SPANDIDOS PUBLICATIONS

Ultraviolet light exposure influences skin cancer in association with latitude

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Abstract. The increase in the amount of solar ultraviolet (UV) light that reaches the earth is considered to be responsible for the worldwide increase in skin cancer. It has been reported that excessive levels of UVA and UVB light have multiple effects, which can be harmful to humans. Experimental measurements were obtained using wide-band solar light YES biometers from 2006 to 2009 in Arica, Chile and from 2003 to 2006 in Valdivia, Chile, both instruments having been calibrated according to the World Health Organization (WHO) criteria and integrated into the Chilean Meteorological Organization network. To explain the possible effect of radiation on skin cancer, revised pathological reports in Arica and Valdivia were analyzed. In Arica, data on men and women were collected between 1997 and 1998-2002, and in Valdivia, between 1997-2000 and 2001-2007. In this study, comparative values of ultraviolet index (UVI) from the above datasets, were analyzed. Arica is a city located in the subtropical zone of northern Chile, 25 meters above sea level, with a latitude of 18˚49'S and a longitude of 70˚19'W. It has a microclimate characterized by stable meteorological conditions throughout the year, including low precipitation (<5 mm per decade), predictable winds, a high percentage of clear sky days and high ground reflectivity due to the presence of light sand. Due to its location near sea level, the population performs a great number of outdoor activities. Valdivia is a city located in the southern part of Chile, 19 meters above sea level with a latitude of 39˚38'S and a longitude of 73˚5'W. The aim of the present study was to determine the relationship between latitude and the risk of skin cancer in two cities with different latitudes. The incidence of skin cancer per 100,000 persons significantly ($P<0.05$) increased in both genders between the periods 1997-2000 and 2001-2007 in Arica. However, it decreased in men between the periods 1993-1997 and 1998-2002 in Valdivia. The results of this study indicate a steady increase in the incidence of skin cancer in Arica, most probably due to the high levels of UV light and the latitude to which individuals are exposed throughout the year, as well as the accumulative effect of this type of radiation on the skin. It can be concluded that Arica presented a greater UVI than Valdivia, which can explain the high prevalence of skin cancer in this population according to the pathological reports.

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Introduction

The increase in the amount of ultraviolet (UV) light that reaches the earth due to the destruction of the ozone layer is considered to be responsible for the worldwide increase in skin cancer. For physical and biological reasons, UV light has been divided into three regions: UVA (320-400 nm), UVB (290-320 nm) and UVC (100-290 nm). UV light has very high energy, and although human exposure to UV radiation causes a few beneficial health effects such as vitamin D3 formation, it causes many detrimental health effects such as sunburn, ocular damage, photoaging, immune suppression and skin cancer (1). Ozone depletion, the level of UV light, elevation, latitude, altitude and weather conditions influence the emission of UV radiation reaching the surface of the earth. Skin cancer has been associated with prolonged exposure to UVB. It has been reported that excessive levels of UVA and UVB lights have multiple effects, which can be harmful to humans (2-9). The amount of light that reaches the earth is strongly dependent on the ozone layer, with absorption increasing with shorter wavelengths. UVA light has high atmospheric transmission (3), while short-wavelength UVC light is completely absorbed and does not reach the surface of the earth (9). Solar UVB light (290-320 nm) has multiple effects that can be harmful to humans. Even if a small amount of UVB light reaches the surface of the earth, it can be the most dangerous of the UV light types (3). The risk of skin cancer varies with altitude, latitude and skin pigmentation, which are all modified by overexposure to UV light (3). As the incidence of skin cancer in fair-skinned individuals is increasing at an alarming rate each year around the world, it is important to know the UV doses that people around the world are exposed to throughout their lives. In countries with fair-skinned populations, skin cancer is the most diagnosed

of all cancers. It has been reported that in the United States there were over one million new skin cancer cases in 2002 (10). UV doses increase with increasing altitude and decreasing latitude. It is estimated that most indoor-working adult Europeans are exposed to 10,000-20,000 J/m^2 per year, Americans to 20,000-30,000 J/m^2 per year and Australians to 20,000-50,000 J/m^2 per year (excluding vacation, which can increase the dose by ≥30%). The outdoor UV doses are weighted for different biological effects, the time that people spend outdoors, their ambient exposures and the terrestrial and personal UV doses of adult outdoor and indoor workers as well as children and adolescents around the world.

