**Urban blue space and health and wellbeing in Hong Kong: Results from a survey of older adults**

**Abstract**

The potential benefits of aquatic environments for public health have been understudied in Asia. We investigated the relationships between blue space exposures and health outcomes in Hong Kong. Those with a view of blue space from the home were more likely to report good general health, while intentional exposure was linked to greater odds of high wellbeing. Visiting blue space regularly was more likely for those within 10-15 mins walk, and who believed the location had good facilities and wildlife present. High recalled wellbeing on blue space visits was more likely for longer visits and higher intensity activities. Our evidence suggests Hong Kong’s blue spaces are a public health resource for a predominantly older local population.

**Keywords:**

Blue Space, Health and Wellbeing; Hong Kong; Public health; Urban design.

**Introduction**

The number of people living in densely populated urban areas globally is increasing annually (United Nations, 2015). Despite numerous advantages to health and wellbeing (Dye, 2008; Godfrey and Julien, 2005), This growth of urban living, or urbanisation, also poses challenges to human health including air and water pollution and associated respiratory (Liu *et al.,* 2017; Samet et al., 2000; Taylor et al., 2004; Tong and Chen, 2002), cardiovascular (Mustafić *et al.,* 2012) and gastro-intestinal illnesses (Brunekreef and Holgate, 2002; McLellan *et al.,* 2018). Densely populated urban areas can also be cognitively and emotionally stressful, undermining mental health and wellbeing (Gong et al., 2012; Peen et al., 2010). Depression, for instance, is predicted to be the leading cause of Disability Adjusted Life Years (DALYs) in middle to high income countries by 2030 (World Health Organization, 2004) with urbanisation playing an important role in this trend (Goryakin et al., 2017).

Elements of ‘natural environments’ within urban settings (e.g. parks) can, in part, mitigate some of these threats through improvements in air quality, encouraging physical activity and reducing stress (Hartig and Kahn, 2016; Hartig et al., 2014). People who live in urban areas with more green space tend to have: better self-reported health (Maas et al., 2006; Mitchell and Popham, 2007; Seresinhe et al., 2015); a lower risk of cardiovascular and respiratory illnesses (Alcock et al., 2017; Kardan et al., 2015; Maas et al., 2009), diabetes (Astell-Burt et al., 2014a) and some cancers (Demoury et al., 2017); better mental health and wellbeing (Gascon et al., 2015; Mitchell et al., 2015; Author et al., 2013b); better birth outcomes (Dadvand et al., 2012); and ultimately lower mortality risk (Gascon et al., 2016; James et al., 2016; Mitchell and Popham, 2008; Takano et al., 2002; Villeneuve et al., 2012).Evidence has also emerged that proximity to aquatic environments, termed blue space in this paper (e.g. coastlines, lakes, rivers) may have similarly beneficial effects (Burkart et al., 2016; Gascon et al., 2017; Volker and Kistemann, 2011; Wheeler et al., 2012) especially for mental health and wellbeing (de Bell et al., 2017; de Vries et al., 2016; Nutsford et al., 2016; Author et al., 2014).

Potential pathways linking green spaces to health have been categorised as reducing harm, restoring capacities and building capacities (Markevych *et al.,* 2017). Blue spaces may offer benefits through similar mechanisms. Reducing harm includes reducing the effects from air and noise pollution which have been found to mediate the relationship between green space and mental health in Barcelona (Gascon *et al.,* 2018). Restoring capacities includes attention restoration and physiological stress recovery (Markevych *et al.,* 2017). Visits to the coast are perceived to be more restorative as compared to other natural environments (White *et al.,* 2013). Finally, building capacities includes offering opportunities for physical activity and social interactions both of which may be important in blue spaces. Coastal environments were associated with the greatest amount of energy expenditure in comparison to other natural environments (Elliott *et al.,* 2015) and one third of visitors responded that spending time with friends or family was the most important benefit they received from a visit to (freshwater) blue space (de Bell *et al.,* 2017).

Associating objectively assessed green/blue space proximity, or area coverage, with health data tells us little about people’s actual use of these locations (Ekkel and de Vries, 2017). Simply living near them does not necessarily mean individuals visit or use them. Nor do we understand how green and blue spaces can be best used to promote health and wellbeing (Chaix et al., 2013). Additionally, most research investigating blue space and health has been conducted in Europe, the US and Australia (Gascon et al., 2017) with few studies in regions such as Asia, despite rapid urbanisation. The aim of the current research was to address some of these issues, in particular the paucity of research in this topic in Asia and the use of geographical measures of green/blue space, using one of the world’s most densely populated coastal cities, Hong Kong. Similar to cities elsewhere, those living in the greenest areas have lower risk of mortality from a range of causes including cardiovascular disease, stroke and diabetes (Wang et al., 2017; Xu et al., 2017). However, we know of no research investigating blue space and psychological health in Hong Kong.

We focused on three key research questions. First, to what extent is self-reported general health and wellbeing in Hong Kong related to an individual’s exposure to the city’s blue spaces? We explore three different types of exposures: indirect (view from the home), incidental (work commute) and intentional (recreational visit) contact (Cox et al., 2017a; Cox et al., 2017b; Keniger et al., 2013). Second, which environmental factors predict blue space visit frequency in Hong Kong? Environmental characteristics of nature have been found to be related to visit frequency around the world( Morris et al., 2011; Reynolds et al., 2007; Schipperijn et al., 2010)?Third, are some visit and environmental characteristics associated with better short-term recalled wellbeing outcomes, as also has been found elsewhere (Shanahan et al., 2016; Author et al., 2013c)? An overview of the research questions is provided in Figure 1.



Figure 1: Schematic of research questions (RQ) and analysis

**Method**

**Location**

Hong Kong is a unique location within which to study nature interactions and health and wellbeing. It is one of the most densely populated countries in the world; the district Kwun Tong is the densest with 57,250 people per square km (Census and Statistics Dept, 2015). However, there is also much countryside and 40 % is designated as country park or special area for nature conservation (Agriculture, 2016). Hong Kong consists of multiple islands and there is a wide range of aquatic environments including urban waterfronts; fountains and ponds in parks; inland rivers, waterfalls and reservoirs; as well as beaches and bays. Aquatic areas of specific interest include a UNESCO Global Geopark, Hong Kong Wetland Park and several marine parks.

