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ORIGINAL PAPERS

Seasonal and lifelong changes in skin colour and pigmentation of Austrian farming families: an exploratory study

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Abstract

Farmers are exposed chronically to solar ultraviolet radiation. Their chronically exposed skin undergoes alterations in pigmentation, but quantitative measurements have not be done yet. Therefore, we followed skin color and pigmentation in Austrian farming families (male and female farmers, their spouses, and children) for one year by objective tri-stimulus measurements on different body sites. The difference between constitutive and facultative pigmentation was quantified by the "degree-of-tan" (TAN°), which we defined as the difference in individual typology angle between constitutive and facultative pigmentation. Personal sun exposure was measured in parallel. Measurements of skin colour showed that independent of occupation, adult males had a darker red component in skin color of the forehead than adult females and children, with the highest values observed in males only. This difference develops during puberty and adolescence. Even in late winter, an obvious TAN° was found in all groups at continuously and intermittently exposed body sites. TAN° was higher in adults than in children and highest in farmers. The seasonal changes in TAN° were pronounced in all groups on intermittently exposed body sites but less so on the forehead. In conclusion, TAN° increases in farmers on average during their lifetime but not in their spouses, even though many spouses have higher TAN° than farmers of the same age. Such high TAN° is reversible if sun exposure is low in the following seasons. The highest TAN° values were found in farmers older than 50 years.

Keywords Ultraviolet radiation · Skin colour · Pigmentation · Farmer · Degree or tan

1 Introduction

Farmers are chronically exposed to solar ultraviolet radiation (UVR). However, the level of UVR exposure is determined by the amount of manual and automated work, type of farming [1, 2] and region [3] and ranges from relatively low in some cases [1, 3] up to relatively high [1, 4] resulting in very heterogenic measurement outcomes. The classical picture of a homogeneously extremely sun exposed occupational group is no longer valid. However, all have in common that photoprotection at work, e.g. sunscreen application, finds low acceptance [5–7].

Clothing impacts facultative pigmentation (tanning). Garment choice depends on ambient temperature, gender, and age [8] and therefore changes during the day and year. Clothes determine habitually exposed and protected body sites as well as the frequency and amount of UVR exposure of intermittently exposed body sites. In addition, UVR exposure of different body sites varies with posture [2, 9]. Thus, intermittent UVR exposure is body site dependent, and with that is pigmentation [10]. We lack literature on skin colour changes in well defined populations [11] with season and month of measurement has not always been considered. Therefore, observed differences by anatomical site [12, 13] often remain unexplained. Facultative pigmentation (e.g. on face) may accumulate [14, 15] during life but individual data are rare. Evidence for pigmentation as a reliable indicator for lifetime personal UVR exposure is missing. Furthermore, differences in skin colour by gender [13] must be considered.

The study aim was to investigate skin colour changes of Austrian farming families for one year. Periodic objective

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measurements were made, using reflectometry on different body parts, which were either continuously, or intermittently or non-exposed to the sun. Analysis was done by occupation, gender, and age.

2 Materials and methods

2.1 Participants

Volunteers (6–72 years, 50 females, mean 39.3 years and 48 males, mean 40.4 years) were 51 Austrian fulltime farmers (female: 24, mean 50.5 years, male: 27 mean 52.5 years), their spouses (female: 13, mean 45.0 years, male: 11, mean 49.5 years) (i.e. those not working outdoors on the farm), and their children or grandchildren (< 18 years, female: 12, mean 13.7 years male: 11, mean 12.8 years) when living in the same household. Children originated from 18 familys. In ten couples both partners were farmers, in 24 couples only one partner was farmer and seven farmers participated without spouses.

The farms, < 300 m above sea level within 200 km of Vienna (48° N, 16° E), were of mixed agriculture reflecting typical Austrian practises. Often both partners worked together and were both classified as farmers.

Farmers were recruited by announcement in a weekly and a monthly Austrian farming magazine.They have been informed personally about the aim of the study and procedure of measurements and have given written consent.

Exclusion criteria were visible skin irregularities at measurement sites, recent skin diseases, present or previous skin cancer, skin photosensitivity disorders or intake of photosensitizing medicines, use of solaria or sun holidays in the previous 6 months and nudists.

Fitzpatrick skin type (FST) distribution was I (7%), II (38%), III (48%) and IV (6%). Ethical approval was obtained from the Viennese Research Ethics Committee (No. EK 978/2011).

