ORIGINAL ARTICLE

Evaluation of tourists' UV exposure in Paris

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Abstract

Background Ultraviolet (UV) exposure is one of the most important risk factor for skin cancers. If UV hazard has been evaluated in tropical countries or in some population – children, outdoor activities – little information is available about UV hazard in high latitude towns like Paris, considered as the most 'charismatic city' in the world.

Objective To evaluate UV exposure in Paris in spring, in sun and shade, in real life conditions.

Methods We evaluated erythemal UV exposure, during four sunny days in May-June in eight Paris touristic sites during peak hours (2 days), and during two walks in touristic downtown of Paris. Measures were performed in sun and shade. UV radiation exposure was evaluated with UV index performed with a 'Solarmeter ultraviolet index (UVI)' and UV dose with 'standard erythema dose' (SED) and 'minimal erythema dose' (MED) calculations.

Results Despite 'average' UVI in sunny conditions, a 4-h sun exposure reaches 13–20 SED and 3–10 MED according to phototype. Clouds were inefficient to protect against UV. Shade of places reduces moderately UVI (50–60%) in forecourts. Exposure during 1-h walk reach at least one MED in real life conditions for skin phototypes I–IV.

Conclusions UV risk for tourist is quite high in spring in Paris. UVI remains high despite high cloud fraction. Shade reduces UVI, but UV protection factor is only 2–3 in large places such as *Place Notre Dame* and *Place Charles de Gaulle*. So sun protection campaigns should be proposed, and sun protective strategies could be integrated in urban planning.

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Conflicts of Interest

Authors declare no conflict of interest in this study.

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Introduction

Advocating the benefits of reasonable exposure to sunlight is a public health priority in most Western countries. Sun exposure has positive effects on health such as 25 OH-D3 synthesis, and induction of a feeling of general wellbeing. However, overexposure to ultraviolet (UV) remains the major external causal factor in the development of skin cancer. For the most part, non-melanoma skin cancers are induced by chronic sunlight exposure, whilst melanoma is associated with repeated burning exposure mainly early in life and chronic exposure.[1–3]

A few studies has evaluated UV hazard and behaviours during school, professional, sport, and beach exposure, or in populations

at risk of UV-induced skin cancers.[4–7] Exposure studies and sun prevention campaigns have focused mainly on situations of obviously high exposure such as outdoor sport, beach and tourism in high UV risk countries (mainly Mediterranean countries, South America, Australia and Africa).[8–13] A few UV exposure and prevention campaigns have also focused on every day life activities including school children, workers, of 'typical lifestyle behaviours'.[14–17] To our knowledge no study evaluated UV exposure during cultural tourism.

Paris can be considered to be a moderate risk zone for developing skin tumours because of its relatively high latitude (49′ N). On the other hand, it is one of the most visited cities in the world. As an example, more than 20 sites are visited by more than 1 000 000 tourists per year, and every day more than 100 000 persons frequent the famous 'Avenue des Champs Elysées'.[18] Moreover, in 2009, Paris ranked first as the 'most charismatic city' ahead of London and Sydney, according to a study carried out by Anholt-GfK Roper City Brands Index.[19]

The aim of the study was to evaluate UV hazard during touristic visits in Paris for fair phenotypes. The UV hazard was evaluated in four conditions: exposure in parks, during shopping (streets), in squares (conditions comparable to long-time queues) and in typical touristic walks, in three conditions: 'total sunny exposure', 'total shady protection' and without respect of shade or sun exposure. This study was performed within the RISC-UV project (http://www.gisclimat.fr/projet/risc-uv) a collaboration between dermatologists, geophysicists and epidemiologists.[4,20,21]

Methods

We evaluated UV radiation exposure during four sunny days in May-June 2009. The measurements were performed under two different situations: (i) static measurement performed by volunteers in eight touristic sites during peak hours (12 h–16 h); and (ii) dynamic measurements, performed during two walks in touristic downtown of Paris.

Selection of dates for evaluation

From 25th May to 25th June 2009 (week-end excluded) we selected sunny days for ultraviolet index (UVI) measurements in several touristic sites of Paris. According to the weather forecasts (http://france.meteofrance.com), UVI were close to 6 during the period. We selected two main episodes for measurements: a cloudy day (forecast: >25% and <75% of cloud fraction), 29 May, and a sunny day (forecast: <25% of cloud fraction), 2nd June. The walks (dynamic measurements) were held in two different days, 25th May and 3rd June, under variable atmospheric conditions.

Touristic sites evaluated

The evaluations were focused on sites chosen according to their popularity. For the eight popular touristic sites, we selected two streets: *Rue de Rennes*, and *Avenue des Champs Elysées* (in front of the 'Lido'); three forecourts: *Place Notre Dame*, *Arc de Triomphe* (*Place Charles de Gaulle*) and *Sacré Cœur* Basilica at *Montmartre* (*Parvis du Sacré Cœur*), and three parks/gardens: *Champs de Mars* (*Tour Eiffel*), *Bois de Boulogne* (near Rolland Garros tennis courts) and *Père Lachaise* Cemetery. Precise locations of the eight touristic sites are detailed in Fig 1a

For the walks, we tried to include the maximum of touristic sites in a 4–5 km/1–1.5 h walk. The first walk started in front of *Notre Dame* and finished at *Place de La Concorde*. Walk 2 started at the *Arc de Triomphe* (*Place Charles de Gaulle*) and finished at *Rue de Rivoli*. Precise locations of the two walks are detailed in Fig 1b,c.

Six of the top 10 monuments and museum visited in Paris were included either in the eight locations, or in the walks: *Notre Dame* (13 600 000 visits/year), *Sacré Cœur* Basilica (10 500 000 visits/y), Louvre Museum (8 400 000 visits/year), *Tour Eiffel* (6 900 000 visits/year), *Beaubourg Centre* (2 750 000 visits/year), and *Arc de Triomphe* (1 500 000 visits/year).[18]

UV radiation exposure evaluation

UV radiation exposure was evaluated from UVI measurements. UVI is a standardized tool[22] that expresses the erythemal power of the sun accompanied by photoprotection advice. An UVI score of 1–2 is considered to represent weak sun, 3–5 is average, 6–7 is strong, 8–10 is very strong and over 11 is extreme. The 'biologically effective doses' of UV radiation (J/m^2) received during the sun exposure were evaluated from UVI measurements as follows:

$$UVDose(SED) = \left(\sum \frac{UVI_i}{40}\Delta t_i\right)/100$$

Where Δt_i is time (in seconds) between two consecutive UVI_i measurements. The term '40′ in equation converts UVI in W/m^2. UV dose is expressed in terms of 'standard erythema dose' (SED), equivalent to effective erythemal exposure of 100 J/m^2.

