Photochemistry and Photobiology, 2019, 95: 1068–1075

Influence of Air Temperature on the UV Exposure of Different Body Sites Due to Clothing of Young Women During Daily Errands

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Received 25 October 2018, accepted 18 January 2019, DOI: 10.1111/php.13088

ABSTRACT

Clothing is one of the main influencing factors for personal ultraviolet radiation (UVR) exposure. Despite that, little attention was put on this topic till now. In this study, the clothing habits of young females have been investigated in dependence of meteorological conditions. Observations were made from spring to autumn during daylight in the urban region of Vienna, Austria. For this, a scheme dividing the body into six different sections was developed as well as a coding scale that corresponds to the different garments and indicates the body sites that are exposed. It was found that air temperature is the dominating factor for exposure. With increasing temperature, the first area of the body to be exposed to solar UVR is, aside from face and hands, the décolleté, followed by nape, ankles, instep and forearms. Observations further indicate that the frequency of people's being outdoors decreases significantly at temperatures higher than 30°C. This paper provides detailed frequency distributions of uncovered body sites in dependence of temperature. These can be used together with measurements of temperature and UVR to calculate the relative exposure at any time and at many locations, and could help to explain the body distribution of UVR caused skin alterations.

INTRODUCTION

Solar ultraviolet (UV) radiation (UVR) exerts a considerable influence on human health. Exposure to UVR has beneficial effects (*e.g.* Vitamin D), but due to its high photobiological efficiency, it alters absorbing surfaces like the skin or hair. Alterations may be harmless, but can be cosmetically undesirable (*e.g.* premature skin aging) and can become even pathogenic (*e.g.* skin cancer).

Intensity and progress of alterations depend on personal sensitivity to UVR (*e.g.* skin phototype) and on the amount of personal UV exposure. Personal UV exposure of people is influenced by the UVR environment and by personal habits—including clothing.

The general purpose of clothes in everyday life is to gain thermal comfort and protection (*e.g.* from rain). However, there are many other factors involved in an individual's choice of clothing (*e.g.* fashion, dress code and faith), which may even contradict thermal comfort. Sun protection is rarely a reason for choosing clothes (1), except for sunglasses and partly headwear.

Internally, thermal comfort depends on the metabolic rate which differs by gender, by activity, but also individually and changes in the course of one's life. For a short while, the metabolic rate can be modified by food intake (*e.g.* hot/cool drinks). Externally, thermal comfort depends on several meteorological parameters such as ambient temperature, wind speed, humidity and sunshine (2). Humans can physically adapt to thermal comfort (*e.g.* clothing) and can alter their behavior (*e.g.* sun/shade). Psychologic adaption (*e.g.* naturalness of environment, expectation) was also recognized (3).

In respect to thermal comfort, the thermal insulation of the clothes is of importance, as well as the body area covered (4). In respect to UV exposure, the material is less important. Transmission through garment is characterized by the UV protection factor (UPF). In general, clothing protects the human body well (5), but wetness (6) or stretching can reduce the UPF (7). Also, very thin fabrics or nylons/pantyhose have a low UPF (8). For personal UV exposure, the amount of layers (undershirt, shirt and slipover) does not matter. Most important for UV exposure is the location of the area which is uncovered. The irradiance received at a certain body site depends on its inclination against the sun. Surfaces which are inclined perpendicular to the solar beam receive the highest irradiance (9). At high solar elevation, the irradiance on a horizontal surface (*e.g.* top of shoulders during walking) is much higher than on a vertical one (*e.g.* shoulder blade) and vice versa at low solar elevation. On some body parts, irradiance changes permanently (*e.g.* calf or forearm during walking) (10). Therefore, a mean clothing factor for the whole body (*e.g.* percentage of uncovered skin) would not be an appropriate measure.

As mentioned above, alterations of the skin caused by UVR depend on personal photosensitivity. The photosensitivity of the skin to UVR is not the same all over an individual's body. The UV exposure needed to cause a just visible redness (minimal erythema dose) may differ all over the body by the same amount as it differs between different individuals with the same Fitzpatrick skin phototype (11,12). This is caused by physiological differences in the skin (*e.g.* variation of skin thickness) (13) but

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also by photoadaptation (*e.g.* pigmentation). This is another reason for the importance of knowing the exact body sites that are being exposed.

Until now, little is known about clothing habits of people in relation to UV exposure. Some studies focused on clothing as a tool of sun protection and found that clothing is rarely used for protection even at places with high UVR like a beach in summer (1). Only a personal history in skin cancer or a very sensitive skin (*e.g.* tendency for blistering sunburns) is a reason for people to wear protective clothes (14). In general, coverage is anticorrelated with temperature which means mostly, little clothes when UVR is high and vice versa (1,15,16). Fitting this, it was found that the number of sunburns increases with temperature (17).