2.2 Body sites and time of skin colour measurements

Constitutive unexposed skin colour was measured on the upper right buttock and the medial aspect of the right upper arm (henceforth called inner upper arm). The forehead was the site to determine effects of continuous solar exposure and intermittent exposure was assessed on the right shoulder and the lateral aspect of right upper arm (henceforth called outer upper arm). Three measurements were made at each site. Visits to the volunteers took place approximately every 6 to 7 weeks from April 2011 to February 2012. Not all participants were available for every measurement.

2.3 Tri-stimulus measurements of skin colour and derivatives

Skin colour was measured with a portable tristimulus Chromameter CR-300 (Minolta, Osaka, Japan) [16] that records the tri-stimulus analysis of a reflected xenon flashlight expressed as L^* (0 = black and 100 = white), a^* (> 0 = red) and b^* (> 0 = yellow) following the CIE colour system [17, 18]. These parameters were also used to differentiate between two colour stimuli ΔE: $\Delta E = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$. Whereas ΔL^* is the difference of two measurements in L^*, Δa^* in a^* and Δb^* in b^*. ΔE can quantify the colour difference between two body sites or provides the measurement accuracy of repeated measurements. In the latter case, ΔE should be ≤ 1.0, because this difference can be recognised visually [19]. Pigmentation is described by the so-called "Individual Typology Angle" (ITA°, ITA° = (arctan $((L^* - 50)/b^*) \times 180/\pi$) [20] and the degree-of-tan TAN° [21] as the difference between ITA° of constitutive pigmentation (unexposed site, buttock) and ITA° of facultative pigmentation (exposed site). TAN° was calculated separately for the four body parts. ΔE and TAN° refer to buttock skin measured on the same day. The device was calibrated against its white-plate standard before use and was very robust in the field campaign and any calibration corrections were minor.

2.4 Personal UVR measurements

Participants wore an electronic UVR called SunSavers [22] on their wrists. These dosimeters, calibrated against the sun, measure erythemally effective irradiance [23] and stored mean values every 5 min. Daily exposure, obtained by summation of 5-min readings, was in standard erythema doses (SED) where 1 SED is 100 J/m^2 of erythemally weighted radiant exposure [23]. Measurements were not taken between November and February.

2.5 Statistical analyses

For analysis, arithmetic mean values ± standard deviation have been calculated. Correlation analysis and linear trend analyses was done using Pearson's correlation coefficient and two-tailed t test (with OriginPro 8.5, OriginLab Corporation, Northhampton, MA, USA) to determine effects of season, UVR exposure, occupation, gender, and age. Significance as set at $p < 0.05$. Multiple comparison corrections were not applied.

3 Results

3.1 Skin colour and pigmentation in winter

3.1.1 Constitutive skin colour

Table 1 shows winter (February) measurements to gain information on skin colour not affected by recent UVR exposure. There were no differences ($p > 0.05$) in buttock L^* and b^* values (and ITA°) between any group (L^*: 67.5–68.5, b: 11.5–12.2) nor any differences in L^* and b* values at the upper inner arm (L: 68.0–68.2, b: 11.9–12.5). Thus, constitutive pigmentation was the same in all groups. Skin colour and pigmentation (L^*, b^*, ITA°,) on buttock and inner upper arm were almost identical ($p > 0.5$), but buttock skin was significantly redder (a^*) in all groups by 1.9 on average (1.6–2.2). A difference of 1 can be recognised by a experienced observer. FST correlated with ITA° on the inner arm ($p < 0.001$) and approached close to significance for buttock skin ($p = 0.07$).

3.1.2 Children and adults

Adult foreheads, shoulders and upper arms were darker (L^*, ΔL) with higher facultative pigmentation (ITA°), and greater tan (TAN°) ($p < 0.05$). In adults, the colour of these body parts differs significantly more from buttock skin than in children (respectively differ significant in ΔE). Children forheads are less red (a^*) than adults.

