)	0.539*** (0.0210)		
Mixed-sex \times Fixed-lane	-0.0005	0.0041		

	(0.0004)	(0.0237)		
Mixed-sex × Woman × Fixed-lane	−0.0029**	0.0571		
	(0.0011)	(0.0519)		
Fixed-lane	0.00101***	−0.0647***	0.0009***	−0.067***
	(0.0001)	(0.0097)	(0.0001)	(0.0095)
Fixed-lane × Woman	0.0024***	0.0076	0.0026***	0.0041
	(0.0006)	(0.0283)	(0.0006)	(0.0280)
Number of opposite sex competitors			−0.0005***	−0.0960***
			(8.85e-05)	(0.0051)
Number of opposite sex competitors × Woman			0.0012***	0.216***
			(0.0001)	(0.0076)
Number of opposite sex competitors × Fixed-lane			−5.65e-05	0.0138
			(0.0003)	(0.0167)
Number of opposite sex competitors × Woman × Fixed-lane			−0.0008**	0.00251
			(0.0004)	(0.0199)
Constant	4.741***	4.148***	4.740***	4.073***
	(0.0112)	(0.607)	(0.0112)	(0.606)
Lane dummies (1–5)	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included
Observations	485,703	625,959	485,703	625,959
R-squared	0.331	0.329	0.331	0.330

Note: Columns (1)–(2) report pooled estimates for the expanded sample based on a specification that includes the triple interaction among *Mixed-sex*, *Fixed-lane*, and *Woman*. Columns (3)–(4) report alternative pooled specifications in which the mixed-sex race dummy is replaced by the number of opposite-sex competitors in the race. Columns (1) and (3) use goal time as the dependent variable, while Columns (2) and (4) use finishing position. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see [Section 4](#) for details). The sample includes races with incomplete finishing information (i.e., races reporting only the top three finishers).

Columns (3)–(4) provide similar evidence using the number of opposite-sex competitors as an alternative measure of mixed-sex exposure. The coefficient on *Number of opposite-sex competitors* × *Woman* is positive and statistically significant, indicating that greater exposure to opposite-sex competitors worsens female performance in quasi fixed-lane races. In contrast, the triple interaction term, *Number of opposite-sex competitors* × *Fixed-lane* × *Woman*, is negative and statistically significant for goal time, indicating that the adverse effect of exposure to opposite-sex competitors is significantly weaker in fixed-lane races than in quasi fixed-lane races.

Overall, these findings suggest that the weaker mixed-sex effects observed in fixed-lane races are unlikely to be driven solely by limited statistical power. Even after substantially increasing the number of fixed-lane observations, the results remain consistent with the interpretation that institutional constraints on pre-competition strategic interaction are associated with a weaker gender-specific performance disadvantage under mixed-sex competition. Detailed regression results are reported in [Appendix Table A10](#).

5.3.3. Adjacent-Lane Exposure to Opposite-Sex Competitors

Mixed-sex effects may operate through proximity to opposite-sex competitors in adjacent lanes rather than through race-level gender composition alone. The baseline analysis identifies whether a race is mixed-sex but does not distinguish between racers who face opposite-sex competitors in adjacent lanes and those who do not. We therefore examine exposure to opposite-sex competitors in adjacent lanes, where direct influence is likely to be strongest. If physical proximity alone explains the observed performance differences, similar patterns should be observed in both quasi fixed-lane and fixed-lane races.

Table 5, Panels A and B, report estimation results using an indicator for exposure to opposite-sex competitors in adjacent lanes. In quasi fixed-lane races, the presence of opposite-sex competitors in adjacent lanes is associated with systematic performance changes. Female racers experience statistically significant declines in performance when racing adjacent to male competitors, whereas male racers perform better when racing next to female competitors.

In fixed-lane races, however, no comparable systematic effects are observed, as strategic interaction is prohibited by design. The estimated effects of adjacent opposite-sex exposure for both female and male racers are small, unstable in sign, or statistically insignificant. Detailed results are reported in **Appendix Table A8**.

Table 5. Adjacent-Lane Exposure to Opposite-Sex Competitors and Performance

Panel A: Finishing Position

	Finishing Position			
	Quasi Fixed-Lane Races		Fixed-Lane Races	
	(1) Men	(2) Women	(3) Men	(4) Women
Adjacent Opposite-Sex Exposure	-0.099*** (0.0190)	0.261*** (0.0546)	-0.102 (0.193)	-0.829 (1.072)
Constant	5.089*** (1.316)	12.04*** (2.872)	9.396 (10.76)	33.17 (27.90)
Other Controls	Included	Included	Included	Included
Lane dummies (1–5)	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes
Observations	148,849	20,372	3,895	623
R-squared	0.341	0.375	0.679	0.818

Note: *Adjacent Opposite-Sex Exposure* equals one if at least one adjacent lane is occupied by an opposite-sex competitor, and zero otherwise. Columns (1)–(2) correspond to quasi fixed-lane races, and columns (3)–(4) correspond to fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Panel B: Goal Time

	Goal Time			
	Quasi Fixed-Lane Races		Fixed-Lane Races	
	(1) Men	(2) Women	(3) Men	(4) Women
Adjacent Opposite-Sex Exposure	-0.00114*** (0.000240)	0.00193*** (0.000726)	-0.000327 (0.00263)	-0.00271 (0.0147)
Constant	4.758*** (0.0184)	4.817*** (0.0420)	4.846*** (0.147)	5.177*** (0.326)
Other Controls	Included	Included	Included	Included
Lane dummies (1–5)	Included	Included	Included	Included
Race-grade dummies (1–4)	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes
Observations	169,140	22,032	3,895	623
R-squared	0.393	0.455	0.698	0.818

Note: *Adjacent Opposite-Sex Exposure* equals one if at least one adjacent lane is occupied by an opposite-sex competitor, and zero otherwise. Columns (1)–(2) correspond to quasi fixed-lane races and columns (3)–(4) to fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Taken together, these results suggest that proximity to opposite-sex competitors alone cannot explain the mixed-sex performance differences documented in **Section 5.2**. If physical proximity alone explained the observed performance differences, similar patterns would appear in both quasi fixed-lane and fixed-lane races. Instead, gender-differentiated responses are observed only in quasi fixed-lane races, where racers may anticipate potential interference before the start. This pattern is consistent with the interpretation that pre-competition uncertainty is associated with the observed performance differences. These findings motivate a closer examination of the underlying mechanisms, which we explore in the next section.

5.3.4. Addressing Selection into Quasi Fixed-Lane Races: IPW Approach

As discussed in **Section 3.4**, the classification of quasi fixed-lane races may be subject to endogenous selection, as the absence of lane changes reflects racers' strategic decisions prior to the start. If such selection is systematically related to unobserved determinants of performance, the baseline estimates may be biased.

To address this concern, we implement an IPW approach. Specifically, we estimate the probability that a standard race results in no lane changes (i.e., is classified as quasi fixed-lane) as a function of observable race and racer characteristics, and then reweight the outcome regressions by the inverse of this predicted probability.

In the first stage, we estimate the probability that a race is classified as quasi fixed-lane using a logit model:

$$\Pr(Quasi = 1 | \mathbf{X}'_{irt}) = \Lambda(a_0 + a_1 MixRace_{irtk} + \mathbf{X}'_{irt}\boldsymbol{\beta} + \mathbf{Y}'_{irt}\boldsymbol{\gamma} + \mathbf{Z}'_{irtk}\boldsymbol{\delta} + m_{tk} + \theta_i)$$

where *Quasi* is an indicator equal to one if race *r* involves no lane changes, and zero otherwise. *MixRace* indicates mixed-sex composition, \mathbf{X}' includes observable racer characteristics (e.g., experience, weight, and age), \mathbf{Y}' captures characteristics of competitors in the same race, and \mathbf{Z}' includes race-level conditions. m_{tk} denotes stadium \times day fixed effects, and θ_i denotes racer fixed effects.

In the second stage, we estimate the outcome equation using inverse probability weights derived from the first stage:

$$\ln(\text{Time})_{irtk} = a_0 + a_1 \text{MixRace}_{irtk} + \mathbf{X}'_{irt} \boldsymbol{\beta} + \mathbf{Y}'_{irt} \boldsymbol{\gamma} + \mathbf{Z}'_{irtk} \boldsymbol{\delta} + m_{tk} + \theta_i + \varepsilon_{irtk},$$

where observations are weighted by:

$$w = 1/\text{Pr}(\text{Quasi} = 1 | \mathbf{X}'_{irt})$$

We also estimate analogous specifications using finishing position as the dependent variable. To avoid extreme weights, we verify that the distribution of predicted probabilities is well behaved.

