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Occupational Exposure to Natural UV Radiation and Premature Skin Ageing

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The skin is the part of the human body most vulnerable to ultraviolet (UV) radiation. The spectrum of the negative effects of UV radiation on the skin ranges from acute erythema to carcinogenesis. Between these extreme conditions, there are other common skin lesions, e.g., photoageing. The aim of this study was to assess the skin for signs of photoageing in a group of 52 men occupationally exposed to natural UV radiation. There were 2 types of examinations: an examination of skin condition (moisture, elasticity, sebum, porosity, smoothness, discolourations and wrinkles) with a device for diagnosing the skin, and a dermatological examination. The results of both examinations revealed a higher percentage of skin characteristics typical for photoageing in outdoor workers compared to the general population.

UV radiation   outdoor workers   photoageing

1. INTRODUCTION

When natural sunlight reaches the surface of the earth, it is in the range of electromagnetic radiation of 100–4000 nm [1]. It consists of visible light (380–760 nm), and infrared (760–4000 nm) and ultraviolet (UV) radiation (100–380 nm), which consists of three main wavebands: UVC (100–280 nm), UVB (280–315 nm) and UVA (315–380 nm). UVC radiation practically does not exist on the surface of the earth, like 90% of UVB radiation. Therefore, the environment is mainly exposed to UV radiation in the range of 290–400 nm, i.e., UVA and partly UVB. Among all components of solar radiation, UV radiation has the greatest impact on the human body. The skin is very sensitive to UV radiation [2]. Its biological effects on the skin include both early reactions like erythema and sun burn, and long-term consequences associated with damage of the skin at the molecular and biochemical levels, including preneoplastic lesions, neoplasms and the most frequent change, i.e., premature skin ageing [3]. Since the skin is exposed directly to the destructive activity of external factors, it usually ages faster than the other organs of the human body; moreover, the effect of this process is more visible. Skin ageing, like ageing of the whole body, runs concurrently. Physiological (intrinsic) ageing is time-related; it is sometimes referred to as chronological ageing. At the same time, there is extrinsic ageing, which depends on environmental factors. Among the extrinsic factors, UV radiation is recognized as the most harmful to the skin. It is believed that up to 80% of the signs of skin ageing result from chronic exposure to UV radiation. Skin ageing associated with UV radiation is known as photoageing [4, 5].

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The effects of extrinsic ageing are most evident on exposed parts of the body, e.g., the face, neck and shoulders. Signs of photoageing include thickening of the skin, dryness, roughness and keratosis. The production of collagen and elastin fibres is disturbed. Metalloproteinases, enzymes are produced by fibroblasts, which are normally responsible for regulation of skin regeneration. When exposed to UV radiation, they become overactive, which in turn leads to degradation of collagen fibres and, as a result, reduced skin firmness and deep wrinkles. On the other hand, elastin fibres become curled and deformed, which is called solar elastosis. Other clinical signs of photoageing include telangiectasias (dilated blood vessels), areas of hyper- and hypopigmentation (discolouration and decolouration of the skin) and an increase in the number of blackheads [6, 7, 8].

Until recently, it was mainly the UVB range that was considered responsible for early and late consequences of exposure to UV radiation. In recent years, an increasing use of artificial sources of solar energy in the UVA range both for medical treatment (phototherapy and photochemotherapy) and for cosmetic purposes (solaria) revealed a harmful role of this radiation in the pathophysiology of solar changes. The action of UVA radiation is slow and results from the accumulation of frequent subacute exposures. Due to its longest wavelength, over 50% of UVA radiation penetrates to the reticular and papillary layer of the dermis, while 90% of UVB radiation is retained by the corneal layer of the epidermis [9].

The total amount of sunlight that affects the human skin varies depending on geography, climate, pollution, season, time of day, lifestyle, age, clothes, occupation, etc. While in everyday life we can try to avoid excessive exposure to UV radiation, occupational exposure is not so easy to avoid. Numerous employees who work outdoors are occupationally exposed to UV radiation. In 2009, ~9% of all employees (~1 146 000 people) worked in such conditions (e.g., in construction, agriculture and forestry) in Poland [10]. Among outdoor workers, the spectrum of dermatological disorders associated with UV radiation is broad, with most diseases requiring medical intervention. Even though skin photoageing itself is more of an aesthetic than medical problem, it is still an important matter for those affected. Increasingly often, people of various social status want to look young, and photoageing prevention is the best and cheapest way to keep the skin looking good.

