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Gender and used/preferred differences of bicycle routes, parking, intersection signals, and bicycle type: Professional middle class preferences in Hangzhou, China

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ABSTRACT

Objective: To assess preference differences of females, bicyclists, bicyclists/non-bicyclists, and >3 days/week bicyclists about cycle tracks, surrounding environments, parking, signals, and bicycle type among middle class professionals in Hangzhou, a premier bicycling city in China.

Methods: Surveys were distributed to 1200 middle school students that 1150 parents/adults completed (95.8% completion rate). Multiple linear regression was used to study associations between frequency of bicycling and age, gender, education, income, obesity, and car ownership.

Results: Cycle tracks were a maximum of 15 feet wide, enabling side-by-side bicycling, with continuous landscaped islands a maximum of 7 feet wide between the road and the cycle track with trees over 40 years old. Almost all knew how to bicycle, 77% of men and 72% of women owned a car, and, of these car owners, 43.8% bicycled each week. Only 47.1% of men and 55.1% of women did not bicycle. Bicycling was deemed enjoyable due to the beautiful surrounding environment (52.7% strongly agreed/agreed). Gender differences were statistically significant for preferring bicycle signals (63.7% men, 69.1% women) and cycle tracks (53.9% men, 60.2% women). Used/preferred differences were statistically significant for bicycle signals (33.8% used versus 71.4% preferred), parking sheds (39.8% used versus 62.7% preferred) and cycle tracks (34.4% used versus 58.6% preferred). Percentages for overweight were significantly different between owning a car (28.8%) and not owning a car (21.0%).

Conclusions: Cities could test other city's innovations including parking sheds, bicycle signals, public bicycles, and wide-landscaped cycle tracks with trees between the cycle track and the road.

1. Introduction

Bicycling can help an individual live a long and healthy life (Cooper et al., 2006; Andersen et al., 2009; Hendriksen et al., 2000; Andersen et al., 2000; Andersen et al., 2010; Eriksson et al., 2010; Baan et al., 1999; Schnohr et al., 2011; de Hartog et al., 2010; Wardman et al., 2007; Borrestad et al., 2012; Whitaker, 2005; Matthews et al., 2007), especially by controlling weight (Lusk et al., 2010; Bassett et al., 2008; Dudas and Crocetti, 2008; Janssen et al., 2005; Wen and Rissel, 2008). Furthermore, biking does not require discretionary time, like many other sports, and can be enjoyed as a routine part of life yet people's willingness to bicycle is largely dependent on the existence of safe and high-quality routes (Wardman et al., 2007; Rietveld and Daniel, 2004; Yang et al., 2010; Wegman et al., 2010; de Vries et al., 2010; Pooley et al., 2011; Pucher et al., 2011; Winters et al., 2011) and comfortable bicycle amenities. If these are not provided, fewer will bicycle, (Reynolds et al., 2009) especially women (Garrard, 2003; Garrard et al., 2008; Emond et al., 2009). In the U.S., only 0.6% of the population 16 years and older uses a bicycle for transportation, of whom only 27% are female (U.S. Census Bureau, 2011).

One of the many reasons for these low rates of bicycling in the U.S. may be because cycle tracks, barrier-protected bicycle-exclusive paths beside the sidewalk, have been discouraged in the past American engineering guidelines (American Association of State Highway and Transportation Officials, 1974; American Association of State Highway and Transportation Officials, 1981; American Association of State Highway and Transportation Officials, 1991; American Association of State Highway and Transportation Officials, 1999; American

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Association of State Highway and Transportation Officials, 2012; Lusk et al., 2013). Recently, cycle tracks have been identified in preference surveys and studies as being preferred compared to bicycling in the road (de Vries et al., 2010; Winters and Teschke, 2010; Lusk et al., 2011; Strauss and Miranda-Moreno, 2013; Monsere et al., 2011). Cycle tracks are now being built and studied more (Teschke et al., 2012; Thomas and DeRobertis, 2013; Bikes Belong, 2012) but in the U.S., the cycle tracks are often rare, short, only 6 feet wide,(Bikes Belong, 2012) and separated from vehicles by plastic delineator posts and painted lines (National Association, 2011).

In the Netherlands, where cycle tracks are common, 27% of trips are by bicycle, 55% of bicyclists are female, and cycle tracks are wider and usually separated from vehicles by angled cobblestones or a concrete curb (C.R.O.W, 2006). The U.S. and Dutch cycle tracks do not feature trees between the cycle tracks and the road, and the American (National Association, 2011) and Dutch (C.R.O.W, 2006) bicycle facility guidelines do not detail preferred tree locations. Other amenities that also might encourage more people to bike include public bicycle rentals, but only about 18 U.S. cities have them (Buck, 2012; Shaheen et al., 2012); bicycle traffic signals (bicycles symbols over traffic lights) that might better guide bicyclists and drivers at intersections, but only 16 U.S. cities have them (Loew and Perez, 2012); and secure bicycle parking stations, but only about 16 public bike-parking stations exist in the U.S. (Bikestation, 2013).