3.1.3 Gender

Male vs. female comparisons showed differences at the forehead in L^* and a^*. Males were darker (lower L^*) and redder (a^*) on average. Figure 1 shows L^* and a^* forehead values of all participants. L^* and a^* values occupy a specific region in the $L^* - a^*$ plane ($52 < L^* < 72$, $8 < a^* < 23$). Most children (open triangles) appear in the upper left region, whereas adult females (filled circles) are in the middle region ($9 < a^* < 18$) and adult males (filled squares) present on the lower right ($10 < a^* < 23$). Values of a^* higher than 18 (forehead) were observed in males only. Neither in adult females nor in adult males a^* correlates with age at any body site. This indicates that a^* increases at the forehead during puberty or adolescence. The change of a^* in children is smaller in females than in males.

3.1.4 3.1.4 Farmers and spouses

Comparison of farmers with spouses showed differences in ITA° and TAN° at intermittently exposed sites, due to higher pigmentation (L^* and b^*) in farmers. Whereas the difference at the shoulder is significant. This indicates that they have

Table 1 Skin colour measurements (L^*, a^*, b^*) taken in winter, individual typology angle ITA° and differences in colour (ΔE) and pigmentation (TAN°) to buttock skin

Group	Female ($n=47$)		Male ($n=44$)		Farmer ($n=48$)		Spouses ($n=25$)		Adults ($n=73$)		Children ($n=18$)		All ($n=91$)	
Colour	L^*	ΔE	L^*	ΔE	L^*	ΔE	L^*	ΔE	L^*	ΔE	L^*	ΔE	L^*	ΔE
	a^*	TAN°	a^*	TAN°	a^*	TAN°	a^*	TAN°	a^*	TAN°	a^*	TAN°	a^*	TAN°
	b^*	ITA°	b^*	ITA°	b^*	ITA°	b^*	ITA°	b^*	ITA°	b^*	ITA°	b^*	ITA°
Fore-	63.5*	7.2*	60.1*	10.5*	60.8	9.4	60.6	10.0	60.7**	9.6**	66.4**	6.0**	61.9	8.8
head	12.8*	13.9*	16.4*	19.9*	14.8	19.5	15.1	19.8	14.9**	19.6**	11.5**	5.4**	14.5	16.8
	13.6	44.3*	13.7	35.1*	14.0	36.7	13.5	37.3	13.8	36.9**	12.8	51.7**	13.6	39.9
Outer	62.8	8.0	61.3	7.7	61.4	8.3	62.3	7.3	61.7	8.0	62.4	7.1	62.1	7.8
Upper	9.2	21.1	9.7	21.1	9.6	23.0	9.0	19.7	9.4	21.9**	9.6	17.9**,[a]	9.4	21.1
Arm	16.9	37.0	16.6	34.0	17.3	33.3	16.1	37.4	16.9	34.7**	16.4	39.2**,[a]	16.8	35.6
Shoulder	62.6	8.1	62.1	7.4	61.2	8.8	62.6	7.2	61.7**	8.3**	64.9**	5.8**	62.3	7.8
	10.4	21.1	12.0	18.1	11.6	22.8*	11.3	18.0*	11.5	21.1**	10.0	13.7**,[b]	11.2	19.7
	16.4	37.0	16.3	36.9	17.1	33.5*	15.4	39.1*	16.5	35.4**	15.8	43.4**,[b]	16.4	37.0
Inner	68.1	1.9	68.1	2.1	68.1	2.3	68.2	1.8	68.1	2.1	68.0	1.2	68.1	1.9
Upper	6.4	2.8	7.1	1.0	6.7	1.0	6.8	0.6	6.7	0.9	6.6	1.5	6.7	1.0
Arm	12.5	55.3	12.2	56.1	12.5	55.2	11.9	56.5	12.5	55.1	12.0	56.6	12.3	55.7
Buttock	68.5	0.0	67.5	–	67.7	0.0	68.1	–	67.8	–	68.7	–	68.0	–
	8.0	0.0	9.1	–	8.9	0.0	8.6	–	8.8	–	7.7	–	8.6	–
	11.5	58.1	12.2	55.1	11.8	56.2	11.6	57.1	11.7	56.5	12.1	57.1[a,b]	11.8	56.6

Single asterisk (*) indicate statistically significant differences between females and male, double asterisk (**) between adults and children