Participants

Ethical approval was provided by the Joint Chinese University of Hong Kong-New Territories East Cluster Clinical Research Ethics Committee (CREC) [Ref. no.: 2016.349]. Participants were a convenience sample of 1000 adult Hong Kong residents who completed the survey voluntarily during visits to a community-based health centre for free-of-charge colorectal cancer (CRC) screening between December 2016 and June 2017. Participants were informed in writing (in traditional Chinese) of the nature of the study and gave their signed consent as approved by the ethics committee. The following inclusion criteria were applied: (1) aged 18-70; (2) local resident; and (3) able to understand and complete the questionnaire independently.

The 1000 people were approximately evenly distributed with regard to sex (505 females; 493 males; 2 people did not say). The sample was not representative of Hong Kong’s population by age as 80% of respondents were >50 years old. However, an older adult sample is itself interesting because of research showing: a) the importance of mental health for health overall in older age (Chen et al., 2017; Jerkovic et al., 2017; Rosness et al., 2016); and b) the benefits of natural environments for older people, for example in encouraging physical activity and reducing mortality risk (Astell-Burt et al., 2014b; Moran et al., 2014; Sulander et al., 2016).

Materials and methods

*Outcome variables*

For the first research question, the associations between blue space exposure and health were investigated for both self-reported i) general health and ii) wellbeing. Self-reported health (henceforth ‘health’) was assessed using the single-item ‘SF1’: ‘How is your health in general?’. Response options were: ‘Very bad’, ‘Bad’, ‘Fair’, ‘Good’ and ‘Very good’. Comparable measures predict mortality (Idler and Benyamini, 1997), have been positively associated with coastal proximity (Author et al., 2013a), and are used internationally (European Social Survey, 2016). As a result of the very low sample sizes in some categories (“Very bad” n = 2; “Very good” n = 26) and negative skew we dichotomised this variable into ‘Good’ (Good/Very good) and ‘Not good’ (Very bad/Bad/Fair) following previous work (Wheeler et al., 2015)(see Supplementary Table 1 for further explanation of all variables). Our analysis thus predicted the likelihood of someone being in good vs. not good health, as a function of a variety of environmental and other predictors.

Subjective wellbeing was assessed using the World Health Organisation’s 5 item Wellbeing Index (WHO-5), a measure of overall psychological wellbeing (Linton *et al.,* 2016; Topp et al., 2015), which has been shown to be associated with reported green space access in Europe, for instance (Mitchell et al., 2015). Participants responded to five statements about their feelings during the past two weeks: ‘*I have felt cheerful and in good spirits’, ‘I have felt calm and relaxed’, ‘I have felt active and vigorous’, ‘I woke up feeling fresh and rested’ and ‘My daily life has been filled with things that interest me’* with response options ranging from ‘*At no time’* (numerical value = 0)to *‘All of the time’* (value = 5)(Supplementary Table 1). These items have been confirmed to each measure a unique dimension (Blom *et al.,* 2012; Lucas-Carrasco *et al.,* 2012; Topp *et al.,* 2015). The WHO-5 correlates with measures of depression, psychological distress and suicide (Garland *et al.,* 2018; Thelin *et al.,* 2017; Sisask *et al.,* 2008; Topp *et al.,* 2015). Response values were summed and multiplied by 4 to give a total wellbeing score out of 100 (Cronbach’s alpha = 0.89, 95 % CI = 0.88 – 0.90) (Topp et al., 2015). Following (Gao et al., 2014), respondents were dichotomised into those with ‘High’ (≥50) vs. ‘Low’ (<50) wellbeing, for analytical purposes. An exploration of an alternative threshold reflecting ‘High’ (<28) vs. (Low ≥28) risk of depression (Löwe et al., 2004; Nicolucci et al., 2014) was conducted as a robustness check with details found in Supplementary Table 11.

For the third research question, recalled wellbeing was assessed for a specific visit to the respondent’s nearest blue space. A bespoke composite score (Cronbach’s alpha = 0.69, 95 % CI = 0.66 – 0.72) was calculated from responses to four items drawn from the English Monitor of Engagement with the Natural Environment (MENE) survey (Natural England, 2017), which represent aspects of subjective wellbeing with the most academic and policy consensus (Kahneman et al., 1999; O'Donovan et al., 2017).These were: ‘it made me feel happy’ and ‘it made me feel anxious’ together representing positive and negative experiential wellbeing; ‘I found the visit worthwhile’ reflecting eudaimonic wellbeing; and ‘I was satisfied with the visit’ representing evaluative wellbeing. There were seven’ response options from ‘strongly disagree’ (value= 1) to ‘strongly agree’ (value=7). Responses were left-skewed, therefore the score was dichotomised for analysis. Mean values ≥6 were categorised as ‘High recalled wellbeing’ and mean values <6 were ‘Low recalled wellbeing’. We chose the value of 6 because it a) included those respondents who typically responded with “Agree” or “Strongly agree” to each question and b) resulted in appropriate sample sizes for each group (high n = 420; low n = 280).

*Exposures*

Respondents were told that for the purposes of this survey ‘blue spaces’ included: inland aquatic areas (lakes, canals, rivers, fountains and pools), urban coastal areas (seaside resorts, harbours, ports and piers) and other coastal areas (beaches, cliffs and headlands). They were asked not to think about indoor locations (such as swimming pools), places visited as part of their job, or private locations such as within gardens or private pools. *Indirect exposure* was measured by asking whether the respondent had a view of blue space from their home (Nutsford et al., 2016). *Incidental exposure* was measured by asking “Do you usually pass by/through this blue space when commuting, to or from work/school/other daily activities?” (Honold et al., 2016). *Intentional exposure* was measured by asking participants how often they visited *any* blue spaces in the last four weeks. In addition to these three types of exposure, we included a simple measure of proximity to blue space: ‘Is this blue space within a 10-15 min walk from your home?’ (Schipperijn et al., 2010; Völker et al., 2018).

For the second and third research questions, participants were asked to focus specifically on the blue space *closest* to their home, and therefore the one most likely to be visited frequently (Schipperijn et al., 2010). For this section *intentional exposure* was measured by asking participants how often they visited this particular blue space in the last four weeks. They were also asked to rate four characteristics of their nearest blue space: a) safety, b) presence of wildlife, c) whether it is generally free from litter and d) whether it has good facilities (examples given: parking, footpaths, toilets); on seven-point scales ranging from ‘strongly disagree’ (1) to ‘strongly agree’ (7) (Supplementary Table 2). No examples were provided for wildlife and could refer to any species perceived to be present. Respondents were asked to recall characteristics, including duration and the main activity, of the most recent visit (Supplementary Table 3). Activity intensity was categorised according to the metabolic equivalent of task (MET) rate of the activities as in Author *et al.,* (2015) (Supplementary Table 3). The variable “water contact” categorised visits as having water contact (swimming, fishing or on a boat/ferry) or not.

