Changes in the pattern of sun exposure and sun protection in young children from tropical Australia

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Background: Australia has one of the highest rates of skin cancer globally. Lifetime risk is associated with childhood sun exposure.

Objective: We sought to investigate whether skin cancer prevention programs have resulted in improvements in sun-exposure and sun-protection behavior among young children in tropical Australia.

Methods: Two cohorts of 12-to 35-month-old children from Townsville, Australia, were compared: cohort 1 was recruited from hospital birth records (1991) and cohort 2 was recruited via local child-care centers (1999-2002). Children's phenotypic characteristics were assessed. Parents completed questionnaires detailing children's demographic characteristics, and sun-exposure and sun-protective practices.

Results: Although 1-year-old children from cohort 2 spent more time in the sun than those from cohort 1 (median 2.2 vs 2.8 h/d; $P = .002$), a higher proportion almost always wore sunscreen and a swim-shirt year round. Although more 1-year-old children in cohort 2 had experienced a sunburn (35.5% vs 51.2%; $P = .007$), both cohort 2 age groups experienced fewer hours of sun exposure to the back of the trunk ($P < .001$), were less likely to have been sunburned on the back/shoulders (age 1 year 34.8% vs 10.1% and age 2 years 52% vs 10.1%; $P < .001$), and acquired fewer melanocytic nevi at these sites ($P < .001$).

Limitations: There was potential for socially desirable responses (information bias).

Conclusion: Although duration of sun exposure in early childhood did not decrease during an 8-year period, reported use of personal sun protection did. The observed increase in popularity of swim-shirts and sunscreen between cohorts coincided with the development of significantly fewer melanocytic nevi in these children. (J Am Acad Dermatol 2013;68:774-83.)

Key words: early childhood; melanocytic nevi; skin cancer prevention; sun exposure; sun protection; sunburn; trends over time; tropical Australia.

Queensland, Australia, has one of the highest rates of skin cancer[1] with melanoma incidence continuing to increase.[2] The risks of developing melanoma and melanocytic nevi (MN), the strongest risk factor for melanoma,[3] are directly linked to high levels of sun exposure in early childhood.[4-6] Evaluation of prevention campaigns suggests sun-protective behaviors have improved[7-9] but

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it is uncertain whether this will translate into a reduction in melanoma incidence.

National Skin Cancer Prevention goals for Australia target children and adolescents for primary prevention[10] and align with those of the World Health Organization[11] to minimize sun damage and foster lifelong sun-protective behaviors.[10] These are best achieved through multifaceted skin cancer programs[9] advocating use of shade, sunscreen, hats, and clothing, and sun avoidance at peak ultraviolet (UV) radiation times,[7,12] some of which are underused, particularly in childhood.[10,13]

MN, the precursor lesions of up to 60% of melanomas,[14] are the most important biomarker for melanoma.[3,15] Children raised in Queensland, Australia, develop MN earlier and in higher numbers than children raised elsewhere.[5,16,17] As nevus development is related to sun exposure during childhood,[5,16] MN offer a short-term measure of the efficacy of sun protection thereby facilitating objective assessment of skin cancer prevention programs.[13]

Few studies have evaluated trends in childhood sun protection using modifiable biomarkers such as MN.[13] We assessed changes in sun-safety practices during a period of more than 8 years to inform current and future skin cancer prevention activities.

CAPSULE SUMMARY

- The risk of developing melanoma and melanocytic nevi is linked to high levels of sun exposure in early childhood.
- Although sun exposure in early childhood did not decrease over an 8-2year period in Townsville, Australia, reported sun-protective practices improved and children developed significantly fewer melanocytic nevi.
- Maintaining the focus on reducing sun exposure and increasing sun protection in infants and young children is important, particularly in regions of high ultraviolet radiation.

