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MEASUREMENTS AND ASSESSMENT OF SOLAR ULTRAVIOLET EXPOSURE IN AYDIN, TURKEY. A PILOT STUDY

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Abstract. To assess and alert public on the seasonal ultraviolet radiation levels were the main aims of this study. UV, humidity and temperature measurements were performed at 4 locations in Aydin. The UV dose is expressed in minimum erythemal dose per h (MED/h). Data were collected for a week in the cloudless day between 8.00 a.m. and 8.00 p.m. A questionnaire was performed among young adults in the main campus of Adnan Menderes University, Aydin. The highest values of MED/h were measured in summer days around 2.00 p.m. in Aydin province. Correlations were found between the values of temperature, humidity and MEDs/h. Most of the participants reported that they do not have enough information about UV radiations and that they usually do their outdoor activities in the afternoons. The high UV exposure is observed through the April to October in Aydin. Although skin cancer is first most common cancer form in Aydin province, there is no alarming system in this issue. Furthermore, educated young adults have inefficient information about the harmful effects of UV radiation. UV index value should accept as a quick monitoring indicator for the level of UV radiation and the UV precautions which have to be taken by the public.

Keywords: health effect assessment, minimum erythemal dose, radiation, ultraviolet, UV index.

AIMS AND BACKGROUND

The aims of this study were to measure and analyse the UV radiation, humidity and temperature at various points in the city of Aydin, Turkey, and also to determine the knowledge of UV exposure and sun protection behaviour of young people.

The sunlight has been used for the treatment of skin disorders for ancient ages. Also the beneficial and harmful effects of sun exposures have been discussed by scientists for decades[1,2]. Sunlight is the ultimate source of energy and is vitally important to life. Approximately 50, 45 and 5% of energy radiating from sun are

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in visible light, infrared radiation and ultraviolet radiation, respectively. Dangerous part of this energy for life ca not reach the earth surface because it is filtered in the earth atmosphere[3]. Two portions of sunlight (visible radiation-light and infrared radiation-warmth) are perceived directly by our senses, however ultraviolet (UV) radiation which is capable of causing both physiologic and pathologic events can not be noticed by our senses. UV radiation can be sub-divided into three parts. UV-C or 'far-UV' (100–280 nm) is completely absorbed by stratospheric ozone and does not reach the earth surface. UV-B (280–315 nm) which is mostly absorbed by stratospheric ozone affects the human, plant and animal cells because UV-B is absorbed mostly by aromatic amino acids and nucleic acids[3]. The responses of humans to UV-B include vitamin-D_3 production, erythema, hyper-pigmentation, cataracts, immune suppression and skin cancer. UV-A or 'black light' (315–400 nm) is only slightly absorbed by ozone and is needed for vitamin-D synthesis, however too much UV-A may lead to photo-ageing, immune suppression, erythema and cataracts[3]. The depletion of the stratospheric ozone is responsible for allowing increased UV-B penetrate to the Earth surface. The accumulation of manmade chlorofluorocarbons (CFC) can cause depletion of the stratospheric ozone column. Furthermore, an individuals UV exposure is increasing because of various factors such as barely clothing, occupation, changing lifestyle, age, and geographic factors such as altitude and latitude. The heat, wind, humidity, pollutants, cloud cover, snow, season, location and time of day are the other factors that influence the exposure to UV radiation[4]. The clouds will attenuate much more solar infrared (decrease in temperature) and visible light than the solar UV. Furthermore, on the cloudy days, UV levels are usually lower than during the clear skies as clouds can deflect solar rays up into space. On the other hand, clouds in the vicinity of the sun reflect additional radiation to the ground, the increase in UV radiation is observed. Humidity strongly affects atmospheric visibility by direct influencing cloud height. The moist air (relative humidity > 60%) is a precondition for the observed cloud formation. Bakalova and Bakalov[5] suggested that the response of cloud appearance to the change of meteorological conditions such as relative humidity, temperature, pressure, wind speed, etc. is practically immediate. Temperature, humidity and UV radiation should be measured at the same time because changes in the temperature and humidity may affect the UV radiation value by changing atmospheric conditions[5]. Therefore, UV radiation should be measured on the cloudless days. World Health Organisation (WHO) and the other organisations founded Intersun, a Global UV Project. Intersun aims to encourage countries to take action to reduce UV-induced health risks and to provide guidance to national authorities about the effective sun awareness programs[6]. However, the level of public awareness of the potential health effects of UV radiation can still be improved in Turkey. General public and especially young people intentionally tan outdoors and/or use sunbeds. Most of these young people have accumulated a higher UV dose and incidences of

