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Mortality in Italian veterans deployed in Bosnia–Herzegovina and Kosovo

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Background and Aims: The possible increase of cancer risk in military personnel deployed in Balkans during and after the 1992–1999 wars, mainly related to the depleted uranium, was addressed by several studies on European veterans of those war theatres. This article reports on the results of the mortality study on the Italian cohort of Bosnia and Kosovo veterans (Balkan cohort). **Methods:** Mortality rates for the Balkan cohort (71 144 persons) were compared with those of the Italian general population as well as to those of a comparable and unselected control cohort of not deployed military personnel (114 269 persons). Ascertainment of vital status during the period 1995–2008 of all the persons in the two cohorts has been carried out through deterministic record linkage with the national death records database, from information provided by the respective Armed Force General Staff, and through the civil registry offices of the veterans' residence or birth municipalities. **Results:** The Balkan cohort experienced a mortality rates lower than both the general population (SMR = 0.56; 95% CI 0.51–0.62) and the control group (SMR = 0.88; 95% CI 0.79–0.97). Cancer mortality in the deployed cohort group was half of that from the general population mortality rates (SMR = 0.50; 95% CI 0.40–0.62) and slightly lower if compared with the control group cancer mortality rates (SMR = 0.95; 95% CI 0.77–1.18). **Conclusion:** Balkan veteran cohort did not show any increase in general mortality or in cancer mortality.

Introduction

The presence of an increased cancer risk in military personnel deployed in Balkans during and after the 1992–1999 wars has been widely debated, mainly related to the depleted uranium (DU) enforced projectiles used on the battlefields. There is a general consensus that inhalation of impact aerosol and dust in target areas represents the most significant route of exposure.[1] The hazard is attributable to either the chemical toxicity of the metal and the internal exposure to alpha and beta radioactivity in body tissues.[2,3] Lung cancers, leukaemias and lymphomas are the cancer types expected to be most likely associated with this kind of exposure.[4]

As a consequence of the public concern, specific studies to evaluate an excess cancer risk in military personnel deployed in war theatres during the 1990s and 2000s have been carried out, first on US and UK veterans of the Gulf war,[5–14] and then on UK, Swedish, Danish, Canadian, Italian, Dutch and Norwegian peace-keeping soldiers deployed in the Balkans region.[14–19] Italian Armed Forces have been massively involved since the year 1995 in peace restoring and peace keeping operations in Bosnia and Kosovo. A committee appointed by the Italian Ministry of Defence reported[20] a significant excess of Hodgkin Lymphoma cases diagnosed in the period 1996–2001, and no increased risk for other cancers.

The longitudinal Bosnia Kosovo (BK) Study has been started in 2005, through a collaboration between the Italian General Directorate of Military Health, the Italian Ministry of Health and the National Institute of Health,[21] to describe the health profile of the Italian veterans cohort deployed in Bosnia and Kosovo (Balkan

Table 1 Demographic variables and army distribution in the deployed and non-deployed cohorts

Cohort	Deployed		Non-deployed	
	Persons	%	Persons	%
Sex				
Men	70 806	99.5	114 267	99.9
Women	338	0.5	2	0.1
Age at 1st mission				
<20	6990	9.8	6862	6.0
20–29	42 586	59.9	39 551	34.6
30–39	14 445	20.3	50 904	44.5
40–49	6228	8.8	14 032	12.3
50–59	878	1.2	2880	2.5
60–69	6	0.0	32	0.0
70–79	0	–	8	0.0
n.s.	11	0.0	0	–
Area of birth				
North	7943	11.2	21 112	18.5
Centre	10 738	15.1	23 722	20.8
South	45 505	64.0	66 103	57.8
Foreign	2246	3.2	3330	2.9
n.s.	4712	6.6	0	–
Force				
Army	51 779	72.8	–	–
Air	6547	9.2	–	–
Navy	6543	9.2	–	–
Carabinieri	6275	8.8	114 269	100.0
War theatre				
Bosnia	12 796	17.99		
Kosovo	30 559	42.95		
Bosnia & Kosovo	13 474	18.94		
Other Balkans (Albania, Croatia, Macedonia, Navy personnel board on ships anchored in Balkan harbours)	14 315	20.12		

Table 2 Results of the linkage validation study through direct inquiry to the municipality registers