Table 6 reports the results using both goal time and finishing position as performance measures under IPW. Across all specifications, we observe a consistent pattern of gender asymmetry. Using goal time as the outcome variable, female racers experience a statistically significant deterioration in performance in mixed-sex races, whereas male racers exhibit a statistically significant improvement.

Table 6: Robustness to Alternative Performance Measures and IPW

	Goal Time		Finishing Position	
	(1) Women	(2) Men	(3) Women	(4) Men
Mixed-sex	0.0026*** (0.0008)	-0.0013*** (0.0001)	0.4872*** (0.0506)	-0.1061*** (0.0082)
Controls	Yes	Yes	Yes	Yes
Racer FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Racecourse FE	Yes	Yes	Yes	Yes
Round FE	Yes	Yes	Yes	Yes
Sample	Quasi Fixed Lane (IPW weighted)			
Observations	17,851	144,597	17,851	144,597
R-squared	0.4589	0.4026	0.3669	0.3364

Note: Standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications use inverse probability weights estimated from a logit model of selection into quasi fixed-lane races.

The results are even more pronounced when using finishing position as the outcome variable. Female racers show a substantial deterioration in finishing position (coef. = 0.487, $p < 0.01$), while male racers exhibit a significant improvement (coef. = -0.106, $p < 0.01$). The direction of the effects is identical across both performance measures, indicating that the findings are not driven by the choice of outcome

variable. The larger magnitudes observed for goal time further suggest that these effects are economically meaningful.

All specifications include a rich set of controls and fixed effects and are weighted using IPW. The consistency of the estimates across outcome variables indicates that the results are unlikely to be driven by selection on observables. Overall, the findings provide strong evidence of a considerable gender asymmetry in performance under mixed-sex competition in quasi fixed-lane races.

5.4. Mechanism: Pre-Start Uncertainty

The main analyses in **Section 5.2** show that female performance declines in mixed-sex quasi fixed-lane races, yet the underlying mechanisms remain unclear. Quasi fixed-lane races allow lane changes during the pre-start positioning stage, whereas fixed-lane races explicitly prohibit them. By construction, no lane changes occur in quasi fixed-lane races, making them similar to fixed-lane races in terms of realized starting positions. This raises the question of why gender-differentiated performance arises in quasi fixed-lane races despite the absence of observable lane changes.

We consider two competing interpretations. The first suggests that subtle physical obstruction by male racers toward female racers may occur before the start—even without observable lane changes—leading to performance disadvantages. The second suggests that, even in the absence of such behavior, the mere possibility of obstruction before the start creates strategic uncertainty that adversely affects female performance after the start.

To distinguish between these mechanisms, we examine start time. Start time is defined as the time at which a racer crosses the starting line after the race clock reaches zero (see **Section 3.3**). In Japanese speedboat racing, the start phase is a critical acceleration stage in which racers attempt to cross the starting line at the optimal time under the flying-start system. As racers approach the starting line at high speed and in close proximity to one another, any interference during the pre-start positioning stage would directly impair their ability to time the start accurately.

If male racers engage in physical obstruction toward female racers prior to the start, such interference should be reflected in longer start times for female racers. If no such deterioration in start time is observed, this would suggest that physical obstruction is unlikely during the pre-start positioning stage. The observed gender differences in finishing positions and goal time can then be more plausibly attributed to psychological effects arising from pre-start uncertainty.

Table 7 reports results for start time for female racers. We find no evidence that exposure to male racers in adjacent lanes adversely affects start time for female racers in quasi fixed-lane races. The estimated effects are small and statistically insignificant. Similarly, no significant effect is observed in fixed-lane races, suggesting that the two race formats are comparable in terms of pre-start conditions and start-time performance. If direct obstruction or physical interference were responsible for the deterioration in finishing positions and goal time observed in quasi fixed-lane races, such effects would

be expected to appear at the starting stage, when precise timing and positioning are most sensitive to nearby competitors. Therefore, the absence of detectable start-time deterioration provides little support for a direct obstruction-based explanation.

Table 7. Effects of Adjacent Male Racers on Female Start Time

	Quasi Fixed-Lane Races	Fixed-Lane Races
	(1)	(2)
Adjacent	0.001 (0.010)	0.006 (0.050)
Constant	-1.112 (0.667)	-0.312 (2.933)
Other Controls	Included	Included
Lane dummies (1–5)	Included	Included
Race grade dummies (1–4)	Included	Included
Stadium × Day FE	Yes	Yes
Observations	66,690	2,856
R-squared	0.117	0.504

Note: The sample is restricted to female racers. The dependent variable is start time. *Adjacent* equals one if one or both adjacent lanes are occupied by male racers, and zero otherwise. Columns (1) and (2) correspond to quasi fixed-lane and fixed-lane races, respectively. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, stadium × day fixed effects, and controls for racer characteristics and race conditions (see **Section 4** for details).

Despite the absence of start-time effects, female racers exhibit significantly worse finishing positions in mixed-sex quasi fixed-lane races, as documented in **Section 5.2**. The start phase is highly standardized and tightly regulated, with strict penalties for false starts, leaving little scope for behavioral adjustment. In contrast, post-start performance involves a range of discretionary decisions, such as positioning and overtaking, where strategic interaction is more likely to influence behavior.

Taken together, these findings suggest that the observed performance decline is unlikely to be driven by physical interference prior to the start and is more consistent with post-start performance effects arising from pre-start uncertainty. Detailed results are reported in **Appendix Table A11**.

6. Discussion

In this section, we analyze how institutional rule design related to pre-competition uncertainty generates asymmetric gender performance effects and discuss the managerial and policy implications of this mechanism.

6.1. Summary of Main Findings

This study examines whether exposure to pre-competition uncertainty arising from institutional variations in race formats systematically shapes gender differences in competitive performance. The findings provide strong support for our hypotheses.

First, female racers perform worse than male racers in mixed-sex quasi fixed-lane races, which expose competitors to pre-competition uncertainty. However, no such performance gaps are observed in fixed-lane races, where this uncertainty is absent. Additional analyses based on adjacent-lane exposure yield a similar pattern: gender-differentiated performance responses are observed in quasi fixed-lane races but not in fixed-lane races. Importantly, these effects are observed even in the absence of realized interference or actual lane repositioning. This pattern is consistent with the interpretation that exposure to pre-competition uncertainty contributes to the observed performance differences through anticipatory psychological responses.

Second, in fixed-lane races, proximity to opposite-sex competitors does not generate systematic performance differences for either gender. Therefore, gender performance gaps in mixed-sex competitions appear to depend not only on competitor gender composition but also on whether institutional rules permit pre-competition uncertainty.

6.2. Strategic Uncertainty and Gender Performance

Our findings contribute to the growing literature demonstrating that gender differences in competitive performance are context-dependent. Earlier studies have attributed gender gaps in mixed-sex competition to differences in preferences, such as competitiveness, risk attitudes, and overconfidence (e.g., Gneezy et al. 2003; Niederle and Vesterlund 2007), or to realized strategic behavior and differential aggressiveness in settings where strategic interaction is possible (Booth and Yamamura 2018; Booth et al. 2022). More recent work further emphasizes that such differences are shaped by institutional and social environments rather than fixed traits.

Our results refine this perspective by distinguishing between realized strategic behavior and exposure to pre-competition uncertainty. We show that gender performance gaps can arise even in the absence of observable interference, driven by the institutional possibility of strategic maneuvering prior to competition. One plausible mechanism is that such uncertainty creates anticipatory psychological burdens that disproportionately affect female racers. Anticipation of potential interference may influence attention allocation, confidence, and post-start risk-taking decisions, thereby leading to slower goal times or poorer finishing positions. Importantly, the adjacent-lane analysis reinforces the broader conclusion that pre-competition uncertainty, rather than exposure to opposite-sex competitors alone, is associated with the observed gender differences in performance.

This interpretation is consistent with prior research documenting that gender differences become more pronounced under ambiguity and strategic uncertainty (e.g., Dato and Nieken 2020; Hernandez-Arenaz and Iriberry 2023), as well as with evidence that women experience larger performance declines

under competitive pressure or stress (e.g., Ors et al. 2013; Cahliková et al. 2020; Booth and Lee 2021). However, unlike these studies—which typically examine realized interactions or externally induced stress—our findings isolate the effects of institutionalized pre-competition uncertainty arising from rules that permit strategic interaction. Thus, we provide evidence that the mere possibility of strategic maneuvering embedded in rule design can shape gender-differentiated performance outcomes.

6.3. Institutional Design, Competitive Efficiency, and Performance Distortions

Our findings show that male and female racers respond differently to pre-competition uncertainty, underscoring the central role of institutional design. In quasi fixed-lane races, which involve such uncertainty, male racers experience modest performance gains, whereas female racers incur larger performance losses. In contrast, fixed-lane races—where such uncertainty is absent—show no robust evidence of performance differences: the estimates are small, statistically insignificant, and imprecise. Taken together, this contrast suggests that pre-competition uncertainty systematically affects performance and may distort it in a gender-asymmetric manner.