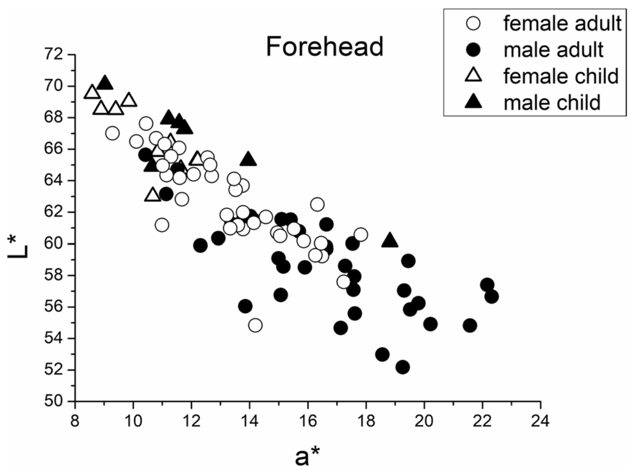

Fig. 1 *L** (brightness) and *a** (redness) values of all participants measured at the forehead. Open triangles depict values for children (female: blue, male red). Blue filled circles depict values of adult females and red filled squares values of adult males

accumuled higher pigmentation that persists through winter. No differences between farmers and spouses were found at the continuously exposed forehead.

3.2 Influence of age (winter skin)

Neither buttock, nor inner upper arm colour, nor FST correlates with age. The only correlation with age was for TAN°, but not in all groups or body sites. For example, in children, only forehead TAN° increased with age but in farmers TAN° increased with age at all exposed body sites. The results for significant correlations are shown in Table 2, together with parameters from corresponding linear regression analysis. Age-dependent TAN° values for intermittently and continuously exposed body sites are shown in Fig. 2. The values for males and females are not shown because correlations are not significant.

3.2.1 Farmers and spouses

TAN° increases in farmers (both genders) with age. Forehead TAN° changes by 0.33° ± 0.13° per year, by 0.34° ± 0.12° per year at the outer upper arm and by 0.48° ± 0.12° per year at the shoulder (see Table 2). From 20 to 70 years, these would denote an increase in TAN° on average of 16° (forehead), 17° (outer arm) and 24° (shoulder) respectively. Highest TAN° occurs in farmers > 50 years and may reach 50° on all body sites. However, TAN° values below 10° are also observed up to the age of 60 years. Unlike farmers, there is no age-dependent change in TAN° in spouses (both genders) at any body site. Figure 2 shows that some spouses may reach higher TAN° values at a younger age than farmers, indicating that personal sun exposure of some spouses is comparable to that of farmers. On average spouses tend to have lower TAN° on intermittendly exposed body sites. The highest TAN° values in spouses are at 30°–40° at all body sites and are achieved at 30 years.

3.2.2 Children

In children (Fig. 2, panels g–i) only the forehead changes ($p < 0.05$) by a TAN° of 0.58° per year, leading to a change of 11° from birth to 18 years. Although, no significant age-trend was found at the outer upper arm and shoulder, a clear TAN° can be recognised, which is even larger than at the forehead (for both $p < 0.001$).

3.2.3 Gender

In males (farmers and spouses) and females (farmers and spouses), no significant change with age is detectable.

3.2.4 Lifetime changes

Differences ($p < 0.01$) between facultative and constitutive pigmentation occur in children with a TAN° of up to 30° (Fig. 2, panels g–i) and may continue throughout life, but with considerable inter-personal variation (Fig. 2, panels j–l). Gender has no influence on this progress. In our sample, farmers tend to darken more than both other groups with an accumulation of pigmentation resulting in a TAN° of up to 50 (Fig. 2, a–c). Some of the spouses and children (both genders) had individually higher facultative pigmentation earlier in life than farmers (Fig. 2, d–i). As there is no

Table 2 Significant linear trends in TAN° with age in farmers and children

Group	Body site	TAN° ± SE at birth (intercept *d*)	Change in TAN° per year ± SE (slope *k*)	*c*	r^2	*p*
Farmers	Forehead	3.10 ± 6.83	0.328 ± 0.133	0.311	0.0970	0.0177
	Outer upper arm	6.05 ± 6.11	0.339 ± 0.120	0.361	0.130	0.00682
	Shoulder	− 1.04 ± 6.14	0.476 ± 0.120	0.489	0.239	0.000250
Children	Forehead	− 2.07 ± 2.94	0.577 ± 0.207	0.546	0.298	0.0137

No significant trends were found in spouses, in females (farmers and spouses), and males (famers and spouses) or body sites not listed. Here *c* is the correlation coefficient, r^2 is the coefficient of determination and *p* is the probability value [of standard error (SE)]