		3 Cohort 1995–1998	4 Cohort 1999–2008	5 ISTAT	6 Total
Cases sent	TN	711	3053	15 003	18 767
Cases without reply	NR	27	110	772	909
Cases with reply	N	684	2943	14 231	17 858
Cases linked	A	569	2847	13 654	17 070
Cases not linked	b = N – a	115	96	577	788
Cases moved	c	199	324	81	604
Eligible to check vital status	d = a – c	370	2523	13 573	16 466
Discordance in vital status	e	–	98	43	
Correction coefficient		0.235[a]	0.111[b]		

a: = 1 – (1 – b3/N3)∗(1 – b5/N5)∗(1 – e4/d4)∗(1 – e5/d5).
b: = 1 – (1 – b4/N4)∗(1 – b5/N5)∗(1 – e4/d4)∗(1 – e5/d5).

cohort) during the period 1995–2004. This article reports on the results of the BK Study obtained by linking the Balkan cohort database with the Italian National mortality database at individual level.

Methods

Study cohorts

The study cohort (hereafter indicated as Balkan cohort) consists in all the subjects enrolled in Italian armed forces who participated in at least one peacekeeping mission in one of the Balkan theatres (Bosnia, Kosovo, Croatia, Albania and Macedonia) since January 1995 through December 2004. Individual data were provided by the General Staffs of all the involved forces (Army, Navy, Air Force) in the period 1995–2004 and included: name, gender, date of birth, municipality of birth, individual fiscal code, municipality of residence, military rank, army and detachment of service, and areas, tasks and dates of deployments of all the missions carried out. All the data were carefully checked by removing duplicated records, assure consistency across different data fields of the same records, retrieving missing information. Data about tasks done during mission were largely incomplete and were not considered in the analysis. The control cohort (hereafter indicated as the 'Carabinieri' cohort) included all the military personnel of Carabinieri Army, a corp with tasks of military police, who were in service on 1st January 1999. Carabinieri are enrolled with the same selection criteria as soldiers of the other armies and for the great majority are not deployed outside the national territory. For them, the same demographic data available for the Balkans cohort were collected. Both cohorts were followed up for vital status until the end of the year 2008.

The size and the main characteristics of the enrolled cohorts are shown in table 1. The Balkan cohort consists of 71 144 persons, the great majority (99.5%) men. Approximately 60% of them were aged 20–29 at the time of their first mission in the area, about 20% were aged 30–39 and about 10% were under 20 and 50 or more years old. The mean age at entering the cohort was 27 years (range 17–62, SD = 8). The control cohort included 114 269 persons, all men except for two women. Only 35% of controls were aged 20–29, while the most frequent age class was the 30–39, accounting for 45% of the group. About 15% were aged 40 or more. The mean age of the control cohort was 32 (range 16–79). The majority of subjects in both cohorts were born in southern Italian regions. The northern regions, that are the most populous Italian area, are the least represented. A small, but not negligible proportion (3%) was born overseas. Finally, 73% of the deployed in the Balkans belonged to the land Army, while each of the other three Corps accounted for <10%. Almost 43% of the members of the Balkan cohort participated to actions only in Kosovo, about 18% exclusively in Bosnia and 19% in both area. The remaining 20% were employed exclusively in other areas (Croatia, Macedonia, Albania and on board of Navy ships anchored in harbours of the Balkan area).

Life status ascertainment

Ascertainment of vital status during the period 1999–2008 of all the persons in the Balkan and in the control cohorts has been carried out through deterministic record linkag[22–24] with the death records database, provided by the Italian National Institute of Statistics (ISTAT) and by the Statistical Offices of the autonomous provinces of Trento and Bolzano. Linkage keys were name, surname, date of birth or when these data were either not available or not complete, fiscal code. Alternative approaches on vital status information were used for subjects deployed in the years 1995–1998. First, we assumed participation to any mission from 1st January 1999 as an evidence of being alive at this date. Out of the 2463 persons with no subsequent mission registered in the database, 1666 subjects resulted as still in service or discharged after the year 1998 on the basis of information provided by the respective Armed Force General Staff. Among the remaining 797 subjects for which no information on their life status after 1998 was available, 86 were discarded because of missing information on both place of birth and place of residence. For the other 711 subjects, active search of vital status was carried out through the civil registry offices of their residence or birth municipalities. A total of 454 different municipalities were contacted for this purpose, with a final 98% accomplishment rate.

