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Validation of Sun Exposure Reported Annually Against Interim Self-report and Daily Sun Diaries

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Abstract

Data on personal sun exposure over a period exceeding the immediate past days or weeks are typically self-reported in brief questionnaire items. The validity of such self-reporting of longer term personal sun exposure, for example over a year, including detail on variation across seasons, has not previously been investigated. In a volunteer sample (n = 331) of Australian adults aged 18 years and over, we assessed the 12-month reliability of sun exposure reported separately for each season, and its accuracy compared to a daily sun diary in the same season. Seasonal time outdoors displayed fair-to-good reliability between baseline and end of study (12 months), with responses showing higher agreement at lower levels of time outdoors. There was good agreement for ranking of individuals' time outdoors with the daily sun diary data, although the *actual* diary time outdoors was typically considerably lower than the self-reported questionnaire data. Place of residence, education, being a smoker, day of the week (i.e. working day *vs*nonworking day) and working mainly outdoors were significant predictors of agreement. While participants overestimated their actual time outdoors, the self-report questionnaire provided a valid ranking of long-term sun exposure against others in the study that was reliable over time.

Introduction

Both too much and too little exposure to ultraviolet (UV) radiation have adverse effects on human health [1]. Excessive exposure increases the risk of skin cancers such as melanoma and eye diseases such as cataracts, and insufficient exposure causes vitamin D deficiency which in turn increases the risks of the bone diseases such as rickets and osteomalacia [2] and possibly some autoimmune diseases [3]. Apart from acute effects of excessive sun exposure, such as sunburn, these diseases arise in relation to chronic sun exposure (or lack of it) over at least months and commonly years, or with a long lag-time from risk exposure to disease outcome [4]. For example, high-dose intermittent sun exposure during the childhood years is associated with increased rates of malignant melanoma and basal cell carcinoma many years later [5]. An increased risk of multiple sclerosis (MS) has been linked to low sun exposure *in utero* [6] or in childhood [7]. Some of the UV-related diseases, for example melanoma, MS and type 1 diabetes, show a seasonal effect for diagnosis—melanoma is diagnosed more frequently in summer [8], and MS [9] and type 1 diabetes [10] more frequently in winter.

The received dose of UV radiation to relevant biological molecules is determined by the intensity of ambient UV radiation, time spent outdoors and to what degree the eyes and skin are exposed, and each of these varies by season. The amount of seasonal variation in UV radiation, as well as in temperature and time spent outdoors, is greater at higher latitude [11]. The intensity of ambient UV radiation also varies by time of day, as may duration of exposure under the influence of climatic factors such as temperature and rainfall. Furthermore, time spent outdoors varies according to the day of the week (working *versus* nonworking day), whether the individual works/studies predominantly indoors or outdoors, and from day to day, according to a range of factors [12].

It is difficult to measure chronic sun exposure accurately in epidemiological studies. Previous studies have used satellite-derived data on ambient UV radiation as a proxy, but this omits the influence of time outdoors and coverage of the skin/eyes. Thus, satellite-derived data are a useful but coarse proxy for the received dose of UV radiation [13]. Other studies have used self-reported sun exposure with no time frame stipulated [14], or over specific years of life, sometimes separated according to a 2-season year (warmer *versus* colder seasons) and/or for leisure time *versus* work time periods [15]. Where resources are available, detailed measurement using personal sun diaries and/or UV dosimeters provides more accurate data on the dose of UV radiation [16], but repeated measurement across the year is required to take account of the multiple sources of variation previously noted, and this is time-consuming and expensive, and incurs a high participant burden. Sun diaries rely on participants completing the diary accurately each day, while UV dosimeters rely on them wearing the dosimeter appropriately [13]. The resulting data provide a very detailed snapshot of sun exposure that may not be representative of a "usual" day or week in terms of outdoor activity or environmental conditions [17].

Self-report data remain the mainstay of sun exposure measurement in epidemiological studies because they allow collection of information for the (sometimes long) relevant time period, are inexpensive and have relatively low participant burden. Ideally, questions capture the factors that determine the dose of UV radiation, and do so with a degree of accuracy, for example providing data on time outdoors according to season, working/nonworking day and time of day. To date, the validity and reliability of self-reported sun exposure over different seasons, captured at a single time point, are unknown. It is unclear how well this type of measure represents actual sun exposure over longer time periods, and what personal factors may influence responses when compared over time and with other measures.

Here, we test the reliability of self-reported seasonal sun exposure across a 12-month period and the agreement with data from a daily sun diary that was maintained for one week in each season. In addition to these main aims, we examine what factors were associated with agreement, and determine to what extent these factors affected the reliability and internal validity of the sun exposure questions.

Materials and Methods

Study sample and setting

The Seasonal D Study was a longitudinal study conducted between October 2012 and July 2014 [18]. The study aimed to identify the determinants of intra-individual seasonal variation in vitamin D status, as assessed by serum levels of 25-hydroxyvitamin D. Volunteers aged 18 years and over were recruited from the Canberra region (Australian Capital Territory and surrounding New South Wales, latitude of 35°S) and Brisbane city (Queensland, latitude 27°S) through recruitment emails and flyers, word-of-mouth and "snowballing," as well as follow-up of participants in the AusD Study [19] who had expressed an interest in being involved in future studies. Participants were enrolled in the study for one year, over which they were interviewed up to seven times (every 2 months). Ethics approval was obtained from the Human Research Ethics Committees of the Australian National University (2012/004) and the Queensland University of Technology (1100001457). Each participant gave written informed consent before joining the study.