The aim of this study was to analyze clothing habits, and with that location of uncovered skin, of a well-defined subpopulation, that is representative for everyday life, in respect to several meteorological parameters. For this, we observed the clothing habits of mothers of toddlers and developed a body chart, dividing the body into eight sections (including sunglasses and headwear) as well as a coding scheme that corresponds to garments. Although this scheme is more detailed than others (18), it enables a person's garment to be described using only eight numbers. In this paper, the clothing habits will be described as frequency values for coverage of the body sections: feet, legs, lower trunk, arms and shoulders, décolleté and back, together with the usage of headwear and sunglasses in dependence of the relevant meteorological condition. Additionally the corresponding relative frequency of being outdoors will be provided.

MATERIALS AND METHODS

Subpopulation under study. We have recorded clothing of young females which drive toddlers in a pram in the urban region of Vienna. Advantage of this group is that they go outside almost daily for a certain period (*e.g.* recommended for Vitamin D photosynthesis of toddlers), cloth in response to the weather situation and do not stay outside for longer periods when in the city. Another advantage is that parenthood can be found in all social classes throughout the town. At the time, 70% of the Austrians become parents, having two children on average. The mean age for Austrian mothers to have their first child is 29 years. The age of mothership/parenthood is verifiable influenced by education. The longer a person's education lasts, the later their first child is born (19).

In respect to observations, mothers with pushchairs are easy to recognize already from a considerable distance and it is also easy to visually follow them within groups of other pedestrians. What is more, their lower frequency of appearance enables researchers to observe almost all mothers with pushchairs during the time of observation. Due to these factors, a selection bias is avoided.

Exclusion criteria. Excluded are persons following a religious or any other dress code or being accompanied by such a person, persons being obviously not of Austrian origin (skin type, language, etc.), persons on travel, tourists, persons wearing athletic clothes, obvious pregnant women and those for whom the observer is in doubt.

Observation. Several locations within the urban region of Vienna (48°12′N, 16°22′E, 150-250 masl, 1.8 Mil. Inhabitants, 4500 inh. km^{-2}) along the south–north axis of the town were selected. The river Danube divides the town from west to east and there could be an urbanistic difference between the northern and the southern part. Locations have been local centers implemented as open places with good public transport connections but restricted accessibility for cars (pedestrian area). Additional some observations have been made in pedestrian areas of two smaller towns to check representativeness: Mödling (48°5′N, 16°17′E, 246 m asl, 21 000 inhabitants, 2100 inh. km^{-2}) and Wiener Neustadt (47°49′N, 16°15′E, 265 m asl, 44 000 inhabitants, 730 inh. km^{-2}).

The observations started in April and lasted until the end of September. Almost daily on weekdays, 30 consecutive females (fulfilling the criteria) have been recorded at different locations between 9:00 and 10:00 and 16:00 and 17:00 (MEST) each. In between (10:00–16:00), observations were done in the same manner but not daily. The restriction to 30 females per observation avoids that certain days contribute stronger (for unknown reasons) than others.

Observations were made visually by three observers after a joint training. Joint observations were made periodically to check for any observational bias. Clothing was recorded by hand on a paper list (with one separate column for each body site), using the body chart (see below). Date, time and meteorological parameters were also recorded. Females were generally not aware of the observation.

Categorization of clothes—Body chart and coding. For reporting clothes, we have developed a body chart that divides the body into six sections and codes coverage into up to six categories (Fig. 1) in the way that the higher the number is the more skin is exposed (Table 1). Division and coding follow the design of common garments. Coding represents the type of garment, the exposed body site and indirectly also the size of the exposed area. The coverage by hair is included also and handled like clothes. For example, if the nape is covered by hair, then the coding is the same as if the nape is covered by a collar. Some categories were defined (see Fig. 1) but have not been observed: feet: -1: low boots or high socks when code for legs ≥2, feet: -2: stocking till above knee when code for legs ≥3) and therefore are not included in Table 1. Additionally, decimal numbers can be used. For example, if trousers cover just the knees, code for leg can be set to 1.5. If the sleeves end at the elbow, coding is also 1.5.

A simple exposure index EI can be gained as the sum of the code numbers for all six body sections except headwear (scalp) and sunglasses (eyes):

$$\mathrm{EI} = c_{\mathrm{Neckline}} + c_{\mathrm{Back}} + c_{\mathrm{Arms}} + c_{\mathrm{Belly}} + c_{\mathrm{Legs}} + c_{\mathrm{Feet}}$$

This sum could range from 0 to 27 and represent the size of exposed skin area, as well as the type of clothes. A value of zero denotes that only the head and the hands are uncovered.

Meteorological parameters. For analysis, we have used air temperature, relative humidity and wind speed from the meteorological stations in Vienna, which are updated every 15 min, while cloudiness was recorded by the observer. No observations of clothes have been made on rainy days or after thunderstorms. Furthermore, observations of clothes were only taken for analysis when temperature change was not more than 1°C within 1 h to be sure (with high probability) that females are adapted to the current temperature.

Relative exposure in dependence of meteorological conditions. The relative exposure frequency $RE_{bs,c}(X)$ is defined as the product of the frequency $f_{bs,c}(X)$ of coverage c of a certain body section *bs* at a certain meteorological condition *(X)*, and the relative frequency of being outside $f_{out}(X)$ at condition *X*.

$$\mathrm{RE}_{\mathrm{bs,c}}(X) = f_{\mathrm{bs,c}}(X) \cdot f_{\mathrm{out}}(X)$$

The frequency $f_{bs,c}(X)$ of coverage/exposure *c* of a certain body site *bs* is gained by observation.