The 'minimal erythema dose' (MED) is defined as the quantity of UV radiation needed to cause slight erythema with clearly defined edges 16–24 h after exposure.[2] This quantity varies depending on individual sensitivity to the sun. We assessed this sensitivity using Fitzpatrick's skin phototype (SP) classification, focusing on Caucasian phototypes (SPI–SPIV).[23] MED for SPI is 200 J/m^2 (2.0 SED), SPII: 250 J/m^2 (2.5 SED), SPIII: 300 J/m^2 (3 SED) and SPIV: 450 J/m^2 (4.5 SED).[24]

UVI evaluation

UVI measurements were performed with a Solarmeter UVI meter model 6.5 (Solartech, Harrison Twp, MI, USA) in each touristic site. The sensitivity of this instrument was validated in a previous study.[20]

In the eight preselected places, UVI was measured every 5 min during peak hours (12–16 h) always at the same place. UVI was

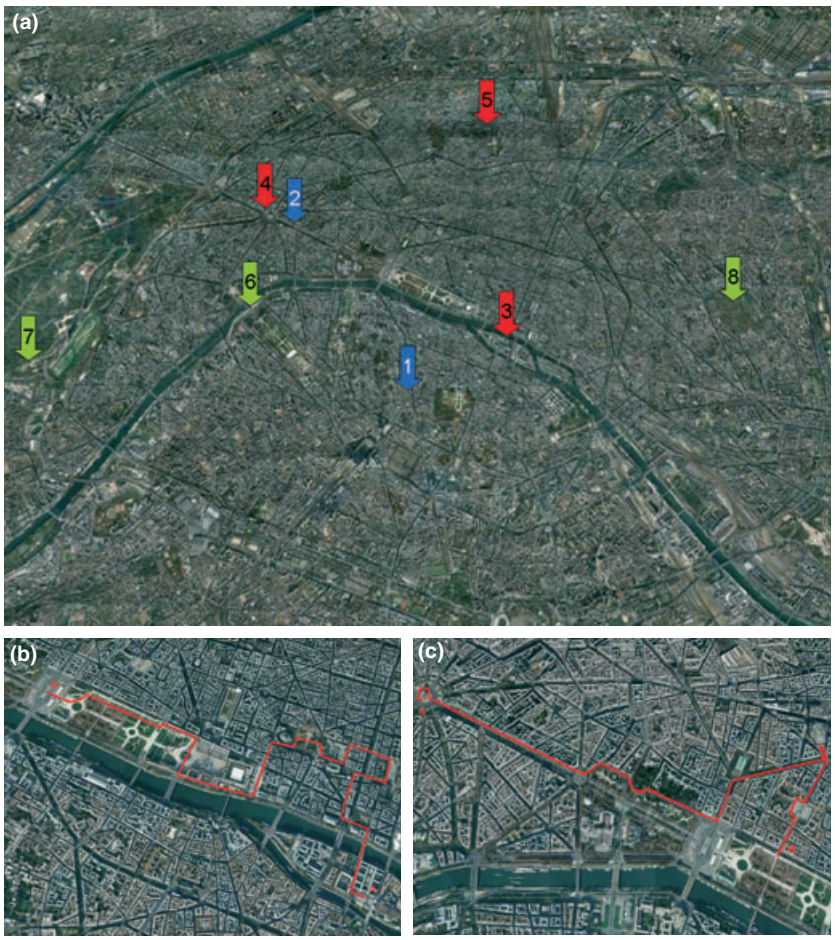

Figure 1 Location (Google Map, http://maps.google.fr) of (a) The eight locations in Paris where UVI measurements were performed: in blue; streets: 1: Rue de Rennes; 2: Champs Elysées Avenue; in red: places: 3: Notre Dame Cathedral; 4: Arc de Triomphe; 5: Sacré Cœur Basilica; in green, parks: 6: Champs de Mars; 7: Bois de Boulogne; 8: Père Lachaise Cemetary; (b) Walk 1 from Notre Dame Cathedral to Place de La Concorde (5.1 km); (c) Walk 2 from Arc de Triomphe (Place Charles de Gaulle) to Rue de Rivoli (3.9 km).

taken alternating in sun and shade. So we had sun and shade UVI measures every 10 min (24 UVI in sun and 23 UVI in shade during the 4-h evaluation). The evaluators had been trained by a geophysist (MDPC) to respect UVI measurements with the Solarmeter as recommended by the supplier.

Walks were done by two investigators (EM, MDPC) during peak hours. In the 'walk' experiment, we performed UVI measurements in different intervals of time: each 1 min under cloudy or shaded conditions until 5 min under clear sky conditions. We consider that UVI did not change between two consecutive measurements.

Cloud fraction

Cloud fraction was estimated by a whole sky-imager at the SIRTA observatory in Palaiseau, France.[25] Cloud fraction was given in percentage of the sky that is covered by clouds. Herein, 'sunny' condition was defined as a day with forecasted maximal cloud fraction less than 25% all day long, and 'cloudy' condition as a day with forecasted maximal cloud fraction between 25% and 75% all day long.

Statistics

The data were summarized using descriptive statistics. Quantitative data were expressed as the mean ± standard deviation and qualitative data as frequency and per cent. The reduction of UVI (Mean UVI reduction = $[\Sigma$ (sun UVI ^{t} − shade UVI $^{t+5\ min})$/sun UVI $^{t}]/23 \times 100$) and SED (SED reduction = (sun SED $^{15:50\ PM}$ − shade SED $^{15:55\ PM}$)/sun SED $^{15:50\ PM}$) in shade has been expressed as a percentage of UVI and SED in the sun. Statistical analyses were performed using SAS software 9.2 (SAS Institute Inc, Cary, NC, USA).

