



**The Independent Associations of Recorded Crime and  
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in New Zealand**

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-004058
Article Type:	Research
Date Submitted by the Author:	17-Sep-2013
Complete List of Authors:	Lovasi, Gina; Columbia University Mailman School of Public Health, Epidemiology Goh, Charlene; Columbia University Mailman School of Public Health, Epidemiology Pearson, Amber; University of Otago, Public Health Breetzke, Gregory; University of Canterbury, Geography
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, Health & safety < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, EPIDEMIOLOGY

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## The Independent Associations of Recorded Crime and Perceived Safety with Physical Health for Men and Women in New Zealand

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MeSH Terms: Crime, Health Status, New Zealand, Police, Residence Characteristics

Word Count: 2,771

## ABSTRACT

**Background:** Neighborhood crime may influence health through pathways involving direct trauma, chronic stress, or behaviors including physical activity. We investigated associations of both officially recorded crime and perceived neighborhood safety with physical health, evaluating potential effect modification by gender. **Methods:** Individual-level data including the SF-12 health index and perceived neighborhood safety from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to crime rates from the New Zealand Police (2008-2010) for each census area unit. Mixed effects regression models accounted for clustering using neighborhood-level random intercepts, and adjusted for sociodemographic characteristics and smoking. **Results:** Crime rates, especially those involving a weapon, predicted adults' perception of the neighborhood as unsafe to walk at night. Police-recorded crime rates, especially violent crime and crime occurring at night, were associated with worse physical health; the association with crime at night was significantly stronger among women (interaction p-value: 0.01). Adjustment for perceived safety slightly attenuated these associations. Perceiving the neighborhood as unsafe was independently associated with worse physical health (1.0 unit difference, 95% CI: -1.5 to -0.5). **Conclusions:** Gender may differentially modify the associations of officially recorded crime rates with physical health, but perceived neighborhood safety problems were consistently associated with worse physical health.

## Strengths and limitations of this study

### *Strengths*

- Use of geographically linked national data
- Multiple officially recorded crime rates by category
- Survey question on perceived neighborhood safety
- Crime rates from 2008-2010 were selected for their temporal correspondence with the data collection in 2010-2011, characterizing a period largely preceding our outcome measurement and using three years of data to obtain more stable rates
- SF-12 instrument used for outcome assessment has been validated[1] and recommended as a population health measure[2]
- Power to test for interaction by gender on the association between neighborhood crime and health

### *Limitations*

- Cross sectional and observational study design limit our ability to eliminate non-causal explanations
- Physical health status was self-reported, which could result in misclassification
- Missing data may lead to a biased estimate of the associations between crime rates, perceived safety, and health status
- Misclassification or reasons for missing data could differ by gender, potentially distorting the observed pattern of effect modification
- Measure of perceived safety did not explicitly state the source for concern with safety and some participants may be considering factors such as traffic hazards instead of crime
- Lower crime rates and other unique sociocultural factors may change how New Zealand neighborhoods function and influence health, limiting generalizability

## INTRODUCTION

Neighborhood characteristics have previously been shown to influence health.[3-5] Crime is one such neighborhood characteristic. Residents living in areas of higher crime have been shown to have worse physical health,[6-8] even after controlling for the potential confounding effect of sociodemographic characteristics. There are several causal pathways by which local crime rates can affect health, including trauma resulting from victimization or chronic stress[9] and anxiety related to a perceived threat.[10] Behavioral pathways could also play a role if outdoor physical activities such as walking in the neighborhood were restricted to minimize victimization risk, adversely affecting physical health.[11-13] Thus, potential health benefits may be among the reasons to pursue local crime prevention.

Although recorded crime may be thought to influence health status through perceived safety,[6] the role of perceived safety as a mediator of this relationship has often been assumed rather than tested empirically.[12] Independent or divergent associations have been observed for officially recorded crime as compared with perceived safety problems in analyses predicting health and health behaviors,[14-20] suggesting that recorded crime and perceived safety may not be simply serving as proxies for each other. In addition to officially recorded crime, the perception of safety may be influenced by environmental and neighborhood level factors such as social cohesion, street lighting and neighborhood physical disorder.[11 12] Yet, individual perceptions and responses to the local environment may not be the same for all groups.[21] Associations of local crime rates with health have been shown to vary based on local[22] or national socioeconomic context,[23] as well as by gender.[12 16 19 24-26]

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7 This study sought to assess the association of officially recorded crime and self-reported  
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9 perception of safety on physical health status in a national sample of adult New Zealanders using  
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11 data from the New Zealand General Social Survey (NZGSS) and crime data obtained from the  
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13 New Zealand Police. We hypothesized that recorded crime would be negatively associated with  
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15 physical health, and that the perception of a neighborhood as being ‘unsafe’ would both partially  
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17 mediate the relationship between recorded crime and physical health, as well as independently  
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19 predict worse physical health after controlling for recorded crime in the neighborhood of  
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21 residence. Distinguishable subsets of officially recorded crime rates (by crime type, time of  
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23 occurrence, involvement of a weapon) allow us to investigate what categories of crime are most  
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25 associated with perceiving a neighborhood as unsafe and with experiencing worse physical  
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27 health.[27] We explored whether these associations differed by gender, as men and women may  
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29 differ in their perception of neighborhood problems, or their stress and behavioral responses to  
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31 perceived safety hazards.  
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## 42 **MATERIALS AND METHODS**

### 43 **Study design and population**

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48 The New Zealand General Social Survey (NZGSS) was designed to provide information on the  
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50 well-being of New Zealanders. The NZGSS is a nationally representative cross-sectional survey  
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52 of New Zealand residents aged 15 years and over. Detailed information on sampling and  
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54 methodology of the NZGSS has been previously published.[28]  
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7 Briefly, the survey employed a multi-stage sample, and a total of 8,550 participants answered the  
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9 NZGSS personal questionnaire over a 12-month period from April 2010 to March 2011 (81%  
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11 response rate). The NZGSS was interviewer-administered in person using computer-assisted  
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13 personal interviews which covered a wide range of social and economic topics, including  
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15 sociodemographic characteristics, perceived neighborhood safety, and self-reported health.  
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### 22 **Physical health status outcome based on self-report**

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25 The outcome variable of interest--physical health status-- was self-assessed and measured in the  
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27 NZGSS by the commonly used SF-12 Health Index, a short version of the SF-36.[29] The SF-12  
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29 consists of twelve questions, covering aspects of both physical and mental health.[30] Example  
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31 questions: “In general, would you say your health is excellent, very good, good, fair or poor?”,  
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33 “During the past four weeks, how much of the time were you limited in the kind of work or other  
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35 regular daily activities you do as a result of your physical health?” Responses were weighted and  
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37 combined into a physical health summary score, the Transformed Physical Composite Score  
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39 (TPCS) ranging from 0 to 100.[31]  
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### 49 **Officially recorded crime rates**

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52 Data of officially recorded crime throughout New Zealand for the period (2008-2010) were  
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54 obtained from the New Zealand Police. The data included over 360,000 incidents of crime  
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56 recorded nationally, which have been geocoded and aggregated to the census area unit (CAU).  
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3 Each CAU contains approximately 2000 people. Crime data were categorized by type, whether a  
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Each CAU contains approximately 2000 people. Crime data were categorized by type, whether a weapon was involved, and whether the offence occurred at night. For overall crime and each category, the average count over the three-year period was combined with CAU population data to create average annual rates per 100,000 population (see Table 1). Crime rates were then linked to individual-data from the NZGSS based on the CAU corresponding to the residential address provided at the time of the NZGSS survey.

### **Perceptions of neighborhood as unsafe at night**

Perceptions of the neighborhood as being ‘unsafe’ at night was assessed by asking NZGSS participants: “How safe do you feel walking alone at night in your neighborhood?” Potential answers ranged on a Likert-type 4-point scale from 1 “very safe” to 4 “very unsafe”. Responses were dichotomized such that feeling “unsafe/very unsafe” was considered as representing a perceived safety problem for analyses. Similar measures have been used in previous studies either as an individual measure or as part of a composite scale.[16 32-34]

### **Individual sociodemographic characteristics and smoking**

Age group (age 15-24, age 25-44, age 45-64, and age 65+ years), gender, ethnicity (Māori, the indigenous population of New Zealand (1) vs. Non-Māori (0)), individual-level socio-economic status (SES), country of birth, and smoking status (never, former, current) were considered as physical health determinants that are also potentially associated with place of residence but not on the causal pathway, and thus as potential confounders. SES is a well-known confounder of the relationship between neighborhood characteristics and health;[5] available SES measures



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3 included education (none or national certificate 1-4, diploma or bachelors, or masters or  
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5 doctorate), employment (currently working for pay (1) vs. otherwise (0)), and income (\$0 to  
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7 20,000, \$20,001 to \$40,000, \$40,001 to 60,000, > \$60,000 per year). Being foreign-born has  
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9 been found to be associated with both neighborhood of residence and physical health status.[35]  
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11 Place of birth was dichotomized into New Zealand-born (1) and born outside of New Zealand (0).  
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### 20 **Statistical analyses**

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22 A linear probability model with cluster robust standard errors was used to explore the  
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24 relationships between crime rates and perception of the neighborhood as unsafe. Multi-level  
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26 mixed effects linear regression analyses were used to examine the associations between of  
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28 officially reported crime rates and perception of the neighborhood as unsafe predicting physical  
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30 health status. An intraclass correlation coefficient (ICC) was used to assess, and random  
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32 intercepts were used to account for, the potential non-independence of physical health status  
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34 scores within the same CAU. Due to the correlations between the different types of crime rates  
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36 (see Table 1), we assessed associations for each recorded crime rate separately and did not  
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38 mutually adjust for multiple categories of crime in the same model. All models controlled for age,  
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40 gender, ethnicity, place of birth, education, employment, income, and smoking status.  
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50 Perception of safety was added to models with officially recorded crime rates to test for  
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52 independent associations with health and to check for patterns of association consistent with  
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54 mediation of the crime rate-health associations. Mediation was expected to manifest as (1) an  
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56 association between higher crime rate and lower perceived safety, (2) an association between  
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3 lower perceived safety and worse health status, and (3) attenuation of the crime rate-health  
4 association when perceived safety is added to the model. Furthermore, as gender was of interest  
5 as a potential effect measure modifier, gender stratification was considered for all analyses; Wald  
6 p-values to evaluate the statistical significance of observed effect modification were calculated  
7 from models including a gender interaction. Participants with missing values for any of the  
8 analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.  
9 All statistical analyses were carried out in a secure data lab in Wellington, New Zealand using  
10 Stata 11.0 software (Stata Corp., College Station, TX, USA).  
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## 30 **RESULTS**

### 31 **Study participants**

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34 Table 2 shows the characteristics of the study population (N=6,995). There were similar numbers  
35 of men (n= 3,310) and women (n=3,685). Twelve percent of the study participants were of Māori  
36 ethnicity. Most participants were New Zealand born (77%) and 65% of participants were  
37 currently employed. Approximately 21% of men reported feeling unsafe or very unsafe walking  
38 alone at night in their neighborhood compared with 52% of women.  
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53 The physical health index (TPCS based on SF-12) had a theoretical range from 0 to 100, with  
54 higher values indicating better physical health. The observed mean and standard deviation were  
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3 similar for men and women. The ICC for the physical health index across CAUs suggests that  
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5 3.1% of the outcome variation may be explained at the CAU level (95% confidence interval:  
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7 1.7% to 4.5%).  
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### 14 **Association between officially recorded crime rates and perceived safety**

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18 Total and category-specific crime rates were significantly associated with the perception of one's  
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20 neighborhood as unsafe for walking at night (Table 3). Associations were statistically significant  
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22 for both genders and for all categories of crimes rates, except among men the trend was not  
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24 statistically significant for dishonesty crime (gender interaction p-value = 0.03). The crime  
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26 category that most strongly predicted perceived safety was crime with a weapon: for each  
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28 additional crime per 100,000 residents in this category women were 15.7% more likely to  
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30 perceive their neighborhood as unsafe and men were 10.0% more likely to perceive their  
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32 neighborhood as unsafe.  
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### 41 **Association between officially recorded crime and physical health status**

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44 Total crime rate had a non-significant association with lower physical health overall and among  
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46 men (Table 4). However, among women, the total crime rate, violent crime rate, and crime at  
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48 night were significantly associated with a lower physical health index (coefficients were -0.15, -  
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50 0.32, and -0.29, respectively). This suggests that for each additional crime per 100,000 residents  
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52 we would expect a decrease in the physical health index of 0.15 units, or perhaps an  
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3 approximately 0.3 unit decrease if the additional crime were violent or committed at night. The  
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5 effect modification by gender was only statistically significant for crime at night ( $p=0.01$ ).  
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11 To assess if the perception of one's neighborhood as being unsafe mediated the associations  
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13 between recorded crime and physical health status, an indicator of perceived safety was added to  
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15 models of recorded crime and health status. The addition of perceived safety changed the  
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17 magnitude of the statistically significant regression coefficients by 9 to 23 percent (see Table 4).  
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19 For women, the rates of violent crime and crime occurring at night remained significantly  
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21 associated with physical health after controlling for perception of neighborhood as unsafe.  
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### 30 **Association between perceived crime and physical health status**

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32 Both men and women perceiving their neighborhood as unsafe for walking at night had lower  
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34 predicted physical health index: men perceiving their neighborhood as unsafe versus safe had a  
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36 predicted difference of 1.3 units on the physical health index, and women had a predicted  
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38 difference of 0.9 units (Table 5). These associations remained statistically significant and similar  
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40 in magnitude after controlling for recorded crime rates.  
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## 50 **DISCUSSION**

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52 For this population of adults living in New Zealand, we observed robust associations between  
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54 objectively recorded crime rates and perceived neighborhood safety, and between perceived  
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3 neighborhood safety and physical health. However, there was some evidence of effect  
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5 modification by gender in the association between objectively recorded crime rates and physical  
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7 health. Moreover, the category of crime rates most strongly associated with perceived safety  
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9 (crime with a weapon) was not among the categories most strongly associated with physical  
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11 health (violent crime and crime at night). The observed patterns were somewhat supportive of  
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13 the hypothesized role of perceived safety as a mediator between officially recorded crime rates  
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15 and physical health among women. However, the observed patterns indicate potential  
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17 heterogeneity by crime type and gender.  
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26 An understanding of the several causal pathways through which crime may affect health can help  
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28 explain these separate associations, and differences across categories of crime. It appears that for  
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30 women, violent crime and crimes occurring at night were negatively associated with health status  
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32 even after controlling for any indirect association through perceived safety. Yet the magnitude of  
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34 association between perceived neighborhood safety and physical health showed a trend to be  
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36 larger for men than women. These findings highlight separate associations of officially recorded  
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38 crime versus perceived safety hazards on health, and that these associations may differ by gender.  
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40 Our results corroborate other studies[15 16 19 36] which have found independent associations  
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42 for between the perception of safety and officially recorded crime with health status or health-  
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44 related behavior.[14 19]. Perceived safety - instead of merely being a reflection of recorded  
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46 crime - is an independent construct that can be influenced by a variety of environmental cues  
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48 such as the physical features of public spaces, lighting levels, media stories and social  
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50 incivilities.[11] While perceived safety may in part mediate the association between recorded  
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52 crime and physical health status among women in our study, the association of perceived crime  
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3 with adverse physical health was notable and statistically significant among men, even though  
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5 recorded crime rates were not associated with physical health for these same men.  
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11 It is worth noting that when effect modification by gender has been explored in previous studies  
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13 of crime or safety as predictors of physical health, the patterns have not always been consistent  
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15 with our findings. For example, others have reported a stronger association between perceived  
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17 safety and health status for women,[12] whereas in this study we found a trend in the opposite  
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19 direction, though the effect modification was not statistically significant. Some of the literature  
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21 on perceived safety and physical activity has pointed to stronger associations for men[25 37] or  
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23 failed to detect an association among women[19 38 39]. One potential explanation for the  
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25 stronger associations between perceived safety and physical activity and physical health among  
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27 men involve reverse causation, with physically healthy men more likely to perceive themselves  
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29 as being safe from crime. The inconsistent evidence for the association between perceived crime  
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31 on health status by gender underscores the importance of using both officially recorded and  
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33 perceived crime measures and presenting gender stratified results even when the pattern of effect  
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35 modification seems contrary to current assumptions.  
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#### 47 *Strengths and Limitations*

