



Does access to neighborhood green space promote a healthy duration of sleep? Novel findings from 259,319 Australians

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-003094
Article Type:	Research
Date Submitted by the Author:	22-Apr-2013
Complete List of Authors:	Astell-Burt, Thomas; University of Western Sydney, School of Science and Health Feng, Xiaoqi; Centre for Health Research, School of Medicine Kolt, Gregory; University of Western Sydney, School of Science and Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Sociology
Keywords:	EPIDEMIOLGY, PUBLIC HEALTH, SOCIAL MEDICINE

SCHOLARONE™
Manuscripts

1
2
3 **Does access to neighborhood green space promote a healthy duration of sleep? Novel findings**
4 **from 259,319 Australians**
5
6
7

8 **ABSTRACT**
9

10
11 **Objectives:** Experiments demonstrate that exposure to parks and other 'green spaces' promote
12 favorable psychological and physiological outcomes. As a consequence, people who reside in greener
13 neighborhoods may also have a lower risk of short sleep duration (<6 hours). This is potentially
14 important as short sleep duration is a correlate of obesity, chronic disease, and mortality, but so far
15 this hypothesis has not been previously investigated.
16
17
18
19

20
21
22 **Design:** Cross-sectional data analysis
23

24
25 **Setting:** New South Wales, Australia
26
27

28 **Participants:** This study investigated whether neighborhood green space was associated with a
29 healthier duration of sleep (to the nearest hour) among 259,319 Australians who completed the 45 and
30 Up Study baseline questionnaire between 2006 and 2009 inclusive.
31
32
33

34
35 **Primary and secondary outcome measures:** Multinomial logit regression was used to investigate
36 the influence of an objective measure of green space on categories of sleep duration: 8 hours (normal);
37 between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours (mid-
38 short sleep); less than 6 hours (short sleep). Models were adjusted for psychological distress, physical
39 activity, and a range of demographic and socioeconomic characteristics.
40
41
42
43
44

45
46 **Results:** People living in greener neighborhoods reported a lower risk of short sleep. For example,
47 compared to participants living in areas with 20% green space land-use, the relative risk ratios for
48 participants with 80%+ green space was 0.86 (95% confidence interval (95%CI) 0.81, 0.92) for
49 durations between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6-hours sleep.
50
51
52

53
54 Unexpectedly, the benefit of more green space for achieving 8 hours of sleep was not explained by
55 controls for psychological distress, physical activity, or other socioeconomic factors.
56
57
58
59
60

1
2
3 **Conclusion:** Green space planning policies may have wider public health benefits than previously
4 recognized. Further research on the role of green space in promoting healthier sleep durations and
5 patterns is warranted.
6
7
8
9

10 11 12 13 **Article Summary**

14 15 16 **Article Focus**

- 17
18 • Previous work suggests that more green space within the neighborhood environment can
19 promote better mental health and more active lifestyles
20
21
- 22 • Better mental health and more active lifestyles are correlates of a healthy duration of sleep
23 (usually around 8 hours a night)
24
25
- 26 • Greener neighborhoods, therefore, may guard against short sleep duration (usually less than 6
27 hours per night), which is correlated with obesity, chronic disease, and mortality
28
29
30
31
32
33
34
35
36

37 **Key Messages**

- 38
39 • In a large study of Australian adults, we found those in greener neighborhoods were at a
40 lower risk of short sleep (< 6 hours a night)
41
42
- 43 • More green space was not associated with longer sleep durations (which are also correlated
44 with poor health outcomes)
45
46
- 47 • Unexpectedly, the benefit of more green space for achieving a healthier duration of sleep was
48 not explained by controls for psychological distress, physical activity, and socioeconomic
49 variables
50
51
52
53
54
55
56
57
58
59
60

Strengths and Limitations

- This study benefits from a large sample size focusing on adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of health services
- This study is strengthened by use of validated measures of sleep duration, psychological distress, physical activity, and an objective measure of green space exposure
- Cross-sectional data prohibits causal inference, though follow up of the participants across time will allow the opportunity for replication of this study with a longitudinal design

Introduction

Positive psychological and physiological outcomes from exposure to parks and other forms of natural environment in experimental studies¹⁻³ have fuelled support for the integration of these 'green spaces' within planning policy.^{4,5} Health benefits are thought to accrue via psycho-neuro-endocrine pathways, wherein the experience of nature triggers restoration.⁶⁻⁸ These benefits are likely to be in tandem with physical activity, more of which is not only correlated with better mental health,⁹ but also increasingly likely among people who live in greener neighborhoods.^{10,11}

While the epidemiological literature is increasingly replete with studies documenting association between green spaces, mental health and physical activity, less attention has been paid to other important health behaviors and outcomes. One such outcome is sleep duration. Many studies have reported a parabolic association¹² between the number of hours a person sleeps and their subsequent risk of poor self-rated health¹³, obesity^{14,15}, cardiovascular disease¹⁶, diabetes^{17,18} and death.¹⁹⁻²¹ Favorable mental health and active lifestyles are thought to be drivers of a healthier duration of sleep (usually around 8 hours per night).²²⁻²⁴ Since these drivers are widely reported to be positive outcomes of living in greener neighborhoods, we hypothesized that people with access to more green space would therefore be more likely to achieve a healthier duration of sleep.

This hypothesis was investigated in a large sample of Australian adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of healthcare in Australia.

METHOD

Data

A sample of 259,319 participants with valid data on sleep duration were selected from 267,151 in the 45 and Up Study.²⁵ The questionnaire is available online from www.45andup.org.au. Participants were randomly selected from the Medicare Australia database (the national provider of universal

1
2
3 health insurance) and surveyed between 2006 and 2009. The survey response rate was 18%, though
4
5 previous work has shown that results from the 45 and Up Study are comparable to those derived from
6
7 a representative population survey.²⁶ Geocoding of participants in the 45 and Up Study was available
8
9 at the Census Collection Districts (CCD) scale. CCDs contain 225 people on average and were the
10
11 smallest geography at which 2006 Census data were disseminated.²⁷ The University of New South
12
13 Wales Human Research Ethics Committee approved The 45 and Up Study.

14 15 16 17 18 19 *Outcome measure*

20
21
22 Sleep duration was derived from responses to the following question: “About how many hours in each
23
24 24 hour day do you usually spend sleeping (including at night and naps)?” and has been used in
25
26 previous analyses of the same data.^{13 14 24 28} Responses to this question were missing for 7,755 people
27
28 and these were omitted from the analyses. To account for the curvilinear association between sleep
29
30 duration and health,¹² responses were classified into a multinomial variable as follows: 8 hours
31
32 (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours
33
34 (mid-short sleep); less than 6 hours (short sleep). This classification allows for the healthiest duration
35
36 (8 hours) to be used as a reference group for all other categories.

37 38 39 40 41 42 *Green space*

43
44
45 Meshblocks classified as ‘parkland’ in the Australian Bureau of Statistics (ABS) land-use
46
47 classification for 2006 were used to construct the measure of green space. ‘Farmland’ meshblocks
48
49 were not used as they do not strictly represent spaces available for recreation. The measure of green
50
51 space was based upon the percentage available within a 1 kilometer (km) buffer around the
52
53 population-weighted centroid of each CCD. A 1km buffer was selected so as to represent land-use
54
55 within a reasonable walking distance from home. The percentage green space measure was classified
56
57 into fifths to explore for potential non-linearities (0-20%, 20-40%, 40-60%, 60-80%, 80%+).

1
2
3
4
5
6 *Other individual and neighborhood measures*
7

8
9 The Kessler Psychological Distress Scale (K10) was used to assess mental health status.^{29 30} The K10
10 measures symptoms of psychological distress experienced over the past four weeks, including feeling
11 tired for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five
12 choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3,
13 most of the time =4, all of the time=5). The K10 is constructed by summing responses to each of the
14 questions, with scores of 22 and over identified those with a high risk of psychological distress.³¹ The
15 K10 has been used in this way in previous published analyses of the 45 and Up Study.³²
16
17
18
19
20
21
22
23

24 The measure of physical activity was an aggregate of the number of 10 minute sessions spent either
25 walking or in moderate to vigorous physical activity (MVPA), assessed using the Active Australia
26 Survey.³³ The question was “How many times did you do each of these activities last week?”
27
28 Participants could indicate walking, moderate (e.g. gentle swimming) and vigorous (e.g. jogging)
29 forms activity separately.
30
31
32
33
34

35 A range of other individual characteristics were also taken account of, including age, gender, ethnicity,
36 country of birth, body mass index (BMI), annual income, highest educational qualifications, economic
37 status (employed, unemployed, retired, inactive due to poor health), couple status, number of
38 alcoholic drinks consumed in the last week, smoking status, language other than English spoken at
39 home, and the Duke Social Support Index.³⁴
40
41
42
43
44
45

46 Two other characteristics at the neighborhood-level were considered. The Socio-Economic Index for
47 Areas (SEIFA) ‘Index of Relative Socio-Economic Advantage/Disadvantage’ was used to measure
48 local socioeconomic circumstances. Differences between urban and rural areas were controlled using
49 the ‘Accessibility / Remoteness Index of Australia’ (ARIA). Like the measure of green space, both of
50 these neighborhood indicators were created using data from 2006 to fit with the baseline questionnaire.
51
52
53
54
55
56
57
58
59
60

Statistical analysis

Cross-tabulations were used to compare the patterning of each sleep duration category according to proximity to green space and all other explanatory variables. A multinomial logit regression was used to assess the risk of short sleep versus an 8-hour sleep duration (reference), accounting for longer sleeps as separate categories simultaneously within the same model. Parameters were exponentiated to relative risk ratios (RRR). RRRs over 1 indicated positive association, whereas RRRs below 1 denoted negative association. Bivariate models containing the measure of green space (fitted as a categorical variable) were initially adjusted for interactions between age and gender. The robustness of any associations found were then tested with controls for psychological distress and physical activity. Socioeconomic and other explanatory variables were then added sequentially, with any change in the potential association between green space exposure and sleep duration documented. To account for the nested data structure, the Huber-White method was utilized in all models to adjust standard errors.^{35 36} The log-likelihood ratio test ($p < 0.05$) was used to identify statistically significant associations. Analyses were conducted in STATA 12 (StataCorp, TX, USA).

RESULTS

In Table 1 the prevalence of sleep for 8 hour duration (adjusted for age and gender) was demonstrably higher in neighborhoods with a higher percentage of green space. This was also for sleep durations between 9 and 10 hours, but not for those of 10 hours or more. Meanwhile, the prevalence of sleep durations less than 8 hours was higher in neighborhoods with less green space. The percentage point difference reported between neighborhoods with 80%+ and less than 20% green space proximity was 3.6 for a mid-short sleep duration between 6 and 7 hours ($p < 0.001$). A smaller, though statistically significant gap was also reported for short sleeps less than 6 hours (0.9 percentage points, $p < 0.001$). The risk of short sleep duration (6 hours or less per day) was 4 times higher among participants at high risk of psychological distress (95%CI 3.8, 4.3), 1.5 times higher among obese people versus

1
2
3 those normal BMI (95%CI 1.46, 1.63), 1.8 times higher among people earning less than \$20,000 a
4
5 year (95%CI 1.7, 1.9), 1.6 times higher for residents of the most deprived quintile of neighborhoods
6
7 (95%CI 1.5, 1.7) and 1.1 times higher for those in remote and rural versus urban areas (95%CI 1.0,
8
9 1.2).

10
11 Preliminary multinomial logit regression took a bivariate format with green space as the sole predictor
12
13 of sleep duration. The 259,319 participants were nested within 11,719 CCDs. Compared to
14
15 participants reporting 8 hour sleep as the base category, the risk of shorter sleep durations was lower
16
17 for those with access to more green space. For example, the Relative Risk Ratios (RRRs) for
18
19 participants with 80%+ versus less than 20% green space was 0.86 (95%CI 0.81, 0.92) for durations
20
21 between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6 hours sleep. In contrast, there was
22
23 no association between neighborhood green space and the risk of longer sleep durations between 9
24
25 and 10 hours (RRR 1.06, 95%CI 0.99, 1.14), or over 10 hours (RRR 0.85, 95%CI 0.70, 1.03).

26
27
28
29 These results appeared to corroborate our hypothesis. However, this was founded on the basis that
30
31 greener neighborhoods stimulate mental health and more active lifestyles, which would then promote
32
33 a healthier duration of sleep. Ergo, we expected that the association between green space and sleep
34
35 duration would be explained by controls for mental health and physical activity. Adding the K10
36
37 variable showed participants at a high risk of psychological distress were more likely to report sleeps
38
39 of less and also more than 8 hours in duration ($p<0.001$). Conversely, adding physical activity to the
40
41 model did not result in a significant association with sleep duration. Unexpectedly, and counter to our
42
43 hypothesis, adjusting for these variables had negligible impact on the association between green space
44
45 and sleep duration.

46
47
48 The final step was to interrogate the consistency of the green space parameters against other factors
49
50 shown to be associated with short and long sleep duration. These variables were added sequentially to
51
52 the previous model, with Figure 1 illustrating the results of the final multinomial logit regression.
53
54 Many characteristics of individuals were associated with sleep duration in line with previous work,
55
56 such as unemployment and sleeps of less than 6 hours (RRR 1.20, 95%CI 1.02, 1.32) and more than
57
58
59
60

1
2
3 10 hours (RRR 3.17, 95%CI 2.66, 3.78). Participants in more affluent and geographically remote
4 neighborhoods were also at a lower risk of short and long sleep durations ($p<0.001$). Controlling for
5 all of these variables did attenuate the negative association between green space and short sleep
6 duration, but not fully. For participants with access to 80%+ green space within their neighborhood
7 compared to those with less than 20%, the RRR of sleeping between 6 and 7 hours was 0.92 (95%CI
8 0.87, 0.98) and 0.81 (95%CI: 0.69, 0.96) for sleeps of less than 6 hours in duration. There remained
9 no association between green space exposure and sleeps of more than 8 hours.
10
11
12
13
14
15
16
17
18
19
20

21 DISCUSSION

22
23
24 As countries invest in large scale green space planning policies,^{4,5} it would be prudent to ask whether
25 parks and other forms of natural environment have any other health benefits aside from those which
26 are already widely reported (namely, better mental health and increased physical activity). This study
27 has demonstrated that people who live in greener environs are more likely to achieve a healthier
28 duration of sleep. The protective effect of green space was isolated to guarding against the risk of
29 short sleep (less than 8 hours), with no association found for longer sleeps. These results were
30 consistent after controlling for factors already known to be associated with short and long sleep and,
31 surprisingly, were not explained by indicators of mental health and physical activity. The significance
32 of these findings are put in context when one considers that sleep durations of less than 6 hours are
33 consistently associated with many of the major chronic health conditions¹⁴⁻¹⁸ that threaten the
34 sustainability of health systems.^{37,38} As such, these results suggest that large-scale investments in
35 green space policy could have a wider public health benefit than has been previously acknowledged.
36
37
38
39
40
41
42
43
44
45
46
47
48

49 Restoration from access to nature can occur directly¹, although exposure to green space is
50 undoubtedly entwined, to a potentially large extent, with active lifestyles for which parks and other
51 public open spaces are attractive environments for participation³⁹. This makes the finding that green
52 space was associated with a healthier duration of sleep, irrespective of psychological distress or
53 participation in physical activity, more intriguing. One possible explanation is that the physical
54
55
56
57
58
59
60

1
2
3 activity variable measures participation, but not with any specific reference to the place in which it
4 occurs. Participants scoring higher on the physical activity variable therefore do not necessarily
5 perform those activities in the green spaces where they live and this interaction between behavior and
6 environment may be important to control.⁴⁰ Another plausible mechanism is the dispersal of traffic
7 density⁴¹ and noise pollution in areas with more green space, which could otherwise have a
8 detrimental influence on sleep duration.^{42,43} No measure of traffic density or noise pollution was
9 available for this study however. Thus, while more green space appears to be protective against a
10 short duration of sleep, it is not yet clear whether this is demonstrably because of a direct effect on
11 restoration that is not picked up by the K10, or if it operates via other structural processes operating at
12 the neighborhood level. Further research on the spatial patterning of sleep duration that accounts for
13 other structural variables, such as noise pollution, is warranted to isolate the potentially causal
14 mechanism(s) at play.

15
16
17
18
19
20
21
22
23
24
25
26
27
28 This study benefited from a large sample size and an objective measure of green space. However, the
29 focus on a population of 45 years and older limits the generalisability to younger people, for whom
30 further studies are advised. The survey response rate was 18%, though previous work has shown that
31 results from the 45 and Up Study are comparable to those from a representative survey²⁶. While the
32 cross-sectional design limits prospects for causal inference, such inferences might not be achieved
33 with longitudinal data either, as contemporaneous exposure to green space, rather than one that is
34 temporally lagged may be what counts most for determining sleep duration. Longitudinal studies
35 would nevertheless be useful for testing hypotheses related to temporal effects. It is plausible that
36 sleep duration varies across the week and during the day (e.g. naps), particularly between weekdays
37 and weekends, but the measure of sleep available in the 45 and Up Study was generalist and could not
38 facilitate these more detailed enquiries. Similarly, the Active Australia Survey is a measure of overall
39 physical activity, but did not afford a distinction between leisure and other types (e.g. active travel).
40
41
42
43
44
45
46
47
48
49
50
51
52
53 Finally, not all green spaces are the same and those of subjectively higher quality may be more
54 important for determining health outcomes⁴⁴, including sleep duration.

1
2
3 **Ethics:** The University of New South Wales Human Research Ethics Committee approved The 45
4 and Up Study. Local ethical approval for this study was awarded by the University of Western
5
6
7 Sydney.

8
9
10 **Funding:** No funding was sought for this study.

11
12
13 **Data sharing:** Data from the 45 and Up Study is only accessible via a data licence issued through
14 blinded peer-review. It is not available for sharing with parties who do not possess an approved
15
16 Agreement with the Data Custodian.

17
18
19 **Competing Interests:** None

20
21 **Contributorship:** Conceived and designed the experiments: TAB XF GK

22
23 Performed the experiments: TAB XF.

24
25 Analyzed the data: TAB XF.