Results

UV exposure in 'sun' in eight touristic sites

On 29th May: sky was cloudy from 12 h to 15 h (ranges: 31–88%) (Fig 2a) Mean UVI was 4.8 (ranges: 1.2–7.8). During cloudy conditions (12 h–15 h), mean UVI was 4.6 (ranges: 1.2–7.8) and during sunny times (15 h–16 h), 5.1 (ranges: 4.0–6.5). UVI variation was largest during cloudy conditions, from one measure to the next, and at the same time from one site to another: maximal UVI

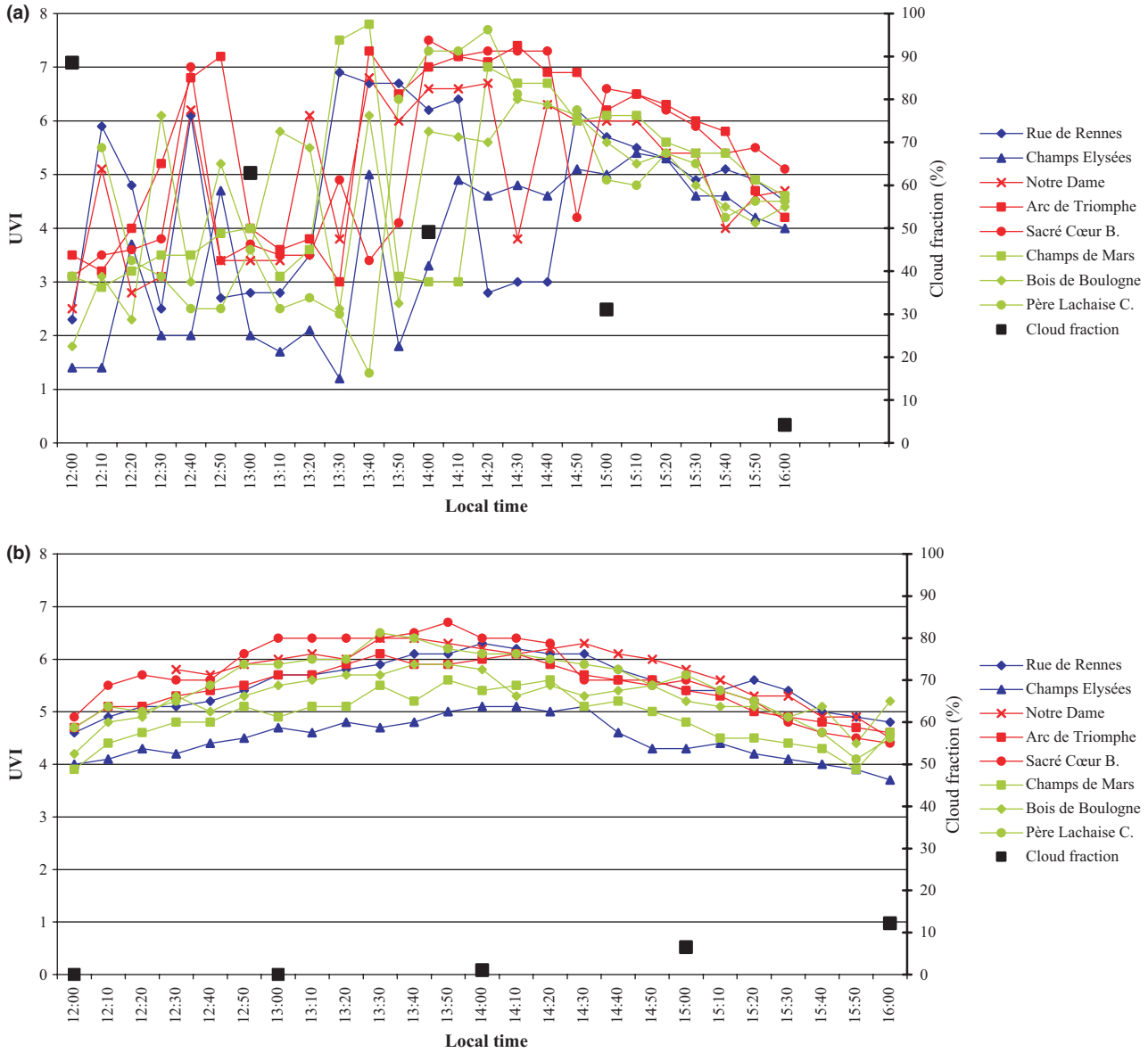

Figure 2 Ultraviolet index in sun, and cloud fraction in eight touristic locations in Paris on 29th May 2009 (a) and 2nd June 2009 (b). In blue: streets; in green: parks; in red: places. B., Basilica; C., Cemetery.

differences between two sites: 6.5 at 13:40 h – UVI = 1.3 in *Père Lachaise* Cemetery and 7.8 in *Champs de Mars*; and also the highest UVI measures (UVI > 6.8), including 18 UVI > 7 while forecast of maximum UVI was 6 (http://france.meteofrance.com) (Fig 2a).

On 2nd June: cloud fraction was less than 15% (ranges: 0–13%) (Fig 2b). Mean UVI was 5.3 (ranges: 3.7–6.7). If UVI curves were regular with a peak at 14 h (Mean UVI= 5.9), there were significant differences between sites. The lowest UVI were observed in the *Avenue des Champs Elysées* (mean UVI: 4.4, ranges: 3.7–5.1), and the highest on the *Parvis du Sacré Coeur* (mean UVI: 5.7, ranges: 4.4–6.7).

A person who was exposed 4 h in the sun at peak hours reached from 13 (*Avenue des Champs Elysées*) to 20.5 SED (*Arc de Triomphe*) on 29th May (Fig 3a), and from 16.2 (*Avenue des Champs Elysées*) to 20.7 SED (*Parvis du Sacré Cœur*) on 2nd June (Fig 3b). For SPI, the number of MED varied from 6.5 to 10.2 on 29th May and from 8.1 to 10.3 on 2nd June. On the same days, it varied from 2.9 to 4.6 and from 3.6 to 4.6 respectively for SPIV.