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50 Key strengths of this study are the use of geographically linked national data, and the availability  
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52 of multiple officially recorded crime rates by category as well as a survey question on perceived  
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54 neighborhood safety. Crime rates from 2008-2010 were selected for their temporal  
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56 correspondence with the data collection in 2010-2011, characterizing a period largely preceding  
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3 our outcome measurement and using three years of data to obtain more stable rates. The SF-12  
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5 instrument used for outcome assessment has been validated[1] and recommended as a population  
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7 health measure.[2]  
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12 However, the cross sectional and observational study design limit our ability to eliminate non-  
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14 causal explanations such as reverse causation and unmeasured confounding. Physical health  
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16 status was self-reported and this could result in misclassification. Missing data was also an  
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18 important limitation. In particular, the large number of participants who selected “Not  
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20 applicable”, “Don’t know” or “Refused” in response to the question on perceived safety  
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22 (N=1092) may have included those who already avoided walking home at night due to safety  
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24 concerns or health limitations, and this could lead to a biased estimate of the associations  
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26 between crime rates, perceived safety, and health status. Misclassification or reasons for missing  
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28 data could also differ by gender, potentially distorting the observed pattern of effect modification.  
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30 The measure of perceived safety also did not explicitly state the source for concern with safety  
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32 and some participants may be considering factors such as traffic hazards instead of crime. Last,  
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34 crime rates in New Zealand are lower than in many other countries (for example in 2000, the  
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36 New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000  
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38 population in the USA[40]); this and other unique sociocultural factors may change how its  
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40 neighborhoods function and influence health, limiting the generalizability of our results.  
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54 *Conclusion*  
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3 In conclusion, complex patterns of association were observed linking crime rates to physical  
4 health among men and women in New Zealand. Future studies should continue to explore  
5 differences by crime category and by gender, and across the multiple pathways that may link  
6 crime rates to physical health status. Usage of both officially recorded crime and perceived  
7 safety measures is important to tease apart the differences in what they reflect and how they may  
8 influence health differently for men and women. Perceived neighborhood safety in particular  
9 appears to be a robust predictor of physical health independent of officially recorded crime rates,  
10 and potentially modifiable neighborhood characteristics affecting perceived safety warrant  
11 further investigation.  
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## Summary Box

### *What is already known on this subject?*

Findings on the association between neighborhood crime and health differ with the use of officially recorded crime rates or self-reported perception of safety. Effect modification by gender has been observed in some settings, but many studies lacked the power to test for interaction by gender or the data to explore such interactions across multiple safety-related measures.

### *What this study adds?*

Our study illustrates the importance of using both officially recorded crime and perceived safety measures and exploring effect modification by gender. The multiple pathways by which local crime rates affect physical health may differ between men and women and by category of crime, yet perceived neighborhood safety was independently associated with physical health for both men and women even after accounting for local crime rates. Further investigation of perceived safety may be needed in order to identify key neighborhood characteristics for public health interventions.

**Table 1. Correlation matrix of New Zealand Police recorded crime rates by category**

Category label and definition	Mean (SD)	Total	Violent	Property	Dishonesty	Drug	Weapon
Total crime	2.2 (2.2)	-					
Violent crime (minor assault, serious assault and grievous assault)	1.0 (1.4)	0.56	-				
Property crime (burglary and theft)	0.5 (0.8)	0.42	0.64	-			
Dishonesty crime (involving destruction of property)	0.7 (1.1)	0.42	0.49	0.52	-		
Drug and antisocial crime (drug-related and disorder)	0.6 (1.2)	0.46	0.45	0.46	0.35	-	
Crime with a weapon	0.1 (0.3)	0.32	0.51	0.50	0.34	0.38	-
Crime at night (committed between 8pm and 7:59am)	1.2 (1.6)	0.56	0.80	0.65	0.57	0.57	0.48

Notes: Mean annual rate of crime was calculated for 2008-2010 using count per 100,000 residents for each census area unit; descriptive statistics and Pearson's correlations shown are calculated across individual NZGSS participants (N=6,995)

**Table 2. Characteristics of 2010 New Zealand General Social Survey Participants**

	Total N=6,995	Men N=3,310	Women N=3,685
Age group			
15-24	12	13	12
25-44	36	34	37
45-64	35	34	35
65+	18	18	17
Ethnicity			
Māori	12	10	13
Nativity			
Born in New Zealand	77	76	78
Highest completed education			
None or national certificate 1-4	66	70	63
Diploma or bachelors	25	22	27
Masters or doctorate	9	8	9
Employment			
Currently working for pay	65	70	60
Income			
≤ \$20,000	36	28	43
\$20,001-40,000	27	24	30
\$40,001-60,000	18	21	15
\$60,001+	19	27	12
Smoking status			
Regular smoker, current	20	20	19
Regular smoker, former	29	31	26
Never smoker	52	49	54
Neighborhood safety (self-report)			
Safe or very safe	63	79	48
Unsafe or very unsafe	37	21	52
Physical health (TPCS)	49.6 (9.9)	49.8 (9.5)	49.5 (10.2)

Notes: Values shown are % or mean (SD)

**Table 3. Associations between Recorded Crime Rates and Self-Reported Perception of Neighborhood as Unsafe among Men and Women in New Zealand**

	Overall β (95% CI)	Men β (95% CI)	Women β (95% CI)	Gender interaction p-value
Total Crime	<b>1.9 (1.2, 2.5)</b>	<b>1.4 (0.6, 2.1)</b>	<b>2.2 (1.4, 3.1)</b>	0.15
Violent Crime	<b>4.3 (3.1, 5.4)</b>	<b>4.0 (2.6, 0.5)</b>	<b>4.5 (3.0, 5.9)</b>	0.89
Property Crime	<b>5.4 (3.4, 7.4)</b>	<b>4.2 (1.9, 6.4)</b>	<b>6.5 (4.1, 9.0)</b>	0.14
Dishonesty crime	<b>2.1 (0.6, 3.5)</b>	0.7 (-0.7, 2.2)	<b>3.2 (1.2, 5.2)</b>	<b>0.03</b>
Drug and Antisocial Crime	<b>2.2 (0.9, 3.4)</b>	<b>1.9 (0.4, 3.4)</b>	<b>2.4 (0.8, 3.9)</b>	0.85
Crime with a weapon	<b>12.9 (8.8, 17.0)</b>	<b>10.0 (5.0, 15.1)</b>	<b>15.7 (9.9, 21.4)</b>	0.19
Crime occurring in the night	<b>3.0 (2.0, 4.0)</b>	<b>2.7 (1.6, 3.9)</b>	<b>3.2 (1.9, 4.5)</b>	0.80

Notes: Rescaled coefficients and 95% confidence intervals from linear probability models with cluster robust standard errors are shown, and coefficients (which have been multiplied by 100) can be interpreted as in the expected increase in percentage of participants reporting their neighborhood as unsafe per 1 unit increase in the category-specific crime rate; models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added to separate models (not mutually adjusted); boldface is used to indicate statistical significance (p<0.05)

**Table 4. Associations between Recorded Crime Rates and Self-reported Physical Health Status among Men and Women in New Zealand**

	Overall β (95% CI)	Men β (95% CI)	Women β (95% CI)	Gender interaction p-value
Total crime	-0.09 (-0.19, 0.01)	-0.04 (-0.17, 0.10)	<b>-0.15</b> <b>(-0.29, -0.01)</b>	0.27
with perceived safety	-0.07 (-0.17, 0.02)	-0.02 (-0.16, 0.12)	-0.13 (-0.27, 0.00)	
Violent crime	<b>-0.17</b> <b>(-0.34, -0.01)</b>	-0.03 (-0.25, 0.19)	<b>-0.32</b> <b>(-0.55, -0.09)</b>	0.07
with perceived safety	<b>-0.13</b> <b>(-0.30, 0.03)</b>	-0.02 (-0.20, 0.24)	<b>-0.29</b> <b>(-0.52, -0.05)</b>	
Property crime	-0.13 (-0.41, 0.14)	0.08 (-0.29, 0.45)	-0.33 (-0.73, 0.06)	0.14
with perceived safety	-0.08 (-0.35, 0.19)	0.13 (-0.24, 0.50)	-0.28 (-0.68, 0.12)	
Dishonesty crime	-0.10 (-0.30, 0.10)	0.05 (-0.22, 0.32)	-0.27 (-0.55, 0.02)	0.11
with perceived safety	-0.08 (-0.28, 0.12)	0.06 (-0.21, 0.33)	-0.24 (-0.53, 0.05)	
Drug and Antisocial crime	0.17 (-0.01, 0.36)	0.24 (-0.01, 0.50)	0.10 (-0.16, 0.36)	0.40
with perceived safety	<b>0.19</b> <b>(0.01, 0.38)</b>	<b>0.27</b> <b>(0.02, 0.52)</b>	0.12 (-0.14, 0.38)	

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Crime with a weapon	0.32 (-0.35, 0.99)	0.61 (-0.29, 1.51)	-0.04 (-1.00, 0.92)	0.33
with perceived safety	0.44 (-0.22, 1.11)	0.74 (-0.16, 1.64)	0.09 (-0.87, 1.06)	
Crime at night	-0.11 (-0.25, 0.03)	0.05 (-0.14, 0.24)	<b>-0.29</b> <b>(-0.49, -0.09)</b>	<b>0.01</b>
with perceived safety	-0.08 (-0.22, 0.06)	0.08 (-0.11, 0.27)	<b>-0.26</b> <b>(-0.46, -0.06)</b>	

Notes: Coefficients and 95% confidence intervals from linear mixed models are shown, and the coefficients can be interpreted as the predicted difference in self-reported physical health status (as measured by the SF-12 transformed physical component score) associated with a 1 unit increase in the category-specific crime rate; all models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates for different categories were added to separate models (not mutually adjusted), and results are shown before and after the addition of perceived safety to the models; boldface is used to indicate statistical significance (p<0.05)

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**Table 5. Associations between Perception of Safety and Self-Reported Physical Health Status, Controlling for Recorded Crime among Men and Women Living in New Zealand (2010-2011)**

	Overall $\beta$ (95% CI)	Men $\beta$ (95% CI)	Women $\beta$ (95% CI)	Gender interaction p-value
Neighborhood perceived as unsafe	<b>-0.99</b> <b>(-1.46, -0.51)</b>	<b>-1.31</b> <b>(-2.05, -0.57)</b>	<b>-0.86</b> <b>(-1.48, -0.24)</b>	0.31
with total crime	<b>-0.96</b> <b>(-1.44, -0.48)</b>	<b>-1.30</b> <b>(-2.04, -0.56)</b>	<b>-0.80</b> <b>(-1.43, -0.17)</b>	
with violent crime	<b>-0.94</b> <b>(-1.42, -0.46)</b>	<b>-1.32</b> <b>(-2.06, -0.57)</b>	<b>-0.77</b> <b>(-1.39, -0.14)</b>	
with property crime	<b>-0.98</b> <b>(-1.45, -0.50)</b>	<b>-1.33</b> <b>(-2.07, -0.59)</b>	<b>-0.82</b> <b>(-1.44, -0.19)</b>	
with dishonesty crime	<b>-0.98</b> <b>(-1.46, -0.51)</b>	<b>-1.31</b> <b>(-2.05, -0.57)</b>	<b>-0.82</b> <b>(-1.45, -0.20)</b>	
with drug and antisocial crime	<b>-1.02</b> <b>(-1.49, -0.54)</b>	<b>-1.35</b> <b>(-2.09, -0.61)</b>	<b>-0.88</b> <b>(-1.50, -0.25)</b>	
with crime with a weapon	<b>-1.02</b> <b>(-1.49, -0.54)</b>	<b>-1.36</b> <b>(-2.10, -0.62)</b>	<b>-0.87</b> <b>(-1.49, -0.24)</b>	
with crime at night	<b>-0.96</b> <b>(-1.44, -0.48)</b>	<b>-1.34</b> <b>(-2.08, -0.60)</b>	<b>-0.78</b> <b>(-1.41, -0.16)</b>	

Notes: Coefficients and 95% confidence intervals from multi-level linear models predicting the physical health index are shown, and coefficients can be interpreted as the predicted difference in physical health status (as measured by the SF-12 transformed physical component score) for comparing those reporting their neighborhood as unsafe for walking at night versus safe for walking at night; covariates include age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added one at a time to adjusted models, and the coefficients for perceiving neighborhood as unsafe are shown before and after adjustment for each of these crime rates; boldface is used to indicate statistical significance ( $p < 0.05$ )

## Disclaimer

Access to the data used in this study was provided by Statistics New Zealand under conditions designed to uphold the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the authors, not Statistics New Zealand.

## Acknowledgements

We would also like to acknowledge the support of New Zealand Police who provided crime data for this work; and to Statistics New Zealand who provided us with access to data from the General Social Survey.

## Competing Interests

None

## Funding

The authors of this report would like to acknowledge the Christchurch City Council for initiating the research and Ministry of Justice Crime Prevention Unit for the provision of funding, which allowed the project to commence smoothly. The first author would also like to thank the National Institute for Child Health and Human Development (K01HD067390) for their financial support.

## Contributorship

All authors critically reviewed manuscript drafts and approved the submission. GSL, ALP and GB conceived the project. GB prepared the official crime rate data for linkage to the NZ GSS. ALP conducted analyses in the secure data lab, with syntax and input from GSL. CEG created tables from the output files and drafted the initial manuscript. GSL revised and integrated comments on the final tables and text.