The facilities in the U.S. and the Netherlands contrast dramatically with China where, following the new communist government coming to power in 1949 with its goal of increasing industrialization, cities built bicycle-mass-transit (BMT) systems. Cycle tracks up to 22 feet wide were created that had densely planted continuous landscaped islands up to 18 feet wide between the vehicles and bicyclists (Lusk, 2012). Though the percentages for bicycling in Beijing dropped from 62.6% to 17.9% between 1986 and 2010 (Zhao, 2013), the percentages for bicycling in Hangzhou, the capital of Zhejiang province and a premier bicycling city, dropped comparably less, from 60.8% to 33.5% between 1997 and 2007 (Shaheen et al., 2012) According to the 2010 census, Hangzhou has a population of about 8.7 million people, of whom nearly 20% (1.6 million) have completed at least a college education. The mean per capita yearly income in Hangzhou is higher than the average Chinese income, helping make Hangzhou one of the richest Chinese cities (Shaheen et al., 2011).

Hangzhou retains many of its original 15 foot wide cycle tracks that are separated from the street and moving vehicles by allées of mature trees in landscaped islands 7 feet wide. Hangzhou has also added cycle tracks and other bicycle provisions so that bicyclists are now separated from vehicles on 84% of its main and secondary roads (Shaheen et al., 2012). In 2008, Hangzhou officials set a target of building a low-carbon city, and as part of this initiative 2416 bicycle rental stations were installed with 60,600 rental bicycles in 2011 (Shaheen et al., 2011), resulting in the world's largest bike sharing program with 200,000 daily rental riders (Shi et al., 2011). The Hangzhou bicycle rental system includes kiosks that are near mass transit or 100 m apart (Meng and Xu, 2012), and some of the bicycles include a child seat. Residents can use their bus or citizen card to get a bike rental card and bike for free for the first hour (Company HMCfCIPHCG, 2012). If arriving by bus, the bus ticket can be used for 90 min of free bike rental riding (Information Office of Hangzhou Municipal People's Government, 2013). The rental bicycle is used by car owners because, as in some other Chinese cities, cars with certain license plates are not to be driven on specific days. For non-car owners, the added benefit is it is impossible to differentiate between a wealthy car owner and a non-car owner because the rental bicyclist could own a car but not be allowed to drive that day.

In addition to the regular stop signs and vehicle red/green traffic lights at intersections, Hangzhou has bicycle red/green traffic lights. These are sometimes accompanied by red and green directional turning arrows to indicate to bicyclists when they can turn. For bicycle parking, Hangzhou also offers covered and secure bicycle parking sheds or stations, in addition to outside racks and other alternatives such as inside homes or offices.

Though the bicycle literature has discussed cycle tracks, gender, rental bicycles, and bicycle parking, no study has been conducted in a city where historically almost all of the respondents know how to bicycle and all have exposure to superior bicycle infrastructure including bicycling environments with mature trees in landscaped islands between a wide cycle track and the road, highly engineered bicycle signals at intersections, and the world's largest bike rental system. We therefore conducted this research in Hangzhou to: (a) assess reasons the city's adult bicyclists did or did not bicycle; (b) compare gender differences for used and preferred bicycle routes, parking, signals, and private/public bicycles; (c) identify differences for these used and preferred bicycle facilities and amenities between: (1) bicyclists; (2) the whole study population (bicyclists and non-bicyclists) and (3) bicyclists who bicycled 3 or more days per week; (d) determine which variables, including age, gender, education, car ownership, Body Mass Index (BMI), and income, best predicted bicycling; and e. investigate the associations between owning a car, bicycling frequency, and BMI.

2. Methods

The methods are described under these categories: Study participants and data collection in Section 2.1; Questionnaire in Section 2.2; Measurements of the study environment in Section 2.3; and Statistical analysis in Section 2.4.

2.1. Study participants and data collection

The participants were adults who were reached through the middle school students in their family. The practice of a student taking a survey home to be completed by parents or another adult in the household is common in China, where teachers are highly respected and students and parents usually comply with their request. In 2012, 32 middle schools (students 14–15 years of age) in Hangzhou were provided with information about the study, objective, and research plan, and 12 schools replied they would like to be included for the study. Because some of these schools were in the same district, we selected 8 schools from 4 districts (2 schools from 1 district each). From these schools, 3–4 classes with approximately 150 students each were randomly chosen. Each student took a questionnaire to be filled out by an adult in their family, and the signed consent forms plus the completed survey were returned by the student. In total, 1200 surveys were distributed and 1150 returned, resulting in a return rate of 95.8%. Human Subjects approval for conducting this survey was received from the Research Ethics Committee at Zhejiang University.

2.2. Questionnaire

Our questionnaire was first written in English, translated to Chinese, and then back translated to English to verify its accuracy. Specific questions were asked using yes/no questions, such as can you ride a bicycle, or the categories of strongly agree, agree more or less, disagree, and strongly disagree, e.g., there is a high rate of bicycle theft. Bicyclists were asked to select from several possible answers, e.g., "How long do you ride each day?" They were also asked the percentages of use for: five bicycle environments (1. roads shared with vehicles; 2. shared use paths; 3. painted line bicycle-exclusive lane with parallel parked cars; 4. painted line separated bicycle-exclusive lane without parallel parked cars; and 5. cycle tracks); five bicycle parking options; four types of traffic signals/signs; and public/private bicycle, each totaling 100%. The bicycle parking facilities included: (1) Shed; (2) Storage room; (3) Room at home/office; (4) Areas beside the office or apartment buildings; and (5) Roadside. The whole study population was asked what, of all the same amenities, they preferred.

