Original Article

doi: 10.16926/par.2022.10.22

Bike-sharing systems: Effects on physical activity in a Spanish municipality

Alberto Sanmiguel-Rodríguez

Faculty of Language and Education, University of Camilo José Cela, Madrid, Spain
Faculty of Language and Education, Nebrija University, Madrid, Spain
Faculty of Education and Sport Sciences, University of Vigo, Pontevedra, Spain

Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation

Abstract

Introduction: Urban mobility (such as walking or biking) and public Bike-Sharing Systems (BSS) have begun to emerge through programs and services that drive change from the strong culture of dependence on motor vehicles in most developed countries. At the international level, the 2030 Agenda of the United Nations (UN) opted to establish objectives for sustainable development, addressing the need to establish changes in urban mobility. The World Health Organization (WHO) has concluded that physical inactivity and being overweight / obesity are the fourth and fifth risk factors for non-communicable diseases in the world, respectively. The objective of this study is to know if a BSS has been able to serve as a means of promoting Physical Activity (PA) in the urban environment. *Material and Methods:* A quantitative and longitudinal study has been designed with data collection and analysis from July 2009 to January 2012. The sample consisted of a total of 3,268 users and a total of 59998 observations were recorded (Men: n = 42,411; Women: n = 17,587). SPSS 21.0 and ANOVA were used for statistical analysis. *Results:* Users between the ages of 20 and 44 have spent an average of 30.7 minutes, between 45 and 64 years an average of 36 minutes and between 65 and 79 years an average of 51.1 minutes. *Conclusions*: The data suggest that the WHO (2010) PA recommendations may be being met. BSS can favor the practice of PA in the urban environment, and thus, be able to promote less polluted and traffic-congested environments. Men from 65 to 79 years old have had the most average minutes of use. The routes that took the most minutes were those that go between the same stations and those that pass between stations on the urban outskirts.

Keywords: Bicycle Sharing Systems; Physical Activity, Public Health, Promotion Health, Urban Environment

Author for correspondence: Alberto Sanmiguel-Rodríguez, email: asrgz2014@gmail.com

Recevied: 24.03.2022; Accepted: 7.04.2022; Published online: 6.07.2022

Cite this article as: Sanmiguel-Rodríguez A. Bike-sharing systems: Effects on physical activity in a Spanish municipality. Phys Act Rev 2022; 10(2): 66-76. doi: 10.16926/par.2022.10.22

INTRODUCTION

Background to bike-sharing systems

The first public bicycle scheme was started in the 1960s by Luud Schimmelpenninck in the city of Amsterdam. This first generation of shared bikes started with normal bikes, painted white. They consisted of a group of bicycles randomly distributed around the city to be freely used by anyone. No registration was required and the bikes could be returned anywhere in the city where they could be used by other users. The system closed shortly after due to lack of political support and vandalism [1-4]. Years later, in 1974, a similar free bicycle service called Velos Jaunes was created in Paris, so that citizens could use the bicycle freely and independently [5].

Between 1991 and 1993, three public bicycle systems (Farsø, Grenå and Nakskov) were developed in Denmark, giving rise to a second generation of systems [2, 4]. Also, in 1993, another program with 300 bicycles was launched in Cambridge, in the United Kingdom (UK), in which a small deposit had to be paid to avoid damage, loss or theft [6]. The most referenced example, due to the large scale of the project, was the Copenhagen system, implemented in 1995 with notable improvements [2, 4]. Unlike the system started in Amsterdam in the 60s, bicycles were grouped in stations and access to bicycles was not totally free, but it was necessary to introduce a coin [1, 2]. However, due to the anonymity of the users, many of the bikes were still being stolen. This gave way to a new generation of Bike-Sharing Systems (BSS) with improved user tracking [2].

The first third-generation BSS was Bikeabout in 1996 at the University of Portsmouth in the UK, where students could use bicycles via swipe cards. Thus, therefore, advances in electronics and telecommunications were successfully applied to BSS, allowing greater control over the use of bicycles [2, 4]. BSS grew slowly in successive years. In 1998, the first third-generation system, called Vélo à la Carte, was launched in Rennes (France), which included compulsory registration and automatic bicycle delivery system by cards [2, 4], and in Munich in 2000 Call a Bike was launched, but it was not until 2005 that the third generation of shared bikes took hold with the launch of Velo'v in the French city of Lyon [2]. Thus, in Europe, the adoption of third generation systems was very limited until 2005 with less than 10 systems. The Velo'v system in Lyon has become one of the most notable third generation systems. Velo'v opened with 1,500 bicycles, this being the largest third-generation system, surpassing, with 300 more bicycles, that of Oslo in Norway [4].

The evolution of these innovations introduces the concept of an emerging fourth generation, which will be able to integrate the latest technologies: such as stations with solar energy docking, electric assisted bicycles, integration of smart transit cards, as well as the use of mobile phone applications with real-time updates on bike availability [4].

Current bike-sharing systems

Today, the loan of BSS has seen a very popular increase, with an estimated 375 programs in 33 countries around the world, spread over more than 135 cities [7]. Mobility improvements and environmental impacts in public health advances offered by shared bikes mean that 193 systems are in planning or construction [8].