METHODS

Sun-protective practices of 2 cohorts of 12-to 35-month-old children from Townsville, Australia, were compared more than eight years apart: in 1991 and in 1999 through 2002. Townsville (latitude 19°16'S) in North Queensland, Australia, has a dry, tropical climate and high levels of ambient solar UV radiation throughout the year.[18]

Recruitment

The first cohort was recruited in 1991 from hospital birth records of the 2 main maternity hospitals in Townsville, Australia. A letter and questionnaire were sent to mothers, inviting them to participate. Cohort 1 included all children younger than 3 years from the original article.[5] This subset was selected to match the approximate age of cohort 2. There were 201 children who fulfilled the inclusion criteria: Caucasian (at least 3 grandparents of European origin), with parents who intended to remain in the study area and provided written consent. Cohort 1 included 201 children (n = 95 age 1 year [12-23 months] and n = 106 age 2 years [24-35 months]).

The second cohort was recruited via 26 local child-care centers in Townsville, Australia, between 1999 and 2002. In all, 25 (96.2%) child-care centers participated. Center directors provided enrollment lists (first name, date of birth, and attendance pattern of children age <3 years). A study information sheet, questionnaire, and consent form were sent to parents of eligible children via child-care centers. The inclusion criteria for cohort 2 were the same as for cohort 1 plus regular attendance at a participating child-care center between November 1999 and July 2002. Cohort 2 included 463 children aged 12 to 35 months (n = 394 age 1 year [12-23 months] and n = 69 age 2 years [24-35 months]). Cohort 2 formed the baseline group for a randomized controlled intervention trial to determine whether the development of MN in early childhood can be prevented or delayed by using sun-protective clothing.[13]

Demographics

Age (months), sex, place of birth, and time spent in the tropics were determined from birth and child-care records and parent questionnaires. Socioeconomic status of the child's suburb was classified using the Socioeconomic Indexes for Areas (3 levels).[19] Parents' education levels were determined from questionnaires, and ethnicity was assessed according to the number of the child's Caucasian grandparents.

Clinical examination (phenotype and MN)

Hair and eye color were recorded by reference to standard charts as described previously[5] and categorized for analysis following the method of Kelly et al.[17] Skin reflectance of the inner upper aspect of the arm was determined using a reflectance spectrophotometer (Colormet 3.1, Instrumar, St John's, Newfoundland, Canada, at 680 nm [cohort 1]; Evans Electroselenium Ltd, model 99; Diffusion Systems Ltd, London, United Kingdom at 685 nm [cohort 2]) for melanin discrimination and then categorized as fair/medium/olive based on previously defined cut-points.[20] Freckling was recorded as present or absent. Baseline spectrophotometer measurements were missing for 56 children in cohort 2 because of instrument repairs. Subjective assessment of skin color was assigned to these children (53 fair, 3 medium).

At baseline full-body examinations for MN of all sizes (30 body sites excluding the buttocks, genitals, and scalp) were conducted using a standard international protocol.[21] The presence or absence of MN, body site distribution (back of trunk), and mean number of MN were recorded by one of the authors (S. H.), after training by dermatologists in the recognition of MN.

Questionnaires

Participants' parents completed a comprehensive baseline questionnaire covering the child's demographic and pigmentary characteristics, sunburn history, and sun-exposure and sun-protective practices throughout the year. Habitual sun exposure was determined using charts where parents marked on a line divided into hourly intervals, the time their child usually spent outside in the sun between 6 AM and 7 PM. Information about the hours spent outside on typical weekdays and weekend days and the frequency of sun exposure at locations such as the beach and pool were collected along with "playing outside in the sun during the warmer months of the year" (classified according to UV index of Townsville, Australia). Sunburn history was assessed according to frequency and nature of sunburn "redness without peeling," "redness with peeling," and "pain and blistering." Parents were asked to mark the site of sunburn on a body-site diagram from which the frequency of sunburn on the back and shoulders was derived.

The variable "sun-protective practice" was derived from scores for frequency of sunscreen and swim-shirt use in the summer and winter months (never = 0, less than half the time = 1, half the time = 2, more than half the time = 3, almost always = 4) recorded by parents in both summer and winter months. Data relating to frequency of hat use in the summer and winter months were only recorded for cohort 2.

Both studies were approved by James Cook University Human Ethics Committee and written consent was provided by parents/guardians of participants.

Statistical analysis

Numeric variables with a skewed distribution were described using median values and interquartile ranges; approximately normally distributed numeric variables were described using means and SD. Bivariate analysis of demographic factors, skin phenotypic factors, and sun-exposure and sun-protective practice analysis used standard statistical tests (χ^2 test, t test, nonparametric Mann-Whitney, and Kruskal-Wallis tests as appropriate).