2.3. Measurements of the study environment

Within each of the 4 districts in the main urban area of Hangzhou (Xihu, Shangcheng, Xiacheng, and Gongshu), 3 main roads were chosen that had cycle tracks, totaling 12 cycle tracks to be measured. These 12 cycle tracks represent approximately 5–10% of the roads with cycle tracks in Hangzhou. Of these 12, nine had parallel landscaped islands between the cycle track and the road. We measured the widths of cycle tracks to determine their means, along with the widths of the continuous landscaped islands that separated these cycle tracks from the road, as well as the girth of the trees in these islands.

2.4. Statistical analysis

Demographic characteristics were determined and compared based on gender and mean percentages for reasons for bicycling and not bicycling among the 1150 adults. A two-tailed independent *t*-test was used to determine differences between men and women. Chi squared test was applied to determine the difference of percentage in different categories (education, income, car ownership, if they can bicycle, bikes owned, cycling frequency, times cycle each day, cycling speed, and bicycle type used). Two-tailed Paired *t*-test was applied to determine the difference between the facilities they currentl`y use and the ones they prefer. For the main analysis, we divided respondents into two groups that included bicyclists and the whole study population (bicyclists and non-bicyclists). We also compared what bicyclists, who bicycled 3 or more days per week, used and preferred resulting in three categories for comparison: (1) bicyclists; (2) the whole study population; and (3) those who bicycled >3 days/week. Multiple linear regression was used to study associations between frequency of bicycling and age, gender, education, income, BMI, and car ownership, using cycling frequency as dependent variable and others as independent variables. All statistical analyses were conducted using SPSS Windows 17.0 software.

3. Results

Based on the findings, the results have been categorized into: Study population in Section 3.1; Characteristics of the cycle tracks and landscape strips in Section 3.2; Reasons for bicycling/not bicycling in Section 3.3; Used/preferred routes, parking, signals and bike, by gender in Section 3.4; Used/preferred routes, parking, signals, and bike, including >3 days/wk bicyclists in Section 3.5; Car ownership and bicycling in Section 3.6.

3.1. Study population

The average age of the study participants was a mean of 41 for men and 39 for women and almost all could ride a bicycle (97.5% men, 95.5% women) (Table 1). Approximately half our sample had a monthly family income between ¥3001 and 10,000 and 41% earned a family monthly income $>$¥10,000. These family incomes would be high compared with individuals in all of China but these represent a range of middle income salaries for Hangzhou. Even though three-quarters of the participants owned a car (77.7% men, 72.2% women), only half indicated they did not ride a bicycle (47.1% men, 55.1% women). Most rode their own bicycle (69.1% men, 67.9% women) while one-third used rental bicycles (30.9% men, 31.7% women).

3.2. Characteristics of the cycle tracks and landscape strips

The mean width of the cycle tracks was 11.6 feet (3.55 m; SD 0.79) with some cycle tracks close to 15 feet (4.52 m) in width. The mean width of the continuous landscaped islands between the cycle tracks and the road that existed on 9 of the 12 measured cycle tracks was 3.3 feet (1.01 m; SD 0.60) with 7 feet (2.13 m) the maximum width. The trees in the landscaped islands had a mean girth (circumference) of 2.2 feet (0.66 m; SD 0.32) with a minimum girth of 4.68 in. (0.12 m) and a maximum girth of 3.6 feet (1.10 m). Thus, the maximum diameter of the trees was 1.15 feet (0.35 m). As the specific growth factors for trees within this street environment are not known, the largest trees could be between 41 and 103 years old, and thus well over 40 years old (Nix, 2014).

3.3. Reasons for bicycling/not bicycling

In reasons for bicycling or not bicycling, over half indicated that bicycling was enjoyable in Hangzhou because of the beautiful surrounding environment (52.7% strongly agreed/agreed) (Table 2). Some deemed the distance too far to the destination (53.5% strongly agreed/agreed) but hilliness was not a deterrent (7.1% strongly agreed/agreed). Not many indicated it was difficult find a place to park their bicycle (17.0% strongly agreed/agreed). About half did not view lighting as an issue (58.3% strongly disagreed/disagreed), did not perceive a problem with traffic (50.4% strongly disagreed/disagreed), and did not feel air pollution affected bicycling (45.0% strongly disagreed/disagreed).

Table 1
Socio-demographic characteristics of study sample (adults in Hangzhou, China) by gender.[a]