Hu *et al* found that exposure to solar radiation plays a role in the development of melanoma in both Hispanics and blacks (11). For both Hispanics and blacks, the incidence of melanoma was positively associated with the ultraviolet index (UVI) and negatively associated with the latitude of residency. Hispanics and blacks have a significantly lower incidence of melanoma than whites, with blacks having the lowest rates of melanoma. Eide and Weinstock estimated the association between UVI, latitude and melanoma incidence in different racial and ethnic populations in a national data set and they found that the incidence of melanoma was associated with increased UVI and lower latitude only in non-Hispanic whites (12). There was no evidence to support the association of UV exposure and melanoma incidence in black or Hispanic populations. They presented data from 11 United States cancer registries on patients with malignant melanoma of the skin reported between 1992 and 2001. A statistical analysis of the relationship of age-adjusted melanoma incidence rates (2,000 US standard population) with the UVI or latitude within racial and ethnic groups, was carried out. They showed a higher mean UVI that was associated with an increase in melanoma incidence only in non-Hispanic whites, although a non-significant association was noted in Native Americans and negative correlations with incidence were observed in blacks, Hispanics and Asians (12). Latitude also had a significant correlation with incidence only in non-Hispanic whites. A substantial portion of the variance in registry incidence in non-Hispanic whites could be explained by the UVI. They concluded that melanoma incidence was associated with increased UVI and lower latitude only in non-Hispanic whites. However, there was no evidence to support the association of UV light exposure and melanoma incidence in black or Hispanic populations.

It is known that recreational sun exposure and sunburn are strong predictors of melanoma at all latitudes, whereas measures of occupational and total sun exposure appear to predict melanoma predominately at low latitudes. Grant investigated the risk variation by tumor site and latitude and found that melanoma risk was related to sun exposure (13). A pooled analysis of 15 case-control studies (5700 melanoma cases and 7216 controls) was performed, correlating patterns of sun exposure, sunburn and solar keratoses with melanoma risk. The results indicated that recreational sun exposure was a risk factor for melanoma on the trunk and limbs, but not on the head and neck at various latitudes. Occupational sun exposure was associated with the risk of melanoma on the head and neck at low latitudes. Total sun exposure was associated with the increased risk of melanoma on the limbs at low latitudes, but not on other body sites or at other latitudes. Sunburn in children associated with melanoma on the trunk, limbs, and head and neck showed little variation across latitudes. It was also reported that the presence of head and neck solar keratoses was associated with the increased risk of melanoma on the head and limbs.

Ionizing radiation, environmental pollutants, chemical carcinogens and work-related exposures have been associated with skin cancers. Exposure to artificial UV radiation (tanning beds and lamps), aging, skin color, diet and smoking are considered important risk factors. Consequently, the interest in the prevention of sun overexposure is increasing, as is the knowledge of photo-protection methods and radiation levels. The UVI is a well-known tool recommended by the World Health Organization (WHO) to avoid the harmful effects of UV sunlight. UVI forecasts are provided by many national meteorological services, but local UVI measurements can provide a more realistic and appropriate evaluation of radiation exposure levels.