UV-induced erythema are higher among them. Furthermore, large portion of tourists either from the EU countries or Commonwealth of Independent States (CIS) prefer both sunbed use and outdoor tanning in their summer vacations. The UV Index is a forecast of the probable intensity of erythemal UV radiation reaching the earth surface at solar noon (12:30–13:30 local daylight time). It informs the public of the level of UV exposure expected on a given day and reminds people to protect themselves when engaging in their normal outdoor activities. UV index values as given by the WHO, range from 1 to 11+ and are subdivided into different exposure categories: low (UV index 1 and 2, no protection required), moderate (UV index 3–5, protection required), high (UV index 6 and 7, protection required), very high (UV index 8–1, extra protection) and extreme (UV index 11+, extra protection)[6]. The incidence of non-melanoma skin cancer is annually increased 1–6% in the last 20 years. This increment varies with the exposure of solar UV light and the degree of skin pigmentation. Therefore, non-melanoma skin cancer is most common among fair-skinned whites lived in sunny districts[7]. 1 of 5 Americans will develop skin cancer in the course of a lifetime. In 1930, the lifetime risk of invasive melanoma was 1 of 1500 in the US. The risk in the US was determined 1 of 63 in 2007 and estimated 1 of 50 of 2010 for invasive malinoma[8]. In Europe, the melanoma incidence has been increasing over the past decades in Caucasian population[9]. The melanoma incidence standardised by age is varying between 0.6 and 14% per 100 000 and the highest incidence rate is recorded in the 20–30-year age. The UV exposure in childhood and long latent period of melanoma are blamed for this highest melanoma incidence among young adults. Furthermore, the significant increase in the level of UV-B depended on stratospheric problems was determined especially on clear weather in varies parts of Europe[10]. It is unfortunately difficult to identify the scientific skin cancer prevalence or incidence rates for the province of Aydin before 2003 because skin cancer data did not record properly before 2003 in Aydin. According to Izmir Cancer Registration Center, located in a neighbourhood city, malignant melanoma incidence was 0.8% (for both sexes) per 100 000 in 1994. Furthermore, the incidence of non-melanoma skin cancer in 1994 was reported on 8.8% (female) and 11.5% (male) per 100 000 in Izmir, Turkey[11]. The incidences of skin cancer in Aydin (for both sexes) were reported on 3.1 and 6.7% per 100 000 in 2003 and 2005, respectively. At that time period, the incidence of skin cancer in Turkey was 5.3 and 8.3% per 100 000, respectively. During the national cancer week (April 1–7, 2009), the Ministry of Health of Turkey reported that the prevalence of skin cancer was 16.67% per 100 000 and the skin cancer is 4th most commonly diagnosed cancer in Turkey. However, the skin cancer incidence rate has increased dramatically in Aydin and has become the most common type of cancer in Aydin since 2004 (Ref. 12). The Aydin province has a typical Mediterranean climate with mild winters and hot summers, providing a long tourist season. Domestic and foreign tourists are in high demand for sea and

sun tourism in addition to visiting historic places throughout the province. First tourism movement in Turkey was started in Kusadasi, Aydin and many summer homes has been built since the 1980's in the province. Thus, Kusadasi and Didim become famous summer seaside resort towns. Recently, tourists and summer-home owners are started to demand information about the environmental issues such as UV index, electromagnetic radiation levels, air quality levels, etc. and they request to be informed on the health effect of these issues.

EXPERIMENTAL

Study area and population. The area of this study was in the Aydin province, Turkey (37–38°N latitudes), with a total population about 1 million in 2007. The summer population of Aydin is almost twice of this population because the summer homes are first located at the coast of Aydin in Turkey. Also two worldwide famous summer seaside resort towns, Kusadasi and Didim, are situated in the province. Therefore, many tourists come to the province for summer vacation. Also, mostly the UK citizens bought second home in these resort towns and stay at either during the summer season or all year long. Furthermore, most families from the Aydin province have summer homes in these two resort towns and prefer to stay at their summer home during all summer season.

