



# Impacts of sociodemographic factors, identities and neighbourhood safety on the relationship between urban green space and adolescent mental well-being: Findings from Tāmaki Makaurau Auckland, Aotearoa New Zealand

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## ABSTRACT

This study explored the relationship between green space accessibility (GSA) in residential area and adolescents' mental well-being, and whether the relationship was moderated by sociodemographic factors (sex, ethnicity, neighbourhood deprivation), identities (gender and sexuality minority, disability) and perceived neighbourhood safety simultaneously. Data from 3813 adolescents who lived in Tāmaki Makaurau Auckland, Aotearoa New Zealand were obtained from the Youth19 Rangatahi Smart Survey. A Gaussian-based two-step floating catchment area method was employed to measure the spatial accessibility to green space at the neighbourhood level. The World Health Organization-5 Well-being Index was used to assess emotional well-being (EW), and the Reynolds Adolescent Depression Scale-short form was employed to measure depressive symptoms (DS). Through moderation analyses, results showed that perceived neighbourhood safety plays a vital role in the GSA – mental well-being association, with a negative trend in adolescents who reported being less safe in neighbourhoods. Adverse associations of GSA were found in gender and sexuality minority, disabled, Asian and Pacific adolescents, under the condition of not feeling safe in neighbourhoods all the time. The results showed marginalised adolescents tended to feel less safe in neighbourhoods, have lower EW and a higher level of DS. Additionally, the results from bivariate correlations showed there were inequalities in GSA for adolescents who lived in most deprived neighbourhoods and adolescents of Māori ethnicity. This study provides novel evidence of the importance of safe and inclusive green space for effectively promoting mental health and mitigating health inequalities of adolescents in urban areas.

## 1. Introduction

Youth worldwide experience a high prevalence of mental health issues, with one in seven adolescents (aged 10-19 years) experiencing a mental disorder (WHO, 2021). A cross-sectional study at the regional level in Aotearoa New Zealand (NZ) revealed a dramatic decline in emotional well-being (EW) among adolescents from 2012 to 2019, along with a rise in depressive symptoms (DS) within the same time span

(Fleming, Tiatia-Seath, et al., 2020). Adolescence is a crucial phase of development, which makes it vital to explore factors that can prevent/mitigate mental health problems and develop practical interventions that can be implemented across different social groups and neighbourhoods.

Urban planning integrating green space is increasingly recommended and utilised by international organisations and governments to address public health in neighbourhoods (UN-Habitat and WHO, 2020;

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WHO, 2016). Green space can be defined from a public health perspective as an environment that is able to provide healing and 'green care' (Haubenhof, Elings, Hassink, & Hine, 2010). Most recently, COVID-19 movement restrictions increased appreciation for nearby green space, which was found to contribute to less depression, anxiety, stress, and more happiness and life satisfaction for residents (Labib, Browning, Rigolon, Helbich, & James, 2022). The mental well-being of young people is gaining attention in light of the pandemic along with the importance of accessibility of green space (Rowley, Topciu, & Owens, 2022; Venter, Barton, Gundersen, Figari, & Nowell, 2020). Adolescents have little control over their immediate environment while simultaneously they are experiencing challenging developmental and life transitions, making them more vulnerable and susceptible to mental health problems.

While studies exploring relationships between green space and youth mental well-being are accumulating, there is a dearth of studies specifically focused on adolescents aged 10-19 years. These studies vary, which may be due to the heterogeneity in green space definitions and research methods, mental well-being outcomes, participants socio-demographic factors and the context of the study areas (Bray, Reece, Sinnott, Martin, & Hayward, 2022; Moll, Collado, Staats, & Corraliza, 2022; Sprague, Bancalari, Karim, & Siddiq, 2022; Tillmann, Tobin, Avison, & Gilliland, 2018; Vanaken & Danckaerts, 2018; Zhang, Mavoa, Zhao, Raphael, & Smith, 2020). For example, Huynh, Craig, Janssen, and Pickett (2013) reported no significant relationship between Canadian adolescents' (aged 11-16 years) positive EW and green space within a 5 km radius circular buffer around schools. However, another study in Canada showed a negative relationship between nature schools and emotions in 10-year-olds (Dopko, Capaldi, & Zelenski, 2019). In contrast, Mavoa et al. (2019) found a positive association between neighbourhood greenness and EW among adolescents (aged 12-19 years) in NZ.