Data collection

Data were collected at baseline on date of birth, sex, smoking status, employment type, education level and natural skin type [20].

Time outdoors

At the baseline and 12-month interviews, participants provided data (hereafter referred to as "interview time outdoors") on their usual time outdoors for each hour during a working day and nonworking day, and for each season in the previous year. Data on interview time outdoors were collected only at the baseline and 12-month interviews (and not at interim interviews) as this time outdoors question captured sun exposure behavior over the previous 12 months (Fig. 1). Season was defined as Summer = December, January, February; Autumn = March, April, May; Winter = June, July, August; and Spring = September, October, November. These questions were phrased: "In Summer, how long would you be outside for on a typical working day for each hour between 6–7 am, 7–8 am … through to 6–7 pm?" Response options were "never," "less than 15 min," "15–29 min," "30–44 min" and "45–60 min."

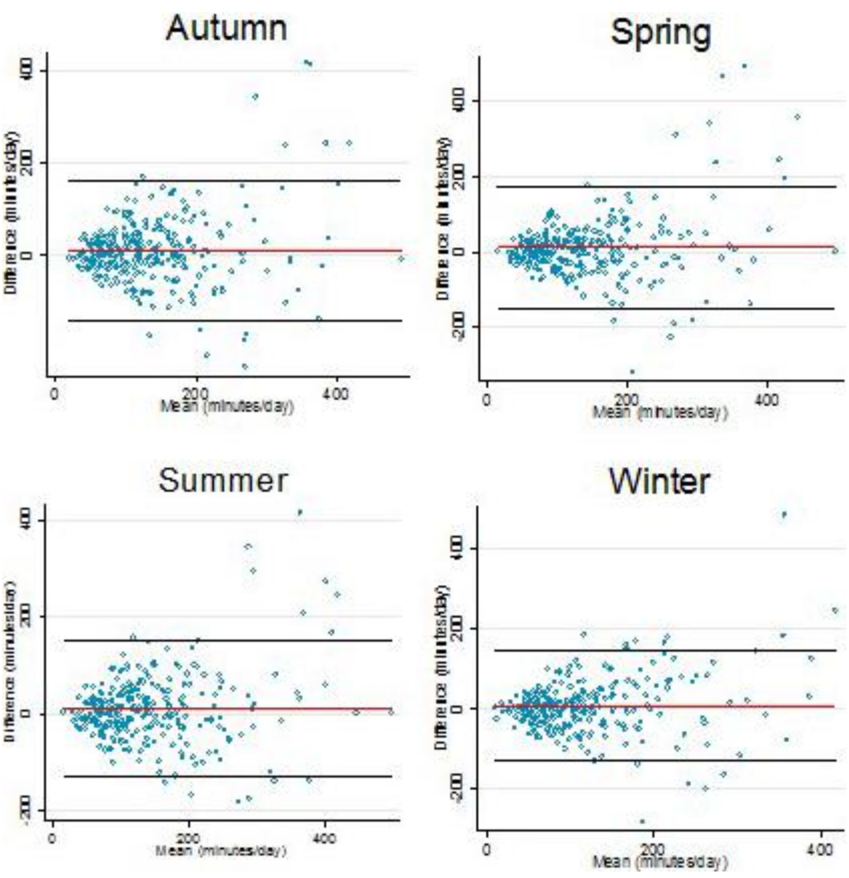

Figure 1.

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Study flowchart depicting the stage at which each type of data were collected.

Participants completed a daily sun diary for each of the 7 days before each 2-monthly interview, including at baseline. The sun diary asked participants to recall their actual time outdoors for every hour from 6 am to 7 pm in categories of: 0 min, <15 min, 15–29 min, 30–44 min and 45–60 min, on five working days and two nonworking days. These data are referred to below as “sun diary time outdoors.” The sun diary also recorded sunscreen use, clothing worn and level of physical activity for each hour [18].

Statistical analysis

Descriptive statistics for the characteristics of the study sample are reported as counts and percentages. Diary records for time outdoors were obtained for all participants. Diary days were excluded from the analysis if data were missing for an hour in the day. Sun diaries were retained in the analysis if there were data for at least three working days and at least one nonworking day, as in previous work by Sun *et al*. [13].

We converted time outdoors (for both the self-reported interview data and the sun diary were averaged separately) from categories (see above) to a number of minutes by taking the midpoint of each categorical response for each hour (i.e. the category 15–29 min was converted to 22 min). For each of the self-reported interview time outdoors and the sun diary time outdoors, we then averaged each hour of the day across working days and nonworking days (separately). The values for each hour were also summed to estimate total time outdoors each day between 6 am and 7 pm and between 10 am and 3 pm [19], and these were averaged separately across working and nonworking days. Interview time outdoors and sun diary time outdoors are summarized as median and quartiles (Q1, Q3) due to the skewed distribution of the data.