Analyses controlled for a range of factors which may affect health, wellbeing and/or visits to nature including age, income and occupation (see Supplementary Table 4 for full list; (Bijl et al., 2002; Nan et al., 2005; Author et al., 2014)). Respondents chose one of 18 districts as their home, we categorised these into four groups to account for low sample sizes in some districts (e.g. Central and Western district, Hong Kong Island n = 8). There was a higher proportion of people living in Sha Tin in our sample than in Hong Kong as a whole. We therefore grouped location of residence as Hong Kong Island, Kowloon, New Territories excluding Sha Tin and Sha Tin as a separate district (Supplementary Fig. 1). Measures of general physical functioning, recreational physical activity, and access to private outdoor spaces were also included. These potential confounders have been found to be related to health and wellbeing (Awata *et al.,* 2007; Fonta *et al.,* 2017; Mammen and Faulkner, 2013; McMahon et al., 2017; Nielsen and Hansen, 2007; Poitras et al., 2016). Furthermore, with regard to physical functioning, visits to the coast have been found to be more likely if respondents did not have an illness or disability (Author et al., 2014). Due to the reciprocal relationship between self-reported health and wellbeing (Dolan et al., 2008), analysis of each variable (SF1 & WHO-5) controlled for the other. This was important to reduce the chances of any findings resulting from the shared variance between them, and to ensure that any relationships to blue space reflected the unique variance of our respective target outcomes. Similarly, in our analysis of experiential well-being for specific visits, we controlled for WHO-5 responses to partial out general well-being levels.

***Statistical Analysis***

Analyses were carried out in R (v3.4.0) (R Core Team, 2017). Unadjusted and adjusted logistic regressions were conducted for each outcome variable using a generalised linear modelling approach with a binomial error structure. Respondents with missing data were excluded. Model fit was estimated using the conservative Cox & Snell pseudo-*R*2 and the Akaike Information Criterion (AICc) which accounts for number of predictors (Akaike, 1974).

**Results**

*Exposure descriptives*

The number of respondents self-reporting good/not good health and high/low wellbeing as a function of blue space exposure is shown in Table 1 (full counts in Supp. Table 5). Blue space exposure was high among this sample: 39% had indirect exposure, 59% had incidental exposure, 38% had intentional exposure at least once a week, and 56% reported that a blue space was within a 10-15 minute walk of their home. A high proportion (70 %) of respondents recalled their most recent visit to their nearest blue space. Of those who provided a date for their visit (n = 463), 97 % were within four weeks. The median duration of these visits was 60 minutes (Supplementary Fig. 2), and the most frequent activity was ‘strolling’ (n = 387).

*Research question 1: Blue space exposure, health and wellbeing*

Statistical results for health (self-reported health) and wellbeing outcomes (WHO-5) as a function of the various blue space exposures can be seen in Table 2 We present results for models both unadjusted and adjusted for sociodemographics and other variables (see Supplementary Table 6 for full model results; including all covariates).

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| Table 1: Number of respondents for each exposure and health outcome for RQ1 (Hong Kong, Dec 2016 – June 2017)  (Supp. Table 5 for full counts). | | | | | | | | | | | | |
|  | Total | | Total in regression sample | | Self-reported health\* | | | | WHO-5 Wellbeing Index\* | | | |
| Exposure or accessibility | Good | | Not good | | High | | Low | |
| N | (%) | N | (%) | N | (%) | N | (%) | N | (%) | N | (%) |
| **Blue space** |  |  |  |  |  |  |  |  |  |  |  |  |
| Indirect (view) |  |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 390 | 39 | 368 | 38.45 | 150 | 40.76 | 218 | 59.24 | 232 | 63.04 | 136 | 36.96 |
| *No (ref)* | 610 | 61 | 589 | 61.55 | 175 | 29.71 | 411 | 69.78 | 317 | 53.82 | 269 | 45.67 |
| Incidental (commute) |  |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 589 | 59 | 559 | 58.60 | 216 | 38.64 | 343 | 61.36 | 353 | 63.15 | 206 | 36.85 |
| *No (ref)* | 408 | 41 | 395 | 41.40 | 109 | 27.59 | 286 | 72.41 | 196 | 49.62 | 199 | 50.38 |
| Intentional (visits) |  |  |  |  |  |  |  |  |  |  |  |  |
| *≥1 a week* | 381 | 38 | 360 | 37.74 | 144 | 40.00 | 216 | 60.00 | 241 | 66.94 | 119 | 33.06 |
| *1-2 a month* | 353 | 35 | 345 | 36.16 | 120 | 34.78 | 225 | 65.22 | 200 | 57.97 | 145 | 42.03 |
| *Not at all (ref)* | 260 | 26 | 249 | 26.10 | 61 | 24.50 | 188 | 75.50 | 108 | 43.37 | 141 | 56.63 |
| Within walking distance |  |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 561 | 56 | 531 | 55.66 | 200 | 37.66 | 331 | 62.34 | 333 | 62.71 | 198 | 37.29 |
| *No (ref)* | 439 | 44 | 423 | 44.34 | 125 | 29.55 | 298 | 70.45 | 216 | 51.06 | 207 | 48.94 |
| **Green space** (intentional) |  |  |  |  |  |  |  |  |  |  |  |  |
| *≥1 a week* | 570 | 57 | 540 | 56.60 | 212 | 39.26 | 328 | 60.74 | 341 | 63.15 | 199 | 36.85 |
| *1-2 a month* | 343 | 34 | 329 | 34.49 | 101 | 30.70 | 228 | 69.30 | 175 | 53.19 | 154 | 46.81 |
| *Not at all (ref)* | 87 | 9 | 85 | 8.91 | 12 | 14.12 | 73 | 85.88 | 33 | 38.82 | 52 | 61.18 |
| \*These represent totals for regression modelling sample | | | | | | | | | | | | |