Beyond the absence of systematic mixed-sex effects, the fixed-lane results also indicate that performance is less strongly associated with observable racer characteristics, such as experience, rank, and body weight. This pattern suggests that fixed-lane races may provide a more ability-revealing environment by minimizing uncertainty arising from potential strategic positioning, competitive pressure, and other contextual factors. As a result, underlying skills play a more central role in determining race outcomes.

Further supporting this interpretation, **Appendix Figure A2** shows that lane-related performance differences are preserved in fixed-lane races. Average goal times increase monotonically from Lane 1 to Lane 6 for both male and female racers, with a steeper gradient in fixed-lane races than in quasi fixed-lane races. This pattern indicates that structural determinants of performance, such as lane advantage, become more pronounced when pre-competition uncertainty is removed, reinforcing the view that fixed-lane rules enhance the transparency of ability differences.

Taken together, these findings suggest that reducing pre-competition uncertainty improves not only equity but also the informational efficiency of outcomes, in the sense that results more closely reflect underlying ability.

From a practical and policy perspective, designing competitive environments that minimize pre-competition uncertainty may help reduce gender-related performance disparities. Such improvements can enhance both fairness and allocative efficiency by ensuring that outcomes reflect true ability rather than differential behavioral responses to institutional uncertainty. In this sense, the design of the pre-competition environment constitutes an important, yet often overlooked, lever for building competitive systems that are both fair and efficient.

6.4. Limitations and Directions for Future Research

Several limitations of this study should be acknowledged. First, although our results are consistent with a mechanism based on pre-competition uncertainty, we do not directly observe racers' beliefs, expectations, or psychological responses. Future research that combines performance data with surveys or experimental measures of perceived risk, anticipatory stress, and confidence could provide more direct evidence on the underlying mechanisms.

Second, our analysis focuses on a professional racing environment with highly specific institutional rules. Although this setting provides unusually clear variation in exposure to pre-competition uncertainty, the external validity of our findings to other domains warrants further investigation. Importantly, however, the structure of pre-competition uncertainty examined here closely parallels that of many real-world competitive environments. In workplace settings, for example, employees often operate under the possibility of strategic maneuvering—such as colleagues lobbying supervisors during promotion decisions, influencing evaluation criteria behind the scenes, competing for speaking time in meetings, or negotiating role definitions under opaque performance standards—even if such actions are not ultimately realized. Similarly, in our setting, individuals may adjust their preparation, attention, and risk-taking behavior in anticipation of others' potential actions.

Future research could examine whether reducing ambiguity in evaluation criteria, clarifying promotion procedures, or limiting discretionary strategic positioning similarly affects gender-differentiated performance outcomes in organizational contexts. Such extensions would help assess the broader applicability of the mechanisms identified here.

7. Conclusion

This study provides evidence that gender performance gaps in mixed-sex competition can emerge in environments characterized by pre-competition uncertainty embedded in institutional rules, even in the absence of realized strategic interaction. Leveraging variation in race formats in professional speedboat racing, we examine how exposure to rule-based pre-competition uncertainty is associated with competitive performance. Gender disparities are observed in environments that permit the possibility of strategic maneuvering and are substantially weaker when such maneuvering is prohibited by design. These effects are asymmetric: pre-competition uncertainty yields modest performance gains for men but substantially larger performance losses for women.

To our knowledge, this study provides direct evidence on the role of institutionalized pre-competition uncertainty in generating gender-differentiated performance outcomes. By demonstrating that gender gaps arise even without observable interference, our findings suggest that some differences previously attributed to preferences or abilities may instead reflect rule-based uncertainty embedded in competitive environments. These results shift the focus from individual traits to institutional design. Gender gaps do not necessarily reflect inherent differences in competitiveness or ability; rather, they

may arise from subtle rule structures that differentially shape behavior and performance under uncertainty. More broadly, the design of the pre-competition environment represents a powerful—and often overlooked—lever for improving both equity and efficiency in competitive systems.

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Appendix A. Other Details of Speedboat Racing in Japan

A.1. Race Grades and Racer Ranks

Boat racing is categorized into five grades: Special Grade (SG), Grade 1 (GI), Grade 2 (GII), Grade 3 (GIII), and General Competition, with SG being the highest and General Competition the lowest. **Table A1** presents the characteristics of each race grade.

Table A1. Grade Characteristics

Race Grade	Number of Events (per year)	Prize Money for the Winner (Yen)	Type of Grade
SG	8	17–100 million	The highest-grade races, featuring top-ranked racers and offering the largest prize money.
GI	Approximately 35	4.8–15 million	High-grade races that serve as a stepping stone to SG races; participation is often restricted to higher-ranked racers.
GII	Approximately 8	4.5 million	Mid-level races offering competitive prize money and opportunities for mid- to high-ranked racers.
GIII	Approximately 50	1.05 million	Lower-grade races compared to GII, open to a broader range of racers, including those aiming to advance to higher grades.
General Competition	Approximately 365	740,000 yen	The lowest-grade races, open to all racers regardless of class, often serving as a starting point for beginners.

Racers are classified into four ranks: A1, A2, B1, and B2, where A1 represents the highest rank and B2 the lowest. These rankings are updated twice a year based on racers' win rates and accident rates. Specifically, rankings are evaluated over two six-month periods (May 1–October 31 and November 1–April 30) and become effective on January 1 and July 1, respectively. Because accident rates are included in the evaluation criteria, racers with poor safety records may be downgraded (e.g., from A1 to A2 or from A2 to B1).

Rankings play an important role in determining earning opportunities. Higher-ranked racers are eligible to compete in prestigious SG and GI races that offer substantially larger prize money, whereas lower-ranked racers primarily participate in General Competition events with smaller purses. Consequently, higher-ranked racers generally have greater opportunities to earn higher annual income.

A.2. Penalties in Boat Racing

Penalties in boat racing are enforced to ensure fairness, safety, and compliance with regulations. These penalties vary in severity, ranging from race disqualification to long-term suspension, depending on the nature of the violation.

Start violations are among the most important infractions in professional boat racing. Under the flying-start system, racers must cross the starting line within a narrow time window relative to the official race clock. A false start occurs when a racer crosses the line before the designated time, whereas a late start occurs when the racer crosses the line after the permitted time window has expired. In either case, the racer is immediately disqualified and forfeits any prize money. Repeated start violations may

also result in additional sanctions, including temporary suspension from prestigious races (e.g., SG and GI events) and exclusion from race assignments.

Accidents and interferences are subject to strict penalties. If a racer capsizes, falls overboard, or experiences an engine malfunction, they are unable to complete the race and are disqualified. Intentional obstruction of another racer's course or violations of navigational rules—such as unlawful lane changes or improper turns—result in additional sanctions. Racers with high accident rates may be demoted in rank (e.g., from A1 to A2 or lower). If the accident rate exceeds a specific threshold, temporary suspension may be imposed. Severe interference may lead to the long-term suspension or fines.

Another important regulation concerns minimum weight requirements. Male racers must weigh at least 50 kg, whereas female racers must weigh at least 47.5 kg. Racers who fail to meet this requirement are disqualified from all races scheduled for that day. Repeated violations may result in longer suspension periods.

Appendix B. Supplementary Descriptive Statistics and Additional Inference Results

This appendix provides detailed information on the empirical model, data construction, variable definitions, descriptive statistics, and supplementary inference analyses supporting the analysis presented in the main text.

B.1. Permutation Test Results for Fixed-Lane Races

To complement the regression-based analysis, we conduct permutation tests using 1,000 random reassignments of mixed-sex status at the race level. This procedure preserves the clustering structure of the data while generating the empirical distribution of the test statistic under random reassignment.

For goal time, the permutation test yields p -values of 0.366 for female racers and 0.151 for male racers, indicating that the observed coefficients fall well within the range expected under random assignment.

For finishing position, the permutation test yields p -values below 0.001 for both female and male racers, as none of the 1,000 random reassignments produce coefficients as extreme as the observed estimates. This result contrasts with the corresponding regression estimates, which are statistically insignificant.

One possible explanation is that finishing position is an ordinal measure that is mechanically linked to the performance of other racers within the same race, whereas goal time provides a continuous measure of individual performance. As a result, inference based on ranking outcomes may be more sensitive to small shifts in the distribution than inference based on goal time.

Overall, the permutation results differ across outcome measures. Goal-time measures yield relatively large permutation p -values, whereas finishing-position measures yield substantially smaller p -values. This difference may reflect the ordinal and relative nature of ranking outcomes.