The relative frequency of females being outside $f_{out}(X)$ is gained by dividing the number of recorded persons by the duration of the observation.

RESULTS

Data yield

In total, the clothes of approximately 4200 young females have been recorded, which represent approximately 2/3 of those young females passing by with a pram. Most were not monitored because of religious dress code or having skin type V and VI. More than 90% of the passing young females (which fulfilled the criteria) were recorded. Left out have been also those which were too fast for the observer to fill in the protocol or for which the observer was in doubt.

Air temperature during observation was between 10 and 36°C, humidity between 26% and 90% and wind speed between

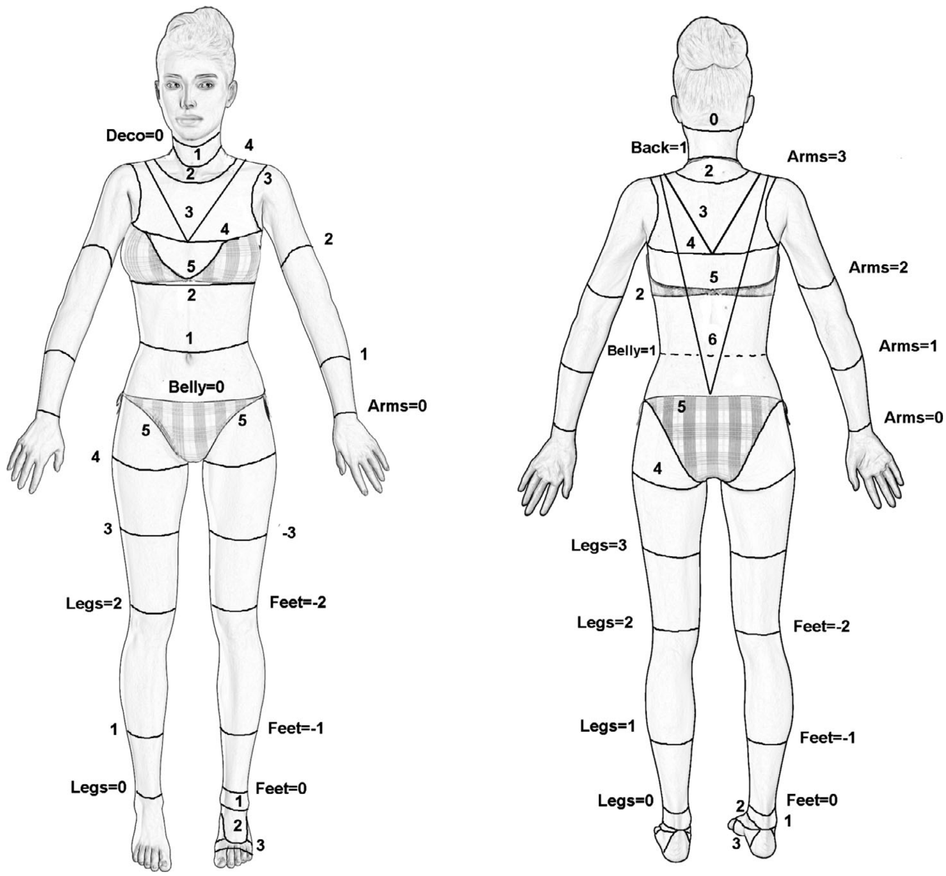

Figure 1. Division of the female body and coding of clothing/coverage.

Table 1. Coding scheme to evaluate clothing.

Code No./body site	0	1	2	3	4	5	6
Scalp	Broad-brimmed hat	Hat	Cap	No head cover	—	—	—
Eyes	Sunglasses	No sunglasses	—	—	—	—	—
Neckline (Décolleté)	Covered	Open collar	Medium	Deep	Deep and wide	Bikini-like top	—
Back (and nape)	Covered (by hair or cloth)	Free nape	Free nape and upper back	Shoulder blade uncovered, low cut back	Backless top	Bikini-like top	Deep cut back
Arms (and shoulders)	Covered	¾ sleeves	Short sleeves	Shoulder free	Spaghetti straps or strapless	—	—
Belly/lower trunk	Covered	Free up to belly	Free above belly	—	—	—	—
Legs	Long legs	¾ legs	Above knee	Shorts	Short shorts	Bikini bottom	—
Feet	Shoes with socks (ankle covered)	Low shoes (free skin between trousers and shoes)	Open shoes (pumps, ballerinas)	Sandals	Flip-flops	—	—

0 and 30 km h^{-1}. Cloud cover was mostly between 0 and 7 octa. In a few cases (high thin translucent clouds), observations were made at 8 octa. It should be mentioned that cloud cover within the city seems lower than observed on a free field because of the obstructed horizon. At low cloud cover (*e.g.* 1 – 2 octa), clouds are denser near the horizon which is hidden within an urban region. A cloud cover of 1 octa on a free field is frequently seen (and recorded) as 0 octa within the city. At each temperature, between 100 and 250 mothers were recorded.