Its origins go back to Europe, but it has been deployed by the rest of the continents [2, 4]. Europe is the continent with the most BSS, since around 88% of the systems are located in European countries [1]. Due to its leading role in the third generation of shared bicycles and the large number of systems implemented, France has become one of the benchmark countries for public bicycles, as well as Germany, Italy and Spain [1]. The BSS is concentrated in Europe mainly in its western part, while in Eastern Europe it is still in the introduction phase [1]. Despite the relevance of Europe, in recent years this service has also gained prominence in other continents. In the same way, the BSS has also emerged in China since 2005, and so far, there are more than 10 cities that show their interest in building these services [9]. In America, Asia and Oceania the bicycle is very present, representing 7%, 4% and 1% of the total systems that exists worldwide [1].

Thus, in recent years, and especially today, BSS have become popular in a very significant and successful way [4]. Indeed, today there are numerous studies [1-3, 6, 9, 10] that show a more widespread use of public bicycle rental as an alternative means of urban transport to reduce the greenhouse effect and the search for sustainable transport solutions. Urban mobility (such as walking

or biking) and BSS have begun to emerge through programs and services that drive change from the strong culture of dependence on motor vehicles in most developed countries [6, 7, 11]. The potential of BSS as a means of commuting to work or as a recreational purpose should be exploited in terms of expansion as a strategy for future growth and less polluted and traffic-congested cities [11-16]. BSS services have a great dimension and relevance as a healthy and economical means of transport that favour a change of approach in the choice of trips within the urban nucleus, in order to develop new policies that promote urban mobility and Physical Activity (PA) as a sustainable means of transport [12, 13, 15-23], and with this to be able to face in a more effective way climate change, pollution, improve regional mobility, traffic problems in cities and encourage healthy and social factors. The World Health Organization (WHO) defines PA as any movement produced by in the body, with the consequent consumption of energy [24]. The WHO has concluded that physical inactivity and being overweight / obesity are the fourth and fifth risk factors for non-communicable diseases in the world, respectively [25, 26]. For the WHO [26], resistance PA improves cardiorespiratory function and this can consist of: brisk walking, running, cycling, skipping or swimming. Total PA can be done in several short sessions or in a single long session, in order to reach the goal of PA that allows maintaining body weight [26]

At the international level, the 2030 Agenda of the United Nations (UN) opted to establish objectives for sustainable development, addressing the need to establish changes in urban mobility [27].Without losing sight of the concept of urbanism referred to the set of knowledge that is applied to the study of the creation, development, reform and progress of populations in order to the material needs of human life, and taking into account that the primary objective is always satisfy all the present and future needs, both functional and aesthetic, of the urban population, services that help promote PA as a means of transport should be promoted from institutions and local governments [15, 25]. Especially in the current urbanization in which essential importance is attached to the rational development of population centres and there is a tendency to build new cities or expand and rebuild the old ones following a meticulous urbanization plan and trying to meet the general needs of its inhabitants through its services and programs. Without losing sight, as we said, of such a concept of urbanism, we will study whether the urban environment that different governments try to promote can facilitate or hinder the individual's ability to perform PA [28]. For all these reasons, the objective of this study is to know the time of use of the VaiBike system and check if the average time exceeds the PA recommendations by the WHO.

MATERIAL AND METHODS

Participants, design and sample

A quantitative and longitudinal study has been designed with data collection and analysis of the BSS of Vilagarcía de Arousa (Galicia, northwestern Spain) from July 2009 to January 2012.

The sample consisted of a total of 3,268 users of the Vilagarcía de Arousa shared bicycle service. The user's identification is associated with a numerical value, maintaining their anonymity at all times. The number of uses of the VaiBike bicycle system of the Municipality of Vilagarcía de Arousa was counted daily and a total of 59,998 observations were recorded (Men n=42,411; Women n=17,587). The data was provided and authorized by the Vilagarcía de Arousa city council.

The variable studied was minutes of use, whose behaviour was determined according to blocks of age, sex and minutes of use. From this information, other variables have been derived that were also the object of study, which were: the routes between the five stations and the minutes of use (calculated from the start and end date of the trips). The date of birth was coded as day / month / year, so it was decided to decode the age according to a numerical value through a formula of the Excel spreadsheet so that the SPSS statistical program could identify it correctly.

Procedure and data analysis

First, the Vilagarcía de Arousa City Council was contacted in order to obtain an anonymized database of the system and the consent for the transfer of data was signed. Afterwards, the data extracted from the system were collected and statistically analyzed through the IBM SPSS program version 21.0.

A significance value p <0.05 has been established in the hypothesis contrast tests; SPSS 21.0 and ANOVA were used for statistical analysis. Next, descriptive data such as means or standard deviations were calculated and finally comparisons of means were made through the *t*-test, in the case of two independent samples, and the analysis of variance when the comparisons were made between more than two independent samples.

Ethical aspects

The code of ethics for research in general has been complied with, as well as the commitment to data confidentiality and good research practices. The conducted research is not related to human or animal use. All procedures performed in this manuscript were performed in accordance with ethical research standards. On the other hand, the informed consent of the administration that governs the BSS was obtained.