Figures A1 and **A2** display the corresponding permutation distributions for male and female racers. The vertical line denotes the coefficient estimated from the observed data. For goal time, the observed coefficient falls within the central region of the permutation distribution for both sexes, consistent with the relatively large permutation p -values reported above.

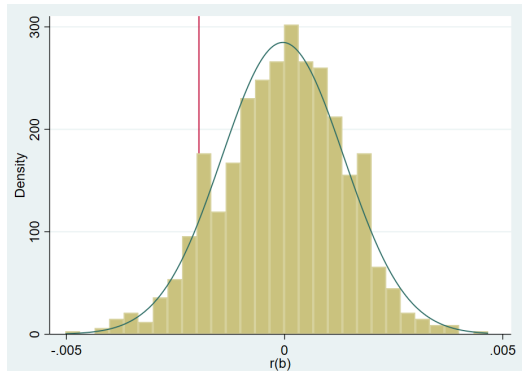


Figure A1. Permutation Distribution for Male Racers

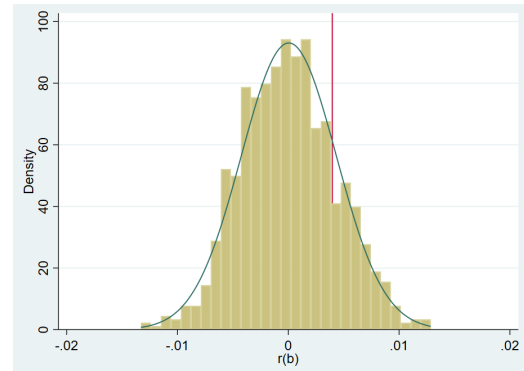


Figure A2. Permutation Distribution for Female Racers

B.2. Summary Statistics by Race Format

Table A2 presents summary statistics for key racers and race characteristics separately for quasi fixed-lane and fixed-lane races. The table reports mean values, p -values from Welch’s two-sample t -tests, and standardized mean differences measured using Cohen’s d .

Table A2. Summary Statistics by Race Format

	(1)		(2)		(3)		(4)	
	Full Sample (1,800m races)		Quasi Fixed-Lane Races		Fixed-Lane Races		Difference between (2) and (3): p -values and Cohen’s d	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	p -value	Cohen’s d
Woman	0.107	0.309	0.119	0.324	0.138	0.345	0.000	0.053
Mixed-sex	0.145	0.352	0.143	0.350	0.142	0.349	0.769	-0.004
Start time	0.172	0.074	0.170	0.072	0.169	0.073	0.194	-0.019
Goal time	113.012	2.740	112.895	2.739	113.530	2.737	0.000	0.231
Finishing positions	3.500	1.708	3.44	1.708	3.500	1.708	0.027	0.031
Number of higher-grade racers	1.462	1.499	1.430	1.485	1.628	1.413	0.000	0.136
Number of lower- grade racers	1.462	1.699	1.470	1.696	1.628	1.812	0.000	0.089
Number of more experienced racers	2.458	1.707	2.447	1.695	2.461	1.708	0.593	0.008
Number of less experienced racers	2.458	1.708	2.466	1.695	2.461	1.707	0.836	-0.003
Number of lightweight racers	0.942	1.473	0.966	1.508	1.021	1.524	0.017	0.035
Number of heavyweight racers	2.774	1.452	2.753	1.463	2.866	1.454	0.000	0.076
Weight	53.241	3.361	53.195	3.357	53.314	3.543	0.026	0.034
Age	38.242	9.274	38.267	9.086	36.642	9.643	0.000	-0.173

Note: Columns (1)–(3) present mean values for each variable in the full sample, quasi fixed-lane races, and fixed-lane races, respectively. Column (4) reports *p*-values and effect sizes (Cohen’s *d*) from t-tests comparing quasi fixed-lane races (2) and fixed-lane races (3). Goal time is the finishing time in seconds. Start time is the time at which the racer crosses the starting line, measured in seconds relative to the race start signal. Finishing position refers to the racer’s final rank in the race (e.g., 1 = first place, 6 = last place). The mixed-sex dummy equals 1 if the race includes both male and female racers. The variable *Woman* equals 1 if the racer is female. Age is measured in years, and weight is the racer’s pre-race weight in kilograms. The number of higher-grade racers refers to competitors with a higher rank than the focal racer, while the number of lower-grade racers refers to those with a lower rank. The number of more (less) experienced racers refers to competitors with more (fewer) years of professional experience. The number of heavyweight racers refers to competitors whose weight falls in the top 75th percentile of the male weight distribution, and the number of lightweight racers refers to competitors whose weight falls in the bottom 25th percentile of the female weight distribution.

Approximately 10% of racer–race observations involve female racers, and roughly 15% of races are mixed-sex. Fixed-lane races represent a relatively small share of the analytical sample, accounting for 4,518 racer–race observations (approximately 2.3% of all observations).

Given the large sample size, several variables exhibit statistically significant mean differences across race formats. However, the corresponding standard differences are generally small. The largest effect sizes are observed for goal time (Cohen’s *d* = 0.231) and age (Cohen’s *d* = 0.173), both of which remain below conventional thresholds for moderate imbalance. For most other variables, including mixed-sex composition, body weight, and measures of racer experience, standardized differences are negligible.

Overall, the standardized differences are generally small, suggesting that quasi fixed-lane and fixed-lane races are broadly comparable in terms of observable characteristics.

B.3. Gender Differences in Performance by Race Format

Table A3 presents descriptive statistics for the key performance measures by gender and race format. All statistics are calculated at the racer level.

Table A3. Comparison of Male and Female Performance in Quasi Fixed-Lane and Fixed-Lane Races

	Quasi Fixed-Lane Races			Fixed-Lane Races		
	(1) Men	(2) Women	(1) – (2) Difference	(1) Men	(2) Women	(1) – (2) Difference
Goal time	112.847	113.387	–0.539***	113.486	113.803	–0.317***
Start time	0.169	0.181	–0.012***	0.167	0.181	–0.014**
Finishing positions	3.417	3.642	–0.225***	3.462	3.734	–0.272***
Number of higher-grade racers	1.409	1.628	–0.218***	1.609	1.748	–0.139***
Number of lower-grade racers	1.482	1.417	0.064***	1.667	1.387	0.280***
Number of more experienced racers	2.427	2.593	–0.166***	2.439	2.600	–0.161**
Number of less experienced racers	2.485	2.323	0.162***	2.486	2.307	0.179***
Number of lightweight racers	0.521	4.236	–3.715***	0.533	4.072	–3.539**
Number of heavyweight racers	3.026	0.787	2.756***	3.196	0.799	2.397**
Weight	53.938	47.789	6.149***	54.155	48.053	6.102***
Age	38.711	34.665	4.046***	37.104	33.754	3.349***
Race Grade (SG)	0.014	0.009	0.005***	0.000	0.000	-
Race Grade (GI)	0.069	0.013	0.056***	0.000	0.000	-
Race Grade (GII)	0.016	0.036	–0.020***	0.000	0.000	-

Race Grade (GIII)	0.043	0.308	-0.264***	0.040	0.366	-0.326***
Race Grade (Usual)	0.853	0.610	0.242***	0.960	0.634	0.326***
Lane 1 (inner lane)	0.192	0.167	0.025***	0.172	0.134	0.038
Lane 2	0.177	0.170	0.006**	0.169	0.149	0.020
Lane 3	0.169	0.168	0.001	0.165	0.173	-0.008
Lane 4	0.158	0.159	-0.001	0.168	0.157	0.0011
Lane 5	0.148	0.155	-0.006**	0.165	0.171	-0.006
Lane 6 (outer lane)	0.154	0.179	-0.024***	0.159	0.213	-0.054**
No. of observations	148849	20372		3895	623	

Note: Columns (1)–(2) present sample means for men and women, respectively. Column (1) – (2) reports the difference in means (men minus women). Goal time and start time are measured in seconds; higher values indicate slower performance. Finishing position refers to the final rank in the race, where a higher value indicates worse performance. The number of higher-grade (lower-grade) racers represents the number of competitors in the race whose grade is higher (lower) than that of the focal racer. More experienced and less experienced racers are defined analogously based on cumulative years of racing experience. Race grade indicators (SG, GI, GII, GIII, and Usual) are mutually exclusive. Lane indicators denote the assigned lane at pit-out, with Lane 1 representing the innermost lane and Lane 6 the outermost lane. Differences are based on two-sided t-tests. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Across both race formats, male racers exhibit faster average goal times and earlier start times than female racers. Men also achieve better average finishing positions. The gender gap in goal time is approximately 0.54 seconds in quasi fixed-lane races and 0.32 seconds in fixed-lane races, while differences in start times are relatively small.