Existing theoretical frameworks suggest that sociodemographic factors are important considerations in comprehending how the role of green space access might relate to mental health. (Lachowycz & Jones, 2013; Markevych et al., 2017). Sociodemographic factors have been suggested to moderate the relationship between green space accessibility (GSA) and mental health due to the potential effects on the opportunity and motivation to use green space (Lachowycz & Jones, 2013). Besides, individual and neighbourhood factors are frequently reported predictors of mental health-related outcomes (Silva, Loureiro, & Cardoso, 2016). Potential risks of mental health problems are unequally distributed across social groups within adolescents and neighbourhoods. Marginalised population groups (i.e., gender and sexuality minority (hereafter rainbow youth), those with long-time health conditions or disabled (hereafter disabled) youth, girls, ethnic minorities and those who live in deprived neighbourhoods) who are socially and economically disadvantaged are more vulnerable and prone to experiencing poorer mental well-being (Fleming, Tiatia-Seath, et al., 2020; Hafeez, Zeshan, Tahir, Jahan, & Naveed, 2017; Honey, Emerson, & Llewellyn, 2011). Hereafter, the term "sociodemographic factors" in this study refers to the variables that indicate sex, ethnicity, neighbourhood deprivation and identities (rainbow, disability). Largely unanswered questions remain, in particular does green space show a stronger association with mental well-being for marginalised or privileged populations, and is this association protective or adverse? Few studies have a particular focus on whether green space matters more for the mental health of differing sociodemographic groups. A recent systematic review found women have a tendency to benefit more from green space and the authors addressed inadequate research on gender and sex differences in environmental health literature (Fernandez Nunez et al., 2022). However, less research focuses on the relationship between green space and mental well-being in other marginalised groups, especially in adolescents (Bray et al., 2022).

In addition, GSA varies across different sociodemographic groups and neighbourhoods. Evidence suggests that spatial inequality in green

space distribution is likely to hinder the benefits that people can derive from green space and further exacerbate health inequities (Lee, Baek, Kim, & Newman, 2022). Further, studies of GSA found that disadvantaged areas tend to have fewer amenities, lower environmental quality and more neighbourhood safety concerns (Hoffmann, Barros, & Ribeiro, 2017; Nesbitt, Meitner, Girling, Sheppard, & Lu, 2019). Reduced neighbourhood safety has been identified as playing a role in declining outdoor time among adolescents in the past decades (Carver, Timperio, & Crawford, 2008; Mainella, Agate, & Clark, 2011), and safety concerns can also lead to a reduction of accessing green space (Chaudhury, Hinckson, Badland, & Oliver, 2017). As such, marginalised groups are more likely to be discouraged from using green space when concerned about safety issues (Williams, Logan, Zuo, Liberman, & Guikema, 2020). For example, research has demonstrated that park utilisation, particularly by females, can be influenced by crime and the sense of security (Marquet et al., 2019). Such disparity has also been highlighted under the framework of environmental justice, as the dimension of interactional justice addressed the quality of interaction and the importance of perception of safety and welcome in public space (Low, 2013). Although perceived safety is a pivotal factor that impacts perceived access (Crawford et al., 2008), knowledge is limited regarding whether sociodemographic factors shape safety perception, which in turn impacts the mental health outcomes gained from green space differently.

Promoting mental well-being in adolescents is complex and requires context-specific, and population-specific approaches (WHO and UNICEF, 2021). As highlighted in systematic reviews (Bray et al., 2022; Fernandez Nunez et al., 2022; Zhang et al., 2020), few studies have explored possible differences between green space and mental well-being associations among adolescents with different sociodemographic characteristics, and perceived safety was seldom included simultaneously. Marginalised groups such as rainbow young people and disabled adolescents have been rarely addressed in green space and mental health research. Therefore, it is necessary to conduct research to explore whether the relationships between GSA and mental well-being are moderated by sociodemographic factors and perceived neighbourhood safety among adolescents, and how and to what extent these factors modify the green space-mental health relation. Findings from this study can shed light on which sociodemographic and neighbourhood factors modify the green space-adolescents' mental well-being association, and whether disparities exist in different sociodemographic groups. Findings can also aid in informing what practical, equitable public health interventions can be utilised to mitigate discrepancies, with implications for green space provision and management.

In light of the gap identified in the literature, this study is an exploratory study, aiming to explore whether the contribution of green space to adolescents' mental well-being is modified by sociodemographic factors and neighbourhood safety simultaneously.

## 2. Methods

We have used the ISLE-ReST (Jia et al., 2020) to report the study methods (Appendix C).

### 2.1. Protocol

The data of participants for the study was extracted from the Youth19 Rangatahi Smart Survey (Youth19), a cross-sectional survey on adolescent health and well-being that is the most recent survey to the Youth2000 series in NZ. The full information of the survey is detailed elsewhere (Fleming, Peiris-John, et al., 2020). Adolescent participants aged 12 to 19 years were recruited across secondary schools in three regions of NZ (Auckland, Northland and Waikato) in 2019. Participants' usual residing places were linked to 2018 census meshblock number without storing actual residential addresses. Social desirability response was limited by ensuring anonymity and privacy during survey

administration. The ethical approval for the survey was granted by the University of Auckland Human Subjects Ethics Committee (No. 022244).

## 2.2. Setting

The current study included participants residing in urban Auckland neighbourhoods. Auckland is New Zealand's most densely populated region, with nearly 94% living in urban areas (Statistics New Zealand, 2018b). The city skews younger, with 26.1% between 10 and 19 years old in 2018 (Statistics New Zealand, 2018b). Auckland is highly ethnic diverse, with 11.5% Māori, 15.5% Pacific Islanders, and 28.2% Asian (Statistics New Zealand, 2018b). This diverse, predominantly urban population makes it an excellent place to study the link between the city environment and adolescent mental well-being.