Multivariate linear regression analyses were used to assess the effect of the 2 cohorts on: (1) the average number of hours spent outside in the sun on a typical day in the previous year; and (2) the total number of MN. Both outcome measures were skewed and were log-transformed to meet the normality assumptions of the model. Both multivariate analyses included the following characteristics: cohort (1991 or 1999), gender, age in months, socioeconomic index of advantage according to Australian Bureau of Statistics[19] (categorized as low, medium, high), ethnicity (Caucasian or not), level of parental education (neither, one, or both parents tertiary qualified), born in the tropics, hair color (black/brown, fair/blond, red), eye color (brown/black, hazel, blue/green), measurement of skin reflectance (olive, medium, fair), propensity to burn (tends to burn, does not tend to burn), and tanning ability (deep, moderate, slight, never). Four characteristics (ethnicity n = 31; skin reflectance n = 49; propensity to burn n = 107; tanning ability n = 68) had 5% or more missing values. For those characteristics, separate missing categories were created and the model adjusted accordingly.

Statistical analysis was conducted using software (SPSS for Windows, Release 18, IBM Corp, Armonk, NY). All significance tests were 2-sided at the .05 level. A P value of less than .05 was considered significant a priori.

RESULTS

Description of participating children

Of the 201 children in cohort 1, 51.6% of 1-year-olds (mean age 18.8 ± 3 months) and 49.1% of 2-year-olds (mean age 29.6 ± 4.1 months) were boys (Table I). Of the 463 children in cohort 2, 54.6% of 1-year-olds (mean age 16.9 ± 3.4 months) and 50.7% of 2-year-olds (mean age 27 ± 2.9 months) were boys (Table I). Children in both cohorts were predominantly Caucasian, born in the tropics, and from higher socioeconomic groups. More children in cohort 2 had fair skin, whereas children in cohort 1 were more likely to develop a moderate tan (Table I).

Sun exposure

The median number of hours spent in the sun on a typical day was higher in cohort 2 although this did not reach statistical significance among the 2-year-olds (Table II). The median number of hours spent

Table I. Demographic and pigmentary characteristics of 2 cohorts of young children of same age recruited more than 8 years apart in tropical Australia