Overall clothing in dependence of meteorological conditions

For a first analysis, the simple exposure index *EI* was used. The highest observed value was 20. The *EI* correlates best with air temperature ($c = +0.98$, $P < 0.001$), followed by humidity ($c = -0.91$, $P < 0.001$), whereas humidity is stronger anticorrelated to air temperature ($c = -0.96$) than it is correlated with the EI. Cloudiness ($c = -0.23$, $P = 0.31$) and wind speed ($c = -0.03$, $P = 0.96$) do not exert any influence that would be statistically significant.

Following this, the median exposure index $\overline{\mathrm{EI}}(T)$ at each air temperature T was calculated (visualized in Fig. 2). A polynomial function of degree 2 was fitted through the $\overline{\mathrm{EI}}(T)$ using T as the only indeterminate.

$$\overline{\mathrm{EI}}(T)_{\mathrm{Fit}} = a \cdot T^2 + b \cdot T + c$$

The values of the constants are $a = -0.0095$, $b = 1.00$ and $c = -9.66$, whereas the coefficient of determination $r^2 = 0.97$.

The differences between this function $\overline{\mathrm{EI}}(T)_{\mathrm{Fit}}$ and the observed $\overline{\mathrm{EI}}(T)$ are not statistically significant correlated with any of the other meteorological parameters (all $P > 0.1$). For this, neither cloudiness nor wind speed, nor humidity exerts a significant influence on clothing habits.

Season and time of the day

To find a potential influence of the time of day on clothing habits, the EIs, observed at the same temperature but at different times during the day, were compared. For this, observations at temperatures up to 30° C could be used. Correlation analysis did not show a significant correlation ($P > 0.5$). In the same manner, the influence of the date, respectively, season, was proven. As for the time of the day, correlation analysis did not give any significant relation ($P > 0.5$).

Garments in dependence of temperature

Table 2 provides the coverage for the six body sections in dependence of temperature. Listed are frequency values f (expressed in percentage) for each code number c.

The skin of the décolleté is already exposed at very low temperatures. Although at 10°C (50°F), deep necklines ($c = 3$, $f = 13\%$) could be observed due to open jackets, most females expose only hands and face ($\mathrm{EI}_{\mathrm{median}} = 0$).

At 11°C (52°F), the ankle becomes uncovered ($c = 1$, $f = 2\%$), generally due to reduced trousers length and low shoes (*e.g.* loafer) with sneaker socks. The instep ($c = 2$, $f = 4\%$) becomes exposed at 12°C ($\mathrm{EI}_{\mathrm{median}} = 1$). Pumps and ballet flats release now the skin of the instep.

At 13°C (55°F), ($\mathrm{EI}_{\mathrm{median}} = 2$) the nape becomes exposed ($c = 1$, $f = 16\%$) as well as the forearms ($c = 1$, $f = 6\%$). At lower temperatures, the nape is covered by the collar of jackets and/or hair. Waistcoats with ¾-sleeves become worn or sleeves of garments are pulled up.

At 15°C (59°F), ($\mathrm{EI}_{\mathrm{median}} = 3$) deep and wide necklines ($c = 4$, $f = 2\%$) can be observed due to open jackets or waistcoats. First parts of the back are exposed ($c = 2$, $f = 4\%$). Although most of the women wear shirts with long sleeves, a low percentage decides already for shoulder-free shirts ($c = 3$, $f = 2\%$). A few females dress in 3/4-trousers ($c = 1$, $f = 6\%$). Also, sandals become to be worn ($c = 3$, $f = 4\%$) and with these toes and heels become exposed.

At 16°C (61°F), ($\mathrm{EI}_{\mathrm{median}} = 3$) a reduced length of skirts and trousers ($c = 2$, $f = 1\%$) releases the knees.

Tops with very slim straps start to be worn ($c = 4$, $f = 1\%$) and the upper back becomes exposed ($c = 3$, $f = 1\%$) at 17°C ($\mathrm{EI}_{\mathrm{median}} = 3$).

At 18°C (64°F), ($\mathrm{EI}_{\mathrm{median}} = 5$) wide back cuts ($c = 4$, $f = 1\%$) according the spaghetti straps tops appear and females start to wear flip-flops ($c = 4$, $f = 1\%$). The 1st panel of Fig. 3 visualizes the typical outfit worn at 18°C. It consists of a shirt with a medium-sized neckline ($c = 2$, $f = 47\%$). Half of the shirts have long sleeves ($c = 0$, $f = 53\%$). The nape is covered by a collar or by hair ($c = 0$, $f = 59\%$). The combination of shoes and trousers enables sun exposure of the ankle and instep in more than half of the women ($c \geq 1$, $f = 56\%$).

At 19°C (66°F), ($\mathrm{EI}_{\mathrm{median}} = 5$) the first shorts and miniskirts ($c = 3$, $f = 3\%$) can be observed.

At 21°C (70°F), the skin of the décolleté is no longer covered ($c = 0$, $f = 0\%$).