26
27 Wrote the paper: TAB XF GK

28 29 30 31 32 33 34 **References**

- 35
36 1. Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS. A systematic review of evidence for the added
37 benefits to health of exposure to natural environments. *BMC Public Health* 2010;10.
38 2. Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence.
39 *Journal of Public Health* 2010;33(2):212-22.
40 3. Lachowycz K, Jones AP. Greenspace and obesity: a systematic review of the evidence. *Obesity*
41 *Reviews* 2011;12(5):e183-e89.
42 4. Nilsson K, Sangster M, Konijnendijk CC. Introduction. In: Nilsson K, Sangster M, Gallis C, Hartig T,
43 de Vries S, Seeland K, et al., editors. *Forests, trees and human health*. Netherlands:
44 Springer, 2011:1-19.
45 5. Australian Government. *Our Cities Our Future: A national urban policy for a productive,*
46 *sustainable and liveable future*. Canberra: Department of Infrastructure and Transport,
47 2011.
48 6. Sternberg EM. *Healing spaces: The science of place and well-being*. Cambridge: Harvard
49 University Press, 2009.
50 7. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective*: Cambridge University
51 Press, 1989.
52 8. Ulrich RS. View through a window may influence recovery from surgery. *Science*
53 1984;224(4647):420.
54 9. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological
55 review 2000–2003. *Journal of Science and Medicine in Sport* 2004;7(1):6-19.
56
57
58
59
60

10. Giles-Corti B, Broomhall MH, Knuiaman M, Collins C, Douglas K, Ng K, et al. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 2005;28(2S2):169-76.
11. Astell-Burt T, Feng X, Kolt GS. Neighbourhood green space is associated with more frequent walking and moderate to vigorous physical activity (MVPA) in middle-to-older aged adults. Findings from 203,883 Australians in The 45 and Up Study. *British Journal of Sports Medicine* 2013;In press.
12. Knutson KL, Turek FW. The U-shaped association between sleep and health: the 2 peaks do not mean the same thing. *Sleep* 2006;9:881-89.
13. Magee CA, Caputi P, Iverson DC. Relationships between self-rated health, quality of life and sleep duration in middle aged and elderly Australians. *Sleep medicine* 2011;12(4):346-50.
14. Magee CA, Iverson DC, Caputi P. Sleep duration and obesity in middle-aged Australian adults. *Obesity* 2009;18(2):420-21.
15. Cappuccio FP, Taggart FM, Kandala NB, al. e. Cappuccio, F. P., Taggart, F. M., Kandala, N. -B. et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31:619-26.
16. Cappuccio FP, Cooper D, D Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur. Heart J.* 2011;32:1484-92.
17. Chaput JP, Despre´ s J-P, Bouchard C, Tremblay A. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia* 2007;50:2298-304.
18. Knutson KL, Spiegel K, Penev P, Van Cauter E. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.* 2007;11:163-78.
19. Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 2002;59:131-36.
20. Heslop P, Smith GD, Metcalfe C, Macleod J, Hart C. Sleep duration and mortality: the effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine* 2003;3:305-14.
21. Hublin C, Partinen M, Koskenvuo M, Kaprio J. Sleep and mortality: a population-based 22-year follow-up study. *Sleep* 2007;30:1245-53.
22. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders. *JAMA: the journal of the American Medical Association* 1989;262(11):1479-84.
23. Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and good sleep. *Journal of psychosomatic research* 2008;64(4):409-15.
24. Magee CA, Iverson DC, Caputi P. Factors associated with short and long sleep. *Preventive Medicine* 2009;49(6):461-67.
25. 45 and Up Study Collaborators. Cohort Profile: The 45 and Up Study. *International Journal of Epidemiology* 2008;37(5):941-47.
26. Mealing NM, Banks E, Jorm LR, Steel DG, Clements MS, Rogers KD. Investigation of relative risk estimates from studies of the same population with contrasting response rates and designs. *BMC medical research methodology* 2010;10(1):26.
27. Australian Bureau of Statistics. *Research Paper. Socio-Economic Indexes for Areas: Introduction, Use and Future Directions*. Canberra: ABS, 2006.
28. Magee CA, Kritharides L, Attia J, Mcelduff P, Banks E. Short and long sleep duration are associated with prevalent cardiovascular disease in Australian adults. *Journal of sleep research* 2012;21(4):441-47.
29. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand SL, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine* 2002;32:959-76.
30. Furukawa TA, Kessler RC, Slade T, Andrews G. The performance of the K6 and K10 screening scales for psychological distress in the Australian National Survey of Mental Health and Well-Being. *Psychological medicine* 2003;33(2):357-62.

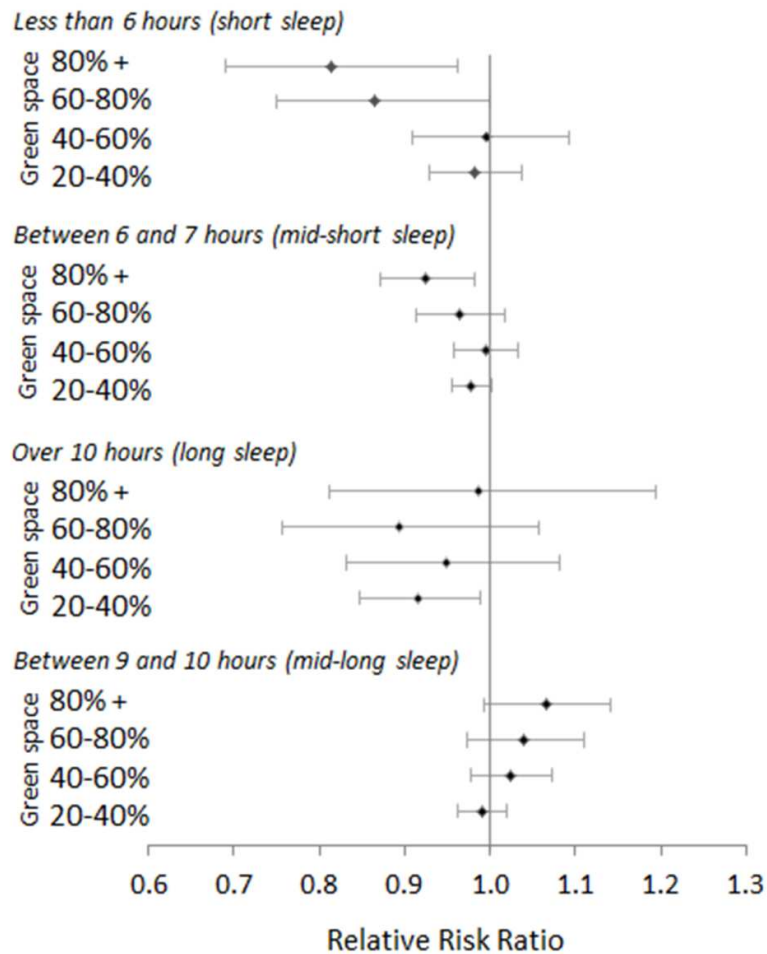
31. Australian Bureau of Statistics. *Information paper: use of the Kessler Psychological Distress Scale in ABS Health Surveys, Australia*. Canberra: Australian Bureau of Statistics, 2003.
32. Feng X, Astell-Burt T, Kolt GS. Ethnic density, social interactions and psychological distress: Evidence from 226,487 Australian adults. *BMJ Open* 2013;In press.
33. Australian Institute of Health and Welfare. *The active Australia survey: A guide and manual for implementation, analysis and reporting*. Canberra: AIHW, 2003.
34. Koenig HG, Westlund RE, George LK, Hughes DC, Blazer DG, Hybels C. Abbreviating the Duke Social Support Index for use in chronically ill elderly individuals. *Psychosomatics* 1993;34:61-69.
35. UCLA: Academic Technology Services SCG. *Analyzing Correlated (Clustered) Data*, 2008.
36. Williams R. A note on robust variance estimation for cluster-correlated data. *Biometrics* 2000;56(2):645-46.
37. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the projected obesity trends in the USA and the UK. *The Lancet* 2011;378(9793):815-25.
38. Hossain P, Kavar B, El Nahas M. Obesity and diabetes in the developing world—a growing challenge. *New England Journal of Medicine* 2007;356(3):213-15.
39. Hug SM, Hartig T, Hansmann R, Seeland K, Hornung R. Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency. *Health & Place* 2009;15:971-80.
40. Mitchell R. Is physical activity in natural environments better for mental health than physical activity in other environments? *Social Science & Medicine* 2012;In Press.
41. Gidlöf-Gunnarsson A, Öhrström E. Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning* 2007;83(2):115-26.
42. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic noise on sleep and recuperation. *Sleep* 2011;34(1):11.
43. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews* 2007;11(2):135-42.
44. Francis J, Wood LJ, Knuiman M, Giles-Corti B. Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science & Medicine* 2012;74(10):1570-77.

Table 1: Age-gender adjusted patterning of sleep duration by proximity to green space

	8 hours (normal)	Between 9 and 10 hours (mid-long sleep)	Over 10 hours (long sleep)	Between 6 and 7 hours (mid-short sleep)	Less than 6 hours (short sleep)
N (259,319)	104,432	47,424	4,938	92,860	9,665
Green space % (n)	% (95% Confidence Interval)				
0-20% (177,106)	40.0 (39.8, 40.3)	17.5 (17.3, 17.7)	1.6 (1.5, 1.6)	35.6 (35.3, 35.8)	3.7 (3.6, 3.8)
20-40% (49,316)	40.4 (39.9, 40.8)	16.9 (16.6, 17.3)**	1.4 (1.3, 1.5)***	36.2 (35.7, 36.7)*	3.6 (3.4, 3.8)
40-60% (18,045)	40.5 (39.7, 41.3)	17.9 (17.3, 18.6)	1.4 (1.2, 1.6)*	35.3 (34.4, 36.1)	3.3 (3.1, 3.6)**
60-80% (8,253)	41.2 (40.0, 42.3)*	18.6 (17.6, 19.6)**	1.3 (1.1, 1.5)	34.4 (33.2, 35.7)*	2.9 (2.5, 3.3)***
80%+ (6,599)	41.9 (40.7, 43.2)**	20.1 (19.1, 21.2)***	1.6 (1.3, 1.9)	32.0 (30.8, 33.2)***	2.8 (2.3, 3.2)***

*** p < 0.001; ** p < 0.01; * p < 0.05 (from 0-20% green space as the reference group)

Figure 1: Association between proximity to green space and duration of sleep (fully adjusted)



*reference group = less than 20% green space

** multinomial logit regression with robust standard errors and base category comprising participants reporting 8 hours sleep duration. Models were adjusted for: age; gender; Kessler scale of psychological distress; physical activity (measured by the Active Australia survey); weight status; couple status; ethnicity; country of birth; annual household income; highest qualifications; economic status; language spoken at home; number of alcoholic drinks consumed per week; smoking status; social support; the Socio-Economic Index for Areas (SEIFA) 'Index of Relative Socio-Economic Advantage/Disadvantage'; and the 'Accessibility/Remoteness Index of Australia' (ARIA).



Does access to neighborhood green space promote a healthy duration of sleep? Novel findings from 259,319 Australians

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-003094.R1
Article Type:	Research
Date Submitted by the Author:	16-Jun-2013
Complete List of Authors:	Astell-Burt, Thomas; University of Western Sydney, School of Science and Health Feng, Xiaoqi; Centre for Health Research, School of Medicine Kolt, Gregory; University of Western Sydney, School of Science and Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Sociology
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

SCHOLARONE™
Manuscripts

1
2
3 **Does access to neighborhood green space promote a healthy duration of sleep? Novel findings**
4 **from 259,319 Australians**
5
6
7

8 **ABSTRACT**
9

10 **Objectives:** Experiments demonstrate that exposure to parks and other 'green spaces' promote
11 favorable psychological and physiological outcomes. As a consequence, people who reside in greener
12 neighborhoods may also have a lower risk of short sleep duration (<6 hours). This is potentially
13 important as short sleep duration is a correlate of obesity, chronic disease, and mortality, but so far
14 this hypothesis has not been previously investigated.
15
16
17
18
19
20
21

22 **Design:** Cross-sectional data analysis
23

24 **Setting:** New South Wales, Australia
25
26
27

28 **Participants:** This study investigated whether neighborhood green space was associated with a
29 healthier duration of sleep (to the nearest hour) among 259,319 Australians who completed the 45 and
30 Up Study baseline questionnaire between 2006 and 2009 inclusive.
31
32
33
34

35 **Primary and secondary outcome measures:** Multinomial logit regression was used to investigate
36 the influence of an objective measure of green space on categories of sleep duration: 8 hours (normal);
37 between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours (mid-
38 short sleep); less than 6 hours (short sleep). Models were adjusted for psychological distress, physical
39 activity, and a range of demographic and socioeconomic characteristics.
40
41
42
43
44
45

46 **Results:** People living in greener neighborhoods reported a lower risk of short sleep. For example,
47 compared to participants living in areas with 20% green space land-use, the relative risk ratios for
48 participants with 80%+ green space was 0.86 (95% confidence interval (95%CI) 0.81, 0.92) for
49 durations between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6-hours sleep.
50
51
52
53

54 Unexpectedly, the benefit of more green space for achieving 8 hours of sleep was not explained by
55 controls for psychological distress, physical activity, or other socioeconomic factors.
56
57
58
59
60

1
2
3 **Conclusion:** Green space planning policies may have wider public health benefits than previously
4 recognized. Further research on the role of green space in promoting healthier sleep durations and
5 patterns is warranted.
6
7
8
9

10
11
12 **Ethics:** The University of New South Wales Human Research Ethics Committee approved The 45
13 and Up Study. Local ethical approval for this study was awarded by the University of Western
14 Sydney.
15
16
17
18
19

20
21
22 **Funding:** No funding was sought for this study.
23
24
25
26
27
28

29 **Data sharing:** Data from the 45 and Up Study is only accessible via a data license issued through
30 blinded peer-review. It is not available for sharing with parties who do not possess an approved
31 Agreement with the Data Custodian.
32
33
34
35
36
37
38

39 **Article Focus**

- 40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
- Previous work suggests that more green space within the neighborhood environment can promote better mental health and more active lifestyles
 - Better mental health and more active lifestyles are correlates of a healthy duration of sleep (usually around 8 hours a night)
 - Greener neighborhoods, therefore, may guard against short sleep duration (usually less than 6 hours per night), which is correlated with obesity, chronic disease, and mortality

Key Messages

- In a large study of Australian adults, we found those in greener neighborhoods were at a lower risk of short sleep (< 6 hours a night)
- More green space was not associated with longer sleep durations (which are also correlated with poor health outcomes)
- Unexpectedly, the benefit of more green space for achieving a healthier duration of sleep was not explained by controls for psychological distress, physical activity, and socioeconomic variables

Strengths and Limitations

- This study benefits from a large sample size focusing on adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of health services
- This study is strengthened by use of validated measures of sleep duration, psychological distress, physical activity, and an objective measure of green space exposure
- Cross-sectional data prohibits causal inference, though follow up of the participants across time will allow the opportunity for replication of this study with a longitudinal design

Introduction

Positive psychological and physiological outcomes from exposure to parks and other forms of natural environment in experimental studies¹⁻³ have fuelled support for the integration of these ‘green spaces’ within planning policy.^{4,5} Health benefits are thought to accrue via psycho-neuro-endocrine pathways, wherein the experience of nature triggers restoration.⁶⁻⁸ These benefits are likely to be in tandem with physical activity, more of which is not only correlated with better mental health,⁹ but also increasingly likely among people who live in greener neighborhoods.¹⁰⁻¹²

While the epidemiological literature is increasingly replete with studies documenting association between green spaces, mental health and physical activity, less attention has been paid to other important health behaviors and outcomes. One such outcome is sleep duration. Many studies have reported a parabolic association¹³ between the number of hours a person sleeps and their subsequent risk of poor self-rated health¹⁴, obesity^{15,16}, cardiovascular disease¹⁷, diabetes^{18,19} and death.²⁰⁻²² Favorable mental health and active lifestyles are thought to be drivers of a healthier duration of sleep (usually around 8 hours per night).²³⁻²⁵ Since these drivers are widely reported to be positive outcomes of living in greener neighborhoods, we hypothesized that people with access to more green space would therefore be more likely to achieve a healthier duration of sleep.

This hypothesis was investigated in a large sample of Australian adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of healthcare in Australia.

METHOD

Data

A sample of 259,319 participants with valid data on sleep duration were selected from 267,151 in the 45 and Up Study.²⁶ The questionnaire is available online from www.45andup.org.au. Participants were randomly selected from the Medicare Australia database (the national provider of universal

1
2
3 health insurance) and surveyed between 2006 and 2009. The survey response rate was 18%, though
4
5 previous work has shown that results from the 45 and Up Study are comparable to those derived from
6
7 a representative population survey.²⁷ Geocoding of participants in the 45 and Up Study was available
8
9 at the Census Collection Districts (CCD) scale. CCDs contain 225 people on average and were the
10
11 smallest geography at which 2006 Census data were disseminated.²⁸ The University of New South
12
13 Wales Human Research Ethics Committee approved The 45 and Up Study.

14 15 16 17 18 19 *Outcome measure*

20
21
22 Sleep duration was derived from responses to the following question: “About how many hours in each
23
24 24 hour day do you usually spend sleeping (including at night and naps)?” and has been used in
25
26 previous analyses of the same data.^{14 15 25 29} Responses to this question were missing for 7,755 people
27
28 and these were omitted from the analyses. To account for the curvilinear association between sleep
29
30 duration and health,¹³ responses were classified into a multinomial variable as follows: 8 hours
31
32 (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours
33
34 (mid-short sleep); less than 6 hours (short sleep). This classification allows for the healthiest duration
35
36 (8 hours) to be used as a reference group for all other categories.