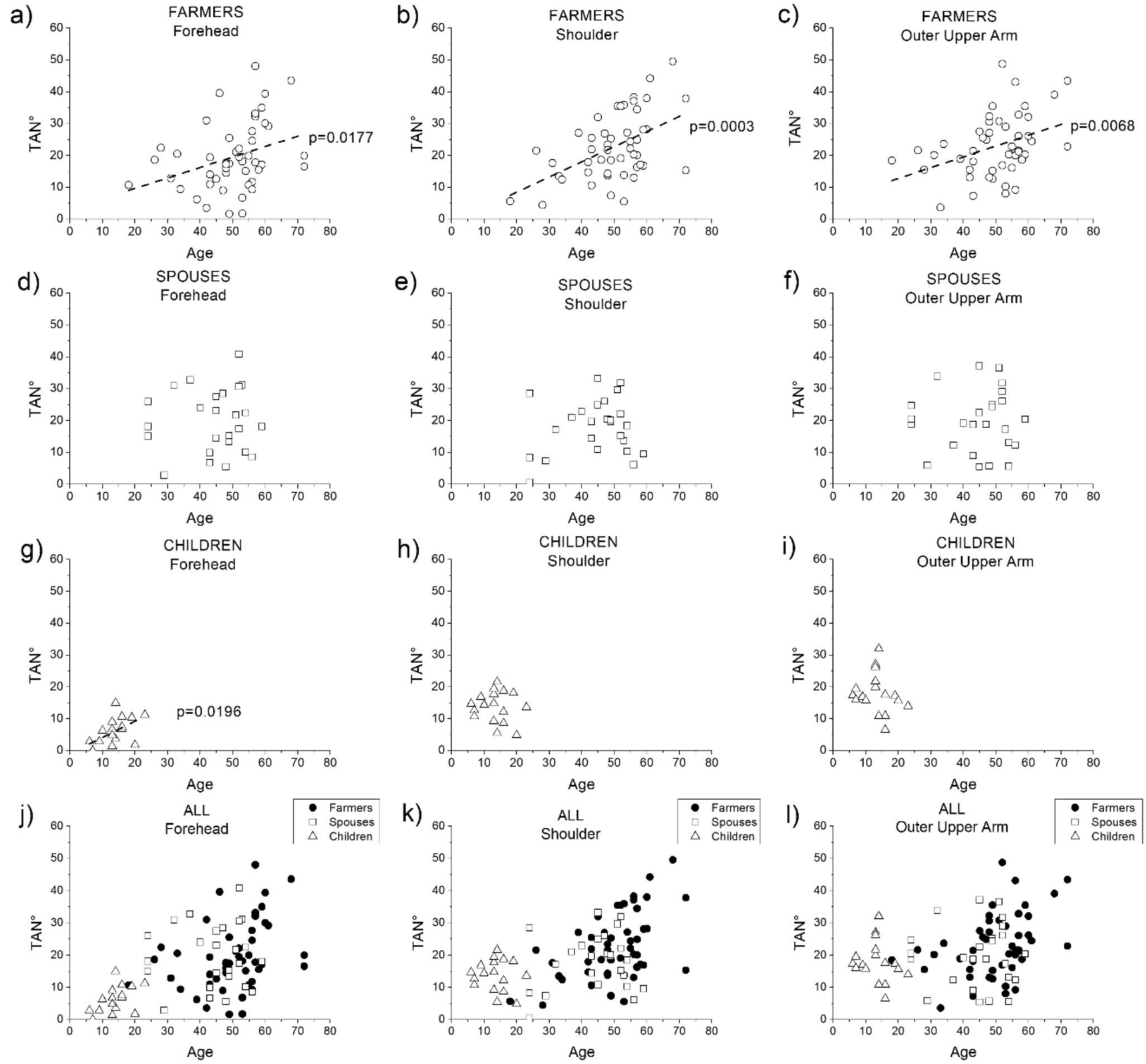

Fig. 2 Degree-of-tan TAN° (difference between constitutive and facultative pigmentation), with age on continuously and intermittently exposed body sites [forehead (**a**, **d**, **g**, **k**), outer shoulder (**b**, **e**, **h**, **j**) and upper arm (**c**, **f**, **I**, **j**)] for farmers (**a–c**), spouses (**d–f**), children (**g–i**), and all (**j–l**) participants. Linear regression is only shown when correlation is significant ($p < 0.05$)

