Cities 132 (2023) 104058

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

The effects of COVID-19 on female and male bike sharing users: Insights from Lisbon's *GIRA*

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ARTICLE INFO

Keywords:
Coronavirus
Bike sharing
Gender gap
Travel behaviour

ABSTRACT

Women are among the groups most affected by the pandemic as they are more likely to be dependent on public transport (PT), which was heavily restricted during COVID-19. Thus, there is a need to consider transport alternatives such as bike sharing that can ensure their mobility needs.

By conducting a survey to the bike sharing system (BSS) of Lisbon, we explored differences in travel behaviour and attitudes between female and male users before and during COVID-19. We found men to have higher bike ownership rates, a higher modal share of personal bicycle regarding commuting, and more likely to use their own bikes if BSS was unavailable. Conversely, women more frequently combined BSS with PT and were more likely to use PT if BSS was unavailable. Moreover, while men were using BSS more frequently than women pre-pandemic, during COVID-19 women are using BSS as frequently as men.

Our research provides evidence on the potential role of BSS as a transport alternative during pandemics, inducing women to take up cycling who otherwise would not cycle, therefore, potentially decreasing the current cycling gender gap. Findings suggest that introducing family/friend discounts and promoting BSS for exercising may increase the share of female cyclists.

1. Introduction

The COVID-19 pandemic triggered significant changes in mobility patterns and travel behaviour in cities worldwide (Sharifi & Khavarian-Garmsir, 2020). In effect, this unprecedented period of uncertainty entailed a series of disruptive measures, such as lockdowns, social distancing, and teleworking (Hadjidemetriou et al., 2020; Kamga & Eickemeyer, 2021), which led to drastic changes in individual travel patterns, and, consequently, a significant reduction in travel demand (Das et al., 2021; Qi et al., 2021).

Therefore, a growing body of research has examined changes in people's attitudes toward different modes of transport during the pandemic. Accordingly, empirical evidence revealed an increased positive perception of the car (Eisenmann et al., 2021), leading to a growth in motorised trips (Das et al., 2021). On the other hand, public transport (PT) suffered severe ridership drops (Teixeira & Lopes, 2020) due to the perceived risk of infection (Shamshiripour et al., 2020; Teixeira et al., 2022) and the imposed precautionary measures, such as mandatory mask-wearing (Rothengatter et al., 2021). Concurrently, active modes have increased in popularity due to their ability to provide a healthy and socially distanced way of transport (Nikitas et al., 2021).

Nevertheless, scholars acknowledge that the current coronavirus pandemic not only influenced a substantial modal shift (Thombre & Agarwal, 2021) but also exacerbated transport inequities. For instance, groups at risk of transport disadvantage before COVID-19, including the elderly, poor, women, and physically disabled, were more likely to report difficulties while avoiding public transport (Palm et al., 2021; Wang et al., 2022). Likewise, these groups tend to suffer the burdens of being exposed to the virus since they lack alternative solutions to perform daily activities. Among the most affected groups, women are highlighted as a critical group of concern (Fischer & Winters, 2021; Shaer et al., 2021) since they are more likely to be PT dependent (Hamilton & Jenkins, 2000; Lubitow et al., 2017; Nasrin & Bunker, 2021). In addition, since women tend to have multiple attached roles, they are more likely to undertake multipurpose and chained trips than men (Mahadevia & Advani, 2016). Furthermore, they are more sensitive to traffic congestion, overcrowded buses, and the risk of harassment (Plyushteva & Boussauw, 2020).

As a result, researchers, planners and policymakers have drawn greater attention to cycling (Nikitas et al., 2021) to address the mobility

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https://doi.org/10.1016/j.cities.2022.104058
Received 27 April 2022; Received in revised form 30 August 2022; Accepted 21 October 2022
Available online 25 October 2022

demand for alternative and inclusive solutions during the COVID-19 outbreak (Büchel et al., 2022; Fischer & Winters, 2021). During the pandemic, several cities have designed street and public spaces for cyclists through the implementation of pro-bike interventions like pop-up bicycle lanes (Kraus & Koch, 2021; Shirgaokar et al., 2021), traffic calming measures and the dissemination and improvement of bicycle sharing systems (BSS) (Nikitas et al., 2021). In addition, since the bicycle is a flexible, low-carbon, affordable and healthy mode of transport (Pucher & Buehler, 2008), it has the potential to increase access to opportunities for disadvantaged and minority groups (Cunha & Silva, 2022).

Accordingly, the provision of BSS emerges as a fundamental strategy to facilitate bicycle uptake and foster utilitarian cycling trips. BSS has been shown to increase both the number and diversity of cyclists, providing a sustainable, competitive and affordable mode of transport (Teixeira et al., 2021a). With the coronavirus continuing to affect the world, it is paramount to ensure that alternative modes such as cycling and BSS are available to all the population, addressing current inequalities such as the gender unbalance registered, especially in cities with residual bicycle modal share - the so-called starter cycling cities (Silva et al., 2019).

The potential of BSS in providing a low-carbon and safe mode of transport has already been recognised during the current coronavirus pandemic, including their ability to attract PT users (Teixeira et al., 2021b, 2022; Teixeira & Lopes, 2020). Nevertheless, considering starter cycling cities' social and cultural context, the extent to which BSS can mitigate transport inequalities and reduce the gender gap in bicycle use within the pandemic situation remains unclear. Therefore, this paper asserts that BSS has the potential to bridge the gap between women and the bicycle as a transport mode, ultimately normalising cycling in these cities.

In response, this study examines whether there are significant gender discrepancies in BSS use in a European starter cycling city (i.e., Lisbon), including the effects of the COVID-19 outbreak on the individual's travel behaviour and attitudes. By conducting a travel behaviour survey to the users of *GIRA* (Lisbon's BSS), we present, to the best of our knowledge, the first study examining the effects of COVID-19 on travel behaviour and the motivations and safety perceptions of female comparatively to male BSS users. Moreover, by examining the context of a starter cycling city, which encounters deep political and social resistance toward cycling, this study highlights policy implications and research pathways to support planning practitioners and policymakers in creating sustainable, equitable and inclusive BSS systems.

The paper is organised into five sections. After this introduction, the second section briefly explores the literature review encompassing gender differences in cycling. The third section presents the proposed methodology to explore the gender-equity impacts of a local BSS in a European starter cycling city. The fourth section is dedicated to the analysis of the collected survey data. Finally, the last section discusses the results as well as the research conclusions.

2. Gender differences in cycling

Over the last decade, equity-oriented studies have highlighted social-spatial inequalities encompassing active mobility in cities worldwide (Biehl et al., 2019; Feitelson, 2002; Lee et al., 2017). Empirical evidence indicates that despite the general political efforts to improve cycling conditions in cities, the use of the bicycle for daily activities remains limited to specific demographic and socioeconomic segments of society (Goodman et al., 2013; Mora et al., 2021; Tucker & Manaugh, 2018).

Research encompassing bicycle equity is fundamentally concerned with the question of how pro-cycling investments can contribute to the development of more inclusive and sustainable societies (Barajas, 2019; Lee et al., 2017) and how vulnerable and minority groups can benefit from such investments. Scholars acknowledge that providing safer and accessible bicycle infrastructure increases the appropriateness of this mode for vulnerable segments of society, especially women, children, and the elderly, who are especially sensitive to traffic dangers.