Measurements and data collection. All UV, humidity and temperature measurements were performed in two locations on the coast (Kusadasi and Akbuk/Didim) and two locations in the city of Aydin (University campus and downtown) at an altitude of 64 m a.s.l. The study was performed around 1.5 year from March 2007 to August 2008. Data were collected for a week in cloudless days between 8.00 a.m. and 8.00 p.m. The study was approved by the Ethical Committee of Adnan Menderes University, Aydin, Turkey. 501 A UV biometers (Solar Light Company, Glenside, PA) were used to collect UV-B data (Fig. 1*a*). This broad-band radiometer (290–320 nm) measures the erythemal dose of solar radiation as the human skin can respond to UV in several ways: UV-erythema, ageing, DNA damage, etc. The temperature and humidity measurements were recorded during the UV recording by using a Lutron (Model HD-3008, Taiwan) hygrometer (Fig. 1*b*). All equipments which were calibrated by manufacturer were used for the first time in this study and did not need any further calibration. Furthermore, all measurements were performed on the roof either of summer homes or university buildings. A questionnaire was performed during the study in the main campus of Adnan Menderes University, Aydin. 60 questionnaires were distributed to receive a response from 48 university students. Participation (26 men and 22 women; 20.2±1.4 years) was on a voluntary basis and a written informed consent was filled out. Subjects were determined among the students of Adnan Menderes University.

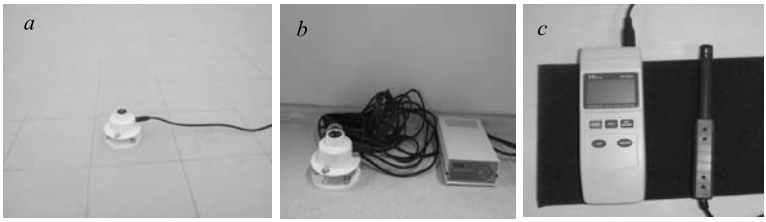

Fig. 1. Measurement equipments: 501 A UV biometers during measurements and experimental settings and a Lutron hygrometer

Convertion of MED/h to UV index. The biological effectiveness of the UV exposure is measured in MED/h (minimum erythema dose per hour) where the amount of sun exposure which causes barely perceptible skin sunburn redness is considered. Therefore, 1 MED/h would cause minimum redness of the average skin after an hour irradiation. For a MED scale factor of 1.0, a dose rate of 4.3 MEDs per h is equivalent to an UV Index of 10. Stated other way, the base MED rate is 3/7 of the UV index value[13]. In this work, MED/h values were converted to UV index.

Questionnaire survey. The questionnaire was designed to cover the tanning habits, sun protective behaviour, cognitive aspects and background information about UV radiation. Outdoor tanning habits, sunbed use, skin type, self-reported health problems related to solar exposure and harmful effects of UV exposure were questioned in this survey.

Statistical methods. Data were analysed using GraphPad Instat version (San Diego California USA). One-way analysis of variance (ANOVA) followed by Tukey Comparison test was performed to evaluate measurements variables. Data were expressed as the mean ± standard deviation and the significance level was defined as $p<0.05$.

RESULTS AND DISCUSSION

Table 1 shows the weekly mean of cloud-free daily values of UV index, temperature and humidity measurements at solar noon. There were statically significant differences in UV values between winter and other seasons ($p<0.001$) but no difference was determined among the UV measurements in spring ($p>0.05$). Also, UV measurements at summer were statistically different from that of autumn and spring measurements ($p<0.05$). In the coastal resort towns, the UV indices were recorded to be higher than that of measured in the city of Aydin (Table 1). The distributions of daily MED/h values are shown in Fig. 2. Solar noon time was determined around 2.00 p.m. at Kusadasi, Aydin on August 11, 2008. Therefore, considerable deviations between true solar time and standard local time were recorded in this study.

Table 1. Weekly means of cloud-free daily values of UV index, temperature and humidity measurements at solar noon for each location