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| Table 2: Odds ratios (OR) and 95% Confidence Intervals (CIs) for unadjusted and adjusted results for RQ1 (Hong Kong, Dec 2016 – June 2017) (Supp. Table 6 for full model results). | | | | | | | | | | | |
|  | Self-reported health outcome | | | | |  | WHO-5 Wellbeing Index outcome | | | | |
|  | Unadjusted | |  | Adjusted | |  | Unadjusted | |  | Adjusted | |
|  | OR | 95% CIs |  | OR | 95% CIs |  | OR | 95% CIs |  | OR | 95% CIs |
| **Exposures** |  |  |  |  |  |  |  |  |  |  |  |
| Indirect (View) |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 1.4\* | 1.0 – 1.9 |  | 1.7\*\* | 1.2 – 2.4 |  | 1.1 | 0.8 – 1.5 |  | 1.0 | 0.7 – 1.4 |
| *No (ref)* | - | - |  | - | - |  | - | - |  | - | - |
| Incidental (Commute) |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 1.4 | 1.0 – 1.9 |  | 1.1 | 0.8 – 1.6 |  | 1.3 | 1.0 – 1.8 |  | 1.1 | 0.8 – 1.6 |
| *No (ref)* | - | - |  | - | - |  | - | - |  | - | - |
| Intentional (Visits) |  |  |  |  |  |  |  |  |  |  |  |
| *≥1 a week* | 1.2 | 0.8 – 1.9 |  | 1.0 | 0.6 – 1.6 |  | 1.8\*\* | 1.2 – 2.7 |  | 1.7\* | 1.1 – 2.6 |
| *1-2 a month* | 1.3 | 0.9 – 1.9 |  | 1.0 | 0.7 – 1.6 |  | 1.5\* | 1.1 – 2.2 |  | 1.4 | 1.0 – 2.2 |
| *Not at all (ref)* | - | - |  | - | - |  | **-** | **-** |  | - | - |
| Walking distance |  |  |  |  |  |  |  |  |  |  |  |
| *Yes* | 1.0 | 0.7 – 1.4 |  | 0.8 | 0.6 – 1.2 |  | 1.1 | 0.8 – 1.5 |  | 1.1 | 0.8 – 1.5 |
| *No (ref)* | - | - |  | - | - |  | - | - |  | - | - |
| Green space visits |  |  |  |  |  |  |  |  |  |  |  |
| *≥1 a week* | 3.0\*\* | 1.5 – 6.0 |  | 3.3\*\* | 1.5 – 7.0 |  | 1.7\* | 1.0 – 2.8 |  | 1.3 | 0.7 – 2.3 |
| *1-2 a month* | 2.2\* | 1.1 – 4.4 |  | 2.7\* | 1.3 – 5.7 |  | 1.3 | 0.8 – 2.2 |  | 1.1 | 0.6 – 1.9 |
| *Not at all (ref)* |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **Covariates** |  |  |  |  |  |  |  |  |  |  |  |
| Other health/wellbeing outcome | NO |  |  | YES |  |  | NO |  |  | YES |  |
| *Socio-demographics* | NO |  |  | YES |  |  | NO |  |  | YES |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| Intercept | -2.05 | |  | -4.35 |  |  | -0.72 |  |  | -2.24 |  |
| N | 954 | |  | 954 |  |  | 954 |  |  | 954 |  |
| AIC | 1211 | |  | 1019.7 |  |  | 1270.30 | |  | 1147.1 | |
| Cox & Snell R2 (%) | 4.1 |  |  | 23.5 |  |  | 4.8 |  |  | 19.5 |  |
| OR = Odds Ratio. CI = Confidence Interval. \* p <.05; \*\* p <.01, \*\*\*p < 0.001 | | | | | | | | | | | |

*Self-reported health (Good vs. not good)*

Indirect blue space exposure (a view from the home) was associated with significantly higher odds of ‘good’ health in both the unadjusted and adjusted models (ORadj = 1.7, 95 % CI 1.2-2.4). There were no significant relationships with either intentional or incidental exposure to blue space, or walking distance, in either unadjusted or adjusted models. By contrast, visiting green spaces at least once a week (ORadj = 3.3, 95 % CI 1.5-7.0) and 1-2 visits in the last month (ORadj = 2.7, 95 % CI 1.3-5.7) were both associated with significantly higher odds of reporting good health in unadjusted and adjusted models. Figure 2a illustrates the strength of blue space exposure on self-reported health relative to selected covariates. The size of the association between health and indirect blue space exposure was similar to that between health and being male *vs.* female. Confidence in the overall results was gained from noting that, as might be expected, the strongest predictor of general health was the absence of restricted physical functioning. By themselves, the socio-demographic variables explained, 22% of the variation in health, with blue and green space variables explaining a further (and significant) 2% (Supp. Table 6; Likelihood ratio test, *p*= 0.003).

*Subjective wellbeing (High vs. low)*

In contrast to self-reported health, intentional exposure (visiting blue space ≥ once a week), was positively associated with high wellbeing in both the unadjusted and adjusted models (ORadj = 1.7, 95 % CI, 1.1-2.6). The size of this association was similar to that between wellbeing and those who were retired *vs*. working full time (Figure 2b). Visiting blue space less often (once or twice a month) was significant only in the unadjusted model (ORadj = 1.4, 95 % CI, 1.0-2.1). Neither incidental nor indirect exposure, nor having a blue space within walking distance, were significant in either the unadjusted or adjusted models (Table 2). Visiting green space at least once a week was significant only in the unadjusted model, though individuals with access to private outdoor spaces were more likely to report high levels of wellbeing compared to those without (Figure 2b). By themselves, the socio-demographic variables explained 19 % of the variation in wellbeing, with blue and green space exposures explaining a further significant 1% (Supp. Table 6; Likelihood ratio test, *p* = 0.025). Of note, visiting blue space ≥ once a week, was also positively associated with a lower risk of depression (Supplementary Table 11, ORadj = 1.8, 95 % CIs, 1.0-3.1) suggesting potential clinical relevance.

Figure 2 Odds ratios and 95% confidence intervals for the adjusted model for a) ‘Good’ self-reported health and b) ‘High’ wellbeing for research question 1.

*Research question 2: Intentional blue space exposure*

Using the results from research question 1 to identify a threshold for wellbeing in relation to blue space visit frequency, we dichotomised intentional exposure into ‘≥ once a week’ and ‘< once a week’ (Supplementary Table 2).

Numbers of respondents self-reporting blue space exposure as a function of environmental characteristics are shown in Table 3 (Supp. Table 7). Intentional exposure was significantly positively related to indirect exposure (ORadj = 1.7, 95 % CI, 1.2-2.5), incidental exposure (ORadj = 3.0, 95 % CI, 2.0-4.5) and walking distance from home (ORadj = 2.7, 95%CIs, 1.8-4.2). Of the perceived local blue space qualities, agreement that the site had good facilities and wildlife were both significantly related to intentional blue space exposure in the unadjusted and adjusted models (facilities: ORadj = 2.0, 95 % CI, 1.2-3.3; wildlife: ORadj = 1.6, 95 % CI, 1.1 -2.3). The effect size of facilities was similar to that for meeting recommended physical activity levels and the effect size for the presence of wildlife was similar to that of high vs. low income (Figure 3; Supp. Table 8). Perceived safety was significant only in the unadjusted model and presence of litter was not significant in either unadjusted or adjusted models (Table 3). Socio-demographic variables explained 15% of the variation in visit frequency, with nearby blue space variables explaining a further (significant) 13% (Table 4; Supp. Table 8; Likelihood ratio test, *p*<0.001).