## 2.3. Variables and measures

### 2.3.1. Green space accessibility (GSA)

In this study, green space is defined as urban public open area with vegetation (Taylor & Hochuli, 2017). Based on the definition, parks, reserves and forests were included as green space according to the context of NZ. The categorisation of these factors was determined by the OpenStreetMap platform. Gaussian-based two-step floating catchment area (2SFCA) (Dai, 2011) was applied to quantify GSA at statistical area 1 level (SA1, the smallest output geography for census and contains 100 to 200 residents on average in NZ (Statistics New Zealand, 2018a)). We subsequently linked meshblock number to SA1 code. 2SFCA accounts for the distance decay effect, considering green space location and size, proximity, and population distribution, which address the spatial access of green space (Dai, 2011). GSA measures are detailed elsewhere (Author et al., under review) and are summarised in Appendix A.

### 2.3.2. Mental well-being outcomes

The study employed the World Health Organization-5 Well-being Index (WHO-5), a self-reported measure consisting of five items that gauges current emotional well (Bech, Olsen, Kjoller, & Rasmussen, 2003) to assess the EW of adolescents. Participants used a rating scale that ranged from "at no time (0)" to "most of the time (5)" to score each item. The sum of the scores produced a summed raw score ranging from 0 to 25, with a higher score illustrating better EW.

The study utilised the Reynolds Adolescent Depression Scale-short form (RADS-SF) to measure current levels of depressive symptomatology in adolescents. RADS-SF is a self-reported measure comprising of ten statements, and participants rated these statements on a scale from "never (1)" to "most of the time (4)". The scores were added together and ranged from 10 to 40; higher scores corresponded with increased DS (Milfont et al., 2008).

### 2.3.3. Moderators

A total of six moderating variables were included in this study: sex (girl; boy), ethnicity (European; Asian; Māori; Pacific), and identities that are often marginalised including rainbow young people (an umbrella term that includes transgender, gender diverse young people and/or same-sex or multiple-sex attracted young people) (yes; no), and disabled adolescents (yes; no). Neighbourhood deprivation (low; medium; high) was measured using NZ Index of Deprivation 2018 (NZDep2018) to represent the SA1 level socioeconomic deprivation (Atkinson, Salmond, & Crampton, 2019). Neighbourhood safety was measured with the question, "Do you feel safe in your neighbourhood?" (4-level Likert scale: 1 = all the time, 4 = never)". Due to the small number of responses, "not often" and "never", neighbourhood safety was treated as a binary variable: feel safe in your neighbourhood all the time (yes/no) (Appendix D).

## 2.4. Data analyses

In analyses of green space-adolescent mental well-being relationships, we quantified GSA across all urbanised areas in Auckland and linked these data to adolescent participants through the SA1 code. First, descriptive analysis and bivariate correlation were carried out using IBM SPSS 25.0 (IBM Cooperation). Next, to test whether the relationship between GSA and adolescent mental well-being varies by sociodemographic factors and neighbourhood safety simultaneously, ten moderation models were performed using PROCESS Macro Ver. 4.1 (model 2). Each moderation model contained GSA, two moderators (one socio-demographic factor, neighbourhood safety), one mental well-being outcome, and interaction terms between green space and moderators. This same analysis format was repeated for five moderator variables and two mental well-being outcomes. The proportion of missing data of variables included in this study was less than 10% and was treated by pairwise deletion. For the analyses, a 95% bias-corrected percentile bootstrapped confidence interval was employed (bootstrap samples = 2000), p-value <0.05 was considered statistically significant. Further, conditional effect (simple slope) analysis was conducted to demonstrate the specific pattern of results for each of the significant interactions between GSA and sociodemographic factors and neighbourhood safety in the preceding analysis.

## 3. Results

### 3.1. Preliminary analysis

This study included 2408 SA1. Descriptive statistics for each variable are presented in Table 1. This study included 3813 adolescent participants, of whom 10% were rainbow young people and 26% were disabled adolescents (Table 1). Approximately one-third of adolescents were European, one-third were Asian, followed by Pacific (17.4%) and Māori (11.9%) ethnicities. Regarding neighbourhood deprivation, 29% of participants lived in the most deprived areas, while 31.6% lived in the least deprived neighbourhoods. More than half of the participants (53%)

**Table 1**  
Variables and their descriptive statistics for participants.

		Descriptive statistics <sup>a</sup>	Missing (%)
Emotional well-being (EW)		15.2 ± 5.7	158 (4.1%)
Depressive symptoms (DS)		22.7 ± 6.4	107 (2.8%)
Green space accessibility (GSA)		52.1 ± 130.6	0 (0.0%)
Sex	Girl	2144 (56.2%)	50 (1.3%)
	Boy	1619 (42.5%)	
Rainbow adolescents	Yes	381 (10.0%)	14 (0.4%)
	No	3418 (89.6%)	
Disabled adolescents	Yes	993 (26.0%)	151 (4.0%)
	No	2669 (70.0%)	
Ethnicity	European	1272 (33.4%)	208 (5.5%)
	Asian	1217 (31.9%)	
	Māori	454 (11.9%)	
	Pacific	662 (17.4%)	
Neighbourhood deprivation	Least	1204 (31.6%)	0 (0.0%)
	Moderate	1502 (39.4%)	
	Most	1107 (29.0%)	
Always feel safe in neighbourhood	Yes	2022 (53.0%)	229 (6.0%)
	No	1562 (41.0%)	

Note.