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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Title and abstract	Item No	Recommendation
	1	<p>(a) Indicate the study's design with a commonly used term in the title or the abstract  <i>The design is indicated in the abstract: "Individual-level data including the SF-12 health index and perceived neighborhood safety from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to crime rates from the New Zealand Police (2008-2010) for each census area unit."</i></p> <hr/> <p>(b) Provide in the abstract an informative and balanced summary of what was done and what was found  <i>We have endeavoured to provide an informative and balanced summary in the abstract:</i>  <i>"Background: Neighborhood crime may influence health through pathways involving direct trauma, chronic stress, or behaviors including physical activity. We investigated associations of both officially recorded crime and perceived neighborhood safety with physical health, evaluating potential effect modification by gender.</i>  <i>Methods: Individual-level data including the SF-12 health index and perceived neighborhood safety from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to crime rates from the New Zealand Police (2008-2010) for each census area unit. Mixed effects regression models accounted for clustering using neighborhood-level random intercepts, and adjusted for sociodemographic characteristics and smoking.</i>  <i>Results: Crime rates, especially those involving a weapon, predicted adults' perception of the neighborhood as unsafe to walk at night. Police-recorded crime rates, especially violent crime and crime occurring at night, were associated with worse physical health; the association with crime at night was significantly stronger among women (interaction p-value: 0.01). Adjustment for perceived safety slightly attenuated these associations. Perceiving the neighborhood as unsafe was independently associated with worse physical health (1.0 unit difference, 95% CI: -1.5 to -0.5).</i>  <i>Conclusions: Gender may differentially modify the associations of officially recorded crime rates with physical health, but perceived neighborhood safety problems were consistently associated with worse physical health."</i></p>
<b>Introduction</b>	2	<p>Explain the scientific background and rationale for the investigation being reported  <i>Background and rationale are described in the first paragraph of the introduction: "Neighborhood characteristics have previously been shown to influence health.[1-3] Crime is one such neighborhood characteristic. Residents living in areas of higher crime have been shown to have worse physical health,[4-6] even after controlling for the potential confounding effect of sociodemographic characteristics... Although recorded crime may be thought to influence health status through perceived safety,[4] the role of perceived safety as a mediator of this relationship has often been assumed rather than tested empirically.[10] Independent or divergent associations have been observed for officially recorded crime as compared with perceived safety problems in analyses predicting health and health behaviors,[12-18] suggesting that recorded crime and perceived safety may not be simply serving as proxies for each other.</i></p>

*Associations of local crime rates with health have been shown to vary based on local[20] or national socioeconomic context,[21] as well as by gender.”*

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Objectives	3	<p>State specific objectives, including any prespecified hypotheses</p> <p><i>Objectives and hypotheses are provided in the last paragraph of the introduction: “This study sought to assess the association of officially recorded crime and self-reported perception of safety on physical health status in a national sample of adult New Zealanders using data from the New Zealand General Social Survey (NZGSS) and crime data obtained from the New Zealand Police. We hypothesized that recorded crime would be negatively associated with physical health, and that the perception of a neighborhood as being ‘unsafe’ would both partially mediate the relationship between recorded crime and physical health, as well as independently predict worse physical health after controlling for recorded crime in the neighborhood of residence. Distinguishable subsets of officially recorded crime rates (by crime type, time of occurrence, involvement of a weapon) allow us to investigate what categories of crime are most associated with perceiving a neighborhood as unsafe and with experiencing worse physical health.[25] We explored whether these associations differed by gender, as men and women may differ in their perception of neighborhood problems, or their stress and behavioral responses to perceived safety hazards.”</i></p>
<b>Methods</b>		
Study design	4	<p>Present key elements of study design early in the paper</p> <p><i>The study design is discussed briefly in the first paragraph of the methods section and a reference for detailed methodological information given: “The New Zealand General Social Survey (NZGSS) was designed to provide information on the well-being of New Zealanders. The NZGSS is a nationally representative cross-sectional survey of New Zealand residents aged 15 years and over. Detailed information on sampling and methodology of the NZGSS has been previously published.[26]”</i></p>
Setting	5	<p>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection</p> <p><i>This information is provided in the methods</i></p> <p><i>“Briefly, the survey employed a multi-stage sample, and a total of 8,550 participants answered the NZGSS personal questionnaire over a 12-month period from April 2010 to March 2011 (81% response rate). The NZGSS was interviewer-administered in person using computer-assisted personal interviews which covered a wide range of social and economic topics, including sociodemographic characteristics, perceived neighborhood safety, and self-reported health.”</i></p>
Participants	6	<p>(a) Give the eligibility criteria, and the sources and methods of selection of participants</p> <p><i>This was briefly covered with further details available from the reference: “The NZGSS is a nationally representative cross-sectional survey of New Zealand residents aged 15 years and over”</i></p>
Variables	7	<p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable</p> <p><i>Measures are described within the following methods sub-sections:</i></p> <p><i>Physical health status outcome based on self-report</i></p> <p><i>Officially recorded crime rates</i></p> <p><i>Perceptions of neighborhood as unsafe at night</i></p> <p><i>Individual sociodemographic characteristics and smoking</i></p>

Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group <i>The sources of data and details of methods of measurement are described in their respective methods sub-sections.</i>
Bias	9	Describe any efforts to address potential sources of bias <i>We used covariate adjustments, neighbourhood-level random intercepts, and assessed associations for each recorded crime rate separately to account for potential sources of bias, as described in the methods section.</i> <i>“A linear probability model with cluster robust standard errors was used to explore the relationships between crime rates and perception of the neighborhood as unsafe. Multi-level mixed effects linear regression analyses were used to examine the associations between of officially reported crime rates and perception of the neighborhood as unsafe predicting physical health status. An intraclass correlation coefficient (ICC) was used to assess, and random intercepts were used to account for, the potential non-independence of physical health status scores within the same CAU. Due to the correlations between the different types of crime rates (see Table 1), we assessed associations for each recorded crime rate separately and did not mutually adjust for multiple categories of crime in the same model. All models controlled for age, gender, ethnicity, place of birth, education, employment, income, and smoking status.”</i>
Study size	10	Explain how the study size was arrived at <i>The present analysis was on a subset of the analytic database, restricted based on a complete-case approach.</i> <i>“Participants with missing values for any of the analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.”</i>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why <i>In order to make the quantitative results more informative, recorded crime rates were rescaled, such that one unit was equal to one standard deviation regardless of the original scale:</i> <i>“Coefficients and 95% confidence intervals from linear mixed models are shown, and the coefficients can be interpreted as the predicted difference in self-reported physical health status (as measured by the SF-12 transformed physical component score) associated with a one standard deviation higher crime rate.”</i>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding <i>Confounder selection and adjustment is described in the methods, and noted in table footnotes. Covariates were entered in the form shown in Table 2. In addition, we note that we did not mutually adjust associations for the other category-specific crime rates, and that mutual adjustment of officially recorded crime rates and perceived safety was considered apart from the main analysis, due to potential mediation.</i> <i>“Due to the correlations between the different types of crime rates (see Table 1), we assessed associations for each recorded crime rate separately and did not mutually adjust for multiple categories of crime in the same model. All models controlled for age, gender, ethnicity, place of birth, education, employment, income, and smoking status.</i>

*Perception of safety was added to models with officially recorded crime rates to test for independent associations with health and to check for patterns of association consistent with mediation of the crime rate-health associations.”*

(b) Describe any methods used to examine subgroups and interactions

*Gender was considered as potentially modifying the effect of officially recorded crime or perceived safety.*

*“Furthermore, as gender was of interest as a potential effect measure modifier, gender stratification was considered for all analyses; Wald p-values to evaluate the statistical significance of observed effect modification were calculated from models including a gender interaction.”*

(c) Explain how missing data were addressed

*We used a complete-case analysis.*

*“Participants with missing values for any of the analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.”*

(d) If applicable, describe analytical methods taking account of sampling strategy

*Our study did not use sample weights, but did account for the potential non-independence of observations in the same census area unit.*

(e) Describe any sensitivity analyses

*Our analyses considered the sensitivity of our findings to the measure of safety used by considering categories of officially recorded crime (type, weapon use, time of day) and perception of neighbourhood safety as predictors of interest.*

## Results

Participants	13*	<p>(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed</p> <p><i>We presented this briefly in the Methods sections and included a reference for the more detailed methodology.</i></p> <p>(b) Give reasons for non-participation at each stage</p> <p><i>We do not have information for the reasons for non-participation in the NZGSS, but provide the response rate, which is 81%.</i></p> <p>(c) Consider use of a flow diagram</p> <p><i>We felt that the numbers participating in the study (N= 8550) and those finally analysed (N=6995) in the text was succinct, and we are at the journal-specified limit for tables and figures.</i></p>
Descriptive data	14*	<p>(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders</p> <p><i>This information is given in Table 2. We elected to present gender stratified groups rather than stratifying on exposure because of our interest in effect modification by gender, and our interest in multiple crime and safety-related exposures, some of which are continuous.</i></p> <p>(b) Indicate number of participants with missing data for each variable of interest</p> <p><i>We provided the number of participants with missing data for perception of safety in the Discussion as this made up the majority (70%) of the observations excluded due to missing data and was of greatest concern for the validity of the analyses.</i></p> <p><i>“In particular, the large number of participants who selected “Not applicable”, “Don’t know” or “Refused” in response to the question on perceived safety (N=1092) may have included those who already avoided walking home at night due to safety concerns or health limitations, and this could lead to a biased estimate of the</i></p>



*associations between crime rates, perceived safety, and health status.”*

Outcome data	15*	Report numbers of outcome events or summary measures <i>Table 2 provides the mean physical health score, and additional information is provided in the second paragraph of the results section: “The physical health index (TPCS based on SF-12) had a theoretical range from 0 to 100, with higher values indicating better physical health. The observed mean and standard deviation were similar for men and women. The ICC for the physical health index across CAUs suggests that 3.1% of the outcome variation may be explained at the CAU level (95% confidence interval: 1.7% to 4.5%).”</i>
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included <i>We do not present the unadjusted estimates as we felt that the sociodemographic confounders considered are crucial to account for when interpreting this association. Tables 3, 4, and 5 present adjusted estimates (and 95% confidence intervals), with footnotes clarifying the adjustment strategy. The rationale for confounder selection is discussed in the Methods section.</i> <hr/> <i>(b) Report category boundaries when continuous variables were categorized Table 2 shows the maximum and minimum of each category for the covariates age and income.</i> <hr/> <i>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Not applicable.</i>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses <i>Subgroups, interactions, and sensitivity analyses are all presented. Time constraints imposed by working in a secure data lab required us to focus narrowly on the analyses that would address our hypotheses.</i>
<b>Discussion</b>		
Key results	18	Summarise key results with reference to study objectives <i>Key findings are described in the first paragraph of the discussion: “For this population of adults living in New Zealand, we observed robust associations between objectively recorded crime rates and perceived neighborhood safety, and between perceived neighborhood safety and physical health. However, there was some evidence of effect modification by gender in the association between objectively recorded crime rates and physical health. Moreover, the category of crime rates most strongly associated with perceived safety (crime with a weapon) was not among the categories most strongly associated with physical health (violent crime and crime at night). The observed patterns were somewhat supportive of the hypothesized role of perceived safety as a mediator between officially recorded crime rates and physical health among women. However, the observed patterns indicate potential heterogeneity by crime type and gender.”</i>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <i>Limitations are discussed as follows: “However, the cross sectional and observational study design limit our ability to eliminate non-causal explanations such as reverse causation and unmeasured confounding. Physical health status was self-reported and this could result in</i>

*misclassification. Missing data was also an important limitation. In particular, the large number of participants who selected “Not applicable”, “Don’t know” or “Refused” in response to the question on perceived safety (N=1092) may have included those who already avoided walking home at night due to safety concerns or health limitations, and this could lead to a biased estimate of the associations between crime rates, perceived safety, and health status. Misclassification or reasons for missing data could also differ by gender, potentially distorting the observed pattern of effect modification. The measure of perceived safety also did not explicitly state the source for concern with safety and some participants may be considering factors such as traffic hazards instead of crime. Last, crime rates in New Zealand are lower than in many other countries (for example in 2000, the New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000 population in the USA[40]); this and other unique sociocultural factors may change how its neighborhoods function and influence health, limiting the generalizability of our results.”*

Interpretation	20	<p>Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence</p> <p><i>We have made an effort to keep our conclusions cautious, putting them within a larger perspective of the evidence surrounding crime rates and health, with the need for further investigations :</i></p> <p><i>“In conclusion, complex patterns of association were observed linking crime rates to physical health among men and women in New Zealand. Future studies should continue to explore differences in by crime category and by gender, and across the multiple pathways that may link crime rates to physical health status. Usage of both officially recorded crime and perceived safety measures is important to tease apart the differences in what they reflect and how they may influence health differently for men and women. Perceived neighborhood safety in particular appears to be a robust predictor of physical health independent of officially recorded crime rates, and potentially modifiable neighborhood characteristics affecting perceived safety warrant further investigation.”</i></p>
Generalisability	21	<p>Discuss the generalisability (external validity) of the study results</p> <p><i>We note that our findings cannot be generalized beyond the country of study:</i></p> <p><i>“Last, crime rates in New Zealand are lower than in many other countries (for example in 2000, the New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000 population in the USA[40]); this and other unique sociocultural factors may change how its neighborhoods function and influence health, limiting the generalizability of our results.”</i></p>
<b>Other information</b>		
Funding	22	<p>Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based</p> <p><i>Details of funding for this project are provided:</i></p> <p><i>“The authors of this report would like to acknowledge the Christchurch City Council for initiating the research and Ministry of Justice Crime Prevention Unit for the provision of funding, which allowed the project to commence smoothly. The first author would also like to thank the National Institute for Child Health and Human Development (K01HD067390) for their financial support.”</i></p> <p><i>Also, the role of funders was noted under funding in the online submission form:</i></p> <p><i>“The funders had no role in the design, conduct, or publication of the research.”</i></p>

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2 \*Give information separately for exposed and unexposed groups.  
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4 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and  
5 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely  
6 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at  
7 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is  
8 available at [www.strobe-statement.org](http://www.strobe-statement.org).  
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Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-004058.R1
Article Type:	Research
Date Submitted by the Author:	17-Jan-2014
Complete List of Authors:	Lovasi, Gina; Columbia University Mailman School of Public Health, Epidemiology Goh, Charlene; Columbia University Mailman School of Public Health, Epidemiology Pearson, Amber; University of Otago, Public Health Breetzke, Gregory; University of Canterbury, Geography
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	PUBLIC HEALTH, Health & safety < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, EPIDEMIOLOGY

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# The Independent Associations of Recorded Crime and Perceived Safety with Physical Health in a Nationally Representative Cross-Sectional Survey of Men and Women in New Zealand

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MeSH Terms: Crime, Health Status, New Zealand, Police, Residence Characteristics

Word Counts: 300 words in abstract, 2,931 words in text

## ABSTRACT

**Objectives:** We investigated associations of officially recorded crime and perceived neighborhood safety with physical health, evaluating potential effect modification by gender.

**Setting:** Nationally representative population-based survey in New Zealand

**Participants:** Individual-level data from 6,995 New Zealand General Social Survey (2010-2011) participants with complete data on physical health status, perceived neighborhood safety, sociodemographic characteristics, and smoking. Crime rate for each participant's home census was estimated based on data from the New Zealand Police (2008-2010).

**Primary outcome measure:** The Transformed Physical Composite Score from the SF-12, a physical health summary score based on self-report ranging from 0 to 100.