Reliability of interview time outdoors over 12 months

We tested agreement (whether responses were the same between baseline and 12-month interview) of the number of minutes spent outdoors across the 12 months of the study, as well as whether individuals had the same ranking in terms of time outdoors compared to other participants at both time points. Agreement was assessed visually for each season using the Bland–Altman method [21], plotting the difference between the participant's weekly total interview time outdoors as recorded at the baseline and 12-month interviews for the corresponding season (12-month interview—baseline interview) against the average of the two times and estimating the mean difference and limits of agreement.

Agreement of duration of time outdoors during the middle hours of the day at baseline and 12-month interview time outdoors questionnaires was assessed by a Cohen's weighted kappa statistic, by season, and separately for working and nonworking days. Each hour between 10 am and 3 pm was assessed separately to determine the consistency of participants' choice of the same categorical response for that hour at baseline and 12-month interview.

Intraclass correlation (ICC) coefficients of the type 3,1 (ICC 3,1 two-way mixed intraclass correlation, Shrout and Fleiss [22]) were used to assess agreement between absolute values of total interview time outdoors at baseline and 12 months between 10 am and 3 pm. This analysis was performed separately for each season and for working and nonworking days.

We also used Spearman's rho to assess how well the a participant's ranking compared to other participants for total daily time outdoors was maintained over a year (reliability), comparing interview time outdoors at baseline with that at 12 months.

Participant data were excluded from the reliability analysis if either baseline or 12-month interview data were not available.

Assessment of internal validity (accuracy) of interview time outdoors against sun diary time outdoors

Interview time outdoors was compared to sun diary time outdoors, with the season in which the sun diary was completed matched to the corresponding response at interview for that season, that is up to four comparisons per individual.

ICC 3,1 was used to assess agreement between average daily sun diary time outdoors and average daily interview time outdoors as a summed continuous variable at baseline and 12-month interview, separately for working and nonworking days and seasons.

The strength of agreement was classified according to the criteria outlined by Landis and Koch [23] for kappa analyses, and Shrout and Fleiss [22] for intraclass correlations.

Determinants of reliability and accuracy

We created a new binary outcome variable to indicate whether or not the same response category for time spent outdoors, for example "<15 min," was reported for the same hour interval (from 10 to 3 pm) for working and nonworking days and each season (i.e. five-one-hour intervals on each of 7 days for each of four seasons), with a variable created for agreement between each of the baseline and 12-month interviews; sun diary and baseline interview; and sun diary and 12-month interviews. We used logistic regression to determine participant characteristics that were associated with each of the three agreement measures across all time points. This was conducted within a generalized estimating equations (GEE) approach with an exchangeable (compound symmetry) correlation structure to adjust for the correlation of outcomes for multiple observations within individuals. The participant characteristics in the regression were those which were likely to influence sun exposure behavior (e.g. type of employment, age, sex, education level, smoking status), as well as location of residence. Smoking status was included as our study was conducted in Australia, where smoking is banned indoors in public buildings, which may affect the amount of time current smokers spend outdoors. Results are reported as odds ratios and 95% confidence intervals.

Stata Statistical Software (version 14 for Windows) was used for data analysis (StataCorp (2015) *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP). Statistical tests were considered significant at $P < 0.05$.

Results

Characteristics of the study sample

The data shown in Table 1 describe the characteristics of the 331 participants in the Seasonal D Study. The age ranged from 18 to 78 years old (median 48 years, IQR 24.7 years) at the time of the baseline interview; the majority of volunteers were women (61.9%), university educated (63.5%) and current nonsmokers (94.3%). Thirty-seven participants were excluded from the reliability of interview time outdoors analysis as they were missing results from either baseline or 12-month interview time outdoors.

Table 1. Characteristics of participants in the Seasonal D Study with sufficient data to be included in this study of reliability and validity of questionnaire measures of time outdoors[a]

Variable	Number (%)
Location	
Canberra (ACT)	169 (51.1)
Brisbane (QLD)	162 (48.9)
Sex	
Male	126 (38.1)
Female	205 (61.9)
Age group (age at baseline)	
<30	25 (7.6)
30–39	76 (22.9)
40–49	49 (14.8)
50–59	70 (21.2)
60–69	58 (17.5)
70+	49 (14.8)
Smoking	

[a] Numbers may not add to total sample size due to missing data.

Variable	Number (%)
Never	223 (67.4)
Past	89 (26.9)
Current	19 (5.7)
Education	
Year 12 or less	51 (15.4)
Trade/certificate	70 (21.1)
University Degree	210 (63.5)
Self-Rated Health	
Poor to Fair	18 (5.4)
Good	103 (31.1)
Very Good	145 (43.8)
Excellent	65 (19.7)
Type of employment	
Mostly Indoors	269 (81.3)
Half-Outdoors to Mostly Outdoors	62 (18.7)

A total of 14 773 diary days were recorded, with 14 491 used for analysis and 282 blank diary days excluded. 87% of the 7-day sun diaries were completed in full (1848 of 2124 sun diaries), 8.5% had 6 days completed (*n* = 180), and 4.5% of diaries had five or fewer days completed (*n* = 96). 255 participants had complete sun diary data (seven sun diaries with seven completed days in each).