<sup>a</sup> Frequencies (%) for binary or ordinal variables; mean ± standard deviation for continuous.

felt safe in their neighbourhood all the time.

Bivariate correlations between GSA and moderating variables are presented in Table 2. Nominal variables (i.e., ethnicity and neighbourhood safety) were treated as dummy variables. GSA had positive relationships with being of European ethnicity and residing in the least deprived neighbourhoods, while negative correlations were found for adolescents of Māori ethnicity and those who lived in the most deprived neighbourhoods. Rainbow youth, disabled adolescents, girls, adolescents of Māori ethnicity and those who lived in the most deprived neighbourhoods showed significant negative correlations with neighbourhood safety. In contrast, adolescents of European ethnicity and adolescents who lived in the least deprived neighbourhood were significantly positively correlated with neighbourhood safety.

### 3.2. Associations of GSA, sociodemographic factors and neighbourhood safety with mental well-being outcomes

Table 3 and Table 4 show the results for the associations of GSA, sociodemographic factors, and neighbourhood safety with adolescents' EW and DS, respectively (the full results are shown in Appendix B).

Statistically significant relationships were found between several sociodemographic factors and adolescents' mental well-being. Specifically, rainbow youth ( $b = -3.590, p < 0.001$ ), disabled adolescents ( $b = -2.530, p < 0.001$ ), and girls ( $b = -2.098, p < 0.001$ ) had significantly lower EW. Pacific youth ( $b = 1.819, p < 0.001$ ) had significantly higher EW than European youth. Compared to the participants who lived in the least deprived neighbourhoods, those who resided in the most deprived areas ( $b = 1.113, p < 0.001$ ) had higher EW (Table 3). Regarding DS, rainbow youth ( $b = 4.574, p < 0.001$ ), disabled adolescents ( $b = 3.232, p < 0.001$ ), and girls ( $b = 2.409, p < 0.001$ ) had significant positive relationships with DS. Compared to adolescents of European ethnicity, Asian ( $b = 0.980, p < 0.001$ ) and Māori ( $b = 0.983, p = 0.013$ ) young people had higher DS (Table 4). Neighbourhood safety was positively associated with adolescents' EW (Table 3) while negatively associated with DS (Table 4). A negative relationship between GSA and EW was detected in the moderation model with rainbow youth and neighbourhood safety ( $b = -0.003, p = 0.025$ ).

### 3.3. Double moderating effects on the relationship between GSA and adolescents' mental well-being

We tested whether the associations between GSA and adolescents' mental well-being were moderated by sociodemographic factors and

neighbourhood safety simultaneously. The results of conditional effects are provided in Table 5 and Table 6. For EW, the results revealed significant interactions between GSA and rainbow adolescents ( $b = -0.005, p = 0.044$ ) and neighbourhood safety ( $b = 0.004, p = 0.018$ ) on adolescents' EW (Table 3). The adverse association of green space is lower for rainbow adolescents ( $b = -0.008, p = 0.002$ ) than their peers ( $b = -0.003, p = 0.025$ ) if both of them reported not feeling safe all the time in their neighbourhood. The negative association above were cancelled for those with a higher neighbourhood safety perception. The moderation model with ethnicity also detected a significant interaction between GSA and neighbourhood safety ( $b = 0.003, p = 0.039$ ). Under the condition of not feeling safe in the neighbourhood all the time, for Asian ( $b = -0.004, p = 0.048$ ) and Pacific adolescents ( $b = -0.008, p = 0.011$ ), GSA was significantly negatively associated with EW. For DS, a significant interaction was found between GSA and disabled adolescents ( $b = 0.004, p = 0.033$ ). GSA was positively associated with DS if disabled young people could not feel safe in their neighbourhood all the time. No significant moderating effect was found in other associations.