In cycling maturated countries, such as the Netherland, Germany and Denmark, the bicycle appears as an equitable transport mode since cycling trips for different daily purposes are distributed evenly across distinct income, age, and gender groups (Pucher & Buehler, 2008). However, in starter cycling cities in the global north and south, there is evidence that the distribution of bicycle-related benefits tends to favour wealthy and advantaged representatives (Cunha & Silva, 2022), disregarding the needs and constraints of disadvantaged and vulnerable groups.

Such a phenomenon is particularly evident in the case of BSS (Gavin et al., 2016) since the benefits associated with these systems are often unevenly distributed within the geographic space and among different sociodemographic groups (Chen et al., 2019). For instance, BSS users tend to be disproportionately young, male, and white (Blanford, 2020; Chen et al., 2019; Hirsch et al., 2019; Ji et al., 2017). Additionally, individuals residing in income-deprived areas are less likely to use the systems than more affluent households (Goodman & Cheshire, 2014; Mooney et al., 2019; Qian & Jaller, 2020; Winters et al., 2019) since central and densely populated regions concentrate the location and distribution of stations (Duran-Rodas et al., 2021).

Building on previous research, empirical evidence indicates significant differences in women's trip purposes compared to men (Aldred et al., 2016). For instance, females tend to cycle for non-commute or leisure trips (Abasahl et al., 2018; Goodman & Cheshire, 2014; Mitra & Nash, 2019). Likewise, they cycle shorter distances over a shorter time when compared to men (Abasahl et al., 2018; Goodman & Aldred, 2018). Furthermore, regarding travel purpose and cycling distance, women have higher odds of using bicycles for non-commute trips within a 2–5 km distance range (Mitra & Nash, 2019). Finally, females are likely to make trips within their local neighbourhood (Bourke et al., 2019) for escorting (i.e., travelling with children), maintenance activities (i.e., supermarkets, healthcare), and running errands (Singleton & Goddard, 2016).

Females are more sensitive to the built environment and infrastructure characteristics than males (Abasahl et al., 2018; Wang & Akar, 2019). Women prefer to cycle off-road in dedicated, well-connected bike lanes (Aldred et al., 2017; Shaer et al., 2021). Likewise, living nearby the bicycle infrastructure, such as BSS stations and bicycle racks, also play a key role for this group (Heesch et al., 2012; Misra & Watkins, 2018; Wang & Akar, 2019). Overall, factors related to the built environment, such as traffic calming, bicycle infrastructure, vegetation, intersections safety, land use diversity and destination accessibility, increased women's odds of cycling and using BSS (Wang & Akar, 2019).

The literature also indicates that safety and personal security concerns significantly affect overall cycling among women. For instance, the number of street intersections was found to be positively associated with female trip attractions and the share of female trip arrivals since intersection densities decrease vehicle speed, increasing the perception of safety (Wang & Akar, 2019). However, it also represents increased vehicle-bicycle interactions, which may be counteracted with improved connectivity and intersection safety measures. Finally, women are more likely to avoid cycling due to fear of collision, injury, violence, and harassment (Graystone et al., 2022).

Regarding self-reported motivations, female representatives are more motivated to use bicycles based on environmental concerns, monetary savings, and for fun when compared to men (Maas et al., 2020). Moreover, scholars argue that social and cultural norms significantly affect bicycle use among women. For instance, the traditional sexual division of labour, cultural differences, assigned gender roles (Doran et al., 2021), and living with family or parents significantly decreases the likelihood of cycling for women. From an individual perspective, females self-report to be less experienced and confident cyclists than males (Abasahl et al., 2018; Wang & Akar, 2019). Other barriers refer to operating BSS, including technology and cost barriers

(Hirsch et al., 2019). Nevertheless, seeing other people cycling and encouragement from relatives and friends increase the likelihood of bicycle uptake among women (Heesch et al., 2012).

In the specific case of bike sharing, several studies identified gender biases in BSS usage, varying in time and space (Blanford, 2020), especially in the cases of starter cycling cities (Maas et al., 2020). Scholars argue that women are less likely to use BSS due to safety concerns and social-attached issues (Carroll et al., 2020; Prati, 2018; Prati et al., 2019). Furthermore, the built-environment and land-use characteristics of the surrounding environments at BSS stations and the current pandemic situation may also influence the gender disparity in BSS usage (Abasahl et al., 2018).

In short, Table 1 presents the main dimensions related to the gender gap in cycling and BSS uptake identified in the literature, considering differences in travel behaviour, individual attitudes, perceptions of the built environment, safety, perceived security, as well as influences of social and cultural norms.

Scholars argue that improving the BSS infrastructure is essential to make this transport mode an alternative for women without access to an individual bicycle (Shaer et al., 2021). Nevertheless, there is still a lack of evidence that providing BSS might reduce the gender gap in cycling. For instance, in London, although the local BSS has become more equitably distributed over time, being more attractive and feasible to women and people living in poorer areas, women still make fewer than 20 % of all registered BSS trips (Goodman & Cheshire, 2014).

Moreover, despite the increasing attention to the gender gap in cycling, few studies have examined the impact of the COVID-19 outbreak on tackling cycling gender inequalities. One of the few studies addressing this topic examined the connection between perceived built environment components and men's and women's active travel before and during the outbreak in Iran (Shaer et al., 2021). This study found that despite the increased bicycle use among the population in general, the cycling participation of men before and during the pandemic outbreak was higher, with women mostly cycling for recreation. However, this study is particular to Iran's context, where religious prejudice restricts cycling among women (Shaer et al., 2021).

Therefore, to address this research gap, this paper explores the effects of COVID-19 on travel behaviour and the motivations and safety perceptions of females compared to male BSS users in the context of a starter cycling city, providing a new understanding of the factors that explain gender differences in BSS participation during disruptive public health emergencies.

3. Methodology

3.1. Study area

The municipality of Lisbon was selected as a suitable case study to explore the gender-equity impacts of the local BSS during the pandemic outbreak. The municipality of Lisbon occupies an area of approximately 89 km^2, with a population of 563,279 inhabitants, according to the last available Census data (INE, 2011), with females representing around 54 % of the total population. To encourage a significant shift toward the bicycle during this decade, Lisbon developed a Bicycle Master Plan (Lisbon, 2020b), currently under implementation, in line with the national cycling strategy (Ministério do Ambiente e da Transição Energética, 2020). Aligned with such a strategy, the city launched in September 2017 the local BSS entitled *GIRA* to increase the attractiveness of the bicycle as a viable mode of transport.

Regarding the pandemic impact in Portugal, the first reported COVID-19 case in the country occurred in early March 2020, and since then, the local government has started to implement restrictive measures to control the pandemic situation over the last two years (Tamagusko & Ferreira, 2020). The main strategies encompassed teleworking, closing of schools and universities, social isolation measures in both private and public spaces, as well as full and partial lockdown periods, which profoundly affected the travel behaviour of the citizens. Accordingly, studies acknowledge that the ongoing COVID-19 pandemic is creating disruptive changes in urban mobility, affecting the suitability of the public transportation system (Aparicio et al., 2021).

We examined the spatial distribution of *GIRA* stations using the GIS network analyst tool in ArcMap to measure the BSS accessibility catchment area, considering a walking distance of 300 m to each station (Fig. 1). In addition, we collected data on the cycling network, including pop-up cycling lanes using the municipal open-source database (Lisbon, 2020a). Furthermore, information encompassing population count and demographic characteristics was collected within the Census tract level (Lisbon, 2011). Finally, data on station location and the number of available bicycles were provided by the local BSS (Lisbon, 2022). As illustrated in Fig. 1, during the COVID-19 outbreak period, the *GIRA* system provided around 700 bicycles allocated across 83 stations in the central and northeast zones of the municipality, with all stations located close to the cycling network, including bicycle paths and pop-up cycling lanes. Moreover, during this period, the BSS catchment area covered 26 % of the total population and 21 % of the municipality area.