Female racers also tend to compete against higher-grade and more experienced opponents, whereas male racers more frequently face lower-grade and less experienced competitors. These differences motivate the inclusion of controls for competitor quality and experience in the regression analyses.

The proportion of female racers is broadly similar across race formats, accounting for approximately 12.0% of observations in quasi fixed-lane races and 13.8% in fixed-lane races. Overall, **Table A3** provides descriptive evidence of gender differences in performance and competitive environments prior to the multivariate analyses.

B.4. Race Grade Composition and Competitive Environment

This subsection documents differences in race-grade composition across gender and race formats.

In quasi fixed-lane races, male racers are more concentrated in the lowest race grade (“Usual”). Specifically, 85.3% of male observations fall into this category, compared with 61.0% of female racers. In contrast, female racers are more frequently assigned to intermediate-grade races such as GIII, accounting for 30.8% of female observations, compared with only 4.3% for men. Participation in top-tier races (SG, GI, and GII) is rare for both sexes, although male racers appear slightly more frequently in these categories.

In fixed-lane races, the grade structure is more restrictive because all races are classified as either GIII or Usual. Within this format, 96.0% of male racers compete in Usual races, compared with 63.4%

of female racers. Conversely, 36.6% of female racers participate in GIII races, whereas only 4.0% of male racers do so.

Overall, substantial gender differences exist in the distribution of race grades across both race formats. These patterns motivate the inclusion of race-grade controls in the regression analyses presented in the main text.

B.5. Distribution of Goal Times and Lane Effects

Figure A3 displays the distribution of goal times by gender for quasi fixed-lane and fixed-lane races. In quasi fixed-lane races, female racers tend to record slower goal times than male racers, as reflected in the slight rightward shift of the distribution. In fixed-lane races, the distributions for male and female racers overlap more closely, indicating a smaller gender difference in performance.

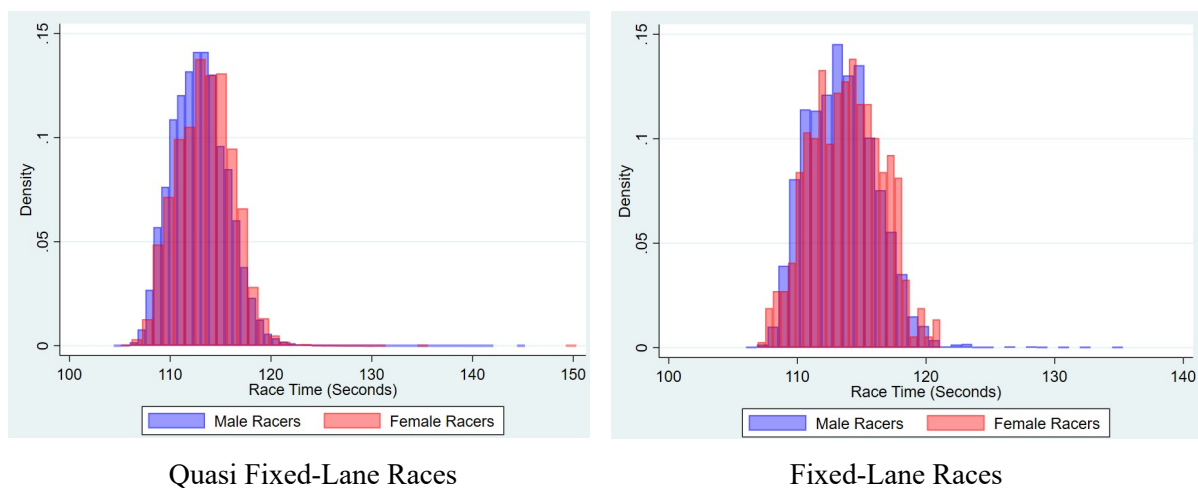
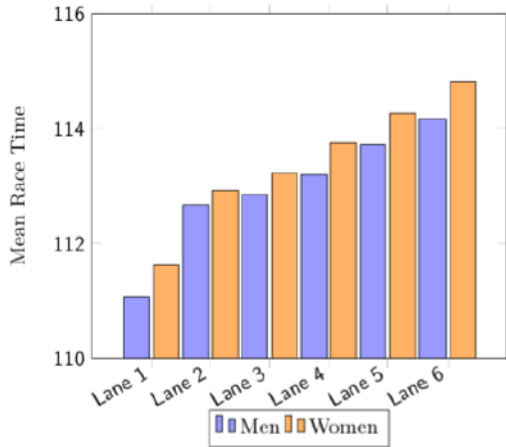


Figure A3. Distribution of Goal Times by Gender

Figure A4 reports mean goal times by lane assignment and gender for both race formats. In both quasi fixed-lane and fixed-lane races, average goal times increase steadily from Lane 1 to Lane 6 for both male and female racers, indicating a substantial performance advantage associated with inner lanes.

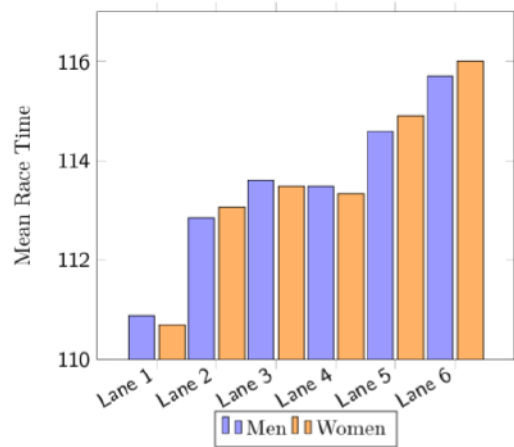
These descriptive patterns highlight the role of lane assignment in shaping race outcomes and motivate the inclusion of lane indicators and other race-level controls in the regression analyses presented in the main text.

Mean Race Time by Gender and Lane (Quasi-Fixed Races)



Quasi Fixed-Lane Races

Mean Race Time by Gender and Lane (Fixed Races)



Fixed-Lane Races

Figure A4. Mean Goal Time by Gender and Lane

Appendix C. Supplementary Regression and Inference Results

This appendix presents supplementary regression results and additional inference analyses referenced in the main text but omitted from the main manuscript for brevity. The tables and figures provide detailed coefficient estimates, robustness checks, and supporting evidence for the results reported in Sections 5 and 6.

Table A4. Estimation Results for Quasi Fixed-Lane Races

	Finishing Position				Goal Time			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Women	Men	Women	Men	Women	Men	Women	Men
Mixed-sex	0.501*** (0.0662)	-0.103*** (0.0146)			0.002*** (0.0009)	-0.001*** (0.0002)		
Number of opposite sex competitors			0.146*** (0.0163)	-0.100*** (0.0104)			0.0009*** (0.0002)	-0.0010*** (0.0001)
Number of higher-grade racers	0.104*** (0.0122)	0.102*** (0.0121)	0.122*** (0.0043)	0.122*** (0.0043)	0.0009*** (0.0001)	0.0008*** (0.0001)	0.00105*** (6.11e-05)	0.00105*** (6.11e-05)
Number of lower grade racers	-0.149*** (0.0116)	-0.145*** (0.0115)	-0.127*** (0.0042)	-0.126*** (0.0042)	-0.0014*** (0.0001)	-0.0013*** (0.0001)	-0.0011*** (6.18e-05)	-0.0011*** (6.19e-05)
Number of more experienced racers	0.0145 (0.0322)	0.0135 (0.0322)	0.0118 (0.0135)	0.0120 (0.0135)	0.00028 (0.0004)	0.00027 (0.0004)	0.00019 (0.0001)	0.00019 (0.0001)
Number of less experienced racers	-0.0285 (0.0331)	-0.0271 (0.0331)	0.0177 (0.0135)	0.0181 (0.0135)	-0.0003 (0.00047)	-0.0002 (0.00047)	8.52e-05 (0.00018)	8.85e-05 (0.00018)
Number of lightweight racers	0.0092 (0.0169)	0.0314 (0.0178)	-0.0101 (0.0068)	0.0020 (0.0070)	-0.00027 (0.0002)	-8.60e-05 (0.0002)	-7.49e-05 (9.18e-05)	1.39e-05 (9.52e-05)
	0.0094	-0.0053	-0.014***	-0.014***	0.0002	0.0001	-1.97e-05	-2.34e-05

Number of heavyweight racers	(0.0178)	(0.0181)	(0.0034)	(0.0034)	(0.0002)	(0.0002)	(4.65e-05)	(4.65e-05)
Weight	0.0143	0.0173	0.0121**	0.0126**	0.0002	0.0003	0.0002***	0.0002***
	(0.0145)	(0.0145)	(0.005)	(0.005)	(0.0002)	(0.0002)	(8.12e-05)	(8.12e-05)
Age	-0.140	-0.138	-0.161***	-0.161***	-0.002**	-0.002**	-0.002***	-0.002***
	(0.0908)	(0.0906)	(0.0328)	(0.0328)	(0.0012)	(0.0012)	(0.0004)	(0.0004)
Age2	0.0003	0.0003	0.0019***	0.0019***	1.85e-05	1.85e-05	3.05e-05***	3.05e-05***
	(0.0011)	(0.0011)	(0.0003)	(0.0003)	(1.48e-05)	(1.48e-05)	(5.15e-06)	(5.15e-06)
Constant	12.3***	11.92***	5.105***	5.049***	4.835***	4.831***	4.758***	4.757***
	(3.021)	(3.011)	(1.315)	(1.314)	(0.0407)	(0.0406)	(0.0189)	(0.0189)
Lane dummies (1-5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1-4)	Included	Included	Included	Included	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,635	18,635	148,849	148,849	18,635	18,635	148,849	148,849
R-squared	0.363	0.364	0.341	0.341	0.452	0.452	0.403	0.403

Note: Columns (1)–(4) report estimates using finishing position as the dependent variable, while columns (5)–(8) use goal time as the dependent variable. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include lane dummies, race-grade dummies, and stadium × day fixed effects.