Risk factor	Age 1 y (12-23 mo) Cohort 1 (1991) N = 95	Age 1 y (12-23 mo) Cohort 2 (1999-2002) N = 394	*P* value	Age 2-y (24-35 mo) Cohort 1 (1991) N = 106	Age 2-y (24-35 mo) Cohort 2 (1999-2002) N = 69	*P* value
Demographic characteristics						
Mean age, mo (±SD)	18.8 (3.0)	16.9 (3.4)	.0005*	29.6 (4.1)	27 (2.9)	.0005*
Median age, mo (IQR)	19 (17-22)	16.8 (14-20)		30 (25-33.25)	27 (25-29)	
Boys	49 (51.6%)	215 (54.6%)	.6†	52 (49.1%)	35 (50.7%)	.829†
Girls	46 (48.4%)	179 (45.4%)		54 (50.9%)	34 (49.3%)	
SES of residence‡						
Children living in low SES suburb	10 (10.6%)	115 (29.3%)	.0005†	14 (13.2%)	20 (29.0%)	.0005†
Children living in medium SES suburb	83 (83.3%)	216 (55.0%)		92 (86.8%)	35 (50.7%)	
Children living in high SES suburb	1 (1.1%)	62 (15.8%)		0 (0%)	14 (20.3%)	
Ethnicity						
Caucasian (≥3 European grandparents)	93 (97.9%)	347 (88.1%)	.004†	103 (97.2%)	64 (92.8%)	.266§
Non-Caucasian (≥2 Non-European grandparents)	2 (2.1%)	47 (11.9%)		3 (2.8%)	5 (7.2%)	
Combined education level of parents						
Neither parent tertiary qualified	59 (62.1%)	232 (61.6%)	.859†	71 (67%)	45 (67.2%)	.972†
One tertiary-educated parent	25 (26.3%)	93 (24.7%)		22 (20.8%)	13 (19.4%)	
Two tertiary-educated parents	11 (11.6%)	51 (13.6%)		13 (12.3%)	9 (13.4%)	
Birthplace						
Children born in temperate zone	0 (0%)	40 (10.2%)	.001†	0 (0%)	10 (14.5%)	.0005§
Children born in tropics	95 (100%)	354 (89.8%)		106 (100%)	59 (85.5%)	
Duration living in tropics, mo						
Mean (±SD)	18.8 (3.0)	15.8 (4.7)	.0005*	29.6 (4.1)	25.4 (5.9)	.0005*
Median (IQR)	19 (17-22)	16 (13-19)		30 (25-33.25)	26 (24-29)	
Pigmentary characteristics						
Hair color						
Black	0 (0%)	1 (0.3%)	.063§	0 (0%)	0 (0%)	.941§
Brown	14 (14.7%)	95 (24.1%)		31 (29.2%)	19 (27.5%)	
Blond/fair	78 (82.1%)	271 (68.8%)		73 (68.9%)	49 (71.0%)	
Red	3 (3.2%)	27 (6.9%)		2 (1.9%)	1 (1.4%)	
Eye color						
Brown/black	18 (18.9%)	112 (28.4%)	.122§	30 (28.3%)	14 (20.3%)	.036§
Hazel	14 (14.7%)	36 (9.1%)		15 (14.2%)	6 (8.7%)	
Blue	63 (66.3%)	245 (62.2%)		61 (57.5%)	45 (65.2%)	
Green	0 (0%)	1 (0.3%)		0 (0%)	4 (5.8%)	
Reflectance categories of inner upper aspect of the arm						
Olive/dark (<64%)	14 (15.1%)	3 (0.8%)	.0005†	8 (7.8%)	0 (0%)	.01§
Medium (64%-66.9%)	11 (11.8%)	14 (3.9%)		11 (10.7%)	2 (3.2%)	
Fair (≥67%)	68 (73.1%)	340 (95.2%)		84 (81.6%)	60 (96.8%)	
Freckling						
Absent	83 (87.4%)	376 (95.4%)	.003†	77 (72.6%)	61 (88.4%)	.013†
Present	12 (12.6%)	18 (4.6%)		29 (27.4%)	8 (11.6%)	
Propensity to sunburn						
Rarely/never burns	2 (3.7%)	71 (19.2%)	.005†	10 (14.1%)	13 (20.6%)	.316†
Tends to burn	52 (96.3%)	298 (80.8%)		61 (85.9%)	50 (79.4%)	
Tanning ability						
Deep tan	4 (4.3%)	16 (4.7%)	.0005†	5 (4.8%)	2 (3.6%)	.0005§
Moderate tan	53 (56.4%)	72 (21.1%)		68 (64.8%)	9 (16.4%)	
Slight/light/minimal tan	10 (10.6%)	210 (61.4%)		10 (9.5%)	37 (67.3%)	
Never develops a tan	27 (28.7%)	44 (12.9%)		22 (21.0%)	7 (12.7%)	

IQR, Interquartile range; *SES*, socioeconomic status.
*Nonparametric Mann-Whitney test.
†Pearson χ^2 test.
‡SES of suburb was based on Socioeconomic Indexes for Areas (Australian Bureau of Statistics 1996).[19]
§Fisher exact test.

Table II. Changes in sun exposure habits of young children of same age in 2 cohorts recruited more than 8 years apart in tropical Australia