## 4. Discussion

In this study, we add new evidence to understand whether the contribution of green space to adolescents' mental well-being is modified by sociodemographic factors and neighbourhood safety simultaneously. Both being in the rainbow adolescent group and neighbourhood safety moderated the GSA-EW relationship, with a negative association between GSA and EW detected. The adverse relationship of GSA was reduced for those who reported feeling safe all the time in neighbourhoods. Rainbow adolescents were likely to have lower EW, more DS and lower perceived safety in their neighbourhoods than non-rainbow peers. To the best of our knowledge, this is the first attempt to unravel the relationship between GSA and mental health in sexual and gender minorities. These findings suggested that feeling safe in the neighbourhood is likely to play an essential role in whether a space impacts adolescents' EW or not. Rainbow communities experience considerable discrimination and violence in public spaces (Dunn, 2011), which may lead to the deprivation of opportunity to use certain green space and further exacerbate mental health disparities. For example, sports fields are a common public green space, however, LGBTQ+ people experience significant discrimination in sports (Denison, Bevan, & Jeanes, 2021). Such conditions could influence how gender and sexual minorities behave, feel, and socialise in green space, which in turn could impact the activation of benefits of green space on mental well-being. In

**Table 2**  
Bivariate correlation between variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
GSA (1)													
Rainbow (2)	.011												
Disabled (3)	0	.127***											
Sex (girl) (4)	.023	.118***	.040**										
Least deprived neighbourhood (5)	.078**	.005	-.001	.006									
Moderately deprived neighbourhood (6)	.009	.025	.028†	-.020	-.548***								
Most deprived neighbourhood (7)	-.089**	-.031†	-.029†	.016	-.434***	-.516***							
European (8)	.057**	.005	.058***	.007	.377***	-.026	-.358***						
Pacific (9)	-.018	-.062***	-.074***	-.036**	-.243***	-.124***	.383***	-.325***					
Asian (10)	-.006	.025	-.055***	.008	-.097***	.171***	-.084***	-.486***	-.315***				
Māori (11)	-.041*	.018	.064***	.008	-.105***	-.086***	.200***	-.261***	-.169***	-.252***			
Neighbourhood safety (12)	.018	-.066***	-.074***	-.132***	.138***	.007	-.153***	.066***	-.047***	-.027	.004		
Emotional well-being (13)	-.017	-.206**	-.220**	-.219**	-.023	-.03	.057**	-.025	.096**	-.042*	.006	.224**	
Depressive symptoms (14)	.005	.238**	.246**	.230**	-.060**	.013	.048**	-.087**	-.013	.062**	.023	-.255**	-.682**

Note: \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ , † $p < 0.1$ .



**Table 3**  
Moderating effects of sociodemographic factors and neighbourhood safety on the association between GSA and adolescents' EW.

	Rainbow	Disability	Sex (girl)	Ethnicity	Neighbourhood deprivation
	Coef.	Coef.	Coef.	Coef.	Coef.
GSA	-.003*	.003	-.002	-.002	-.001
Neighbourhood safety	2.221***	2.18***	2.095***	2.487***	2.609***
GSA x Neighbourhood safety	.004*	.003	.003‡	.003*	.002
Rainbow youth	-3.59***				
GSA x rainbow youth	-.005*				
Disability		-2.53***			
GSA x Disability		-.001			
Sex (girl)			-2.098***		
GSA x Sex (girl)			-.001		
Asian <sup>a</sup>				.127	
Māori <sup>a</sup>				.389	
Pacific <sup>a</sup>				1.819***	
GSA x Asian <sup>a</sup>				-.002	
GSA x Māori <sup>a</sup>				-.004	
GSA x Pacific <sup>a</sup>				-.005‡	
Moderately deprived <sup>b</sup>					.344
Most deprived <sup>b</sup>					1.113***
GSA x Moderately deprived <sup>b</sup>					-.003
GSA x Most deprived <sup>b</sup>					.001
ΔR <sup>b</sup>	.24%	.11%	.13%	.27%	.19%

Note: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, †p < 0.1.

<sup>a</sup> reference group is European.

<sup>b</sup> reference group: least deprived neighbourhoods.

**Table 4**  
Moderating effects of sociodemographic factors and neighbourhood safety on the association between GSA and adolescents' DS.

	Rainbow	Disability	Sex (girl)	Ethnicity	Neighbourhood deprivation
	Coef.	Coef.	Coef.	Coef.	Coef.
GSA	.002	-.001	.001	.001	.001
Neighbourhood safety	-2.935***	-2.970***	-2.785***	-3.075***	-3.102***
GSA x Neighbourhood safety	-.002	.001	-.002	-.003	-.002
Rainbow youth	4.574***				
GSA x rainbow youth	.004‡				
Disability		3.232***			
GSA x Disability		.004*			
Sex (girl)			2.409***		
GSA x Sex (girl)			.001		
Asian <sup>a</sup>				.980***	
Māori <sup>a</sup>				.983*	
Pacific <sup>a</sup>				.220	
GSA x Asian <sup>a</sup>				.002	
GSA x Māori <sup>a</sup>				.004	
GSA x Pacific <sup>a</sup>				.000	
Moderately deprived <sup>b</sup>					.268
Most deprived <sup>b</sup>					.356
GSA x Moderately deprived <sup>b</sup>					.001
GSA x Most deprived <sup>b</sup>					.001
ΔR <sup>b</sup>	.12%	.13%	.06%	.11%	.07%

Note: \*\*\*p < 0.001, \*\*p < 0.01, \*p < 0.05, †p < 0.1.