correlation of TAN° with age in spouses, this may indicate that a certain level of facultative pigmentation (TAN° of up to 40°), which holds during winter, may be reversible and is lost if UVR exposure is lower in the following seasons. In addition, individual non-occupational sun exposure, and resulting pigmentation, may be several times higher than that caused by occupation (Fig. 2, panel j–l). TAN° on intermittently exposed body sites is only slightly higher (by 4°) in farmers (on average) than in other groups. In the case of the forehead, there is no difference in TAN° by occupation but differences between males and females in L^* and a^* and derived measurements are gender specific but independent of age.

3.3 Seasonal changes

TAN° is seasonal in all groups at continuously and intermittently exposed body sites, with highest values between late July and early September. Figure 3 depicts the annual course of TAN° on all body sites. Farmers and spouses were divided into two groups by bisecting their age range (18–72 years) with a cut-off at 45 years. This results in a total in 5 groups:

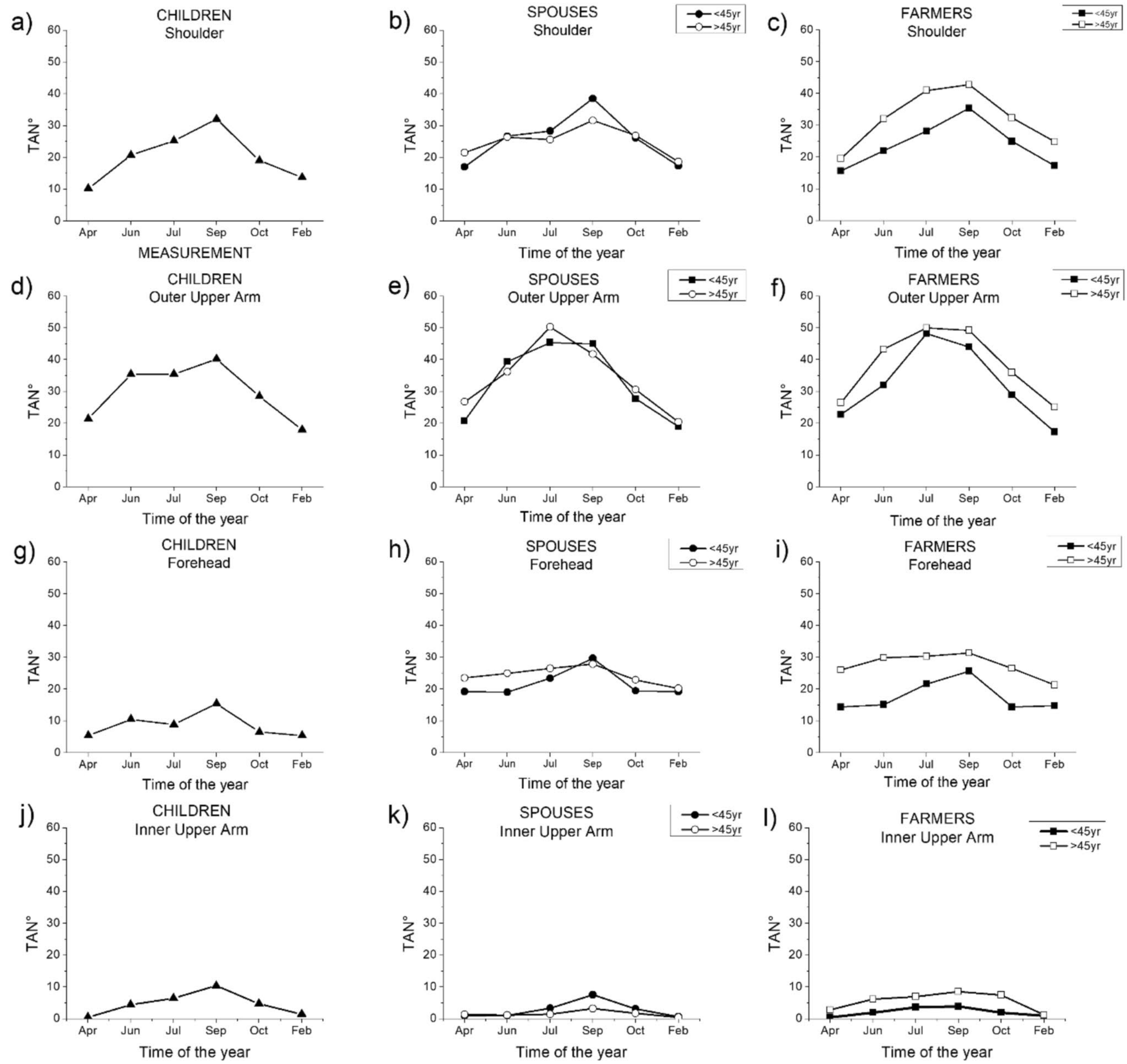

Fig. 3 Degree of tan TAN° (difference to buttock skin) in Austrian farming families throughout a year, at four different body parts [shoulder (**a**–**c**), outer upper arm (**d**–**f**), forehead (**g**–**i**) and inner upper arm (**j**–**l**)], shown separately for two age groups in farmers and spouses: aged 18–45 years and over 45 years and for children

farmers younger than 45 years (mean: 35.9 years, 16 persons), farmers older than 45 years (mean: 55.2 years, 35 persons), spouses younger than 45 years (mean 35.9 years, 12 persons), spouses older than 45 years (mean 52.0 years, 13 persons) and children (mean: 13.9 years, 18 persons).

Outer upper arm TAN° (Fig. 3, panels d–f) shows the greatest seasonal changes in all groups, with highest values between July and September. There is an age-dependent effect in farmers. Annual time-courses are similar, but older farmers start with higher values ($p < 0.01$), which supports the results described above, i.e. that winter pigmentation correlates with age. It should be noted that the older group did not have higher UVR exposure in that year during monitoring (< 45 years: mean $= 1.6$ SED/day, > 45 years: mean $= 1.5$ SED/day), but it is likely that the have higher lifetime UVR exposure as they are 20 years older on average. In agreement with the results above, there are no age-dependent differences in spouses annual time-course.

Similar annual time-courses in the outer arm and shoulders are observed (Fig. 3, panels a–c). Again, it is possible to distinguish between both age groups in farmers ($p < 0.01$) but not in spouses. The time-courses in spouses and children are similar but less pronounced than in farmers. Seasonal forehead changes (Fig. 3, panels g–i) are less obvious, though age differences in farmers can be recognised (start at higher values, $p < 0.01$). The seasonal course in children shows a lower pigmentation level, indicating that pigmentation increases with adulthood.