Table A5. Estimation Results for Fixed-lane Races

	Finishing Position				Goal Time			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Women	Men	Women	Men	Women	Men	Women	Men
Mixed-sex	2.594	-0.301			0.0471	-0.0024		
	(2.114)	(0.244)			(0.0328)	(0.0035)		
Number of opposite sex competitors			0.011	-0.001			0.526	-0.128
			(0.006)	(0.002)			(0.483)	(0.145)
Number of higher-grade racers	0.0312	0.0834	0.0328	0.0853	-0.0022	-0.0001	-0.00213	-0.0001
	(0.160)	(0.0468)	(0.160)	(0.0446)	(0.0023)	(0.0007)	(0.00229)	(0.0007)
Number of lower grade racers	-0.0146	-0.0185	-0.0128	-0.0178	0.0030	-0.0001	0.0030	-0.0001
	(0.160)	(0.0441)	(0.160)	(0.041)	(0.0023)	(0.0007)	(0.002)	(0.0007)
Number of more experienced racers	-0.346	-0.095	-0.362	-0.082	-0.0021	-0.0012	-0.0022	-0.0013
	(0.343)	(0.139)	(0.368)	(0.140)	(0.004)	(0.001)	(0.004)	(0.001)
Number of less experienced racers	-0.357	-0.078	-0.362	-0.082	-0.0020	-0.0010	-0.0020	-0.0011
	(0.367)	(0.140)	(0.368)	(0.140)	(0.004)	(0.001)	(0.004)	(0.001)
Number of lightweight racers	0.0695	0.0370	0.0081	0.0247	0.00105	-0.0009	0.0014	-0.0011
	(0.268)	(0.102)	(0.273)	(0.104)	(0.003)	(0.001)	(0.003)	(0.001)
Number of heavyweight racers	-0.146	-0.0122	-0.138	-0.0132	-0.00605	3.74e-06	-0.0065	-2.95e-07
	(0.394)	(0.054)	(0.390)	(0.054)	(0.006)	(0.001)	(0.005)	(0.001)
Weight	-0.0758	0.0570	-0.0790	0.0572	-0.0007	0.0008	-0.0008	0.0008
	(0.170)	(0.040)	(0.170)	(0.040)	(0.002)	(0.001)	(0.002)	(0.001)
Age	-0.619	-0.271	-0.626	-0.269	-0.0105	-0.0031	-0.0107	-0.0030
	(0.766)	(0.241)	(0.766)	(0.241)	(0.00882)	(0.0033)	(0.0088)	(0.0033)
Age2	0.0042	0.0025	0.004	0.00250	7.19e-05	1.50e-05	7.55e-05	1.50e-05
	(0.010)	(0.0028)	(0.010)	(0.002)	(0.0001)	(3.86e-05)	(0.0001)	(3.85e-05)

Constant	29.80 (27.23)	9.457 (10.70)	29.97 (27.28)	9.366 (10.71)	5.111*** (0.319)	4.846*** (0.146)	5.106*** (0.320)	4.846*** (0.147)
Lane dummies (1–5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	623	3,895	623	3,895	623	3,895	623	3,895
R-squared	0.773	0.680	0.772	0.680	0.821	0.698	0.822	0.698

Note: Columns (1)–(4) report results using finishing position as the dependent variable, and columns (5)–(8) report results using goal time as the dependent variable. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table A6. Results for the Stadium Subsample Hosting Fixed-Lane Races

Panel A: Finishing Position

	Finishing Position							
	Quasi-Fixed Races				Fixed Races			
	(1) Women	(2) Men	(3) Women	(4) Men	(5) Women	(6) Men	(7) Women	(8) Men
Mixed-sex	0.533*** (0.0673)	-0.095*** (0.0156)			2.594 (2.114)	-0.301 (0.244)		
Number of opposite sex competitors			0.139*** (0.0163)	-0.090*** (0.0112)			0.526 (0.438)	-0.128 (0.145)
Number of higher grade racers	0.104*** (0.0125)	0.121*** (0.0045)	0.103*** (0.0124)	0.121*** (0.0045)	0.0312 (0.160)	0.0834* (0.0468)	0.0328 (0.160)	0.0853* (0.0466)
Number of lower grade racers	-0.149*** (0.0122)	-0.122*** (0.0046)	-0.146*** (0.0122)	-0.122*** (0.0046)	-0.0146 (0.160)	-0.0185 (0.0441)	-0.0128 (0.160)	-0.0173 (0.0441)
Number of more experienced racers	0.0235 (0.0348)	0.0139 (0.0143)	0.0222 (0.0348)	0.0140 (0.0143)	-0.346 (0.343)	-0.0959 (0.139)	-0.351 (0.345)	-0.0989 (0.139)
Number of less experienced racers	-0.0226 (0.0354)	0.0187 (0.0144)	-0.0210 (0.0355)	0.0190 (0.0144)	-0.357 (0.367)	-0.0785 (0.140)	-0.362 (0.368)	-0.0821 (0.140)
Number of lightweight racers	0.0153 (0.0162)	-0.0097 (0.0072)	0.0338** (0.0171)	0.00037 (0.0075)	0.0695 (0.268)	0.0370 (0.102)	0.0817 (0.273)	0.0247 (0.104)
Number of heavyweight racers	0.0043 (0.0174)	-0.013*** (0.0037)	-0.0047 (0.0176)	-0.013*** (0.0037)	-0.146 (0.394)	-0.0122 (0.0540)	-0.138 (0.390)	-0.0132 (0.0541)
Weight	0.0001 (0.0153)	0.0130** (0.00591)	0.0027 (0.0154)	0.0135** (0.0059)	-0.0758 (0.170)	0.0570 (0.0403)	-0.0790 (0.170)	0.0572 (0.0404)
Age	-0.0788 (0.0875)	-0.156*** (0.0350)	-0.0810 (0.0879)	-0.156*** (0.0350)	-0.619 (0.766)	-0.271 (0.241)	-0.626 (0.766)	-0.269 (0.241)
Age2	-0.0007 (0.0010)	0.0021*** (0.0003)	-0.0006 (0.0010)	0.0021*** (0.0003)	0.0042 (0.0101)	0.0025 (0.0028)	0.0042 (0.0101)	0.0025 (0.0028)
Constant	13.47*** (3.294)	4.077*** (1.406)	13.17*** (3.305)	4.029*** (1.405)	29.80 (27.23)	9.457 (10.70)	29.97 (27.28)	9.366 (10.71)
Lane dummies (1–5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included	Included	Included

Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17,504	127,498	17,504	127,498	623	3,895	623	3,895
R-squared	0.380	0.345	0.381	0.345	0.773	0.680	0.772	0.680

Note: This table reports results for a restricted stadium subsample consisting only of venues that host fixed-lane races. Accordingly, quasi fixed-lane races are limited to the same set of stadiums, allowing for direct comparison while controlling for unobserved stadium heterogeneity. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects.