37 38 39 40 41 42 *Green space*

43
44
45 Meshblocks classified as ‘parkland’ in the Australian Bureau of Statistics (ABS) land-use
46
47 classification for 2006 were used to construct the measure of green space. ‘Farmland’ meshblocks
48
49 were not used as they do not strictly represent spaces available for recreation. The measure of green
50
51 space was based upon the percentage available within a 1 kilometer (km) buffer around the
52
53 population-weighted centroid of each CCD. A 1km buffer was selected so as to represent land-use
54
55 within a reasonable walking distance from place of residence, and has been used in previous studies of
56
57
58
59
60

1
2
3 green space and health.^{11 12 30 31} The percentage green space measure was classified into fifths to
4
5 explore for potential non-linearities (0-20%, 20-40%, 40-60%, 60-80%, 80%+).
6
7
8
9

10 *Other individual and neighborhood measures*

11
12
13
14 The Kessler Psychological Distress Scale (K10) was used to assess mental health status.^{32 33} The K10
15
16 measures symptoms of psychological distress experienced over the past four weeks, including feeling
17
18 tired for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five
19
20 choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3,
21
22 most of the time =4, all of the time =5). The K10 is constructed by summing responses to each of the
23
24 questions, with scores of 22 and over identified those with a high risk of psychological distress.³⁴ The
25
26 K10 has been used in this way in previous published analyses of the 45 and Up Study.³⁵
27
28

29
30 The measure of physical activity was an aggregate of the number of 10 minute sessions spent either
31
32 walking or in moderate to vigorous physical activity (MVPA), assessed using the Active Australia
33
34 Survey.³⁶ The question was “How many times did you do each of these activities last week?”
35
36 Participants could indicate walking, moderate (e.g. gentle swimming) and vigorous (e.g. jogging)
37
38 forms activity separately.
39

40
41 A range of other individual characteristics were also taken account of, including age, gender, ethnicity,
42
43 country of birth, body mass index (BMI), annual income, highest educational qualifications, economic
44
45 status (employed, unemployed, retired, inactive due to poor health), couple status, number of
46
47 alcoholic drinks consumed in the last week, smoking status, language other than English spoken at
48
49 home, and the Duke Social Support Index.³⁷
50

51
52 Two other characteristics at the neighborhood-level were considered. The Socio-Economic Index for
53
54 Areas (SEIFA) ‘Index of Relative Socio-Economic Advantage/Disadvantage’ was used to measure
55
56 local socioeconomic circumstances. Differences between urban and rural areas were controlled using
57
58
59
60

1
2
3 the 'Accessibility / Remoteness Index of Australia' (ARIA). Like the measure of green space, both of
4 these neighborhood indicators were created using data from 2006 to fit with the baseline questionnaire.
5
6
7
8
9

10 *Statistical analysis*

11
12
13
14 Cross-tabulations were used to compare the patterning of each sleep duration category according to
15 proximity to green space and all other explanatory variables. A multinomial logit regression was used
16 assess the risk of short sleep versus an 8-hour sleep duration (reference), accounting for longer sleeps
17 as separate categories simultaneously within the same model. Parameters were exponentiated to
18 relative risk ratios (RRR). RRRs over 1 indicated positive association, whereas RRRs below 1
19 denoted negative association. Bivariate models containing the measure of green space (fitted as a
20 categorical variable) were initially adjusted for interactions between age and gender. The robustness
21 of any associations found were then tested with controls for psychological distress and physical
22 activity. Socioeconomic and other explanatory variables were then added sequentially, with any
23 change in the potential association between green space exposure and sleep duration documented.
24 To account for the nested data structure, the Huber-White method was utilized in all models to adjust
25 standard errors.^{38 39} The log-likelihood ratio test ($p < 0.05$) was used to identify statistically significant
26 associations. Analyses were conducted in STATA 12 (StataCorp, College Station, TX, USA).
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

47 **RESULTS**

48
49
50 In Table 1 the prevalence of sleep for 8 hour duration (adjusted for age and gender) was demonstrably
51 higher in neighborhoods with a higher percentage of green space. This was also for sleep durations
52 between 9 and 10 hours, but not for those of 10 hours or more. Meanwhile, the prevalence of sleep
53 durations less than 8 hours was higher in neighborhoods with less green space. The percentage point
54 difference reported between neighborhoods with 80%+ and less than 20% green space proximity was
55
56
57
58
59
60

1
2
3 3.6 for a mid-short sleep duration between 6 and 7 hours ($p<0.001$). A smaller, though statistically
4 significant gap was also reported for short sleeps less than 6 hours (0.9 percentage points, $p<0.001$).
5
6 The risk of short sleep duration (6 hours or less per day) was 4 times higher among participants at
7 high risk of psychological distress (95%CI 3.8, 4.3), 1.5 times higher among obese people versus
8 those normal BMI (95%CI 1.46, 1.63), 1.8 times higher among people earning less than \$20,000 a
9 year (95%CI 1.7, 1.9), 1.6 times higher for residents of the most deprived quintile of neighborhoods
10 (95%CI 1.5, 1.7) and 1.1 times higher for those in remote and rural versus urban areas (95%CI 1.0,
11 1.2).
12
13
14
15
16
17
18
19

20 Preliminary multinomial logit regression took a bivariate format with green space as the sole predictor
21 of sleep duration. The 259,319 participants were nested within 11,719 CCDs. Compared to
22 participants reporting 8 hour sleep as the base category, the risk of shorter sleep durations was lower
23 for those with access to more green space. For example, the Relative Risk Ratios (RRRs) for
24 participants with 80%+ versus less than 20% green space was 0.86 (95%CI 0.81, 0.92) for durations
25 between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6 hours sleep. In contrast, there was
26 no association between neighborhood green space and the risk of longer sleep durations between 9
27 and 10 hours (RRR 1.06, 95%CI 0.99, 1.14), or over 10 hours (RRR 0.85, 95%CI 0.70, 1.03).
28
29
30
31
32
33
34
35
36

37 These results appeared to corroborate our hypothesis. However, this was founded on the basis that
38 greener neighborhoods stimulate mental health and more active lifestyles, which would then promote
39 a healthier duration of sleep. Ergo, we expected that the association between green space and sleep
40 duration would be explained by controls for mental health and physical activity. Adding the K10
41 variable showed participants at a high risk of psychological distress were more likely to report sleeps
42 of less and also more than 8 hours in duration ($p<0.001$). Conversely, adding physical activity to the
43 model did not result in a significant association with sleep duration. Unexpectedly, and counter to our
44 hypothesis, adjusting for these variables had negligible impact on the association between green space
45 and sleep duration.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 The final step was to interrogate the consistency of the green space parameters against other factors
4 shown to be associated with short and long sleep duration. These variables were added sequentially to
5 the previous model, with Figure 1 illustrating the results of the final multinomial logit regression.
6
7 Many characteristics of individuals were associated with sleep duration in line with previous work,
8 such as unemployment and sleeps of less than 6 hours (RRR 1.20, 95%CI 1.02, 1.32) and more than
9 10 hours (RRR 3.17, 95%CI 2.66, 3.78). Participants in more affluent and geographically remote
10 neighborhoods were also at a lower risk of short and long sleep durations ($p<0.001$). Controlling for
11 all of these variables did attenuate the negative association between green space and short sleep
12 duration, but not fully. For participants with access to 80%+ green space within their neighborhood
13 compared to those with less than 20%, the RRR of sleeping between 6 and 7 hours was 0.92 (95%CI
14 0.87, 0.98) and 0.81 (95%CI: 0.69, 0.96) for sleeps of less than 6 hours in duration. There remained
15 no association between green space exposure and sleeps of more than 8 hours.
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

31 DISCUSSION

32
33
34 As countries invest in large scale green space planning policies,⁴⁵ it would be prudent to ask whether
35 parks and other forms of natural environment have any other health benefits aside from those which
36 are already widely reported (namely, better mental health and increased physical activity). This study
37 has demonstrated that people who live in greener environs are more likely to achieve a healthier
38 duration of sleep. The protective effect of green space was isolated to guarding against the risk of
39 short sleep (less than 8 hours), with no association found for longer sleeps. These results were
40 consistent after controlling for factors already known to be associated with short and long sleep and,
41 surprisingly, were not explained by indicators of mental health and physical activity. The significance
42 of these findings are put in context when one considers that sleep durations of less than 6 hours are
43 consistently associated with many of the major chronic health conditions¹⁵⁻¹⁹ that threaten the
44 sustainability of health systems.^{40 41} As such, these results suggest that large-scale investments in
45 green space policy could have a wider public health benefit than has been previously acknowledged.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Restoration from access to nature can occur directly ¹, although exposure to green space is
4 undoubtedly entwined, to a potentially large extent, with active lifestyles for which parks and other
5 public open spaces are attractive environments for participation ⁴². This makes the finding that green
6 space was associated with a healthier duration of sleep, irrespective of psychological distress or
7 participation in physical activity, more intriguing. One possible explanation is that the physical
8 activity variable measures participation, but not with any specific reference to the place in which it
9 occurs. Participants scoring higher on the physical activity variable therefore do not necessarily
10 perform those activities in the green spaces where they live and this interaction between behavior and
11 environment may be important to control.⁴³ Another plausible mechanism is the dispersal of traffic
12 density ⁴⁴ and noise pollution in areas with more green space, which could otherwise have a
13 detrimental influence on sleep duration.^{45 46} No measure of traffic density or noise pollution was
14 available for this study however. Thus, while more green space appears to be protective against a
15 short duration of sleep, it is not yet clear whether this is demonstrably because of a direct effect on
16 restoration that is not picked up by the K10, or if it operates via other structural processes operating at
17 the neighborhood level. Further research on the spatial patterning of sleep duration that accounts for
18 other structural variables, such as noise pollution, is warranted to isolate the potentially causal
19 mechanism(s) at play.

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38 This study benefited from a large sample size and an objective measure of green space. However, the
39 focus on a population of 45 years and older limits the generalisability to younger people, for whom
40 further studies are advised. The survey response rate was 18%, though previous work has shown that
41 results from the 45 and Up Study are comparable to those from a representative survey²⁷. While the
42 cross-sectional design limits prospects for causal inference, such inferences might not be achieved
43 with longitudinal data either, as contemporaneous exposure to green space, rather than one that is
44 temporally lagged may be what counts most for determining sleep duration. Longitudinal studies
45 would nevertheless be useful for testing hypotheses related to temporal effects. It is plausible that
46 sleep duration varies across the week and during the day (e.g. naps), particularly between weekdays
47 and weekends, but the measure of sleep available in the 45 and Up Study was generalist and could not
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 facilitate these more detailed enquiries. Similarly, the Active Australia Survey is a measure of overall
4 physical activity, but did not afford a distinction between leisure and other types (e.g. active travel).
5
6
7 Finally, while previous work has shown that different measures of green space yield similar
8
9 associations with health outcomes,⁴⁷ we recognize that not all green spaces are the same and future
10
11 work should explore whether variation in subjective quality⁴⁸ or type⁴⁹ (e.g. parks versus conservation
12
13 areas) results in systematic differences in health outcomes, including sleep duration.
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

References

1. Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 2010;10.
2. Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health* 2010;33(2):212-22.
3. Lachowycz K, Jones AP. Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews* 2011;12(5):e183-e89.
4. Nilsson K, Sangster M, Konijnendijk CC. Introduction. In: Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., editors. *Forests, trees and human health*. Netherlands: Springer, 2011:1-19.
5. Australian Government. *Our Cities Our Future: A national urban policy for a productive, sustainable and liveable future*. Canberra: Department of Infrastructure and Transport, 2011.
6. Sternberg EM. *Healing spaces: The science of place and well-being*. Cambridge: Harvard University Press, 2009.
7. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective*: Cambridge University Press, 1989.
8. Ulrich RS. View through a window may influence recovery from surgery. *Science* 1984;224(4647):420.
9. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *Journal of Science and Medicine in Sport* 2004;7(1):6-19.
10. Giles-Corti B, Broomhall MH, Knuiaman M, Collins C, Douglas K, Ng K, et al. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 2005;28(2S2):169-76.
11. Astell-Burt T, Feng X, Kolt GS. Neighbourhood green space is associated with more frequent walking and moderate to vigorous physical activity (MVPA) in middle-to-older aged adults. Findings from 203,883 Australians in The 45 and Up Study. *British Journal of Sports Medicine* 2013:doi:10.1136/bjsports-2012-092006.
12. Astell-Burt T, Feng X, Kolt GS. Greener neighborhoods, slimmer people? Evidence from 246,920 Australians. *International Journal of Obesity* 2013:doi:10.1038/ijo2013.64.
13. Knutson KL, Turek FW. The U-shaped association between sleep and health: the 2 peaks do not mean the same thing. *Sleep* 2006;9:881-89.
14. Magee CA, Caputi P, Iverson DC. Relationships between self-rated health, quality of life and sleep duration in middle aged and elderly Australians. *Sleep medicine* 2011;12(4):346-50.
15. Magee CA, Iverson DC, Caputi P. Sleep duration and obesity in middle-aged Australian adults. *Obesity* 2009;18(2):420-21.
16. Cappuccio FP, Taggart FM, Kandala NB, al. e. Cappuccio, F. P., Taggart, F. M., Kandala, N. -B. et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31:619-26.
17. Cappuccio FP, Cooper D, D Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur. Heart J.* 2011;32:1484-92.
18. Chaput JP, Despre´ s J-P, Bouchard C, Tremblay A. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia* 2007;50:2298-304.
19. Knutson KL, Spiegel K, Penev P, Van Cauter E. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.* 2007;11:163-78.
20. Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 2002;59:131-36.
21. Heslop P, Smith GD, Metcalfe C, Macleod J, Hart C. Sleep duration and mortality: the effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine* 2003;3:305-14.

- 1
- 2
- 3 22. Hublin C, Partinen M, Koskenvuo M, Kaprio J. Sleep and mortality: a population-based 22-year
- 4 follow-up study. *Sleep* 2007;30:1245-53.
- 5 23. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders.
- 6 *JAMA: the journal of the American Medical Association* 1989;262(11):1479-84.
- 7 24. Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and
- 8 good sleep. *Journal of psychosomatic research* 2008;64(4):409-15.
- 9 25. Magee CA, Iverson DC, Caputi P. Factors associated with short and long sleep. *Preventive*
- 10 *Medicine* 2009;49(6):461-67.
- 11 26. 45 and Up Study Collaborators. Cohort Profile: The 45 and Up Study. *International Journal of*
- 12 *Epidemiology* 2008;37(5):941-47.
- 13 27. Mealing NM, Banks E, Jorm LR, Steel DG, Clements MS, Rogers KD. Investigation of relative risk
- 14 estimates from studies of the same population with contrasting response rates and
- 15 designs. *BMC medical research methodology* 2010;10(1):26.
- 16 28. Australian Bureau of Statistics. *Research Paper. Socio-Economic Indexes for Areas:*
- 17 *Introduction, Use and Future Directions*. Canberra: ABS, 2006.
- 18 29. Magee CA, Kritharides L, Attia J, Mcelduff P, Banks E. Short and long sleep duration are
- 19 associated with prevalent cardiovascular disease in Australian adults. *Journal of sleep*
- 20 *research* 2012;21(4):441-47.
- 21 30. Maas J, Verheij RA, Groenewegen PP, de Vries S, Spreeuwenberg P. Green space, urbanity, and
- 22 health: how strong is the relation? *Journal of Epidemiology & Community Health*
- 23 *2006;60(7):587-92*.
- 24 31. de Vries S, Verheij RA, Groenewegen PP, Spreeuwenberg P. Natural environments-healthy
- 25 environments? An exploratory analysis of the relationship between greenspace and health.
- 26 *Environment and Planning A* 2003;35(10):1717-32.
- 27 32. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand SL, et al. Short screening scales
- 28 to monitor population prevalences and trends in non-specific psychological distress.
- 29 *Psychological Medicine* 2002;32:959-76.
- 30 33. Furukawa TA, Kessler RC, Slade T, Andrews G. The performance of the K6 and K10 screening
- 31 scales for psychological distress in the Australian National Survey of Mental Health and
- 32 Well-Being. *Psychological medicine* 2003;33(2):357-62.
- 33 34. Australian Bureau of Statistics. *Information paper: use of the Kessler Psychological Distress*
- 34 *Scale in ABS Health Surveys, Australia*. Canberra: Australian Bureau of Statistics, 2003.
- 35 35. Feng X, Astell-Burt T, Kolt GS. Ethnic density, social interactions and psychological distress:
- 36 Evidence from 226,487 Australian adults. *BMJ Open* 2013;3:e002713.
- 37 36. Australian Institute of Health and Welfare. *The active Australia survey: A guide and manual for*
- 38 *implementation, analysis and reporting*. Canberra: AIHW, 2003.
- 39 37. Koenig HG, Westlund RE, George LK, Hughes DC, Blazer DG, Hybels C. Abbreviating the Duke
- 40 Social Support Index for use in chronically ill elderly individuals. *Psychosomatics*
- 41 *1993;34:61-69*.
- 42 38. UCLA: Academic Technology Services SCG. *Analyzing Correlated (Clustered) Data*, 2008.
- 43 39. Williams R. A note on robust variance estimation for cluster-correlated data. *Biometrics*
- 44 *2000;56(2):645-46*.
- 45 40. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the
- 46 projected obesity trends in the USA and the UK. *The Lancet* 2011;378(9793):815-25.
- 47 41. Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing
- 48 challenge. *New England Journal of Medicine* 2007;356(3):213-15.
- 49 42. Hug SM, Hartig T, Hansmann R, Seeland K, Hornung R. Restorative qualities of indoor and
- 50 outdoor exercise settings as predictors of exercise frequency. *Health & Place* 2009;15:971-
- 51 *80*.
- 52 43. Mitchell R. Is physical activity in natural environments better for mental health than physical
- 53 activity in other environments? *Social Science & Medicine* 2012;In Press.
- 54
- 55
- 56
- 57
- 58
- 59
- 60

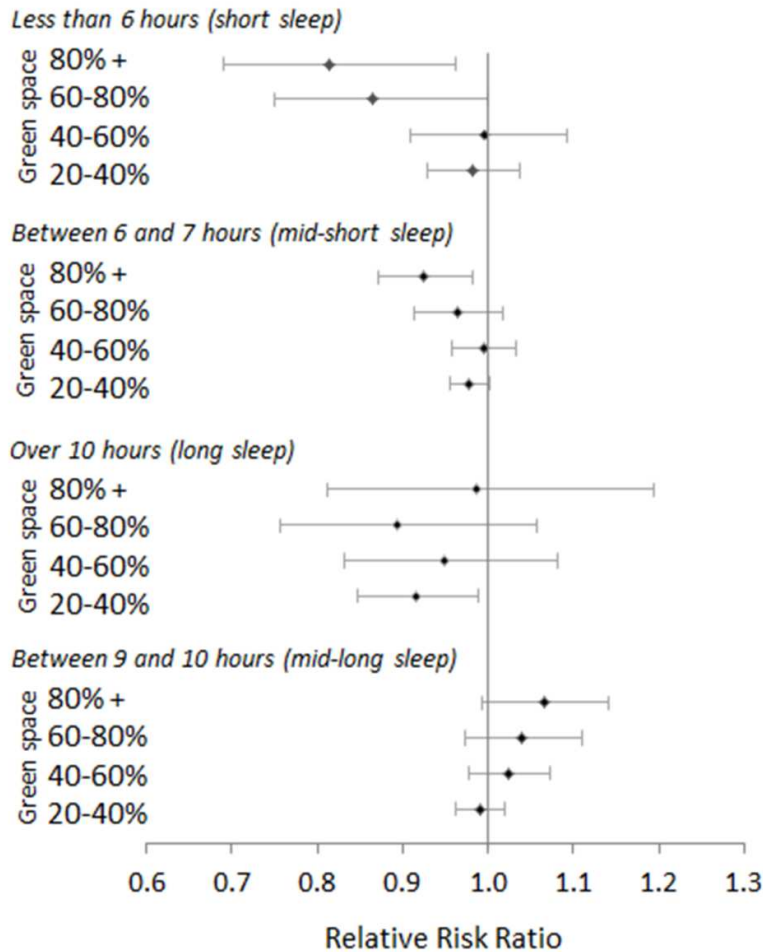
- 1
2
3 44. Gidlöf-Gunnarsson A, Öhrström E. Noise and well-being in urban residential environments: The
4 potential role of perceived availability to nearby green areas. *Landscape and Urban*
5 *Planning* 2007;83(2):115-26.
6 45. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic
7 noise on sleep and recuperation. *Sleep* 2011;34(1):11.
8 46. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews* 2007;11(2):135-42.
9 47. Mitchell R, Astell-Burt T, Richardson EA. A comparison of green space measures for
10 epidemiological research. *Journal of Epidemiology and Community Health*
11 2011;65(10):853-58.
12 48. Francis J, Wood LJ, Knuiiman M, Giles-Corti B. Quality or quantity? Exploring the relationship
13 between Public Open Space attributes and mental health in Perth, Western Australia.
14 *Social Science & Medicine* 2012;74(10):1570-77.
15 49. Fan Y, Das KV, Chen Q. Neighborhood green, social support, physical activity, and stress:
16 Assessing the cumulative impact. *Health & Place* 2011;17(6):1202-11.
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1: Age-gender adjusted patterning of sleep duration by proximity to green space

	8 hours (normal)	Between 9 and 10 hours (mid-long sleep)	Over 10 hours (long sleep)	Between 6 and 7 hours (mid-short sleep)	Less than 6 hours (short sleep)
N (259,319)	104,432	47,424	4,938	92,860	9,665
Green space % (n)	% (95% Confidence Interval)				
0-20% (177,106)	40.0 (39.8, 40.3)	17.5 (17.3, 17.7)	1.6 (1.5, 1.6)	35.6 (35.3, 35.8)	3.7 (3.6, 3.8)
20-40% (49,316)	40.4 (39.9, 40.8)	16.9 (16.6, 17.3)**	1.4 (1.3, 1.5)***	36.2 (35.7, 36.7)*	3.6 (3.4, 3.8)
40-60% (18,045)	40.5 (39.7, 41.3)	17.9 (17.3, 18.6)	1.4 (1.2, 1.6)*	35.3 (34.4, 36.1)	3.3 (3.1, 3.6)**
60-80% (8,253)	41.2 (40.0, 42.3)*	18.6 (17.6, 19.6)**	1.3 (1.1, 1.5)	34.4 (33.2, 35.7)*	2.9 (2.5, 3.3)***
80% + (6,599)	41.9 (40.7, 43.2)**	20.1 (19.1, 21.2)***	1.6 (1.3, 1.9)	32.0 (30.8, 33.2)***	2.8 (2.3, 3.2)***

*** p < 0.001; ** p < 0.01; * p < 0.05 (from 0-20% green space as the reference group)

Figure 1: Association between proximity to green space and duration of sleep (fully adjusted)



*reference group = less than 20% green space

** multinomial logit regression with robust standard errors and base category comprising participants reporting 8 hours sleep duration. Models were adjusted for: age; gender; Kessler scale of psychological distress; physical activity (measured by the Active Australia survey); weight status; couple status; ethnicity; country of birth; annual household income; highest qualifications; economic status; language spoken at home; number of alcoholic drinks consumed per week; smoking status; social support; the Socio-Economic Index for Areas (SEIFA) 'Index of Relative Socio-Economic Advantage/Disadvantage'; and the 'Accessibility/Remoteness Index of Australia' (ARIA).