The inner arm is often regarded as unexposed, but the data suggest this is not the case. In farmers (both age groups) and children, changes in TAN° are visible, but the time course is quite flat (Fig. 3, panels j–l). UVR exposure of the inner arm denotes sleeveless clothes and physical activity that enables solar exposure. However, TAN° does fade by late winter.

3.4 Personal UVR radiant exposure and TAN°

Figure 4 depicts changes in TAN° in younger and older farmers between two visits versus daily mean radiant exposure for two intermittently exposed body sites. Measurements from 50 participants could be collected over approximately 190 days. As time between visits was not identical for all participants, the daily mean radiant exposure was calculated by dividing the radiant exposure (gained during the period in between) by the number of recording days. Linear regression lines pass through zero (i.e. no change in pigmentation) at a daily mean average of 1.4 SED in both age groups. This indicates that radiant exposure (doses) > 1.4 SED/day led to increased pigmentation, whilst lower doses result in fading pigmentation. In spouses and children (male and female) there was no correlation at any body site between mean radiant exposure and TAN°. This suggests that farmers expose their skin rather continuously to the sun, so that changes in TAN° and measured radiant exposure correlate over longer periods. However, it cannot be assumed that exposure is necessarily daily, so threshold values may > 1.4 SED/day when skin is exposed. In addition, it can be seen from Fig. 4, that older farmers did not receive higher radiant exposure than younger farmers and is therefore not the cause of higher TAN° in higher age. However, as they are older they are very likely to have received a higher accumulated UV exposure and it is therefore very likely that higher lifetime UV exposure is the cause of higher TAN in higher age. Changes in forehead pigmentation between visits were too small for analysis (see also Fig. 3).

4 Discussion

Buttock skin was the baseline to determine the degree of TAN° (difference between facultative and constitutive pigmentation). Pigmentation (ITA) was the same at the inner upper arm and at the buttock in winter, but the latter was redder, indicating higher blood flow [24]. However, there were differences between constitutive and facultative pigmentation (TAN°) at all exposed body sites in late February in all groups. Thus, some facultative pigmentation lasted months, although decreased compared to late summer, and became the baseline for further pigmentation.