Panel B: Goal Time

	Goal Time							
	Quasi Fixed-Lane Races				Fixed Races			
	(1) Women	(2) Men	(3) Women	(4) Men	(5) Women	(6) Men	(7) Women	(8) Men
Mixed-sex	0.0030*** (0.0009)	-0.001*** (0.0002)			0.0471 (0.0328)	-0.00241 (0.00357)		
Number of opposite sex competitors	0.001*** (0.0001)	0.001*** (6.48e-05)	0.0008*** (0.000214)	-0.001*** (0.000151)			0.0110* (0.00634)	-0.0005 (0.00227)
Number of higher grade racers	-0.001*** (0.0001)	-0.0012*** (6.70e-05)	0.0010*** (0.0005)	0.0010*** (6.47e-05)	-0.0022 (0.00231)	-0.0001 (0.000760)	-0.00213 (0.00229)	-0.0001 (0.000760)
Number of lower grade racers	0.00037 (0.0004)	0.000235 (0.0001)	-0.0015*** (0.0001)	-0.0012*** (6.71e-05)	0.00302 (0.00233)	-0.00013 (0.0007)	0.00303 (0.0023)	-0.00012 (0.0007)
Number of more experienced racers	-0.000284 (0.00048)	2.22e-05 (0.00018)	0.000371 (0.00046)	0.000234 (0.00018)	-0.00218 (0.00448)	-0.00128 (0.00190)	-0.00220 (0.00449)	-0.00133 (0.00190)
Number of less experienced racers	-0.00027 (0.00021)	-0.000145 (9.34e-05)	-0.000268 (0.0004)	2.45e-05 (0.00018)	-0.00206 (0.00484)	-0.00106 (0.00195)	-0.0020 (0.00485)	-0.0011 (0.00195)
Number of lightweight racers	0.00034 (0.00024)	-6.22e-05 (4.88e-05)	-0.00014 (0.00021)	-6.49e-05 (9.66e-05)	0.00105 (0.0037)	-0.0009 (0.00138)	0.00149 (0.0037)	-0.0011 (0.00143)
Number of heavyweight racers	-8.85e-05 (0.00063)	0.00050** (0.00022)	0.000278 (0.00025)	-6.58e-05 (4.88e-05)	-0.00605 (0.00605)	3.74e-06 (0.00076)	-0.00658 (0.00573)	-2.95e-07 (0.00077)
Weight	2.98e-05 (0.00022)	0.00017** (8.63e-05)	1.18e-05 (0.00063)	0.00051** (0.0002)	-0.0007 (0.00203)	0.0008 (0.00057)	-0.00083 (0.00202)	0.0008 (0.00057)
Age	-0.00124 (0.00118)	-0.0030*** (0.000508)	4.80e-05 (0.000224)	0.00017** (8.62e-05)	-0.0105 (0.00882)	-0.00310 (0.00334)	-0.0107 (0.00882)	-0.00309 (0.00334)
Age2	6.57e-06 (1.37e-05)	3.82e-05*** (5.65e-06)	-0.00124 (0.00118)	-0.0030*** (0.000508)	7.19e-05 (0.0001)	1.50e-05 (3.86e-05)	7.55e-05 (0.0001)	1.50e-05 (3.85e-05)
Constant	4.817*** (0.0480)	4.739*** (0.0197)	6.80e-06 (1.37e-05)	3.81e-05*** (5.65e-06)	5.111*** (0.319)	4.846*** (0.146)	5.106*** (0.320)	4.846*** (0.147)
Lane dummies (1-5)	Included	Included	Included	Included	Included	Included	Included	Included
Race-grade dummies (1-4)	Included	Included	Included	Included	Included	Included	Included	Included
Place Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Place-by-Day Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,778	143,600	18,778	143,600	623	3,895	623	3,895
R-squared	0.455	0.394	0.455	0.394	0.821	0.698	0.822	0.698

Note: This table reports results for a restricted stadium subsample consisting only of venues that host fixed-lane races. Accordingly, quasi fixed-lane races are limited to the same set of stadiums, allowing for direct comparison while controlling for unobserved stadium heterogeneity. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and place-by-day fixed effects.

Table A8. Impact of Adjacent Opposite-Sex Competitors on Performance
Panel A: Finishing Position

	Finishing Position			
	Quasi Fixed-Lane Races		Fixed-Lane Races	
	(1)	(2)	(3)	(4)
	Men	Women	Men	Women
Adjacent Opposite-Sex Exposure	-0.0990*** (0.0190)	0.261*** (0.0546)	-0.102 (0.193)	-0.829 (1.072)
Number of higher-grade racers	0.107*** (0.0117)	0.122*** (0.00435)	0.0866* (0.0466)	0.0244 (0.163)
Number of lower grade racers	-0.152*** (0.0109)	-0.127*** (0.0042)	-0.0166 (0.0442)	-0.0131 (0.158)
Number of more experienced racers	0.0156 (0.0322)	0.0112 (0.0135)	-0.103 (0.139)	-0.386 (0.348)
Number of less experienced racers	-0.0330 (0.0329)	0.0174 (0.0135)	-0.0873 (0.140)	-0.419 (0.374)
Number of lightweight racers	-0.0175 (0.0148)	-0.0221*** (0.0063)	-0.00269 (0.0909)	0.00676 (0.278)
Number of heavyweight racers	0.0151 (0.0153)	-0.0141*** (0.0034)	-0.0119 (0.0540)	0.207 (0.359)
Weight	0.0101 (0.0140)	0.0117** (0.0054)	0.0577 (0.0404)	-0.0781 (0.170)
Age	-0.0756 (0.0825)	-0.162*** (0.0329)	-0.273 (0.241)	-0.598 (0.772)
Age2	-0.0004 (0.0010)	0.0019*** (0.0003)	0.0025 (0.0028)	0.0033 (0.0097)
Constant	5.089*** (1.316)	12.04*** (2.872)	9.396 (10.76)	33.17 (27.90)
Lane dummies (1–5)	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes
Observations	148,849	20,372	3,895	623
R-squared	0.341	0.375	0.680	0.772

Note: *Adjacent* equals one when one or both adjacent lanes are occupied by opposite-sex competitors, and zero otherwise. Columns (1) and (2) report results for quasi fixed-lane races, while columns (3) and (4) report results for fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects.

Panel B: Goal Time

	Goal Time			
	Quasi Fixed-Lane Races		Fixed-Lane Races	
	(1)	(2)	(3)	(4)
	Men	Women	Men	Women

Adjacent Opposite-Sex Exposure	-0.00114*** (0.000240)	0.00193*** (0.000726)	-0.000327 (0.00263)	-0.00271 (0.0147)
Number of higher-grade racers	0.107*** (0.0117)	0.122*** (0.00435)	-0.00222 (0.00230)	-0.000133 (0.000764)
Number of lower grade racers	-0.152*** (0.0109)	-0.127*** (0.00426)	0.00271 (0.00231)	-0.000123 (0.000774)
Number of more experienced racers	0.0156 (0.0322)	0.0112 (0.0135)	-0.00276 (0.00457)	-0.00134 (0.00190)
Number of less experienced racers	-0.0330 (0.0329)	0.0174 (0.0135)	-0.00293 (0.00496)	-0.00113 (0.00195)
Number of lightweight racers	-0.0175 (0.0148)	-0.0221*** (0.00634)	-8.91e-05 (0.00385)	-0.00129 (0.00126)
Number of heavyweight racers	0.0151 (0.0153)	-0.0141*** (0.00343)	-0.00124 (0.00492)	4.80e-06 (0.000767)
Weight	0.0101 (0.0140)	0.0117** (0.00549)	-0.000921 (0.00205)	0.000813 (0.000571)
Age	-0.0756 (0.0825)	-0.162*** (0.0329)	-0.0104 (0.00876)	-0.00311 (0.00334)
Age2	-0.000476 (0.00102)	0.00196*** (0.000358)	6.08e-05 (0.000121)	1.53e-05 (3.87e-05)
Constant	4.758*** (0.0184)	4.817*** (0.0420)	4.846*** (0.147)	5.177*** (0.326)
Lane dummies (1-5)	Included	Included	Included	Included
Race-grade dummies (1-4)	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes
Observations	169,140	22,032	3,895	623
R-squared	0.393	0.455	0.698	0.818

Notes: *Adjacent* equals one when one or both adjacent lanes are occupied by opposite-sex competitors, and zero otherwise. Columns (1) and (2) report results for quasi fixed-lane races, while columns (3) and (4) report results for fixed-lane races. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects.