1
2
3 **Does access to neighborhood green space promote a healthy duration of sleep? Novel findings**
4 **from 259,319 Australians**
5
6
7

8 **ABSTRACT**
9

10
11 **Objectives:** Experiments demonstrate that exposure to parks and other 'green spaces' promote
12 favorable psychological and physiological outcomes. As a consequence, people who reside in greener
13 neighborhoods may also have a lower risk of short sleep duration (<6 hours). This is potentially
14 important as short sleep duration is a correlate of obesity, chronic disease, and mortality, but so far
15 this hypothesis has not been previously investigated.
16
17
18
19

20
21
22 **Design:** Cross-sectional data analysis
23

24
25 **Setting:** New South Wales, Australia
26
27

28 **Participants:** This study investigated whether neighborhood green space was associated with a
29 healthier duration of sleep (to the nearest hour) among 259,319 Australians who completed the 45 and
30 Up Study baseline questionnaire between 2006 and 2009 inclusive.
31
32
33

34
35 **Primary and secondary outcome measures:** Multinomial logit regression was used to investigate
36 the influence of an objective measure of green space on categories of sleep duration: 8 hours (normal);
37 between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours (mid-
38 short sleep); less than 6 hours (short sleep). Models were adjusted for psychological distress, physical
39 activity, and a range of demographic and socioeconomic characteristics.
40
41
42
43
44

45
46 **Results:** People living in greener neighborhoods reported a lower risk of short sleep. For example,
47 compared to participants living in areas with 20% green space land-use, the relative risk ratios for
48 participants with 80%+ green space was 0.86 (95% confidence interval (95%CI) 0.81, 0.92) for
49 durations between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6-hours sleep.
50
51
52

53
54 Unexpectedly, the benefit of more green space for achieving 8 hours of sleep was not explained by
55 controls for psychological distress, physical activity, or other socioeconomic factors.
56
57
58
59
60

1
2
3 **Conclusion:** Green space planning policies may have wider public health benefits than previously
4 recognized. Further research on the role of green space in promoting healthier sleep durations and
5 patterns is warranted.
6
7
8

9
10
11
12 **Ethics:** The University of New South Wales Human Research Ethics Committee approved The 45
13 and Up Study. Local ethical approval for this study was awarded by the University of Western
14 Sydney.
15
16
17
18

19
20
21
22 **Funding:** No funding was sought for this study.
23
24
25
26

27
28
29 **Data sharing:** Data from the 45 and Up Study is only accessible via a data license issued through
30 blinded peer-review. It is not available for sharing with parties who do not possess an approved
31 Agreement with the Data Custodian.
32
33
34
35

36 37 38 39 **Article Focus**

- 40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
- Previous work suggests that more green space within the neighborhood environment can promote better mental health and more active lifestyles
 - Better mental health and more active lifestyles are correlates of a healthy duration of sleep (usually around 8 hours a night)
 - Greener neighborhoods, therefore, may guard against short sleep duration (usually less than 6 hours per night), which is correlated with obesity, chronic disease, and mortality

Key Messages

- In a large study of Australian adults, we found those in greener neighborhoods were at a lower risk of short sleep (< 6 hours a night)
- More green space was not associated with longer sleep durations (which are also correlated with poor health outcomes)
- Unexpectedly, the benefit of more green space for achieving a healthier duration of sleep was not explained by controls for psychological distress, physical activity, and socioeconomic variables

Strengths and Limitations

- This study benefits from a large sample size focusing on adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of health services
- This study is strengthened by use of validated measures of sleep duration, psychological distress, physical activity, and an objective measure of green space exposure
- Cross-sectional data prohibits causal inference, though follow up of the participants across time will allow the opportunity for replication of this study with a longitudinal design

Introduction

Positive psychological and physiological outcomes from exposure to parks and other forms of natural environment in experimental studies¹⁻³ have fuelled support for the integration of these ‘green spaces’ within planning policy.^{4,5} Health benefits are thought to accrue via psycho-neuro-endocrine pathways, wherein the experience of nature triggers restoration.⁶⁻⁸ These benefits are likely to be in tandem with physical activity, more of which is not only correlated with better mental health,⁹ but also increasingly likely among people who live in greener neighborhoods.¹⁰⁻¹²

While the epidemiological literature is increasingly replete with studies documenting association between green spaces, mental health and physical activity, less attention has been paid to other important health behaviors and outcomes. One such outcome is sleep duration. Many studies have reported a parabolic association¹³ between the number of hours a person sleeps and their subsequent risk of poor self-rated health¹⁴, obesity^{15,16}, cardiovascular disease¹⁷, diabetes^{18,19} and death.²⁰⁻²² Favorable mental health and active lifestyles are thought to be drivers of a healthier duration of sleep (usually around 8 hours per night).²³⁻²⁵ Since these drivers are widely reported to be positive outcomes of living in greener neighborhoods, we hypothesized that people with access to more green space would therefore be more likely to achieve a healthier duration of sleep.

This hypothesis was investigated in a large sample of Australian adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of healthcare in Australia.

METHOD

Data

A sample of 259,319 participants with valid data on sleep duration were selected from 267,151 in the 45 and Up Study.²⁶ The questionnaire is available online from www.45andup.org.au. Participants were randomly selected from the Medicare Australia database (the national provider of universal

1
2
3 health insurance) and surveyed between 2006 and 2009. The survey response rate was 18%, though
4
5 previous work has shown that results from the 45 and Up Study are comparable to those derived from
6
7 a representative population survey.²⁷ Geocoding of participants in the 45 and Up Study was available
8
9 at the Census Collection Districts (CCD) scale. CCDs contain 225 people on average and were the
10
11 smallest geography at which 2006 Census data were disseminated.²⁸ The University of New South
12
13 Wales Human Research Ethics Committee approved The 45 and Up Study.

14 15 16 17 18 19 *Outcome measure*

20
21
22 Sleep duration was derived from responses to the following question: “About how many hours in each
23
24 24 hour day do you usually spend sleeping (including at night and naps)?” and has been used in
25
26 previous analyses of the same data.^{14 15 25 29} Responses to this question were missing for 7,755 people
27
28 and these were omitted from the analyses. To account for the curvilinear association between sleep
29
30 duration and health,¹³ responses were classified into a multinomial variable as follows: 8 hours
31
32 (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours
33
34 (mid-short sleep); less than 6 hours (short sleep). This classification allows for the healthiest duration
35
36 (8 hours) to be used as a reference group for all other categories.

37 38 39 40 41 42 *Green space*

43
44
45 Meshblocks classified as ‘parkland’ in the Australian Bureau of Statistics (ABS) land-use
46
47 classification for 2006 were used to construct the measure of green space. ‘Farmland’ meshblocks
48
49 were not used as they do not strictly represent spaces available for recreation. The measure of green
50
51 space was based upon the percentage available within a 1 kilometer (km) buffer around the
52
53 population-weighted centroid of each CCD. A 1km buffer was selected so as to represent land-use
54
55 within a reasonable walking distance from place of residence, **and has been used in previous studies**

1
2
3 **of green space and health.**^{11 12 30 31} The percentage green space measure was classified into fifths to
4 explore for potential non-linearities (0-20%, 20-40%, 40-60%, 60-80%, 80%+).
5
6
7
8
9

10 *Other individual and neighborhood measures*

11
12
13
14 The Kessler Psychological Distress Scale (K10) was used to assess mental health status.^{32 33} The K10
15 measures symptoms of psychological distress experienced over the past four weeks, including feeling
16 tired for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five
17 choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3,
18 most of the time =4, all of the time =5). The K10 is constructed by summing responses to each of the
19 questions, with scores of 22 and over identified those with a high risk of psychological distress.³⁴ The
20 K10 has been used in this way in previous published analyses of the 45 and Up Study.³⁵
21
22
23
24
25
26
27
28

29 The measure of physical activity was an aggregate of the number of 10 minute sessions spent either
30 walking or in moderate to vigorous physical activity (MVPA), assessed using the Active Australia
31 Survey.³⁶ The question was “How many times did you do each of these activities last week?”
32
33 Participants could indicate walking, moderate (e.g. gentle swimming) and vigorous (e.g. jogging)
34 forms activity separately.
35
36
37
38
39

40 A range of other individual characteristics were also taken account of, including age, gender, ethnicity,
41 country of birth, body mass index (BMI), annual income, highest educational qualifications, economic
42 status (employed, unemployed, retired, inactive due to poor health), couple status, number of
43 alcoholic drinks consumed in the last week, smoking status, language other than English spoken at
44 home, and the Duke Social Support Index.³⁷
45
46
47
48
49

50
51 Two other characteristics at the neighborhood-level were considered. The Socio-Economic Index for
52 Areas (SEIFA) ‘Index of Relative Socio-Economic Advantage/Disadvantage’ was used to measure
53 local socioeconomic circumstances. Differences between urban and rural areas were controlled using
54
55
56
57
58
59
60

1
2
3 the 'Accessibility / Remoteness Index of Australia' (ARIA). Like the measure of green space, both of
4 these neighborhood indicators were created using data from 2006 to fit with the baseline questionnaire.
5
6
7
8
9

10 *Statistical analysis*

11
12
13
14 Cross-tabulations were used to compare the patterning of each sleep duration category according to
15 proximity to green space and all other explanatory variables. A multinomial logit regression was used
16 assess the risk of short sleep versus an 8-hour sleep duration (reference), accounting for longer sleeps
17 as separate categories simultaneously within the same model. Parameters were exponentiated to
18 relative risk ratios (RRR). RRRs over 1 indicated positive association, whereas RRRs below 1
19 denoted negative association. Bivariate models containing the measure of green space (fitted as a
20 categorical variable) were initially adjusted for interactions between age and gender. The robustness
21 of any associations found were then tested with controls for psychological distress and physical
22 activity. Socioeconomic and other explanatory variables were then added sequentially, with any
23 change in the potential association between green space exposure and sleep duration documented.
24 To account for the nested data structure, the Huber-White method was utilized in all models to adjust
25 standard errors.^{38 39} The log-likelihood ratio test ($p < 0.05$) was used to identify statistically significant
26 associations. Analyses were conducted in STATA 12 (StataCorp, College Station, TX, USA).
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

47 **RESULTS**

48
49
50 In Table 1 the prevalence of sleep for 8 hour duration (adjusted for age and gender) was demonstrably
51 higher in neighborhoods with a higher percentage of green space. This was also for sleep durations
52 between 9 and 10 hours, but not for those of 10 hours or more. Meanwhile, the prevalence of sleep
53 durations less than 8 hours was higher in neighborhoods with less green space. The percentage point
54 difference reported between neighborhoods with 80%+ and less than 20% green space proximity was
55
56
57
58
59
60

1
2
3 3.6 for a mid-short sleep duration between 6 and 7 hours ($p<0.001$). A smaller, though statistically
4 significant gap was also reported for short sleeps less than 6 hours (0.9 percentage points, $p<0.001$).
5
6
7 The risk of short sleep duration (6 hours or less per day) was 4 times higher among participants at
8
9 high risk of psychological distress (95%CI 3.8, 4.3), 1.5 times higher among obese people versus
10 those normal BMI (95%CI 1.46, 1.63), 1.8 times higher among people earning less than \$20,000 a
11 year (95%CI 1.7, 1.9), 1.6 times higher for residents of the most deprived quintile of neighborhoods
12 (95%CI 1.5, 1.7) and 1.1 times higher for those in remote and rural versus urban areas (95%CI 1.0,
13 1.2).
14
15
16
17
18
19

20 Preliminary multinomial logit regression took a bivariate format with green space as the sole predictor
21 of sleep duration. The 259,319 participants were nested within 11,719 CCDs. Compared to
22 participants reporting 8 hour sleep as the base category, the risk of shorter sleep durations was lower
23 for those with access to more green space. For example, the Relative Risk Ratios (RRRs) for
24 participants with 80%+ versus less than 20% green space was 0.86 (95%CI 0.81, 0.92) for durations
25 between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6 hours sleep. In contrast, there was
26 no association between neighborhood green space and the risk of longer sleep durations between 9
27 and 10 hours (RRR 1.06, 95%CI 0.99, 1.14), or over 10 hours (RRR 0.85, 95%CI 0.70, 1.03).
28
29
30
31
32
33
34
35
36

37 These results appeared to corroborate our hypothesis. However, this was founded on the basis that
38 greener neighborhoods stimulate mental health and more active lifestyles, which would then promote
39 a healthier duration of sleep. Ergo, we expected that the association between green space and sleep
40 duration would be explained by controls for mental health and physical activity. Adding the K10
41 variable showed participants at a high risk of psychological distress were more likely to report sleeps
42 of less and also more than 8 hours in duration ($p<0.001$). Conversely, adding physical activity to the
43 model did not result in a significant association with sleep duration. Unexpectedly, and counter to our
44 hypothesis, adjusting for these variables had negligible impact on the association between green space
45 and sleep duration.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 The final step was to interrogate the consistency of the green space parameters against other factors
4 shown to be associated with short and long sleep duration. These variables were added sequentially to
5 the previous model, with Figure 1 illustrating the results of the final multinomial logit regression.
6
7 Many characteristics of individuals were associated with sleep duration in line with previous work,
8 such as unemployment and sleeps of less than 6 hours (RRR 1.20, 95%CI 1.02, 1.32) and more than
9 10 hours (RRR 3.17, 95%CI 2.66, 3.78). Participants in more affluent and geographically remote
10 neighborhoods were also at a lower risk of short and long sleep durations ($p<0.001$). Controlling for
11 all of these variables did attenuate the negative association between green space and short sleep
12 duration, but not fully. For participants with access to 80%+ green space within their neighborhood
13 compared to those with less than 20%, the RRR of sleeping between 6 and 7 hours was 0.92 (95%CI
14 0.87, 0.98) and 0.81 (95%CI: 0.69, 0.96) for sleeps of less than 6 hours in duration. There remained
15 no association between green space exposure and sleeps of more than 8 hours.
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

31 DISCUSSION

32
33
34 As countries invest in large scale green space planning policies,⁴⁵ it would be prudent to ask whether
35 parks and other forms of natural environment have any other health benefits aside from those which
36 are already widely reported (namely, better mental health and increased physical activity). This study
37 has demonstrated that people who live in greener environs are more likely to achieve a healthier
38 duration of sleep. The protective effect of green space was isolated to guarding against the risk of
39 short sleep (less than 8 hours), with no association found for longer sleeps. These results were
40 consistent after controlling for factors already known to be associated with short and long sleep and,
41 surprisingly, were not explained by indicators of mental health and physical activity. The significance
42 of these findings are put in context when one considers that sleep durations of less than 6 hours are
43 consistently associated with many of the major chronic health conditions¹⁵⁻¹⁹ that threaten the
44 sustainability of health systems.^{40 41} As such, these results suggest that large-scale investments in
45 green space policy could have a wider public health benefit than has been previously acknowledged.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Restoration from access to nature can occur directly ¹, although exposure to green space is
4 undoubtedly entwined, to a potentially large extent, with active lifestyles for which parks and other
5 public open spaces are attractive environments for participation ⁴². This makes the finding that green
6 space was associated with a healthier duration of sleep, irrespective of psychological distress or
7 participation in physical activity, more intriguing. One possible explanation is that the physical
8 activity variable measures participation, but not with any specific reference to the place in which it
9 occurs. Participants scoring higher on the physical activity variable therefore do not necessarily
10 perform those activities in the green spaces where they live and this interaction between behavior and
11 environment may be important to control.⁴³ Another plausible mechanism is the dispersal of traffic
12 density ⁴⁴ and noise pollution in areas with more green space, which could otherwise have a
13 detrimental influence on sleep duration.^{45 46} No measure of traffic density or noise pollution was
14 available for this study however. Thus, while more green space appears to be protective against a
15 short duration of sleep, it is not yet clear whether this is demonstrably because of a direct effect on
16 restoration that is not picked up by the K10, or if it operates via other structural processes operating at
17 the neighborhood level. Further research on the spatial patterning of sleep duration that accounts for
18 other structural variables, such as noise pollution, is warranted to isolate the potentially causal
19 mechanism(s) at play.

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38 This study benefited from a large sample size and an objective measure of green space. However, the
39 focus on a population of 45 years and older limits the generalisability to younger people, for whom
40 further studies are advised. The survey response rate was 18%, though previous work has shown that
41 results from the 45 and Up Study are comparable to those from a representative survey²⁷. While the
42 cross-sectional design limits prospects for causal inference, such inferences might not be achieved
43 with longitudinal data either, as contemporaneous exposure to green space, rather than one that is
44 temporally lagged may be what counts most for determining sleep duration. Longitudinal studies
45 would nevertheless be useful for testing hypotheses related to temporal effects. It is plausible that
46 sleep duration varies across the week and during the day (e.g. naps), particularly between weekdays
47 and weekends, but the measure of sleep available in the 45 and Up Study was generalist and could not
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 facilitate these more detailed enquiries. Similarly, the Active Australia Survey is a measure of overall
4 physical activity, but did not afford a distinction between leisure and other types (e.g. active travel).