RESULTS

The minutes of use have been analysed according to three age ranges and the gender of the VaiBike users by age ranges. VaiBike users between the ages of 20 and 44 have completed an average of 30.7 minutes (±31.1), between 45 and 64 years an average of 36 minutes (±32.9) and between 65 and 79 years an average of 51.1 minutes (±34.2). In terms of gender, men between 20 and 44 years old have registered an average of 30.5 minutes (±32.3), those between 45 and 64 have registered 37.2 minutes (±33.7) and men between 65 and 79 years old have registered the highest average with 52 minutes (±34.0). Regarding the female gender, women between 20 and 44 years old have registered the highest average with 38.8 minutes (±29.8), women between 45 and 64 have registered an average of 32.3 minutes (±30.0) and finally, women from 65 to 79 years have logged an average of 34 minutes (±33.6) (Figure 1 and Table 1).

Regarding the analysis of the average number of minutes of use according to the routes, the data showed that route 11 (Vilagarcía-urban centre), with an average of 51.5 minutes, was the route with the longest use of the bicycle, closely followed by the routes 34 of the urban outskirts of Carril and Vilaxoán, 55 (suburbs), 22 (at the railway station), 45 (Vilaxoán-suburbs), 43 (Vilaxoán-Carril), 33 (Carril-Carril) and 54 (suburbs-Vilaxoán), with a mean time of 49.4 minutes, 45.7 minutes, 45.1 minutes, 43.4 minutes, 43.3 minutes, 41.7 minutes and 41.6 minutes respectively (Figure 2), being statistically significant with a value of $F_{24.84160}$= 408.35 (p <0.001) as shown in Table 2.

The differences between genders showed that in men the route 34 (Carril-Vilaxoán) and 11 (urban centre) were the ones in which more minutes of use of the VaiBike were observed, with an average of 55.5 minutes and 54 minutes (Figure 2). In women, the minutes of shared bicycle use remained with more balanced values, exceeding the 40-minute barrier on routes 35 (Carril-suburbs), with an average of 46.3 minutes, 55 (suburbs) , with an average of 45.5 minutes, 22 (at the railway station), with an average of 44.5 minutes, 11 (urban centre), with an average of 44.1 minutes, 43 (Vilaxoán-Carril), with an average of 43.6 minutes and 53 (suburbs-Carril), with an average of 40.6 minutes (Figure 2), being statistically significant in both men and women with a value of $F_{24.84133}$= 220.11 (p <0.001) as shown in Table 3.

For its part, the highest average number of minutes of bicycle use by stations according to origin corresponded to the station in the center of Vilagarcía, with a total of 39 minutes. The one with the least usage time was that of Carril, with a total of 31.5 minutes. According to the destination station, the average number of minutes of bicycle use was greater at the suburbs with an average of 38.7 minutes, while the Carril station with 33.3 minutes was the one with the lowest records of time filed.

In men, the train station, in Vilagarcía, with 40.9 minutes, was the one with the highest average according to origin, while with 35.1 the Carril station was the one with the fewest minutes. On the other hand, the stations of the center and Carril were the stations with the most and least time of use, respectively, according to the destination with an average of 39.5 and 35.7 minutes. With regard to women, the station located at the train station, with 37.1, was the one with the highest records of minutes according to their origin, while on the opposite side the Carril station was found with an average of 25.5 minutes. The minutes of use according to the destination in women determined that the station of the suburbs, in the periphery, with 39.4 minutes, has been the one in which the highest

values were observed, while Carril, with 28.4 minutes on average, it has once again been the one with the fewest minutes according to its destination.

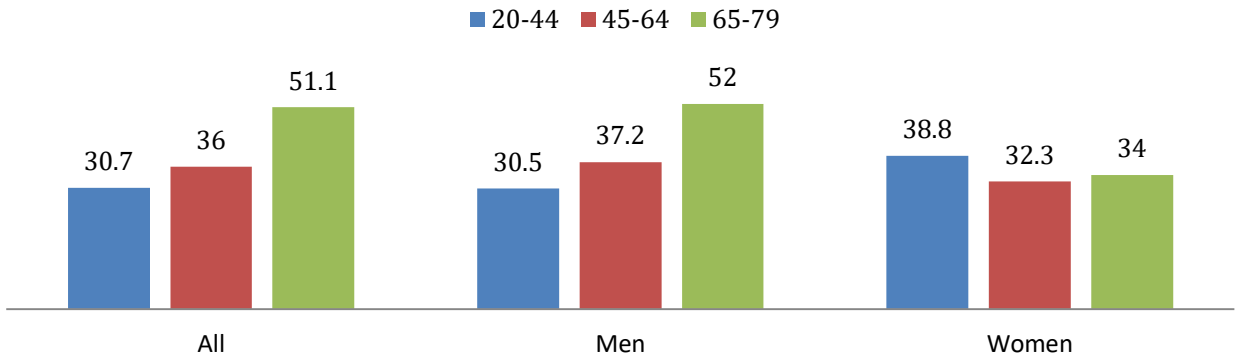

Figure 1. Average minutes of use according to age groups.

Table 1. Minutes of use by age range.