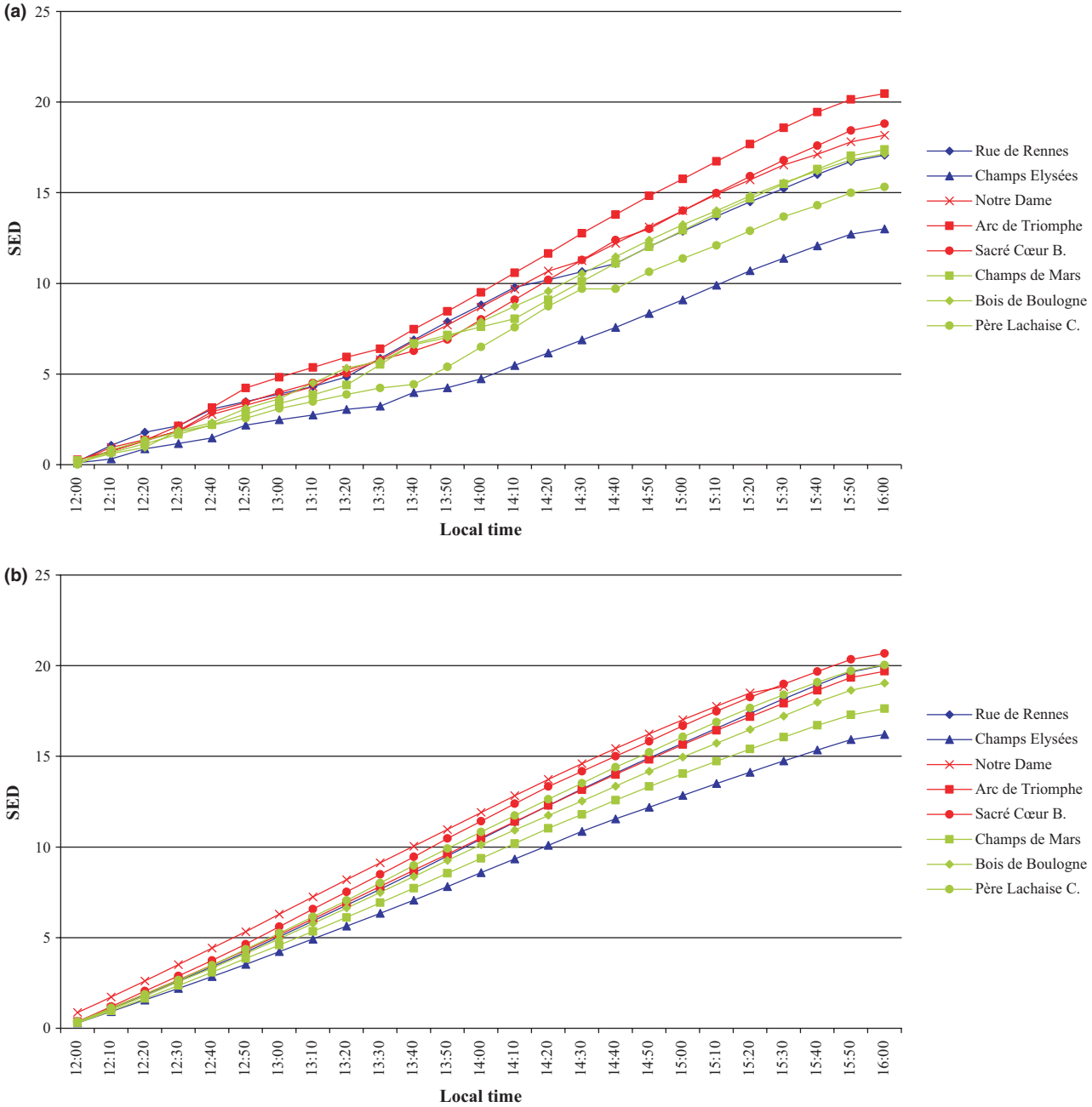

Figure 3 Cumulative standard erythemal dose (1 SED = 100 J/m^2) in eight touristic locations in Paris on 29th May 2009 (a) and 2nd June 2009 (b). In blue: streets; in green: parks; and in red: places. B., Basilica; C., Cemetery.

UV exposure in shade in 8 touristic sites

On 29th May in shade, mean UVI was 1.3 (ranges: 0–3.0). There were moderate variations of UVI from time to time with a minimum of 0.9 at 15:55 h and a maximum of 1.4 at 12:55 h. There was large variations of mean UVI from one site to the next with a minimum of 0.1 (ranges: 0–0.2) in shade of *Père Lachaise* Cemetery, and a maximum mean UVI of 2.8 (ranges: 1.7–3) in shade of *Arc de Triomphe* (Fig 4a).

On 2nd June in shade, mean UVI was 1.3 (ranges: 0.4–2.4). There were moderate variations of mean UVI from time to time with a minimum mean UVI of 1.1 at 15:45 h, and a maximum of 1.5 at 12:45 h. There was also a moderate UVI