The $\mathrm{EI}_{\mathrm{median}}$ increases continuously and reaches a value of 9 at 24°C (75°F). The second panel of Fig. 3 depicts the typical outfit at 24°C. The majority of shirts have medium ($c = 2$, $f = 38\%$) or deep necklines ($c = 3$, $f = 39\%$), short sleeves ($c = 2$, $f = 55\%$) and do not cover the nape ($c \geq 1$, $f = 62\%$). Long hair is often pined up or worn in a bun. Most of trousers and skirts worn do not have full length anymore ($c \geq 1$, $f = 55\%$), and in median, shoes release the instep ($c = 2$).

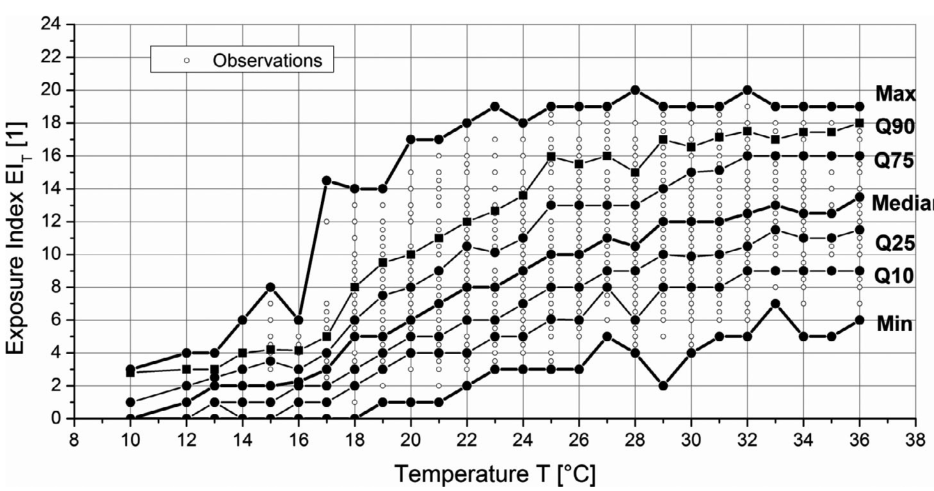

Figure 2. Observed Exposure Index EI_T of young women in dependence of temperature (open circles). The filled symbols connected with lines indicate percentiles Q.

Table 2. Frequency distribution of coverage of different body parts.

Percentage of use

T	Neckline (Décolleté)					Nape + back						Arms					Belly + L. trunk			Legs					Feet					EI Medi.
(°C)	0	1	2	3	4	0	1	2	3	4	5	0	1	2	3	4	0	1	2	0	1	2	3	4	0	1	2	3	4	Total
10	***70***	13	4	13	0	***100***	0	0	0	0	0	***100***	0	0	0	0	100	0	0	***100***	0	0	0	0	***100***	0	0	0	0	0.0
11	***65***	20	7	8	0	***100***	0	0	0	0	0	***100***	0	0	0	0	100	0	0	***100***	0	0	0	0	***98***	2	0	0	0	0.0
12	***54***	16	18	12	0	***100***	0	0	0	0	0	***100***	0	0	0	0	100	0	0	***100***	0	0	0	0	***85***	10	4	0	0	1.0
13	14	***41***	39	6	0	***84***	16	0	0	0	0	***94***	6	0	0	0	100	0	0	***100***	0	0	0	0	***86***	6	8	0	0	2.0
14	21	29	***32***	18	0	***79***	21	1	0	0	0	***95***	5	0	0	0	100	0	0	***99***	1	0	0	0	***80***	12	8	0	0	2.0
15	18	24	***42***	14	2	***90***	6	4	0	0	0	***82***	10	6	2	0	100	0	0	***94***	6	0	0	0	***68***	14	14	4	0	3.0
16	9	28	***41***	21	1	***78***	21	1	0	0	0	***89***	6	5	0	0	100	0	0	***94***	5	1	0	0	***74***	19	7	1	0	2.3
17	3	22	***51***	23	1	***78***	17	3	1	0	0	***83***	7	8	0	1	100	0	0	***90***	9	1	0	0	***60***	21	13	6	0	3.0
18	1	10	***47***	35	6	***59***	33	5	1	1	0	***53***	15	25	4	2	100	0	0	***83***	10	6	0	0	***44***	23	22	10	1	5.0
19	1	5	***55***	34	5	***47***	44	7	1	1	0	39	15	***41***	3	1	100	0	0	***76***	10	10	3	0	***35***	20	18	24	3	5.0
20	2	6	***49***	36	8	36	***47***	12	2	3	0	10	28	***50***	7	6	100	0	0	***69***	14	15	2	0	***34***	30	15	18	3	6.0
21	0	4	***45***	42	9	41	***44***	7	4	4	0	22	12	***48***	12	6	100	0	0	***61***	18	18	3	0	***28***	19	22	22	8	7.0
22	1	4	***42***	35	18	***41***	***38***	11	6	4	0	13	14	***41***	22	10	100	0	0	***51***	26	15	8	0	19	25	16	***27***	13	8.0
23	0	4	41	***45***	10	37	***41***	11	5	5	0	3	7	***55***	29	6	100	0	0	***58***	13	16	13	0	15	27	17	***29***	11	8.0
24	0	3	38	***39***	20	31	***38***	14	10	7	0	6	6	***51***	23	14	100	0	0	***45***	23	23	9	0	17	22	15	***36***	10	9.0
25	0	4	32	***44***	20	28	***30***	16	12	13	1	1	4	***48***	27	20	100	0	0	***31***	20	***31***	18	0	11	18	14	***39***	18	10.0
26	0	3	35	***42***	20	24	***44***	9	12	12	0	0	6	***45***	34	15	100	0	0	***33***	21	29	14	2	9	16	19	***39***	17	10.0
27	0	4	29	***48***	20	19	***40***	17	12	13	0	0	2	38	***41***	19	100	0	0	28	16	***32***	25	0	4	23	11	***38***	24	11.0
28	0	1	31	***45***	24	24	***33***	19	12	13	0	0	3	***42***	34	22	99	1	0	***34***	16	30	20	0	9	21	13	***37***	20	10.5
29	1	3	23	***44***	30	19	***27***	18	19	16	1	1	2	36	***37***	25	100	0	0	18	10	***45***	28	0	3	15	18	***38***	27	12.0
30	0	0	23	***43***	34	13	***28***	23	15	21	0	1	1	***38***	35	26	100	0	0	25	15	***30***	***30***	0	5	16	17	***36***	26	12.0
31	0	2	14	***48***	36	14	***32***	13	15	25	0	0	1	***35***	32	32	100	0	0	19	18	***34***	29	0	5	11	15	***38***	32	12.0
32	0	1	21	34	***44***	16	***24***	18	15	26	0	0	1	33	28	***39***	100	0	0	14	13	***36***	35	1	2	14	13	***37***	34	12.5
33	0	1	9	***50***	40	8	21	***26***	19	25	0	1	1	25	***40***	33	100	0	0	11	10	***41***	37	0	2	15	14	***37***	32	13.0
34	0	0	13	***44***	43	12	***33***	16	11	28	0	0	0	***37***	34	29	99	0	1	13	16	29	***41***	0	1	15	12	***38***	34	12.5
35	0	0	9	44	***47***	17	25	***28***	11	19	0	0	0	28	***45***	27	100	0	0	0	18	***43***	39	0	1	14	18	***35***	32	12.5
36	0	0	5	45	***50***	11	24	14	21	***28***	1	0	1	22	33	***44***	99	0	1	12	9	37	***42***	0	1	15	13	28	***43***	14.0