<sup>a</sup> reference group is European.

<sup>b</sup> reference group: least deprived neighbourhoods.

addition, lacking peer support is another possible reason to explain the adverse effect of green space on rainbow adolescents' EW. Adolescence is a time of heightened peer engagement, thus, perceived peer support, to some extent, can buffer negative emotions while increasing better mental well-being in natural environments (Dolgin, 2014). Being with a friend was observed to increase positive affect in green space among adolescents (Greenwood & Gatersleben, 2016). However, difficulties for rainbow adolescents to access peers (Pallotta-Chiarolli & Martin, 2009), may reduce the benefits rainbow young people can enjoy from public spaces.

GSA was associated with increased DS for disabled adolescents if they did not always feel safe in their neighbourhood. Disabled adolescents tended to feel less safe in their neighbourhoods, have more DS and have a lower level of EW. Few studies have tested for disability and/or

neighbourhood safety as moderators of the green space-mental well-being link. Our results may be partially attributed to the fact that that disabled adolescents are more dependent on both the accessible design of, and proximity to, neighbourhood green space than their non-disabled peers, as the former has less mobility compared to the latter (Murphy, Carbone, & American Academy of Pediatrics Council on Children With D, 2008; Statistics New Zealand, 2013). However, suboptimal public green space design can turn it into an unfriendly space for disabled adolescents. As addressed in recent NZ research, although the protective effects of green space on mental well-being were highlighted by disabled young participants, their needs and preferences are marginalised in green space design, making green space hard to access (Smith et al., 2021). On the other hand, specially designed green space can result in disabled people feeling uncomfortable due to their position being too

**Table 5**

Slope for GSA predicting EW at the condition of neighbourhood safety, rainbow identity and ethnicity.

Neighbourhood safety		Effect (95%CI)	se	t	p
<b>Identified as rainbow</b>					
Yes	No	-.008** (-.013, -.003)	.003	-3.039	.002
Yes	Yes	-.004† (-.009, 0)	.002	-1.794	.073
No	No	-.003* (-.006, 0)	.001	-2.242	.025
No	Yes	.001 (-.001, .002)	.001	.805	.421
<b>Ethnicity</b>					
European	No	-.002 (-.005, .001)	.001	-1.480	.139
European	Yes	.001 (-.001, .003)	.001	1.205	.228
Asian	No	-.004* (-.008, 0)	.002	-1.982	.048
Asian	Yes	-.001 (-.003, .002)	.001	-.399	.690
Māori	No	-.006† (-.012, 0)	.003	-1.876	.061
Māori	Yes	-.003 (-.009, .003)	.003	-.890	.373
Pacific	No	-.008* (-.013, .002)	.003	-2.547	.011
Pacific	Yes	-.004 (-.010, .001)	.003	-1.520	.129

Note: \*\*p < 0.01, \*p < 0.05, †p < 0.1, For neighbourhood safety, no = reported not to feel safe in the neighbourhood all the time, yes = feel safe in the neighbourhood all the time.

**Table 6**

Slope for GSA predicting DS at the condition of neighbourhood safety and disabled identity.

Neighbourhood safety		Effect (95%CI)	se	t	p
<b>Disabled</b>					
Yes	No	.003* (.001, .005)	.001	2.444	.015
Yes	Yes	.003† (0, .006)	.002	1.898	.058
No	No	-.001 (-.005, .003)	.002	-.531	.596
No	Yes	-.001 (-.003, .001)	.001	-.671	.503

Note: \*p < 0.05, †p < 0.1, For neighbourhood safety, no = reported not to feel safe in the neighbourhood all the time, yes = feel safe in the neighbourhood all the time.

prominent (Seeland & Nicolè, 2006), adding to the burden and mental load of using public green space. Similar to rainbow young people, a lack of social inclusion is another possible reason limiting the benefits of being in green space for disabled adolescents. The lack of equal participation opportunities in green spaces is attributed to the ableist physical and social structures that restrict experience and benefits from green space (Smith et al., 2021). For those who have visible differences, everyday ableism and profoundly negative social experiences occur in public spaces (Calder-Dawe, Witten, & Carroll, 2019). Disabled youth show lower levels of physical activity participation than their non-disabled counterparts (Murphy et al., 2008), commonly experiencing exclusion from normative/abled sports settings (Carroll, Witten, & Duff, 2021; Lynch & Hill, 2020).