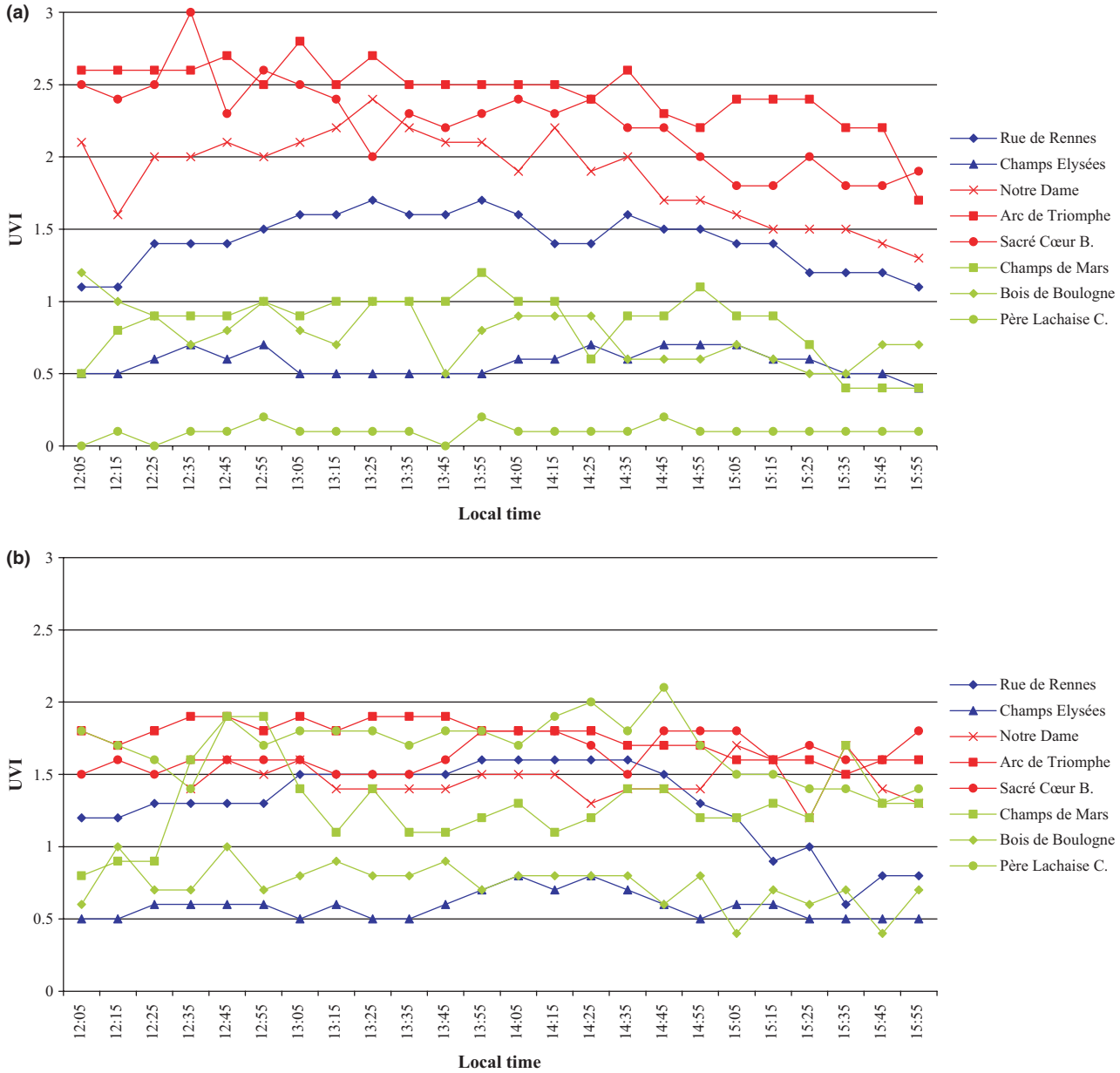

Figure 4 Ultraviolet index in shade in eight touristic locations in Paris on 29th May 2009 (a) and 2nd June 2009 (b). In blue: streets; in green: parks; in red: places. B., Basilica; C., Cemetery.

variations from one site to the next with a minimum of 0.6 (ranges: 0.5–0.8) in shade of *Avenue des Champs Elysées*, and a maximum mean UVI of 1.8 (ranges: 1.5–1.9) in shade of *Arc de Triomphe* (Fig 4b).

A person who was exposed 4 h in shade reached from 0.4 (*Père Lachaise* Cemetery) to 8.9 SED (*Arc de Triomphe*) on 29th May (Fig 5a), and from 2.2 (*Avenue des Champs Elysées*) to 6.4 (*Arc de Triomphe*) on 2nd June (Fig 5b). The number of MED varied from 0.2 to 4.5 on 29th May and from 8.1 to 10.3 on 2nd June for SPI. For SPIV it varied from 0.1 to 2.0 and from 0.5 to 1.4 on the same days.

The impact of shade on reduction of UV exposure was evaluated with mean UVI reduction and SED reduction, site by site, at each date. On 29th May the mean UVI reduction induced by shade was relatively low in places (51.7–58.2%) and always higher (65.3–97.5%) in parks and streets. The same trends were observed with SED reduction. On 2nd June, the impact of shade was also lower in forecourts than in parks and streets (Table 1).