Variable		Men – Mean (n=516, 45%)	Women – Mean (n=634, 55%)
Age	Mean ± SD (years)	41.2 ± 4.48	39.0 ± 4.03**
Height	Mean ± SD (centimeters)	171.2+5.05	160.5+4.38**
Weight	Mean ± SD (kilograms)	69.9 ± 11.90	54.8 ± 7.12**
BMI	Mean ± SD (kg/m^2)	23.8 ± 3.55	21.2 ± 2.53**
	Variable	**Men – Mean %**	**Women – Mean %**
Education	Finished junior middle school or less	18.1	18.2
Education	Finished high school or junior college	35.5	41.1*
Education	Finished college or more	46.4	40.7
Monthly family income	< ¥3000	5.0	7.5
Monthly family income	¥3001 ~ ¥10,000	52.4	52.1
Monthly family income	> ¥10,000	42.5	40.4
Own a car?	Yes	77.7	72.2*
Can ride a bike?	Yes	97.5	95.5
How many bikes do you own?	0	31.0	33.5
How many bikes do you own?	1	52.1	55.0
How many bikes do you own?	≥ 2	16.9	11.4**
Cycling frequency	< 1 Day/week	17.0	14.7
Cycling frequency	1–2 Day/week	16.0	12.6
Cycling frequency	3–4 Day/week	10.1	8.5
Cycling frequency	5–6 Day/week	5.9	5.0
Cycling frequency	7 Day/week	3.8	4.2
Cycling frequency	Do not ride bike	47.1	55.1**
Time cycle each day	1–10 min	33.3	30.7
Time cycle each day	11–20 min	33.7	40.4
Time cycle each day	21–30 min	20.2	17.8
Time cycle each day	31–60 min	9.7	7.0
Time cycle each day	1–2 h	1.6	3.0
Time cycle each day	> 2 h	1.6	1.1
Cycling speed	Very slow	1.1	1.4
Cycling speed	Slow	11.4	16.7
Cycling speed	Medium speed	64.8	70.7
Cycling speed	Fast	20.1	10.1**
Cycling speed	Very fast	2.7	0.7
Bicycle usage	Private bike	69.1	67.9*
Bicycle usage	Public bike (rental)	30.9	31.7*

[a] *$P<$ .05; **$P<$ .01 (independent t-test for mean, Chi squared test for percentage).

Table 2
Reasons for bicycling or not bicycling in Hangzhou, China.

Reasons for bicycling or not bicycling	Strongly agree %	Agree %	More or less %	Disagree %	Strongly disagree %
Bicycling is enjoyable with beautiful surrounding environment	20.9	31.8	29.9	11.5	5.9
My destinations are too far away	22.9	30.6	18.4	20.5	7.7
It is always difficult to find a parking place for my bicycle	5.4	11.6	24.2	37.7	21.0
The road is very hilly, making it difficult for bicycling	2.8	4.3	13.8	42.5	36.4
No street lights and darkness during night or morning reduce my bicycling	5.1	11.7	22.9	40.0	18.3
There is so much traffic along the streets nearby, making it difficult or unpleasant for bicycling	7.7	17.2	24.4	34.3	16.1
Air pollution along the street nearby, making it difficult or unpleasant for bicycling	10.2	16.5	28.0	29.7	15.3
Too many cars on the road make it dangerous for bicycling. I am worried about being hit by a car	13.4	23.5	28.2	23.3	11.4
There is a high rate of bicycle theft in my neighborhood	12.3	24.1	29.8	23.9	9.8

3.4. Used/preferred routes, parking, signals and bike, by gender

Few male and female bicyclists bicycled on the road with the cars and the difference in gender for time spent bicycling in the road was statistically significant (14.7% men, 10.8% women) (P=0.028) (Table 3). In preference indications, few men and women in the whole study population preferred to use the road and the difference between men and women preferring to use the road was statistically significant with women preferring to use the road even less (5.3% men, 3.0% women) (P=0.000). Cycle tracks were the most frequently used facility (33.2% men, 35.2% women). Preference for bicycling on cycle tracks in the study population was almost double in both genders and the difference was statistically significant with women preferring to use cycle tracks even more than men (53.9% men, 60.2% women) (P=0.004).

Parking sheds were the most used (39.7% men, 42.1% women) and the most highly preferred by both genders (60.0% men, 62.2% women). Bicyclists used regular motor vehicle traffic signals (42.9% men, 45.9% women) but also, where available, followed bicycle signals (32.8% men, 34.4% women). The study population highly preferred to follow bicycle signals with a statistically significant difference with women preferring bicycle signals more (63.7% men, 69.1% women) (P=0.009). Though high percentages of the bicyclists used private

Table 3
Currently used versus preferred bicycle routes, parking, intersection signals and bike type, by gender.[a]