2. AIM

Since outdoor workers are exposed to intense and prolonged natural UV radiation, their skin is exposed to premature ageing. The aim of this study was to assess the skin for signs of photoageing in subjects who, on account of their work, were exposed to natural UV radiation.

3. METHODOLOGY

The study involved 52 males aged, *M* (*SD*), 38.7 (0.04) years (range: 23–63). They were divided into groups:

20–29-year-olds: $N = 12$;
30–39-year-olds: $N = 15$;
40–49-year-olds: $N = 11$;
≥50-year-olds: $N = 14$.

The subjects had been occupationally exposed to natural UV radiation for, *M* (*SD*), 11.8 (7.4) years (range: 3–30). The subjects came from five occupational groups, most (77%) were construction workers.

The subjects' skin was examined. There was an overall examination of skin condition with a device for skin diagnostics Aramo TS device (Aram Huvis, Korea) and a dermatological examination. The device is a comprehensive system for noninvasive, optical analysis of several dimensionless parameters of the skin: moisture, elasticity, sebum (in the T zone, i.e., the central part of the face, and in the U zone, i.e., lateral parts of the face), porosity, smoothness (evenness), discolourations and wrinkles. The measurements were taken in very specific points located on the skin of the face, and the results were compared with standards expected in each age group (according to the manufacturer of the device). This made it possible to assess skin condition in relation to the subject's age. A dermatologist conducted the other examination. The study had been approved by the Bioethics Committee for Scientific Studies at the Central Institute for Labour Protection – National Research Institute (CIOP-PIB), Poland. The results were analysed with Statistica 9.0 (Wilcoxon signed-rank test).

4. RESULTS

4.1. Analysis of the Skin

4.1.1. Moisture, elasticity and smoothness

Table 1 compares the results for skin moisture, elasticity and smoothness in age groups with age-appropriate standards.

Statistical analysis showed negative correlation between the subjects' age and mean moisture ($p \leq .005$). Moreover, there was a significant difference between mean moisture in 30–39- and ≥50-year-olds ($p < .05$). There was a significant difference between mean elasticity in 20–29- and 30–39-year-olds, and 30–39- and 40–49-year-olds ($p < .05$). There was also positive correlation between mean moisture and mean elasticity ($p < .05$). There was positive correlation between age and duration of occupational exposure to UV radiation, and mean smoothness ($p < .05$).

4.1.2. Sebum in U and T zones

Figure 1 shows mean level of sebum in U and T zones by age.

Statistical analysis showed positive correlation between mean sebum in the T zone and mean moisture, and mean elasticity ($p < .05$). Moreover, there was a significant difference between mean sebum in the T zone in 20–29- and 40–49-year-olds ($p < .05$).

4.1.3. Porosity, discolourations and wrinkles

Table 2 compares the results of the size of pores, the number of skin discolourations and deep wrinkles in age groups with age-appropriate standards.

Statistical analysis showed positive correlation between mean size of skin pores and mean moisture, and mean sebum in the T zone ($p < .05$). It also revealed positive correlation between age and duration of occupational exposure to UV radiation, and mean number of skin discolourations ($p < .05$). There was positive correlation between age and duration of occupational exposure to UV radiation, and mean depth of wrinkles. On the other hand, there was negative correlation

TABLE 1. Skin Moisture, Elasticity and Smoothness: Age-Appropriate Standards, *M* (*SD*)

Age Group (years)	N	Exposure to UV[a] (years)	Moisture[b] Standard	Moisture[b] In Group	Elasticity[b] Standard	Elasticity[b] In Group	Smoothness[b] Standard	Smoothness[b] In Group
20–29	12	5.5	40.0	46.2 (18.9)	73.0	60.6 (13.1)*	44.0	28.8 (5.4)
30–39	15	7.9	37.0	44.1 (12.5)*	68.0	66.8 (12.6)**	50.0	27.4 (7.3)
40–49	11	15.0	35.0	40.1 (9.7)	65.0	62.6 (12.8)*	54.0	29.0 (7.1)
≥50	14	20.4	33.0	39.9 (9.0)*	58.0	63.8 (17.4)	60.0	30.7 (5.7)

Notes. $*p < .05$, $**p < .01$; the measurements were taken on the skin of the cheeks; UV = ultraviolet; a = *M*; b = dimensionless.