Variable	All (n=59998)			Men (n=42411)			Women (n=17587)		
Minutes of use	n	Mean	SD	n	Mean	SD	n	Mean	SD
20-44 years	23321	30.7	31.1	12577	30.5	32.3	10744	38.8	29.8
45-64 years	25702	36.0	32.9	19444	37.2	33.7	6258	32.3	30.0
65-79 years	10975	51.1	34.2	10390	52.0	34.0	585	34.0	33.6

SD – standard deviation

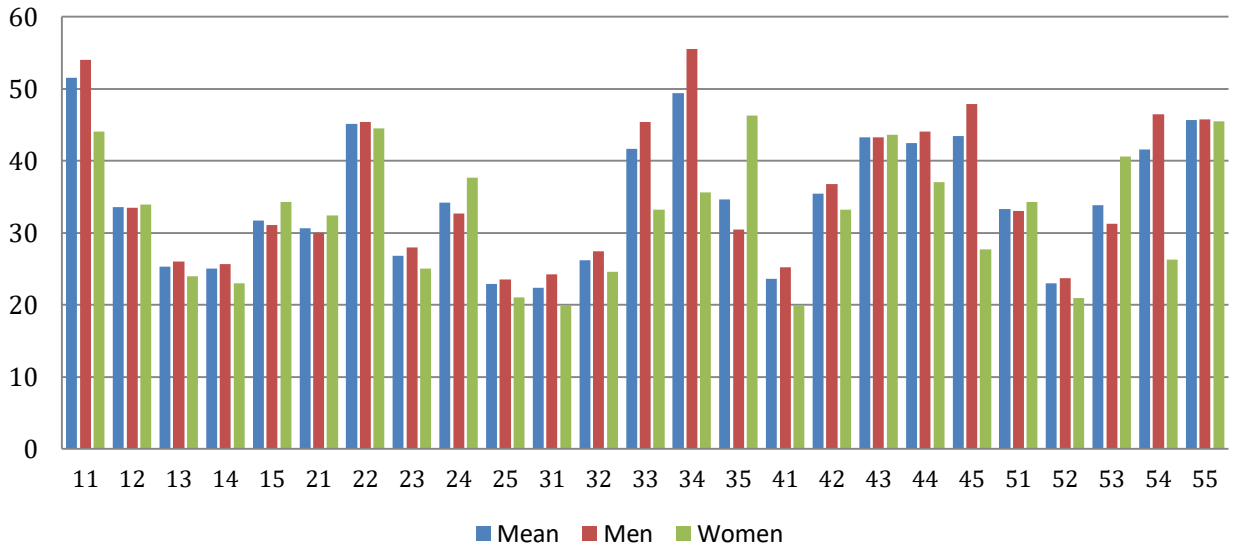

Figure 2. Average total minutes of use per route.

Table 2. ANOVA of minutes of use by routes.

Source	SS	df	MS	F	p-value
Inter-groups	9885643.43	24	411901.809	408.35	<0.001
Intra-groups	84892658.8	84160	1008.70555		

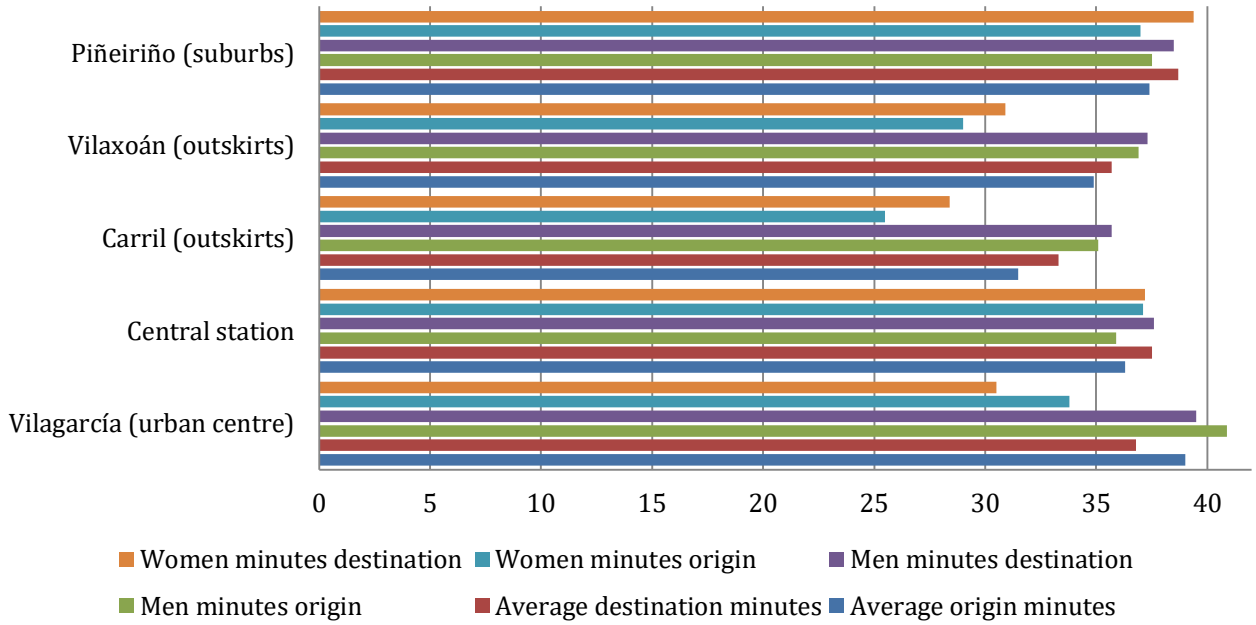

Figure 3. Average minutes of use by stations of the total at the origin and destination

Table 3. ANOVA of the minutes of use according to route and gender

Source	SS	df	MS	F	p-value
Model	10769016.7	49	219775.852	220.11	<0.001
Route	7160880.85	24	298370.036	298.82	<0.001
Gender	57556.4815	1	57556.4815	57.64	<0.001
Route by gender	465743.837	24	19405.9932	19.44	<0.001
Residuals	84006885.7	84133	998.501013		