Adolescents of Pacific ethnicity tended to have a higher level of EW than European adolescents, while Māori and Asian adolescents had more DS than adolescents of European ethnicity. The moderation effect of perceived neighbourhood safety was also found in green space-EW relationship among adolescents of different ethnicities. The moderation effect is mainly observed in Asian and Pacific adolescents who did not feel safe in neighbourhoods all the time, with a negative association between green space and EW. It is unclear why there would be ethnic differences in green space for factors like emotional wellbeing, but this may be related to wider socio-cultural determinants including racism, poverty and safety (Sutcliffe et al., 2023). Few studies have examined ethnicity as a moderator of the green space-mental health association. Systematic reviews identified a shortfall of consideration of subgroups such as race and ethnicity when exploring relationships between green space and adolescent mental well-being (Sprague et al., 2022; Zhang et al., 2020), and mixed results were found in adults studies (Browning

& Rigolon, 2018; McEachan et al., 2016; Pun, Manjourides, & Suh, 2018). It is worth recalling that the cut-off value of statistical significance was  $p < 0.05$  in the current research, however, results close to  $p < 0.05$  (e.g., the interaction between GSA and Pacific adolescents) may also have a potential trend tendency to moderate the relationship of interest. Further, since more adolescents of Pacific ethnicity lived in most deprived areas (42.2% vs 27.2% Asian, 23.2% Māori, 7.4% European) and perceived less safety in their neighbourhoods, future research with more social and physical environmental factors that might affect the usability of green space are required to explore health equity among different ethnicities in green space-health association.

Our analyses showed no moderation effect of sex in the relationship between neighbourhood GSA and mental health among adolescents. The findings do not align with previous research that indicated gender differences in visit and appropriation of certain public spaces among adolescents (Bromley & Stacey, 2012; Fleckney, 2023; van der Burgt, 2013). This adds new knowledge to the limited literature on the important role of sex in green space-mental health association (Fernandez Nunez et al., 2022; Mouly, Knibbs, & Mishra, 2021). One possible reason for the non-significant results is that both boys/men and girls/women were equally fearful of some potential risks in public spaces, for example, a group of drunken teenagers (Bromley & Stacey, 2012; van der Burgt, 2013). Although the moderating role of neither neighbourhood safety nor sex was detected in the models, results showed girls had lower EW, more DS and felt less safe in their neighbourhood than boys. These findings were in line with previous adult-based evidence that females are more vulnerable to some mental health outcomes (Vloo, Alessie, Mierau, & Lifelines Corona Research, 2021) and have a heightened concern for safety in public spaces (Sonti, Campbell, Svendsen, Johnson, & Novem Auyeung, 2020). Meanwhile, the result could hint at the potential role of GSA in mitigating gender-based health inequalities, as existing evidence has shown women could benefit more from green space (Fernandez Nunez et al., 2022; Mouly et al., 2021; Sillman, Rigolon, Browning, Yoon, & McAnirlin, 2022). Future research is recommended to explore associations between green space-based and internal/social barriers and girls' usage and perception of green space.

Regarding adolescents who lived in the most deprived areas, neighbourhood deprivation and perceived neighbourhood safety did not moderate the GSA-mental well-being association. Our results contrast with previous studies in adults and children that showed people living in more deprived neighbourhoods benefit more from green space (Flouri, Midouhas, & Joshi, 2014; McEachan et al., 2016). It is possible that the inequality of neighbourhood GSA led to less opportunity to use green space among those who live in more deprived neighbourhoods, which results in a limited time of being in green space. Hartig (2004) suggested that longer nature exposure provides stronger protective effects on mental well-being. Our findings indicated that the most deprived neighbourhoods in Auckland tend to have less neighbourhood GSA than the least deprived neighbourhoods. As noted earlier, green space in more deprived areas is likely to have lower maintenance and quality, which may discourage the motivation to access green space. Our results also showed that people who lived in the least deprived neighbourhoods tended to have higher neighbourhood GSA. Moreover, people living in affluent communities might have higher mobility and may be able to travel longer distances to use green space outside their immediate neighbourhoods. The exclusive use of gardens is another common feature among residents of more affluent communities (Xiao, Wang, Li, & Tang, 2017). Therefore, inequities in health-promoting green space may still persist for adolescents residing in more deprived neighbourhoods, even with a higher level of neighbourhood GSA. The current finding of the null moderation effect of neighbourhood deprivation highlights the importance of context and population-specific considerations in terms of neighbourhood green space-mental health association, including household access to green space and transport deprivation.

Overall, the current research indicates the importance of taking

sociodemographic factors and perceived safety into account in exploring neighbourhood GSA – adolescents' mental well-being associations. The disparities in EW and DS between marginalised adolescents and their peers highlight existing health inequality among adolescents and a need for improved urban safety and green space in Auckland. Social and physical realms that perpetuate normative values (e.g., those that are ableist, homophobic, transphobic) can make the public realm unsafe for adolescents. Any positive impact of green space is likely to be conditional on these being safe and inclusionary spaces for young people, particularly for marginalised adolescents who are the most susceptible to these factors. Accordingly, these adolescents are possibly unable to realise the potential mental well-being benefits provided by green space, or the positive aspects of green space get cancelled, making it insufficient to overcome these lower rates of mental well-being. Therefore, involving evaluations of safety and inclusion is a critical consideration for existing and future green space projects.