5
6
7 **Finally, while previous work has shown that different measures of green space yield similar**
8 **associations with health outcomes,⁴⁷ we recognize that not all green spaces are the same and**
9 **future work should explore whether variation in subjective quality⁴⁸ or type⁴⁹ (e.g. parks versus**
10 **conservation areas) results in systematic differences in health outcomes, including sleep**
11 **duration.**
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

1. Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 2010;10.
2. Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health* 2010;33(2):212-22.
3. Lachowycz K, Jones AP. Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews* 2011;12(5):e183-e89.
4. Nilsson K, Sangster M, Konijnendijk CC. Introduction. In: Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., editors. *Forests, trees and human health*. Netherlands: Springer, 2011:1-19.
5. Australian Government. *Our Cities Our Future: A national urban policy for a productive, sustainable and liveable future*. Canberra: Department of Infrastructure and Transport, 2011.
6. Sternberg EM. *Healing spaces: The science of place and well-being*. Cambridge: Harvard University Press, 2009.
7. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective*: Cambridge University Press, 1989.
8. Ulrich RS. View through a window may influence recovery from surgery. *Science* 1984;224(4647):420.
9. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *Journal of Science and Medicine in Sport* 2004;7(1):6-19.
10. Giles-Corti B, Broomhall MH, Knuiaman M, Collins C, Douglas K, Ng K, et al. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 2005;28(2S2):169-76.
11. Astell-Burt T, Feng X, Kolt GS. Neighbourhood green space is associated with more frequent walking and moderate to vigorous physical activity (MVPA) in middle-to-older aged adults. Findings from 203,883 Australians in The 45 and Up Study. *British Journal of Sports Medicine* 2013:doi:10.1136/bjsports-2012-092006.
12. Astell-Burt T, Feng X, Kolt GS. Greener neighborhoods, slimmer people? Evidence from 246,920 Australians. *International Journal of Obesity* 2013:doi:10.1038/ijo2013.64.
13. Knutson KL, Turek FW. The U-shaped association between sleep and health: the 2 peaks do not mean the same thing. *Sleep* 2006;9:881-89.
14. Magee CA, Caputi P, Iverson DC. Relationships between self-rated health, quality of life and sleep duration in middle aged and elderly Australians. *Sleep medicine* 2011;12(4):346-50.
15. Magee CA, Iverson DC, Caputi P. Sleep duration and obesity in middle-aged Australian adults. *Obesity* 2009;18(2):420-21.
16. Cappuccio FP, Taggart FM, Kandala NB, al. e. Cappuccio, F. P., Taggart, F. M., Kandala, N. -B. et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31:619-26.
17. Cappuccio FP, Cooper D, D Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur. Heart J.* 2011;32:1484-92.
18. Chaput JP, Despre' s J-P, Bouchard C, Tremblay A. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia* 2007;50:2298-304.
19. Knutson KL, Spiegel K, Penev P, Van Cauter E. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.* 2007;11:163-78.
20. Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 2002;59:131-36.
21. Heslop P, Smith GD, Metcalfe C, Macleod J, Hart C. Sleep duration and mortality: the effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine* 2003;3:305-14.

- 1
- 2
- 3 22. Hublin C, Partinen M, Koskenvuo M, Kaprio J. Sleep and mortality: a population-based 22-year
- 4 follow-up study. *Sleep* 2007;30:1245-53.
- 5 23. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders.
- 6 *JAMA: the journal of the American Medical Association* 1989;262(11):1479-84.
- 7 24. Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and
- 8 good sleep. *Journal of psychosomatic research* 2008;64(4):409-15.
- 9 25. Magee CA, Iverson DC, Caputi P. Factors associated with short and long sleep. *Preventive*
- 10 *Medicine* 2009;49(6):461-67.
- 11 26. 45 and Up Study Collaborators. Cohort Profile: The 45 and Up Study. *International Journal of*
- 12 *Epidemiology* 2008;37(5):941-47.
- 13 27. Mealing NM, Banks E, Jorm LR, Steel DG, Clements MS, Rogers KD. Investigation of relative risk
- 14 estimates from studies of the same population with contrasting response rates and
- 15 designs. *BMC medical research methodology* 2010;10(1):26.
- 16 28. Australian Bureau of Statistics. *Research Paper. Socio-Economic Indexes for Areas:*
- 17 *Introduction, Use and Future Directions*. Canberra: ABS, 2006.
- 18 29. Magee CA, Kritharides L, Attia J, Mcelduff P, Banks E. Short and long sleep duration are
- 19 associated with prevalent cardiovascular disease in Australian adults. *Journal of sleep*
- 20 *research* 2012;21(4):441-47.
- 21 30. Maas J, Verheij RA, Groenewegen PP, de Vries S, Spreeuwenberg P. Green space, urbanity, and
- 22 health: how strong is the relation? *Journal of Epidemiology & Community Health*
- 23 *2006;60(7):587-92*.
- 24 31. de Vries S, Verheij RA, Groenewegen PP, Spreeuwenberg P. Natural environments-healthy
- 25 environments? An exploratory analysis of the relationship between greenspace and health.
- 26 *Environment and Planning A* 2003;35(10):1717-32.
- 27 32. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand SL, et al. Short screening scales
- 28 to monitor population prevalences and trends in non-specific psychological distress.
- 29 *Psychological Medicine* 2002;32:959-76.
- 30 33. Furukawa TA, Kessler RC, Slade T, Andrews G. The performance of the K6 and K10 screening
- 31 scales for psychological distress in the Australian National Survey of Mental Health and
- 32 Well-Being. *Psychological medicine* 2003;33(2):357-62.
- 33 34. Australian Bureau of Statistics. *Information paper: use of the Kessler Psychological Distress*
- 34 *Scale in ABS Health Surveys, Australia*. Canberra: Australian Bureau of Statistics, 2003.
- 35 35. Feng X, Astell-Burt T, Kolt GS. Ethnic density, social interactions and psychological distress:
- 36 Evidence from 226,487 Australian adults. *BMJ Open* 2013;3:e002713.
- 37 36. Australian Institute of Health and Welfare. *The active Australia survey: A guide and manual for*
- 38 *implementation, analysis and reporting*. Canberra: AIHW, 2003.
- 39 37. Koenig HG, Westlund RE, George LK, Hughes DC, Blazer DG, Hybels C. Abbreviating the Duke
- 40 Social Support Index for use in chronically ill elderly individuals. *Psychosomatics*
- 41 *1993;34:61-69*.
- 42 38. UCLA: Academic Technology Services SCG. *Analyzing Correlated (Clustered) Data*, 2008.
- 43 39. Williams R. A note on robust variance estimation for cluster-correlated data. *Biometrics*
- 44 *2000;56(2):645-46*.
- 45 40. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the
- 46 projected obesity trends in the USA and the UK. *The Lancet* 2011;378(9793):815-25.
- 47 41. Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing
- 48 challenge. *New England Journal of Medicine* 2007;356(3):213-15.
- 49 42. Hug SM, Hartig T, Hansmann R, Seeland K, Hornung R. Restorative qualities of indoor and
- 50 outdoor exercise settings as predictors of exercise frequency. *Health & Place* 2009;15:971-
- 51 *80*.
- 52 43. Mitchell R. Is physical activity in natural environments better for mental health than physical
- 53 activity in other environments? *Social Science & Medicine* 2012;In Press.
- 54
- 55
- 56
- 57
- 58
- 59
- 60

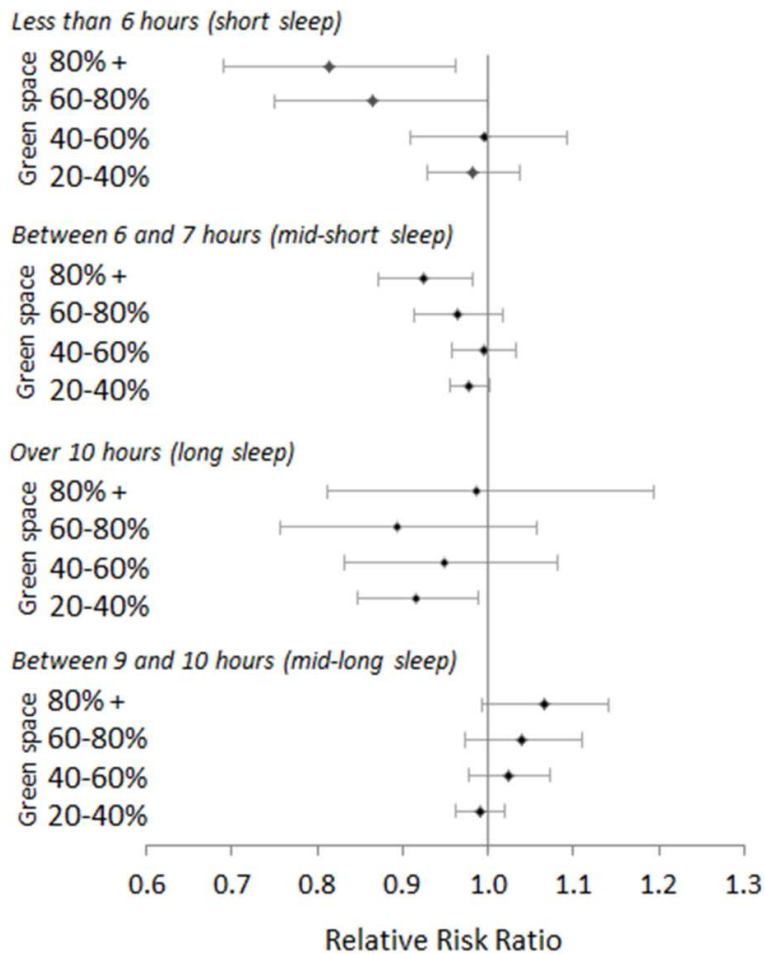
- 1
2
3 44. Gidlöf-Gunnarsson A, Öhrström E. Noise and well-being in urban residential environments: The
4 potential role of perceived availability to nearby green areas. *Landscape and Urban*
5 *Planning* 2007;83(2):115-26.
6 45. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic
7 noise on sleep and recuperation. *Sleep* 2011;34(1):11.
8 46. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews* 2007;11(2):135-42.
9 47. Mitchell R, Astell-Burt T, Richardson EA. A comparison of green space measures for
10 epidemiological research. *Journal of Epidemiology and Community Health*
11 2011;65(10):853-58.
12 48. Francis J, Wood LJ, Knuiman M, Giles-Corti B. Quality or quantity? Exploring the relationship
13 between Public Open Space attributes and mental health in Perth, Western Australia.
14 *Social Science & Medicine* 2012;74(10):1570-77.
15 49. Fan Y, Das KV, Chen Q. Neighborhood green, social support, physical activity, and stress:
16 Assessing the cumulative impact. *Health & Place* 2011;17(6):1202-11.
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1: Age-gender adjusted patterning of sleep duration by proximity to green space

	8 hours (normal)	Between 9 and 10 hours (mid-long sleep)	Over 10 hours (long sleep)	Between 6 and 7 hours (mid-short sleep)	Less than 6 hours (short sleep)
N (259,319)	104,432	47,424	4,938	92,860	9,665
Green space % (n)	% (95% Confidence Interval)				
0-20% (177,106)	40.0 (39.8, 40.3)	17.5 (17.3, 17.7)	1.6 (1.5, 1.6)	35.6 (35.3, 35.8)	3.7 (3.6, 3.8)
20-40% (49,316)	40.4 (39.9, 40.8)	16.9 (16.6, 17.3)**	1.4 (1.3, 1.5)***	36.2 (35.7, 36.7)*	3.6 (3.4, 3.8)
40-60% (18,045)	40.5 (39.7, 41.3)	17.9 (17.3, 18.6)	1.4 (1.2, 1.6)*	35.3 (34.4, 36.1)	3.3 (3.1, 3.6)**
60-80% (8,253)	41.2 (40.0, 42.3)*	18.6 (17.6, 19.6)**	1.3 (1.1, 1.5)	34.4 (33.2, 35.7)*	2.9 (2.5, 3.3)***
80% + (6,599)	41.9 (40.7, 43.2)**	20.1 (19.1, 21.2)***	1.6 (1.3, 1.9)	32.0 (30.8, 33.2)***	2.8 (2.3, 3.2)***

*** p < 0.001; ** p < 0.01; * p < 0.05 (from 0-20% green space as the reference group)

Figure 1: Association between proximity to green space and duration of sleep (fully adjusted)



*reference group = less than 20% green space

** multinomial logit regression with robust standard errors and base category comprising participants reporting 8 hours sleep duration. Models were adjusted for: age; gender; Kessler scale of psychological distress; physical activity (measured by the Active Australia survey); weight status; couple status; ethnicity; country of birth; annual household income; highest qualifications; economic status; language spoken at home; number of alcoholic drinks consumed per week; smoking status; social support; the Socio-Economic Index for Areas (SEIFA) 'Index of Relative Socio-Economic Advantage/Disadvantage'; and the 'Accessibility/Remoteness Index of Australia' (ARIA).



Does access to neighborhood green space promote a healthy duration of sleep? Novel findings from 259,319 Australians

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-003094.R2
Article Type:	Research
Date Submitted by the Author:	08-Jul-2013
Complete List of Authors:	Astell-Burt, Thomas; University of Western Sydney, School of Science and Health Feng, Xiaoqi; Centre for Health Research, School of Medicine Kolt, Gregory; University of Western Sydney, School of Science and Health
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology, Sociology
Keywords:	EPIDEMIOLGY, PUBLIC HEALTH, SOCIAL MEDICINE

SCHOLARONE™
Manuscripts

1
2
3 **Does access to neighborhood green space promote a healthy duration of sleep? Novel findings**
4 **from 259,319 Australians**
5
6

7
8 *Astell-Burt¹, Thomas; Feng, Xiaoqi²; Kolt, Gregory¹
9

10
11 **Corresponding Author - ***

12
13 **Affiliations**

- 14
15
16 1. University of Western Sydney - School of Science and Health
17
18 2. Centre for Health Research - School of Medicine University of Western Sydney
19

20
21
22 **Keywords:** EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE
23

24 Word count: 2658

25
26 Reference Count: 49
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

ABSTRACT

Objectives: Experiments demonstrate that exposure to parks and other 'green spaces' promote favorable psychological and physiological outcomes. As a consequence, people who reside in greener neighborhoods may also have a lower risk of short sleep duration (<6 hours). This is potentially important as short sleep duration is a correlate of obesity, chronic disease, and mortality, but so far this hypothesis has not been previously investigated.

Design: Cross-sectional data analysis

Setting: New South Wales, Australia

Participants: This study investigated whether neighborhood green space was associated with a healthier duration of sleep (to the nearest hour) among 259,319 Australians who completed the 45 and Up Study baseline questionnaire between 2006 and 2009 inclusive.

Primary and secondary outcome measures: Multinomial logit regression was used to investigate the influence of an objective measure of green space on categories of sleep duration: 8 hours (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours (mid-short sleep); less than 6 hours (short sleep). Models were adjusted for psychological distress, physical activity, and a range of demographic and socioeconomic characteristics.

Results: People living in greener neighborhoods reported a lower risk of short sleep. For example, compared to participants living in areas with 20% green space land-use, the relative risk ratios for participants with 80%+ green space was 0.86 (95% confidence interval (95%CI) 0.81, 0.92) for durations between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6-hours sleep.

Unexpectedly, the benefit of more green space for achieving 8 hours of sleep was not explained by controls for psychological distress, physical activity, or other socioeconomic factors.

1
2
3 **Conclusion:** Green space planning policies may have wider public health benefits than previously
4 recognized. Further research on the role of green space in promoting healthier sleep durations and
5 patterns is warranted.
6
7
8
9
10
11
12
13
14
15

16 **Article Focus**

- 17 • Previous work suggests that more green space within the neighborhood environment can
18 promote better mental health and more active lifestyles
- 19 • Better mental health and more active lifestyles are correlates of a healthy duration of sleep
20 (usually around 8 hours a night)
- 21 • Greener neighborhoods, therefore, may guard against short sleep duration (usually less than 6
22 hours per night), which is correlated with obesity, chronic disease, and mortality
- 23
24
25
26
27
28
29
30
31
32
33
34
35
36

37 **Key Messages**

- 38 • In a large study of Australian adults, we found those in greener neighborhoods were at a
39 lower risk of short sleep (< 6 hours a night)
- 40 • More green space was not associated with longer sleep durations (which are also correlated
41 with poor health outcomes)
- 42 • Unexpectedly, the benefit of more green space for achieving a healthier duration of sleep was
43 not explained by controls for psychological distress, physical activity, and socioeconomic
44 variables
- 45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Strengths and Limitations

- This study benefits from a large sample size focusing on adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of health services
- This study is strengthened by use of validated measures of sleep duration, psychological distress, physical activity, and an objective measure of green space exposure
- Cross-sectional data prohibits causal inference, though follow up of the participants across time will allow the opportunity for replication of this study with a longitudinal design

Introduction

Positive psychological and physiological outcomes from exposure to parks and other forms of natural environment in experimental studies¹⁻³ have fuelled support for the integration of these 'green spaces' within planning policy.^{4,5} Health benefits are thought to accrue via psycho-neuro-endocrine pathways, wherein the experience of nature triggers restoration.⁶⁻⁸ These benefits are likely to be in tandem with physical activity, more of which is not only correlated with better mental health,⁹ but also increasingly likely among people who live in greener neighborhoods.¹⁰⁻¹²

While the epidemiological literature is increasingly replete with studies documenting association between green spaces, mental health and physical activity, less attention has been paid to other important health behaviors and outcomes. One such outcome is sleep duration. Many studies have reported a parabolic association¹³ between the number of hours a person sleeps and their subsequent risk of poor self-rated health¹⁴, obesity^{15,16}, cardiovascular disease¹⁷, diabetes^{18,19} and death.²⁰⁻²² Favorable mental health and active lifestyles are thought to be drivers of a healthier duration of sleep (usually around 8 hours per night).²³⁻²⁵ Since these drivers are widely reported to be positive outcomes of living in greener neighborhoods, we hypothesized that people with access to more green space would therefore be more likely to achieve a healthier duration of sleep.

This hypothesis was investigated in a large sample of Australian adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of healthcare in Australia.

METHOD

Data

A sample of 259,319 participants with valid data on sleep duration were selected from 267,151 in the 45 and Up Study.²⁶ The questionnaire is available online from www.45andup.org.au. Participants were randomly selected from the Medicare Australia database (the national provider of universal

1
2
3 health insurance) and surveyed between 2006 and 2009. The survey response rate was 18%, though
4
5 previous work has shown that results from the 45 and Up Study are comparable to those derived from
6
7 a representative population survey.²⁷ Geocoding of participants in the 45 and Up Study was available
8
9 at the Census Collection Districts (CCD) scale. CCDs contain 225 people on average and were the
10
11 smallest geography at which 2006 Census data were disseminated.²⁸ The University of New South
12
13 Wales Human Research Ethics Committee approved The 45 and Up Study.