Ultraviolet radiation exposure, latitude and skin cancer are important factors to analyze. In this study, comparative UVI values from Arica and Valdivia were considered. Arica is a city located in the subtropical zone of northern Chile, 25 meters above sea level, with a latitude of 18˚49'S and a longitude of 70˚19'W. It has a microclimate characterized by stable meteorological conditions throughout the year, including low precipitation (<5 mm per decade), predictable winds, a high percentage of clear sky days and high ground reflectivity due to the presence of light sand. Due to its location near sea level, the population performs a great number of outdoor activities. Valdivia is a city located in the southern part of Chile, 19 meters above sea level with a latitude of 39˚38'S and a longitude of 73˚5'W. The aim of the present study was to determine the relationship between latitude and the risk of skin cancer in two cities with different latitudes.

Materials and methods

A national UV network exists in Chile that informs the population regarding the daily value of UVI from the city of Arica to Antarctica. Experimental measurements from Arica were obtained using a wide-band solar light biometer YES between 2006 and 2009. Experimental measurements from Valdivia were obtained by using a wide-band solar light biometer YES from 2003 to 2006. UVI measurements were classified according to the WHO parameters. Both instruments were calibrated according to the regulations of the World Meteorological Organization (WMO) and to an agreement with Tarapacá University and the Chilean Meteorological Organization (Dirección Metereológica de Chile, DMC) UV network. To explain the possible effect of radiation on skin cancer, revised pathological reports were analyzed in men and women from Arica and Valdivia, Chile. In Arica, data were collected between the periods 1997-2000 and 2001-2007, and in Valdivia between 1993-1997 and 1998-2002.

Results

In the present study, we investigated the characteristics of UV light in relation to skin cancer in populations from Arica and

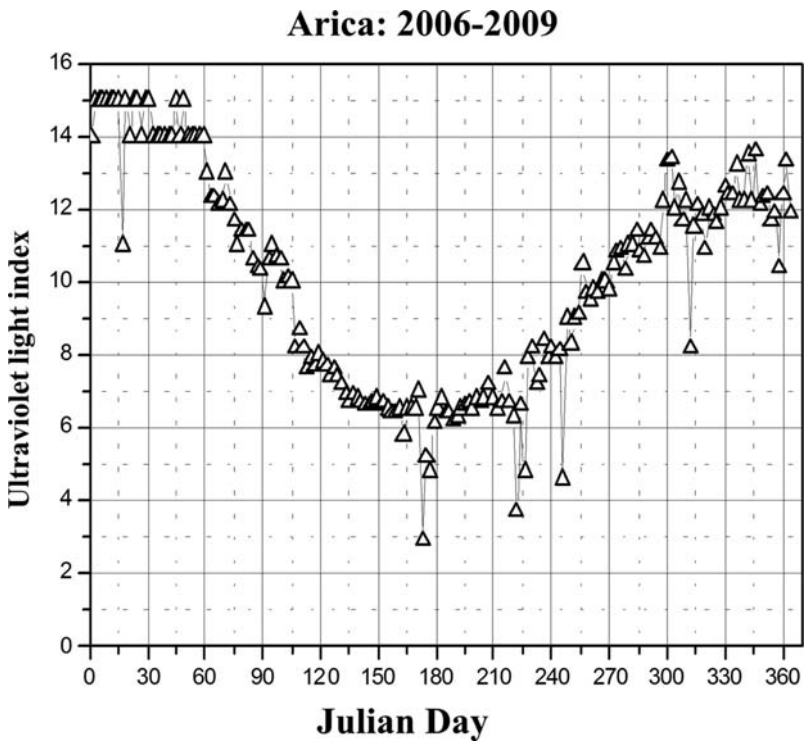

Figure 1. Daily mean values of ultraviolet solar light index (UVI) obtained between 2006 and 2009 in Arica.