**Results:** We used cluster robust multivariable regression models to examine the associations among neighborhood crime rates, perceived neighborhood safety, and the physical health summary score. Crime rates predicted adults' perception that it was unsafe to walk in their neighborhood at night: for each additional crime per 100,000 residents adults were 1.9% more likely to perceive their neighborhood as unsafe (95% CI: 1.2% to 2.5%). While relatively uncommon, the rate of crime with a weapon strongly predicted perceived safety: for each additional crime per 100,000 residents in this category adults were 12.9% more likely to report the neighborhood as unsafe (95% CI: 8.8% to 17.0%). Police-recorded violent and night crime rates were associated with worse physical health among women: for each additional crime per 100,000 residents in these category women had a 0.3 point lower physical health score (95% CIs: -0.6 to -0.1 for violent crime and -0.5 to -0.1 for crime at night, gender interaction p-values 0.08

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3 and 0.01, respectively). Perceiving the neighborhood as unsafe was independently associated  
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5 with 1.0 point lower physical health score (95% CI: -1.5 to -0.5).  
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9 **Conclusions:** Gender may modify the associations of officially recorded crime rates with  
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11 physical health. Perceived neighborhood safety was independently associated with physical  
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13 health.  
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## 15 16 17 18 19 20 21 22 23 24 25 26 27 28 **Strengths and limitations of this study** 29

### 30 31 *Strengths* 32

- 33
- 34 • Use of geographically linked national data
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- 36 • Multiple officially recorded crime rates by category using three years of data to obtain  
37 more stable rates
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- 39 • Survey question on perceived neighborhood safety
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- 41 • SF-12 instrument used for outcome assessment has been validated and recommended as a  
42 population health measure
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- 44 • Power to test for interaction by gender on the association between neighborhood crime  
45 and health  
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### 48 49 50 51 *Limitations* 52

- 53
- 54 • Cross sectional and observational study design limit our ability to eliminate non-causal  
55 explanations  
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- Physical health status was self-reported, which could result in misclassification
- Missing data may lead to a biased estimate of the associations between crime rates, perceived safety, and health status
- Misclassification or reasons for missing data could differ by gender, potentially distorting the observed pattern of effect modification
- Measure of perceived safety did not explicitly state the source for concern with safety and some participants may be considering factors such as traffic hazards instead of crime
- Lower crime rates and other unique sociocultural factors may change how New Zealand neighborhoods function and influence health, limiting generalizability



## INTRODUCTION

Neighborhood characteristics have previously been shown to influence health.[1-3] Crime is one such neighborhood characteristic. Residents living in areas of higher crime have been shown to have worse physical health,[4-6] even after controlling for the potential confounding effect of sociodemographic characteristics. There are several causal pathways by which local crime rates can affect health, including trauma resulting from victimization or chronic stress[7] and anxiety related to a perceived threat.[8] Stress pathways could involve mental health, sleep duration, or stress coping behaviors such as tobacco use or alcohol intake. Other behavioral pathways could also play a role if outdoor physical activities such as walking in the neighborhood were restricted to minimize victimization risk, adversely affecting physical health.[9-11] Thus, potential health benefits may be among the reasons to pursue local crime prevention.

Although recorded crime may be thought to influence health status through perceived safety,[4] the role of perceived safety as a mediator of this relationship has often been assumed rather than tested empirically.[10] Independent or divergent associations have been observed for officially recorded crime as compared with perceived safety problems in analyses predicting health and health behaviors,[12-17] suggesting that recorded crime and perceived safety may not be simply serving as proxies for each other.[10 12 17] In addition to officially recorded crime, the perception of safety may be influenced by environmental and neighborhood level factors such as social cohesion, street lighting and neighborhood physical disorder.[9 10] A recent systematic review highlighted the many inconsistencies in the literature on the link between officially recorded crime and perceived safety with physical activity.[10] Yet, individual perceptions and

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3 responses to the local environment may not be the same for all groups.[18] Associations of local  
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5 crime rates with health have been shown to vary based on local[19] or national socioeconomic  
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7 context,[20] as well as by gender.[10 14 16 21-23]  
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14 Men and women have been shown to differ in their perceived risk of victimization and fear  
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16 depending on the type of crime;[24] they have also been observed to vary in their likelihood of  
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18 exercise associated with perceived safety.[23] It has also been suggested that women might be  
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20 more exposed to their local area than men,[25] which may contribute to the differences in  
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22 associations with officially recorded crime and self-reported perception of safety on health.  
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31 This study sought to assess the association of officially recorded crime and self-reported  
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33 perception of safety on physical health status in a national sample of adult New Zealanders using  
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35 data from the New Zealand General Social Survey (NZGSS) and crime data obtained from the  
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37 New Zealand Police. We hypothesized that recorded crime would be negatively associated with  
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39 physical health, and that the perception of a neighborhood as being ‘unsafe’ would both partially  
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41 mediate the relationship between recorded crime and physical health, as well as independently  
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43 predict worse physical health after controlling for recorded crime in the neighborhood of  
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45 residence. Distinguishable subsets of officially recorded crime rates (by crime type, time of  
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47 occurrence, involvement of a weapon) allow us to investigate what categories of crime are most  
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49 associated with perceiving a neighborhood as unsafe and with experiencing worse physical  
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51 health.[24] We explored whether these associations differed by gender, as men and women may  
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3 differ in their perception of neighborhood problems, or their stress and behavioral responses to  
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6 perceived safety hazards.  
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## 10 11 12 **MATERIALS AND METHODS** 13

### 14 15 **Study design and population** 16 17

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19 The New Zealand General Social Survey (NZGSS) was designed to provide information on the  
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21 well-being of New Zealanders. The NZGSS is a nationally representative cross-sectional survey  
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23 of New Zealand residents aged 15 years and over. Detailed information on sampling and  
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25 methodology of the NZGSS has been previously published.[26]  
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33 Briefly, the survey employed a multi-stage sample, and a total of 8,550 participants answered the  
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35 NZGSS personal questionnaire over a 12-month period from April 2010 to March 2011 (81%  
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37 response rate). The NZGSS was interviewer-administered in person using computer-assisted  
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39 personal interviews which covered a wide range of social and economic topics, including  
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41 sociodemographic characteristics, perceived neighborhood safety, and self-reported health.  
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### 49 **Physical health status outcome based on self-report** 50 51

52 The outcome variable of interest--physical health status-- was self-assessed and measured in the  
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54 NZGSS by the commonly used SF-12 Health Index, a short version of the SF-36.[27] The SF-12  
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56 consists of twelve questions, covering aspects of both physical and mental health.[28] Example  
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3 questions: “In general, would you say your health is excellent, very good, good, fair or poor?”,  
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6 “During the past four weeks, how much of the time were you limited in the kind of work or other  
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8 regular daily activities you do as a result of your physical health?” Responses were weighted and  
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10 combined into a physical health summary score, the Transformed Physical Composite Score  
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12 (TPCS) ranging from 0 to 100.[29]  
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### 15 16 17 18 19 **Officially recorded crime rates**

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22 Data of officially recorded crime throughout New Zealand for the period (2008-2010) were  
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24 obtained from the New Zealand Police. Crime rates from 2008-2010 were selected for their  
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26 temporal correspondence with the data collection in 2010-2011,[30] characterizing a period  
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28 largely preceding our outcome measurement and using three years of data to obtain more stable  
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30 rates. The data included over 360,000 incidents of crime recorded nationally, which have been  
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32 geocoded and aggregated from the meshblock level to the census area unit (CAU). Each CAU  
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34 contains approximately 2000 people. Crime data were categorized by type (violent, property,  
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36 dishonesty, or drug and antisocial), whether a weapon was involved, and whether the offence  
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38 occurred at night (defined as between 8pm and 7:59am). For overall crime and each category, the  
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40 average count over the three-year period was combined with CAU population data to create  
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42 average annual rates per 100,000 population (see Table 1). Crime rates were then linked to  
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44 individual-data from the NZGSS based on the CAU corresponding to the residential address  
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46 provided at the time of the NZGSS survey.  
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### 56 57 **Perceptions of neighborhood as unsafe at night**

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3 Perceptions of the neighborhood as being ‘unsafe’ at night was assessed by asking NZGSS  
4 participants: “How safe do you feel walking alone at night in your neighborhood?” Potential  
5 answers ranged on a Likert-type 4-point scale from 1 “very safe” to 4 “very unsafe”. Responses  
6 were dichotomized such that feeling “unsafe/very unsafe” was considered as representing a  
7 perceived safety problem for analyses. Similar measures have been used in previous studies  
8 either as an individual measure or as part of a composite scale.[14 31-33]  
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### 22 **Individual sociodemographic characteristics and smoking**

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24 Age group (age 15-24, age 25-44, age 45-64, and age 65+ years), gender, ethnicity (Māori, the  
25 indigenous population of New Zealand (1) vs. Non-Māori (0)), individual-level socio-economic  
26 status (SES), country of birth, and smoking status (never, former, current) were considered as  
27 physical health determinants that are also potentially associated with place of residence but not  
28 on the causal pathway, and thus as potential confounders. SES is a well-known confounder of the  
29 relationship between neighborhood characteristics and health;[3] available SES measures  
30 included education (none or national certificate 1-4, diploma or bachelors, or masters or  
31 doctorate), employment (currently working for pay (1) vs. otherwise (0)), and income (\$0 to  
32 20,000, \$20,001 to \$40,000, \$40,001 to 60,000, > \$60,000 per year). Being foreign-born has  
33 been found to be associated with both neighborhood of residence and physical health status.[34]  
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### 55 **Statistical analyses**

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3 A linear probability model with cluster robust standard errors was used to explore the  
4 relationships between crime rates and perception of the neighborhood as unsafe. Cluster robust  
5 linear regression analyses were used to examine the associations between of officially reported  
6 crime rates and perception of the neighborhood as unsafe predicting physical health status. An  
7 intraclass correlation coefficient (ICC) was used to assess, and cluster robust standard errors  
8 were used to account for, the potential non-independence of physical health status scores within  
9 the same CAU. Due to the correlations between the different types of crime rates (see Table 1),  
10 we assessed associations for each recorded crime rate separately and did not mutually adjust for  
11 multiple categories of crime in the same model. All models controlled for age, gender, ethnicity,  
12 place of birth, education, employment, income, and smoking status.  
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31 Perception of safety was added to models with officially recorded crime rates to test for  
32 independent associations with health and to check for patterns of association consistent with  
33 mediation of the crime rate-health associations. Mediation was expected to manifest as (1) an  
34 association between higher crime rate and lower perceived safety, (2) an association between  
35 lower perceived safety and worse health status, and (3) attenuation of the crime rate-health  
36 association when perceived safety is added to the model. Furthermore, as gender was of interest  
37 as a potential effect measure modifier, gender stratification was considered for all analyses; Wald  
38 p-values to evaluate the statistical significance of observed effect modification were calculated  
39 from models including a gender interaction. Participants with missing values for any of the  
40 analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.  
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55 Compared to the full sample, participants in our analyses were somewhat more likely to be male,  
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3 young, educated, or employed. All statistical analyses were carried out in a secure data lab in  
4 Wellington, New Zealand using Stata 11.0 software (Stata Corp., College Station, TX, USA).  
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## 11 12 13 14 15 16 **RESULTS**

### 17 18 19 **Study participants**

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22 Table 2 shows the characteristics of the study population (N=6,995). There were similar numbers  
23 of men (n= 3,310) and women (n=3,685). Twelve percent of the study participants were of Māori  
24 ethnicity. Most participants were New Zealand born (77%) and 65% of participants were  
25 currently employed. Approximately 21% of men reported feeling unsafe or very unsafe walking  
26 alone at night in their neighborhood compared with 52% of women.  
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39 The physical health index (TPCS based on SF-12) had a theoretical range from 0 to 100, with  
40 higher values indicating better physical health. The observed mean and standard deviation were  
41 similar for men and women. The ICC for the physical health index across CAUs suggests that  
42 3.1% of the outcome variation may be explained at the CAU level (95% confidence interval:  
43 1.7% to 4.5%).  
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### 55 **Association between officially recorded crime rates and perceived safety**

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3 Total crime rate was significantly associated with the perception of one's neighborhood as  
4 unsafe for walking at night (Table 3). Associations were statistically significant for both genders  
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6 and for all four types of crimes, except among men the trend was not statistically significant for  
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8 dishonesty crime (gender interaction p-value = 0.03). While relatively uncommon, the rate of  
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10 crime with a weapon predicted perceived safety: for each additional crime per 100,000 residents  
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12 in this category women were 15.7% more likely to perceive their neighborhood as unsafe and  
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14 men were 10.0% more likely to perceive their neighborhood as unsafe.  
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#### 24 **Association between officially recorded crime and physical health status**

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27 Total crime rate had a non-significant association with lower physical health overall and among  
28  
29 men (Table 4). However, among women, the total crime rate, violent crime rate, and crime at  
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31 night were significantly associated with a lower physical health index (coefficients were -0.15, -  
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33 0.32, and -0.29, respectively). This suggests that for each additional crime per 100,000 residents  
34  
35 we would expect a decrease in the physical health index of 0.15 units, or perhaps an  
36  
37 approximately 0.3 unit decrease if the additional crime were violent or committed at night. The  
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39 effect modification by gender was only statistically significant for crime at night (p=0.01).  
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To assess if the perception of one's neighborhood as being unsafe mediated the associations  
between recorded crime and physical health status, an indicator of perceived safety was added to  
models of recorded crime and health status. The addition of perceived safety changed the  
magnitude of the statistically significant regression coefficients by 8 to 28 percent (see Table 4).



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3 For women, the rates of violent crime and crime occurring at night remained significantly  
4 associated with physical health after controlling for perception of neighborhood as unsafe.  
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### 10 11 **Association between perceived crime and physical health status** 12

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14 Both men and women perceiving their neighborhood as unsafe for walking at night had lower  
15 predicted physical health index: men perceiving their neighborhood as unsafe versus safe had a  
16 predicted difference of 1.3 units on the physical health index, and women had a predicted  
17 difference of 0.9 units (Table 5). These associations remained statistically significant and similar  
18 in magnitude after controlling for recorded crime rates.  
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## 32 **DISCUSSION** 33 34

35 For this population of adults living in New Zealand, we observed robust associations between  
36 objectively recorded crime rates and perceived neighborhood safety, and between perceived  
37 neighborhood safety and physical health. However, there was some evidence of effect  
38 modification by gender in the association between objectively recorded crime rates and physical  
39 health. Moreover, the category of crime rates most strongly associated with perceived safety  
40 (crime with a weapon) was not among the categories most strongly associated with physical  
41 health (violent crime and crime at night). The observed patterns were somewhat supportive of  
42 the hypothesized role of perceived safety as a mediator between officially recorded crime rates  
43 and physical health among women. However, the observed patterns indicate potential  
44 heterogeneity by crime type and gender.  
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7 An understanding of the several causal pathways through which crime may affect health can help  
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9 explain these separate associations, and differences across categories of crime. It appears that for  
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11 women, violent crime and crimes occurring at night were negatively associated with health status  
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13 even after controlling for any indirect association through perceived safety. Yet the magnitude of  
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15 association between perceived neighborhood safety and physical health showed a trend to be  
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17 larger for men than women. These findings highlight separate associations of officially recorded  
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19 crime versus perceived safety hazards on health, and that these associations may differ by gender.  
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21 Our results corroborate other studies[13 14 16 35] which have found independent associations  
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23 for between the perception of safety and officially recorded crime with health status or health-  
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25 related behavior.[12 16]. Perceived safety - instead of merely being a reflection of recorded  
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27 crime - is an independent construct that can be influenced by a variety of environmental cues  
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29 such as the physical features of public spaces, lighting levels, media stories and social  
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31 incivilities.[9] Future longitudinal research should consider how short-term fluctuations and  
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33 long-term trends in crime rates and other neighborhood shifts alter individuals' perceptions of  
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35 neighborhood safety. While perceived safety may in part mediate the association between  
36  
37 recorded crime and physical health status among women in our study, the association of  
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39 perceived crime with adverse physical health was notable and statistically significant among men,  
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41 even though recorded crime rates were not associated with physical health for these same men.  
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53 It is worth noting that when effect modification by gender has been explored in previous studies  
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55 of crime or safety as predictors of physical health, the patterns have not always been consistent  
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3 with our findings. For example, others have reported a stronger association between perceived  
4 safety and health status for women,[10] whereas in this study we found a trend in the opposite  
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8 direction, though the effect modification was not statistically significant. Some of the literature  
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10 on perceived safety and physical activity has pointed to stronger associations for men[22 36] or  
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12 failed to detect an association among women[16 37 38]. One potential explanation for the  
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14 stronger associations between perceived safety and physical activity and physical health among  
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16 men involve reverse causation, with physically healthy men more likely to perceive themselves  
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18 as being safe from crime. The inconsistent evidence for the association between perceived crime  
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20 on health status by gender underscores the importance of using both officially recorded and  
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22 perceived crime measures and presenting gender stratified results even when the pattern of effect  
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24 modification seems contrary to current assumptions.  
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### 33 *Strengths and Limitations*