3.2. Survey description

A survey was developed aimed at analysing the travel behaviour as

Table 1
Summary of identified gender differences in cycling.

Dimensions	Main findings	References
Travel behaviour	Women are less likely to cycle for commuting. Instead, they prefer shorter distances and multipurpose trips. Women are more likely to cycle in their local neighbourhood.	Abasahl et al. (2018) **[S]**, Goodman and Cheshire (2014) **[C]**, Mitra and Nash (2019) **[S]**, Blanford (2020) **[S]**, Bourke et al. (2019) **[S]**, Heesch et al. (2012) **[S]**.
Individual attitudes and motivations	Women's motivations include cycling convenience, environmental protection, cycling for fun and affordability.	Maas et al. (2020) **[S]**, Heesch et al. (2012) **[S]**, Wang and Akar (2019) **[S]**, Bourke et al. (2019) **[S]**.
Built environment	Women prefer to cycle off-road in dedicated and well-connected bike lanes. In addition, living close to BSS stations, traffic-calming measures, vegetation, safe intersections, and land use diversity increases women's odd cycling.	Wang and Akar (2019) **[S]**, Goodman and Aldred (2018) **[S]**, Heesch et al. (2012) **[S]**, Shaer et al. (2021) **[S]**
Safety	Women avoid cycling close to high-speed traffic because of fear of collision or injury. They are risk-aversion.	Aldred et al. (2016) **[C]**, Mitra and Nash (2019) **[C]**, Carroll et al. (2020) **[C]**, Graystone et al. (2022) **[S]**, Prati et al. (2019) **[S]**.
Security	Fear of harassment and violence toward women cyclists.	Graystone et al. (2022) **[S]**, Poulos et al. (2019) **[S]**, Ravensbergen et al. (2020) **[I]**.
Social and cultural norms	The traditional sexual division of labour, assigned gender roles, and living with family or parents are factors that inhibit women's participation in transport cycling. Self-confidence, seeing other people cycling, and encouragement from others increase the likelihood of bicycle uptake among women.	Prati (2018) **[S]**, Abasahl et al. (2018) **[S]**, Wang and Akar (2019) **[S]**, Ravensbergen et al. (2020) **[I]**, Heesch et al. (2012) **[S]**, Maas et al. (2020) **[S]**, Doran et al. (2021) **[D]**.

[C] Census data analysis; **[D]** Documentation analysis; **[I]** Interview; **[S]** Survey.

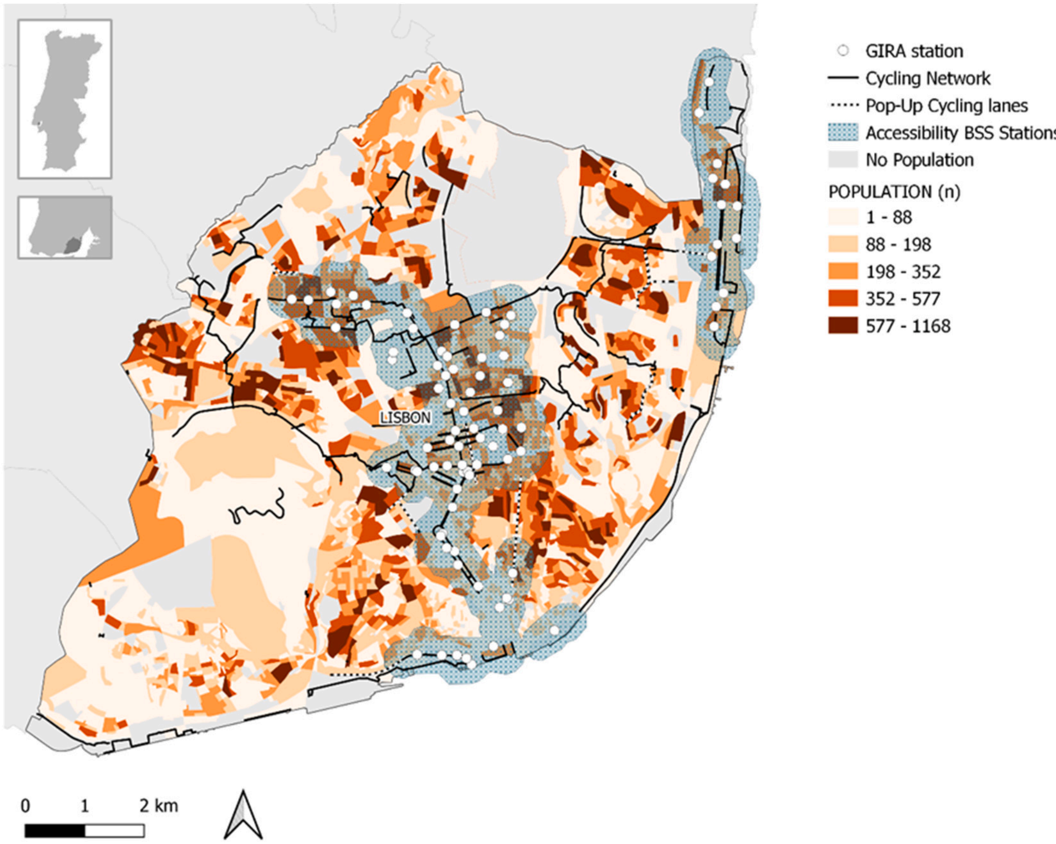

Fig. 1. *GIRA* stations distribution within 300 m accessibility catchment area and population density.

well as the motivations and safety perceptions of *GIRA* users before and during COVID-19. The questionnaire was divided into three major groups of questions. The first group asked respondents about their travel behaviour regarding *GIRA* usage (such as the frequency of use, trip motive, multimodality and modal shift). The second group questioned respondents about their main motivations for using *GIRA*. Table 2 presents the 19 motivations, which were selected based on the available literature (Teixeira et al., 2021b) as well as their perceived safety when using several modes of transport in Lisbon (specifically, walking; private car; personal bike; *GIRA* shared bike; and PT). The last group of questions focused on the main socioeconomic and demographic characteristics of the respondents.

In order to analyse the effect of COVID-19 on the travel behaviour and attitudes of BSS users, we asked the respondents to compare their behaviour before and during COVID-19 through the use of retrospective questions (the respondents were instructed to consider the first two months of 2020 when answering the questions regarding the pre-pandemic period).

The survey was disseminated exclusively through online channels and was available between September and October 2020. In addition, several survey distribution ways were adopted for collecting responses, including publicising on social media (particularly in cycling/bike sharing and neighbourhood association groups), sending invitations through faculties emailing lists and announcing it in the local press.

3.3. Statistical methods

To begin, we used descriptive statistics to provide a first assessment of possible differences between female and male BSS users regarding their travel behaviour as well as motivations and perceptions before and during COVID-19. Furthermore, group comparison statistics, specifically Mann-Whitney U (*MW*) and Chi-square tests (χ^2), were also applied to analyse the socioeconomic and demographic profile of female versus male BSS users. The Mann-Whitney U (*MW*) and Chi-square tests (χ^2) are the non-parametric equivalents of the independent *t-test* and are used when the dependent variable is, respectively, ordinal or binary (Field, 2013a).