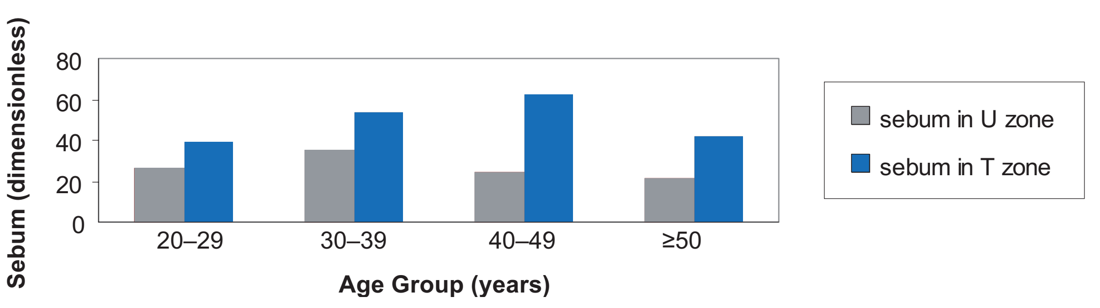

Figure 1. Skin sebum in U (central part of the face) and T (lateral parts of the face) zones by age group (*N* = 52).

TABLE 2. Skin Porosity, Discolourations and Wrinkles: Age-Appropriate Standards, *M* (*SD*)

Age Group (years)	N	Exposure to UV[a] (years)	Pore Size[b]		Number of Discolourations[b]		Depth of Skin Wrinkles[b]	
			Standard	In Group	Standard	In Group	Standard	In Group
20–29	12	5.5	23.0	93.7 (16.2)	15.0	24.9 (10.5)	20.0	27.6 (24.0)*
30–39	15	7.9	33.0	91.2 (22.4)	25.0	25.1 (11.7)	25.0	20.4 (23.9)**
40–49	11	15.0	48.0	95.00 (18.9)	40.0	26.0 (11.3)	35.0	38.1 (24.4)*
≥50	14	20.4	48.0	91.39 (23.7)	54.0	28.4 (10.0)	55.0	41.9 (24.1)**

Notes. Notes. *$p < .05$, **$p < .01$; the measurements were taken on the skin of the cheeks; UV = ultraviolet; a = *M*; b = dimensionless.

between mean depth of wrinkles and mean moisture, and mean sebum in the U zone. There was also a significant difference between mean depth of wrinkles in 20–29- and ≥50-year-olds, 30–39- and 40–49-year-olds, and 30–39- and ≥50-year-olds ($p < .05$).

4.2. Dermatological Examination

The skin was properly hydrated in 40 subjects (76.9%) and dry in 12 subjects (23.1%). The dermatological examination revealed the following signs of skin photoageing: dryness, roughness in 20 subjects (38.4%), discolourations in 10 subjects (19.2%), including lentigos in 8 subjects (15.4%), decolouration in 1 subject (1.9%), deep wrinkles in 22 subjects (42.3%), furrows in 5 subjects (9.6%), thickened skin in 7 subjects (13.5%), dilated blood vessels (telangiectasias) in 12 subjects (23.1%). Statistical analysis showed positive correlation between age and signs of skin photoageing such as discolourations and deep furrows. There was also positive correlation between duration of occupational exposure to UV radiation and presence of lentigos and deep furrows.

5. DISCUSSION

While serious dermatological consequences of chronic exposure to UV radiation among outdoor workers have been discussed in numerous publications [11, 12, 13], considerably less attention has been paid to the problem of premature ageing in this group of subjects. Perhaps this is so because most outdoor workers are male, and are reputedly indifferent to the condition of their skin. This study involved two types of examinations: an overall examination of skin condition and a specialist dermatological examination, whose aim was to assess the skin for signs of photoageing. There were 52 male subjects, they were all outdoor workers. They had been occupationally exposed to natural UV radiation for 3–30 years, so, at least for some, exposure had been long enough for them to develop signs of skin photoageing. The study was conducted over two summer months of 2010. First, a device for skin diagnostics was used. Moisture, which is essential for proper functioning of the skin and its healthy appearance, was analysed first. Mean moisture significantly decreased with age ($p \leq .005$) in this study. Probably moisture progressively decreases with age due to a steadily decreasing amount of lipids. As a result, the corneal layer of the epidermis loses its ability to bind and retain water; additionally, especially over 50, there is a considerably reduced production of glycosaminoglycans, which capture and store water [14]. This mechanism is disturbed not only by the process of natural ageing, but also by the influence of external factors, e.g., UV radiation. Mac-Mary, Sainthillier, Jeudy, et al. studied 10 people in whom only one side of the face had been exposed to UV radiation for a long time; they showed statistically significant differences in skin hydration between the exposed and unexposed sides of the face [15]. In the present study, even though mean moisture for all workers decreased with age, mean moisture was higher than age-appropriate standards in each age group. It is likely that in the studied group of workers, sweating stimulated by physical effort could increase moisture. Furthermore, studies show that UV radiation leads to an overgrowth of sebaceous glands and a temporary increase in the production of sebum, which in turn is responsible for the protection of the skin against water loss [16].