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36 Key strengths of this study are the use of geographically linked national data, and the availability  
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38 of multiple officially recorded crime rates by category as well as a survey question on perceived  
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40 neighborhood safety. The SF-12 instrument used for outcome assessment has been validated[39]  
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42 and recommended as a population health measure.[40]  
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50 However, the cross sectional and observational study design limit our ability to eliminate non-  
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52 causal explanations such as reverse causation and unmeasured confounding. Physical health  
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54 status was self-reported and this could result in misclassification. Missing data was also an  
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56 important limitation. In particular, the large number of participants who selected “Not  
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3 applicable”, “Don’t know” or “Refused” in response to the question on perceived safety  
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5 (N=1092) may have included those who already avoided walking home at night due to safety  
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7 concerns or health limitations, and this could lead to a biased estimate of the associations  
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9 between crime rates, perceived safety, and health status. Misclassification or reasons for missing  
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11 data could also differ by gender, potentially distorting the observed pattern of effect modification.  
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13 The measure of perceived safety also did not explicitly state the source for concern with safety  
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15 and some participants may be considering factors such as traffic hazards instead of crime. Last,  
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17 crime rates in New Zealand are lower than in many other countries (for example in 2000, the  
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19 New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000  
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21 population in the USA[41]); this and other unique sociocultural factors may change how its  
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23 neighborhoods function and influence health, limiting the generalizability of our results.  
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### 33 *Conclusion*

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36 In conclusion, complex patterns of association were observed linking crime rates to physical  
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38 health among men and women in New Zealand. Future studies should continue to explore  
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40 differences by crime category and by gender, and across the multiple pathways that may link  
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42 crime rates to physical health status. Usage of both officially recorded crime and perceived  
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44 safety measures is important to tease apart the differences in what they reflect and how they may  
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46 influence health differently for men and women. Perceived neighborhood safety in particular  
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48 appears to be a robust predictor of physical health independent of officially recorded crime rates,  
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50 and potentially modifiable neighborhood characteristics affecting perceived safety warrant  
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52 further investigation.  
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## Summary Box

### *What is already known on this subject?*

Findings on the association between neighborhood crime and health differ with the use of officially recorded crime rates or self-reported perception of safety. Effect modification by gender has been observed in some settings, but many studies lacked the power to test for interaction by gender or the data to explore such interactions across multiple safety-related measures.

### *What this study adds?*

Our study illustrates the importance of using both officially recorded crime and perceived safety measures and exploring effect modification by gender. The multiple pathways by which local crime rates affect physical health may differ between men and women and by category of crime, yet perceived neighborhood safety was independently associated with physical health for both men and women even after accounting for local crime rates. Further investigation of perceived safety may be needed in order to identify key neighborhood characteristics for public health interventions.

**Table 1. Correlation matrix of New Zealand Police recorded crime rates by type, weapon use, and time of day across census area units inhabited by New Zealand General Social Survey participants**

Category label and definition	Mean (SD)	Percentiles [25 <sup>th</sup> , 50 <sup>th</sup> , 75 <sup>th</sup> ]	Total	Violent	Property	Dishonesty	Drug	Weapon
Total crime	2.2 (2.2)	[0.7, 1.4, 3.3]	-					
Violent crime (minor assault, serious assault and grievous assault)	1.0 (1.4)	[0, 0.7, 1.3]	0.56	-				
Property crime (burglary and theft)	0.5 (0.8)	[0, 0.3, 0.7]	0.42	0.64	-			
Dishonesty crime (involving destruction of property)	0.7 (1.1)	[0, 0.3, 1.0]	0.42	0.49	0.52	-		
Drug and antisocial crime (drug-related and disorder)	0.6 (1.2)	[0, 0, 0.7]	0.46	0.45	0.46	0.35	-	
Crime with a weapon	0.1 (0.3)	[0, 0, 0]*	0.32	0.51	0.50	0.34	0.38	-
Crime at night (committed between 8pm and 7:59am)	1.2 (1.6)	[0, 0.7, 1.7]	0.56	0.80	0.65	0.57	0.57	0.48

Notes: Mean annual rate of crime was calculated for 2008-2010 using count per 100,000 residents for each census area unit; descriptive statistics and Pearson's correlations shown are calculated across individual NZGSS participants (N=6,995)

\* The rate of crime with a weapon had a 90<sup>th</sup> percentile of 0.3

**Table 2. Characteristics of New Zealand General Social Survey participants in our analytic dataset (2010-2011, participants with missing data have been excluded)**

	Total N=6,995	Men N=3,310	Women N=3,685
Age group			
15-24	12	13	12
25-44	36	34	37
45-64	35	34	35
65+	18	18	17
Ethnicity			
Māori	12	10	13
Nativity			
Born in New Zealand	77	76	78
Highest completed education			
None or national certificate 1-4	66	70	63
Diploma or bachelors	25	22	27
Masters or doctorate	9	8	9
Employment			
Currently working for pay	65	70	60
Income			
≤ \$20,000	36	28	43
\$20,001-40,000	27	24	30
\$40,001-60,000	18	21	15
\$60,001+	19	27	12
Smoking status			
Regular smoker, current	20	20	19
Regular smoker, former	29	31	26
Never smoker	52	49	54
Neighborhood safety (self-report)			
Safe or very safe	63	79	48
Unsafe or very unsafe	37	21	52
Physical health (TPCS)	49.6 (9.9)	49.8 (9.5)	49.5 (10.2)

Notes: Values shown are % or mean (SD)



**Table 3. Associations between recorded crime rates and self-reported perception of neighborhood as unsafe among men and women in New Zealand (2010-2011)**

	Overall	Men	Women	Gender interaction
	$\beta$ (95% CI)	$\beta$ (95% CI)	$\beta$ (95% CI)	p-value
Total Crime	<b>1.9 (1.2, 2.5)</b>	<b>1.4 (0.6, 2.1)</b>	<b>2.2 (1.4, 3.1)</b>	0.15
Violent Crime	<b>4.3 (3.1, 5.4)</b>	<b>4.0 (2.6, 0.5)</b>	<b>4.5 (3.0, 5.9)</b>	0.89
Property Crime	<b>5.4 (3.4, 7.4)</b>	<b>4.2 (1.9, 6.4)</b>	<b>6.5 (4.1, 9.0)</b>	0.14
Dishonesty crime	<b>2.1 (0.6, 3.5)</b>	0.7 (-0.7, 2.2)	<b>3.2 (1.2, 5.2)</b>	<b>0.03</b>
Drug and Antisocial Crime	<b>2.2 (0.9, 3.4)</b>	<b>1.9 (0.4, 3.4)</b>	<b>2.4 (0.8, 3.9)</b>	0.85
Crime with a weapon	<b>12.9 (8.8, 17.0)</b>	<b>10.0 (5.0, 15.1)</b>	<b>15.7 (9.9, 21.4)</b>	0.19
Crime occurring in the night	<b>3.0 (2.0, 4.0)</b>	<b>2.7 (1.6, 3.9)</b>	<b>3.2 (1.9, 4.5)</b>	0.80

Notes: Rescaled coefficients and 95% confidence intervals from linear probability models with cluster robust standard errors are shown, and coefficients (which have been multiplied by 100) can be interpreted as in the expected increase in percentage of participants reporting their neighborhood as unsafe per 1 unit increase in the category-specific crime rate; models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added to separate models (not mutually adjusted); boldface is used to indicate statistical significance (p<0.05)

**Table 4. Associations between recorded crime rates and self-reported physical health status among men and women in New Zealand (2010-2011)**

	Overall $\beta$ (95% CI)	Men $\beta$ (95% CI)	Women $\beta$ (95% CI)	Gender interaction p-value
Total crime	-0.09 (-0.20, 0.01)	-0.04 (-0.18, 0.09)	<b>-0.15</b> <b>(-0.29, -0.01)</b>	0.22
with perceived safety	-0.08 (-0.18, 0.03)	-0.02 (-0.16, 0.11)	-0.13 (-0.27, 0.00)	
Violent crime	<b>-0.18</b> <b>(-0.34, -0.01)</b>	-0.04 (-0.27, 0.20)	<b>-0.32</b> <b>(-0.55, -0.10)</b>	0.08
with perceived safety	-0.13 (-0.30, 0.03)	0.02 (-0.22, 0.25)	<b>-0.29</b> <b>(-0.51, -0.06)</b>	
Property crime	-0.13 (-0.40, 0.13)	0.07 (-0.25, 0.38)	-0.33 (-0.76, 0.09)	0.13
with perceived safety	-0.08 (-0.34, 0.19)	0.12 (-0.19, 0.44)	-0.28 (-0.71, 0.15)	
Dishonesty crime	-0.10 (-0.29, 0.09)	0.05 (-0.20, 0.30)	<b>-0.27</b> <b>(-0.52, -0.01)</b>	0.06
with perceived safety	-0.08 (-0.27, 0.10)	0.06 (-0.19, 0.30)	-0.24 (-0.49, 0.01)	
Drug and Antisocial crime	<b>0.17</b> <b>(0.00, 0.33)</b>	<b>0.24</b> <b>(0.03, 0.44)</b>	0.10 (-0.17, 0.37)	0.38

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with perceived safety	<b>0.19</b> <b>(0.03, 0.35)</b>	<b>0.26</b> <b>(0.06, 0.47)</b>	0.12 (-0.14, 0.39)	
Crime with a weapon	0.29 (-0.37, 0.95)	0.58 (-0.24, 1.39)	-0.04 (-0.97, 0.89)	0.28
with perceived safety	<b>0.42</b> <b>(-0.24, 1.18)</b>	<b>0.71</b> <b>(-0.09, 1.52)</b>	0.09 (-0.84, 1.02)	
Crime at night	-0.11 (-0.26, 0.03)	0.04 (-0.14, 0.23)	<b>-0.29</b> <b>(-0.51, -0.07)</b>	<b>0.01</b>
with perceived safety	-0.09 (-0.23, 0.06)	0.08 (-0.11, 0.27)	<b>-0.26</b> <b>(-0.48, -0.04)</b>	

Notes: Coefficients and 95% confidence intervals from cluster robust linear models are shown, and the coefficients can be interpreted as the predicted difference in self-reported physical health status (as measured by the SF-12 transformed physical component score) associated with a 1 unit increase in the category-specific crime rate; all models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates for different categories were added to separate models (not mutually adjusted), and results are shown before and after the addition of perceived safety to the models; boldface is used to indicate statistical significance (p<0.05)

**Table 5. Associations between perception of safety and self-reported physical health status, controlling for recorded crime among men and women living in New Zealand (2010-2011)**

	Overall $\beta$ (95% CI)	Men $\beta$ (95% CI)	Women $\beta$ (95% CI)
Neighborhood perceived as unsafe	<b>-1.00</b> <b>(-1.51, -0.49)</b>	<b>-1.31</b> <b>(-2.18, -0.44)</b>	<b>-0.86</b> <b>(-1.49, -0.23)</b>
with total crime	<b>-0.97</b> <b>(-1.48, -0.45)</b>	<b>-1.30</b> <b>(-2.17, -0.43)</b>	<b>-0.80</b> <b>(-1.43, -0.17)</b>
with violent crime	<b>-0.95</b> <b>(-1.46, -0.43)</b>	<b>-1.32</b> <b>(-2.19, -0.44)</b>	<b>-0.77</b> <b>(-1.40, -0.13)</b>
with property crime	<b>-0.99</b> <b>(-1.50, -0.47)</b>	<b>-1.33</b> <b>(-2.20, -0.46)</b>	<b>-0.82</b> <b>(-1.45, -0.18)</b>
with dishonesty crime	<b>-0.99</b> <b>(-1.50, -0.48)</b>	<b>-1.31</b> <b>(-2.18, -0.44)</b>	<b>-0.82</b> <b>(-1.46, -0.19)</b>
with drug and antisocial crime	<b>-1.03</b> <b>(-1.54, -0.52)</b>	<b>-1.35</b> <b>(-2.22, -0.48)</b>	<b>-0.88</b> <b>(-1.50, -0.25)</b>
with crime with a weapon	<b>-1.03</b> <b>(-1.54, -0.51)</b>	<b>-1.36</b> <b>(-2.23, -0.48)</b>	<b>-0.87</b> <b>(-1.50, -0.24)</b>
with crime at night	<b>-0.97</b> <b>(-1.48, -0.46)</b>	<b>-1.34</b> <b>(-2.22, -0.47)</b>	<b>-0.78</b> <b>(-1.41, -0.15)</b>

Notes: Coefficients and 95% confidence intervals from cluster robust linear models predicting the physical health index are shown, and coefficients can be interpreted as the predicted difference in physical health status (as measured by the SF-12 transformed physical component score) for comparing those reporting their neighborhood as unsafe for walking at night versus safe for walking at night; covariates include age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added one at a time to adjusted models, and the coefficients for perceiving neighborhood as unsafe are shown before and after adjustment for each of these crime rates; boldface is used to indicate statistical significance ( $p < 0.05$ )

## Disclaimer

Access to the data used in this study was provided by Statistics New Zealand under conditions designed to uphold the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the authors, not Statistics New Zealand.

## Acknowledgements

We would also like to acknowledge the support of New Zealand Police who provided crime data for this work; and to Statistics New Zealand who provided us with access to data from the General Social Survey.

## Funding

The authors of this report would like to acknowledge the Christchurch City Council for initiating the research and Ministry of Justice Crime Prevention Unit for the provision of funding, which allowed the project to commence smoothly. The first author would also like to thank the National Institute for Child Health and Human Development (K01HD067390) for their financial support.

## Contributorship Statement

All authors critically reviewed manuscript drafts and approved the submission. GSL, ALP and GB conceived the project. GB prepared the official crime rate data for linkage to the NZ GSS. ALP conducted analyses in the secure data lab, with syntax and input from GSL. CEG created tables from the output files and drafted the initial manuscript. GSL revised and integrated comments on the final tables and text.

## Data Sharing Statement

Details on data availability may be found at [www.stats.govt.nz](http://www.stats.govt.nz).

## Competing Interests

None

For peer review only

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**The Independent Associations of Recorded Crime and Perceived Safety with  
Physical Health in a Nationally Representative Cross-Sectional Survey of  
Men and Women in New Zealand**

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MeSH Terms: Crime, Health Status, New Zealand, Police, Residence Characteristics

Word Counts: 300 words in abstract, 2,771,931 words in text

## ABSTRACT

**Background Objectives:** ~~Neighborhood crime may influence health through pathways involving direct trauma, chronic stress, or behaviors including physical activity.~~ We investigated associations of ~~both~~ officially recorded crime and perceived neighborhood safety with physical health, evaluating potential effect modification by gender.