Interview and sun diary measures of time outdoors

Table 2 shows median, Q1 and Q3 daily minutes outdoors per day in each season (working and nonworking days assessed separately) for interview time outdoors and sun diary time outdoors.

Table 2. Summary time outdoors for interview and sun diary, by season and nonworking *versus*working day

		Baseline interview (mins per day), median (Q1, Q3)	12-month interview (mins per day), median (Q1, Q3)	Diary (n day), n (Q1,
Summer	Nonworking day	157.5 (105.0, 157.5)	120.0 (75.0, 120.0)	65.0 (22.0
	Working day	97.5 (52.5, 150.0)	82.5 (37.5, 82.5)	75.7 (28.0
Autumn	Nonworking day	157.5 (86.2, 266.2)	112.5 (75.0, 112.5)	57.0 (22.0
	Working day	97.5 (60.0, 150.0)	75.0 (37.5, 75.0)	85.0 (31.0
Winter	Nonworking day	127.5 (67.5, 210.0)	105.0 (45.0, 105.0)	62.0 (24.0
	Working day	75 (45.5, 127.5)	67.5 (37.5, 67.5)	65.0 (24.0
Spring	Nonworking day	157.5 (90.0, 270.0)	120.0 (75.0, 120.0)	62.0 (24.0
	Working day	97.5 (60.0, 150.0)	82.5 (37.5, 82.5)	85.0 (28.0

Median daily interview time outdoors was 103 min (Q1, Q3 88.1, 136.8); for diary time outdoors, this was 65 min (Q1, Q3 62.0, 80.4). Median interview time outdoors per day was highest in spring and summer on nonworking days at both baseline and 12 months, but this was not replicated in the diary data. For interview data, median time spent outdoors on nonworking days was 45 min higher than for working days, but this relationship was reversed in the diary time outdoors (Table 2). For working days, diary time outdoors and interview time outdoors were similar, but for nonworking days, diary time outdoors was less than half of interview time outdoors. Consequently, there was much less separation between working and nonworking day exposure estimates obtained from sun diaries than there was between working and nonworking days obtained via interview.

Participants' interview responses for time outdoors both at baseline and at 12 months strongly favored lower levels of time outdoors for all seasons (Table S1). For each hour between 10 am and 3 pm in every season, over 60% of participants reported zero to less than fifteen minutes of time outdoors.

Reliability of interview time outdoors at baseline and 12-month interview

Bland–Altman plots to assess agreement for mean daily time spent outdoors at baseline compared to 12-month interview are presented in Fig. 2a–d. They show that at low levels of time outdoors there is good agreement in the responses between baseline and 12-month interview, but there is much poorer agreement at higher levels of mean time outdoors. Responses in winter were the most reliable, perhaps because most participants spent little time outdoors. Of note, the mean difference was close to zero for all seasons.

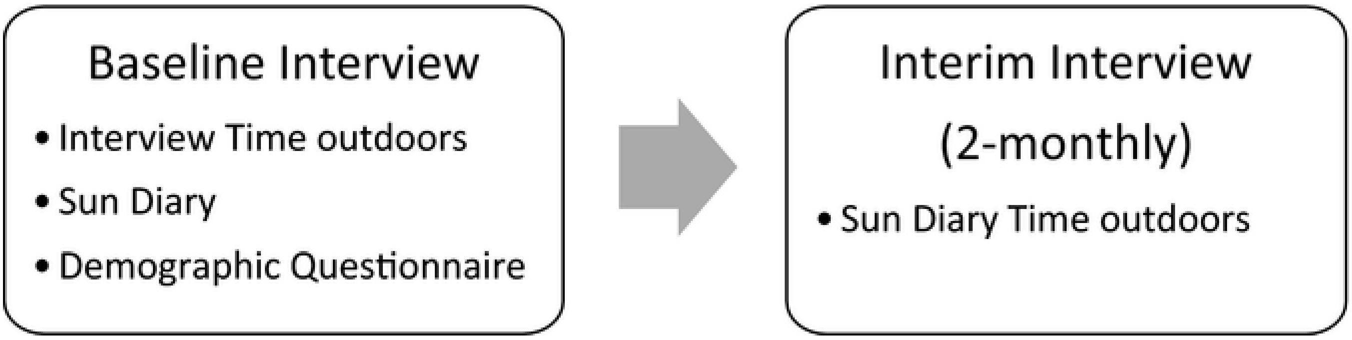

Figure 2.

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Bland–Altman plots of discrepancy between interview time outdoors at baseline and 12-month interview of average weekly time outdoors in summer, autumn, winter and spring. Horizontal lines mark the mean difference (solid red line) and 95% limits of agreement (solid black lines). Note: Bland–Altman plot calculated here as 12-month minus baseline.