14 15 16 17 18 19 *Outcome measure*

20
21
22 Sleep duration was derived from responses to the following question: “About how many hours in each
23
24 24 hour day do you usually spend sleeping (including at night and naps)?” and has been used in
25
26 previous analyses of the same data.^{14 15 25 29} Responses to this question were missing for 7,755 people
27
28 and these were omitted from the analyses. To account for the curvilinear association between sleep
29
30 duration and health,¹³ responses were classified into a multinomial variable as follows: 8 hours
31
32 (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours
33
34 (mid-short sleep); less than 6 hours (short sleep). This classification allows for the healthiest duration
35
36 (8 hours) to be used as a reference group for all other categories.

37 38 39 40 41 42 *Green space*

43
44
45 Meshblocks classified as ‘parkland’ in the Australian Bureau of Statistics (ABS) land-use
46
47 classification for 2006 were used to construct the measure of green space. ‘Farmland’ meshblocks
48
49 were not used as they do not strictly represent spaces available for recreation. The measure of green
50
51 space was based upon the percentage available within a 1 kilometer (km) buffer around the
52
53 population-weighted centroid of each CCD. A 1km buffer was selected so as to represent land-use
54
55 within a reasonable walking distance from place of residence, and has been used in previous studies of
56
57
58
59
60

1
2
3 green space and health.^{11 12 30 31} The percentage green space measure was classified into fifths to
4
5 explore for potential non-linearities (0-20%, 20-40%, 40-60%, 60-80%, 80%+).
6
7
8
9

10 11 *Other individual and neighborhood measures*

12
13
14 The Kessler Psychological Distress Scale (K10) was used to assess mental health status.^{32 33} The K10
15
16 measures symptoms of psychological distress experienced over the past four weeks, including feeling
17
18 tired for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five
19
20 choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3,
21
22 most of the time =4, all of the time =5). The K10 is constructed by summing responses to each of the
23
24 questions, with scores of 22 and over identified those with a high risk of psychological distress.³⁴ The
25
26 K10 has been used in this way in previous published analyses of the 45 and Up Study.³⁵
27
28

29
30 The measure of physical activity was an aggregate of the number of 10 minute sessions spent either
31
32 walking or in moderate to vigorous physical activity (MVPA), assessed using the Active Australia
33
34 Survey.³⁶ The question was “How many times did you do each of these activities last week?”
35
36 Participants could indicate walking, moderate (e.g. gentle swimming) and vigorous (e.g. jogging)
37
38 forms activity separately.
39

40
41 A range of other individual characteristics were also taken account of, including age, gender, ethnicity,
42
43 country of birth, body mass index (BMI), annual income, highest educational qualifications, economic
44
45 status (employed, unemployed, retired, inactive due to poor health), couple status, number of
46
47 alcoholic drinks consumed in the last week, smoking status, language other than English spoken at
48
49 home, and the Duke Social Support Index.³⁷
50

51
52 Two other characteristics at the neighborhood-level were considered. The Socio-Economic Index for
53
54 Areas (SEIFA) ‘Index of Relative Socio-Economic Advantage/Disadvantage’ was used to measure
55
56 local socioeconomic circumstances. Differences between urban and rural areas were controlled using
57
58
59
60

1
2
3 the 'Accessibility / Remoteness Index of Australia' (ARIA). Like the measure of green space, both of
4 these neighborhood indicators were created using data from 2006 to fit with the baseline questionnaire.
5
6
7
8
9

10 *Statistical analysis*

11
12
13
14 Cross-tabulations were used to compare the patterning of each sleep duration category according to
15 proximity to green space and all other explanatory variables. A multinomial logit regression was used
16 assess the risk of short sleep versus an 8-hour sleep duration (reference), accounting for longer sleeps
17 as separate categories simultaneously within the same model. Parameters were exponentiated to
18 relative risk ratios (RRR). RRRs over 1 indicated positive association, whereas RRRs below 1
19 denoted negative association. Bivariate models containing the measure of green space (fitted as a
20 categorical variable) were initially adjusted for interactions between age and gender. The robustness
21 of any associations found were then tested with controls for psychological distress and physical
22 activity. Socioeconomic and other explanatory variables were then added sequentially, with any
23 change in the potential association between green space exposure and sleep duration documented.
24 To account for the nested data structure, the Huber-White method was utilized in all models to adjust
25 standard errors.^{38 39} The log-likelihood ratio test ($p < 0.05$) was used to identify statistically significant
26 associations. Analyses were conducted in STATA 12 (StataCorp, College Station, TX, USA).
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

47 **RESULTS**

48
49
50 In Table 1 the prevalence of sleep for 8 hour duration (adjusted for age and gender) was demonstrably
51 higher in neighborhoods with a higher percentage of green space. This was also for sleep durations
52 between 9 and 10 hours, but not for those of 10 hours or more. Meanwhile, the prevalence of sleep
53 durations less than 8 hours was higher in neighborhoods with less green space. The percentage point
54 difference reported between neighborhoods with 80%+ and less than 20% green space proximity was
55
56
57
58
59
60

1
2
3 3.6 for a mid-short sleep duration between 6 and 7 hours ($p<0.001$). A smaller, though statistically
4 significant gap was also reported for short sleeps less than 6 hours (0.9 percentage points, $p<0.001$).
5
6 The risk of short sleep duration (6 hours or less per day) was 4 times higher among participants at
7 high risk of psychological distress (95%CI 3.8, 4.3), 1.5 times higher among obese people versus
8 those normal BMI (95%CI 1.46, 1.63), 1.8 times higher among people earning less than \$20,000 a
9 year (95%CI 1.7, 1.9), 1.6 times higher for residents of the most deprived quintile of neighborhoods
10 (95%CI 1.5, 1.7) and 1.1 times higher for those in remote and rural versus urban areas (95%CI 1.0,
11 1.2).
12
13
14
15
16
17
18
19

20 Preliminary multinomial logit regression took a bivariate format with green space as the sole predictor
21 of sleep duration. The 259,319 participants were nested within 11,719 CCDs. Compared to
22 participants reporting 8 hour sleep as the base category, the risk of shorter sleep durations was lower
23 for those with access to more green space. For example, the Relative Risk Ratios (RRRs) for
24 participants with 80%+ versus less than 20% green space was 0.86 (95%CI 0.81, 0.92) for durations
25 between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6 hours sleep. In contrast, there was
26 no association between neighborhood green space and the risk of longer sleep durations between 9
27 and 10 hours (RRR 1.06, 95%CI 0.99, 1.14), or over 10 hours (RRR 0.85, 95%CI 0.70, 1.03).
28
29
30
31
32
33
34
35
36

37 These results appeared to corroborate our hypothesis. However, this was founded on the basis that
38 greener neighborhoods stimulate mental health and more active lifestyles, which would then promote
39 a healthier duration of sleep. Ergo, we expected that the association between green space and sleep
40 duration would be explained by controls for mental health and physical activity. Adding the K10
41 variable showed participants at a high risk of psychological distress were more likely to report sleeps
42 of less and also more than 8 hours in duration ($p<0.001$). Conversely, adding physical activity to the
43 model did not result in a significant association with sleep duration. Unexpectedly, and counter to our
44 hypothesis, adjusting for these variables had negligible impact on the association between green space
45 and sleep duration.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 The final step was to interrogate the consistency of the green space parameters against other factors
4 shown to be associated with short and long sleep duration. These variables were added sequentially to
5 the previous model, with Figure 1 illustrating the results of the final multinomial logit regression.
6
7 Many characteristics of individuals were associated with sleep duration in line with previous work,
8 such as unemployment and sleeps of less than 6 hours (RRR 1.20, 95%CI 1.02, 1.32) and more than
9 10 hours (RRR 3.17, 95%CI 2.66, 3.78). Participants in more affluent and geographically remote
10 neighborhoods were also at a lower risk of short and long sleep durations ($p<0.001$). Controlling for
11 all of these variables did attenuate the negative association between green space and short sleep
12 duration, but not fully. For participants with access to 80%+ green space within their neighborhood
13 compared to those with less than 20%, the RRR of sleeping between 6 and 7 hours was 0.92 (95%CI
14 0.87, 0.98) and 0.81 (95%CI: 0.69, 0.96) for sleeps of less than 6 hours in duration. There remained
15 no association between green space exposure and sleeps of more than 8 hours.
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

31 DISCUSSION

32
33
34 As countries invest in large scale green space planning policies,^{4,5} it would be prudent to ask whether
35 parks and other forms of natural environment have any other health benefits aside from those which
36 are already widely reported (namely, better mental health and increased physical activity). This study
37 has demonstrated that people who live in greener environs are more likely to achieve a healthier
38 duration of sleep. The protective effect of green space was isolated to guarding against the risk of
39 short sleep (less than 8 hours), with no association found for longer sleeps. These results were
40 consistent after controlling for factors already known to be associated with short and long sleep and,
41 surprisingly, were not explained by indicators of mental health and physical activity. The significance
42 of these findings are put in context when one considers that sleep durations of less than 6 hours are
43 consistently associated with many of the major chronic health conditions¹⁵⁻¹⁹ that threaten the
44 sustainability of health systems.^{40,41} As such, these results suggest that large-scale investments in
45 green space policy could have a wider public health benefit than has been previously acknowledged.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Restoration from access to nature can occur directly ¹, although exposure to green space is
4 undoubtedly entwined, to a potentially large extent, with active lifestyles for which parks and other
5 public open spaces are attractive environments for participation ⁴². This makes the finding that green
6 space was associated with a healthier duration of sleep, irrespective of psychological distress or
7 participation in physical activity, more intriguing. One possible explanation is that the physical
8 activity variable measures participation, but not with any specific reference to the place in which it
9 occurs. Participants scoring higher on the physical activity variable therefore do not necessarily
10 perform those activities in the green spaces where they live and this interaction between behavior and
11 environment may be important to control.⁴³ Another plausible mechanism is the dispersal of traffic
12 density ⁴⁴ and noise pollution in areas with more green space, which could otherwise have a
13 detrimental influence on sleep duration.^{45 46} No measure of traffic density or noise pollution was
14 available for this study however. Thus, while more green space appears to be protective against a
15 short duration of sleep, it is not yet clear whether this is demonstrably because of a direct effect on
16 restoration that is not picked up by the K10, or if it operates via other structural processes operating at
17 the neighborhood level. Further research on the spatial patterning of sleep duration that accounts for
18 other structural variables, such as noise pollution, is warranted to isolate the potentially causal
19 mechanism(s) at play.

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38 This study benefited from a large sample size and an objective measure of green space. However, the
39 focus on a population of 45 years and older limits the generalisability to younger people, for whom
40 further studies are advised. The survey response rate was 18%, though previous work has shown that
41 results from the 45 and Up Study are comparable to those from a representative survey²⁷. While the
42 cross-sectional design limits prospects for causal inference, the ability to detect these types of effects
43 might not necessarily be enhanced with longitudinal data, as contemporaneous exposure to green
44 space, rather than one that is temporally lagged may be what counts most for determining sleep
45 duration. Longitudinal studies would nevertheless be useful for testing hypotheses related to temporal
46 effects and also for exploring potential confounding produced by the possibility of individuals with a
47 propensity for healthier durations of sleep selecting into neighborhoods containing more green space.
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Follow-up of the 45 and Up Study will afford these opportunities, in addition to tracking the longer-
4 term benefits of green space for health more generally.
5
6

7
8 It is plausible that sleep duration varies across the week and during the day (e.g. naps), particularly
9 between weekdays and weekends, but the measure of sleep available in the 45 and Up Study was
10 generalist and could not facilitate these more detailed enquiries. Similarly, the Active Australia
11 Survey is a measure of overall physical activity, but did not afford a distinction between leisure and
12 other types (e.g. active travel). Finally, while previous work has shown that different measures of
13 green space yield similar associations with health outcomes,⁴⁷ we recognize that not all green spaces
14 are the same and future work should explore whether variation in subjective quality⁴⁸ or type⁴⁹ (e.g.
15 parks versus conservation areas) results in systematic differences in health outcomes, including sleep
16 duration.
17
18
19
20
21
22
23
24
25
26

27 In conclusion, this study has found that more green space within the neighborhood of residence is
28 associated with a healthier duration of sleep among a large sample of Australians aged 45 and over.
29 This association appeared to be robust to controls for mental health, physical activity, and other
30 possible individual-level confounders, though unmeasured phenomena operating at the neighborhood-
31 level, such as traffic density, ought to be explored as data becomes available. As it stands, people
32 living in greener areas tend to be at a lower risk of short sleep duration and this could have important
33 subsequent impacts on health, including obesity and cardiovascular disease. It is also plausible that
34 healthier sleep durations promoted by exposure to green space may aid mental health and
35 participation in physical activity. As such, future studies employing longitudinal techniques may
36 consider investigating sleep duration as a possible mediator of associations between green space and
37 health outcomes.
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 **Ethics:** The University of New South Wales Human Research Ethics Committee approved The 45
4 and Up Study. Local ethical approval for this study was awarded by the University of Western
5 Sydney.
6
7
8
9

10
11
12
13 **Funding:** No funding was sought for this study.
14

15
16 **Data sharing:** Data from the 45 and Up Study is only accessible via a data license issued through
17 blinded peer-review. It is not available for sharing with parties who do not possess an approved
18 Agreement with the Data Custodian.
19
20

21
22
23 **Competing Interests:** None
24

25 **Contributorship:**

26
27 Conceived and designed the experiments: TAB XF GK
28

29
30 Performed the experiments: TAB XF.
31

32 Analyzed the data: TAB XF.
33

34
35 Wrote the paper: TAB XF GK
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

1. Bowler DE, Buyung-Ali LM, Knight TM, et al. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 2010;10.
2. Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health* 2010;33(2):212-22.
3. Lachowycz K, Jones AP. Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews* 2011;12(5):e183-e89.
4. Nilsson K, Sangster M, Konijnendijk CC. Introduction. In: Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., editors. *Forests, trees and human health*. Netherlands: Springer, 2011:1-19.
5. Australian Government. *Our Cities Our Future: A national urban policy for a productive, sustainable and liveable future*. Canberra: Department of Infrastructure and Transport, 2011.
6. Sternberg EM. *Healing spaces: The science of place and well-being*. Cambridge: Harvard University Press, 2009.
7. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective*: Cambridge University Press, 1989.
8. Ulrich RS. View through a window may influence recovery from surgery. *Science* 1984;224(4647):420.
9. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *Journal of Science and Medicine in Sport* 2004;7(1):6-19.
10. Giles-Corti B, Broomhall MH, Knuiaman M, et al. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 2005;28(2S2):169-76.
11. Astell-Burt T, Feng X, Kolt GS. Neighbourhood green space is associated with more frequent walking and moderate to vigorous physical activity (MVPA) in middle-to-older aged adults. Findings from 203,883 Australians in The 45 and Up Study. *British Journal of Sports Medicine* 2013;doi:10.1136/bjsports-2012-092006.
12. Astell-Burt T, Feng X, Kolt GS. Greener neighborhoods, slimmer people? Evidence from 246,920 Australians. *International Journal of Obesity* 2013;doi:10.1038/ijo2013.64.
13. Knutson KL, Turek FW. The U-shaped association between sleep and health: the 2 peaks do not mean the same thing. *Sleep* 2006;9:881-89.
14. Magee CA, Caputi P, Iverson DC. Relationships between self-rated health, quality of life and sleep duration in middle aged and elderly Australians. *Sleep medicine* 2011;12(4):346-50.
15. Magee CA, Iverson DC, Caputi P. Sleep duration and obesity in middle-aged Australian adults. *Obesity* 2009;18(2):420-21.
16. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31:619-26.
17. Cappuccio FP, Cooper D, D'Elia L, et al. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur. Heart J.* 2011;32:1484-92.
18. Chaput JP, Despre's J-P, Bouchard C, et al. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia* 2007;50:2298-304.
19. Knutson KL, Spiegel K, Penev P, et al. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.* 2007;11:163-78.
20. Kripke DF, Garfinkel L, Wingard DL, et al. Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 2002;59:131-36.
21. Heslop P, Smith GD, Metcalfe C, et al. Sleep duration and mortality: the effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine* 2003;3:305-14.
22. Hublin C, Partinen M, Koskenvuo M, et al. Sleep and mortality: a population-based 22-year follow-up study. *Sleep* 2007;30:1245-53.