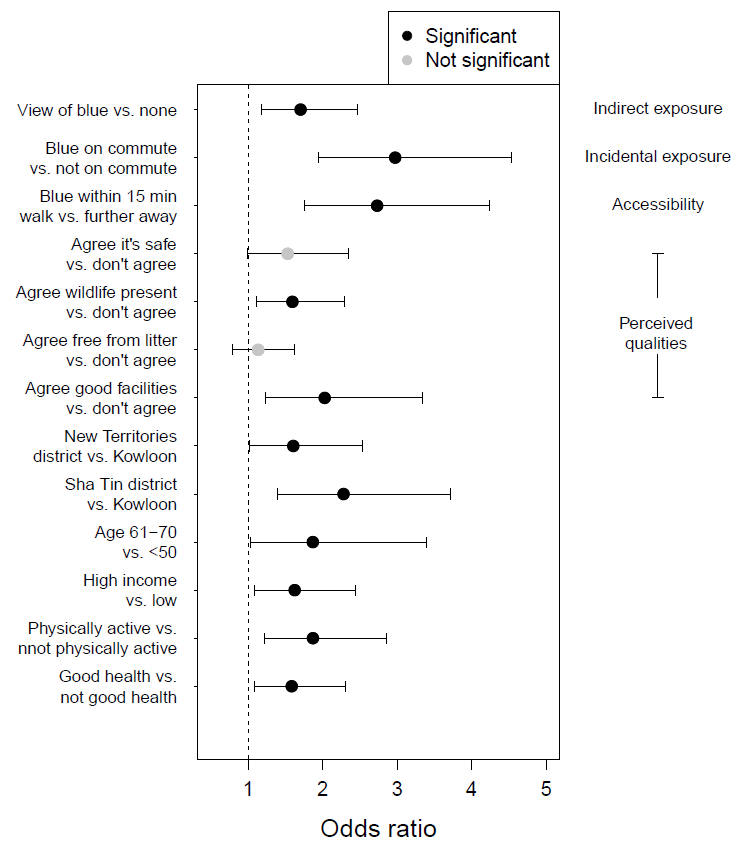
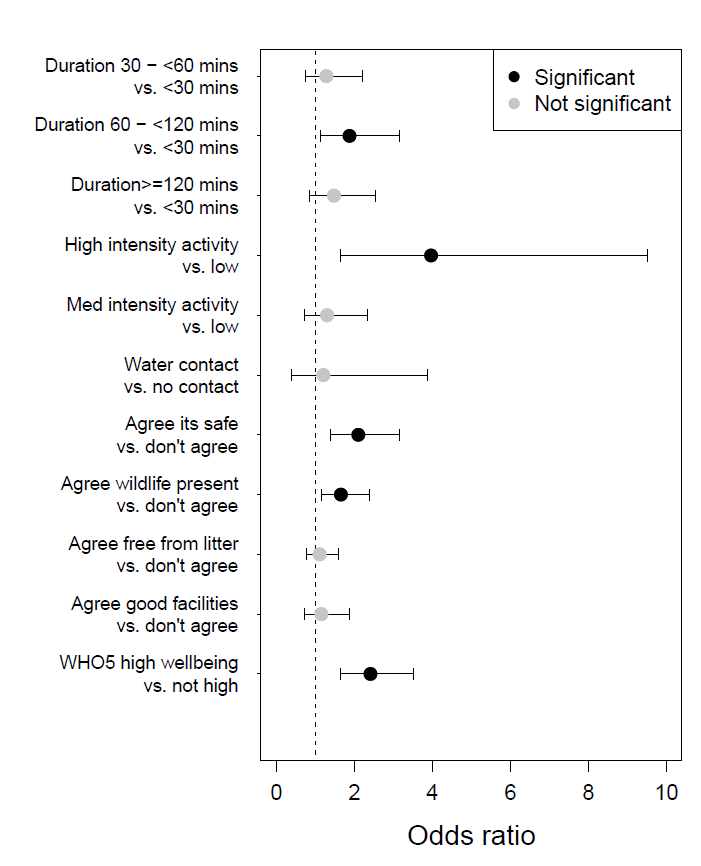


Figure 3: Odds ratios and 95% confidence intervals for the adjusted model for factors affecting nearest blue space visit frequency (research question 2).