Elasticity was analysed, too. In this study, skin elasticity was highest in 30–39-year-olds, followed by ≥50-year-olds, whereas it was lowest 20–29-year-olds. In each age group, except the ≥50-year-olds, mean elasticity was lower than age-appropriate standards, which may suggest that in addition to age, UV radiation influenced a decrease in skin elasticity. This has been confirmed by numerous studies, including Wang, Fang, Wang, et al.'s study on 156 volunteers, which revealed that skin elasticity in areas exposed to UV radiation was statistically significantly lower compared to unexposed sites, regardless of the subjects' age [17].

Next, sebum was analysed. In each age group, mean sebum in the T zone was higher than in the U zone, which is typical in humans.

Smoothness was also analysed. Porosity is one of the main factors which determine smoothness. Skin pores can be enlarged dues to many factors. As mentioned earlier, exposure to UV radiation may also stimulate hypertrophy of sebaceous glands and the enlargement of skin pores. In each age group, mean size of skin pores was significantly above age-appropriate standards. There was a statistically significant relationship between smoothness and sebum in the U zone. Smoothness significantly deteriorated with age and duration of occupational exposure to UV radiation.

Then, skin discolourations were analysed. Pigmentation disorders may result from either endo- or exogenous factors, and UV radiation is the most frequently mentioned exogenous factor that predisposes to discolourations [18]. In the present study, the mean number of skin discolourations significantly increased with age and duration of occupational exposure to UV radiation. Interestingly, in the two youngest age groups, the mean number of skin discolourations was higher than age-appropriate standards, whereas in the two oldest age groups, it was lower.

Wrinkles, a fundamental sign of skin ageing, were the last analysed parameter. In this study, the depth of wrinkles correlated with age and duration of occupational exposure to UV radiation. Fujimura, Haketa, Hotta, et al. analysed the depth of wrinkles in the outer corner of the eye. They found that the higher the total dose of UV radiation throughout the subject's life, the greater the depth of their wrinkles and the smaller their skin elasticity [19]. In both the 20–29- and 40–49-year-olds, mean depth of wrinkles was higher than age-appropriate standards, whereas in the 30–39- and ≥50-year-olds, it was lower. It is difficult to explain these results. Studies conducted in Japan, in a group of 230 subjects, found that the depth of wrinkles caused by chronic exposure to UV radiation was influenced by skin phototype [20]. Those more sensitive to UV radiation (phototype I or II) had deeper wrinkles than those less sensitive (phototype III or IV). Perhaps, long-term exposure to UV radiation in people with phototype I or II induced health problems that prompted them to change their working conditions. Therefore, in the ≥50-year-olds, there were mostly people with phototype III, which is dominant in Poland, or phototype IV, which is less frequent in this region. It is also possible that older workers were more "reasonable", and at least partially avoided exposure to the sun.

The dermatological tests were carried out by a dermatologist according to a research protocol created especially for this study. In most cases (nearly 80% of the subjects), the skin was properly hydrated. Like in studies assessing skin condition, relatively good skin hydration in the subjects may have resulted from the action of sebum, whose excessive secretion is stimulated by UV radiation. In the studied group, there was a variety of skin defects that proved photoageing. Deep wrinkles were found in over 40% of the subjects, skin dryness and roughness in 38%, furrows in under 10% and discolourations in under 2%. There are no accurate epidemiological data on photoageing in Poland; however, in this study, changes in the subjects' skin caused by photoaging seemed quite frequent.

To sum up, the results of both dermatological tests and those conducted with a device for skin diagnostics show that the percentage of skin characteristics typical of photoageing was higher in the subjects than in the general population. This proves excessive chronic exposure to radiation.

Interestingly, many signs of prolonged exposure to UV radiation were reported in younger workers only. This might result from people more susceptible to sun damage changing their jobs, or older workers using more effective protection against UV radiation.

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