In order to explore in more depth these possible gender differences on the determinants affecting BSS usage, we employed binary logit models. The standard model formulation is the following (Washington et al., 2011):

$$P_i = \frac{exp(\beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \ldots + \beta_k X_{k,i})}{1 + exp(\beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \ldots + \beta_k X_{k,i})} \tag{1}$$

On which, β_0 is the model constant and β_1, β_2, …, β_k are the regression coefficients to be estimated with the predictor variables ($X_{1,\,i}$, $X_{2,\,i}$, …, $X_{k,\,i}$) (Washington et al., 2011). We considered two independent binary logit models for each period (before and during COVID-19). A total of 30 variables were initially included (full model) (Table 2). Next, following the parsimony rule, we applied a backward stepwise method aimed at removing the predictors not significant for model fit based on the likelihood ratio test and lowest AIC (Field, 2013b).

3.4. Sample description

A total of 294 respondents completed the survey, with 178 respondents being male (60.5 %) and 116 being female (39.5 %). Table 3 summarises the sample's composition, including a comparison between male and female respondents. Overall, the socioeconomic and demographic characteristics of both male and female respondents are similar, with only statistically significant differences between the groups regarding their place of residence (with a higher percentage of females living in the city of Lisbon) and bike ownership (with a higher percentage of males having a personal bike available for use). Furthermore,

Table 2
Variables included in the binary logit models.

Category	Variables	Abbreviation
Dependent variable	Gender (binary)	
	• Female	Female
	• Male (reference category)	Male
Predictor variables	*GIRA* usage	
	• *GIRA* frequency of use (binary: 0 – 1ess than 3 times per week; 1–3 or more times per week)	Frequency
	• Trip motive (binary: 0 – not work related; 1 – work related)	Motive
	Travel behaviour (binary: 0 – no; 1 – yes)	
	• *GIRA* as main mode of transport in commuting trips	GIRA_Main_Mode
	• *GIRA* trips conducted in combination with PT	GIRA_PT
	Modal shift (binary: 0 – no; 1 – yes)	
	• Would use private motor vehicle if *GIRA* not available	Shift_Car
	• Would use PT if *GIRA* not available	Shift_PT
	• Would walk if *GIRA* not available	Shift_Walk
	• Would use personal bike if *GIRA* not available	Shift_Bike
	Motivations (binary: 0 – not important; 1 – important)	
	• Reductions in travel times	TT
	• Reductions in travel costs	TC
	• Greater trip flexibility	Flex
	• Access to PT	Access_PT
	• Avoid PT	Avoid_PT
	• Environmental concerns	EnvConc
	• Fitness improvement	Fitness
	• Health concerns	HealConc
	• Pleasure of cycling	Pleasure
	• Cycling lanes serving the trip	CycleLane
	• Low car traffic speed in the route	LowTraffic
	• *GIRA* stations near home	StHome
	• *GIRA* stations near destinations	StDest
	• Existence of *GIRA* e-bikes	Ebikes
	• Easiness of using the system	Easiness
	• Influence of people I know	Family
	• Seeing other people using *GIRA* in the city	OtherPeople
	• Marketing campaigns	Marketing
	• Social distancing	SocialDistanc
	Safety concerns (binary: 0 – not safe; 1 – safe)	
	• Safety of walking	Safety_Walk
	• Safety of using a private car	Safety_Car
	• Safety of using a personal bike	Safety_PersonalBike
	• Safety of using PT	Safety_PT
	• Safety of using *GIRA*	Safety_GIRA

in Table 3, we also compared our sample with the 2017 Household Travel Survey (HTS) of Lisbon (INE, 2018), with *GIRA* users being, overall, younger, more likely to be employed as well as to have an academic degree and higher personal bike ownership rates than the general population.

Regarding the representativeness of our sample, we compared it with a more extensive survey conducted by *GIRA*'s operator (Moura & Félix, 2019), finding our sample to be broadly similar to the aforementioned study (the reader is invited to consult REFERENCE 1 (include later to ensure anonymity) for a comprehensive comparison of the two surveys).

Dividing our users into the two periods of analysis (before and during COVID-19), we obtain 259 valid answers (of which 63.3 % are male) in the period before COVID-19 and 195 valid answers (of which 56.9 % are male) in the period during COVID-19.

4. Results

4.1. Descriptive statistics

4.1.1. Travel behaviour

We start our analysis by comparing the frequency of *GIRA* usage between male and female respondents before and during the coronavirus pandemic (Fig. 2). We can observe that before COVID-19, male respondents were using the system more frequently than females (67 % versus 53 % using *GIRA* three or more times per week, respectively). However, during COVID-19, this usage difference has reversed, with female respondents using *GIRA* more frequently than male respondents. Such results suggest that the travel behaviour of male and female BSS users was distinctly affected by the pandemic, with male users seemingly more affected by COVID-19. We hypothesise that this distinct behaviour between male and female users may be related to women using bike sharing for different reasons than men. The following analyses will further explore this supposition.

Next, we looked at possible differences regarding the purposes of the trips conducted with *GIRA* (Fig. 3), specifically if the purpose of the trip was related to work trips (both commuting as well as other work activities such as going to a meeting) or not (leisure trips). The graph reveals that before COVID-19, most male respondents used *GIRA* for work-related trips (54 %) compared to female respondents who were more frequently using *GIRA* for leisure trips (59 %). However, during COVID-19, this difference no longer exists since the majority of both male and female respondents are now using *GIRA* for trips not related to work.

A major aspect of the travel behaviour potentially affected by the pandemic is the mode choice. Fig. 4 compares the primary mode of transport for commuting trips between male and female users before and during COVID-19. Respondents had the option of selecting single or multiple modes. The figure shows that for both male and female respondents, the most used mode of transport before COVID-19 was PT followed by *GIRA*. Nevertheless, the pandemic has provoked a decline on the share of PT while the share of *GIRA* has increased. Indeed, *GIRA* is now the most used mode for both user groups. Additionally, we can also observe that, in both periods, personal bikes represent a higher modal share among males comparatively to females.

We also investigated the share of *GIRA*'s trips conducted in combination with public transport (Fig. 5). The impact of COVID-19 on the multimodality relationship between *GIRA* and PT is apparent in the

Table 3
Socioeconomic and demographic characteristics of our sample ($N = 294$) comparatively to the general population of Lisbon ($N = 12{,}890$), as well as differences between male and female *GIRA* users (and respective group comparison statistics).