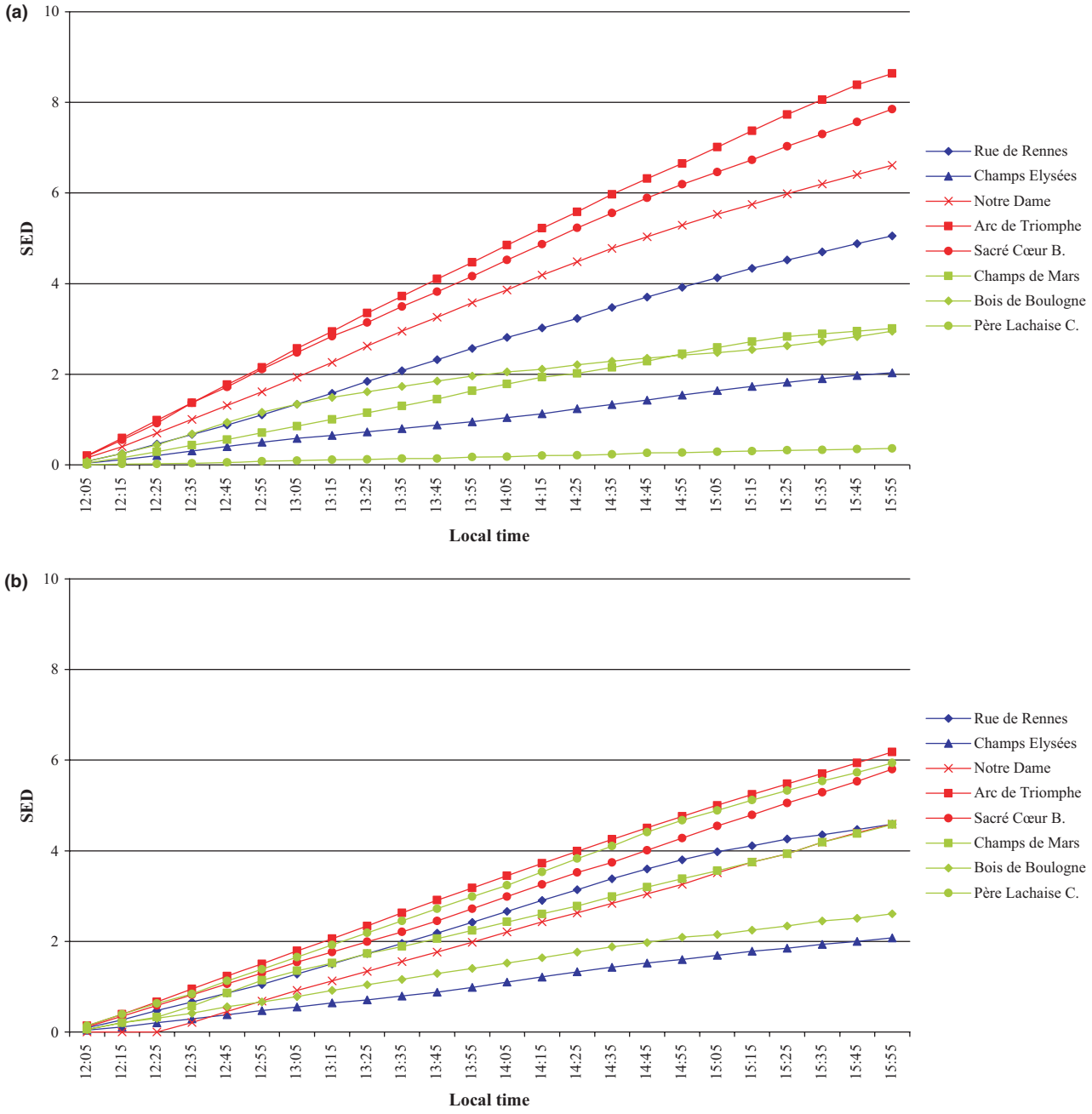

Figure 5 Cumulative standard erythemal dose (1 SED = 100 J/m^2) in shade in eight touristic locations in Paris on 29th May 2009 (a) and 2nd June 2009 (b). In blue: streets; in green: parks; and in red: places. B., Basilica; C., Cemetery.

UV exposure during 1-h walks

For the two walks, the weather was cloudy (cloud fraction 53–85%) and forecast UVI was 6. On 25th May (walk 1), the mean UVI was 4.5 (ranges: 0–7.2), but 5.9 (ranges: 3.6–7.2) if the person always stayed in sun (including values of UVI under clouds), and 1.4 (ranges: 0–3.0) if he always stayed in shade (Fig 6a). A person who did the walk 1 was exposed to 5.8 SED (from 2.9 MED for SPI to 1.3 MED for SPIV) if he had a random walk, 7.2 SED (from 3.6 MED for SPI to 1.6 MED for SPIV) if he always walked in sun, and 1.3 SED (less than 0.7 MED whatever the SP) if he always walked in shade (Fig 7a).

On 5th June (walk 2), the mean UVI was 3.3 (ranges: 0–6.8) in the hypothesis of a random walk, 4.3 (ranges: 1.6–6.8) if the

Table 1 Erythemal UV dose reduction induced by shade*

	UVI reduction, mean ± SD, %		SED reduction, %	
	29th May	2nd June	29th May	2nd June
Rue de Rennes	65.3 ± 14.6	76.7 ± 4.3	69.8	76.7
Avenue des Champs Elysées	80.0 ± 10.0	87.0 ± 1.4	84.0	86.9
Place Notre Dame	58.2 ± 17.5	75.0 ± 3.0	62.9	75.6
Arc de Triomphe	52.5 ± 17.7	67.8 ± 2.3	57.1	68.1
Sacré Cœur Basilica	51.7 ± 19.1	71.1 ± 4.1	57.4	71.5
Champs de Mars	79.9 ± 9.4	73.4 ± 6.2	82.3	73.5
Bois de Boulogne	80.0 ± 13.6	86.0 ± 2.9	82.5	86.0
Père Lachaise Cemetery	97.5 ± 1.7	69.9 ± 2.8	97.6	69.9

Mean UVI reduction = [Σ (sun UVI ^{t} − shade UVI $^{t+5\ min}$)/sun UVI ^{t}]/23 × 100; SED reduction = (sun SED $^{15:50\ PM}$ − shade SED $^{15:55\ PM}$)/sun SED $^{15:50\ PM}$.

SED, standard erythema dose; SD, standard deviation; UV, ultraviolet; UVI, ultraviolet index.

person always stayed in sun (including values of UVI under clouds), and 1.3 (ranges: 0–3.3) if he always stayed in shade (Fig 6b). A person who did the walk 2 was exposed to 3.7 SED (from 1.8 MED for SPI to 0.8 MED for SPIV) if he had a random walk, 5.2 SED (from 2.6 MED for SP I to 1.2 MED for SPIV) if he always walked in sun, and 1.4 SED (less than 0.7 MED whatever the SP) if he always walked in shade (Fig 7b).

Discussion

We evaluated UV hazard in Paris during spring sunny days, in sun and in shade, in eight very touristic sites and in two attractive walks, during peak hours, for tourists with fair phenotypes. As a result of the relatively high latitude of Paris (48° 49′ N) and because Paris is associated to 'culture' and not to sunny activities, there is no information about UV hazard and there is no sun prevention campaigns.

One approach to evaluate UV exposure is to use UV data given by satellites. As pixel of satellite evaluation is about 100–400 km^2, it gives an approximate evaluation for individuals. Moreover UVI programs do not include cloud effects in their forecasts, and give 'clear sky' or 'cloud free' UVI. So we preferred to evaluate erythemal UV doses using individual dosimeters,[20] in the different sites to include architectural and cloud conditions in the UVI evaluation. The main information were that: (i) UV hazard is rather high in spring in Paris (i.e. 3–20 SED/4 h at peak hours); (ii) UV hazard is very dependent on sites (e.g. UVI increase of 50% between *Avenue des Champs Elysées* and *Arc de Triomphe*); (iii) UVI remains high despite high cloud fraction and highest UVI were measured during cloudy times; (iv) and if shade reduce UVI, reduction is only about 50–60% in places.