Percentage riding on the different types of routes	% Time spent riding on a route Men	% Time spent riding on a route Women	Sig (*t*-test)	% Preference for a route Men	% Preference for a route Women	Sig (*t*-test)
Road (bicyclists share with vehicle drivers)	14.7	10.8	**0.028**	5.3	3.0	**0.000**
Shared-use path (bicyclists share with pedestrians)	21.0	22.1	0.622	11.4	8.9	**0.024**
Painted line separated bicycle-exclusive lane (with parallel parked cars beside lane)	17.4	15.6	0.357	15.6	11.3	**0.001**
Painted line separated bicycle-exclusive lane (without parallel parked cars beside lane)	15.3	18.3	0.137	15.2	18.2	**0.018**
Barrier-separated bicycle-exclusive cycle track	33.2	35.2%	0.511	53.9	60.2	**0.004**
Percentage for bicycle parking	**% Use for bicycle parking Men**	**% Use for bicycle parking Women**	Sig (*t*-test)	**% Preference for bicycle parking Men**	**% Preference for bicycle parking Women**	**Sig (*t*-test)**
Bicycle parking shed (station)	39.7	42.1	0.480	60.0	62.2	0.221
Storage room (garage)	17.2	21.1	0.150	12.6	14.5	0.163
Room at home or in office	21.0	19.4	0.573	9.6	7.6	0.071
Areas beside the office or apartment buildings	15.3	12.9	0.226	12.3	10.3	0.072
Roadside parking	6.6	5.6	0.351	6.7	5.4	0.106
Percentage for intersection signals	**% Have intersection signal Men**	**% Have intersection signal Women**	Sig (*t*-test)	**% Preference for intersection signal Men**	**% Preference for intersection signal Women**	**Sig (*t*-test)**
No traffic signals	9.3	6.5	**0.045**	3.7	2.1	0.014
Only traffic signs	15.4	13.9	0.454	7.1	5.4	**0.032**
Traffic lights for motor vehicles	42.9	45.9	0.319	25.7	23.5	0.190
Traffic signals for bicycles (with countdown numbers)	32.8	34.4	0.594	63.7	69.1	**0.009**
Percentage for private versus public bike	**% Use bike Men**	**% Use bike Women**		**% Prefer bike Men**	**% Prefer bike Women**	
Private bicycle	69.1	67.9	0.721	49.4	46.4	0.140
Public bicycle	30.9	31.7	0.812	50.1	53.2	0.131

[a] Bicycle parking includes: (1) Bicycle parking shed (station) – A covered and moderately secure large area to park a bicycle, typically a simple shed without a fence or an area in the basement or ground floor of a large building; (2) Storage room (garage) – A room where cars are parked; (3) Room at home/office – A room where the person lives or a room in their office where a few bikes could be parked.; (4) Areas beside the office or apartment buildings – Outdoor areas near the buildings where a bicycle could be parked; and (5) Roadside parking – Parking on the sidewalk.

bicycles (69.1% men, 67.9% women), the whole study population preferred to use the rental bicycle more (50.1% men, 53.2% women) compared with using their own bicycle (49.4% men, 46.4% women), and the differences were not statistically significant between men and women.

3.5. *Used/preferred routes, parking, signals, and bike, including ≥ 3 day/wk bicyclists*

For use and preference of cycle tracks, bicyclists used cycle tracks (34.4%) and the study population (bicyclists and non-bicyclists) doubly preferred to use cycle tracks (58.6%) with a statistically significant difference ($P=0.000$) (Table 4). The difference between use of bicycle parking sheds by bicyclists (39.8%) and preference of parking sheds by all study participants (62.7%) was also statistically significant ($P=0.000$). Bicycle signals were used by bicyclists (33.8%) and highly preferred by the study population (71.4%) with again a statistically significant difference ($P=0.000$).

For comparison to all bicyclists and the study population (bicyclists and non-bicyclists), analysis was also conducted of participants who bicycled for ≥ 3 days per week. Similar to the bicyclists and the whole study population, the bicyclists who bicycled >3 days per week used and preferred the same bicycle features. Bicycle signals were the most used and preferred feature (33.8% used by bicyclists versus71.4% preferred by population) which is similar when compared with ≥ 3 times per week bicyclists (39.5% used versus 71.9% preferred). The greatest mean differences for used versus preferred bicycle features were, in order, bicycle traffic signals, cycle tracks, bicycle parking sheds, and public bicycles.

3.6. *Car ownership and bicycling*

The results of multiple linear regression showed that age, gender, education, BMI, and family income were not statistically significant in association with bicycling frequency but car ownership was (Table 5). Individuals who did not own a car were likely to bicycle 0.58 more days per week (95% CI: 0.14–0.99) compared with individuals who owned a car. When comparing frequency of cycling, significant differences were found between participants who did and did not own a car ($P=0.000$) (Fig. 1). In individuals who owned a car, 56.3% did not bicycle, 28.9% bicycled <3 days/week, and 14.9% bicycled ≥ 3 days/week, totaling 43.8% who owned a car and bicycled each week. Of non-car owners, a total of 62.2% bicycled each week. Percentages for overweight/obesity (BMI24) were significantly different between individuals who owned a car (28.8%) and did not own a car (21.0%) ($P=0.012$).

Table 4
Paired comparisons for used/preferred – bicyclists, whole population, and ≥ 3 day/week bicyclists.