- 1
- 2
- 3 23. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders.
- 4 *JAMA: the journal of the American Medical Association* 1989;262(11):1479-84.
- 5 24. Steptoe A, O'Donnell K, Marmot M, et al. Positive affect, psychological well-being, and good
- 6 sleep. *Journal of psychosomatic research* 2008;64(4):409-15.
- 7 25. Magee CA, Iverson DC, Caputi P. Factors associated with short and long sleep. *Preventive*
- 8 *Medicine* 2009;49(6):461-67.
- 9 26. 45 and Up Study Collaborators. Cohort Profile: The 45 and Up Study. *International Journal of*
- 10 *Epidemiology* 2008;37(5):941-47.
- 11 27. Mealing NM, Banks E, Jorm LR, et al. Investigation of relative risk estimates from studies of the
- 12 same population with contrasting response rates and designs. *BMC medical research*
- 13 *methodology* 2010;10(1):26.
- 14 28. Australian Bureau of Statistics. *Research Paper. Socio-Economic Indexes for Areas:*
- 15 *Introduction, Use and Future Directions.* Canberra: ABS, 2006.
- 16 29. Magee CA, Kritharides L, Attia J, et al. Short and long sleep duration are associated with
- 17 prevalent cardiovascular disease in Australian adults. *Journal of sleep research*
- 18 *2012;21(4):441-47.*
- 19 30. Maas J, Verheij RA, Groenewegen PP, et al. Green space, urbanity, and health: how strong is
- 20 the relation? *Journal of Epidemiology & Community Health* 2006;60(7):587-92.
- 21 31. de Vries S, Verheij RA, Groenewegen PP, et al. Natural environments-healthy environments?
- 22 An exploratory analysis of the relationship between greenspace and health. *Environment*
- 23 *and Planning A* 2003;35(10):1717-32.
- 24 32. Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population
- 25 prevalences and trends in non-specific psychological distress. *Psychological Medicine*
- 26 *2002;32:959-76.*
- 27 33. Furukawa TA, Kessler RC, Slade T, et al. The performance of the K6 and K10 screening scales for
- 28 psychological distress in the Australian National Survey of Mental Health and Well-Being.
- 29 *Psychological medicine* 2003;33(2):357-62.
- 30 34. Australian Bureau of Statistics. *Information paper: use of the Kessler Psychological Distress*
- 31 *Scale in ABS Health Surveys, Australia.* Canberra: Australian Bureau of Statistics, 2003.
- 32 35. Feng X, Astell-Burt T, Kolt GS. Ethnic density, social interactions and psychological distress:
- 33 Evidence from 226,487 Australian adults. *BMJ Open* 2013;3:e002713.
- 34 36. Australian Institute of Health and Welfare. *The active Australia survey: A guide and manual for*
- 35 *implementation, analysis and reporting.* Canberra: AIHW, 2003.
- 36 37. Koenig HG, Westlund RE, George LK, et al. Abbreviating the Duke Social Support Index for use
- 37 in chronically ill elderly individuals. *Psychosomatics* 1993;34:61-69.
- 38 38. UCLA: Academic Technology Services SCG. Analyzing Correlated (Clustered) Data, 2008.
- 39 39. Williams R. A note on robust variance estimation for cluster-correlated data. *Biometrics*
- 40 *2000;56(2):645-46.*
- 41 40. Wang YC, McPherson K, Marsh T, et al. Health and economic burden of the projected obesity
- 42 trends in the USA and the UK. *The Lancet* 2011;378(9793):815-25.
- 43 41. Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing
- 44 challenge. *New England Journal of Medicine* 2007;356(3):213-15.
- 45 42. Hug SM, Hartig T, Hansmann R, et al. Restorative qualities of indoor and outdoor exercise
- 46 settings as predictors of exercise frequency. *Health & Place* 2009;15:971-80.
- 47 43. Mitchell R. Is physical activity in natural environments better for mental health than physical
- 48 activity in other environments? *Social Science & Medicine* 2012;In Press.
- 49 44. Gidlöf-Gunnarsson A, Öhrström E. Noise and well-being in urban residential environments: The
- 50 potential role of perceived availability to nearby green areas. *Landscape and Urban*
- 51 *Planning* 2007;83(2):115-26.
- 52 45. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic
- 53 noise on sleep and recuperation. *Sleep* 2011;34(1):11.
- 54 46. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews* 2007;11(2):135-42.
- 55
- 56
- 57
- 58
- 59
- 60

- 1
2
3 47. Mitchell R, Astell-Burt T, Richardson EA. A comparison of green space measures for
4 epidemiological research. *Journal of Epidemiology and Community Health*
5 2011;65(10):853-58.
6
7 48. Francis J, Wood LJ, Knuiiman M, et al. Quality or quantity? Exploring the relationship between
8 Public Open Space attributes and mental health in Perth, Western Australia. *Social Science*
9 & *Medicine* 2012;74(10):1570-77.
10
11 49. Fan Y, Das KV, Chen Q. Neighborhood green, social support, physical activity, and stress:
12 Assessing the cumulative impact. *Health & Place* 2011;17(6):1202-11.
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

Table 1: Age-gender adjusted patterning of sleep duration by proximity to green space

	8 hours (normal)	Between 9 and 10 hours (mid-long sleep)	Over 10 hours (long sleep)	Between 6 and 7 hours (mid-short sleep)	Less than 6 hours (short sleep)
N (259,319)	104,432	47,424	4,938	92,860	9,665
Green space % (n)	% (95% Confidence Interval)				
0-20% (177,106)	40.0 (39.8, 40.3)	17.5 (17.3, 17.7)	1.6 (1.5, 1.6)	35.6 (35.3, 35.8)	3.7 (3.6, 3.8)
20-40% (49,316)	40.4 (39.9, 40.8)	16.9 (16.6, 17.3)**	1.4 (1.3, 1.5)***	36.2 (35.7, 36.7)*	3.6 (3.4, 3.8)
40-60% (18,045)	40.5 (39.7, 41.3)	17.9 (17.3, 18.6)	1.4 (1.2, 1.6)*	35.3 (34.4, 36.1)	3.3 (3.1, 3.6)**
60-80% (8,253)	41.2 (40.0, 42.3)*	18.6 (17.6, 19.6)**	1.3 (1.1, 1.5)	34.4 (33.2, 35.7)*	2.9 (2.5, 3.3)***
80% + (6,599)	41.9 (40.7, 43.2)**	20.1 (19.1, 21.2)***	1.6 (1.3, 1.9)	32.0 (30.8, 33.2)***	2.8 (2.3, 3.2)***

*** p < 0.001; ** p < 0.01; * p < 0.05 (from 0-20% green space as the reference group)

1
2
3 **Figure 1: Association between proximity to green space and duration of sleep (fully adjusted)**
4
5
6

7 *reference group = less than 20% green space
8

9 ** multinomial logit regression with robust standard errors and base category comprising
10 participants reporting 8 hours sleep duration. Models were adjusted for: age; gender; Kessler scale
11 of psychological distress; physical activity (measured by the Active Australia survey); weight status;
12 couple status; ethnicity; country of birth; annual household income; highest qualifications; economic
13 status; language spoken at home; number of alcoholic drinks consumed per week; smoking status;
14 social support; the Socio-Economic Index for Areas (SEIFA) 'Index of Relative Socio-Economic
15 Advantage/Disadvantage'; and the 'Accessibility/Remoteness Index of Australia' (ARIA).
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 **Does access to neighborhood green space promote a healthy duration of sleep? Novel findings**
4 **from 259,319 Australians**
5
6
7

8 **ABSTRACT**
9

10
11 **Objectives:** Experiments demonstrate that exposure to parks and other 'green spaces' promote
12 favorable psychological and physiological outcomes. As a consequence, people who reside in greener
13 neighborhoods may also have a lower risk of short sleep duration (<6 hours). This is potentially
14 important as short sleep duration is a correlate of obesity, chronic disease, and mortality, but so far
15 this hypothesis has not been previously investigated.
16
17
18
19

20
21
22 **Design:** Cross-sectional data analysis
23

24
25 **Setting:** New South Wales, Australia
26
27

28 **Participants:** This study investigated whether neighborhood green space was associated with a
29 healthier duration of sleep (to the nearest hour) among 259,319 Australians who completed the 45 and
30 Up Study baseline questionnaire between 2006 and 2009 inclusive.
31
32
33

34
35 **Primary and secondary outcome measures:** Multinomial logit regression was used to investigate
36 the influence of an objective measure of green space on categories of sleep duration: 8 hours (normal);
37 between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours (mid-
38 short sleep); less than 6 hours (short sleep). Models were adjusted for psychological distress, physical
39 activity, and a range of demographic and socioeconomic characteristics.
40
41
42
43
44

45
46 **Results:** People living in greener neighborhoods reported a lower risk of short sleep. For example,
47 compared to participants living in areas with 20% green space land-use, the relative risk ratios for
48 participants with 80%+ green space was 0.86 (95% confidence interval (95%CI) 0.81, 0.92) for
49 durations between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6-hours sleep.
50
51
52

53
54 Unexpectedly, the benefit of more green space for achieving 8 hours of sleep was not explained by
55 controls for psychological distress, physical activity, or other socioeconomic factors.
56
57
58
59
60

1
2
3 **Conclusion:** Green space planning policies may have wider public health benefits than previously
4 recognized. Further research on the role of green space in promoting healthier sleep durations and
5 patterns is warranted.
6
7
8
9

10
11
12 **Ethics:** The University of New South Wales Human Research Ethics Committee approved The 45
13 and Up Study. Local ethical approval for this study was awarded by the University of Western
14 Sydney.
15
16
17
18
19

20
21
22 **Funding:** No funding was sought for this study.
23
24
25
26
27
28

29 **Data sharing:** Data from the 45 and Up Study is only accessible via a data license issued through
30 blinded peer-review. It is not available for sharing with parties who do not possess an approved
31 Agreement with the Data Custodian.
32
33
34
35
36
37
38

39 **Article Focus**

- 40
41
- 42 • Previous work suggests that more green space within the neighborhood environment can
43 promote better mental health and more active lifestyles
44
 - 45 • Better mental health and more active lifestyles are correlates of a healthy duration of sleep
46 (usually around 8 hours a night)
47
 - 48 • Greener neighborhoods, therefore, may guard against short sleep duration (usually less than 6
49 hours per night), which is correlated with obesity, chronic disease, and mortality
50
51
52
53
54
55
56
57
58
59
60

Key Messages

- In a large study of Australian adults, we found those in greener neighborhoods were at a lower risk of short sleep (< 6 hours a night)
- More green space was not associated with longer sleep durations (which are also correlated with poor health outcomes)
- Unexpectedly, the benefit of more green space for achieving a healthier duration of sleep was not explained by controls for psychological distress, physical activity, and socioeconomic variables

Strengths and Limitations

- This study benefits from a large sample size focusing on adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of health services
- This study is strengthened by use of validated measures of sleep duration, psychological distress, physical activity, and an objective measure of green space exposure
- Cross-sectional data prohibits causal inference, though follow up of the participants across time will allow the opportunity for replication of this study with a longitudinal design

Introduction

Positive psychological and physiological outcomes from exposure to parks and other forms of natural environment in experimental studies¹⁻³ have fuelled support for the integration of these ‘green spaces’ within planning policy.^{4,5} Health benefits are thought to accrue via psycho-neuro-endocrine pathways, wherein the experience of nature triggers restoration.⁶⁻⁸ These benefits are likely to be in tandem with physical activity, more of which is not only correlated with better mental health,⁹ but also increasingly likely among people who live in greener neighborhoods.¹⁰⁻¹²

While the epidemiological literature is increasingly replete with studies documenting association between green spaces, mental health and physical activity, less attention has been paid to other important health behaviors and outcomes. One such outcome is sleep duration. Many studies have reported a parabolic association¹³ between the number of hours a person sleeps and their subsequent risk of poor self-rated health¹⁴, obesity^{15,16}, cardiovascular disease¹⁷, diabetes^{18,19} and death.²⁰⁻²² Favorable mental health and active lifestyles are thought to be drivers of a healthier duration of sleep (usually around 8 hours per night).²³⁻²⁵ Since these drivers are widely reported to be positive outcomes of living in greener neighborhoods, we hypothesized that people with access to more green space would therefore be more likely to achieve a healthier duration of sleep.

This hypothesis was investigated in a large sample of Australian adults in middle-to-older age, who simultaneously shoulder the vast burden of chronic disease and are the biggest users of healthcare in Australia.

METHOD

Data

A sample of 259,319 participants with valid data on sleep duration were selected from 267,151 in the 45 and Up Study.²⁶ The questionnaire is available online from www.45andup.org.au. Participants were randomly selected from the Medicare Australia database (the national provider of universal

1
2
3 health insurance) and surveyed between 2006 and 2009. The survey response rate was 18%, though
4
5 previous work has shown that results from the 45 and Up Study are comparable to those derived from
6
7 a representative population survey.²⁷ Geocoding of participants in the 45 and Up Study was available
8
9 at the Census Collection Districts (CCD) scale. CCDs contain 225 people on average and were the
10
11 smallest geography at which 2006 Census data were disseminated.²⁸ The University of New South
12
13 Wales Human Research Ethics Committee approved The 45 and Up Study.

14 15 16 17 18 19 *Outcome measure*

20
21
22 Sleep duration was derived from responses to the following question: “About how many hours in each
23
24 24 hour day do you usually spend sleeping (including at night and naps)?” and has been used in
25
26 previous analyses of the same data.^{14 15 25 29} Responses to this question were missing for 7,755 people
27
28 and these were omitted from the analyses. To account for the curvilinear association between sleep
29
30 duration and health,¹³ responses were classified into a multinomial variable as follows: 8 hours
31
32 (normal); between 9 and 10 hours (mid-long sleep); over 10 hours (long sleep); between 6 and 7 hours
33
34 (mid-short sleep); less than 6 hours (short sleep). This classification allows for the healthiest duration
35
36 (8 hours) to be used as a reference group for all other categories.

37 38 39 40 41 42 *Green space*

43
44
45 Meshblocks classified as ‘parkland’ in the Australian Bureau of Statistics (ABS) land-use
46
47 classification for 2006 were used to construct the measure of green space. ‘Farmland’ meshblocks
48
49 were not used as they do not strictly represent spaces available for recreation. The measure of green
50
51 space was based upon the percentage available within a 1 kilometer (km) buffer around the
52
53 population-weighted centroid of each CCD. A 1km buffer was selected so as to represent land-use
54
55 within a reasonable walking distance from place of residence, and has been used in previous studies of
56
57
58
59
60

1
2
3 green space and health.^{11 12 30 31} The percentage green space measure was classified into fifths to
4
5 explore for potential non-linearities (0-20%, 20-40%, 40-60%, 60-80%, 80%+).
6
7
8
9

10 *Other individual and neighborhood measures*

11
12
13
14 The Kessler Psychological Distress Scale (K10) was used to assess mental health status.^{32 33} The K10
15
16 measures symptoms of psychological distress experienced over the past four weeks, including feeling
17
18 tired for no reason, nervous, hopeless, restless, depressed, sad and worthless. Participants had five
19
20 choices for each of the ten questions (none of the time =1, a little of the time =2, some of the time =3,
21
22 most of the time =4, all of the time =5). The K10 is constructed by summing responses to each of the
23
24 questions, with scores of 22 and over identified those with a high risk of psychological distress.³⁴ The
25
26 K10 has been used in this way in previous published analyses of the 45 and Up Study.³⁵
27
28

29
30 The measure of physical activity was an aggregate of the number of 10 minute sessions spent either
31
32 walking or in moderate to vigorous physical activity (MVPA), assessed using the Active Australia
33
34 Survey.³⁶ The question was “How many times did you do each of these activities last week?”
35
36 Participants could indicate walking, moderate (e.g. gentle swimming) and vigorous (e.g. jogging)
37
38 forms activity separately.
39

40
41 A range of other individual characteristics were also taken account of, including age, gender, ethnicity,
42
43 country of birth, body mass index (BMI), annual income, highest educational qualifications, economic
44
45 status (employed, unemployed, retired, inactive due to poor health), couple status, number of
46
47 alcoholic drinks consumed in the last week, smoking status, language other than English spoken at
48
49 home, and the Duke Social Support Index.³⁷
50

51
52 Two other characteristics at the neighborhood-level were considered. The Socio-Economic Index for
53
54 Areas (SEIFA) ‘Index of Relative Socio-Economic Advantage/Disadvantage’ was used to measure
55
56 local socioeconomic circumstances. Differences between urban and rural areas were controlled using
57
58
59
60

1
2
3 the 'Accessibility / Remoteness Index of Australia' (ARIA). Like the measure of green space, both of
4 these neighborhood indicators were created using data from 2006 to fit with the baseline questionnaire.
5
6
7
8
9

10 *Statistical analysis*

11
12
13
14 Cross-tabulations were used to compare the patterning of each sleep duration category according to
15 proximity to green space and all other explanatory variables. A multinomial logit regression was used
16 assess the risk of short sleep versus an 8-hour sleep duration (reference), accounting for longer sleeps
17 as separate categories simultaneously within the same model. Parameters were exponentiated to
18 relative risk ratios (RRR). RRRs over 1 indicated positive association, whereas RRRs below 1
19 denoted negative association. Bivariate models containing the measure of green space (fitted as a
20 categorical variable) were initially adjusted for interactions between age and gender. The robustness
21 of any associations found were then tested with controls for psychological distress and physical
22 activity. Socioeconomic and other explanatory variables were then added sequentially, with any
23 change in the potential association between green space exposure and sleep duration documented.
24 To account for the nested data structure, the Huber-White method was utilized in all models to adjust
25 standard errors.^{38 39} The log-likelihood ratio test ($p < 0.05$) was used to identify statistically significant
26 associations. Analyses were conducted in STATA 12 (StataCorp, College Station, TX, USA).
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

47 **RESULTS**

48
49
50 In Table 1 the prevalence of sleep for 8 hour duration (adjusted for age and gender) was demonstrably
51 higher in neighborhoods with a higher percentage of green space. This was also for sleep durations
52 between 9 and 10 hours, but not for those of 10 hours or more. Meanwhile, the prevalence of sleep
53 durations less than 8 hours was higher in neighborhoods with less green space. The percentage point
54 difference reported between neighborhoods with 80%+ and less than 20% green space proximity was
55
56
57
58
59
60

1
2
3 3.6 for a mid-short sleep duration between 6 and 7 hours ($p<0.001$). A smaller, though statistically
4 significant gap was also reported for short sleeps less than 6 hours (0.9 percentage points, $p<0.001$).
5
6
7 The risk of short sleep duration (6 hours or less per day) was 4 times higher among participants at
8
9 high risk of psychological distress (95%CI 3.8, 4.3), 1.5 times higher among obese people versus
10
11 those normal BMI (95%CI 1.46, 1.63), 1.8 times higher among people earning less than \$20,000 a
12
13 year (95%CI 1.7, 1.9), 1.6 times higher for residents of the most deprived quintile of neighborhoods
14
15 (95%CI 1.5, 1.7) and 1.1 times higher for those in remote and rural versus urban areas (95%CI 1.0,
16
17 1.2).

18
19
20 Preliminary multinomial logit regression took a bivariate format with green space as the sole predictor
21
22 of sleep duration. The 259,319 participants were nested within 11,719 CCDs. Compared to
23
24 participants reporting 8 hour sleep as the base category, the risk of shorter sleep durations was lower
25
26 for those with access to more green space. For example, the Relative Risk Ratios (RRRs) for
27
28 participants with 80%+ versus less than 20% green space was 0.86 (95%CI 0.81, 0.92) for durations
29
30 between 6 and 7 hours, and 0.68 (95%CI 0.57, 0.80) for less than 6 hours sleep. In contrast, there was
31
32 no association between neighborhood green space and the risk of longer sleep durations between 9
33
34 and 10 hours (RRR 1.06, 95%CI 0.99, 1.14), or over 10 hours (RRR 0.85, 95%CI 0.70, 1.03).