This study has three main limitations: (i) is this two-day UV evaluation representative of UV conditions in Paris in spring and summer? During the 1 month study, UVI forecast (http://france.meteofrance.com) in Paris was 6 or more for 19/31 days (61% of days) [UVI forecast was 6 (n = 12) or 7 (n = 7)]. If we extrapolate to the three main touristic months (i.e. June, July and August) in 2009 and 2010, UVI was 6 or more for 90/184 (49%) dates [forecast UVI = 6: n = 61 (32%); forecast UVI = 7: n = 29 (15%)] so we can consider that the UV conditions of the study were representative of half of the dates; (ii) Some evaluation are not in real life conditions. Evaluation was performed every day, at the same location, during a 4-h period. During walks, real life conditions can be considered. However, tourists labelled with UV-dose meters and followed through their visit of Paris would have given a more exact UV risk evaluation; (iii) UVI was measured as recommended by the supplier of the UV dosimeters: on a horizontal plane. The orientation of a UV sensor is critically important in relating the measurements to skin exposure due to the complex topology of the human form and, so we probably overestimate UV exposure, except probably for face and top of head (especially nose and skin of scalp if bald) and shoulders if uncovered. These anatomical locations are relevance for the measurement data.[26,27]

Shade is considered as one of the main protection strategies against the sun radiation. But it has been appreciated that people under tree,[28–31] hair,[32] cloud,[28,31] shade structure,[33,34] or beach umbrella[33,35,36] shade are exposed to considerable amount of scattered UV radiation.[33] Herein, evaluation of SED reduction by 'town' shade, buildings or trees, varied from 51% to 97%. The less efficient shade on erythemal UV reduction was building shade in large places (i.e. *Place Charles de Gaulle* and *Sacré Coeur* Basilica Place) that is probably explained by the highest indirect UV in comparison to indirect UV in streets and parks. The quality, or 'efficiency', of shade protection can be measured by its UV protection factor (UPF) equivalent of the sun protection factor (SPF) for sunscreen.[37] UPF of shade in these conditions was 2–33. As a comparison this shade could be considered as efficient as sunscreen with 'low efficiency' SPF on erythemal UV as defined by European institutions.[38] On the other hand, Paris has a relatively low UVI conditions. So if shade UPF is quite low, it could decrease UVI to an 'acceptable' level with low skin risk. In fact, in some conditions, a 4-h

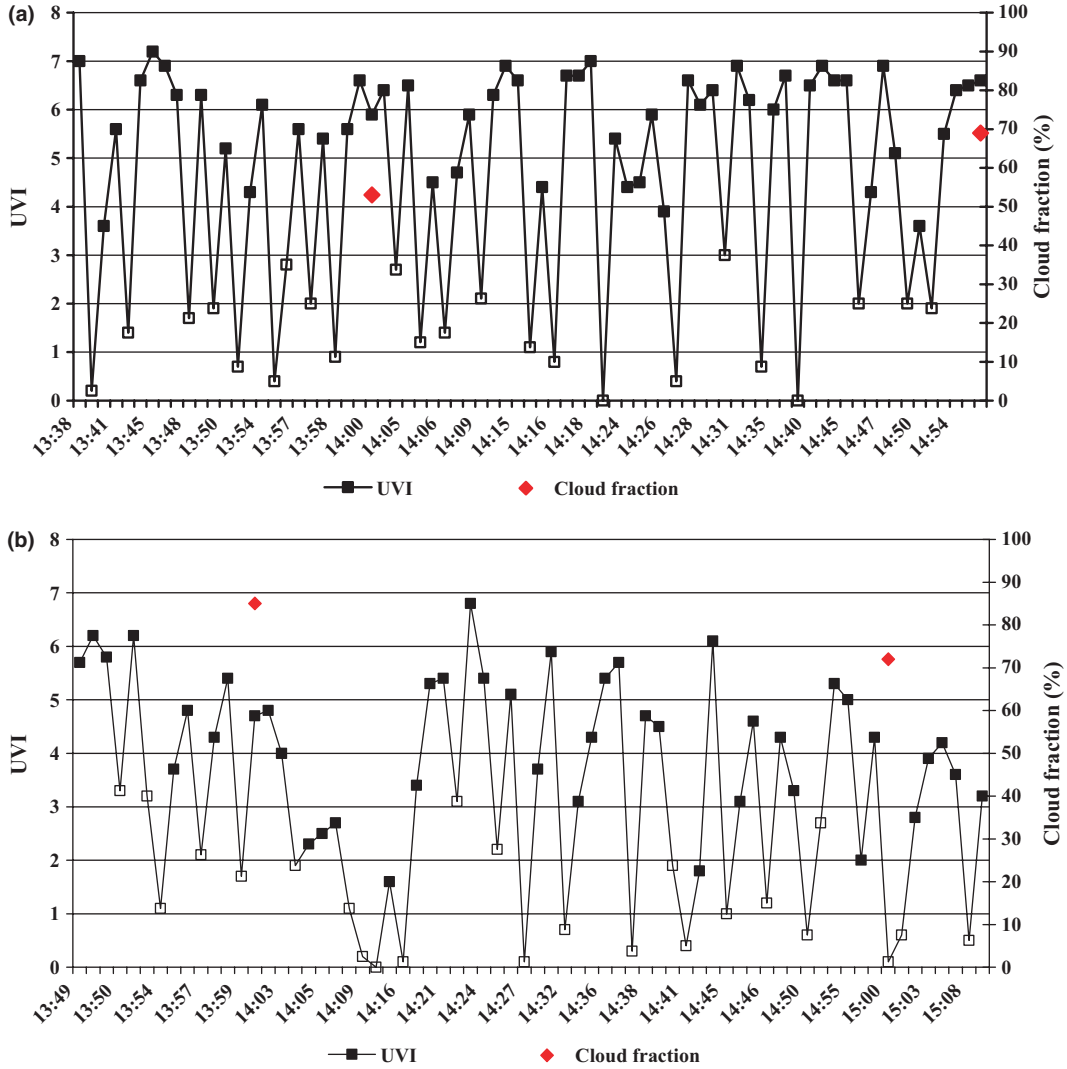

Figure 6 Ultraviolet index (UVI) measurements and cloud fraction (%) evaluation in (a) walk 1 (25th May 2009, from 13:38 PM to 14:57 PM, 5.1 km, 1 h 19 min) and (b) walk 2 (3rd June 2009, from :49 PM to 15:10 PM, 3.9 km, 1 h 21 min). In black UVI measures in sun (with or without cloud); in white, UVI measures in shade.

shade exposure in Paris can reach 8.9 SED (2 MED for a skin phototype IV).