TAN° varied with season, peaking in late summer, and was most pronounced on the outer upper arm in all groups. The annual course was the same in all groups, but winter starting level in farmers becomes darker with increasing age. Pigmentation of the inner upper arm increases slightly during the year in some individuals, which means that pigmentation on this site can only be regarded as constitutive in winter.

Farmers had slightly higher TAN° (approx. 4°) in late winter at all intermittently exposed sites (whereas shoulder was significant), except forehead, than spouses. This indicates greater exposure at least to their shoulders

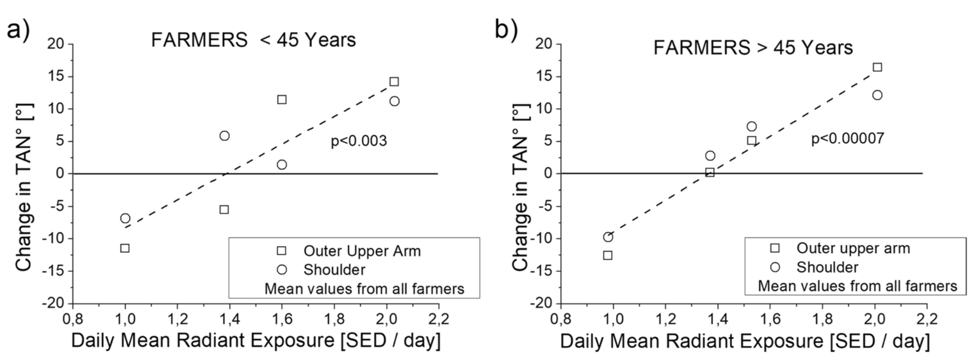

Fig. 4 Change in TAN° (difference between two consecutive colour measurements, mean of all farmers) versus daily mean radiant erythemal UVR exposure received in the corresponding period at the temporary exposed body parts (outer upper arm and shoulder) for farmers **a** aged under 45 years and **b** farmers aged over 45 years, both with the associated linear fit

resulting in more pigmentation that lasts into winter and possibly accumulates during lifetime. There were gender differences in skin colour, especially on the forehead, with males being darker (L^*) and redder (a^*) than females whilst pigmentation (b^*, TAN°) was the same. In children (a^*) is lower and L^* is higher on average. However, some children may already have reached gender specific values found in adults.

Pigmentation differences (TAN°) between adults and children at continuously and intermittently exposed sites were clear, though constitutive values were the same. This may be another indicator of lifetime accumulation of pigmentation. In children, facultative pigmentation differs from constitutive pigmentation by up to a TAN° of 30°. This difference may become individually larger during life though gender has no role. In spouses, TAN° may become greatest (up to 40°) as early as 30 years old, which denotes facultative pigmentation, which holds into late winter, but is reversible and vanishes if UVR exposure is lower in later seasons. It also implies that recreational sun exposure may be much higher than that caused by outdoor occupation. In farmers, TAN° often increases continuously during life, and becomes highest (up to 50°) after 50 years but in some farmers, there is no accumulation of TAN°.

Personal dosimetry in farmers (but not in spouses or children) showed a mean exposure of at least ~ 1.4 SED/day (measured on wrist over 6–7 weeks) is necessary to enhance TAN° on intermittently exposed body parts. Lower exposure causes fading of existing TAN°. Continuous exposure (indicated by the correlation of changes in TAN° of body parts and radiant exposure) may lead to accumulation of pigmentation during life. However, it should be noted that wrist exposure is not significantly higher in farmers than in spouses and that transfer of UVR measurements from wrist to other body sites is not reliable.

The study strengths are that measurements were quantitative over one year in a specific and localised population. Its weakness is that the sample size is relatively small. In summary, we have shown that seasonal changes in TAN° were pronounced in all groups on intermittently exposed body sites but less so on the forehead. TAN° increases on average in farmers during their lifetime but not in their spouses. The highest TAN° values were found in farmers older than 50 years.

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Data availability Data are available on request.

Declarations

Conflict of interest Authors declare no conflict of interest.

Ethic statement Ethical approval was obtained from the Viennese Research Ethics Committee (No. EK 978/2011).

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