Median is marked by gray. The most frequent coverage is indicated by bold and italic numbers. The last column lists the median exposure index (EI Medi. Total) of the whole body.

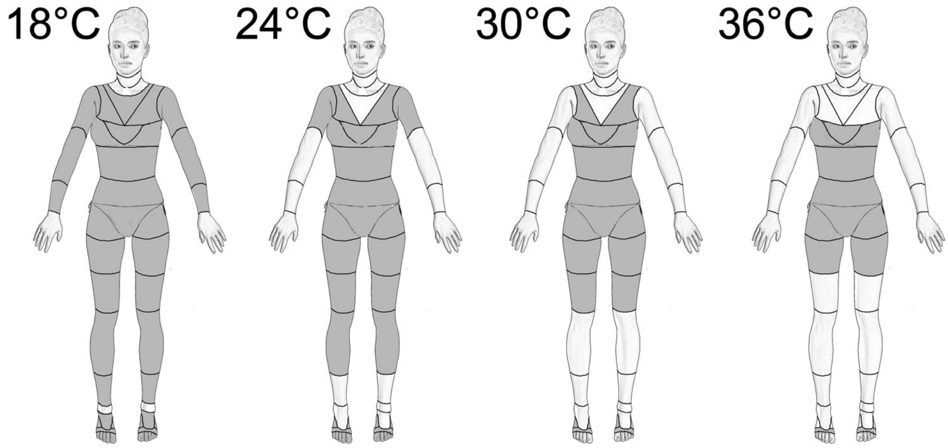

Figure 3. Typical (mean) clothes at 18°C (64°F), 24°C (75°F), 30°C (86°F) and 36°C (97°F) of young females (as observed during daylight between May and September).

Very rarely, back-free tops (c = 5, f = 1%) are worn. They can be reported from 25°C (77°F) (EI_{median} = 10) onwards. At this temperature, long-sleeved tops (c = 0) vanish.

Short shorts (c = 4, f = 2%) appear at 26°C (EI_{median} = 10) but are observed very rarely ($f \leq 2\%$), as well as the cropped tops (c = 2, $f \leq 1\%$) which were first observed at 28°C (82°F) (EI_{median} = 10).

At 30°C (86°F), (EI_{median} = 12) the typical outfit (Fig. 3, third panel) allows exposure by a wide or deep necklines ($c \geq 3$, f = 77%), the upper back ($c \geq 3$, f = 36%) and the shoulders ($c \geq 3$, f = 61%). Legs are covered mostly only above the knees ($c \geq 2$, f = 60%) and sandals are the preferred footwear (c = 3, f = 36%).

At 34°C (93°F), (EI_{median} = 13) the sleeves of tops end above the elbow.