In practice, multiple approaches can be applied to improve safety perceptions and social inclusion, for example, improving lighting and regular maintenance, reducing vegetation density near paths, constructing visible symbols of support (e.g., queer monuments), increasing formal surveillance (e.g., CCTV), and implicating environmental and technological designs (Cozens, Saville, & Hillier, 2005; Harris et al., 2017; Orangias, Simms, & French, 2018; Smith et al., 2021). LGBTQ supportive environments have positive impacts on mental health, including being protective against suicidal behaviour in adolescent girls (Saewyc et al., 2020), and being associated with lower odds of frequent substance use (Eisenberg et al., 2020). Even visible symbols of support (e.g., use of the pride rainbow) could facilitate navigation (although its presentation does not always guarantee supportiveness) (Wolowic, Heston, Saewyc, Porta, & Eisenberg, 2017). Policy makers should pay special attention to marginalised groups, as they are doubly disadvantaged in accessing green space in that their social inclusion is worse than their counterparts. In this context, equitable access and availability are important for all groups, but additional considerations for marginalised groups should be taken into account, for example practical, psychological, or symbolic barriers that make people feel unsafe or unwelcome. New green space projects should also balance the impact of gentrification due to green space investment. It is possible that marginalised groups would become invisible due to neighbourhood gentrification. Thus, inclusive or sustainable development strategies considering contextual conditions, respecting indigenous cultural identity and involving more marginalised groups in decision-making are recommended when drafting afforestation plans in the process of mitigating health inequality by provisioning green space (Raerino, Macmillan, Field, & Hoskins, 2021).

#### 4.1. Limitations and future studies

This study has several limitations. First, the difference in the types, quality, attractiveness and maintenance of neighbourhood green space were not considered in the current research. The characteristics of green space may influence adolescents' perception and usage, and further impact the outcome relationship between green space and well-being. Second, the neighbourhood-level measure of GSA provides the potential opportunity to access to green space, but does not reflect actual green space access among adolescents. Third, due to the nature of the cross-sectional study, causal inferences between green space and adolescents' mental well-being cannot be made. Fourth, this study did not include possible control variables in analysis, thus interpreting the results requires caution because the potential risk of unmeasured confounding.

Future research could build on our findings. It is worth noting that the sociodemographic factors included in the current study are considered independent of each other. It is likely that an intersectional approach (e.g., combining the sociodemographic factors) would have considerable impacts on the prevalence of wellbeing (e.g., disabled +

rainbow) in future studies (Armstrong, Haregu, Young, & Paradies, 2022). Exploring different types of disability as possible moderators is another consideration for future research. Further, how sociodemographic factors interact with social roles and power structure is another consideration regarding marginalised groups. More details and evidence focusing on subgroups among adolescents are needed to explore the relationship between green space and mental well-being of this special age group. Future examination of the impact of ethnicity in use and response to green space, could be important for future research. It is critical to conduct research exploring motivations that encourage adolescents to access to green space, counter to this, barriers preventing them from using green space is another necessity. Further, combined with real-time activity records, data reflecting the daily routine of adolescents is needed to measure the actual green space access in adolescents. While this study focused on specific sociodemographic factors, other individuals and neighbourhood factors are worth exploring in future research. It is worth noting that not all variables used in these analyses have been tested for validity and reliability. Future work would benefit from testing this suite of measures to ensure they are capturing the variables of interest appropriately.

## 5. Conclusion

To the best of our knowledge, this study is the first to test the moderation effects of sociodemographic factors and perceived neighbourhood safety simultaneously in the relationship between neighbourhood GSA and adolescents' EW and DS. Our results showed that perceived neighbourhood safety plays an important role in GSA - EW association, with a negative trend in adolescents who did not feel safe in the neighbourhood all the time. Importantly, our results showed adverse associations of GSA on rainbow adolescents' EW and disabled adolescents' DS under the condition of not feeling safe in neighbourhoods all the time. Our study also highlights the prevalence of lower EW and a higher level of DS among marginalised adolescents, and the inequality of GSA in adolescents who lived in most deprived neighbourhoods and with Māori ethnicity. Our findings uncovered some potential reasons for the mixed conclusions from previous research and highlight the complexity of understanding the green space – mental well-being relationships among adolescents. Given these findings, for urban planners and policy makers, we call for safe and inclusive green space to effectively promote mental health and mitigate health inequalities of young people.

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## Ethical statement

The ethical approval for the survey was granted by the University of Auckland Human Subjects Ethics Committee (No. 022244).

## CRedit authorship contribution statement

**Yijun Zhang:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jinfeng Zhao:** Methodology, Supervision, Writing – review & editing. **Suzanne Mavo:** Supervision, Writing – review & editing. **John Fenaughty:** Writing – review & editing. **Terryann C. Clark:** Writing – review & editing. **Sue Crengle:** Writing – review & editing. **Melody Smith:** Conceptualization, Methodology, Supervision, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Applications for Youth19 data must follow the Data Access Policy for Youth19 as outlined at <https://www.fmhs.auckland.ac.nz/assets/fmhs/faculty/ahrg/docs/2020/youth19-daps-dec2019.pdf>.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2024.101603>.

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