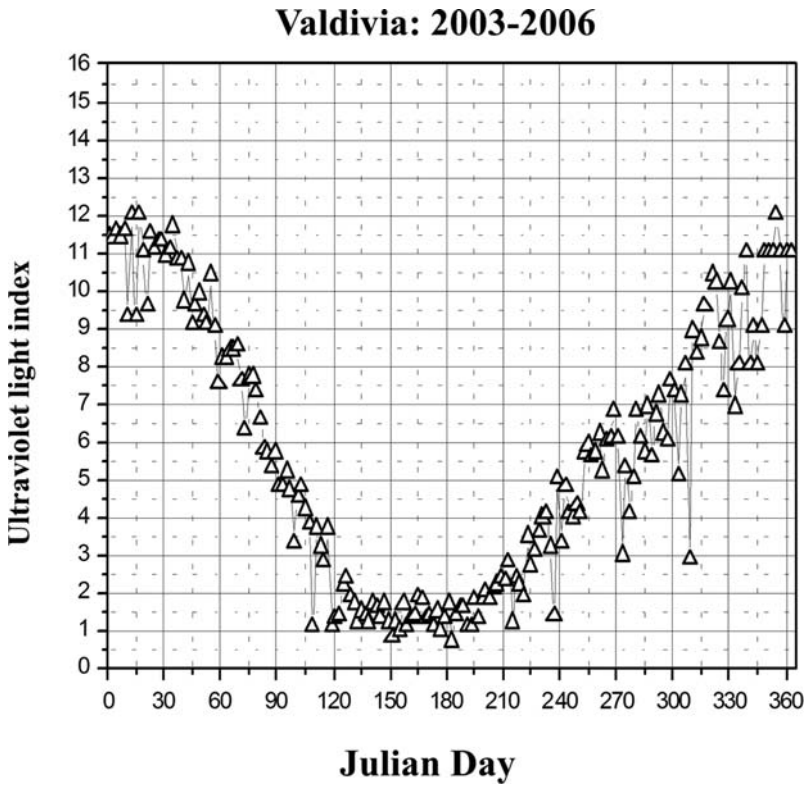

Figure 2. Daily mean values of ultraviolet solar light index (UVI) obtained between 2003 and 2006 in Valdivia.

Valdivia, Chile. In this study, comparative values of UVI were considered to explain the possible effect of radiation on skin cancer in pathological reports from men and women. Figs. 1 and 2 show the daily mean values of UVI obtained from 2006-2009 in Arica, and from 2003-2006 in Valdivia. The UVI fluctuated from 6-15 between 2006 and 2009 in Arica. However, the UVI fluctuated from 1-12 between 2003 and 2009 in Valdivia. Fig. 3 corresponds to the quotient of