The results of the Cohen's weighted kappa agreement across categories of time outdoors comparing the baseline and 12-month interview data are shown in Table 3a and b. Agreement varied from poor to fair across time points and seasons, Cohen's weighted kappa values ranging from 0.12 to 0.39 (Table 3a and b). The strength of the weighted kappa statistic ranged from 0.12 to 0.23 (poor to fair) for nonworking days and 0.22 to 0.39 (fair) for working days. Weighted kappa values were generally higher when assessing working days than nonworking days and generally lowest for the 12–1 pm time period (as specified below). For example, for summer from 2 to 3 pm, the working day agreement was 0.38 compared to 0.19 for nonworking days. This difference between working and nonworking days is consistent with the Bland–Altman plots above, which indicate that interview time outdoors tends to be more reliable with lower time outdoors, such as typically occurs on a working day. In all seasons, there was poorer agreement for the period between 12 and 1 pm during working days than for other times; this trend was not as apparent on nonworking days. The data points within each Bland–Altman plot display a fan shape with differences increasing with increasing time spent outdoors. Log transformation was considered to resolve this, however for ease of interpretation was not performed.

Table 3. Kappa agreement between interview time outdoors from baseline and 12-month interview; (a) nonworking days; (b) working days

(a)				
Hour of day	**Observed agreement (%)**	**Expected agreement by chance (%)**	**Weighted kappa**	**95% CI**
Summer working day				
10–11 am	66.4	46.9	0.37	0.30, 0.42
11–12 pm	69.2	53.5	0.34	0.28, 0.42
12–1 pm	49.3	32.8	0.25	0.22, 0.30
1–2 pm	61.6	44.2	0.31	0.27, 0.35
2–3 pm	70.2	51.6	0.38	0.35, 0.43
Autumn working day				
10–11 am	64.4	46.7	0.33	0.29, 0.36
11–12 pm	66.8	51.8	0.32	0.23, 0.44
12–1 pm	48.3	32.1	0.24	0.21, 0.26
1–2 pm	60.3	43.5	0.30	0.27, 0.33

(a)				
Hour of day	**Observed agreement (%)**	**Expected agreement by chance (%)**	**Weighted kappa**	**95% CI**
2–3 pm	69.9	50.4	0.39	0.32, 0.43
Winter working day				
10–11 am	66.4	49.3	0.34	0.31, 0.36
11–12 pm	65.1	50.4	0.30	0.23, 0.34
12–1 pm	46.6	33.3	0.20	0.14, 0.25
1–2 pm	58.2	44.3	0.25	0.16, 0.27
2–3 pm	67.1	49.6	0.35	0.30, 0.37
Spring working day				
10–11 am	65.7	45.8	0.33	0.30, 0.38
11–12 pm	66.4	50.1	0.33	0.24, 0.36
12–1 pm	46.6	31.4	0.22	0.18, 0.25
1–2 pm	58.6	43.1	0.27	0.23, 0.36
2–3 pm	66.1	49.7	0.33	0.27, 0.35

(b)				
Hour of day	**Observed agreement (%)**	**Expected agreement (%)**	**Weighted kappa**	**95% CI**
Summer nonworking day				

(b)				
Hour of day	**Observed agreement (%)**	**Expected agreement (%)**	**Weighted kappa**	**95% CI**
10–11 am	34.9	21.2	0.17	0.09, 0.28
11–12 pm	40.4	24.9	0.21	0.19, 0.21
12–1 pm	42.8	30.0	0.18	0.16, 0.26
1–2 pm	44.7	30.5	0.20	0.14, 0.28
2–3 pm	39.4	25.3	0.19	0.14, 0.23
Autumn nonworking day				
10–11 am	30.5	21.2	0.12	0.97, 0.15
11–12 pm	37.7	24.9	0.17	0.13, 0.21
12–1 pm	38.7	27.4	0.16	0.10, 0.20
1–2 pm	42.1	28.8	0.19	0.18, 0.23
2–3 pm	42.5	25.2	0.23	0.16, 0.25
Winter nonworking day				
10–11 am	32.5	22.6	0.13	0.11, 0.13
11–12 pm	38.4	25.5	0.17	0.12, 0.21
12–1 pm	34.9	26.9	0.11	0.07, 0.14
1–2 pm	37.3	28.9	0.12	0.10, 0.17

(b)				
Hour of day	**Observed agreement (%)**	**Expected agreement (%)**	**Weighted kappa**	**95% CI**
2–3 pm	42.1	24.7	0.23	0.22, 0.26
Spring nonworking day				
10–11 am	33.2	20.5	0.16	0.08, 0.20
11–12 pm	37.7	24.4	0.18	0.14, 0.20
12–1 pm	39.0	26.2	0.17	0.13, 0.25
1–2 pm	36.6	26.5	0.14	0.04, 0.17
2–3 pm	35.6	23.6	0.16	0.15, 0.22

We summed the time between 10 am and 3 pm and examined the agreement between baseline and 12-month interview using the intraclass correlation coefficient (Table 4). Results ranged from fair to good agreement, being lowest for nonworking days in winter (ICC = 0.46, 95% CI 0.34, 0.57), and highest for summer working days (ICC = 0.74, 95% CI 0.68, 0.79). For all seasons, the intraclass correlation coefficient was higher for working days than for nonworking days. These results are consistent with the weighted kappa analysis.