	2017 Lisbon HTS		2020 GIRA Survey						Differences significant ($p < 0.05$)[a]
			All		Male		Female		
	n	%	n	%	n	%	n	%	
Place of residence									
Lisbon City	12,890	100 %	253	86.1 %	146	82.0 %	107	92.2 %	Yes (χ^2)
Lisbon Metro Area			41	13.9 %	32	18.0 %	9	7.8 %	
Age									
≤24	2748	21.3 %	50	17.0 %	24	13.5 %	26	22.4 %	No (*MW*)
25–44	3306	25.6 %	152	51.7 %	92	51.7 %	60	51.7 %	
45–64	3804	29.5 %	89	30.3 %	59	33.1 %	30	25.9 %	
>64	3032	23.5 %	3	1.0 %	3	1.7 %	0	0.0 %	
Education									
Basic Education	3411	28.7 %	1	0.3 %	1	0.6 %	0	0.0 %	No (*MW*)
Secondary Education	2172	18.3 %	38	12.9 %	25	14.0 %	13	11.2 %	
Higher Education	6297	53.0 %	255	86.7 %	152	85.4 %	103	88.8 %	
Employment status									
Working	6133	54.6 %	213	72.4 %	133	74.7 %	80	69.0 %	No (*MW*)
Not working	641	5.7 %	13	4.4 %	7	3.9 %	6	5.2 %	
Retired	4460	39.7 %	5	1.7 %	5	2.8 %	0	0.0 %	
Studying			63	21.4 %	33	18.5 %	30	25.9 %	
Household size									
1 (only me)	N/A	N/A	84	28.6 %	49	27.5 %	35	30.2 %	No (*MW*)
2			63	21.4 %	39	21.9 %	24	20.7 %	
3 or more			147	50.0 %	90	50.6 %	57	49.1 %	
Having children									
No	N/A	N/A	196	66.7 %	113	63.5 %	83	71.6 %	No (χ^2)
Yes			98	33.3 %	65	36.5 %	33	28.4 %	
Age of the youngest child									
<6 years old	N/A	N/A	39	39.8 %	30	46.2 %	9	27.3 %	No (*MW*)
6–12 years old			28	28.6 %	17	26.2 %	11	33.3 %	
>12 years old			31	31.6 %	18	27.7 %	13	39.4 %	
Driving's license									
No	4237	32.9 %	33	11.2 %	23	12.9 %	10	8.6 %	No (χ^2)
Yes	8653	67.1 %	261	88.8 %	155	87.1 %	106	91.4 %	
PT monthly pass									
No	8285	64.3 %	160	54.4 %	98	55.1 %	62	53.4 %	No (χ^2)
Yes	4162	32.3 %	134	45.6 %	80	44.9 %	54	46.6 %	
Car availability									
No	1534	24.3 %	64	21.8 %	37	20.8 %	27	23.3 %	No (χ^2)
Yes	4772	75.7 %	230	78.2 %	141	79.2 %	89	76.7 %	
Bike availability									
No	4914	77.9 %	122	41.5 %	59	33.1 %	63	54.3 %	Yes (χ^2)
Yes	1392	22.1 %	172	58.5 %	119	66.9 %	53	45.7 %	

[a] The results of the *MW* and χ^2 for each socioeconomic and demographic characteristic are presented as Appendix A.

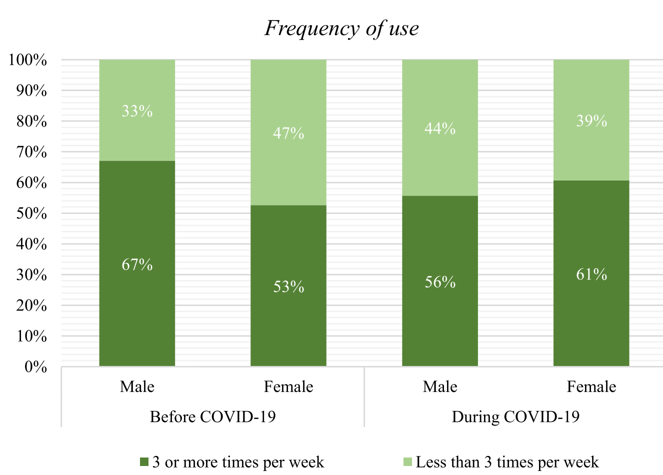

Fig. 2. Comparison of *GIRA* usage frequency between male and female users before and during COVID-19.

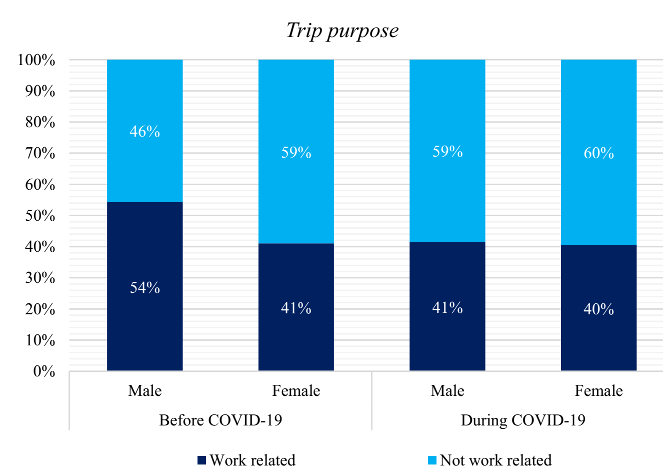

Fig. 3. Comparison of *GIRA*'s trip purposes between male and female users before and during COVID-19.

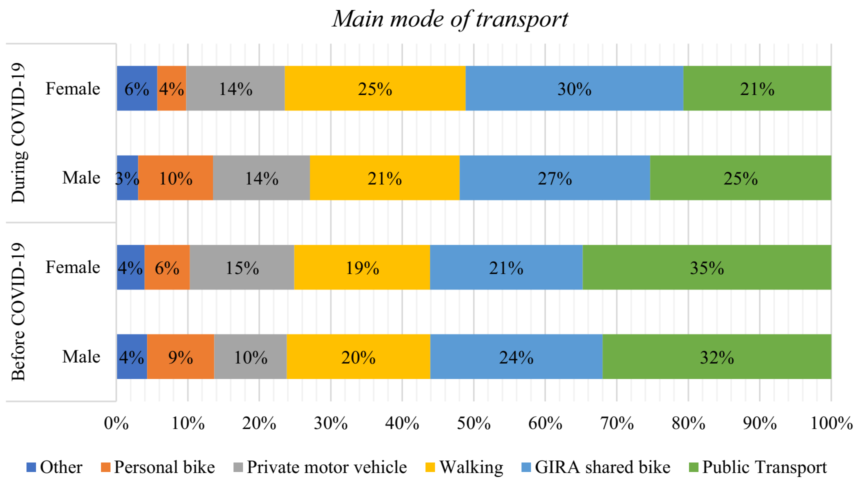

Fig. 4. Comparison of the main mode of transport for commuting between male and female users before and during COVID-19. Note: 24 of respondents that use *GIRA* during COVID-19 declared to no longer commute.

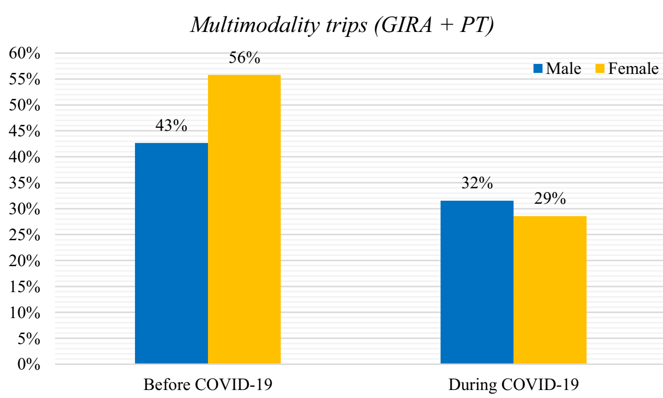

Fig. 5. Comparison of the share of trips conducted by *GIRA* in combination with PT between male and female users before and during COVID-19.

graph, with the share of *GIRA* trips conducted in combination with PT sharply falling between the periods. Female users were particularly affected, registering a more considerable decrease than males. In fact, before COVID-19, the majority of *GIRA* trips conducted by females were in combination with PT (56 % versus 43 % of trips conducted by males), but during COVID-19, only 29 % of female users stated to still combine *GIRA* with PT (being now similar to the share of males).

Finally, we assessed the modal shift dynamics induced by *GIRA* by asking respondents which mode of transport they would use in their most frequent trip with *GIRA* if the system did not exist (Fig. 6). Before COVID-19, PT was the most replaced mode by *GIRA* for both genders, but its share significantly decreased during the pandemic. This may indicate a loss of confidence in PT, with some respondents no longer feeling safe in using PT due to the pandemic and would now use other modes of transport instead. Regarding modal shift differences between genders, female users replace a higher PT share in both periods. Conversely, a much higher percentage of male users reported replacing private bikes, with this difference widening during COVID-19. Additionally, during COVID-19 the share of female users reporting to replace car trips has increased while the share of male users has declined.