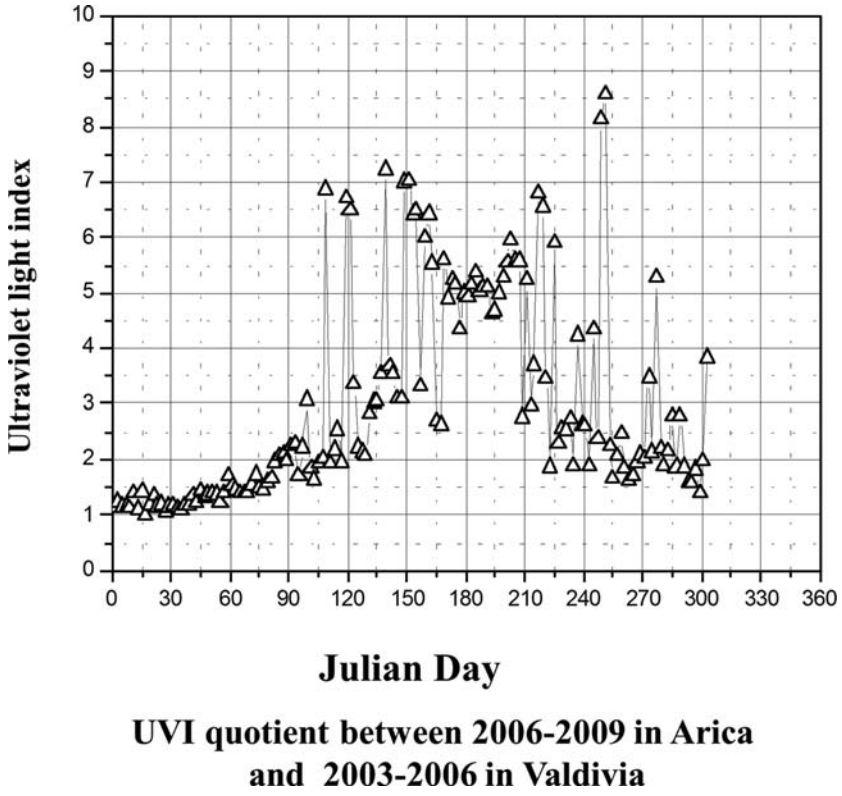

Figure 3. Quotient of maximum mean daily values of ultraviolet solar light index (UVI) obtained between 2006 and 2009 in Arica and between 2003 and 2009 in Valdivia.

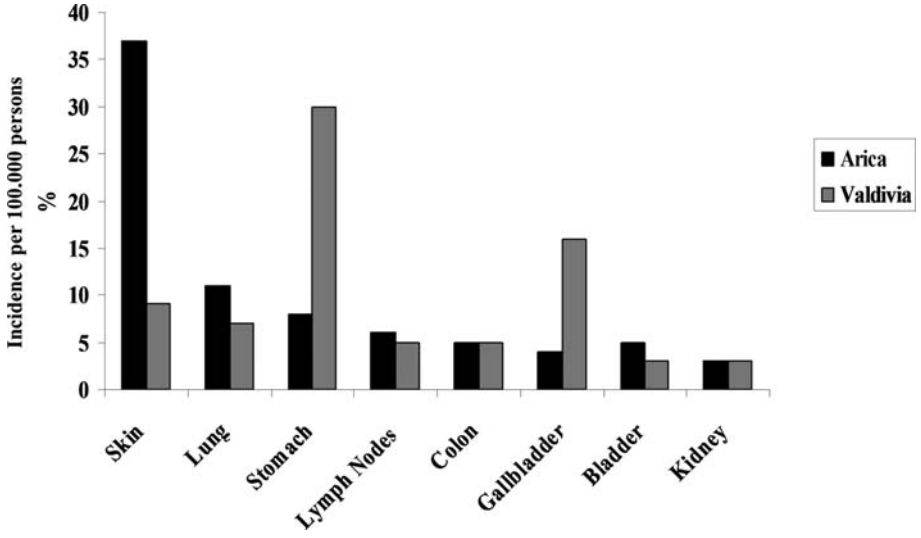

Figure 4. Incidence of several types of cancer registered in Arica and Valdivia. Data show the percentage of cases per 100,000 persons.

maximum mean daily experimental values of UVI obtained between 2006-2009 in Arica and 2003-2006 in Valdivia, where the maximum quotient values were observed during the winter period. In Arica, cancer data were collected between the periods 1997-2000 and 2001-2007, and in Valdivia between the periods 1993-1997 and 1998-2002. When the distribution of several types of cancer was compared between Arica and Valdivia, the results showed that the incidence of skin cancer in Arica per 100,000 persons was the highest among other types, as shown in Fig. 4. Other types of cancer analyzed were lung, stomach, lymphatic nodes, bile ducts, colon, bladder and kidney, being 37% in Arica and only 9.1% in Valdivia.

The incidence of the different types of skin cancer found in both cities is shown in Fig. 5. It can be seen that basocellular (69%) and espinocellular (28%) carcinomas, and melanomas (3%) were more predominant in Arica than in Valdivia (45%, 43% and 11 %, respectively. Fig. 6 shows the distribution of the different types of skin cancer in both cities in relation to gender. It can be seen that basocellular carcinoma