The highest temperature at which observations were done was 36°C (97°F). At this temperature (see Fig. 3, 4th panel), preferable shoulder-free and spaghetti tops (c = 4, f = 44%) are worn so that the neckline is wide and deep ($c \geq 3$, f = 95%) and large parts of the upper back ($c \geq 3$, f = 50%) are exposed. Most frequently worn are miniskirts or short shorts (c = 3, f = 42%), in combination with sandals or flip-flops ($c \geq 3$, f = 71%).

Relative frequency of being outdoors

The relative frequency of young women being outdoors was analyzed, using observations that were carried out outdoors in a certain pedestrian area in Vienna. The frequency was calculated for each observation by dividing the number of recorded females by the duration of the observation. At this plaza, the frequency was around 24 females per 30 min.

The averaged relative frequency from all observations at each temperature, normalized to that of 20°C, is depicted in Fig. 4. The error bars indicate the standard deviation σ. It can be seen that temperature influences the frequency of being outdoors. In the temperature range between 10°C and 30°C, the frequency is almost constant (1.0 ± 0.1), indicated by the fact that frequency values are within the average standard deviation of ±0.0997. At higher temperatures, the frequency noticeably decreases. A linear fit over the range from 30 to 36°C indicates a decrease of 5% per 1°C ($P < 0.002$). Table 3 depicts the frequency values of being outdoors $f_{out}(T)$ in units of percentage according to the above in dependence of temperature T: a constant value from 10°C (50°F) to 30°C (86°F), followed by a decrease of 5% per 1°C.

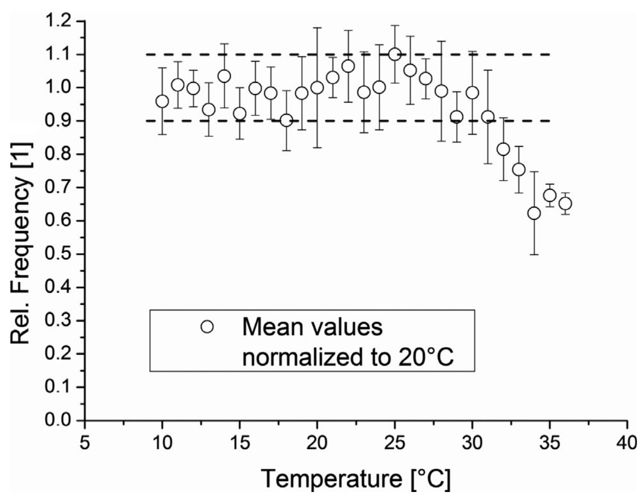

Figure 4. Relative frequency (normalized to the frequency at 20°C) of young females at a certain pedestrian area in Vienna in dependence of temperature. Error bars indicate the standard deviation at each temperature. The dashed lines show the average (over all observations) standard deviation of ±0.0997 to indicate frequencies different from 1.

$$\text{for } 10^{\circ}\text{C} \leq T \leq 30^{\circ}\text{C} : f_{out}(T) = 1.0$$

$$\text{for } T > 30^{\circ}\text{C} : f_{out}(T) = 1.0 - 0.05 \cdot T$$

Sunglasses and headwear

In general, not much use of sunglasses and headwear was observed. Table 3 lists the frequency of use at each temperature.

Observees start to wear sunglasses start at 15°C (59°F). Frequency of usage increases until 20°C (68°F) and stays constant at higher temperatures. Correlation analysis did not provide a significant correlation between temperature (in the range from 15 to 36°C) and the use of sunglasses ($P > 0.10$). Interestingly, cloudiness (apart from 8 octas) did not show any statistical

Table 3. Frequency of using headwear and sunglasses as well as the frequency of being outdoors in dependence of temperature.

Temperature (°C)	Frequency of using						Frequency of being outdoors
	Headwear (%)				Sunglasses (%)		
	No	Cap	Hat	B.hat	No	Yes	(%)
10	100	0	0	0	100	0	100
11	100	0	0	0	100	0	100
12	98	2	0	0	100	0	100
13	100	0	0	0	100	0	100
14	100	0	0	0	100	0	100
15	98	2	0	0	92	8	100
16	100	0	0	0	97	3	100
17	99	1	0	0	93	7	100
18	99	1	0	0	89	11	100
19	98	2	0	0	90	10	100
20	100	0	0	0	79	21	100
21	99	1	0	0	90	10	100
22	99	0	0	1	88	12	100
23	98	1	1	1	86	14	100
24	100	0	0	0	80	20	100
25	99	0	1	1	80	20	100
26	99	1	0	0	84	16	100
27	97	2	1	0	78	22	100
28	98	1	0	1	76	24	100
29	98	1	1	1	82	18	100
30	98	2	1	0	88	12	100
31	99	1	0	0	89	11	95
32	99	0	1	0	79	21	90
33	97	2	1	0	81	19	85
34	93	6	1	0	84	16	80
35	96	2	1	1	91	9	75
36	98	1	1	0	85	15	70

significant influence ($P > 0.10$), either the time of the day, respectively, solar elevation, does not take significant influence ($P > 0.10$) neither. Wearing sunglasses seems to be a very individual habit.