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| *Table 3 Number of respondents for each predictor for RQ2 (Hong Kong, Dec 2016 – June 2017) (Supp. Table 7 for full counts).* | | | | | | | | |
|  | Total | | Total in regression sample | | Visit blue space >=1 a week\* | | Visit blue space <1 a week\* | |
|  | N | % | N | % | N | % | N | % |
| View |  |  |  |  |  |  |  |  |
| *Yes* | 390 | 39.0 | 370 | 38.6 | 173 | 46.8 | 197 | 53.2 |
| *No (ref)* | 610 | 61.0 | 589 | 61.4 | 108 | 18.3 | 481 | 81.7 |
| Commute |  |  |  |  |  |  |  |  |
| *Yes* | 589 | 59.0 | 562 | 58.6 | 240 | 42.7 | 322 | 57.3 |
| *No (ref)* | 408 | 41.0 | 397 | 41.4 | 41 | 10.3 | 356 | 89.7 |
| Walking distance |  |  |  |  |  |  |  |  |
| *Yes* | 561 | 56.0 | 534 | 55.7 | 236 | 44.2 | 298 | 55.8 |
| *No (ref)* | 439 | 44.0 | 425 | 44.3 | 45 | 10.6 | 380 | 89.4 |
| Safe |  |  |  |  |  |  |  |  |
| *Agree* | 661 | 66.1 | 634 | 66.1 | 235 | 37.1 | 399 | 62.9 |
| *Don’t agree (ref)* | 339 | 33.9 | 325 | 33.9 | 46 | 14.2 | 279 | 85.8 |
| Presence of wildlife |  |  |  |  |  |  |  |  |
| *Agree* | 524 | 52.6 | 507 | 52.9 | 191 | 37.7 | 316 | 62.3 |
| *Don’t agree (ref)* | 473 | 47.4 | 452 | 47.1 | 90 | 19.9 | 362 | 80.1 |
| Free from litter |  |  |  |  |  |  |  |  |
| *Agree* | 453 | 45.4 | 440 | 45.9 | 160 | 36.4 | 280 | 63.6 |
| *Don’t agree (ref)* | 545 | 54.6 | 519 | 54.1 | 121 | 23.3 | 398 | 76.7 |
| Good facilities |  |  |  |  |  |  |  |  |
| *Agree* | 755 | 75.6 | 729 | 76.0 | 250 | 34.3 | 479 | 65.7 |
| *Don’t agree (ref)* | 244 | 24.4 | 230 | 24.0 | 31 | 13.5 | 199 | 86.5 |
| \*Totals are given for regression modelling sample | | | | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Table 4: Odds ratios (OR) and 95% Confidence Intervals (CIs) for unadjusted and adjusted models for RQ2 (Hong Kong, Dec 2016 – June 2017) (Supp. Table 8 for full model results).* | | | | |
| Variable | Unadjusted | | Adjusted | |
| OR | 95% CI | OR | 95% CI |
| Exposures |  |  |  |  |
| Indirect (view) |  |  |  |  |
| *Yes* | 1.8\*\*\* | 1.3 - 2.6 | 1.8\*\* | 1.3 - 2.6 |
| *No (ref)* | |  |  |  |
| Incidental (commute) | |  |  |  |
| *Yes* | 3.4\*\*\* | 2.3 - 5.0 | 3.0\*\*\* | 2.0 - 4.5 |
| *No (ref)* | |  |  |  |
| Walking distance | |  |  |  |
| *Yes* | 3.0\*\*\* | 2.0 - 4.4 | 2.7\*\*\* | 1.8 - 4.2 |
| *No (ref)* | |  |  |  |
| Perceived qualities | | |  |  |
| Safe |  |  |  |  |
| *Agree* | 1.7\* | 1.1 - 2.5 | 1.5 | 1.0 - 2.4 |
| *Don’t agree (ref)* | |  |  |  |
| Presence of wildlife | | |  |  |
| *Agree* | 1.7\*\* | 1.2 - 2.4 | 1.6\* | 1.1 - 2.3 |
| *Don’t agree (ref)* | |  |  |  |
| Free from litter | |  |  |  |
| *Agree* | 1.2 | 0.9 - 1.7 | 1.1 | 0.8 - 1.6 |
| *Don’t agree (ref)* | |  |  |  |
| Good facilities | |  |  |  |
| *Agree* | 1.9\*\* | 1.2 - 3.1 | 2.0\*\* | 1.2 - 3.3 |
| *Don’t agree (ref)* | |  |  |  |
| **Covariates** |  |  |  |  |
| Self-reported health | NO |  | YES |  |
| *Socio-demographics* | NO |  | YES |  |
|  |  |  |  |  |
| Intercept | -4.03 |  | -5.25 |  |
| N | 959 |  | 959 |  |
| AIC | 920.95 |  | 895.17 |  |
| Cox & Snell pseudo-*R2* (%) | 23 |  | 28 |  |
| OR = Odds Ratio. CI = Confidence Interval. \* p <.05; \*\* p <.01, \*\*\*p < 0.001 | | | | |

*Research question 3: Wellbeing on blue space visits*

Numbers of respondents self-reporting high/low recalled wellbeing as a function of visit characteristics are shown in Table 5 (Supp. Table 9). Visit duration was approximately evenly distributed amongst all categories. Most visits were of medium activity intensity (n = 537) with fewer either high or low (high n = 87, low n = 66). There were also very few visits which were categorised as having water contact (n = 28).

Compared to visits <30 minutes, a duration of 30-59 minutes was not significantly related to higher odds of recalled wellbeing (ORadj = 1.3, 95 % CI, 0.7-2.2). However, longer visits of 60-119 minutes (ORadj = 1.9, 95% CIs, 1.1-3.1) were associated with a significantly greater likelihood of high recalled wellbeing in both unadjusted and adjusted models (Fig. 4, Table 6). Visit durations of ≥120 minutes were significant only in the unadjusted model. Compared to a low intensity activity, taking part in a high intensity activity was also associated with significantly greater odds of high recalled wellbeing and resulted in the greatest effect size (ORadj = 4.0, 95%CIs, 1.7 - 9.5; Figure 4) while moderate intensity activity was not significant (ORadj = 1.3, 95 % CI 0.7 – 2.3). Water contact was not significant in either unadjusted or adjusted models. Both perceived safety (ORadj 2.1; 95% CI 1.4 – 3.2) and the presence of wildlife (ORadj=1.7, 95 % CI = 1.1 – 2.4) were associated with high recalled wellbeing, while neither presence of litter nor good facilities were significantly related. Socio-demographic variables explained 8% of the variation, with visit characteristics explaining a further (significant) 8% (Table 6; Supp. Table 10; Likelihood ratio test, *p*<0.001).