DISCUSSION

The results of this study indicated that VaiBike users reached an average of 30.7 minutes for the 20 to 44 year old age group, an average of 36 minutes for the 45 to 64 year old age group, and 51.1 minutes on average for the age group 65 to 79 years. These results were reached in another investigation [1] in which it was indicated that the systems are used in Europe for an average of 18 minutes per loan, which would imply an average of 36 minutes in a round trip. Similarly, according to Bao et al. [29], in the Shanghai Mobike (China), 70% of the trips in BSS had an average duration of less than 30 minutes. Following this line, Börjesson and Eliasson [30] showed that travel times were evenly distributed in the range of 15-60 minutes, with a mean of 29 minutes. For their part, Li et al. [31] indicated that trips on the London Cycle Hire (UK) that lasted more than 60 minutes only accounted for 2.87% of the total registered. Thus, some studies [32] noted that BSSs are intended for short commutes between 30 minutes and one hour. This appears to be consistent with the findings of other authors [33, 34] who reported that commutes average approximately 24 minutes in the United States [33] and at the Mevo BSS in Gdansk, Gdynia, and Sopot (Poland) [34]. In the Vélib system in Paris (France), 92% of trips took an average of 22 minutes [35]. Very similar data has been indicated in another investigation [36] in which they have indicated that the duration of the trips generally ranges between 16 and 22 minutes in the BSS in Melbourne (Australia), Brisbane (Australia), Washington DC (United States), Minnesota (United States) and London (UK). Similar findings were reached by Noland and Ishaque [11] who indicated the utilitarian character of the bicycle systems in the city of London (UK), with the average journey time being 18.5 minutes [37]. Rojas-Rueda et al. [38] indicated that the average duration in the Bicing system in Barcelona (Spain) on weekdays was 14.1 minutes, although

this margin was extended to 17.8 minutes during the weekends. Along the same lines, Jensen et al. [39] reported that mean distances traveled in the Vélo'v system in Lyon, France, had a mean duration of just under 15 minutes. According to Teixeira and Lopes [40] at Citi Bike in New York (United States), in March 2020, COVID-19 was affecting the duration of trips with an average daily duration of more than 16 minutes.

The results of this study have shown that men in the age range of 65 to 79 years have made trips of 52 minutes on average while women from 20 to 44 years have reached 38.8 minutes on average. Following these findings, in another study [41] in terms of the total number of trips, men make more trips than women, and people in their 20s, 30s and 40s represent 70% of shared bike users. However, retired men were found to walk the longest distances. For Garrard, Rose and Lo [42] and Krenichyn [43], women were more likely to take shorter trips than men. Leister et al. [44] indicated that 44.13% of the journeys made in BSS were made by women, 8.81% by children, and 10.40% by older adults.

For Raustorp and Koglin [25], approximately 27.9% of the population can reach their workplace in a 15-minute bicycle trip, while 47.2% can reach their workplace in 30 minutes. For these authors [25] it is possible to achieve a modal share of 47.2% for active transport in Scania (Sweden) if all the people who are at a distance from work choose to travel by bicycle. If that happened, 19.2% of the workforce would comply with the WHO global health recommendations only through their displacement. In other research [45] the London (UK) BSS has positive impacts on overall health, but these benefits are clearer for men than women and for users older than for younger users. Along these lines, Goodman and Cheshire [46] pointed out that residents in disadvantaged areas use the London (UK) BSS if they are built in their local areas, and can do so progressively more over time, but only if systems remain affordable relative to other modes.

Thus, many documents allude to the need to develop safe sports infrastructures and spaces in cities (bike lanes, bicycle parking, route planning or improved lighting) that can encourage PA in the urban environment [47-51]. The results show positive associations with the promotion of cycling from the political sphere. That is, if the different governments and administrations try to adapt the city to the use of bicycles, building BSS, promoting routes, increasing safety ... we find a favourable relationship between bicycle lanes and levels of cycling, going to work or school with some regularity [47]. Ruíz-Ariza et al. [52] showed that the average daily active commute time in adolescents is 18 minutes and could increase total daily PA by 13%. However, the results of another study [53] highlight that among Citi Bike users in New York (United States), the main motivation to use the system is related to looking for a less expensive means of transport and more efficient but this motivation is not associated with the practice of PA and health. Some authors [3] indicate that it is essential that functional and aesthetic security elements are put in place and that all this will contribute to active models of displacement. In this way, BSS have a great dimension and relevance as a healthy and economical means of transport that favour a change of approach in the choice of trips within the urban nucleus, in order to develop new policies that promote urban mobility development and PA as a sustainable means of transport [54], and thus be able to cope more effectively with climate change, pollution, improve regional mobility, traffic problems in cities and encourage healthy and social factors.

It should be noted that there are numerous published studies that coincide in highlighting the need to enable or improve infrastructure for greater use, enjoyment and use of active means of movement because that will make the inhabitants more satisfied with it and use it more [49, 55-58] as well as, research articles related to environmental factors, safety and PA in general, and those that reflect the association between the built environment, the determining factors that harm and benefit the behaviour of bicycle use are less common, addressing accessibility and the design of the infrastructure of BSS [49].