4.1.2. Motivations and safety perceptions

Another critical aspect to explore is the potential differences between men and women regarding their motivations for using bike sharing. Figs. 7 and 8 present the motivations for using *GIRA*, respectively, before and during COVID-19, divided by gender and ranked according to the female respondents' highest scores.

The figures reveal that the most important motivation for using *GIRA* both before and during COVID-19, regardless of gender, is the existence of stations near the users' destinations, closely followed by the pleasure

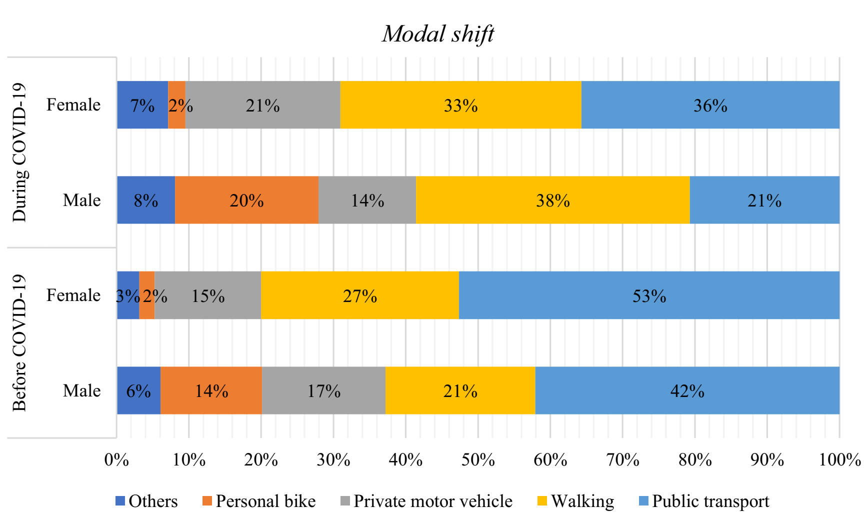

Fig. 6. Comparison of the modal shift to *GIRA* between male and female users before and during COVID-19.

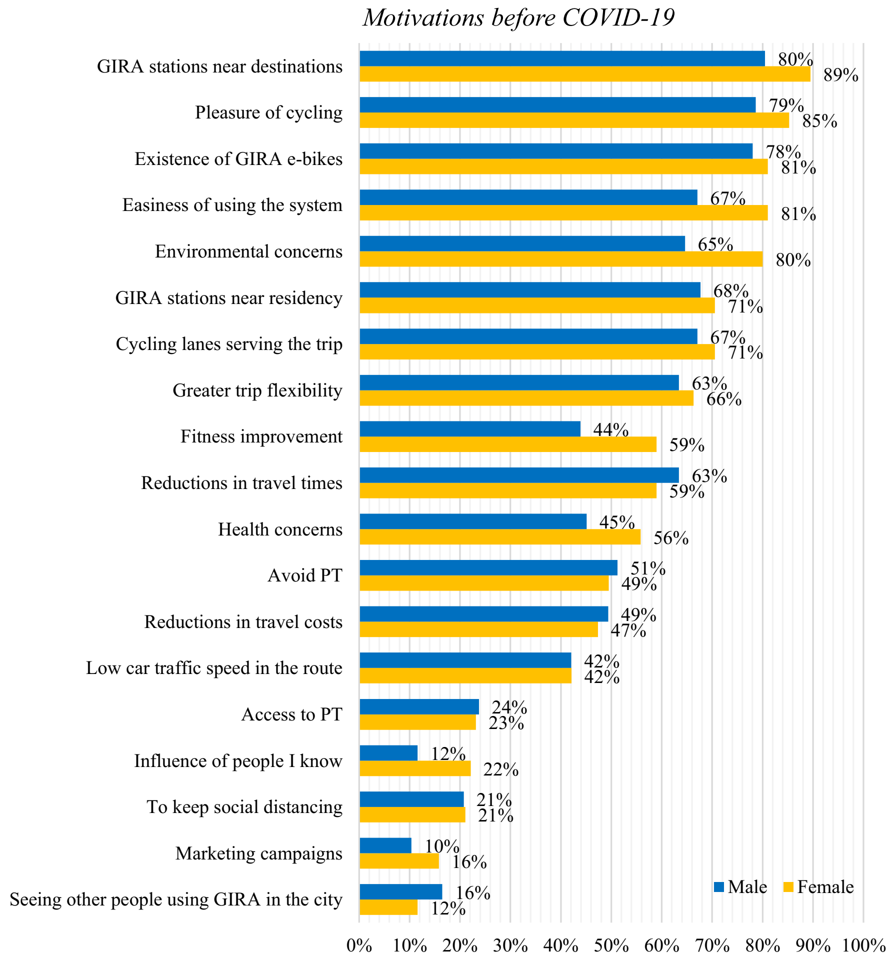

Fig. 7. Comparison of the motivations for using *GIRA* between male and female users ranked according to the female users' importance assessment before COVID-19 (percentage of users considering each motivation as important).

of cycling and the existence of shared e-bikes. However, we can also observe some significant differences between males and females. Firstly, both before and during COVID-19, fitness improvements and the influence of their social circle were more relevant to female users. Furthermore, especially before COVID-19, female users tended to give more importance to environmental and health concerns as well as to the easiness of using *GIRA*. Additionally, during COVID-19 the existence of BSS stations near home became more important for women.

Lastly, we asked our respondents to assess how safe they felt when using different modes of transport in Lisbon before and during COVID-19 (Fig. 9). Firstly, we can clearly see the coronavirus's impact on PT, which before the pandemic was considered as safe as driving or cycling (albeit female users had a lower safety perception), but now is considered, by far, the least safe mode. Regarding gender differences, female users consider using *GIRA* safer than using a personal bike in both periods, especially before COVID-19.

4.2. Logit models

To further explore the previous preliminary results, we employed binary logit models. The final models for the periods before and during COVID-19, including its parameters' estimations and goodness-of-fits measures, are presented in Tables 4 and 5, respectively. No multicollinearity issues were detected in either model (Field, 2013b).

Eleven predictors were retained in the model before COVID-19 and five predictors were retained in the model during COVID-19. As we have selected males as the reference category, a negative coefficient is associated with male users while a positive coefficient is associated with females. Predictors with a higher odds ratio indicate a more significant effect size.

Before COVID-19, six predictors were found to be positively associated with female users, while five predictors were associated with male users. Firstly, regarding differences on *GIRA* usage, males were more likely to be frequent users than females. Furthermore, the modal shift dynamics were also found to differ between men and women, with males more likely to replace personal bikes while females were more likely to replace PT and walking with *GIRA*. In relation to the motivations for using bike sharing, environmental concerns, fitness improvements and the easiness of using the system were all found to be more important for women, while seeing other people using *GIRA* was more associated with men. Lastly, we also found safety perceptions to differ between genders, with female users more likely to consider *GIRA* as safe, while male users were more likely to perceive both personal bike and PT as safer.

During COVID-19, two predictors not only continue to have the same effect as before but have now an increased importance as expressed by their larger coefficients and a higher statistical significance. Specifically, men continue to be more likely to replace personal bikes with BSS, while considering fitness improvements as an important motivation remains more associated with women. Additionally, the importance of three motivations were found to differ between men and women in this period. Considering using *GIRA* to access PT as important was now statistically associated with male users, while having BSS stations near home and the influence of their social circle was more important to females.