**Methods Setting:** Nationally representative population-based survey in New Zealand

**Participants:** Individual-level data from 6,995 New Zealand General Social Survey (2010-2011) participants including with complete data on the physical SF-12 health index health status, and perceived neighborhood safety, sociodemographic characteristics, and smoking. from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to eCrime rate for each participant's home census was estimated based on data es from the New Zealand Police (2008-2010) for each census area unit.

**Primary outcome measure:** The Transformed Physical Composite Score from the SF-12, a physical health summary score based on self-report ranging from 0 to 100.

~~Mixed-effects regression models accounted for clustering using neighborhood-level random intercepts, and adjusted for sociodemographic characteristics and smoking.~~ **Results:** We used cluster robust multivariable regression models to examine the associations among neighborhood crime rates, perceived neighborhood safety, and the physical health summary score. Crime rates, especially those involving a weapon, predicted adults' perception adults' perception that it was of the neighborhood as unsafe to walk in their neighborhood at night: for each additional crime per 100,000 residents adults were 1.9% more likely to perceive their neighborhood as unsafe (95% CI: 1.2% to 2.5%). While relatively uncommon, the rate of crime with a weapon strongly

predicted perceived safety: for each additional crime per 100,000 residents in this category adults were 12.9% more likely to report the neighborhood as unsafe (95% CI: 8.8% to 17.0%). ~~Police-recorded violent and night crime rates, especially violent crime and crime occurring at night, rates~~ were associated with worse physical health among women: for each additional crime per 100,000 residents in these category women had a 0.3 point lower physical health score (95% CIs: -0.6 to -0.1 for violent crime and -0.5 to -0.1 for crime at night, gender interaction p-values 0.08 and 0.01, respectively); the association with crime at night was significantly stronger among women (interaction p-value: 0.01). Adjustment for perceived safety slightly attenuated these associations. Perceiving the neighborhood as unsafe was independently associated with 1.0 point worse lower physical health score (~~1.0 unit difference,~~ 95% CI: -1.5 to -0.5).

**Conclusions:** Gender may ~~differentially~~ modify the associations of officially recorded crime rates with physical health, ~~but p~~ Perceived neighborhood safety ~~problems werewas~~ consistently independently associated with ~~worse~~ physical health.

## Strengths and limitations of this study

### *Strengths*

- Use of geographically linked national data
- Multiple officially recorded crime rates by category using three years of data to obtain more stable rates

- Survey question on perceived neighborhood safety
- ~~Crime rates from 2008–2010 were selected for their temporal correspondence with the data collection in 2010–2011, characterizing a period largely preceding our outcome measurement and using three years of data to obtain more stable rates~~
- SF-12 instrument used for outcome assessment has been validated<sup>[1]</sup> and recommended as a population health measure<sup>[2]</sup>
- Power to test for interaction by gender on the association between neighborhood crime and health

### *Limitations*

- Cross sectional and observational study design limit our ability to eliminate non-causal explanations
- Physical health status was self-reported, which could result in misclassification
- Missing data may lead to a biased estimate of the associations between crime rates, perceived safety, and health status
- Misclassification or reasons for missing data could differ by gender, potentially distorting the observed pattern of effect modification
- Measure of perceived safety did not explicitly state the source for concern with safety and some participants may be considering factors such as traffic hazards instead of crime
- Lower crime rates and other unique sociocultural factors may change how New Zealand neighborhoods function and influence health, limiting generalizability

## INTRODUCTION

Neighborhood characteristics have previously been shown to influence health.[1-3] Crime is one such neighborhood characteristic. Residents living in areas of higher crime have been shown to have worse physical health,[4-6] even after controlling for the potential confounding effect of sociodemographic characteristics. There are several causal pathways by which local crime rates can affect health, including trauma resulting from victimization or chronic stress[7] and anxiety related to a perceived threat.[8] Stress pathways could involve mental health, sleep duration, or stress coping behaviors such as tobacco use or alcohol intake. Other behavioral pathways could also play a role if outdoor physical activities such as walking in the neighborhood were restricted to minimize victimization risk, adversely affecting physical health.[9-11] Thus, potential health benefits may be among the reasons to pursue local crime prevention.

Although recorded crime may be thought to influence health status through perceived safety,[4] the role of perceived safety as a mediator of this relationship has often been assumed rather than tested empirically.[10] Independent or divergent associations have been observed for officially recorded crime as compared with perceived safety problems in analyses predicting health and health behaviors,[12-17] suggesting that recorded crime and perceived safety may not be simply serving as proxies for each other.[10 12 17] In addition to officially recorded crime, the perception of safety may be influenced by environmental and neighborhood level factors such as social cohesion, street lighting and neighborhood physical disorder.[9 10] A recent systematic review highlighted the many inconsistencies in the literature on the link between officially recorded crime and perceived safety with physical activity.[10] Yet, individual perceptions and

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3 responses to the local environment may not be the same for all groups.[18] Associations of local  
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5 crime rates with health have been shown to vary based on local[19] or national socioeconomic  
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7 context,[20] as well as by gender.[10 14 16 21-23]  
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14 Men and women have been shown to differ in their perceived risk of victimization and fear  
15 depending on the type of crime:[24] they have also been observed to vary in their likelihood of  
16 exercise associated with perceived safety.-[23] It has also been suggested that women might be  
17 more exposed to their local area than men,[25] which may contribute to the differences in  
18 associations with officially recorded crime and self-reported perception of safety on health.  
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30 This study sought to assess the association of officially recorded crime and self-reported  
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32 perception of safety on physical health status in a national sample of adult New Zealanders using  
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34 data from the New Zealand General Social Survey (NZGSS) and crime data obtained from the  
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36 New Zealand Police. We hypothesized that recorded crime would be negatively associated with  
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38 physical health, and that the perception of a neighborhood as being ‘unsafe’ would both partially  
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40 mediate the relationship between recorded crime and physical health, as well as independently  
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42 predict worse physical health after controlling for recorded crime in the neighborhood of  
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44 residence. Distinguishable subsets of officially recorded crime rates (by crime type, time of  
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46 occurrence, involvement of a weapon) allow us to investigate what categories of crime are most  
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48 associated with perceiving a neighborhood as unsafe and with experiencing worse physical  
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50 health.[24] We explored whether these associations differed by gender, as men and women may  
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3 differ in their perception of neighborhood problems, or their stress and behavioral responses to  
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6 perceived safety hazards.  
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## 10 11 12 **MATERIALS AND METHODS** 13

### 14 15 16 **Study design and population** 17

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19 The New Zealand General Social Survey (NZGSS) was designed to provide information on the  
20 well-being of New Zealanders. The NZGSS is a nationally representative cross-sectional survey  
21 of New Zealand residents aged 15 years and over. Detailed information on sampling and  
22 methodology of the NZGSS has been previously published.[26]  
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33 Briefly, the survey employed a multi-stage sample, and a total of 8,550 participants answered the  
34 NZGSS personal questionnaire over a 12-month period from April 2010 to March 2011 (81%  
35 response rate). The NZGSS was interviewer-administered in person using computer-assisted  
36 personal interviews which covered a wide range of social and economic topics, including  
37 sociodemographic characteristics, perceived neighborhood safety, and self-reported health.  
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### 49 **Physical health status outcome based on self-report** 50

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52 The outcome variable of interest--physical health status-- was self-assessed and measured in the  
53 NZGSS by the commonly used SF-12 Health Index, a short version of the SF-36.[27] The SF-12  
54 consists of twelve questions, covering aspects of both physical and mental health.[28] Example  
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3 questions: “In general, would you say your health is excellent, very good, good, fair or poor?”,  
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6 “During the past four weeks, how much of the time were you limited in the kind of work or other  
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8 regular daily activities you do as a result of your physical health?” Responses were weighted and  
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10 combined into a physical health summary score, the Transformed Physical Composite Score  
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12 (TPCS) ranging from 0 to 100.[29]  
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### 15 16 17 18 19 **Officially recorded crime rates**

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22 Data of officially recorded crime throughout New Zealand for the period (2008-2010) were  
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24 obtained from the New Zealand Police. Crime rates from 2008-2010 were selected for their  
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26 temporal correspondence with the data collection in 2010-2011,[30] characterizing a period  
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28 largely preceding our outcome measurement and using three years of data to obtain more stable  
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30 rates. The data included over 360,000 incidents of crime recorded nationally, which have been  
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32 geocoded and aggregated from the meshblock level to the census area unit (CAU). Each CAU  
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34 contains approximately 2000 people. Crime data were categorized by type (violent, property,  
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36 dishonesty, or drug and antisocial), whether a weapon was involved, and whether the offence  
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38 occurred at night (defined as between 8pm and 7:59am). For overall crime and each category, the  
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40 average count over the three-year period was combined with CAU population data to create  
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42 average annual rates per 100,000 population (see Table 1). Crime rates were then linked to  
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44 individual-data from the NZGSS based on the CAU corresponding to the residential address  
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46 provided at the time of the NZGSS survey.  
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### 56 57 **Perceptions of neighborhood as unsafe at night**

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3 Perceptions of the neighborhood as being ‘unsafe’ at night was assessed by asking NZGSS  
4 participants: “How safe do you feel walking alone at night in your neighborhood?” Potential  
5 answers ranged on a Likert-type 4-point scale from 1 “very safe” to 4 “very unsafe”. Responses  
6 were dichotomized such that feeling “unsafe/very unsafe” was considered as representing a  
7 perceived safety problem for analyses. Similar measures have been used in previous studies  
8 either as an individual measure or as part of a composite scale.[14 31-33]  
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### 22 **Individual sociodemographic characteristics and smoking**

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24 Age group (age 15-24, age 25-44, age 45-64, and age 65+ years), gender, ethnicity (Māori, the  
25 indigenous population of New Zealand (1) vs. Non-Māori (0)), individual-level socio-economic  
26 status (SES), country of birth, and smoking status (never, former, current) were considered as  
27 physical health determinants that are also potentially associated with place of residence but not  
28 on the causal pathway, and thus as potential confounders. SES is a well-known confounder of the  
29 relationship between neighborhood characteristics and health;[3] available SES measures  
30 included education (none or national certificate 1-4, diploma or bachelors, or masters or  
31 doctorate), employment (currently working for pay (1) vs. otherwise (0)), and income (\$0 to  
32 20,000, \$20,001 to \$40,000, \$40,001 to 60,000, > \$60,000 per year). Being foreign-born has  
33 been found to be associated with both neighborhood of residence and physical health status.[34]  
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### 55 **Statistical analyses**

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3 A linear probability model with cluster robust standard errors was used to explore the  
4 relationships between crime rates and perception of the neighborhood as unsafe. Multi-level  
5 mixed-effects Cluster robust linear regression analyses were used to examine the associations  
6 between of officially reported crime rates and perception of the neighborhood as unsafe  
7 predicting physical health status. An intraclass correlation coefficient (ICC) was used to assess,  
8 and cluster random intercepts robust standard errors were used to account for, the potential non-  
9 independence of physical health status scores within the same CAU. Due to the correlations  
10 between the different types of crime rates (see Table 1), we assessed associations for each  
11 recorded crime rate separately and did not mutually adjust for multiple categories of crime in the  
12 same model. All models controlled for age, gender, ethnicity, place of birth, education,  
13 employment, income, and smoking status.  
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33 Perception of safety was added to models with officially recorded crime rates to test for  
34 independent associations with health and to check for patterns of association consistent with  
35 mediation of the crime rate-health associations. Mediation was expected to manifest as (1) an  
36 association between higher crime rate and lower perceived safety, (2) an association between  
37 lower perceived safety and worse health status, and (3) attenuation of the crime rate-health  
38 association when perceived safety is added to the model. Furthermore, as gender was of interest  
39 as a potential effect measure modifier, gender stratification was considered for all analyses; Wald  
40 p-values to evaluate the statistical significance of observed effect modification were calculated  
41 from models including a gender interaction. Participants with missing values for any of the  
42 analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.  
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56 Compared to the full sample, participants in our analyses were somewhat more likely to be male,  
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3 | young, educated, or employed. All statistical analyses were carried out in a secure data lab in  
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6 | Wellington, New Zealand using Stata 11.0 software (Stata Corp., College Station, TX, USA).  
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## 16 RESULTS

### 20 Study participants

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23 Table 2 shows the characteristics of the study population (N=6,995). There were similar numbers  
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25 of men (n= 3,310) and women (n=3,685). Twelve percent of the study participants were of Māori  
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27 ethnicity. Most participants were New Zealand born (77%) and 65% of participants were  
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29 currently employed. Approximately 21% of men reported feeling unsafe or very unsafe walking  
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31 alone at night in their neighborhood compared with 52% of women.  
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38 The physical health index (TPCS based on SF-12) had a theoretical range from 0 to 100, with  
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40 higher values indicating better physical health. The observed mean and standard deviation were  
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42 similar for men and women. The ICC for the physical health index across CAUs suggests that  
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44 3.1% of the outcome variation may be explained at the CAU level (95% confidence interval:  
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46 1.7% to 4.5%).  
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### 54 Association between officially recorded crime rates and perceived safety

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Total ~~and category-specific~~ crime rates ~~were~~ was significantly associated with the perception of one's neighborhood as unsafe for walking at night (Table 3). Associations were statistically significant for both genders and for all ~~categories~~ four types of crimes ~~rates~~, except among men the trend was not statistically significant for dishonesty crime (gender interaction p-value = 0.03).

While relatively uncommon, the rate of crime with a weapon ~~The crime category that most strongly~~ predicted perceived safety ~~was crime with a weapon~~: for each additional crime per 100,000 residents in this category women were 15.7% more likely to perceive their neighborhood as unsafe and men were 10.0% more likely to perceive their neighborhood as unsafe.

### **Association between officially recorded crime and physical health status**

Total crime rate had a non-significant association with lower physical health overall and among men (Table 4). However, among women, the total crime rate, violent crime rate, and crime at night were significantly associated with a lower physical health index (coefficients were -0.15, -0.32, and -0.29, respectively). This suggests that for each additional crime per 100,000 residents we would expect a decrease in the physical health index of 0.15 units, or perhaps an approximately 0.3 unit decrease if the additional crime were violent or committed at night. The effect modification by gender was only statistically significant for crime at night (p=0.01).

To assess if the perception of one's neighborhood as being unsafe mediated the associations between recorded crime and physical health status, an indicator of perceived safety was added to models of recorded crime and health status. The addition of perceived safety changed the

magnitude of the statistically significant regression coefficients by 89 to 2823 percent (see Table

4). For women, the rates of violent crime and crime occurring at night remained significantly associated with physical health after controlling for perception of neighborhood as unsafe.

### **Association between perceived crime and physical health status**

Both men and women perceiving their neighborhood as unsafe for walking at night had lower predicted physical health index: men perceiving their neighborhood as unsafe versus safe had a predicted difference of 1.3 units on the physical health index, and women had a predicted difference of 0.9 units (Table 5). These associations remained statistically significant and similar in magnitude after controlling for recorded crime rates.