For all the identified deaths, causes were taken from the ISTAT records. Complete death certificated, coded by local experts usually

Table 3 Observed deaths for all causes and for cancer in the deployed cohorts and corresponding number of deaths expected from general population and from control cohort, by calendar year with related SMR and SMR corrected by probability of linkage mismatch

Year	All deaths			Cancer deaths			Person years
	Observed (Balkan cohort)	Expected (general population)	Expected (control cohort)	Observed (Balkan cohort)	Expected (general population)	Expected (control cohort)	
1995	1	0	1	0	0	0	465
1996	0	3	6	0	0	0	2498
1997	2	8	9	0	1	0	6708
1998	2	11	12	0	2	0	10 469
1999	13	16	16	0	2	1	15 195
2000	19	29	26	6	5	3	28 196
2001	41	43	27	2	8	3	41 810
2002	38	56	33	1	11	6	52 019
2003	36	66	45	7	14	7	60 877
2004	53	76	47	11	17	5	66 745
2005	42	78	43	7	18	7	71 330
2006	39	82	52	10	21	8	70 231
2007	49	85	43	17	23	19	70 923
2008	52	133	79	19	38	26	104 207
Total	387	686	440	80	160	84	601 672
SMR Obs/Exp [CI]		0.56 [0.51–0.62]	0.88 [0.79–0.97]		0.50 [0.40–0.62]	0.95 [0.77–1.18]	
Corrected SMR [CI]		0.62 [0.24–1.61]	0.87 [0.34–2.28]		0.56 [0.45–0.69]	0.95 [0.77–1.17]	

Table 4 Observed cancer deaths in the deployed cohorts and corresponding number of deaths expected from general population and from control cohort, by cancer type with related SMR and SMR corrected by probability of linkage mismatch

	Balkan cohort	General population			Control cohort		
	Observed	Expected	SMR	Corrected SMR	Expected	SMR	Corrected SMR
Lung cancer	9	29	0.31 [0.16–0.59]	0.34 [0.18–0.63]	10	0.90 [0.47–1.71]	0.90 [0.48–1.67]
Testicular cancer	1	0	-	-	0	-	-
Hodgkin's lymphoma	1	1	1.00	1.11	0	-	-
Non-Hodgkin lymphoma	3	9	0.33 [0.11–1.03]	0.37 [0.13–1.09]	4	0.75 [0.24–2.33]	0.69 [0.23–2.03]
Leukaemias	7	9	0.78 [0.37–1.64]	0.86 [0.43–1.73]	5	1.40 [0.67–2.96]	1.24 [0.61–2.5]
All haematological malignancies	13	24	0.54 [0.31–0.93]	0.60 [0.36–1.00]	9	1.44 [0.81–2.43]	1.21 [0.72–2.03]
All cancers	80	160	0.50 [0.40–0.62]	0.56 [0.45–0.69]	84	0.95 [0.77–1.18]	0.95 [0.77–1.17]

trained by central ISTAT personnel, were directly requested and retrieved for that period from the municipality of residence of the dead subjects and/or to the Defence Epidemiological Observatory. The proportion of deaths attributed to cancer, the most relevant issue in coding, was similar in the period 2004–2005 and in the other years of follow-up.

Linkage validation

A validation study of the record linkage process has been performed when 454 municipalities were contacted to complete the vital status follow-up of the Balkan cohort during the period 1995–1998. In fact, the same offices were requested to provide data for an additional number of persons (up to 10 per each office) with positive record linkage results and known vital status or date of death in the period 1999–2008. Records at municipalities' registries are known to be accurate and were considered here as the gold standard source. For municipalities having <10 veterans with known vital status to investigate, data for all the resident persons belonging to the Balkan cohort were requested. In addition, information was also requested for up to six resident civilians dead between age 20 and 50 in 1999–2008, not related with the considered cohorts and selected randomly from the ISTAT death records. In conclusion, information for a total of 18 767 persons was asked for validation purposes: 711 with unknown vital status and 3053 with supposed known vital status, plus 15 003 supposed to be dead. The possible bias in death ascertainment among the persons belonging to the study and to the control cohorts was estimated, following a conservative approach, as shown in table 2. Specifically, the probability of linkage mismatch was estimated as the proportion of subjects not found in the cohort (b/N in col. 3), plus the proportion of cases not found in the ISTAT file (b/N in col. 5), plus the proportion of cases found, but with wrong vital status data (e/d in cols. 4 and 5).