CONCLUSIONS AND LIMITATIONS

The data from this research suggest that the PA recommendations of the WHO (2010) could be met by accounting for the time of use of the bicycle from when it is picked up at one station and deposited at another. However, although the results indicated that the average time spent using

bicycles is greater than 30 minutes in all age groups, both total and by gender, the total levels of PA carried out by users have not been recorded, since the minutes indicated the duration of the bicycle rental and not its active use. So that, men from 65 to 79 years old have had the most average minutes of use in rental time. Moreover, the routes that took the most minutes were those that go between the same stations and those that pass between stations on the urban outskirts. As for the average minutes of use according to the stations at their origin and destination, the longest journeys in time have taken place with the station of origin and destination in the center and in the suburbs. Surely this has been favored by the existence of dedicated bicycle lanes and the feeling of greater security offered by these infrastructures for the promotion of PA. Thus, most of the existing publications that deal with urban mobility are on legislation, security and the creation of infrastructures as a benefit to improve health by increasing active trips to work, study centre and as recreation or leisure but there are few studies that reflect the benefits they have as a means of promoting PA and health in the urban environment today. Thus, the current BSS could favour the practice of PA in the urban environment, and thus, be able to promote less polluted and traffic-congested environments.

One of the main limitations of this study has been that public bicycles do not cover, in many cases, cycling mobility needs, although it is difficult to determine the indirect increase in the use of BSS, since it depends on the perception of the bicycle user. In addition, secondly, although the WHO (2010) has recommended a minimum of 30 minutes a day, the quantified use of VaiBike bicycles in time could be affected by other factors (you can stop cycling and the system counts it as usage time), and therefore should be treated with great caution. It was not possible to quantify the time of use of the shared bicycles in the VaiBike in a precise way, nor the intensity of this PA because it should also be taken into account if the recorded time is of active use of the bicycle or if it is really the time of "rental" of the bicycle. For the analysis of the intensity of the practice of PA, heart rate monitors and GPS could be used in the users of the system. On the other hand, the limitation of time for the use and enjoyment of bicycles and space, in turn, can also affect the use of the service, since routes of longer time and outside the region cannot be carried out.

ACKNOWLEDGEMENTS

There are no acknowledgements.

CONFLICTS OF INTEREST

None declared.

REFERENCES

1. Anaya E, Castro A. General balance of public bicycle in Spain [Balance general de la bicicleta pública en España]. Fundación ECA Bureau Veritas. 2012.
2. DeMaio P. Bike-sharing: History, impacts, models of provision, and future. Journal of Public Transportation 2009; 12(4): 41-56. doi: 10.5038/2375-0901.12.4.3
3. García-Palomares JC, Gutiérrez J, Latorre M. Optimizing the location of stations in bike-sharing programs: A GIS approach. Applied Geography 2012; 35(1): 235-246. doi: 10.1016/j.apgeog.2012.07.002
4. Parkes SD, Marsden G, Shaheen SA, Cohen AP. Understanding the diffusion of public bikesharing systems: evidence from Europe and North America. Journal of Transport Geography 2013; 31: 94-103. doi: 10.1016/j.jtrangeo.2013.06.003
5. Midgley P. The role of smart bike-sharing systems in urban mobility. Journeys 2009; 2: 23-31.
6. Li J, Ren C, Shao B, Wang Q, He M, Dong J, Chu F. A solution for reallocating public bike among bike stations. In Proceedings of 2012 9th IEEE International Conference on Networking, Sensing and Control. IEEE 2012; 352-355. doi: 10.1109/ICNSC.2012.6204943
7. Ogilvie F, Goodman A. Inequalities in usage of a public bicycle sharing scheme: Socio-demographic predictors of uptake and usage of the London (UK) cycle hire scheme. Preventive Medicine 2012; 55(1): 40-45. doi: 10.1016/j.ypmed.2012.05.002