	Bicyclst mean % use	Whole popul mean % prefd	Mean diff %	Sig (*t*-test)	≥ 3wk bike mean % use	≥ 3 wk bike mean % prefd	Mean diff %	Sig (*t*-test)
Frequented versus preferred bicycle route								
Road shared with vehicles	12.6	3.6	9.0	**0.000**	12.2	4.4	7.8	**0.000**
Shared-use path (bicyclists with pedestrians)	21.5	10.1	11.5	**0.000**	23.4	12.0	11.4	**0.000**
Painted line separated bicycle-exclusive lane with parallel parked cars	16.5	12.3	4.2	**0.000**	17.3	12.1	5.2	**0.002**
Painted line separated bicycle-exclusive lane without parallel parked cars	16.9	17.3	−0.4	0.694	16.9	18.9	−2.0	**0.287**
Barrier-separated bicycle-exclusive cycle track	34.4	58.6	−24.2	**0.000**	32.4	55.1	−22.7	**0.000**
Frequented bicycle parking versus preferred bicycle parking								
Designated bicycle parking shed (station)	39.8	62.7	−22.9	**0.000**	40.7	61.8	−21.1	**0.000**
Storage room (garage)	19.3	13.6	5.7	**0.000**	18.9	13.2	5.7	**0.002**
Room at home or in office	20.7	9.5	11.1	**0.000**	19.4	12.2	7.2	**0.000**
Areas beside office or apartment buildings	14.6	9.7	4.9	**0.000**	16.3	9.9	6.4	**0.000**
Roadside parking	6.2	4.9	1.3	**0.043**	5.7	4.2	1.5	**0.036**
Frequented intersection signals versus preferred intersection signals								
Intersections with no traffic lights	7.7	2.6	5.2	**0.000**	7.5 vs	2.2	5.3	**0.000**
Intersections with only traffic signs	14.3	5.9	8.4	**0.000**	12.1	5.9	6.2	**0.000**
Intersections with traffic lights for motor vehicles	45.0	20.3	24.7	**0.000**	41.5	20.4	21.1	**0.000**
Intersections with lights for bicycles (with countdown signals)	33.8	71.4	−37.6	**0.000**	39.5	71.9	−32.4	**0.000**
Frequented use of private bicycle or public bicycle versus preferred use of private bicycle or public bicycle								
Private bicycle	68.4	49.9	18.4	**0.000**	70.6	53.2	17.4	**0.000**
Public bicycle (rental)	31.5	49.6	−18.1	**0.000**	29.1	46.1	−17.0	**0.000**

Table 5
Multiple linear regression using different variables to predict bicycle frequency.

	β	95% confidence interval	*P*	Model R^2
Age	0.00	−0.04 to 0.04	0.96	0.03
Gender	0.31	−0.12 to 0.75	0.16	
Education	−0.04	−0.20 to 0.12	0.61	
Car ownership	0.58	0.14 to 0.99	0.01	
BMI	0.03	−0.05 to 0.10	0.48	
Family income	0.00	−0.00 to 0.01	0.33	

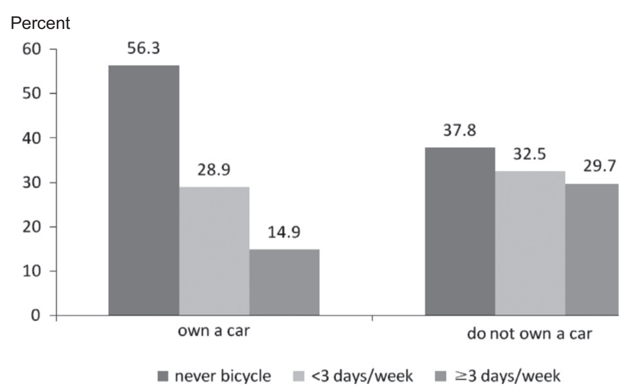

Fig. 1. Bicycling percentages for car owners and those who do not own a car.

4. Discussion

Hangzhou has bicycle traffic signals, bicycle parking sheds, the largest bicycle rental scheme in the world, and cycle tracks up to 15 feet wide (4.52 m) with continuous landscaped islands up to 7 feet (2.13 m) wide between the bicyclists and moving vehicles with trees in some of the islands well over 40 years old. Almost all of the Hangzhou respondents knew how to bicycle and only about half of the men and women did not bicycle. This population might have a higher income/education compared with others in China but the participant's income was average for Hangzhou. Three quarters of the respondents owned a car and, of these car owners, over 40% percent still bicycled each week and of these bicyclists, 15% bicycled more than 3 days per week. Of the non-car owners, over 60% bicycled each week. Bicycling can control weight and thus car owners were more likely to have a BMI > 24 compared with non-car owners. Bicyclists preferred the bicycle signals more than regular traffic signals, cycle tracks more than roads, bicycle parking sheds more than curb side bike parking, and rental bicycles more than private bikes though they used their private bike in higher numbers. Over half the respondents thought bicycling in Hangzhou was enjoyable due to the beautiful surrounding environment.

While it may be difficult for all cities in the U.S., and Europe to duplicate the wide cycle tracks and continuous landscape islands of Hangzhou, if a street is to be completely rebuilt, the cycle tracks' treed landscape island could be an alternative to having individual tree pits in the sidewalk that can make compliance with accessibility requirements in the Americans with Disability Act (ADA) difficult. Right-of-way could be taken from the vehicles or parking removed to create wider cycle tracks and the landscape island. The bicycle signals and rental bicycles exist in some European and American cities and more could be installed. Bicycle parking could be considerably improved with indoor storage sheds as in Hangzhou or even bicycle parking inside homes, offices, and schools. Based on the findings, the discussion will offer more specifics about: (A) Bicycle signals; (B) Wide cycle tracks and beautifying with landscaping; (C) Bicycle parking shed; (D) Rental bicycle; and (E) Car ownership, obesity, and bicycle environments.