## **DISCUSSION**

For this population of adults living in New Zealand, we observed robust associations between objectively recorded crime rates and perceived neighborhood safety, and between perceived neighborhood safety and physical health. However, there was some evidence of effect modification by gender in the association between objectively recorded crime rates and physical health. Moreover, the category of crime rates most strongly associated with perceived safety (crime with a weapon) was not among the categories most strongly associated with physical health (violent crime and crime at night). The observed patterns were somewhat supportive of the hypothesized role of perceived safety as a mediator between officially recorded crime rates

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3 and physical health among women. However, the observed patterns indicate potential  
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6 heterogeneity by crime type and gender.  
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12 An understanding of the several causal pathways through which crime may affect health can help  
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14 explain these separate associations, and differences across categories of crime. It appears that for  
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16 women, violent crime and crimes occurring at night were negatively associated with health status  
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18 even after controlling for any indirect association through perceived safety. Yet the magnitude of  
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20 association between perceived neighborhood safety and physical health showed a trend to be  
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22 larger for men than women. These findings highlight separate associations of officially recorded  
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24 crime versus perceived safety hazards on health, and that these associations may differ by gender.  
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26 Our results corroborate other studies[13 14 16 35] which have found independent associations  
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28 for between the perception of safety and officially recorded crime with health status or health-  
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30 related behavior.[12 16]. Perceived safety - instead of merely being a reflection of recorded  
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32 crime - is an independent construct that can be influenced by a variety of environmental cues  
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34 such as the physical features of public spaces, lighting levels, media stories and social  
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36 incivilities.[9] Future longitudinal research should consider how short-term fluctuations and  
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38 long-term trends in crime rates and other neighborhood shifts alter individuals' perceptions of  
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40 neighborhood safety. While perceived safety may in part mediate the association between  
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42 recorded crime and physical health status among women in our study, the association of  
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44 perceived crime with adverse physical health was notable and statistically significant among men,  
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46 even though recorded crime rates were not associated with physical health for these same men.  
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3 It is worth noting that when effect modification by gender has been explored in previous studies  
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5 of crime or safety as predictors of physical health, the patterns have not always been consistent  
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7 with our findings. For example, others have reported a stronger association between perceived  
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9 safety and health status for women,[10] whereas in this study we found a trend in the opposite  
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11 direction, though the effect modification was not statistically significant. Some of the literature  
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13 on perceived safety and physical activity has pointed to stronger associations for men[22 36] or  
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15 failed to detect an association among women[16 37 38]. One potential explanation for the  
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17 stronger associations between perceived safety and physical activity and physical health among  
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19 men involve reverse causation, with physically healthy men more likely to perceive themselves  
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21 as being safe from crime. The inconsistent evidence for the association between perceived crime  
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23 on health status by gender underscores the importance of using both officially recorded and  
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25 perceived crime measures and presenting gender stratified results even when the pattern of effect  
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27 modification seems contrary to current assumptions.  
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### 38 *Strengths and Limitations*

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41 Key strengths of this study are the use of geographically linked national data, and the availability  
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43 of multiple officially recorded crime rates by category as well as a survey question on perceived  
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45 neighborhood safety. ~~Crime rates from 2008-2010 were selected for their temporal~~  
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47 ~~correspondence with the data collection in 2010-2011, characterizing a period largely preceding~~  
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49 ~~our outcome measurement and using three years of data to obtain more stable rates.~~ The SF-12  
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51 instrument used for outcome assessment has been validated[39] and recommended as a  
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53 population health measure.[40]  
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7 However, the cross sectional and observational study design limit our ability to eliminate non-  
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9 causal explanations such as reverse causation and unmeasured confounding. Physical health  
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11 status was self-reported and this could result in misclassification. Missing data was also an  
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13 important limitation. In particular, the large number of participants who selected “Not  
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15 applicable”, “Don’t know” or “Refused” in response to the question on perceived safety  
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17 (N=1092) may have included those who already avoided walking home at night due to safety  
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19 concerns or health limitations, and this could lead to a biased estimate of the associations  
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21 between crime rates, perceived safety, and health status. Misclassification or reasons for missing  
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23 data could also differ by gender, potentially distorting the observed pattern of effect modification.  
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26 The measure of perceived safety also did not explicitly state the source for concern with safety  
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28 and some participants may be considering factors such as traffic hazards instead of crime. Last,  
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30 crime rates in New Zealand are lower than in many other countries (for example in 2000, the  
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32 New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000  
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34 population in the USA[41]); this and other unique sociocultural factors may change how its  
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36 neighborhoods function and influence health, limiting the generalizability of our results.  
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### 46 *Conclusion*

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49 In conclusion, complex patterns of association were observed linking crime rates to physical  
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51 health among men and women in New Zealand. Future studies should continue to explore  
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53 differences by crime category and by gender, and across the multiple pathways that may link  
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55 crime rates to physical health status. Usage of both officially recorded crime and perceived  
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3 safety measures is important to tease apart the differences in what they reflect and how they may  
4 influence health differently for men and women. Perceived neighborhood safety in particular  
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6 appears to be a robust predictor of physical health independent of officially recorded crime rates,  
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8 and potentially modifiable neighborhood characteristics affecting perceived safety warrant  
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10 further investigation.  
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## Summary Box

### *What is already known on this subject?*

Findings on the association between neighborhood crime and health differ with the use of officially recorded crime rates or self-reported perception of safety. Effect modification by gender has been observed in some settings, but many studies lacked the power to test for interaction by gender or the data to explore such interactions across multiple safety-related measures.

### *What this study adds?*

Our study illustrates the importance of using both officially recorded crime and perceived safety measures and exploring effect modification by gender. The multiple pathways by which local crime rates affect physical health may differ between men and women and by category of crime, yet perceived neighborhood safety was independently associated with physical health for both men and women even after accounting for local crime rates. Further investigation of perceived safety may be needed in order to identify key neighborhood characteristics for public health interventions.

**Table 1. Correlation matrix of New Zealand Police recorded crime rates by type, weapon use, and time of day across census area units inhabited by New Zealand General Social Survey participants by category**

Category label and definition	Mean (SD)	Percentiles [25 <sup>th</sup> , 50 <sup>th</sup> , 75 <sup>th</sup> ]	Total	Violent	Property	Dishonesty	Drug	Weapon
Total crime	2.2 (2.2)	[0.7, 1.4, 3.3]	-					
Violent crime (minor assault, serious assault and grievous assault)	1.0 (1.4)	[0, 0.7, 1.3]	0.56	-				
Property crime (burglary and theft)	0.5 (0.8)	[0, 0.3, 0.7]	0.42	0.64	-			
Dishonesty crime (involving destruction of property)	0.7 (1.1)	[0, 0.3, 1.0]	0.42	0.49	0.52	-		
Drug and antisocial crime (drug-related and disorder)	0.6 (1.2)	[0, 0, 0.7]	0.46	0.45	0.46	0.35	-	
Crime with a weapon	0.1 (0.3)	[0, 0, 0]*	0.32	0.51	0.50	0.34	0.38	-
Crime at night (committed between 8pm and 7:59am)	1.2 (1.6)	[0, 0.7, 1.7]	0.56	0.80	0.65	0.57	0.57	0.48

Notes: Mean annual rate of crime was calculated for 2008-2010 using count per 100,000 residents for each census area unit; descriptive statistics and Pearson's correlations shown are calculated across individual NZGSS participants (N=6,995)

\* The rate of crime with a weapon had a 90<sup>th</sup> percentile of 0.3

**Table 2. Characteristics of 2010-New Zealand General Social Survey participants in our analytic dataset (2010-2011, participants with missing data have been excluded)**

	Total N=6,995	Men N=3,310	Women N=3,685
Age group			
15-24	12	13	12
25-44	36	34	37
45-64	35	34	35
65+	18	18	17
Ethnicity			
Māori	12	10	13
Nativity			
Born in New Zealand	77	76	78
Highest completed education			
None or national certificate 1-4	66	70	63
Diploma or bachelors	25	22	27
Masters or doctorate	9	8	9
Employment			
Currently working for pay	65	70	60
Income			
≤ \$20,000	36	28	43
\$20,001-40,000	27	24	30
\$40,001-60,000	18	21	15
\$60,001+	19	27	12
Smoking status			
Regular smoker, current	20	20	19
Regular smoker, former	29	31	26
Never smoker	52	49	54
Neighborhood safety (self-report)			
Safe or very safe	63	79	48
Unsafe or very unsafe	37	21	52
Physical health (TPCS)	49.6 (9.9)	49.8 (9.5)	49.5 (10.2)

Notes: Values shown are % or mean (SD)

**Table 3. Associations between recorded crime rates and self-reported perception of neighborhood as unsafe among men and women in New Zealand (2010-2011)**

	Overall $\beta$ (95% CI)	Men $\beta$ (95% CI)	Women $\beta$ (95% CI)	Gender interaction p-value
Total Crime	<b>1.9 (1.2, 2.5)</b>	<b>1.4 (0.6, 2.1)</b>	<b>2.2 (1.4, 3.1)</b>	0.15
Violent Crime	<b>4.3 (3.1, 5.4)</b>	<b>4.0 (2.6, 0.5)</b>	<b>4.5 (3.0, 5.9)</b>	0.89
Property Crime	<b>5.4 (3.4, 7.4)</b>	<b>4.2 (1.9, 6.4)</b>	<b>6.5 (4.1, 9.0)</b>	0.14
Dishonesty crime	<b>2.1 (0.6, 3.5)</b>	0.7 (-0.7, 2.2)	<b>3.2 (1.2, 5.2)</b>	<b>0.03</b>
Drug and Antisocial Crime	<b>2.2 (0.9, 3.4)</b>	<b>1.9 (0.4, 3.4)</b>	<b>2.4 (0.8, 3.9)</b>	0.85
Crime with a weapon	<b>12.9 (8.8, 17.0)</b>	<b>10.0 (5.0, 15.1)</b>	<b>15.7 (9.9, 21.4)</b>	0.19
Crime occurring in the night	<b>3.0 (2.0, 4.0)</b>	<b>2.7 (1.6, 3.9)</b>	<b>3.2 (1.9, 4.5)</b>	0.80

Notes: Rescaled coefficients and 95% confidence intervals from linear probability models with cluster robust standard errors are shown, and coefficients (which have been multiplied by 100) can be interpreted as in the expected increase in percentage of participants reporting their neighborhood as unsafe per 1 unit increase in the category-specific crime rate; models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added to separate models (not mutually adjusted); boldface is used to indicate statistical significance ( $p < 0.05$ )

**Table 4. Associations between recorded crime rates and self-reported physical health status among men and women in New Zealand (2010-2011)**

	Overall β (95% CI)	Men β (95% CI)	Women β (95% CI)	Gender interaction p-value
Total crime	-0.09 (-0.1920, 0.01)	-0.04 (-0.1718, 0.1009)	-0.15 (-0.29, -0.01)	0.2722
with perceived safety	-0.087 (-0.1718, 0.0203)	-0.02 (-0.16, 0.1211)	-0.13 (-0.27, 0.00)	
Violent crime	-0.1718 (-0.34, -0.01)	-0.0304 (-0.2527, 0.1920)	-0.32 (-0.55, -0.0910)	0.0708
with perceived safety	-0.13 (-0.30, 0.03)	-0.02 (-0.2022, 0.2425)	-0.29 (-0.5251, -0.0506)	
Property crime	-0.13 (-0.4140, 0.1413)	0.0807 (-0.2925, 0.4538)	-0.33 (-0.7376, 0.0609)	0.1413
with perceived safety	-0.08 (-0.3534, 0.19)	0.1312 (-0.2419, 0.5044)	-0.28 (-0.6871, 0.1215)	
Dishonesty crime	-0.10 (-0.3029, 0.1009)	0.05 (-0.2220, 0.3230)	-0.27 (-0.5552, -0.0201)	0.1106



with perceived safety	-0.08 (-0.2827, 0.1210)	0.06 (-0.2119, 0.3330)	-0.24 (-0.5349, 0.0501)	
Drug and Antisocial crime	<b>0.17</b> (-0.0100, 0.3633)	<b>0.24</b> (-0.0103, 0.5044)	0.10 (-0.1617, 0.3637)	<b>0.3840</b>
with perceived safety	<b>0.19</b> (0.0103, 0.3835)	<b>0.267</b> (0.0206, 0.5247)	0.12 (-0.14, 0.3839)	
Crime with a weapon	0.3229 (-0.3537, 0.9995)	0.6158 (-0.2924, 1.5139)	-0.04 (-1.00097, 0.9289)	<b>0.3328</b>
with perceived safety	0.424 (-0.2224, 1.1118)	0.7471 (-0.1609, 1.6452)	0.09 (-0.8784, 1.0602)	
Crime at night	-0.11 (-0.2526, 0.03)	0.0504 (-0.14, 0.2423)	-0.29 (-0.4951, -0.0907)	<b>0.01</b>
with perceived safety	-0.0809 (-0.2223, 0.06)	0.08 (-0.11, 0.27)	-0.26 (-0.486, -0.0604)	

Notes: Coefficients and 95% confidence intervals from cluster robust linear ~~mixed~~ models are shown, and the coefficients can be interpreted as the predicted difference in self-reported physical health status (as measured by the SF-12 transformed physical component score) associated with a 1 unit increase in the category-specific crime rate; all models controlled for age, ethnicity, place of birth, education, employment, income and smoking status; crime rates for different categories were added to separate models (not mutually adjusted), and results are shown before and after the addition of perceived safety to the models; boldface is used to indicate statistical significance (p<0.05)

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**Table 5. Associations between perception of safety and self-reported physical health status, controlling for recorded crime among men and women living in New Zealand (2010-2011)**

	Overall $\beta$ (95% CI)	Men $\beta$ (95% CI)	Women $\beta$ (95% CI)
Neighborhood perceived as unsafe	<b>-0.9900</b> (-1.4651, -0.5149)	<b>-1.31</b> (-2.0518, -0.5744)	<b>-0.86</b> (-1.4849, -0.2423)
with total crime	<b>-0.9697</b> (-1.4448, -0.4845)	<b>-1.30</b> (-2.0417, -0.4356)	<b>-0.80</b> (-1.43, -0.17)
with violent crime	<b>-0.9495</b> (-1.4246, -0.4643)	<b>-1.32</b> (-2.0619, -0.5744)	<b>-0.77</b> (-1.3940, -0.1413)
with property crime	<b>-0.9899</b> (-1.4550, -0.5047)	<b>-1.33</b> (-2.0720, -0.5946)	<b>-0.82</b> (-1.4445, -0.1918)
with dishonesty crime	<b>-0.9899</b> (-1.4650, -0.5148)	<b>-1.31</b> (-2.0518, -0.5744)	<b>-0.82</b> (-1.4546, -0.2019)
with drug and antisocial crime	<b>-1.0203</b> (-1.4954, -0.5452)	<b>-1.35</b> (-2.0922, -0.6148)	<b>-0.88</b> (-1.50, -0.25)
with crime with a weapon	<b>-1.0203</b> (-1.4954, -0.5451)	<b>-1.36</b> (-2.1023, -0.6248)	<b>-0.87</b> (-1.4950, -0.24)
with crime at night	<b>-0.9697</b> (-1.4448, -0.4846)	<b>-1.34</b> (-2.0822, -0.6047)	<b>-0.78</b> (-1.41, -0.1615)

Notes: Coefficients and 95% confidence intervals from [cluster robust multi-level](#) linear models predicting the physical health index are shown, and coefficients can be interpreted as the predicted difference in physical health status (as measured by the SF-12 transformed physical component score) for comparing those reporting their neighborhood as unsafe for walking at night versus safe for walking at night; covariates include age, ethnicity, place of birth, education, employment, income and smoking status; crime rates were added one at a time to adjusted models, and the coefficients for perceiving neighborhood as unsafe are shown before and after adjustment for each of these crime rates; boldface is used to indicate statistical significance ( $p < 0.05$ )

## Disclaimer

Access to the data used in this study was provided by Statistics New Zealand under conditions designed to uphold the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the authors, not Statistics New Zealand.