Statistical analysis

The number of observed deaths in the Balkan and control cohorts was compared, through age-standardized mortality ratios (SMR), to the corresponding number of expected deaths, calculated from the national mortality rates matched by age (10-years age groups: <20, 20–29, . . . , 70–79), calendar year, gender and area of birth (four macro-areas according to the ISTAT classification: North, Centre, South and Islands). Area of birth has been used as a *proxy* of the residence area. In addition, the number of deaths in the Balkan cohort was also directly compared with that expected from mortality rates in the control cohort, matched by the same age-group and geographic area, and assuming age specific mortality in 1995–1998 to be equal to the one observed in 1999. Person-time at risk was accumulated from the entry in the study (start of the first mission for the Balkan cohort and 1st January 1999 for the control cohort) until death, emigration or end of follow-up. The SMR were also corrected by the estimated probability of linkage mismatch to check the consistency of results in presence of linkage errors.

Results

The results of the linkage validation are shown in table 2. Only 11 out of 454 municipalities did not reply, for a total of 909 subjects (4.8%). Of the remaining 17 858 subjects, 788 (4.4%) were not found in their registries supposedly due to errors in the linkage keys, either in our cohorts databases or in the ISTAT mortality files. The proportion of failures was lower for subjects entered in the Balkan cohort in 1999–2008 (3.3%) and from ISTAT files (4.1%), and higher (16.8%) for the cohort 1995–1998 subjects. Of the 17 070 subjects successfully found by the municipalities registries, 604 had moved their residence and for the remaining 16 466 subjects we obtained an updated vital status. Forty-three cases deriving from the ISTAT mortality files resulted alive (0.3%) and we again assumed this as due to errors in the mortality files. Finally, a probability of 23.5% (95% CI 20.3–26.7) of missing actually occurred deaths was estimated for the years 1995–1998, and of 11.1% (95% CI 10.0–12.1) for the years 1999–2008.

The number of observed deaths in the Balkan cohort are presented by follow-up period in table 3, compared with the number of deaths expected according to mortality rates of the general population and of the control cohort. With the exception of a single death in 1995, the Balkan group experienced mortality rates always lower than the general population (SMR = 0.56; 95% CI 0.51–0.62) and, with the exception of 4 years (2001, 2002, 2004 and 2007), also lower than the control group (SMR = 0.88; 95% CI 0.79–0.97). Similar results were obtained restricting the analysis only to deaths due to cancer. Cancer mortality in the deployed cohort was half of that from the general population mortality rates (SMR = 0.50; 95% CI 0.40–0.62) and slightly lower if compared with the control cohort mortality rates (SMR = 0.95; 95% CI 0.77–1.18). No trend appears in particular sub-periods of the considered period.

A similar analysis was carried out for six cancers indicated in the literature as most likely associated with exposure to DU: those of the lung and testis, Hodgkin and Non-Hodgkin lymphomas, leukaemias, and all haematological malignancies. The results are shown in table 4 where, due to the small number of cases, data are only reported for the whole considered period. Deaths observed in the Balkan cohort were lower than those expected from the general population mortality rates, for all the considered cancers and were similar to those expected when mortality rates of the control cohort are taken as reference. No deaths for testicular cancer and for Hodgkin lymphoma occurred in the control cohort vs. one case occurred in the Balkan cohort. We observed a number of deaths for leukaemias (7 vs. 5 expected) and all haematological malignancies (13 vs. 9 expected) higher in the Balkan cohort, but the corresponding SMR were not statistically significant.

Correcting the results for possible mismatches in the linkage procedure (table 3, last line) does not substantially change the conclusions. SMR of the Balkan cohort with respect to the general population increase from 0.56 to 0.62 for all causes mortality and from 0.50 to 0.56 for cancer mortality. Since the same correction applies to the control cohort, the corresponding SMR change very little, from 0.88 to 0.87 for all causes, while they do not change at all for cancer deaths. Small differences were also obtained when the correction factor was applied to the number of cancer-specific deaths. SMR with respect to the general population increased by about 10%, while those referred to the control cohort remained equal or slightly lowered.

Discussion

The study includes the largest military group (71 144 Italian military subjects) ever studied among those deployed in the Balkan War theatres. Both the Balkan and the control cohorts included all the eligible military personnel, with unbiased approach. In spite of the young age of the enrolled subjects, the dimension of the study was large enough to detect a significantly lower mortality than expected for all causes of death and for all cancers.