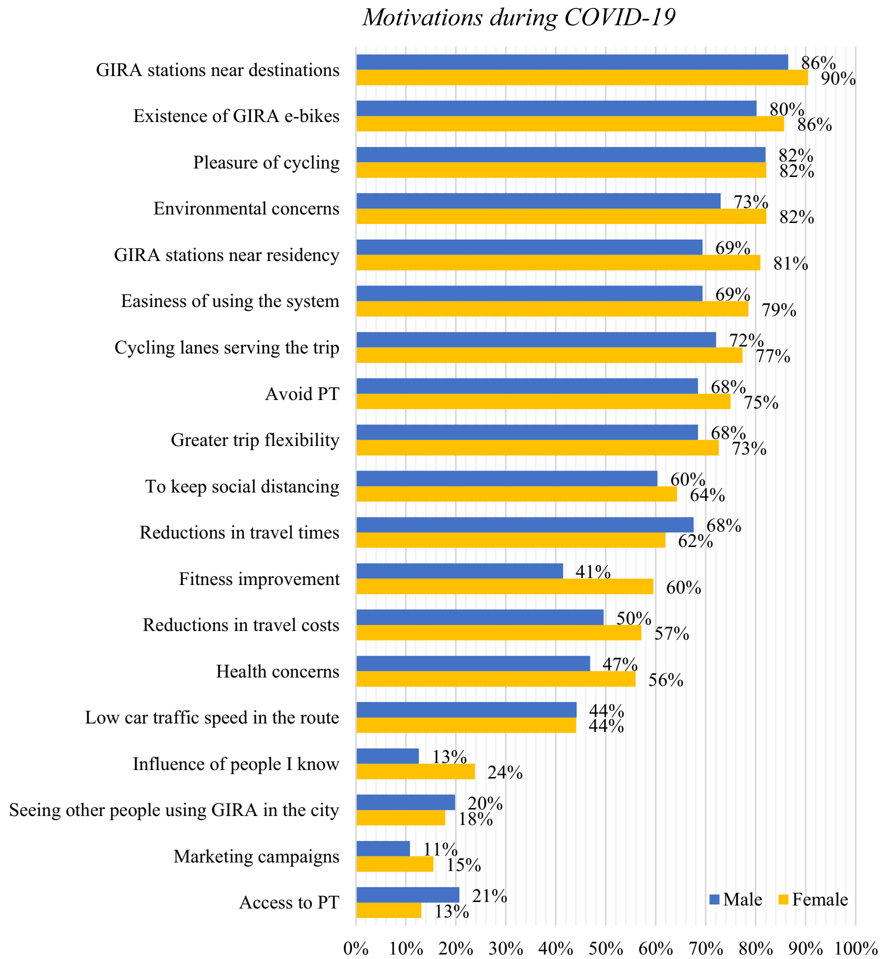

Fig. 8. Comparison of the motivations for using *GIRA* between male and female users ranked according to the female users' importance assessment during COVID-19 (percentage of users considering each motivation as important).

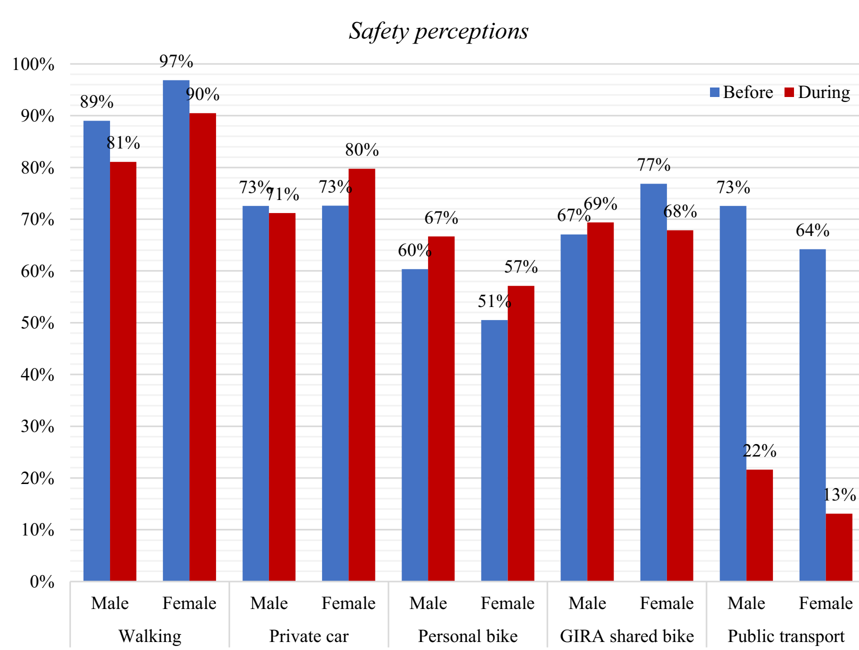

Fig. 9. Comparison of the safety perceptions of using different modes of transport between male and female users before and during COVID-19 (percentage of users considering each mode as safe).

Table 4
Binary logit final model for the period before COVID-19 ($N = 259$).

Variables	B	Std. error	Wald	Sig.	OR	OR 95 % CI
Constant	−1.526	0.582	6.867	**	0.22	
Frequency	−0.971	0.311	9.739	**	0.38	[0.21; 0.70]
Shift_PT	0.948	0.395	5.747	*	2.58	[1.19; 5.60]
Shift_Walk	0.809	0.447	3.266	’	2.25	[0.93; 5.40]
Shift_Bike	−1.530	0.829	3.406	’	0.22	[0.04; 1.10]
EnvConcern	0.832	0.350	5.658	*	2.30	[1.16; 4.56]
Fitness	0.572	0.302	3.578	’	1.77	[0.98; 3.20]
Easiness	0.816	0.348	5.481	*	2.26	[1.14; 4.48]
OtherPeople	−1.205	0.454	7.048	**	0.30	[0.12; 0.73]
Safety_PersonalBike	−0.676	0.343	3.879	*	0.51	[0.26; 1.00]
Safety_GIRA	0.835	0.391	4.565	*	2.30	[1.07; 4.95]
Safety_PT	−0.788	0.347	5.142	*	0.45	[0.23; 0.90]
LL final model	−141.937	AIC final model	307.9	Cox & Snell		0.196
LL null model	−170.222	AIC full model	335.2	Nagelkerke		0.268
LL full model	−134.609	Classification	72.6 %	McFadden		0.166
LR χ^2 (11)	56.571		Hosmer-Lemeshow Test			H_0 not rejected
Sig χ^2	***					

’$p < 0.1$ *$p < 0.05$ **$p < 0.01$ ***$p < 0.001$.

Table 5
Binary logit final model for the period during COVID-19 ($N = 195$).

Variables	B	Std. error	Wald	Sig.	OR	OR 95 % CI
Constant	−1.040	0.374	7.750	**	0.35	
Shift_Bike	−2.340	0.775	9.112	**	0.10	[0.02; 0.44]
Access_PT	−0.980	0.467	4.403	*	0.38	[0.15; 0.94]
Fitness	0.749	0.317	5.561	*	2.11	[1.13; 3.94]
StationResidency	0.731	0.368	3.932	*	2.08	[1.01; 4.27]
Family	1.063	0.443	5.755	*	2.90	[1.21; 6.90]
LL final model	−116.609	AIC final model	245.2	Cox & Snell		0.244
LL null model	−133.288	AIC full model	277.9	Nagelkerke		0.328
LL full model	−105.954	Classification	73.3 %	McFadden		0.205
LR χ^2 (5)	33.359		Hosmer-Lemeshow Test			H_0 not rejected
Sig χ^2	***					

’$p < 0.1$ *$p < 0.05$ **$p < 0.01$ ***$p < 0.001$.