8. Birdsall M. Bikesharing in Full Bloom. ITE Journal 2014; 84(2): 28-31.
9. Zhang Y, Huang Z. Performance evaluation of bike sharing system in Wuchang area of Wuhan, China. In 2012 6th International Association for China planning conference (IACP) IEEE 2012; 1-10.
10. Pellicer-Chenoll M, Pans M, Seifert R, López-Cañada E, García-Massó X, Devís-Devís J, González LM. Gender differences in bicycle sharing system usage in the city of Valencia. Sustainable Cities and Society 2020; 65: 102556. doi: 10.1016/j.scs.2020.102556
11. Noland RB, Ishaque MM. Smart bicycles in an urban area: evaluation of a pilot scheme in London. Journal of Public Transportation 2006; 9(5): 71-95. doi: 10.5038/2375-0901.9.5.5
12. Barbour N, Zhang Y, Mannering F. A statistical analysis of bike sharing usage and its potential as an auto-trip substitute. Journal of Transport & Health 2019; 12: 253-262. doi: 10.1016/j.jth.2019.02.004
13. Hirsch JA, Stratton-Rayner J, Winters M, Stehlin J, Hosford K, Mooney SJ. Roadmap for free-floating bikeshare research and practice in North America. Transport reviews 2019; 39(6): 706-732. doi: 10.1080/01441647.2019.1649318
14. Liu Y, Tian L. A graded cluster system to mine virtual stations in free-floating bike-sharing system on multi-scale geographic view. Journal of Cleaner Production 2021; 281: 124692. doi: 10.1016/j.jclepro.2020.124692
15. Otero I, Nieuwenhuijsen MJ, Rojas-Rueda D. Health impacts of bike sharing systems in Europe. Environment International 2018; 115: 387-394. doi: 10.1016/j.envint.2018.04.014
16. Zhao Y, Ke S, Lin Q, Yu Y. Impact of land use on bicycle usage. Journal of Transport and Land Use 2020; 13(1): 299-316. doi: 10.5198/jtlu.2020.1499
17. Grimes A, Baker M. The effects of a citywide bike share system on active transportation among college students: a randomized controlled pilot study. Health Education & Behavior 2020; 47(3): 412-418. doi: 10.1177/1090198120914244
18. Nordengen S, Ruther DC, Riiser A, Andersen LB, Solbraa A. Correlates of commuter cycling in three norwegian counties. International Journal of Environmental Research and Public Health 2019; 16(22): 4372. doi: 10.3390/ijerph16224372
19. Sanmiguel-Rodríguez A. Analysis of the ages, routes and minutes of use in the use of a shared bicycle system: the case of VaiBike in Vilagarcía de Arousa (Spain) [Análisis de las edades, trayectos y minutos de uso en la utilización de un sistema de bicicletas compartidas: el caso del VaiBike en Vilagarcía de Arousa (España)]. Retos. Nuevas Tendencias en Educación Física, Deporte y Recreación 2019; 35: 314-319. doi: 10.47197/retos.v0i35.66470
20. Sanmiguel-Rodríguez A. Compliance with the recommendations for physical activity set by the WHO by public bicycle users in a Spanish municipality [Cumplimiento de las recomendaciones de actividad física de la OMS por usuarios de bicicletas públicas en un municipio español]. Revista Habanera de Ciencias Médicas 2020; 19(3): e2955.
21. Sanmiguel-Rodríguez A, Arufe Giráldez V. Impact of climate on a bike-sharing system. Minutes of use depending on day of the week, month and season of the year. Cuadernos de Psicología del Deporte 2019; 19(2): 102-112. doi: 10.6018/cpd.338441
22. Teixeira JF, Silva C, Moura e Sá F. Empirical evidence on the impacts of bikesharing: a literature review. Transport Reviews 2020; 41(3): 329-351. doi: 10.1080/01441647.2020.1841328
23. Zhou Q, Che M, Koh PP, Wong YD. Effects of improvements in non-motorised transport facilities on active mobility demand in a residential township. Journal of Transport & Health 2020; 16: 100835. doi: 10.1016/j.jth.2020.100835
24. World Health Organization (WHO). More active people for a healthier world: global action plan on physical activity 2018-2030. 2018.
25. Raustorp J, Koglin T. The potential for active commuting by bicycle and its possible effects on public health. Journal of Transport & Health 2019; 13: 72-77. doi: 10.1016/j.jth.2019.03.012
26. World Health Organization (WHO). Global recommendations on physical activity for health. 2010.
27. Agenda of the United Nations (UN). Resolution A / RES / 70/1 transforming our world: The 2030 agenda for sustainable development. 2015.
28. Gray JA, Zimmerman JL, Rimmer JH. Built environment instruments for walkability, bikeability, and recreation: Disability and universal design relevant? Disability & Health Journal 2012; 5(2): 87-101. doi: 10.1016/j.dhjo.2011.12.002
29. Bao J, He T, Ruan S, Li Y, Zheng Y. Planning Bike Lanes based on Sharing-Bikes' Trajectories. In: Proceedings of the 23rd ACM SIGKDD international conference on knowledge discovery and data mining - KDD '17. ACM Press, New York, New York, USA; 2017. p. 1377–1386. doi: 10.1145/3097983.3098056
30. Börjesson M, Eliasson J. The value of time and external benefits in bicycle appraisal. Transportation Research Part A. 2012; 46: 673-83. doi: 10.1016/j.tra.2012.01.006