No excess of overall and cancer specific mortality was observed in the Balkan cohort over follow-up periods ranging from a minimum of 4 to a maximum of 14 years from the potential exposure. Age-adjusted death risks were 40% lower than those of the general Italian population, matched by age, sex, geographical area and calendar period, and ∼10% lower with respect to a large (∼114 000 subjects) military cohort never deployed overseas, used as control cohort. Corresponding comparisons for cancer-specific mortality gave 50 and 5% lower rates, respectively. A specific analysis was also done for the Balkan cohort subset with total mission stay longer than 6 months, including 49% of the total number of soldiers. The mortality risk of this more exposed sub-cohort was even lower that that found for the entire cohort, with SMR = 0.36 (95% CI 0.31–0.41) with respect to the general population and 0.58 (95% CI 0.49–0.69) with respect to the control cohort (data not presented). This unexpected results could be interpreted in terms of selective longer employment of soldiers in better health condition.

Cancer risk of Balkan veterans has been assessed by several studies, within the NATO multinational force deployed there. The Swedish study[15] of 8347 men deployed in 1989–1999 found a non-significantly higher cancer incidence in veterans (RR = 1.2; 95% CI 0.8–1.8) and a non-significant excess of testicular cancer (RR = 1.9; 95% CI 0.8–3.7) compared with the cases expected according to the general population rates. The Denmark study[16] followed up for cancer incidence 18 012 soldiers deployed in 1992–2001 and reported a non-significantly lower cancer incidence in veterans (RR = 0.9; 95% CI 0.7–1.1) with respect to the Danish population. The same study found no significant excess risk for any cancer sites with exception of bone, for which, however, three out of six cases were diagnoses within 1 year from deployment. The Dutch study,[17] with a similar design to the present one, followed-up for cancer incidence a cohort of 18 175 Balkan veterans and a comparable cohort of 153 530 non-deployed soldiers. In addition, comparison with cancer incidence rates in the general population was carried out. The study concluded that Balkan veterans had a 13% lower cancer incidence with respect to the non-deployed soldiers, and a 15% lower incidence with respect the general population. No excess risk was found for any of the system-specific cancer groupings considered. The study of a cohort of 6074 Norwegians UN military peacekeepers[18] deployed to Kosovo in 1999–2011 and followed up to the end of 2011 did not reveal significant excess of cancer incidence with respect to the general population for any of the considered site. A 2-fold not significant standardized incidence ratio was found for skin melanoma, possibly due to voluntary exposure to sunlight UV radiation. A 5-fold increased risk for bladder cancer was based on only three cases. Finally, veterans had half all causes deaths than expected on the basis of the national mortality rates.

Cancer cases in Italian veterans recorded by the Military Health Staff were less than one half than expected from the population-based cancer registries' rates.[19] However, a further study[25] aimed at assessing the completeness of the case ascertainment procedure by a capture–recapture method estimated a proportion of missed cases of 35–46%. After correction, standardized incidence ratios with respect to the general population were still not significant for all malignancies, but for thyroid cancer. Similar overall results were obtained by a number of retrospective cohort studies focused on incidence and mortality risks of first Gulf War veterans, for which we refer to a previously published review.[26]

Several weaknesses of this analysis have to be considered. First, the study only addresses the risk of death. Even if official mortality is considered a high-quality and highly standardized data source, no data are available from unbiased sources on cancer incidence, a more sensible end-point considering the long period of latency and the relatively good prognosis for most cancers related with DU exposure. This is mainly due to the lack of national cancer registration in Italy. Therefore, no analysis has been carried out for thyroid cancer, a neoplasm also associated with exposure to radiation. Also, very little information (only one detected death in the Balkan cohort vs. one expected) can be drawn on Hodgkin's lymphoma, for which a higher disease risk was reported by the Italian Ministry of Defence commission.[20] On the other hand, mortality is much less sensitive than incidence to possible effects of increasing diagnostic intensity, that could have been occurred for thyroid cancer, and for other cancers, as a consequence of the public awareness on health risk for deployed soldiers.

Second, the expected mortality rates for single cancers are low, due to the young age of the enrolled subjects and to the relatively short period of follow-up. Thus, the study does not provide sufficient statistical power for site-specific analysis. The lack of significance of the slightly elevated risk of death from haematological malignancies in the Balkan with respect of the control cohort cannot be interpreted as a definite absence of additional risk.