Season	Location/period	UV index			Temperature (°C)	Humidity (%)
		mean±sd	median	maximum		
Winter	University campus, February 13–19, 2008	2.09±0.64	2.39	2.64	11.89±4.36	22.60±7.86
Spring	University campus, April 7–13, 2008	6.30±2.64	7.39	8.74	25.94±5.68	21.86±6.99
Spring	downtown of Aydin, March 26-Apr1, 2007	5.52±0.23	5.56	5.84	26.50±1.54	33.10±9.95
Spring	coast of Kusadasi, May 28–Jun 2, 2007	6.01±1.19	6.44	7.58	52.09±3.48	44.99±10.87
Summer	coast of Didim, July 26–August 1, 2007	6.95±0.65	6.81	8.19	35.76±2.59	46.00±2.77
Summer	coast of Kusadasi, August 8–12, 2008	8.63±0.44	8.54	9.24	53.79±2.75	54.83±4.53
Autumn	downtown of Aydin, October 15–21, 2007	5.15±1.28	4.80	7.49	27.03±3.73	34.77±9.37
Autumn	coast of Kusadasi, September 14–20, 2008	6.49±1.04	6.44	8.07	35.23±1.65	36.80±5.26

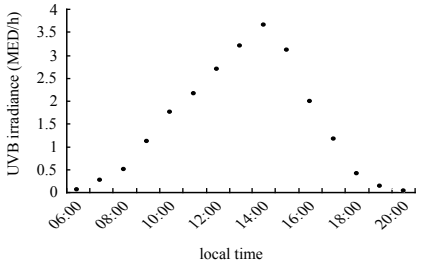

Fig. 2. Solar UVB irradiation at Kusadasi, Aydin on August 11, 2008

The correlations were found between the mean values of temperature and humidity and the value of UV index in summer time ($p<0.05$). This correlations were not statistically significant in late autumn, winter and early spring ($p>0.05$). The questionnaire showed that 29% of participants spent their summer vacation at seaside resort towns and 54.2% of them stay at their hometown, mostly placed near the seaside. The participants spent approximately 27 days of their summer vacation at the seaside towns. They usually go to the seashore around 12:00 (range 06:00 to 17:20) and stay 2.5±1.4 h/day. The participants also reported frequent outdoor tanning in their summer vacations (3.6±1.5 h/day). The ratios of brunette, blonde and light-brown subjects among the participants were 34, 27.7, and 29.8%,

respectively. Also 17% of participants have more than one nevus on their body. The 87.5% of the participants use sun protective methods and their sun protective behaviour is expressed in Table 2. 50% of participants have some information about the UV radiation. However, 89.6% of the subjects thought that they have a lack in information about the harmful effects of solar UV radiation.

Table 2. Sun protective behaviour of participants

	Behaviour	*n*	%
Protective methods	sunscreen	21	72.4
	hat and sunscreen	2	6.9
	hat and sunglass	2	6.9
	others (clothing, sunglass, hat, etc.)	4	13.8
Selection criteria of protective methods	quality	21	31.3
	degree of protection	17	25.4
	brand mark	11	16.4
	price	5	7.5
	quality and brand mark	6	9.0
	quality and degree of protection	5	7.5
	others	2	2.9
Information source on protective methods	prescription	11	24.0
	medical personnel	10	21.7
	salesman	10	21.7
	person who used the product before	9	19.6
	media	6	13.0

Thieden et al.[14] described the UV exposure pattern during the winter half year and compare it with summer half year in Denmark. They suggested that UV precautions are not needed from November to February to latitudes above 45°N in southern Europe, while precautions are necessary the whole year around at lower latitudes[14]. The monthly mean of cloud-free daily values of ultraviolet erythemal solar radiation (UVER) at solar noon from November to February was approximately 5 times lower than that of June which was the highest value on the stations of the Catalonian and Valencian networks[15]. In this study, the highest UV radiation was recorded in the beginning of August at the coast of Kusadasi, Aydin (latitude of 37°52.2′N and longitude of 27°15.0′E). UV radiation was measured higher in early autumn and late spring in the Aydin province. Therefore, outdoor workers need UV protection from February to November between 11:00 and 15:00. Martinez-Lozano et al.[16] measured UV index during the years 2000 and 2001 from the coastal and more densely populated regions on the Iberian Peninsula, and reported that maximum UV-B irradiance values corresponded to solar noon in the cloudless day with a maximum UV index value of 9 during the summer. Marin et al.[15] measured the UV index on the Spanish Mediterranean coast (latitude, between

38°N and 42°N) during 2003 and showed the latitudinal and altitudinal effects on the UVER. When the UV index levels were analysed in the number of cities in Australia and United Kingdom, the geographic locations of the cities (latitude and altitude) were determined as important parameter for the evaluation of UV index[17]. Measurement locations were close to latitude and longitude (latitude of 37°N and longitude of 27°E) of the Aydin province, therefore latitudinal and longitudinal effects on UV measurements were not observed in this plot study.