31. Li H, Zhang Y, Ding H, Ren G. Effects of dockless bike-sharing systems on the usage of the London Cycle Hire. Transportation Research Part A: Policy and Practice. 2019; 130: 398-411. doi: 10.1016/j.tra.2019.09.050
32. Kahn R. Bicycle sharing in the U.S.A.: State of the art. ITE Journal. 2012; 82(9): 32-36.
33. DeMaio P, Gifford J. Will smart bikes succeed as public transportation in the United States? Journal of Public Transportation. 2004; 7(2): 1-16. doi: 10.5038/2375-0901.7.2.1
34. Bieliński T, Kwapisz A, Ważna A. Electric bike-sharing services mode substitution for driving, public transit, and cycling. Transportation research part D: transport and environment. 2021; 96: 102883. doi: 10.1016/j.trd.2021.102883
35. Midgley P. The role of smart bike-sharing systems in urban mobility. Journeys 2009; 2: 23 (accessed 2014 Jun 2). https://pdfs.semanticscholar.org/4f54/bc0c2aeefef21109a0277d4a038d1420652c.pdf
36. Fishman E, Washington S, Haworth N. Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. Transportation Research Part D: Transport and Environment. 2014; 31: 13-20. doi: 10.1016/j.trd.2014.05.013
37. Fuller D, Sahlqvist S, Cummins S, Ogilvie D. The impact of public transportation strikes on use of a bicycle share program in London: Interrupted time series design. Preventive Medicine. 2012; 54(1): 74-6. doi: 10.1016/j.ypmed.2011.09.021
38. Rojas-Rueda D, Nazelle A, Tainio M, Nieuwenhuijsen MJ. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. British Medical Journal. 2011; 343: 1-8. doi: 10.1136/bmj.d4521
39. Jensen P, Rouquier JB, Ovtracht N, Robardet C. Characterizing the speed and paths of shared bicycle use in Lyon. Transportation Research Part D: Transport and Environment. 2010; 15(8): 522-524. doi: 10.1016/j.trd.2010.07.002
40. Teixeira JF, Lopes M. The link between bike sharing and subway use during the COVID-19 pandemic: The case-study of New York's Citi Bike. Transportation research interdisciplinary perspectives. 2020; 6: 100166. doi: 10.1016/j.trip.2020.100166
41. Mobike Global. The Mobike white paper: bike-share in the city. Mobike, Shanghai. 2017 https://mobike.com/sg/blog/post/mobikewhitepaper
42. Garrard J, Rose G, Lo SK. Promoting transportation cycling for women: the role of bicycle infrastructure. Preventive Medicine. 2008; 46(1): 55-59. doi: 10.1016/j.ypmed.2007.07.010
43. Krenichyn K. Women and physical activity in an urban park: Enrichment and support through an ethic of care. Journal of Environmental Psychology 2004; 24(1): 117-130. doi: 10.1016/S0272-4944(03)00053-7
44. Leister EH, Vairo N, Sims D, Bopp M. Understanding bike share reach, use, access and function: An exploratory study. Sustainable Cities and Society 2018; 43: 191-196. doi: 10.1016/j.scs.2018.08.031
45. Woodcock J, Tainio M, Cheshire J, O'Brien O, Goodman A. Health effects of the London bicycle sharing system: health impact modelling study. BMJ 2014; 348. doi: 10.1136/bmj.g425
46. Goodman A, Cheshire J. Inequalities in the London bicycle sharing system revisited: impacts of extending the scheme to poorer areas but then doubling prices. Journal of Transport Geography 2014; 41: 272-279. doi: 10.1016/j.jtrangeo.2014.04.004
47. Pucher J, Buehler R, Seinen M. Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. Transportation Research Part A: Policy and Practice 2011; 45(6): 451-475. doi: 10.1016/j.tra.2011.03.001
48. Castillo-Manzano JI, Sánchez-Braza A. Managing a smart bicycle system when demand outstrips supply: the case of the university community in Seville. Transportation 2013; 40(2): 459-477. doi: 10.1007/s11116-012-9424-7
49. Beenackers MA, Foster S, Kamphuis CB, Titze S, Divitini M, Knuiman M, van Lenthe FJ, Giles-Corti B. Taking up cycling after residential relocation: built environment factors. American Journal of Preventive Medicine 2012; 42(6): 610-615. doi: 10.1016/j.amepre.2012.02.021
50. Braun LM, Rodríguez DA, Cole-Hunter T, Ambros A, Donaire-González D, Jerrett M, Mendez MA, Nieuwenhuijsen MJ, de Nazelle A. Short-term planning and policy interventions to promote cycling in urban centers: Findings from a commute mode choice analysis in Barcelona, Spain. Transportation Research Part A: Policy and Practice 2016; 89: 164-183. doi: 10.1016/j.tra.2016.05.007
51. Mccreedy M, Leslie JG. Get Active Orlando: changing the built environment to increase physical activity. American Journal of Preventive Medicine 2009; 37(6): S395-S402. doi: 10.1016/j.amepre.2009.09.013
52. Ruíz-Ariza A, de la Torre MJ, Suárez S, Martínez EJ. Active commuting to school influences on academic performance of Spanish adolescent girls. Retos: Nuevas Tendencias en Educación Física, Deporte y Recreación 2017; 32: 39-43. doi: 10.47197/retos.v0i32.51614

53. Reilly KH, Noyes P, Crossa A. From non-cyclists to frequent cyclists: Factors associated with frequent bike share use in New York City. Journal of Transport & Health 2020; 16: 100790. doi: 10.1016/j.jth.2019.100790
54. Munkácsy A, Monzón A. Potential User Profiles of Innovative Bike-Sharing Systems: The Case of BiciMAD (Madrid, Spain). Asian Transport Studies 2017; 4(3): 621-638. doi: 10.11175/eastsats.4.621
55. Tin ST, Woodward A, Robinson E, Ameratunga S. Temporal, seasonal and weather effects on cycle volume: an ecological study. Environmental Health 2012; 11(12): 1-9. doi: 10.1186/1476-069X-11-12
56. Orzanco R, Guillén F, Sainz ML, Redín MD, Aguinaga I. Perception of psychosocial and environmental factors related to active displacement [Percepción factores psicosociales y del entorno relacionados con el desplazamiento activo]. Revista de Psicología del Deporte 2018; 27(1): 135-140.
57. Yang, H.H. Green urban public bikes rental system: A case study of Taipei YouBike. Advanced Materials Research, 2013; 723: 968-975. doi: 10.4028/www.scientific.net/AMR.723.968
58. Urbaniak-Brekke AM, Solbraa T. Factors influencing physical activity level of the inhabitants in Norway and Poland – the case of sports and recreation infrastructure. Physical Activity Review 2019; 7: 96-106. doi: 10.16926/par.2019.07.12