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Correspondence and requests for materials should be addressed to S.C.H. (suzanneho@cuhk.edu.hk)

Development and validation of a lifetime exposure questionnaire for use among Chinese populations

ShengHui Wu[1], Suzanne C. Ho[2], Tsz-ping Lam[3], Jean Woo[4], P. Y. Yuen[5], Ling Qin[3] & Susanna Ku[2]

[1]Division of Epidemiology, Department of Medicine, Institute of Medicine and Public Health, Vanderbilt University Medical Center, Nashville, TN, [2]School of Public Health and Primary Care, Chinese University of Hong Kong, Hong Kong SAR, PR China, [3]Department of Orthopaedics and Traumatology, the Chinese University of Hong Kong, [4]Department of Medicine and Therapeutics, the Chinese University of Hong Kong, [5]Physical Education Unit, the Chinese University of Hong Kong.

The sunlight exposure questionnaire for use in the Chinese population was constructed based on extensive literature review and item suitability for measuring life-time exposure. The content validity index (CVI) was derived from ratings by, an expert panel to assess the item content and relevance. 650 population-based Chinese women completed the sunlight exposure questionnaire through telephone interview. To assess the questionnaire reliability, 94 women were re-interviewed after 2 weeks. 98.4% of the sunlight exposure questionnaire items were found to have valid CVI (>0.83). The Scree plot and the Principal Components Factor Analysis showed a two-factor construct was appropriate and no questionnaire item needed to be excluded. The questionnaire also had a good test-retest reliability (ICC: 0.59–0.93; k: 0.51–100). This sunlight exposure questionnaire was found to be adequate for measurement of life-time sunlight exposure among Hong Kong Chinese women.

Vitamin D is produced on exposure of the skin to solar ultraviolent B (UVB) radiation, and solar UVB is the primary source of vitamin D for most persons[1,2]. Vitamin D receptors have been discovered in most cells in the body, and enzymes capable of converting circulating 25-hydroxyvitamin D [25(OH)D] to the active 1,25 hydroxyvitamin D [1,25(OH)D] are now known to exist outside the kidneys, including the skin, prompting a plethora of new discoveries about its function[3]. In addition to its protective effect on bone fractures, rickets, osteomalacia, and osteoporosis, vitamin D is now thought to decrease a spectrum of chronic illnesses including internal cancers, cardiovascular disease, autoimmune diseases, metabolic disorders and mental illness[4,5]. Epidemiological and preclinical studies have provided evidence that vitamin D has protective effects against the development of cancer[6,7]. Garland et al[8]. explored the associations between sunlight and the breast cancer incidence and mortality in the United States, and found a strong, inverse association between sunlight exposure and breast cancer mortality (-0.80, $P < 0.0001$). Although sun exposure increased the risk of skin cancer in Chinese[9] and other[10] populations, the effects of avoidance of suboptimal vitamin D levels on cancer cell proliferation are likely to be beneficial to the melanoma patient[11]. Serum levels in the range 70–100 nmol/L might be a reasonable target for melanoma patients as much as for other members of the population[11]. Individual sunlight exposure can be measured with objective methods including observations, skin reflectance using colorimeters or spectrophotometers, personal dosimetry using polysulphone film, skin swabbing using spectrophotometer and inspections of moles[10,12–14]. Compared with other measurements, questionnaires remain the most cost-effective assessment of population sunlight exposure[10,12,13,15,16]. Existing sunlight exposure questionnaires were mostly applied to Caucasians or non-Asians and generally did not collect the exposure information over lifetime or have not been validated[13–17]. Therefore this study aimed to develop and validate a lifetime sunlight exposure questionnaire for use in the Chinese population[15,16].

Results

Content validity. The CVI of the questionnaire itmes ranged from 0.67 to 1.0. Except for one itme, all had CVI values of 0.83 or above (Table 1). However, this item was still retained in the questionnaire based on the study by Fitzpatrick[18]. The other 61 items were retained in the questionnaire.