Figure 4 Odds ratios and 95% confidence intervals for the adjusted model for factors affecting the wellbeing outcome from a single visit (research question 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Table 5. Number of respondents for each predictor for RQ3 (Hong Kong, Dec 2016 – June 2017) (Supp. Table 9 for full counts).* | | | | | | | | |
| Variables | Total | | Total in regression sample | | High wellbeing\* | | Not high wellbeing\* | |
|  | N | % | N | % | N | % | N | % |
| Duration |  |  |  |  |  |  |  |  |
| *30 - <60 mins* | 162 | 23.8 | 152 | 23.5 | 87 | 57.2 | 65 | 42.8 |
| *60 - <120 mins* | 226 | 33.1 | 218 | 33.7 | 148 | 67.9 | 70 | 32.1 |
| *≥120 mins* | 173 | 25.4 | 160 | 24.8 | 103 | 64.4 | 57 | 35.6 |
| *<30 mins (ref)* | 121 | 17.7 | 116 | 18.0 | 56 | 48.3 | 60 | 51.7 |
| Activity intensity | |  |  |  |  |  |  |  |
| *High* | 87 | 12.6 | 85 | 13.2 | 71 | 83.5 | 14 | 16.5 |
| *Med* | 537 | 77.8 | 500 | 77.4 | 295 | 59.0 | 205 | 41.0 |
| *Low (ref)* | 66 | 9.6 | 61 | 9.4 | 28 | 45.9 | 33 | 54.1 |
| Water contact |  |  |  |  |  |  |  |  |
| *Yes* | 28 | 4.1 | 26 | 4.0 | 21 | 80.8 | 5 | 19.2 |
| *No (ref)* | 662 | 95.9 | 620 | 96.0 | 373 | 60.2 | 247 | 39.8 |
| Safe |  |  |  |  |  |  |  |  |
| *Agree* | 661 | 66.1 | 478 | 74.0 | 320 | 66.9 | 158 | 33.1 |
| *Don’t agree (ref)* | 339 | 33.9 | 168 | 26.0 | 74 | 44.0 | 94 | 56.0 |
| Presence of wildlife | | |  |  |  |  |  |  |
| *Agree* | 524 | 52.6 | 372 | 57.6 | 254 | 68.3 | 118 | 31.7 |
| *Don’t agree (ref)* | 473 | 47.4 | 274 | 42.4 | 140 | 51.1 | 134 | 48.9 |
| Free from litter |  |  |  |  |  |  |  |  |
| *Agree* | 453 | 45.4 | 321 | 49.7 | 210 | 65.4 | 111 | 34.6 |
| *Don’t agree (ref)* | 545 | 54.6 | 325 | 50.3 | 184 | 56.6 | 141 | 43.4 |
| Good facilities |  |  |  |  |  |  |  |  |
| *Agree* | 755 | 75.6 | 539 | 83.4 | 343 | 63.6 | 196 | 36.4 |
| *Don’t agree (ref)* | 244 | 24.4 | 107 | 16.6 | 51 | 47.7 | 56 | 52.3 |
|  |  |  | \*Totals are given for regression modelling sample | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 6: Odds ratios (OR) and 95% Confidence Intervals (CIs) for unadjusted and adjusted models for RQ3 (Hong Kong, Dec 2016 – June 2017) (Supp. Table 10 for full model results). | | | | |
| Variables | Unadjusted | | Adjusted | |
|  | OR | 95% CI | OR | 95% CI |
| **Visit characteristics** |  |  |  |  |
| Duration |  |  |  |  |
| *30 - <60 mins* | 1.3 | 0.8 - 2.2 | 1.3 | 0.7 - 2.2 |
| *60 - <120 mins* | 1.9\*\* | 1.2 - 3.1 | 1.9\* | 1.1 - 3.1 |
| *≥120 mins* | 1.7\* | 1.0 - 2.9 | 1.5 | 0.9 - 2.5 |
| *<30 mins (ref)* |  |  |  |  |
| Activity intensity |  |  |  |  |
| *High* | 4.3\*\*\* | 1.9 - 10.0 | 4.0\*\* | 1.7 - 9.5 |
| *Med* | 1.5 | 0.8 - 2.6 | 1.3 | 0.7 - 2.3 |
| *Low (ref)* |  |  |  |  |
| Water contact |  |  |  |  |
| *Yes* | 1.2 | 0.4 - 3.8 | 1.2 | 0.4 -3.9 |
| *No (ref)* |  |  |  |  |
| **Perceived qualities** |  |  |  |  |
| Safe |  |  |  |  |
| *Agree* | 1.7\*\*\* | 1.5 - 3.2 | 2.1\*\*\* | 1.4 - 3.2 |
| *Don’t agree (ref)* | |  |  |  |
| Presence of wildlife | |  |  |  |
| *Agree* | 1.7\*\* | 1.2 - 2.4 | 1.7\*\* | 1.1 - 2.4 |
| *Don’t agree (ref)* | |  |  |  |
| Free from litter | |  |  |  |
| *Agree* | 1.2 | 0.8 - 1.7 | 1.1 | 0.8 - 1.6 |
| *Don’t agree (ref)* | |  |  |  |
| Good facilities | |  |  |  |
| *Agree* | 1.9 | 0.8 - 1.9 | 1.2 | 0.7 - 1.9 |
| *Don’t agree (ref)* | |  |  |  |
| **Covariates** |  |  |  |  |
| Wellbeing (WHO-5) | NO |  |  | YES |
| *Socio-demographics* | NO |  |  | YES |
|  |  |  |  |  |
| Intercept | -1.52 |  | -1.88 |  |
| N | 646 |  | 646 |  |
| AIC | 812.92 |  | 814.1 |  |
| Cox & Snell pseudo-*R2* (%) | 10.7 |  | 15.4 |  |
| OR = Odds Ratio. CI = Confidence Interval. \* p <.05; \*\* p <.01, \*\*\*p < 0.001 | | | | |

**Discussion**

*Summary of findings*

The current research is, we believe, the first to simultaneously examine how exposure to, and use of, urban blue spaces in a mega-city are related to self-reported health and wellbeing. It is also, as far as we are aware, the first study to explore these issues in an Asian setting. With respect to research question 1, the associations between health and wellbeing and blue space exposures, results varied according to exposure type. Simply having a view of blue space from the home (indirect exposure) was related to better self-reported health, and visiting blue spaces regularly for recreation (intentional exposure) was related to both better subjective wellbeing and a lower risk of depression. Both findings are consistent, at least in part, with results published elsewhere (de Vries et al., 2016; Gascon et al., 2017). For instance, spending time in blue spaces has been found to be particularly beneficial for psychological wellbeing in both Spain (Amoly et al., 2014) and the UK (de Bell *et al.,* 2017; MacKerron and Mourato, 2013). However, coastal views were associated with better mental health in Wellington, New Zealand (Nutsford et al., 2016) while we found an association only with general health in Hong Kong. Experimental research in mainland China has found that nature, and especially blue space views, could aid physiological stress recovery (Li and Sullivan, 2016; Wang et al., 2016) which may affect different aspects of health (Lin and Ensel, 1989) although the mechanisms underlying these associations have yet to be elucidated. A view of the sea, and other natural environments, was associated with reduced annoyance from road noise in Hong Kong (Leung *et al.,* 2017) which may represent one such pathway.

Neither outcome was related to walking distance to the nearest blue space or incidental exposure (e.g. blue spaces as part of commutes). The former is particularly surprising given that many analyses assume home proximity is a sufficient measure of exposure for investigating health and wellbeing associations, including green spaces in Hong Kong and mainland China (Wang et al., 2017; Xu et al., 2017). Issues of objective *vs*. subjective proximity estimates notwithstanding (Macintyre et al., 2008), the current study suggests that proximity may be a less sensitive proxy for blue space contact than intentional exposure. Alternatively, this lack of relationship between walking distance to blue spaces and health outcomes may be affected by characteristics of Hong Kong, such as the presence of an excellent public transport system, including buses and metro system. However, Volker *et al.,* (2018) also find that while perceived walking distance and blue space use were significantly related in a cross-sectional survey in two German cities, when blue space use and perceived walking distance were included as predictors in the same model, blue space use attenuated the effect of perceived walking distance. They therefore also suggest that perceived walking distance may not be an appropriate metric when assessing health outcomes in relation to blue space (specifically inland waters).