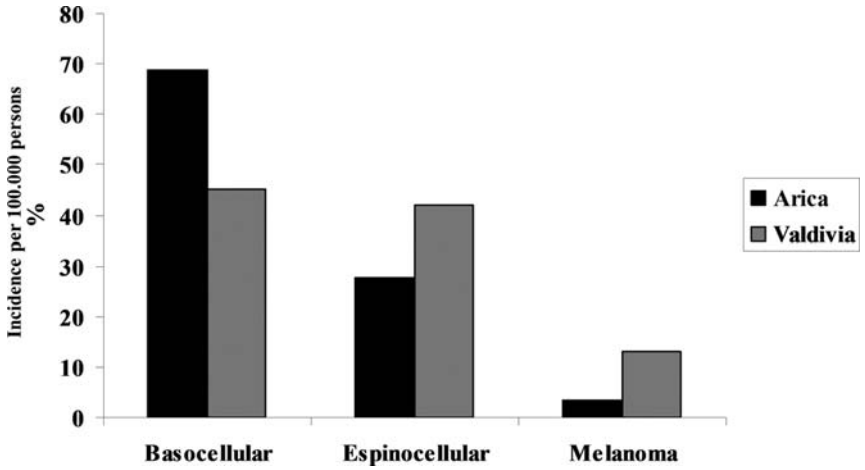

Figure 5. Incidence of several types of skin cancer registered in Arica and Valdivia. Data show the percentage of cases per 100,000 persons.

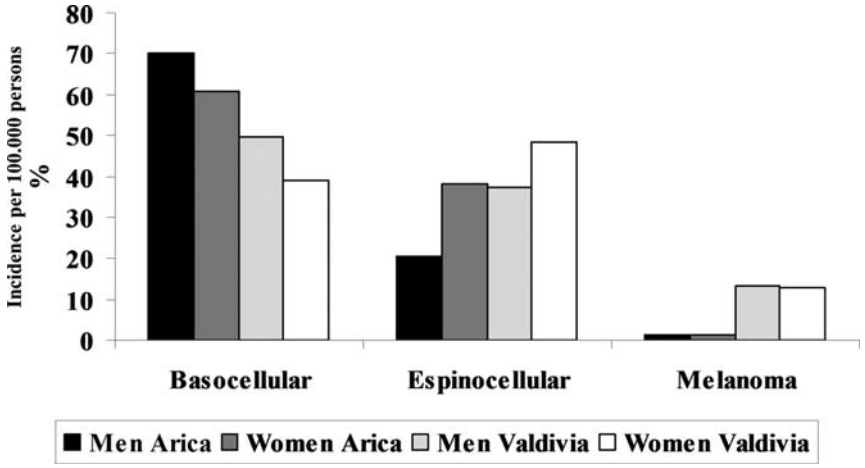

Figure 6. Incidence of skin cancer registered in Arica and Valdivia in relation to gender. Data show the percentage of cases per 100,000 persons.

was more predominant in men (70%) in Arica than in Valdivia. However, espinocellular carcinomas and melanomas were higher in women in Valdivia than in Arica, whereas melanomas were frequent in Valdivia. Fig. 7 shows an increase in the incidence of skin cancer between 1997-2000 and 2001-2007 in men and women in Arica (Fig. 7A) and a slight increase in women between 1993-1997 and 1998-2002 in Valdivia and a decrease in men between 1993-1997 and 1998-2002 (Fig. 7B). It can be concluded that Arica received greater UV than the rest of the country. Arica has registered the highest values of UVI in comparison to Valdivia, thus explaining the high prevalence of skin cancer in that population.

Discussion

It is known that skin cancer is the most common type of cancer affecting fair-skinned populations around the world. The incidence and mortality rates of skin cancer are dramatically increasing and thus pose a threat to public health. Understanding the etiology and pathogenesis of skin cancer is important. In the present study, we examined skin cancer in relation to the maximum mean daily values of UVI obtained from Arica and Valdivia. The quotient of maximum mean daily values of UVI obtained from these two cities gave an indication that latitude played a role in the incidence of skin cancer. The average maximum daily value of UVI was determined based on the experimental measurements taken using the calibrated instruments. The results indicate a steady increase in the incidence of skin cancer in Arica, Chile. Very high levels were noted throughout the year due to the subtropical location of this city, which has a microclimate with a high number of clear sky days and it is also a desert adjacent to the Pacific ocean, causing ground reflectivity. However, Valdivia presented the lowest UVI levels, especially in winter, in comparison to Arica.