Table 1 | Content Validity Index (CVI) Values for Chinese Lifetime Sunlight Exposure Questionnaire

Items summary	CVI	Items summary	CVI
Usual reaction of skin color when first exposed to sunlight (tanned)	0.67	In winter, whether ever went to a summer climate (ages 6–12, 13–19 and 20–34 yr, 35 yr - present)	1.00
Usual reaction of skin when first exposed to sunlight (burned)	0.83	Outdoor activities in the sun from 35 yr to present	1.00
Where the participants lived (ages 6–12, 13–19 and 20–34 yr, 35 yr - present)	0.83	Sun protection methods usually used from 35 yr to present	0.83
Average hours per day spent in the sun in summer (ages 6–12, 13–19 and 20–34 yr, 35 yr - present)	0.83	Frequency and duration of the outdoor jobs in the sun in lifetime	1.00
Average hours per day spent in the sun in other 3 seasons (ages 6–12, 13–19 and 20–34 yr, 35 yr - present)	0.83	The use of a sunlamp (with age when first used, age at last used, and total number of sessions over her lifetime).	1.00
The seasons using sun protection (6–12, 13–19 and 20–34 yr, 35 yr - present)	0.83	The use of a sunbed (with age when first used, age at last used, and total number of sessions over her lifetime).	1.00

Construct validity. A principal components analysis was conducted to evaluate the construct validity of the sunlight exposure questionnaire (n = 650). The Scree Plot (Figure 1) indicated that a two-factor solution was optimal. Four factors had eigenvalues greater than one. Principal components analysis revealed that the Total Variance explained by the first two factors were 52.9% and 17.5% respectively (Table 2) and a corresponding Component Matrix showed the correlation coefficients between each question and the two factors were positive and good (Table 3). Although 4 principal component factors could be extracted, the first two could explain 70.4% of the total variance and included all items analyzed. The two factors were labeled: (1) frequency and duration worked in the sun in four respective seasons in life; (2) hours per day spent in the sun in summer and other 3 seasons in 4 life stages. This analysis indicated that no items (continuous variables) need to be excluded for the Chinese sunlight exposure questionnaire.

Reliability. Table 4 shows that the reliability was excellent for the average hours spent in the sun during the 4 respective life stages (ICC: 0.750–0.925), moderate to good for lifetime duration worked in the sun in the respective four seasons (ICC: 0.586–0.744). The item-total correlations for most items were moderate to good (0.419–0.886). Table 5 shows that eight items (ever went to a summer climate in winter during the four life stages, the living places from age 35 y to present and whether ever walked in the sun from 35 y to present, whether ever used sunlamp or sunbed) were consistent between the first and second interviews. The agreements were excellent (Kappa ranged between 0.82 and