Table A9. Robustness to Specification: Alternative Interaction Models

	Full Sample		Quasi Fixed- Lane		Fixed-Lane	
	(1)	(2)	(3)	(4)	(5)	(6)
	Goal Time	Finishing Position	Goal Time	Finishing Position	Goal Time	Finishing Position
Mixed-sex	-0.001*** (0.0001)	0.104*** (0.0142)	-0.0011*** (0.0001)	-0.103*** (0.0137)	-0.0025 (0.0028)	-0.215 (0.213)
Fixed-lane	0.0003 (0.0003)	-0.0661 (0.024)				
Mixed-sex × Fixed-lane × Woman	-0.002 (0.002)	-0.046 (0.127)				
Mixed-sex × Woman	0.004*** (0.000)	0.564*** (0.041)	0.004*** (0.0004)	0.562*** (0.0371)	0.0007 (0.0062)	1.027 (0.542)
Mixed-sex × Fixed-lane	0.0001 (0.001)	0.024 (0.065)				
Fixed-lane × Woman	0.0002 (0.001)	-0.001 (0.058)				
Number of higher-grade racers	0.0011*** (0.000)	0.122*** (0.004)	0.0011*** (4.78e-05)	0.122*** (0.0036)	0.000 (0.0005)	0.0531 (0.0447)
Number of lower grade racers	-0.0012*** (0.000)	-0.130*** (0.003)	-0.0012*** (0.000)	-0.132*** (0.0036)	-0.0006 (0.0004)	-0.0230 (0.0409)
Number of more experienced racers	0.0001 (0.0001)	0.0122 (0.0125)	0.0001 (0.0001)	0.0141 (0.0122)	-0.00170 (0.0014)	-0.150 (0.124)
Number of less experienced racers	0.000 (0.0001)	0.0012 (0.012)	0.000 (0.0001)	0.0146 (0.0123)	-0.0016 (0.0015)	-0.148 (0.126)
Number of lightweight racers	-0.0001*** (0.000)	-0.009*** (0.006)	-0.0001 (0.000)	-0.0097* (0.0058)	-0.0002 (0.0009)	0.0599 (0.0823)
Number of heavyweight racers	0.000 (0.000)	-0.013*** (0.0033)	0.000 (0.000)	-0.0133*** (0.0033)	-0.000 (0.0006)	-0.0238 (0.0504)
Weight	0.0002*** (0.000)	0.0106* (0.005)	0.0002*** (0.000)	0.0100** (0.0043)	0.0007 (0.0004)	0.0506 (0.0377)
Age	-0.0027*** (0.0004)	-0.144*** (0.0304)	-0.0026*** (0.0003)	-0.142*** (0.0264)	-0.0044 (0.0027)	-0.323 (0.222)
Age2	0.000*** (0.000)	0.001*** (0.0003)	0.000*** (0.000)	0.0016*** (0.0003)	0.000 (0.000)	0.0029 (0.0026)
Constant	4.763*** (0.0174)	5.622*** (1.277)	4.761*** (0.0147)	5.523*** (1.097)	4.878*** (0.112)	10.77 (9.871)
Lane dummies (1–5)	Included	Included	Included	Included	Included	Included
Race grade dummies (1–4)	Included	Included	Included	Included	Included	Included
Observations	169,221	169,221	164,703	164,703	4,518	4,518
R-squared	0.407	0.343	0.405	0.340	0.700	0.678

Note: This table reports estimates using both the full sample and race subsamples. Columns (1) and (2) present results for the full sample based on a specification that includes the triple interaction *Mixed-sex* × *Woman* × *Fixed-lane*. Columns (3)–(6) report separate estimates for quasi fixed-lane and fixed-lane races, where the coefficient of interest is the interaction *Mixed-sex* × *Woman*. Columns (1), (3), and (4) use goal time as the dependent variable, whereas columns (2), (5), and (6) use finishing position. The full-sample specification follows Booth, Hayashi, and Yamamura (2022), and the split-sample analysis follows Booth and Yamamura (2018). Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and place-by-day fixed effects.

Table A10. Robustness to Sample Coverage: Including Races with Incomplete Results

	Fixed-Lane Races							
	Finishing Position				Goal Time			
	(1) Women	(2) Men	(3) Women	(4) Men	(5) Women	(6) Men	(7) Women	(8) Men
Mixed-sex	0.251 (0.505)	-0.0729 (0.0680)			0.0134* (0.0072)	-0.0014 (0.0009)		
Number of opposite sex competitors			-0.0095 (0.117)	-0.0582 (0.0426)			-0.0001 (0.0015)	-0.0008 (0.0006)
Number of higher-grade racers	0.140*** (0.0412)	0.116*** (0.0150)	0.140*** (0.0412)	0.116*** (0.0150)	0.00073 (0.0007)	0.0009*** (0.0002)	0.0007 (0.0007)	0.0009*** (0.0002)
Number of lower grade racers	-0.0602 (0.0464)	-0.081*** (0.0141)	-0.0610 (0.0465)	-0.081*** (0.0141)	-6.05e-05 (0.0007)	-0.0006*** (0.0002)	-8.84e-05 (0.0007)	-0.0006*** (0.0002)
Number of more experienced racers	0.0360 (0.130)	-0.0278 (0.0478)	0.0357 (0.130)	-0.0282 (0.0478)	0.0011 (0.0018)	-0.0001 (0.00061)	0.0011 (0.00185)	-0.0001 (0.00061)
Number of less experienced racers	-0.0396 (0.132)	-0.0329 (0.0476)	-0.0401 (0.132)	-0.0329 (0.0476)	1.75e-05 (0.0018)	-0.0001 (0.00061)	-2.57e-06 (0.00189)	-0.0002 (0.00061)
Number of lightweight racers	0.0792 (0.126)	-0.0286 (0.0324)	0.0532 (0.130)	-0.0228 (0.0332)	0.00129 (0.0016)	-0.0001 (0.00042)	5.73e-05 (0.0016)	-0.000183 (0.00044)
Number of heavyweight racers	0.134 (0.143)	-0.0219 (0.0190)	0.155 (0.150)	-0.0223 (0.0190)	-0.0003 (0.00202)	0.0001 (0.0002)	0.0005 (0.00208)	0.0001 (0.0002)
Weight	0.0334 (0.0325)	0.0169 (0.0112)	0.0331 (0.0324)	0.0170 (0.0112)	0.0006 (0.0004)	0.0002* (0.0001)	0.0006 (0.0004)	0.0002 (0.0001)
Age	-0.248 (0.178)	-0.162*** (0.0548)	-0.248 (0.178)	-0.162*** (0.0548)	-0.0039* (0.0023)	-0.002*** (0.0007)	-0.0039 (0.0023)	-0.002*** (0.0007)
Age2	0.0011 (0.0009)	0.002*** (0.0003)	0.0011 (0.0009)	0.002*** (0.0003)	0.000 (1.28e-05)	0.000*** (4.39e-06)	0.000 (1.28e-05)	0.000*** (4.39e-06)
Constant	15.28 (8.413)	4.244 (3.515)	15.47* (8.424)	4.213 (3.515)	4.890*** (0.115)	4.719*** (0.0470)	4.899*** (0.115)	4.718*** (0.0470)
Lane dummies (1-5)	Included	Included	Included	Included	Included	Included	Included	Included
Race grade dummies (1-4)	Included	Included	Included	Included	Included	Included	Included	Included
Stadium × Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,767	17,675	2,767	17,675	2,767	17,675	2,767	17,675
R-squared	0.686	0.518	0.686	0.518	0.743	0.570	0.743	0.570

Note: This table examines the robustness of the main results to sample coverage. In the baseline analysis, the sample was restricted to races with complete finishing information (1st through 6th places). Because many races report only the top three finishers, this table re-estimates the models using an expanded sample that includes races with incomplete results (top three only). Columns (1)–(4) report estimates for finishing position, and columns (5)–(8) report estimates for goal time. The results are qualitatively similar to the baseline estimates, indicating that the main findings are not driven by the availability of complete information. Robust standard errors are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects.

Table A11. Effects of Adjacent Male Racers on Female Start Times

	Quasi Fixed-Lane Races	Fixed-Lane Races
	(1)	(2)
Adjacent	0.0012 (0.0100)	0.0063 (0.0501)
Number of higher-grade racers	0.0074*** (0.0020)	-0.0037 (0.0139)
Number of lower grade racers	-0.0014 (0.0021)	-0.0023 (0.0130)
Number of more experienced racers	0.0117 (0.0084)	-0.0004 (0.0382)
Number of less experienced racers	-0.0023 (0.0085)	-0.0004 (0.0386)
Number of lightweight racers	-0.0003 (0.0024)	0.0295 (0.0196)
Number of heavyweight racers	-0.0033 (0.0029)	0.0208 (0.0239)
Weight	-0.0026 (0.0039)	0.0004 (0.0145)
Age	-0.0471** (0.0202)	-0.0975 (0.0765)
Age2	0.0006*** (0.0002)	0.0014 (0.0008)
Constant	-1.112 (0.667)	-0.312 (2.933)
Lane dummies (1–5)	Included	Included
Race grade dummies (1–4)	Included	Included
Stadium × Day FE	Yes	Yes
Observations	66,690	2,856
R-squared	0.117	0.504

Note: Columns (1) and (2) report results for quasi fixed lane and fixed-lane races, respectively. The dependent variable is start time. *Adjacent* equals one when one or both adjacent lanes are occupied by opposite-sex competitors, and zero otherwise. Robust standard errors clustered at the race level are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All specifications include control variables, lane dummies, race-grade dummies, and stadium × day fixed effects.