Table 4. Intraclass correlation analysis, and Spearman's Rho analysis of baseline *vs* 12-month interview average daily total time outdoors (between 10 am and 3 pm)

	ICC	**95% CI**	**Spearman's rho**
Summer working day	0.74	0.68, 0.79	0.51

	ICC	95% CI	Spearman's rho
Summer nonworking day	0.62	0.53, 0.70	0.47
Autumn working day	0.71	0.64, 0.77	0.43
Autumn nonworking day	0.50	0.38, 0.60	0.49
Winter working day	0.71	0.64, 0.76	0.49
Winter nonworking day	0.46	0.34, 0.57	0.43
Spring working day	0.69	0.62, 0.75	0.46
Spring nonworking day	0.55	0.43, 0.64	0.47

Spearman's rank coefficient indicated moderate strength for the correlation of ranking of time outdoors between the baseline and 12-month interviews (Table 4). There was little variation between seasons, with Spearman's rho ranging from 0.43 for winter nonworking and autumn nonworking days, to 0.51 for summer working days. For each category of comparison between baseline and 12-month interview, Spearman's rho coefficient was higher for the Canberra subsample than those in Brisbane, with the exception of winter working days. When comparing 12-month and baseline interview time outdoors, participants from Canberra also had higher Spearman's rho than Brisbane participants except for winter nonworking days.

Agreement between interview time outdoors and sun diary time outdoors (accuracy)

Intraclass correlation coefficients (Table 5a and b) indicated good agreement between baseline interview time outdoors and diary time outdoors for a usual working day in all seasons, with the highest agreement for autumn (ICC = 0.73; 95% CI 0.66, 0.78). Agreement for usual nonworking day time outdoors ranged from poor in winter (ICC = 0.39; 95% CI 0.24, 0.51) to fair in autumn (ICC = 0.53; 95% CI 0.42, 0.63). ICC coefficients indicated that agreement between 12-month interview and diary estimates of time spent outdoors was slightly better for all seasons than it was for the baseline interview *versus* the sun diary. Overall, estimated time spent outdoors was higher for the interview than for the sun diary, for both working and nonworking days (Table 2). The ICC for nonworking days was lower than for working days for all seasons.

Table 5. Intraclass correlation coefficients for (a) diary *vs* baseline interview average total time outdoors, (b) diary *vs* 12-month interview average total time outdoors and (c) Spearman's ranking correlation for diary *versus* 12-month interview time outdoors

	ICC				**Spearman's rho**
	(a) diary *vs* baseline		**(b) diary *vs* 12 months**		
	ICC	**95% CI**	**ICC**	**95% CI**	**(c) diary *vs* 12 mon**
Summer working day	0.72	0.65, 0.77	0.75	0.52, 0.67	0.56
Summer nonworking day	0.47	0.34, 0.57	0.50	0.37, 0.60	0.55
Autumn working day	0.73	0.66, 0.78	0.80	0.74, 0.84	0.52
Autumn nonworking day	0.53	0.42, 0.63	0.61	0.50, 0.69	0.52

	ICC				Spearman's rho
	(a) diary *vs* baseline		(b) diary *vs* 12 months		
	ICC	95% CI	ICC	95% CI	(c) diary *vs* 12 mon
Winter working day	0.66	0.57, 0.73	0.73	0.66, 0.79	0.38
Winter nonworking day	0.39	0.24, 0.51	0.45	0.31, 0.57	0.42
Spring working day	0.66	0.57, 0.73	0.72	0.65, 0.78	0.36
Spring nonworking day	0.45	0.32, 0.56	0.49	0.35, 0.59	0.35

Table 5c presents results of Spearman's rank correlation between sun diary and interview time outdoors using data from the 12-month interviews. The ranking validity was moderate for working days in all seasons and weak to moderate for nonworking days. Correlation coefficients ranged from 0.35 to 0.56, with marginally higher coefficients for working days than nonworking days in summer and spring, the same for working and nonworking days in autumn and higher on nonworking days than working days in winter.

What are the factors affecting agreement between baseline and 12-month interview time outdoors and interview and sun diary time outdoors?

Factors associated with the observed agreement between interview time outdoors at baseline and 12-month interview are presented in Table S2.

Overall, there was significantly lower agreement for outdoor workers than indoor workers (AOR = 0.51, 95% CI 0.35, 0.75, $P < 0.001$). Past (AOR = 0.68, 95% CI 0.51, 0.91, $P = 0.01$) or current smokers (AOR = 0.57, 95% CI 0.32, 1.00, $P = 0.05$) had poorer agreement than nonsmokers. Residence in the Brisbane region was associated with poorer agreement (AOR = 0.70, 95% CI 0.55, 0.91, $P = 0.007$), as suggested by Spearman's rank reliability. The odds of agreement between interview time outdoors at baseline and 12 months was similar regardless of season.

Table 6 shows the results of the analysis investigating factors associated with agreement between interview time outdoors and sun diary time outdoors. Characteristics which were significantly associated with lower odds of agreement between interview and sun diary time outdoors at both baseline and 12 months included being a current smoker, working outdoors, nonworking days, living in the Brisbane region and summer and winter season. In the analysis of factors associated with agreement between sun diary and 12-month interview, being university educated was associated with higher odds of agreement.