Table 6
Factors associated with either male or female BSS users before and during COVID-19 obtained from the logit models.

	Before COVID-19	During COVID-19
Frequency	Male	–
Shift_PT	Female	–
Shift_Walk	Female	–
Shift_Bike	Male	Male
Access_PT	–	Male
EnvConcern	Female	–
Fitness	Female	Female
Easiness	Female	–
StationResidency	–	Female
Family	–	Female
OtherPeople	Male	–
Safety_PersonalBike	Male	–
Safety_GIRA	Female	–
Safety_PT	Male	–

As a summary of the logit results, Table 6 presents the factors found to statistically differ between male and female BSS users before and during COVID-19.

5. Discussion and conclusions

Our research uncovered important differences between BSS users regarding gender. Firstly, male users were found to have a much stronger connection with the personal bicycle than female users. Comparatively to women, men have higher bike ownership rates, a higher modal share of personal bicycle regarding commuting trips and were more likely to use their own bike if *GIRA* was not available. Furthermore, especially before COVID-19, male users considered using personal bikes safer comparatively to their female counterparts. In contrast, female users considered *GIRA* to be safer to use than a personal bike, especially before COVID-19. Thus, our findings suggest that bike sharing can have an important role to play in reducing the gender gap between male and female cyclists registered in cities with low cycling shares (Pucher & Buehler, 2008), as BSS may potentially attract women to take up cycling who otherwise would not cycle. Indeed, comparing the share of female cyclists in bike counts conducted by Lisbon Municipality (Moura et al., 2020) both with our survey and with *GIRA*'s user database (Moura & Félix, 2019), the share of female BSS users is significantly higher (39.5 % and 37 % versus 23 %).

This study also found evidence that the factors affecting BSS usage differ between male and female users. Both before and during COVID-19, fitness improvements were found to be more important to female than to male users. Such finding coupled with the fact that in both periods the purpose of the majority of *GIRA* trips conducted by women was not related to work, indicates that women tend to use bike sharing for different reasons than men. This is in line with previous studies that found women to be more likely to cycle for non-commute or leisure trips (Abasahl et al., 2018; Goodman & Cheshire, 2014; Mitra & Nash, 2019). Likewise, women attached more importance to the influence of family/friends/colleagues in their decision to use BSS, especially during COVID-19. Women cyclists have already been found to be more likely to consider social factors as important motivators (Heesch et al., 2012) and this also seems to apply to bike sharing.

We also found that COVID-19 has provoked distinct changes on the travel behaviour of BSS users regarding gender. Before COVID-19, males used *GIRA* more frequently than female users. However, that difference has disappeared during the pandemic, with now women using *GIRA* as frequently as men. Such reversal on the usage difference can mainly be explained by two reasons. On the one hand, men were more likely to use *GIRA* for commuting, which significantly decreased during COVID-19 due to government travel restrictions such as mandatory teleworking. On the other hand, women were more dependent on PT, which was heavily restricted during COVID-19, inducing them to look for transport alternatives. Indeed, the coronavirus pandemic has affected the women's relationship between BSS and PT. Before COVID-19, women were found to more frequently combine bike sharing with PT in their trips (Fig. 5) and were more likely to use PT if *GIRA* was not available. However, with the emergence of COVID-19, the share of women combining BSS with PT has dropped sharply and they are no longer more associated with using PT as an alternative to BSS. Moreover, using *GIRA* to access PT is now more important for men than for women. Since women tend to use PT more than men (Hamilton & Jenkins, 2000; Lubitow et al., 2017; Nasrin & Bunker, 2021), they have been particularly affected by the COVID-19 disruption of PT. In that sense, bike sharing can provide an important alternative to PT during this pandemic, which in turn could potentially also help avoiding a modal shift from female PT users to the private car and all its associated negative impacts.

Furthermore, the fact that during COVID-19 the existence of BSS stations near residential areas was more important for women than for men, coupled with an increased importance on fitness improvements (expressed by the larger coefficient and a higher statistical significance in the logit models), suggests that *GIRA* was an important form of exercising for women during the pandemic. With coronavirus severely limiting the available options for physical activity, particularly indoor facilities such as gyms, bike sharing provided a means for exercising outdoors in which a social distance could be maintained.

Policy implications can be derived from our study. First and foremost, policymakers should take advantage of the bike sharing's potential in increasing the share of female cyclists by better integrating BSS into the broad transport system and through providing specific funding for BSS operators to attract female users. Furthermore, during the current pandemic, policymakers may use BSS as an alternative to PT, which has been particularly battered by COVID-19, as bike sharing provides a transport alternative that is perceived to be safe, therefore, ensuring the mobility needs of vulnerable groups with fewer transport options. Concurrently, our research also provides some insights on how public authorities and BSS operators may increase the attractiveness of bike sharing to women. For instance, marketing campaigns could focus on advertising BSS as a pleasant and convenient way for exercising, which during COVID-19 should also be complemented by promoting BSS as an outdoor activity where a social distance can be maintained. Likewise, operators should consider introducing family/friend discounts to boost the number of female BSS users as women were found to give more importance to their social circle than men.

As limitations, our study used retrospective questions to assess the coronavirus impact on the behaviour of *GIRA* users, which may be susceptible to recall biases. However, at the time of the survey (September to October 2020), the beginning of the pandemic was still relatively recent and as such it is reasonable to assume that respondents were still able to remember their pre-pandemic travel behaviour. Furthermore, we used a convenience sampling method, which may lead to selection bias. However, we have minimised such potential effects by disseminating the survey through several channels and comparing the sample with a representative survey conducted by *GIRA*'s operator.

All in all, our study supports policies that promote the implementation and/or expansion of BSS during the present coronavirus pandemic and beyond, as these systems can potentially foster higher cycling usage levels among women. Future research should continue to investigate the effects of the coronavirus on the gender cycling unbalance as well as the potential role of bike sharing in addressing this gap by increasing the share of female cyclists.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the *Cities* Journal.

CRediT authorship contribution statement

João Filipe Teixeira: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Isabel Cunha:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Acknowledgements

The authors would like to thank the support of the Portuguese Foundation for Science and Technology (FCT) through the PhD scholarships PD/BD/146494/2019 and PD/BD/146480/2019.

Appendix A. Group comparison statistics

Table 7
Mann-Whitney *U* tests (*MW*) and associated significance.

	Gender	Mean rank	Mann-Whitney *U* test (*MW*)		*p*-Value
			U	Z	
Age	Female	155.02	8986.0	−1.933	0.053
	Male	135.97			
Education	Female	145.49	9966.5	−0.854	0.393
	Male	143.79			
Employment status	Female	153.19	9664.0	−1.186	0.236
	Male	148.86			
Household size	Female	145.42	10,082.5	0.236	0.712
	Male	155.02			
Age of the youngest child	Female	46.21	858.5	−1.713	0.087
	Male	55.98			

Table 8
Chi-Square test (χ^2) and associated significance.

	Chi-square test (χ^2)	*p*-Value
Place of residence	6.111	0.013
Having children	2.057	0.151
Driving's license	1.304	0.254
PT monthly pass	0.073	0.787
Car availability	0.256	0.613
Bike availability	12.958	<0.001

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