Skin cancers have been found in dermatoses and various types of keratoses, chronically injured or non-healing wounds and scars. In the present study, we analyzed the incidence of skin cancer in Arica and Valdivia according to pathological type and gender. Pathological reports of skin cancer indicated the possible effects of latitude in relation to radiation in these two cities. A greater percentage of basocellular carcinomas were found in Arica than in Valdivia, being more common in

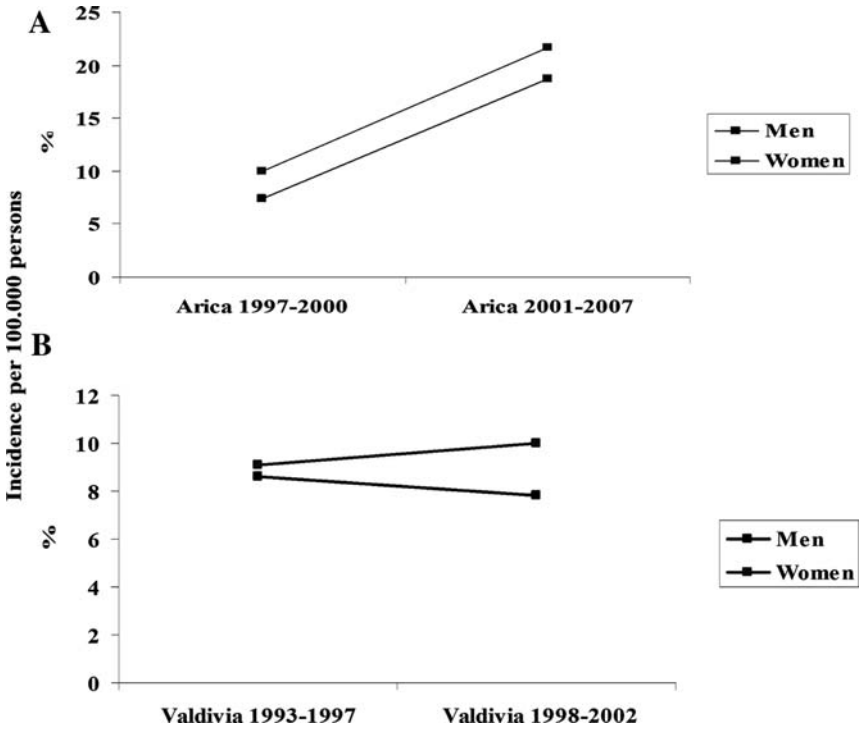

Figure 7. Incidence of skin cancer registered in Arica and Valdivia in relation to gender. In Arica, data were collected between 1997-2000 and 2001-2007, and in Valdivia between 1993-1997 and 1998-2002 Data show the percentage of cases per 100,000 persons.

men than women, whereas espinocellular carcinomas and melanomas were higher in Valdivia than in Arica. The results of this study also indicate a steady increase in the incidence of skin cancer in Arica, most probably due to the high levels of UV light to which individuals are exposed throughout the year, as well as the cumulative effect of this type of radiation on the skin. Therefore, skin cancer incidence increased from 7.4-18.7 in men and from 10.0-21.7 in women in Arica between the periods 1997-2000 and 2001-2007. However, skin cancer incidence in Valdivia was 8.9 between 1993-1997 and 1998-2002 and was similar between men and women.