Table 6. Results of the logistic regression analysis of factors affecting agreement between interview time outdoors and sun diary time outdoors[a]

	Baseline interview *vs* sun diary				12-month interview *vs* sun diary		
	Adjusted OR	**95% CI**		***P***	**Adjusted OR**	**95% CI**	
Smoking status							
Never	Ref				Ref		
Past	0.94	0.79	1.1	0.51	0.89	0.73	1.1
Current	0.69	0.49	0.97	0.03	0.40	0.26	0.58
Age group							
≤39 Years	Ref				Ref		
40–59 Years	0.99	0.85	1.2	0.94	0.96	0.82	1.2
≥60 Years	0.67	0.55	0.83	<0.001	0.85	0.68	1.1
Sex							
Male	Ref						
Female	1.09	0.93	1.3	0.26	1.09	0.92	1.3
Season							
Autumn	Ref				Ref		
Winter	1.01	1.0	1.2	0.01	1.09	1.0	1.2
Spring	0.99	0.93	1.1	0.85	1.06	1.0	1.1

[a] Agreement for the reporting of each hour analyzed by generalized estimating equations (GEE).

	Baseline interview *vs* sun diary				12-month interview *vs* sun diary		
	Adjusted OR	**95% CI**		***P***	**Adjusted OR**	**95% CI**	
Summer	1.13	1.1	1.2	<0.001	1.08	1.0	1.2
Location of Employment							
Mainly Indoor	Ref				Ref		
Half-Outdoor to Mainly Outdoor	0.66	0.53	0.82	<0.001	0.61	0.48	0.77
Residence							
Canberra region	Ref				Ref		
Brisbane region	0.70	0.60	0.81	<0.001	0.67	0.57	0.79
Type of day							
Working day	Ref				Ref		
Nonworking day	0.48	0.45	0.51	<0.001	0.50	0.48	0.54
Education Level							
Not University Educated	Ref				Ref		
University Educated	1.22	0.99	1.51	0.65	1.29	1.03	1.61

The results for age varied depending on which interview time outdoors variable was used. There was significantly lower odds of agreement between the baseline interview and diary time outdoors for participants aged over 60 years compared to younger participants (AOR 0.67, CI 0.55–0.83), but the effect estimate was attenuated and no longer significant for the comparison of baseline interview with 12-month interview time outdoors (AOR 0.5, CI 0.68–1.1: Table 6).

Discussion

Our results suggest that usual time outdoors recalled over a year overestimates actual exposure as measured by a daily sun diary. However, the ranking of participants by time outdoors remained relatively stable between baseline and 12-month interview and according to diary time outdoors. Several factors were consistently associated with agreement for both reliability (baseline compared to 12-month interview time outdoors) and accuracy (interview time outdoors *vs* diary time outdoors): location of residence, smoking status, day of the week (i.e. working day *vs* nonworking day) and outdoor work (*vs* mainly indoor work).

A key advantage of using a series of simple questions to assess time outdoors across the four seasons of a year is that it incurs a lower participant burden than using sun diaries and UV dosimeters that are deployed several times a year [**16**]. One possible value of the interview time outdoors questionnaire data is that it is not influenced by day-to-day fluctuations that may occur with diaries and dosimeters [**16**]. In this analysis, we found poor-to-good positive correlations between ranked time outdoors (baseline *vs* 12-month interview, and 12-month interview *vs* sun diary). This indicates, firstly, that self-reported time outdoors ranks individuals against other participants in terms of time outdoors with some consistency, and secondly, that that ranking is relatively consistent, at least over one year. While the interview questionnaire did not provide an accurate estimate of time outdoors such as might be required to estimate vitamin D production, for many research questions, how participants rank compared to others may be sufficient. We have previously shown that rankings of individuals by self-reported time outdoors are maintained over many years, even after adjusting for season [24]. Thus, responses derived from data reported for a single time point may be generalizable to a longer period of the lifetime, for example yearly exposure, to give a valid assessment of sun exposure, at least to the point of ranking individuals against each other. However, we found that the *absolute* time outdoors self-reported in minutes at interview was much higher than participants reported in their daily sun diary. There was little variation in weighted kappa values according to season, but, for working days, the lowest agreement was consistently for the hour between midday and 1 pm. Higher variability in midday time outdoors has been noted in other studies [25]. These findings presumably reflect that the time outdoors during the usual working day is relatively consistent (and constrained by the requirements of work) and therefore more easily defined and recalled, except during the lunch hour (12–1 pm), when time outdoors may be highly variable from day to day; choosing a "usual" duration of time outdoors is thus more difficult and subject to poorer recall.

Time outdoors was considerably more variable for nonworking days than for working days and showed only poor-to-fair agreement. This may be a limiting factor for the implementation of the interview time outdoors questionnaire, and the use of the measure as a ranking of sun exposure may be most appropriate for assessing nonworking day time outdoors. Poor overall assessment of usual nonworking day time outdoors has been noted in several other studies [14, 26]. In another study, Webb *et al*. [25] found that individuals had twice the sun exposure on nonworking days relative to working days. In contrast, Glanz *et al*. [27] found that agreement for weekend days was better than that for workdays in their study validating short-term self-reported sun exposure This difference may be a result of the differing study populations—while our sample consisted of adults, Glanz *et al*. [27] focused on mothers, children and lifeguards, specifically in the context of outdoor recreation locations.