35
36
37 These results appeared to corroborate our hypothesis. However, this was founded on the basis that
38
39 greener neighborhoods stimulate mental health and more active lifestyles, which would then promote
40
41 a healthier duration of sleep. Ergo, we expected that the association between green space and sleep
42
43 duration would be explained by controls for mental health and physical activity. Adding the K10
44
45 variable showed participants at a high risk of psychological distress were more likely to report sleeps
46
47 of less and also more than 8 hours in duration ($p<0.001$). Conversely, adding physical activity to the
48
49 model did not result in a significant association with sleep duration. Unexpectedly, and counter to our
50
51 hypothesis, adjusting for these variables had negligible impact on the association between green space
52
53 and sleep duration.
54
55
56
57
58
59
60

1
2
3 The final step was to interrogate the consistency of the green space parameters against other factors
4 shown to be associated with short and long sleep duration. These variables were added sequentially to
5 the previous model, with Figure 1 illustrating the results of the final multinomial logit regression.
6
7 Many characteristics of individuals were associated with sleep duration in line with previous work,
8 such as unemployment and sleeps of less than 6 hours (RRR 1.20, 95%CI 1.02, 1.32) and more than
9 10 hours (RRR 3.17, 95%CI 2.66, 3.78). Participants in more affluent and geographically remote
10 neighborhoods were also at a lower risk of short and long sleep durations ($p<0.001$). Controlling for
11 all of these variables did attenuate the negative association between green space and short sleep
12 duration, but not fully. For participants with access to 80%+ green space within their neighborhood
13 compared to those with less than 20%, the RRR of sleeping between 6 and 7 hours was 0.92 (95%CI
14 0.87, 0.98) and 0.81 (95%CI: 0.69, 0.96) for sleeps of less than 6 hours in duration. There remained
15 no association between green space exposure and sleeps of more than 8 hours.
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

31 DISCUSSION

32
33
34 As countries invest in large scale green space planning policies,^{4,5} it would be prudent to ask whether
35 parks and other forms of natural environment have any other health benefits aside from those which
36 are already widely reported (namely, better mental health and increased physical activity). This study
37 has demonstrated that people who live in greener environs are more likely to achieve a healthier
38 duration of sleep. The protective effect of green space was isolated to guarding against the risk of
39 short sleep (less than 8 hours), with no association found for longer sleeps. These results were
40 consistent after controlling for factors already known to be associated with short and long sleep and,
41 surprisingly, were not explained by indicators of mental health and physical activity. The significance
42 of these findings are put in context when one considers that sleep durations of less than 6 hours are
43 consistently associated with many of the major chronic health conditions¹⁵⁻¹⁹ that threaten the
44 sustainability of health systems.^{40,41} As such, these results suggest that large-scale investments in
45 green space policy could have a wider public health benefit than has been previously acknowledged.
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Restoration from access to nature can occur directly ¹, although exposure to green space is
4 undoubtedly entwined, to a potentially large extent, with active lifestyles for which parks and other
5 public open spaces are attractive environments for participation ⁴². This makes the finding that green
6 space was associated with a healthier duration of sleep, irrespective of psychological distress or
7 participation in physical activity, more intriguing. One possible explanation is that the physical
8 activity variable measures participation, but not with any specific reference to the place in which it
9 occurs. Participants scoring higher on the physical activity variable therefore do not necessarily
10 perform those activities in the green spaces where they live and this interaction between behavior and
11 environment may be important to control.⁴³ Another plausible mechanism is the dispersal of traffic
12 density ⁴⁴ and noise pollution in areas with more green space, which could otherwise have a
13 detrimental influence on sleep duration.^{45 46} No measure of traffic density or noise pollution was
14 available for this study however. Thus, while more green space appears to be protective against a
15 short duration of sleep, it is not yet clear whether this is demonstrably because of a direct effect on
16 restoration that is not picked up by the K10, or if it operates via other structural processes operating at
17 the neighborhood level. Further research on the spatial patterning of sleep duration that accounts for
18 other structural variables, such as noise pollution, is warranted to isolate the potentially causal
19 mechanism(s) at play.

20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
This study benefited from a large sample size and an objective measure of green space. However, the
focus on a population of 45 years and older limits the generalisability to younger people, for whom
further studies are advised. The survey response rate was 18%, though previous work has shown that
results from the 45 and Up Study are comparable to those from a representative survey²⁷. While the
cross-sectional design limits prospects for causal inference, the ability to detect these types of effects
might not necessarily be enhanced with longitudinal data, as contemporaneous exposure to green
space, rather than one that is temporally lagged may be what counts most for determining sleep
duration. **Longitudinal studies would nevertheless be useful for testing hypotheses related to
temporal effects and also for exploring potential confounding produced by the possibility of
individuals with a propensity for healthier durations of sleep selecting into neighborhoods**

1
2
3 **containing more green space. Follow-up of the 45 and Up Study will afford these opportunities,**
4 **in addition to tracking the longer-term benefits of green space for health more generally.**
5
6
7

8 It is plausible that sleep duration varies across the week and during the day (e.g. naps), particularly
9 between weekdays and weekends, but the measure of sleep available in the 45 and Up Study was
10 generalist and could not facilitate these more detailed enquiries. Similarly, the Active Australia
11 Survey is a measure of overall physical activity, but did not afford a distinction between leisure and
12 other types (e.g. active travel). Finally, while previous work has shown that different measures of
13 green space yield similar associations with health outcomes,⁴⁷ we recognize that not all green spaces
14 are the same and future work should explore whether variation in subjective quality⁴⁸ or type⁴⁹ (e.g.
15 parks versus conservation areas) results in systematic differences in health outcomes, including sleep
16 duration.
17
18
19
20
21
22
23
24
25
26

27 **In conclusion, this study has found that more green space within the neighborhood of residence**
28 **is associated with a healthier duration of sleep among a large sample of Australians aged 45 and**
29 **over. This association appeared to be robust to controls for mental health, physical activity, and**
30 **other possible individual-level confounders, though unmeasured phenomena operating at the**
31 **neighborhood-level, such as traffic density, ought to be explored as data becomes available. As it**
32 **stands, people living in greener areas tend to be at a lower risk of short sleep duration and this**
33 **could have important subsequent impacts on health, including obesity and cardiovascular**
34 **disease. It is also plausible that healthier sleep durations promoted by exposure to green space**
35 **may aid mental health and participation in physical activity. As such, future studies employing**
36 **longitudinal techniques may consider investigating sleep duration as a possible mediator of**
37 **associations between green space and health outcomes.**
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

1. Bowler DE, Buyung-Ali LM, Knight TM, Pullin AS. A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 2010;10.
2. Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health* 2010;33(2):212-22.
3. Lachowycz K, Jones AP. Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews* 2011;12(5):e183-e89.
4. Nilsson K, Sangster M, Konijnendijk CC. Introduction. In: Nilsson K, Sangster M, Gallis C, Hartig T, de Vries S, Seeland K, et al., editors. *Forests, trees and human health*. Netherlands: Springer, 2011:1-19.
5. Australian Government. *Our Cities Our Future: A national urban policy for a productive, sustainable and liveable future*. Canberra: Department of Infrastructure and Transport, 2011.
6. Sternberg EM. *Healing spaces: The science of place and well-being*. Cambridge: Harvard University Press, 2009.
7. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective*: Cambridge University Press, 1989.
8. Ulrich RS. View through a window may influence recovery from surgery. *Science* 1984;224(4647):420.
9. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *Journal of Science and Medicine in Sport* 2004;7(1):6-19.
10. Giles-Corti B, Broomhall MH, Knuiaman M, Collins C, Douglas K, Ng K, et al. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventive Medicine* 2005;28(2S2):169-76.
11. Astell-Burt T, Feng X, Kolt GS. Neighbourhood green space is associated with more frequent walking and moderate to vigorous physical activity (MVPA) in middle-to-older aged adults. Findings from 203,883 Australians in The 45 and Up Study. *British Journal of Sports Medicine* 2013;doi:10.1136/bjsports-2012-092006.
12. Astell-Burt T, Feng X, Kolt GS. Greener neighborhoods, slimmer people? Evidence from 246,920 Australians. *International Journal of Obesity* 2013;doi:10.1038/ijo2013.64.
13. Knutson KL, Turek FW. The U-shaped association between sleep and health: the 2 peaks do not mean the same thing. *Sleep* 2006;9:881-89.
14. Magee CA, Caputi P, Iverson DC. Relationships between self-rated health, quality of life and sleep duration in middle aged and elderly Australians. *Sleep medicine* 2011;12(4):346-50.
15. Magee CA, Iverson DC, Caputi P. Sleep duration and obesity in middle-aged Australian adults. *Obesity* 2009;18(2):420-21.
16. Cappuccio FP, Taggart FM, Kandala NB, al. e. Cappuccio, F. P., Taggart, F. M., Kandala, N. -B. et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31:619-26.
17. Cappuccio FP, Cooper D, D Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur. Heart J.* 2011;32:1484-92.
18. Chaput JP, Despre' s J-P, Bouchard C, Tremblay A. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia* 2007;50:2298-304.
19. Knutson KL, Spiegel K, Penev P, Van Cauter E. The metabolic consequences of sleep deprivation. *Sleep Med. Rev.* 2007;11:163-78.
20. Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry* 2002;59:131-36.
21. Heslop P, Smith GD, Metcalfe C, Macleod J, Hart C. Sleep duration and mortality: the effect of short or long sleep duration on cardiovascular and all-cause mortality in working men and women. *Sleep Medicine* 2003;3:305-14.

- 1
- 2
- 3 22. Hublin C, Partinen M, Koskenvuo M, Kaprio J. Sleep and mortality: a population-based 22-year
- 4 follow-up study. *Sleep* 2007;30:1245-53.
- 5 23. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders.
- 6 *JAMA: the journal of the American Medical Association* 1989;262(11):1479-84.
- 7 24. Steptoe A, O'Donnell K, Marmot M, Wardle J. Positive affect, psychological well-being, and
- 8 good sleep. *Journal of psychosomatic research* 2008;64(4):409-15.
- 9 25. Magee CA, Iverson DC, Caputi P. Factors associated with short and long sleep. *Preventive*
- 10 *Medicine* 2009;49(6):461-67.
- 11 26. 45 and Up Study Collaborators. Cohort Profile: The 45 and Up Study. *International Journal of*
- 12 *Epidemiology* 2008;37(5):941-47.
- 13 27. Mealing NM, Banks E, Jorm LR, Steel DG, Clements MS, Rogers KD. Investigation of relative risk
- 14 estimates from studies of the same population with contrasting response rates and
- 15 designs. *BMC medical research methodology* 2010;10(1):26.
- 16 28. Australian Bureau of Statistics. *Research Paper. Socio-Economic Indexes for Areas:*
- 17 *Introduction, Use and Future Directions*. Canberra: ABS, 2006.
- 18 29. Magee CA, Kritharides L, Attia J, Mcelduff P, Banks E. Short and long sleep duration are
- 19 associated with prevalent cardiovascular disease in Australian adults. *Journal of sleep*
- 20 *research* 2012;21(4):441-47.
- 21 30. Maas J, Verheij RA, Groenewegen PP, de Vries S, Spreeuwenberg P. Green space, urbanity, and
- 22 health: how strong is the relation? *Journal of Epidemiology & Community Health*
- 23 *2006;60(7):587-92*.
- 24 31. de Vries S, Verheij RA, Groenewegen PP, Spreeuwenberg P. Natural environments-healthy
- 25 environments? An exploratory analysis of the relationship between greenspace and health.
- 26 *Environment and Planning A* 2003;35(10):1717-32.
- 27 32. Kessler RC, Andrews G, Colpe LJ, Hiripi E, Mroczek DK, Normand SL, et al. Short screening scales
- 28 to monitor population prevalences and trends in non-specific psychological distress.
- 29 *Psychological Medicine* 2002;32:959-76.
- 30 33. Furukawa TA, Kessler RC, Slade T, Andrews G. The performance of the K6 and K10 screening
- 31 scales for psychological distress in the Australian National Survey of Mental Health and
- 32 Well-Being. *Psychological medicine* 2003;33(2):357-62.
- 33 34. Australian Bureau of Statistics. *Information paper: use of the Kessler Psychological Distress*
- 34 *Scale in ABS Health Surveys, Australia*. Canberra: Australian Bureau of Statistics, 2003.
- 35 35. Feng X, Astell-Burt T, Kolt GS. Ethnic density, social interactions and psychological distress:
- 36 Evidence from 226,487 Australian adults. *BMJ Open* 2013;3:e002713.
- 37 36. Australian Institute of Health and Welfare. *The active Australia survey: A guide and manual for*
- 38 *implementation, analysis and reporting*. Canberra: AIHW, 2003.
- 39 37. Koenig HG, Westlund RE, George LK, Hughes DC, Blazer DG, Hybels C. Abbreviating the Duke
- 40 Social Support Index for use in chronically ill elderly individuals. *Psychosomatics*
- 41 *1993;34:61-69*.
- 42 38. UCLA: Academic Technology Services SCG. *Analyzing Correlated (Clustered) Data*, 2008.
- 43 39. Williams R. A note on robust variance estimation for cluster-correlated data. *Biometrics*
- 44 *2000;56(2):645-46*.
- 45 40. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the
- 46 projected obesity trends in the USA and the UK. *The Lancet* 2011;378(9793):815-25.
- 47 41. Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing
- 48 challenge. *New England Journal of Medicine* 2007;356(3):213-15.
- 49 42. Hug SM, Hartig T, Hansmann R, Seeland K, Hornung R. Restorative qualities of indoor and
- 50 outdoor exercise settings as predictors of exercise frequency. *Health & Place* 2009;15:971-
- 51 *80*.
- 52 43. Mitchell R. Is physical activity in natural environments better for mental health than physical
- 53 activity in other environments? *Social Science & Medicine* 2012;In Press.
- 54
- 55
- 56
- 57
- 58
- 59
- 60

- 1
2
3 44. Gidlöf-Gunnarsson A, Öhrström E. Noise and well-being in urban residential environments: The
4 potential role of perceived availability to nearby green areas. *Landscape and Urban*
5 *Planning* 2007;83(2):115-26.
6 45. Basner M, Müller U, Elmenhorst E-M. Single and combined effects of air, road, and rail traffic
7 noise on sleep and recuperation. *Sleep* 2011;34(1):11.
8 46. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews* 2007;11(2):135-42.
9 47. Mitchell R, Astell-Burt T, Richardson EA. A comparison of green space measures for
10 epidemiological research. *Journal of Epidemiology and Community Health*
11 2011;65(10):853-58.
12 48. Francis J, Wood LJ, Knuiman M, Giles-Corti B. Quality or quantity? Exploring the relationship
13 between Public Open Space attributes and mental health in Perth, Western Australia.
14 *Social Science & Medicine* 2012;74(10):1570-77.
15 49. Fan Y, Das KV, Chen Q. Neighborhood green, social support, physical activity, and stress:
16 Assessing the cumulative impact. *Health & Place* 2011;17(6):1202-11.
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1: Age-gender adjusted patterning of sleep duration by proximity to green space

	8 hours (normal)	Between 9 and 10 hours (mid-long sleep)	Over 10 hours (long sleep)	Between 6 and 7 hours (mid-short sleep)	Less than 6 hours (short sleep)
N (259,319)	104,432	47,424	4,938	92,860	9,665
Green space % (n)	% (95% Confidence Interval)				
0-20% (177,106)	40.0 (39.8, 40.3)	17.5 (17.3, 17.7)	1.6 (1.5, 1.6)	35.6 (35.3, 35.8)	3.7 (3.6, 3.8)
20-40% (49,316)	40.4 (39.9, 40.8)	16.9 (16.6, 17.3)**	1.4 (1.3, 1.5)***	36.2 (35.7, 36.7)*	3.6 (3.4, 3.8)
40-60% (18,045)	40.5 (39.7, 41.3)	17.9 (17.3, 18.6)	1.4 (1.2, 1.6)*	35.3 (34.4, 36.1)	3.3 (3.1, 3.6)**
60-80% (8,253)	41.2 (40.0, 42.3)*	18.6 (17.6, 19.6)**	1.3 (1.1, 1.5)	34.4 (33.2, 35.7)*	2.9 (2.5, 3.3)***
80% + (6,599)	41.9 (40.7, 43.2)**	20.1 (19.1, 21.2)***	1.6 (1.3, 1.9)	32.0 (30.8, 33.2)***	2.8 (2.3, 3.2)***

*** p < 0.001; ** p < 0.01; * p < 0.05 (from 0-20% green space as the reference group)

1
2
3 **Figure 1: Association between proximity to green space and duration of sleep (fully adjusted)**
4
5
6

7 *reference group = less than 20% green space
8

9 ** multinomial logit regression with robust standard errors and base category comprising
10 participants reporting 8 hours sleep duration. Models were adjusted for: age; gender; Kessler scale
11 of psychological distress; physical activity (measured by the Active Australia survey); weight status;
12 couple status; ethnicity; country of birth; annual household income; highest qualifications; economic
13 status; language spoken at home; number of alcoholic drinks consumed per week; smoking status;
14 social support; the Socio-Economic Index for Areas (SEIFA) 'Index of Relative Socio-Economic
15 Advantage/Disadvantage'; and the 'Accessibility/Remoteness Index of Australia' (ARIA).
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

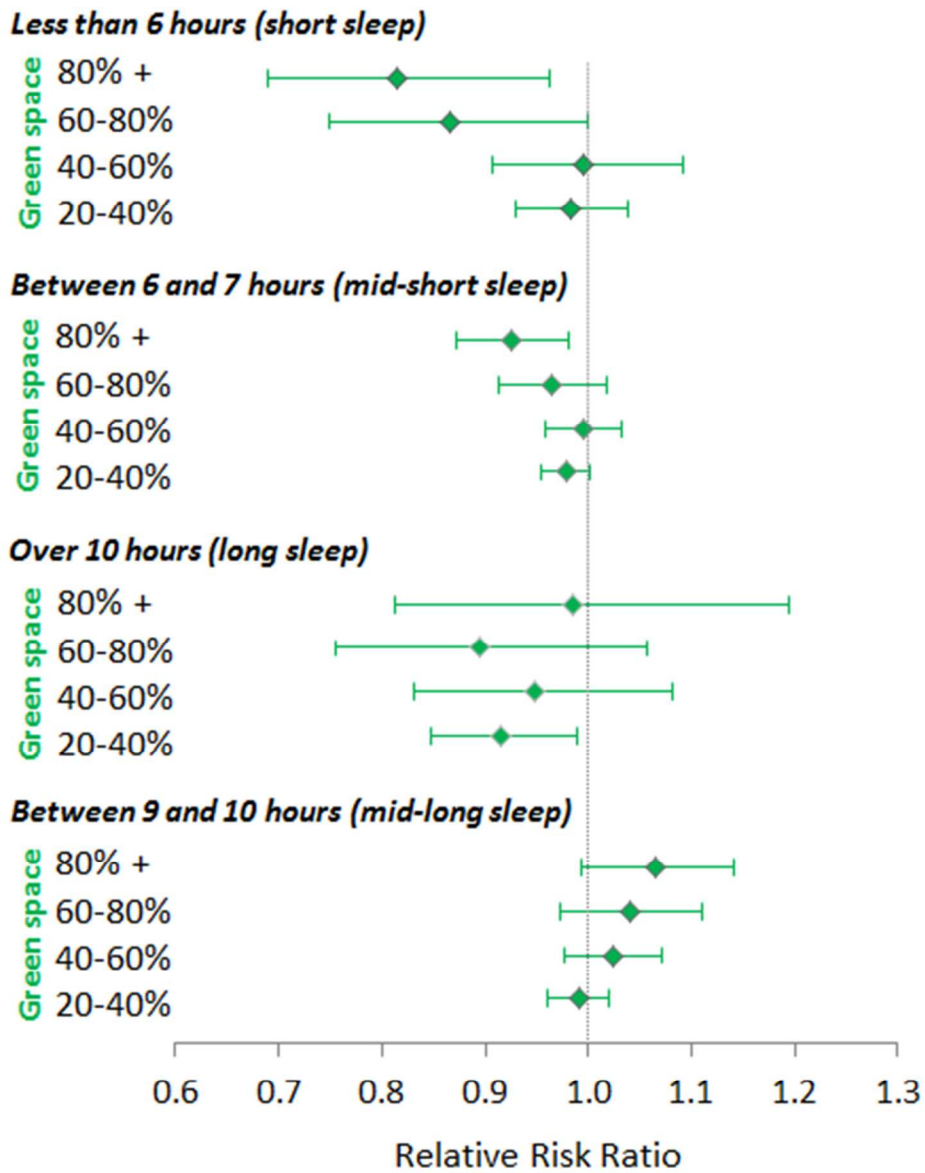


Figure 1
119x149mm (300 x 300 DPI)