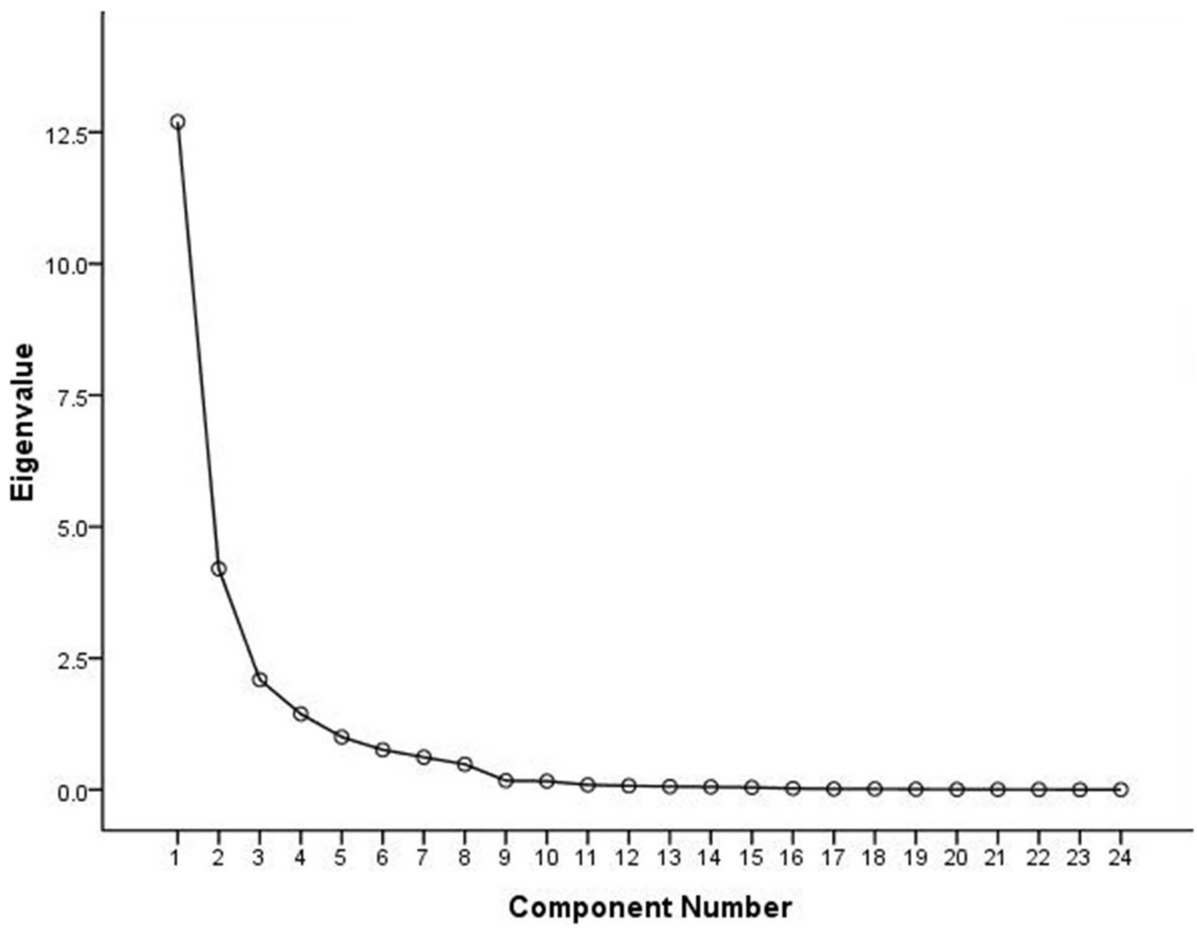

Figure 1 | Scree Plot by Principle Component Analysis of the Chinese Lifetime Sunlight Exposure Questionnaire (n = 650).

Table 2 | Two-factor Solution by Principal Items Loading for the Chinese Version of the Sunlight Exposure Questionnaire (n = 650)

	Initial Eigenvalues			Extraction Sum of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.698	52.908	52.908	12.698	52.908	52.908
2	4.199	17.494	70.402	4.199	17.494	70.402
3	2.092	8.718	79.120	2.092	8.718	79.120
4	1.440	5.999	85.119	1.440	5.999	85.119
5	1.000	4.166	89.285			
6	0.757	3.153	92.438			
7	0.617	2.571	95.009			
8	0.483	2.013	97.022			
9	0.171	0.713	97.735			
10	0.160	0.667	98.403			
11	0.089	0.372	98.775			
12	0.074	0.308	99.083			
13	0.059	0.245	99.328			
14	0.052	0.215	99.542			
15	0.041	0.172	99.714			
16	0.023	0.096	99.810			
17	0.015	0.063	99.872			
18	0.013	0.052	99.925			
19	0.008	0.034	99.959			
20	0.005	0.022	99.981			
21	0.003	0.013	99.995			
22	0.001	0.005	99.999			
23	0.000	0.001	100.000			
24	3.969E-5	0.000	100.000			

0.90) for place of residence, whether usually used sunscreen, umbrella from 35 y to present. The agreements for most items for sun protection during the 4 life stages and the skin reaction to the sun were moderate to good (Kappa ranged between 0.51 and 0.75).