The type of work (e.g. whether the participant is a student, works predominantly indoors and works consistently indoors/outdoors or is retired) tended to influence the consistency of time spent outdoors [28]. The odds of agreement between baseline and 12-month interview time outdoors were significantly higher if participants were indoor workers, as was agreement between baseline interview and the corresponding sun diary in each season relative to autumn. Indoor workers have the least flexibility to vary their time outdoors, making their time outdoors more consistent over time.

There was much poorer agreement between the baseline and 12-month interview in the older age group (see Supporting Information), most likely because of the lower proportion who were in full-time work. For example, in this study 66.5% of participants aged 60 years and over were retired, and 22.2% were working part-time, compared to 61.9% of those aged less than 39 years, and 63.9% of those aged 40–59 years working fulltime. Poorer agreement for the older age group is likely to reflect a more variable routine, with more flexibility in spending time outdoors.

Location (Canberra or Brisbane) was an important determinant of reliability and accuracy. This may be indicative of a number of local factors, as models showing this effect were adjusted for age, indoor/outdoor work and working *vs* nonworking day. This highlights the importance of accounting for location when assessing sun exposure [29].

The analysis of the determinants of agreement demonstrates the importance of being specific when asking about typical time outdoors—such as specifying time of day and season, as these may affect agreement. Our results show that including season and time of day may increase intraclass correlation coefficients compared to questionnaires of time outdoors that did not include a time element [14]. Like us, Cargill *et al*. [14] found a tendency for responses in the brief questionnaire to overestimate time outdoors recorded in a sun diary.

Here, the questionnaire sought information on time outdoors for each hour of the day in each season. In the analysis, total time outdoors was the sum of these hourly estimates. The higher kappa coefficients seen in this study compared to others that did not include this detailed recording by hour of the day and season, may reflect that asking this detailed reporting resulted in improved recall. Additionally, our sample consisted of healthy volunteers that were largely university educated, who we would assume to be highly motivated to complete the questionnaires and may pay more attention to their sun exposure as a result. It is likely that the level of agreement in this study is a “best case” and this may impact the replicability of our findings. Sun exposure studies with a similar distribution of education levels have not made mention of how this affects agreement between their measures [14], although there is some research to suggest that sun exposure behavior, and willingness to change these behaviors differs by education level [30].

Standard demographic information should also be included in studies assessing sun exposure. Usual location of residence, smoking status, being university educated, age, occupational status (full time *vs*part-time *vs* not working) and whether the participant's work is predominantly indoors or outdoors may affect the reliability and accuracy of the recalled time outdoors. Our analysis adjusted for these factors, so the cause behind their importance can only be speculated upon. Current smokers had poorer agreement between sun diary and interview time outdoors compared to nonsmokers. We suggest that this difference may be because the sun diary is capturing the smaller, intermittent time outdoors associated with smoking, while the interview questionnaire, which asks about usual time outdoors, does not. Similarly, location and occupation may affect the reliability and accuracy of time outdoors due to day-to-day fluctuations dependent on factors such as the weather (temperature, sun and rainfall) [31]. Additionally, variations in the type of outdoor work may not be captured in “usual time outdoors”, but may affect exposure to UV radiation.

This study had a number of strengths, in particular that the same question regarding time outdoors was asked at the beginning and end of the study period, and we collected data on individual characteristics which may have affected the reliability of these responses across this time. We were also able to validate the interview time outdoors question against a previously validated and highly detailed sun exposure measure, the sun diary [18]. The study is potentially limited by the wording of the interview time outdoors question, which specifically asked about time outdoors in the *previous* season. This means that the interview time outdoors question when asked at the start and end of the study referred to different time periods, that is different years; this is, of course, unavoidable in seeking to validate a specific question. This may partially explain the difference in estimated time outdoors between the baseline and 12-month interviews, although time outdoors is typically similar from year to year for most people [32]. We also asked about “usual time outdoors” to overcome short periods of holiday where exposure may have been markedly different [33]. Participants had completed up to seven sun diaries by the 12-month interview, which potentially increased their awareness of their actual time outdoors. The difference in the time spent outdoors recorded in the baseline and 12-month interviews could also be due to an actual change in the duration of outdoor exposure from year to year, and may reflect the fact that these two interviews sought information about time spent outdoors in two different years.

Conclusion

This study assessed the reliability and validity of a brief questionnaire asking about typical time spent outdoors during each season. We have demonstrated that although ranking is preserved over time, participants' estimation of their time outdoors from interview overestimates their actual time outdoors gathered from a daily sun diary. The brief questionnaire used here may be of value for epidemiological research seeking to rank participants on their time outdoors over longer periods of time, for example months or years, with a relatively low participant burden. It provides the opportunity for gathering more detailed data according to time of year and time of day than questionnaires that do not specify a time period; these data might then be combined with levels of ambient UV radiation to better estimate an individual's dose of UV radiation.

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