## Acknowledgements

We would also like to acknowledge the support of New Zealand Police who provided crime data for this work; and to Statistics New Zealand who provided us with access to data from the General Social Survey.

## Competing Interests

None

## Funding

The authors of this report would like to acknowledge the Christchurch City Council for initiating the research and Ministry of Justice Crime Prevention Unit for the provision of funding, which allowed the project to commence smoothly. The first author would also like to thank the National Institute for Child Health and Human Development (K01HD067390) for their financial support.

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Title and abstract	Item No	Recommendation
	1	<p>(a) Indicate the study's design with a commonly used term in the title or the abstract  <i>The design is indicated in the abstract: "Individual-level data including the SF-12 health index and perceived neighborhood safety from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to crime rates from the New Zealand Police (2008-2010) for each census area unit."</i></p> <hr/> <p>(b) Provide in the abstract an informative and balanced summary of what was done and what was found  <i>We have endeavoured to provide an informative and balanced summary in the abstract:</i>  <i>"Background: Neighborhood crime may influence health through pathways involving direct trauma, chronic stress, or behaviors including physical activity. We investigated associations of both officially recorded crime and perceived neighborhood safety with physical health, evaluating potential effect modification by gender.</i>  <i>Methods: Individual-level data including the SF-12 health index and perceived neighborhood safety from 6,995 New Zealand General Social Survey (2010-2011) participants were linked to crime rates from the New Zealand Police (2008-2010) for each census area unit. Mixed effects regression models accounted for clustering using neighborhood-level random intercepts, and adjusted for sociodemographic characteristics and smoking.</i>  <i>Results: Crime rates, especially those involving a weapon, predicted adults' perception of the neighborhood as unsafe to walk at night. Police-recorded crime rates, especially violent crime and crime occurring at night, were associated with worse physical health; the association with crime at night was significantly stronger among women (interaction p-value: 0.01). Adjustment for perceived safety slightly attenuated these associations. Perceiving the neighborhood as unsafe was independently associated with worse physical health (1.0 unit difference, 95% CI: -1.5 to -0.5).</i>  <i>Conclusions: Gender may differentially modify the associations of officially recorded crime rates with physical health, but perceived neighborhood safety problems were consistently associated with worse physical health."</i></p>
<b>Introduction</b>	2	<p>Explain the scientific background and rationale for the investigation being reported  <i>Background and rationale are described in the first paragraph of the introduction: "Neighborhood characteristics have previously been shown to influence health.[1-3] Crime is one such neighborhood characteristic. Residents living in areas of higher crime have been shown to have worse physical health,[4-6] even after controlling for the potential confounding effect of sociodemographic characteristics... Although recorded crime may be thought to influence health status through perceived safety,[4] the role of perceived safety as a mediator of this relationship has often been assumed rather than tested empirically.[10] Independent or divergent associations have been observed for officially recorded crime as compared with perceived safety problems in analyses predicting health and health behaviors,[12-18] suggesting that recorded crime and perceived safety may not be simply serving as proxies for each other.</i></p>

*Associations of local crime rates with health have been shown to vary based on local[20] or national socioeconomic context,[21] as well as by gender.”*

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Objectives	3	<p>State specific objectives, including any prespecified hypotheses</p> <p><i>Objectives and hypotheses are provided in the last paragraph of the introduction: “This study sought to assess the association of officially recorded crime and self-reported perception of safety on physical health status in a national sample of adult New Zealanders using data from the New Zealand General Social Survey (NZGSS) and crime data obtained from the New Zealand Police. We hypothesized that recorded crime would be negatively associated with physical health, and that the perception of a neighborhood as being ‘unsafe’ would both partially mediate the relationship between recorded crime and physical health, as well as independently predict worse physical health after controlling for recorded crime in the neighborhood of residence. Distinguishable subsets of officially recorded crime rates (by crime type, time of occurrence, involvement of a weapon) allow us to investigate what categories of crime are most associated with perceiving a neighborhood as unsafe and with experiencing worse physical health.[25] We explored whether these associations differed by gender, as men and women may differ in their perception of neighborhood problems, or their stress and behavioral responses to perceived safety hazards.”</i></p>
<b>Methods</b>		
Study design	4	<p>Present key elements of study design early in the paper</p> <p><i>The study design is discussed briefly in the first paragraph of the methods section and a reference for detailed methodological information given: “The New Zealand General Social Survey (NZGSS) was designed to provide information on the well-being of New Zealanders. The NZGSS is a nationally representative cross-sectional survey of New Zealand residents aged 15 years and over. Detailed information on sampling and methodology of the NZGSS has been previously published.[26]”</i></p>
Setting	5	<p>Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection</p> <p><i>This information is provided in the methods</i></p> <p><i>“Briefly, the survey employed a multi-stage sample, and a total of 8,550 participants answered the NZGSS personal questionnaire over a 12-month period from April 2010 to March 2011 (81% response rate). The NZGSS was interviewer-administered in person using computer-assisted personal interviews which covered a wide range of social and economic topics, including sociodemographic characteristics, perceived neighborhood safety, and self-reported health.”</i></p>
Participants	6	<p>(a) Give the eligibility criteria, and the sources and methods of selection of participants</p> <p><i>This was briefly covered with further details available from the reference: “The NZGSS is a nationally representative cross-sectional survey of New Zealand residents aged 15 years and over”</i></p>
Variables	7	<p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable</p> <p><i>Measures are described within the following methods sub-sections:</i></p> <p><i>Physical health status outcome based on self-report</i></p> <p><i>Officially recorded crime rates</i></p> <p><i>Perceptions of neighborhood as unsafe at night</i></p> <p><i>Individual sociodemographic characteristics and smoking</i></p>

Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group <i>The sources of data and details of methods of measurement are described in their respective methods sub-sections.</i>
Bias	9	Describe any efforts to address potential sources of bias <i>We used covariate adjustments, neighbourhood-level random intercepts, and assessed associations for each recorded crime rate separately to account for potential sources of bias, as described in the methods section.</i> <i>“A linear probability model with cluster robust standard errors was used to explore the relationships between crime rates and perception of the neighborhood as unsafe. Multi-level mixed effects linear regression analyses were used to examine the associations between of officially reported crime rates and perception of the neighborhood as unsafe predicting physical health status. An intraclass correlation coefficient (ICC) was used to assess, and random intercepts were used to account for, the potential non-independence of physical health status scores within the same CAU. Due to the correlations between the different types of crime rates (see Table 1), we assessed associations for each recorded crime rate separately and did not mutually adjust for multiple categories of crime in the same model. All models controlled for age, gender, ethnicity, place of birth, education, employment, income, and smoking status.”</i>
Study size	10	Explain how the study size was arrived at <i>The present analysis was on a subset of the analytic database, restricted based on a complete-case approach.</i> <i>“Participants with missing values for any of the analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.”</i>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why <i>In order to make the quantitative results more informative, recorded crime rates were rescaled, such that one unit was equal to one standard deviation regardless of the original scale:</i> <i>“Coefficients and 95% confidence intervals from linear mixed models are shown, and the coefficients can be interpreted as the predicted difference in self-reported physical health status (as measured by the SF-12 transformed physical component score) associated with a one standard deviation higher crime rate.”</i>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding <i>Confounder selection and adjustment is described in the methods, and noted in table footnotes. Covariates were entered in the form shown in Table 2. In addition, we note that we did not mutually adjust associations for the other category-specific crime rates, and that mutual adjustment of officially recorded crime rates and perceived safety was considered apart from the main analysis, due to potential mediation.</i> <i>“Due to the correlations between the different types of crime rates (see Table 1), we assessed associations for each recorded crime rate separately and did not mutually adjust for multiple categories of crime in the same model. All models controlled for age, gender, ethnicity, place of birth, education, employment, income, and smoking status.</i>

*Perception of safety was added to models with officially recorded crime rates to test for independent associations with health and to check for patterns of association consistent with mediation of the crime rate-health associations.”*

(b) Describe any methods used to examine subgroups and interactions

*Gender was considered as potentially modifying the effect of officially recorded crime or perceived safety.*

*“Furthermore, as gender was of interest as a potential effect measure modifier, gender stratification was considered for all analyses; Wald p-values to evaluate the statistical significance of observed effect modification were calculated from models including a gender interaction.”*

(c) Explain how missing data were addressed

*We used a complete-case analysis.*

*“Participants with missing values for any of the analysis variables (N=1,555) were excluded from descriptive statistics and regression analyses.”*

(d) If applicable, describe analytical methods taking account of sampling strategy

*Our study did not use sample weights, but did account for the potential non-independence of observations in the same census area unit.*

(e) Describe any sensitivity analyses

*Our analyses considered the sensitivity of our findings to the measure of safety used by considering categories of officially recorded crime (type, weapon use, time of day) and perception of neighbourhood safety as predictors of interest.*

## Results

Participants	13*	<p>(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed</p> <p><i>We presented this briefly in the Methods sections and included a reference for the more detailed methodology.</i></p> <p>(b) Give reasons for non-participation at each stage</p> <p><i>We do not have information for the reasons for non-participation in the NZGSS, but provide the response rate, which is 81%.</i></p> <p>(c) Consider use of a flow diagram</p> <p><i>We felt that the numbers participating in the study (N= 8550) and those finally analysed (N=6995) in the text was succinct, and we are at the journal-specified limit for tables and figures.</i></p>
Descriptive data	14*	<p>(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders</p> <p><i>This information is given in Table 2. We elected to present gender stratified groups rather than stratifying on exposure because of our interest in effect modification by gender, and our interest in multiple crime and safety-related exposures, some of which are continuous.</i></p> <p>(b) Indicate number of participants with missing data for each variable of interest</p> <p><i>We provided the number of participants with missing data for perception of safety in the Discussion as this made up the majority (70%) of the observations excluded due to missing data and was of greatest concern for the validity of the analyses.</i></p> <p><i>“In particular, the large number of participants who selected “Not applicable”, “Don’t know” or “Refused” in response to the question on perceived safety (N=1092) may have included those who already avoided walking home at night due to safety concerns or health limitations, and this could lead to a biased estimate of the</i></p>

*associations between crime rates, perceived safety, and health status.*"

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Outcome data	15*	<p>Report numbers of outcome events or summary measures</p> <p><i>Table 2 provides the mean physical health score, and additional information is provided in the second paragraph of the results section:</i></p> <p><i>"The physical health index (TPCS based on SF-12) had a theoretical range from 0 to 100, with higher values indicating better physical health. The observed mean and standard deviation were similar for men and women. The ICC for the physical health index across CAUs suggests that 3.1% of the outcome variation may be explained at the CAU level (95% confidence interval: 1.7% to 4.5%)."</i></p>
Main results	16	<p>(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included</p> <p><i>We do not present the unadjusted estimates as we felt that the sociodemographic confounders considered are crucial to account for when interpreting this association. Tables 3, 4, and 5 present adjusted estimates (and 95% confidence intervals), with footnotes clarifying the adjustment strategy. The rationale for confounder selection is discussed in the Methods section.</i></p> <hr/> <p>(b) Report category boundaries when continuous variables were categorized</p> <p><i>Table 2 shows the maximum and minimum of each category for the covariates age and income.</i></p> <hr/> <p>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period</p> <p><i>Not applicable.</i></p>
Other analyses	17	<p>Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses</p> <p><i>Subgroups, interactions, and sensitivity analyses are all presented. Time constraints imposed by working in a secure data lab required us to focus narrowly on the analyses that would address our hypotheses.</i></p>
<b>Discussion</b>		
Key results	18	<p>Summarise key results with reference to study objectives</p> <p><i>Key findings are described in the first paragraph of the discussion:</i></p> <p><i>"For this population of adults living in New Zealand, we observed robust associations between objectively recorded crime rates and perceived neighborhood safety, and between perceived neighborhood safety and physical health. However, there was some evidence of effect modification by gender in the association between objectively recorded crime rates and physical health. Moreover, the category of crime rates most strongly associated with perceived safety (crime with a weapon) was not among the categories most strongly associated with physical health (violent crime and crime at night). The observed patterns were somewhat supportive of the hypothesized role of perceived safety as a mediator between officially recorded crime rates and physical health among women. However, the observed patterns indicate potential heterogeneity by crime type and gender."</i></p>
Limitations	19	<p>Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias</p> <p><i>Limitations are discussed as follows:</i></p> <p><i>"However, the cross sectional and observational study design limit our ability to eliminate non-causal explanations such as reverse causation and unmeasured confounding. Physical health status was self-reported and this could result in</i></p>

*misclassification. Missing data was also an important limitation. In particular, the large number of participants who selected “Not applicable”, “Don’t know” or “Refused” in response to the question on perceived safety (N=1092) may have included those who already avoided walking home at night due to safety concerns or health limitations, and this could lead to a biased estimate of the associations between crime rates, perceived safety, and health status. Misclassification or reasons for missing data could also differ by gender, potentially distorting the observed pattern of effect modification. The measure of perceived safety also did not explicitly state the source for concern with safety and some participants may be considering factors such as traffic hazards instead of crime. Last, crime rates in New Zealand are lower than in many other countries (for example in 2000, the New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000 population in the USA[40]); this and other unique sociocultural factors may change how its neighborhoods function and influence health, limiting the generalizability of our results.”*

19	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence <i>We have made an effort to keep our conclusions cautious, putting them within a larger perspective of the evidence surrounding crime rates and health, with the need for further investigations :</i> <i>“In conclusion, complex patterns of association were observed linking crime rates to physical health among men and women in New Zealand. Future studies should continue to explore differences in by crime category and by gender, and across the multiple pathways that may link crime rates to physical health status. Usage of both officially recorded crime and perceived safety measures is important to tease apart the differences in what they reflect and how they may influence health differently for men and women. Perceived neighborhood safety in particular appears to be a robust predictor of physical health independent of officially recorded crime rates, and potentially modifiable neighborhood characteristics affecting perceived safety warrant further investigation.”</i>
37	Generalisability	21	Discuss the generalisability (external validity) of the study results <i>We note that our findings cannot be generalized beyond the country of study:</i> <i>“Last, crime rates in New Zealand are lower than in many other countries (for example in 2000, the New Zealand violent crime rates were 132.6 per 100,000 compared to 506.1 per 100,000 population in the USA[40]); this and other unique sociocultural factors may change how its neighborhoods function and influence health, limiting the generalizability of our results.”</i>
46	<b>Other information</b>		
47	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based <i>Details of funding for this project are provided:</i> <i>“The authors of this report would like to acknowledge the Christchurch City Council for initiating the research and Ministry of Justice Crime Prevention Unit for the provision of funding, which allowed the project to commence smoothly. The first author would also like to thank the National Institute for Child Health and Human Development (K01HD067390) for their financial support.”</i> <i>Also, the role of funders was noted under funding in the online submission form:</i> <i>“The funders had no role in the design, conduct, or publication of the research.”</i>

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2 \*Give information separately for exposed and unexposed groups.  
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4 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and  
5 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely  
6 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at  
7 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is  
8 available at [www.strobe-statement.org](http://www.strobe-statement.org).  
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