Recreational sun exposure and sunburn are strong predictors of melanoma at all latitudes, whereas measures of occupational and total sun exposure predict melanoma predominately at low latitudes. Grant investigated risk variation by tumor site and latitude (13). Melanoma risk was related to sun exposure. A pooled analysis of 15 case-control studies (7216 controls and 5700 melanoma cases) was performed, correlating patterns of sun exposure, sunburn and solar keratoses with melanoma risk. The results indicated that recreational sun exposure was a risk factor for melanoma on the trunk and limbs, but not on the head and neck at various latitudes. Occupational sun exposure was associated with the risk of melanoma on the head and neck at low latitudes. Total sun exposure was associated with the increased risk of melanoma on the limbs at low latitudes, but not on other body sites or at other latitudes. Sunburn in children associated with melanoma on the trunk, limbs, and head and neck showed little variation across latitudes. As the presence of head and neck solar keratoses was associated with the increased risk of melanoma on the head and limbs, it was concluded that melanoma risk at different body sites was associated with different amounts and patterns of sun exposure. It has been reported that melanoma risk at different body sites is associated with different amounts and patterns of sun exposure (14).

As shown by Krishnamurthy, ultraviolet light from sunlight is implicated in the etiology of non-ocular malignant melanoma (15). Krishnamurthy reported the relation of such melanomas from seven cancer registries in different parts of India with latitude, altitude, ozone levels and ultraviolet (UV) light exposure. The results showed slight negative associations of melanoma with latitude, and statistically non-significant ones with atmospheric ozone levels, and a positive association with UV. Melanoma incidence from four places was related in a parabolic curve with latitude. The geographical patterns of melanoma in Indians are similar to those in white Caucasians. Ultraviolet light exposure could also be involved in the incidence of skin cancer in non-white Caucasians, such as Indians.

Lee and Scotto found that linked temporal and latitude changes rise in the incidence of and mortality from melanoma of the skin and they found that this is slowing down in younger age groups in the United States (16). In many white populations, including those of the United States, melanoma incidence and mortality rates increased according to proximity of residence to the equator. Variations with age in this gradient do not seem to have been examined. They examined the influence of latitude on melanoma rates and found that it varied with age and found a decline from old age to youth in the influence of latitude for both the incidence of and mortality from melanoma of the skin in men, and for mortality in women. Furthermore, these changes in the relationship to latitude with age correlated with the changes in time trends with age. The link with exposure suggests that the time trends in melanoma are driven by variations in damage to

tes during the early year of life which increases y to sunlight. This has implications for the general understanding of melanoma etiology and for health education. The relationship between tumor incidence rate and habitation patterns was investigated by Eklund and Malec in 3289 patients registered between 1959 and 1968 as cutaneous malignant melanoma in the Swedish Cancer Registry (17). They studied the light and incidence of cutaneous malignant melanoma and the effect of latitude and domicile in Sweden. A linear correlation analysis between latitude and melanoma incidence rate in various regions showed a decreasing incidence with increasing latitude. This result supports the hypothesis that ultraviolet irradiation is the predominant cause of melanoma. However, considerable deviations from the regression line were seen in certain regions. Moreover, a comparison between town and country indicated that melanoma incidence increased with population density, an increase not explained by over diagnosis and thus not in agreement with the working hypothesis of UV-irradiation as the predominant cause of melanoma.

Our previous study showed that the basocellular and espinocellular carcinomas among the malignant skin tumor types were more common in men (44.4 and 16.6%, respectively) than in women (24.9 and 10.7%, respectively) (19). Basocellular carcinoma was observed in individuals between 40 and 79 years of age. The incidence of skin cancer significantly increased between 2000 and 2006 per 100,000 persons. The factor of incidence of skin cancer per 100,000 populations significantly increased between 1980 and 2000 in both genders, but was higher in men (0.79-1.99) than in women (0.63-1.56). The results of this study indicate a steady increase in the incidence of skin cancer in Arica, Chile, most probably due to the high levels of ultraviolet light to which individuals are exposed throughout the year, as well as the cumulative effect of this type of radiation on the skin.

Acknowledgements

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