That the associations remained with self-reported health and wellbeing after controlling for key socio-demographic factors such as age, occupation and income, suggests the relationships are potentially applicable to a wider cross-section of society. Each analysis also controlled for physical activity levels, suggesting that any benefits are not simply due to increased exercise (Richardson et al., 2013), but are likely due to other processes such as stress relief, attention restoration and social cohesion (Cox et al., 2017b; Markevych et al., 2017; Weinstein et al., 2015). Water has previously found to be important in perceived restorativeness of scenes (White *et al.,* 2010) and, in comparison to other environment types, coastal visits were associated with greatest restoration from recent nature visits (White *et al.,* 2013) which can mediate the relationship with mental health (de Vries *et al.,* 2013). We also controlled for the other health/wellbeing outcome variable in our models, demonstrating that these were unique contributions rather than simply reflections of the same underlying process. The effect sizes were as large as some of those from key socio-demographic variables which helps contextualise their importance in relation to policymaking choices.

Finally, although our focus was on blue spaces, we also included recreational use of green spaces to isolate the unique blue space contribution. Intriguingly, we found contrasting relationships between intentional exposures to green and blue space. We found a particularly strong relationship between green space visit frequency and health and yet we found it was unrelated to wellbeing. Previous studies have found relationships between visiting green space and measures of both health and mental health (Sulander *et al.,* 2016; van den Berg  *et al.,* 2016). However, in their study investigating ‘green’ space visits and mental health, van den Berg *et al.,* 2016 included all natural elements in their definition of green spaces which included water bodies. In contrast, we find visiting blue space was associated with wellbeing but was unrelated to general health. Similarly, Volker *et al.,* (2018) also found that blue space use was related to mental health and unrelated to physical health in a survey in one German city. We suggest that visits to each provide a unique contribution to health and wellbeing and further work is needed to investigate the pathways of their respective contributions as well as their relative importance.

For the second research question, we found that indirect exposure, incidental exposure and blue space within a 10-15 minute walk from home were all positively associated with visiting the nearest blue space for recreation (intentional exposure). In terms of quality, perceptions that their nearest blue space had good facilities and wildlife to see predicted how often respondents used that blue space. This latter finding highlights the importance of good environmental quality in people’s willingness to visit blue space locations Previous research spanning survey, experimental and field work in Europe and Hong Kong has also highlighted the importance of both wildlife and facilities in relation to nature visits (Lee *et al.,*2015; McCormack *et al.,* 2010; Schipperijn *et al.,*2010; Veitch *et al.,* 2012; Wan & Shen 2015; White *et al.,* (2017). The lack of relationships between blue space visit frequency amd feelings of safety or incivilities, which had been found to be important in earlier studies (Calogiuri and Chroni, 2014), may be because the public spaces in Hong Kong are typically clean and street crime in Hong Kong is generally low (Barnett et al., 2015; Bouhours and Broadhurst, 2015; Broadhurst et al., 2017). Safety was also not elicited as important by users of green spaces in Hong Kong (Wan & Shen 2015).

Our final research question concerned whether certain characteristics of blue space visits were associated with recalled wellbeing. While perceived safety was not related to blue space visit frequency in the second research question, it was a predictor of recalled wellbeing during a single visit, along with presence of wildlife. Perceived species richness was found to be related to self-reported wellbeing in river side locations in Sheffield, UK (Dallimer *et al.,* 2012). Consistent with previous work, there was a positive association between duration and recalled wellbeing (van den Berg et al., 2016) although the current threshold of 60 minutes was higher than in some earlier studies (Barton and Pretty, 2010; Shanahan et al., 2016). Visits involving relatively high intensity activities were also more likely to be associated with a greater likelihood of reporting higher recalled wellbeing, again consistent with earlier work (MacKerron and Mourato, 2013). Controlling for general wellbeing suggests these effects are not merely the result of happier people being more likely to engage in more intense activities.

*Study Limitations*

Some limitations of this study should be addressed in future work. First, we recruited self-referred subjects who opted to join a screening programme and these individuals could be more health-conscious when compared with the general population. Our sample was also not representative of Hong Kong as a whole, in particular by age and home district. Hence, further studies are needed to explore the generalisability of our results, to the wider Hong Kong population. Nevertheless, findings were consistent with those from other studies in China (Ying et al., 2015), and studies using larger and more representative samples in other countries (de Vries et al., 2016; Wheeler et al., 2015) suggesting further research investment using a more systematic sampling approach is justified. Second, the cross-sectional nature of the data mean that causality cannot be assumed. Despite this, our results are consistent with both experimental findings between views of nature and health (Li and Sullivan, 2016; Wang et al., 2016) and longitudinal findings between blue space visits and wellbeing (MacKerron and Mourato, 2013) suggesting that the directionality inferred is more than possible. Third, we also recognise that surveys might not be able to comprehensively determine individuals’ lived experiences of blue spaces including their personal, historical and cultural significance. More qualitative work is therefore needed to explore these issues (Bell et al., 2015; Bell et al., 2018; Volker and Kistemann, 2013).*Conclusions*

In summary, in a sample of predominantly older adults in Hong Kong those who visit blue spaces regularly were more likely to have good mental wellbeing and those who had a view of blue space were more likely to report good general health. The environmental qualities related to blue space visit frequency were presence of wildlife and presence of good facilities. Finally, both duration and activity intensity were found to be related to the wellbeing outcome from a single visit along with perceived safety and presence of wildlife.

The current findings suggest that in Asian cities such as Hong Kong, maintaining public access to, and residential visibility of, waterfronts and other aquatic settings that are large enough to spend at least an hour in and which allow residents the opportunity to engage in high intensity activities, may offer important opportunities for protecting and promoting public health. While the current evidence suggests that potential benefits may already be experienced by those who regularly use these spaces, future work is needed to better understand how best to use this evidence to inform future urban planning and developments in the city. Despite the high availability of blue spaces in Hong Kong, over a quarter of our sample said they never visited blue space. Further research is needed to find out if interventions to blue spaces, such as improvements to facilities or biodiversity, would result in population level gains in mental wellbeing. Our findings thus have potentially significant implications for the design of living environments that incorporate a public health perspective.

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