Discussion

This is the first sunlight exposure questionnaire developed and validated for use in the Chinese population. The questionnaire was designed to capture the usual time spent in the sun, sun protection used, and outdoor activities in the sun during the different life stages

Table 3 | Two-factor Solution: Factor Loadings by Principal Components Analysis on Items of the Sunlight Exposure Questionnaire (n = 650)

	Component				
Item Content Summary	1	2	3	4	Communalities
In autumn, how many months a year worked in the sun	**.908**	−.199	−.016	−.007	.864
In spring, how many months a year worked in the sun	**.903**	−.222	.000	−.004	.866
In winter, how many months a year worked in the sun	**.903**	−.213	.005	−.013	.860
In summer, how many months a year worked in the sun	**.902**	−.188	−.021	−.016	.854
In autumn, how many days a week worked in the sun	**.896**	−.167	−.211	−.039	.877
In winter, how many days a week worked in the sun	**.892**	−.180	−.201	−.053	.838
In spring, how many days a week worked in the sun	**.888**	−.197	−.192	−.040	.865
In summer, how many days a week worked in the sun	**.880**	−.166	−.222	−.050	.854
In winter, how many hours a day worked in the sun	**.853**	−.020	−.326	−.064	.871
In spring, how many hours a day worked in the sun	**.851**	−.039	−.318	−.050	.830
In autumn, how many hours a day worked in the sun	**.846**	−.013	−.349	−.045	.840
In summer, how many hours a day worked in the sun	**.820**	−.017	−.351	−.057	.799
In summer, how many years worked in the sun	**.779**	−.149	.567	.157	.974
In winter, how many years worked in the sun	**.778**	−.150	.569	.157	.976
In autumn, how many years worked in the sun	**.778**	−.153	.568	.159	.977
In spring, how many years worked in the sun	**.777**	−.156	.569	.159	.977
In 13–19 years, hours per day spent in the sun in other seasons	.344	**.745**	−.078	.291	.765
In 13–19 years, hours per day spent in the sun in summer	.352	**.728**	−.077	.319	.762
In 20–34 years, hours per day spent in the sun in other seasons	.343	**.724**	.177	−.362	.803
In 20–34 years, hours per day spent in the sun in summer	.320	**.719**	.179	−.349	.773
In 6–12 years, hours per day spent in the sun in other seasons	.284	**.680**	−.131	.488	.798
In 6–12 years, hours per day spent in the sun in summer	.306	**.668**	−.157	.500	.814
From 35 to present, hours per day spent in the sun in other seasons	.427	**.628**	.170	−.436	.796
From 35 to present, hours per day spent in the sun in summer	.433	**.616**	.176	−.450	.800

Items sorted according to loadings by factors and sizes for easier comprehension. The bold numbers belong to the respective factors.
Extraction Method: Principal Component Analysis.
Factor 1: frequency and duration worked in the sun in four respective seasons in life.
Factor 2: hours per day spent in the sun in summer and other 3 seasons in 4 life stages.

Table 4 | Medians (P25, P75) of the Time Spent in the Sun as Estimated by the Sunlight Exposure Administered Twice (n = 94)

	Median time spent in the sun (P25, P75)*			
Category	Q1	Q2	ICC	Item-total correlation
Time spent in the sun (hours/day)				
6–12 yrs				
Summer	2.0 (1.0–2.5)	2.0 (1.0–3.0)	0.845	0.737
Other 3 seasons	2.0 (1.0–3.0)	2.0 (1.0–2.5)	0.846	0.736
13–19 yrs				
Summer	2.0 (1.0–2.5)	2.0 (1.0–2.5)	0.767	0.623
Other 3 seasons	1.5 (1.0–3.0)	2.0 (1.0–2.5)	0.787	0.649
20–34 yrs				
Summer	1.5 (1.0–2.5)	1.5 (1.0–2.0)	0.847	0.479
Other 3 seasons	1.5 (1.0–2.0)	1.5 (1.0–2.0)	0.750	0.605
35 yrs-present				
Summer	1.7 (1.0–2.5)	1.5 (0.8–2.0)	0.820	0.697
Other 3 seasons	1.5 (0.9–2.0)	1.5 (0.8–2.5)	0.750	0.601
SPF of sunscreen in summer	25.0 (20.0–30.0)	25.0 (20.0–30.0)	0.925	0.886
Duration worked in the sun in lifetime				
Summer				
Total years	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.740	0.620
Months per year	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.595	0.425
Days per week	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.712	0.554
Hours per day	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.741	0.594
Autumn				
Total years	0.0 (0.0–0.0)	0.0 (0.0–1.0)	0.690	0.543
Months per year	0.0 (0.0–0.0)	0.0 (0.0–2.0)	0.586	0.419
Days per week	0.0 (0.0–0.0)	0.0 (0.0–0.3)	0.698	0.539
Hours per day	0.0 (0.0–0.0)	0.0 (0.0–0.5)	0.744	0.597
Winter				
Total years	0.0 (0.0–0.0)	0.0 (0.0–2.0)	0.682	0.534
Months per year	0.0 (0.0–0.0)	0.0 (0.0–2.5)	0.638	0.474
Days per week	0.0 (0.0–0.0)	0.0 (0.0–0.3)	0.611	0.440
Hours per day	0.0 (0.0–0.0)	0.0 (0.0–0.5)	0.596	0.428
Spring				
Total years	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.691	0.545
Months per year	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.619	0.453
Days per week	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.711	0.553
Hours per day	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.740	0.595