In most places in Europe and Turkey there are considerable deviations between true solar time and standard time because standard time in these countries is set 1 h ahead according to daylight saving time during the summer. Also there is a nearly 1 hour and 36 min time differences between standard time and solar time of the countries in Western and Central Europe using Central European summer time due to their geographic location[18]. In Turkey, Eastern European time, 2 hours ahead of coordinated universal time (UTC), is used during the winter and Eastern European summer time (UTC+3) is used during the summer. The shift between standard time and true solar time adds up to about 2 h in August at the coastal resort town of Kusadasi, Aydin. Therefore, UV exposure values were recorded higher around 14:00 rather than 12:00 at this location in summer season. Dermatologists and public health personnel usually recommend people to take precautions against the UV radiation around noontime in summer[19]. But the true solar time with the geographical and astronomical parameters in that location should be considered for the evaluation of UV radiation. Time of day, season, geographical latitude, clouds, surface reflection and altitude are the factors affecting solar UV radiation[20]. Aerosols also affect solar UV radiation on the earth surface. Our data suggested that there are significant correlations among the temperature, illumination and UV-B radiation at solar noon time ($p<0.05$) in summer. The highest mean of illumination and temperature was recorded at solar noon with a highest UV index value of 9.24. Coogan et al.[21] reported that 76.3% of all Caucasian students in Connecticut, USA were using sun protection methods and that the use of sun protection was inversely related to age and was higher among girls than boys at all ages[21]. Ermertcan et al.[22] observed that avoiding sun exposure during peak hours (42.5%) and wearing sunglasses (50.7%) was the most popular sun prevention behaviour for men and women, respectively, among the students and personnel of Celal Bayar University, Manisa, Turkey. We observed that the use of sunscreen (43.8%) as a sun protective method was highest among the young people. However, most of the participants affirmed that they have a lack in information about UV radiation and protective measures. The research of tanning habits and sunburn in Swedish population suggested that adolescents and young adults were most highly exposed to UV radiation because of their outdoor activities and sunbed use[23]. Chronic exposure to UV radiation with the blistering sunburn sites, especially during childhood and adolescence, increases the risk of skin cancer, particularly squamous cell cancer[24].

We observed that participants in this study spent around 6 h in outdoor activities during the hours with the highest erythemal effective irradiance and almost half of them have no knowledge about the UV radiation and its harmful effects. Around 9% of participants affirmed that they had sun-related health problem such as advance sunburns, conjunctivitis, etc. These results induced us thinking that most of the participants did not recognise sunburns as a health problem. Therefore, the occurrences of sunburn with or without blisters should be reduced by altering sun protective behaviour and promoting sun awareness as a conceptual norm from an early age. Turkish State Meteorological Service is responsible for observing ozone and UV radiation, also research activities have been carried out by Meteorology Service. The UV-B has been measured with an UV-B recorder (Model 501) in 2 locations, Ankara (39°97′N, –32°86′E) and Antalya (located on the southern coast of Turkey and at 54 m altitude, 30°44′ (E) longitude and 36°42′ (N) latitude) since 1997 (Ref. 25). However, UV-biometric measurements of Antalya were over in 2003. In Ankara, the range of UV-B radiation in July between 1997 and 2005 was 556 and 630 MED and their mean value was determined as 601 MED. In Antalya, the range of UV-B radiation in July between 1997 and 2003 was determined as 634 and 732 MED and their mean value was 793 MED. In another study, monthly UV-B radiation was measured in Ankara between November 2006 and September 2008. In this study, the highest UV indices were recorded as 5 in July and August in Ankara[25]. In addition to UV-biometer measurements, Brewer spectrophotometers were recently used to observe UV measurements at 10 stations in Turkey. However, UV radiation has not been measured in the Aydin province before our study. Turkish State Meteorological Service plans to make UV index forecast routinely for the period of 2008–2011 in Turkey.

CONCLUSIONS

Our study has some methodological limitations. The measurements were performed only in 4 locations and data were collected around two times in every season. The sample size of questionnaire was smaller and selected students. It should be accepted that this research was an initial effort to collect a variety of types of information about an unstudied area (in terms of solar exposure and skin cancer prevention). It suggested that the highest UV level during a day is different from 12:00 p.m. during all seasons in the Aydin province. Most of the participants reported that they have not enough knowledge about the harmful effects and precautions against UV radiation. They did not recognise the importance of UV index.

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