4.1. Bicycle signals

In Hangzhou, bicyclists had to rely primarily on vehicular traffic signals (42.9 men, 45.9 women) but both bicyclists and non-bicyclists preferred the bicycle signals with the difference being statistically significant (63.7% men, 69.1% women) ($P=0.009$). Women in Hangzhou may have preferred the bicycle signal because women can be risk averse (Harris et al., 2006; Taylor et al., 2000), be slower getting through lights (Wheeler et al., 2010), and wear clothing challenging for bicycling that may impede their speed (Cycle and Style, 2012). In the U.S., bicycle guidelines have been based on what was comfortable to the male bicyclists who bicycled in the road with the accompanying assumption that what was comfortable to men would be comfortable to women (Lusk et al., 2013). Policies for complete streets have been adopted in many U.S. states based on the principle that roads should serve all drivers, walkers, transit users, and bicyclists, no matter their age, gender, or ability. Even with this principle, the Complete Street facilities for bicyclists are often painted bike lanes and regular traffic signals, facilities that can be less comfortable to women (Emond et al., 2009; Emond, 2009).

Even though more women in the whole study population (bicyclists/non-bicyclists) preferred the bicycle signal, bicyclists who bicycled ≥ 3 days per week were comprised of 19.8% men and 17.9% women. Of these ≥ 3 days per week bicyclists, 39.5% used the bicycle signal but 71.9% preferred the bicycle signal. What women prefer may also be preferred by men but perhaps all male and female bicyclists have not been given the wide selection of alternatives from which to choose their preferred option.

In Hangzhou, the bicycle signal is sometimes accompanied with red/green turning arrows and some Chinese signals include the red/green bicycle plus a red/green countdown number in the middle, giving bicyclists and drivers additional information. The Chinese bicycle signal is most often over the intersection while the Dutch have a bicycle countdown signal at eye level by the sidewalk. Though the Dutch bicycle signal is deemed less safe for crossing an intersection compared to a Dutch roundabout (cycle track on outer perimeter of the car roundabout) or a grade separation (bicyclists travel through a tunnel or on a bridge under or over the road), the bicycle signal can improve safety (C.R.O.W, 2006). The basic red/yellow/green bicycle signal has received interim U.S. approval (U.S. Department of Transportation, 2014) yet this approval only allows the signal to be used when the phase is for bicyclists only. The approved signal also does not include the middle countdown number as in China or the Netherlands.

4.2. Wide cycle tracks and beautifying with landscaping

Over half of the participants indicated that bicycling in Hangzhou was enjoyable because of the beautiful surroundings. Half did not perceive a problem with traffic or feel pollution made it difficult or unpleasant for biking. The cycle tracks being built in the U.S. are typically 6 feet wide and have plastic delineator posts, low concrete islands, paint, or curbs to separate the bicyclists from the moving vehicles. If trees are near the cycle track, they typically are in the sidewalk and not in a continuous landscaped island between the vehicles and bicyclists (National Association, 2011). One exception in the U.S. is the Indianapolis Cultural Trail that includes wide planted bioswales with low plantings between the path and the road.

Preference for cycle tracks is corroborated in other studies in China, though bicyclists do not prefer extremely crowded ones (Li et al., 2012). In Hangzhou, the cycle tracks are even wide enough for bicyclists to bicycle side-by-side and talk. While the Dutch have wide cycle tracks, their cycle tracks are not always as wide as those in China and do not have similar landscaped islands separating bicyclists from the car traffic (C.R.O.W, 2006). Dutch cycle tracks are often wide enough to at least allow side-by-side bicycling (C.R.O.W, 2006; Lehner-Lierz, 2006) in part because parents prefer to ride beside their children, not in front or behind them (Rietveld and Daniel, 2004). Providing wider cycle tracks provides the opportunity for social interaction because bicyclists can bike and talk, just as individuals can talk side-by-side on a sidewalk, in a car, or riding mass transit.

4.3. Bicycle parking shed

Five varieties of parking options exist in Hangzhou and respondents preferred the bicycle parking shed (station) (60.0% men/62.2% women). Studies in Australia have identified the preference of women to have secure bicycle parking stations, perhaps due to women's greater risk aversion (Garrard, 2003; Garrard et al., 2006). In a study in Edmonton, Canada, having secure bicycle parking was even more important than having showers (Hunt and Abraham, 2007). A study in England suggested that, compared with a base work-trip share of 5.8%, bicycling would increase to 6.3% with outdoor parking and 6.6% with indoor parking (Wardman et al., 2007). From a study of current and potential bicyclists in Vancouver, beautiful scenery (0.70) and a flat route (0.61) predicted bicycling but having indoor bicycle parking (0.49) also predicted bicycling with indoor parking being ranked higher than outdoor racks (0.42) (Winters et al., 2011).

In North America, some local governments, including in San Francisco, Portland, Minneapolis, Chicago, New York City, Toronto and Vancouver, are instituting policies specifying that tall residential buildings have ratios of dwelling units/bicycle parking spaces in the garage/storage area just as ratios exist for dwelling units/car parking spaces (Pucher et al., 2011). The Dutch have a policy that specifies new individual homes must have 5 m^2 of protected-against-the-weather secure bicycle parking, as in a separate shed or an addition to the house. Cities in the U.S. do not have policies about private homes requiring minimal bicycle parking but, as a start, some apartment buildings are being designed to accommodate bicycle parking inside the individual apartment unit. Each apartment in a new Boston, Massachusetts building designed by ADD, Inc. with 300 square foot micro-apartments will have a recess to hang a bicycle near the front door. In contrast, some of the bicyclists in Hangzhou parked their bicycle in a room at home or in the office (15.3% men, 12.9% women) but the bicyclists/non-bicyclists did not prefer parking inside the home or office, with women preferring this option even less (9.6% men, 7.6% women).