*Two-sided Wilcoxon Signed Ranks Test comparing time spent in the sun based on Q1 sunlight exposure questionnaire with that based on Q2 = no statistical significant difference. Q1, first administration of the sunlight exposure questionnaire; Q2, second administration of the sunlight exposure questionnaire (2 weeks later).
ICC: intra class coefficient.

among Hong Kong Chinese premenopausal women. The content validity, construct validity and reliability of the questionnaire were adequate.

Content validity is the determination of the content representativeness or content relevance of the elements/items of an instrument. The content validity of questionnaires focusing on various exposure assessments fields has been assessed in a few studies. A newly developed Korean Acupuncture Sensation Questionnaire validated by expert panel judgment has sufficient content validity for *de qi* (CVI > 0.80)[19]. Thrush et al[20] developed and established the content validity of a 43-item fixed-response instrument designed to measure the organizational climate for research integrity in academic health centers and established that the instrument has an excellent content validity (CVI = 0.90). The items included in our lifetime sunlight exposure questionnaire were established with sufficient content validity.

Our Chinese lifetime sunlight exposure questionnaire has also been found to have good construct validity. The Scree plot indicated a two-factor construct for the continuous variables. Principal Components Analysis revealed a satisfactory percentage (70.4%) of the Total Variance was explained by the two factors with eigenvalues greater than one. This analysis indicated that no items (continuous variables) needed to be excluded for the Chinese sunlight exposure questionnaire. Consistently, a Spanish questionnaire evaluated habits, attitudes, and understanding of exposure to sunlight and factorial analysis of the principal components confirmed the construct validity with commonalities and factor saturations > 0.50[21]. Therefore, the construct validity of our questionnaire can be supported.

The existing sunlight exposure questionnaires have mostly been applied to the Caucasian or non-Asian populations; and generally have not collected exposure information over lifetime or have not been validated[13–17]. Knight et al used a sunlight exposure questionnaire to acquire the exposure data from Caucasians for three life periods: 10 to 19, 20 to 29, and 45 to 54 years. Chen et al collected information on sun exposure at different lifetime periods and tested skin reaction after 2-h sun exposure in the Taiwanese population[9]. However, the questionnaires used in these studies have not been validated. The objective measures of sunlight exposure, such as personal UV dosimetry, have been used to validate the questionnaire on recent sunlight exposure; but correlations between questionnaires and objective measures are usually not strong[13]. Our questionnaire was found to have sufficient construct validity to measure lifetime sunlight exposure among Chinese women. It could thus be applied to assess the association between vitamin D from sunlight exposure and health outcomes.

Consistent with other previous studies, the reproducibility for lifetime sunlight exposure questionnaires in other studies was

Table 5 | Variable Reliability on Sunlight Exposure Information and the Agreement between two Repeated Interviews (n = 94)

Category	Kappa
Skin color turn dark under sunlight without protection	0.52
Get burn under sunlight without protection	0.51
Information during 6–12 yrs	
Residence	0.95
Usual sun protection use	0.58
Trips to summer climate in winter	-
Information during 13–19 yrs	
Residence	1.00
Usual sun protection use	0.57
Trips to summer climate in winter	-
Information during 20–34 yrs	
Residence	0.90
Usual sun protection use	0.53
Trips to summer climate in winter	-
Information from 35 yrs to present	
Residence	-
Activities in the sun	
Walking	-
Cycling	0.61
Swimming	0.58
Other sports or exercise	0.57
Trips to summer climate in winter	-
Usual sun protection use	0.56
Usual sunscreen use	0.88
Sunscreen containing UVB	0.52
Usual umbrella use	0.82
Usual brimmed hat use	0.52
Usual clothes with long sleeves use	0.55
Usual long pants use	0.64
Usually sun glasses use	0.63
Usual shade use	0.75
Sunlamp use	-
Sunbed use	-