Third, a complete and accurate ascertainment of mortality is critically important in any longitudinal study. Here, vital status has been collected, for a large part of the Balkan veterans and for all the controls, by means of a passive central linkage with the national death records database. Failures in the linkage procedure could have occurred due to any error in collecting, copying or typing the subjects' name and other linkage keys in either the cohorts or the mortality files. To address this potential drawback, an accurate check of the Balkan cohort data has been performed by simultaneous consideration of multiple data sources, and a validation procedure of vital status and linkage key data has been carried out through municipality archives for a sample of veterans and for a sample of death certificates. The results of this study actually led to estimate a proportion of potential linkage failures of 23.5% for the period 1996–1999 and 11% for the period 2000–2006, the difference is likely due to improved accuracy in cohorts data collection in the more recent years. This estimated proportion of linkage errors leads to a similar proportion of underestimated deaths in the two military cohorts, non-negligible but not large enough to change the final conclusions of the study.

Finally, no direct or indirect measure of exposition to DU or other environmental risk factors were available. It is therefore not possible to study more in detail subgroups of veterans characterized by a specific history of exposition. This problem is common to all the previously cited European studies on Balkan War veterans.[14–20]

Conclusions

Comparison between Balkan veteran and control cohorts did not show any increase in general mortality or in cancer mortality. In addition, both Balkan and control cohorts present a lower mortality with respect to the general population, interpretable as a 'healthy soldier effect' and supporting the need for adequate control groups in any similar analysis of health risks for military personnel. Finally, more powered analyses of mortality risks for specific cancers more likely to be associated with DU or other environmental risk factors exposure, and based on a prolongation of the follow-up period, are recommended.

Ethical issues

Access permission to personal, identifiable, and sensible data of military personnel, and to nominative data from the National Death Index, was obtained for the specific aims of this study by the Italian Privacy Protection Authority. Personal identifiers were only used for data linkage and were kept separate from the files used for all statistical analyses.

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Conflicts of interest: None declared.

Key points

- Mortality rates of the cohort of Italian veterans deployed in the Balkans during the period 1995–2004, and followed-up to the year 2008 was 44% lower than the expected mortality based on the general population rates, adjusted by age, sex and geographical area.
- Mortality of the Balkan cohort was similar to the corresponding rates observed in a control cohort of military personnel never deployed outside Italy.
- The same results were obtained when the analysis was restricted to cancer mortality.

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Private and public modes of bicycle commuting: a perspective on attitude and perception

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Background: Public bicycle-sharing initiatives can act as health enhancement strategies among urban populations. The aim of the study was to determine which attitudes and perceptions of behavioural control toward cycling and a bicycle-sharing system distinguish commuters with a different adherence to bicycle commuting. **Methods:** The recruitment process was conducted in 40 random points in Barcelona from 2011 to 2012. Subjects completed a telephone-based questionnaire including 27 attitude and perception statements. Based on their most common one-way commute trip and willingness to commute by bicycle, subjects were classified into Private Bicycle (PB), public bicycle or Bicing Bicycle (BB), Willing Non-bicycle (WN) and Non-willing Non-bicycle (NN) commuters. After reducing the survey statements through principal component analysis, a multinomial logistic regression model was obtained to evaluate associations between attitudinal and commuter sub-groups. **Results:** We included 814 adults in the analysis [51.6% female, mean (SD): age 36.6 (10.3) years]. BB commuters were 2.0 times [95% confidence interval (CI) = 1.1–3.7] less likely to perceive bicycle as a quick, flexible and enjoyable mode compared to PB. BB, WN and NN were 2.5 (95% CI = 1.46–4.24), 2.6 (95% CI = 1.53–4.41) and 2.3 times (95% CI = 1.30–4.10) more likely to perceive benefits of using public bicycles (bicycle maintenance and parking avoidance, low cost and no worries about theft and vandalism) than did PB. **Conclusion:** Willing non-bicycle and public-bicycle commuters had more favourable perception toward public-shared bicycles compared to private cyclists. Hence, public bicycles may be the impetus for those willing to start bicycle commuting, thereby increasing physical activity levels.

Introduction

Automobile dependence is a global phenomenon in modern societies, even for short trip distances. Almost 50% of trips made in automobiles in Europe cover distances less than five kilometres (1). This despite the fact that commuting to work/school by car has been shown as positively associated with weight gain and obesity (2–4) due to its contribution to a sedentary lifestyle. Hence, the progressive substitution of private motor vehicles to active forms of transport for everyday commuting has become increasingly the focus of current urban transport and public health policies (5,6). Commuting actively by bicycle provides improvements in cardio-respiratory fitness and decreases the incidence of cardiovascular risk factors by intensifying the daily amount of cycling (7,8). Public bicycle-sharing programs have been presented as one means to address concerns of automobile dependency cultures due to their population-level promotion of regular physical activity (9,10). Such systems can also reduce automobile