4.4. Rental bicycle

While 69% of the respondents owned at least one bicycle and a similar percentage used their own bicycle for trips, less than half preferred to use their own bicycle. About one-third of the bicyclists used a rental bicycle and over half of men and women preferred using them. About a third of those who bicycled ≥ 3 days per week used a rental bicycle and almost half preferred using them. Of the respondents to a study about the bike rental system in Hangzhou, 22% of the bike rental members owned cars and, of these car owners, 78% indicated that they rode the rental bicycle rather than drive their vehicle (Shaheen et al., 2011).

The rental bicycle can be more convenient than having to find car parking, less worrisome than fearing an E-bike (electric bicycle with a battery) will be stolen, and less bothersome than having to remove a private bike from its parking space and find parking again at the destination/s. Hangzhou has also done a good job in marketing the rental bicycle compared with the less successful rental bicycle system in Beijing (Wanli, 2010). The widely adopted use of Hangzhou's rental bicycle suggests it does not have the “loser cruiser” association as buses once did in the U.S. (Lusk, 2001).

4.5. Car ownership, obesity, and bicycle environments

For this study population, 52% earned a monthly income between ¥3001 and 10,000 and 41% a monthly income of $>$¥10,000, indicating that the respondendts were higher income for China but middle income for Hangzhou. The calculated mean monthly family income in Hangzhou is ¥9065, suggesting little difference between the study population and other Hangzhou residents in income. The participants were on average 40 years old and would, therefore, have had more education compared with older residents in Hangzhou.

Seventy five percent of the study population in Hangzhou owned a car, and car ownership has been shown in multiple studies to be associated with overweight/obesity (Lindstrom, 2008; Parra et al., 2009), including studies in China (Bell et al., 2002). Though car ownership in this Hangzhou study population best predicted bicycling less, about 44% of the car owners bicycled each week and the mean Body Mass Index (BMI) of the population was within a healthy weight range for men (23.8 kg/m^2, SD 3.55) and for women (21.2 kg/m^2, SD 2.53). In this population, overweight/obesity was higher for the participants who owned a car (28.8%) compared with participants who did not own a car (21.0%) but both percentages are lower compared to the 38.5% for populations in all of China who are overweight/obese (males 45.0%, females 32.0%) (World Health Organization, 2011).

With their income, their education, and three-quarters of the study population owning a car, almost everyone in the study population indicated they could ride a bicycle and only half indicated they did not bicycle. Hangzhou is a wealthy community and residents may have self-selected to live in this city. Even so, the city’s wide landscaped cycle tracks, bicycle traffic signals, bicycle parking sheds, and public bicycles may help the population maintain a healthy weight.

5. Limitations and strengths

This study has limitations in that it involved participants recruited through middle school, and thus the age of most participants ranged from 30 to 50 years old. As Hangzhou is the capital of one of the richest provinces in China, the Hangzhou participant would not be representative of all of the Chinese population. The results may also not be fully generalizable to populations worldwide because it is hard to control for the historic bicycling culture in Hangzhou. It is not known if respondents in China, especially to a survey conducted through their child's school, would respond as negatively to environmental factors, such as pollution and car traffic, as individuals in other countries. The policy of not allowing car drivers to drive their cars on certain days may have increased the number of bicyclists, especially those using the rental bicycle.

The strength of this study is that it was conducted in Hangzhou, China, a city with sophisticated bicycle facilities. Unlike surveys conducted in the U.S., the questions included all aspects of bicycle infrastructure, almost all of the respondents could ride a bicycle, and the respondents had exposure to superior bicycle options. Out of 1200 surveys, the sample included 1150 participants, a 98.5% response rate, with 45% men and 55% women. As half of the study population did not bicycle, they did not answer the questions about their use of the bicycle facilities, but the entire study population did answer questions about preferences. The mixing of bicyclists who bicycled for different times each week may be a serious confounding factor because the preferences expressed by the non-bicyclists may well have been systematically different from the preferences of bicyclists who bicycled more than 3 days per week. Therefore, additional analysis was conducted to compare uses and preferences of bicyclists who bicycled ≥ 3 days per week to all bicyclists and bicyclists/non-bicyclists in the paired comparisons. The uses and preferences were similar. It is understood, though, that the responses from all bicyclists still contained the responses from bicyclists who bicycled ≥ 3 days per week but the sample size was 200 for bicyclists who bicycled ≥ 3 days per week.

6. Conclusions

Instead of having to travel to another country to try the most innovative bicycle facilities, cities could install these innovations on at least one street for local residents to try. These bicycle facilities have been tested extensively in the other countries so the experiments would not be as risky as a new invention. Cities might build a wide cycle track with a continuous landscape island between the cycle track and the road with an allée of trees or install a bicycle signal with turning arrows and a countdown number in the middle. Developers could install superior bicycle parking inside their buildings. Driving restrictions based on license plate numbers might be tested for a month to determine if use of rental bicycles increases. Finally, the BMI of city residents could be measured before and after installation of bike innovations as an alternative to general weight loss goals for a city.

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