- No Kappa values are available since the first and second interviews are completely consistent.

relatively good. The Australian case-control study found that the test-retest k statistic of self-reported sun exposure ranged from 0.43 to 0.74[22]. Another case-control study on skin cancer conducted in Southern Europe showed good reproducibility between answers given on two different occasions to a sunlight exposure questionnaire over several different life stages (ICC: 0.68–0.79)[23].

Our study has a few limitations. These included the difficulties in obtaining the detailed information of time spent in the sun for each activity, and sun protection methods used during the 4 life stages[13,17]. There were no experts in the field of skin cancer or dermatology for our content validity assessment, but the diverse backgrounds of the expert panel and the consistent results from the experts support the good content validity of the questionnaire. Our study population was selected from an ongoing population-based cohort study of premenopausal women recruited from stratified-cluster sampling of housing estates in Shatin (a density populated district in Hong Kong). Therefore, the generalizability of this study to other age groups or gender is limited.

Our study also did not evaluate the concurrent validity of the questionnaire, but correlations between questionnaires and objective measures are usually not strong[13]. A study investigated the self-reported versus observed sun habits in beachgoers in Honolulu found correlations of 0.54 to 0.72 between self-reported use of sunscreen and objective measurement of sunscreen use; and correlations of 0.11 to 0.79 between self-reported and observed use of clothing[24]. Attempts have also been made to validate lifetime sunlight exposure questionnaires with measures on sun damage to the skin for studies of multiple sclerosis[22] or skin cancer[23]. However, the correlation values between questionnaires and objective measures from these studies were also not high probably due to measurement errors or small numbers of cases. In contrast, our study has sufficient validity and good reliability to measure lifetime sunlight exposure.

Accuracy of recall is a concern. The reproducibility of sun exposure-related questions has been examined in a number of studies over time periods ranging from a few weeks to several years[22,23,25]. In general, these studies have found evidence that sun exposure and outdoor activities, whether in childhood and adolescence, or recent years, could be reasonably recalled. In spite of these limitations, to our knowledge, this is the first study to assess the content validity, construct validity and reproducibility of the Chinese version of lifetime sunlight exposure questionnaire.

Future studies might explore the criterion validity of the current questionnaire using UV monitors. More importantly, research into the relationship between diseases such as breast cancer and sun exposure creates new opportunities in diseases prevention. Using our questionnaire could evaluate or determine which life stage(s) of sun exposure is more closely related to the health or disease outcomes. There is much concern among the public with respect to the risks and benefits of sun exposure. Evidence-based recommendations could be generated on the achievable and beneficial sunlight exposure rather than complete avoidance[15,26,27].

In conclusion, this study suggests that lifetime sunlight exposure questionnaire developed in the present study has sufficient content validity, construct validity and good reliability to measure lifetime sunlight exposure among Chinese women in Hong Kong. This questionnaire could be applied to assess the association between vitamin D from sunlight exposure and health outcomes.

Methods

Development of sunlight exposure questionnaire. The sunlight exposure questionnaire (Supplementary Information) was developed based on literature on sunlight exposure assessment[13,14,17] and also on existing sunlight exposure questionnaires that have been used in several previous epidemiological studies of cancer[15,16]. A total of 62 items (questions) were included in the questionnaire covering the skin reaction to sunlight exposure (always/easily burns; burns rarely/never; always/easily tans; tans rarely/never); frequency and duration spent outdoor in the sun over lifetime (6–12 y, 13–19 y and 20–34 y, and from 35 y to present); and personal protection used. Sunlight exposure questions covered for each age group included the following items: place of residence (country, province and city); outdoor activities in the sun and the average hours per day spent in the summer and the other 3 seasons; usual (≥50% of the time) sun protection used in each season; trips to summer climate in winter and the frequency (none, once every 3–4 years, once every 2 years, every year); or under shade when outside in summer and specific outdoor activities from ages 35 yr to present; outdoor jobs in the sun and information on frequency (hours per day) and duration (number of weeks and months per season and total number of years); sunlamp or sunbed use (with age when first used, age at last used, and total number of sessions over lifetime).