Headwear was worn even more rarely then sunglasses. Caps were worn by approximately 1-2% of young females at all temperatures. A statistically significant trend could not be found ($P > 0.10$). Small- and broad-brimmed hats were observed at temperatures higher than 21°C (70°F). Small-brimmed hats are worn twice as frequently as broad-brimmed hats. A statistically significant correlation to temperature could not be found ($P > 0.10$).Text begins here.

DISCUSSION

In this study, we have investigated the body coverage, respectively, exposure of young females due to clothes in dependence of meteorological conditions. It was found that air temperature is the dominating factor in the temperature range from 10°C (50°F) to 36°C (97°F). This is in agreement with the fact that the wind chill effect occurs at temperatures <10°C. On the other hand, the heat index becomes effective at temperatures higher than 27°C when humidity exceeds 40%. This rarely occurs in Vienna because humidity decreases with rising temperatures generally in this city. The difference between air temperature and the heat index was lower than 1°C except for one day (when observations were made). Therefore, detailed frequency distributions of body coverage in dependence only of air temperature are provided.

These frequency distributions are valid for young western female populations with similar thermal adaption, respectively, living under similar climatic conditions. For warmer (*e.g.* Mediterranean climate), respectively, colder regions (*e.g.* Scandinavia), the frequency distributions may be slightly shifted to higher or lower temperatures, according to the observed geographical differences in thermal comfort (20).

We cannot exclude an observational bias. However, during joint training and joint observations, no systematic differences were found between the observers as well as the difference in recorded EI was <1%. Especially, the used body chart helps to avoid an observational bias, as it was developed by analyzing current garments.

As fashion trends change, the validity of our study is restricted in time. For estimates back into the past, we would assume the 1970s as earliest date when fashion has changed significant and, for example, very short trousers and skirts became popular in Austria. Over the years, there have been off course always minor fashion trends like the departed low-rise jeans or the recent wearing flip-flops or wearing short sneaker socks or sock liners (21) which may have a slight influence. Country-specific differences in fashion do not tend to be very large at least within Europe. The socioeconomic status of individuals is reflected rather in design, quality and brands than in coverage (22).

Another restriction may come from the chosen subpopulation. We cannot exclude the possibility that women of the same age, who do not have any children, cloth different in respect to body coverage during their daily errands. However, at the time, there are no studies on this topic available. The results of our study are valid for this age-group only. Female teenagers' cloth different, as well as older females do (22).

In respect to direct representativeness, in Austria, 33% of females, which have children younger than 16 years, are home mums (2016), 50% work part-time and 17% are full-time employed. So there is a large portion of mothers (83%), who can do everyday's errands on working days during daylight. (19).

The provided frequency distributions can be used as to estimate everyday life UV exposure of body sites and corresponding alterations of the skin. These alterations depend on the duration of UV exposure. An analysis of several studies (from Europe and USA) of the time people spend outdoors (23) has shown that the median time spent outdoors is 1 h on weekdays and 1.6 h on weekends. Most frequent are stays which last around 30 min (24). However, there are considerably differences caused by season (*e.g.* weather, length of the day) and by individual behavior (25). In this study, we could show that the frequency of being outdoors is influenced by temperature. In the range from 10 to 30°C, the frequency seems to be constant. At higher temperatures, the frequency decreases. At temperatures around 30°C, evaporation (sweating) becomes the only possibility for the body to stay within the thermos-neutral zone and spending time outdoors becomes exhausting (26). It should be noted that we cannot exclude the possibility that the reduction in the frequency of time spent outdoors could be driven by consideration for children's safety and their well-being, rather than by the influence of well-being of women. However, we noticed a decreased frequency of other by-passers (not statistically evaluated), too.

Quantifiable effects from such a short and with that generally suberythemal UV exposure are Vitamin D photosynthesis (27) or pigmentation (28). Due to the steady repetition of UV exposure, also alterations of the skin (29,30) such as a reduction in elasticity become measureable.

For some effects (*e.g.* Vitamin D photosynthesis), the size of the skin area exposed is of importance when short-time exposed (27). To calculate the size of the body area which is covered by clothes, Lee and Choi (31) have developed a method and an appropriate body chart. Although our developed chart is more detailed at the neckline, the upper back, the hip and the feet, the scheme of Lee and Cho can be used to calculate the size.

To calculate the UV exposure of the uncovered body sites, synchronous measurements of UV irradiance and air temperature are necessary in conjunction to our frequency distributions. Standardized UV measurements, like for the UV-Index (32), are available for many places in Europe (33). In general, these are made for horizontally oriented receivers but can be recalculated by a model developed by Schauberger (34) to any inclined surface. For a walking person, the uncovered body sites, except shoulders (0°), forearms (45°–90°) and calf (60°–90°), are orientated vertically (90°).

The results of this study can be seen as a first step in investigating the impact of clothing on UV exposure. Further investigations are necessary to expand knowledge about clothing to other age-groups as well as to men to enable following UV exposure of people during whole life. This may help to understand the skin status from acute and accumulated UV exposure.

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