It is well known that clouds give incomplete sun protection.[22] It has been shown that the erythemal UV irradiance under skies with 50% or less cloud cover was not remarkably different from that under clear skies.[31] Comparable results have been published on effect of clouds on UVA.[39] Our study confirms these results. Despite high cloudy conditions (until 80% of cloud fraction) mean UV radiation levels is not significantly reduced. Scattering under clouds can have the same effect as the reflectance by different surfaces and thus increase total UV radiation levels. In our study this scattering under clouds is suggested by (i) the mean UVI is quite similar with or without clouds; (ii) and higher UVI were observed during evaluations with high cloud cover.[21] In the study by Grant and Heisler, in the shade, the actual irradiance was greater under partly cloudy than under clear skies.[31] In our study, the same effect has been observed: the lowest effect of shade on UV reduction (50–60% of total SED) was observed in large places in cloudy conditions.

Cultural town visits should be included in sun prevention campaigns because of large population visiting them. The 'basic sun protection messages' (about skin protection) published by the World Health Organization (WHO) are: limit exposure during midday hours; seek shade; wear protective clothing; wear a broad-brimmed hat to protect the eyes, face and neck; use and reapply broad-spectrum sunscreen; avoid tanning bed; and It's important

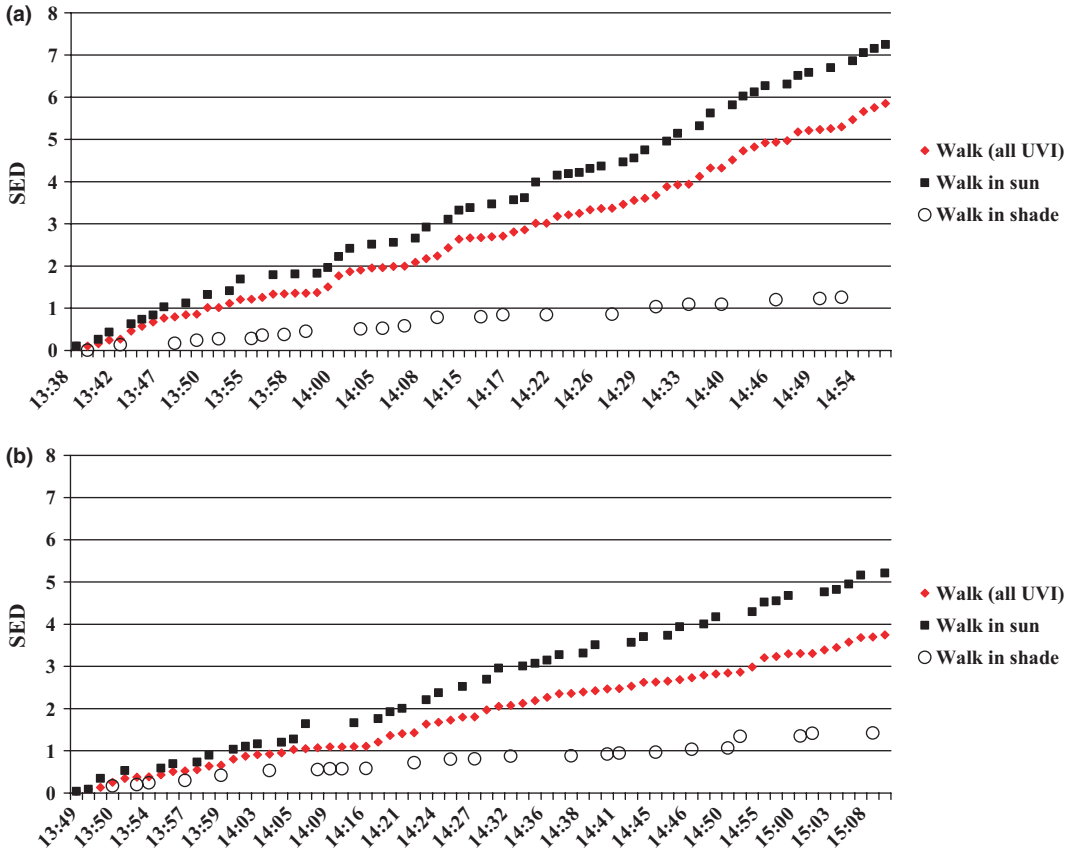

Figure 7 Cumulative standard erythemal dose (1 SED = 100 J/m^2) during walk 1 (a) and 2 (b). SED was evaluated in pragmatic considerations (walk with all ultraviolet index included, patient walk without taking into account shade and sun), and for people who stay always in sun or always in shade.

to protect babies and young children.[40] For a lot of people, physical sun prevention including clothing, hat, and sunscreen is used either to prolong the stay in the sun,[41,42] or if sun 'seems' dangerous (i.e. sunny days without shade). Data show that these physical sun prevention measures should be proposed in cloudy conditions even in shade, and in countries with moderate UV hazard.

There is many opportunities to sun expose during Paris visits: between monuments visits, during shopping, during walks in Paris and its parks, in queues while waiting for visits, during outdoor activities at '*Paris-plage*' or outside '*bistrots Parisiens*'. As a result of the relatively high UV risk in spring and summer, as shown herein, sun protection campaigns should be proposed, and sun protective strategies could be integrated in urban planning (trees, architecture) but probably also in typical lifestyle behaviours such as outdoor workers and sports. In high UV hazard countries, provision of shaded areas in schools, playgrounds and parks, and in public places are encouraged and supported. Such measures should also be encouraged in cultural touristic places, even in relatively high latitude countries without affecting the appearance of these iconic sites.

Conclusion

This study shows that even if Paris is a relatively high latitude town, UV hazard can still be considered as important and should be taken into consideration by Public Health authorities.

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