Content validity. To assess the suitability of questionnaire items for use in a Chinese population, the content validity of the sunlight exposure questionnaire was evaluated by a panel of 6 experts with discipline in women's health, lifestyle and health, environmental health and physical education. The experts were academicians/professionals with relevant experiences between 2 and 25 years (mean [standard deviation; SD] 8.3, 16.1) in research or work on sunlight exposure, physical activity or nutrition. The range of experiences provide a wide and relevant perspective on the appropriateness and validity of the items to be included.

Procedures of the content validity assessment. The experts were provided with a delineation of the full content domain of the questionnaires, with specific questions pertaining to the content relevance of each item, was derived based on the ratings of the content relevance of the questionnaire items. For the level of each question's validity, a 4-point ordinal rating scale was used, where 4 point means "very relevant"; 3, "somewhat relevant"; 2, "hardly relevant" and 1, "totally irrelevant".

The index of content validity (CVI) was derived based on the ratings of the content relevance of the questionnaire items. The CVI is the proportion of items (questions) in the questionnaire that received a rating of 3 or 4 by the experts[28]. Only items with a CVI of 0.83 or above were retained in the questionnaire[28], meaning items regarded as valid by more than 80%of the experts, were selected as significant[28]. Other items were eliminated or revised according to the literature and suggestions from the expert panel.

The experts were also asked to identify any areas that might have been omitted and to suggest any areas requiring improvement or modification.

Test of construct validity and reliability. Two pretests (n = 5 and 22 respectively) were carried out among women aged 27 to 51 years to test the flow and comprehensibility of the questionnaire. The pre-tested questionnaire was adopted for use in the telephone survey conducted from January to April 2010. Participants were invited from an ongoing population-based cohort study of premenopausal women previously recruited through stratified-cluster sampling from different housing types in Shatin, Hong Kong. A letter was first mailed to the study participants explaining the study aim and then, followed by a telephone call for arranging the telephone interview. Among the 676 potential participants, 5 were excluded due to invalid telephone numbers (0.74%). Of the remaining 671 women, 650 participated in the telephone survey, with a response rate of 96.9%. To test the questionnaire reliability, the sunlight exposure questionnaire was re-administered after 2 weeks among a 15% random sample of the study participants (n = 94).

The study was approved by Survey and Behavioural Research Ethics Committee of Chinese University of Hong Kong. Informed consent was obtained from all subjects.

Statistical analysis. The construct validity was estimated based on the questionnaire interview among the 650 women who answered the sunlight exposure questionnaire. Principal components analysis was used to analyze the factorial structure of the continuous variables from the sunlight exposure questionnaire. To eliminate the effect of different measurement units on the results, the variable (x) was standardized (z) using the theoretical (population) mean and standard deviation: $Z = \frac{X - \mu}{\sigma}$, where $\mu = E(x)$ is the mean and σ = the standard deviation of the probability distribution of x[29], z is the standardized value of x.

Reliability of the continuous variables in the questionnaire between the first and second interview (n = 94) was assessed by calculating intraclass correlation coefficient (ICC)[30]. Agreement rates by dichotomous and ordinal variables for the questionnaire were estimated by Cohen's Kappa (k)[31]. The values of k and ICCs less than 0.40, 0.40–0.75, and greater than 0.75 were considered to indicate poor, moderate to good, and excellent agreement, respectively[32].

Statistical significance was defined as two-sided $P < 0.05$. All statistical analyses were done using SPSS version 16.0 for windows.

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Author contributions

S.H.W. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. S.C.H. and S.H.W. conceived and supervised the study and interpreted the results; S.H.W. and S.C.H. acquired data and drafted the manuscript; S.H.W. conducted the statistical analysis; S.C.H., T.P.L., J.W., P.Y.Y., L.Q. and S.K. evaluated the questionnaire as a panel of experts and revised paper.

Additional information

Supplementary information accompanies this paper at http://www.nature.com/scientificreports

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