	Age 1 y (12-23 mo)			Age 2 y (24-35 mo)		
	Cohort 1 (1991) N = 95	Cohort 2 (1999-2002) N = 394	*P* value	Cohort 1 (1991) N = 106	Cohort 2 (1999-2002) N = 69	*P* value
Sun exposure of children while playing outside						
How often child plays outside in sun						
Rarely/never	6 (6.3%)	31 (7.9%)	.061*	3 (2.8%)	7 (10.1%)	.047†
1-2 times/mo	3 (3.2%)	18 (4.6%)		2 (1.9%)	1 (1.4%)	
3-4 times/mo	0 (0%)	20 (5.1%)		0 (0%)	2 (2.9%)	
1-2 times/wk	8 (8.4%)	57 (14.5%)		14 (13.2%)	3 (4.3%)	
3-4 times/wk	24 (25.3%)	69 (17.6%)		25 (23.6%)	14 (20.3%)	
Almost every day	54 (56.8%)	198 (50.4%)		62 (58.5%)	42 (60.9%)	
No. of hours spent outside in sun on typical day in previous year						
Mean (±SD)	2.4 (1.7)	3.1 (2.0)	.002‡	2.7 (1.7)	3.2 (2.1)	.082‡
Median (IQR)	2.2 (0.9-3.6)	2.78 (1.6-4.3)		2.3 (1.5-3.8)	3 (1.7-4.6)	
Outdoor swimming and related aquatic activities						
How often does child swim at outdoor pool?						
Rarely/never	40 (42.1%)	99 (25.2%)	.0005*	38 (35.8%)	15 (21.7%)	.03*
1-2 times/mo	24 (25.3%)	71 (18.1%)		32 (30.2%)	10 (14.5%)	
1-2 times/wk	14 (14.7%)	124 (31.6%)		22 (20.8%)	31 (44.9%)	
3-4 times/wk	12 (12.6%)	52 (13.2%)		8 (7.5%)	9 (13.0%)	
Almost every day	5 (5.3%)	47 (12.0%)		6 (5.7%)	4 (5.8%)	
How often does child go to beach?						
Rarely/never	65 (68.4%)	161 (41.0%)	.0005†	60 (56.6%)	17 (24.6%)	.0005†
1-2 times/mo	22 (23.2%)	129 (32.8%)		42 (39.6%)	30 (43.5%)	
1-2 times/wk	7 (7.4%)	95 (24.2%)		3 (2.8%)	22 (31.9%)	
3-4 times/wk	1 (1.1%)	6 (1.5%)		0 (0%)	0 (0%)	
Almost every day	0 (0%)	2 (0.5%)		1 (0.9%)	0 (0%)	
Median total No. of hours spent playing in water in warmer half of year (IQR)	42 (8-144.1)	72 (10.6-200)	.039‡	60 (12-146)	77 (30-196)	.253‡
Median total No. of hours spent playing in water with back exposed during warmer half of year (IQR)	9 (0-43.2)	0 (0-0)	.0005‡	9 (0-52.9)	0 (0-0)	.0005§
Sunburn						
Ever been sunburned						
No	60 (64.5%)	191 (48.8%)	.007*	49 (47.6%)	30 (44.1%)	.657*
Yes	33 (35.5%)	200 (51.2%)		54 (52.4%)	38 (55.9%)	
Experienced sunburn causing "redness without peeling"						
Never	63 (66.3%)	196 (49.9%)	.021†	51 (48.1%)	30 (43.5%)	.915†
Once-twice only	26 (27.4%)	170 (43.3%)		42 (39.6%)	31 (44.9%)	
1-2 times/y	5 (5.3%)	18 (4.6%)		10 (9.4%)	6 (8.7%)	
≥3 times/y	1 (1.1%)	9 (2.3%)		3 (2.8%)	2 (2.9%)	
Experienced at least 1 sunburn that caused "redness with peeling"						
No	91 (95.8%)	372 (94.7%)	.799†	101 (96.2%)	68 (98.6%)	.649†
Yes	4 (4.2%)	21 (5.3%)		4 (3.8%)	1 (1.4%)	
Experienced at least 1 sunburn that caused "pain and blistering"						
No	95 (100%)	389 (99.0%)	1.0†	105 (100%)	69 (100%)	1.0†
Yes	0 (0%)	4 (1.0%)		0 (0%)	0 (0%)	

Continued

Table II. Cont'd

	Age 1 y (12-23 mo)			Age 2 y (24-35 mo)		
	Cohort 1 (1991) N = 95	Cohort 2 (1999-2002) N = 394	P value	Cohort 1 (1991) N = 106	Cohort 2 (1999-2002) N = 69	P value
Ever sunburned on back or shoulders?						
No	60 (65.2%)	354 (89.9%)	.0005*	49 (48.0%)	62 (89.9%)	.0005*
Yes	32 (34.8%)	40 (10.1%)		53 (52.0%)	7 (10.1%)	
Acquired MN						
Acquired MN on back of trunk						
No	56 (60.2%)	334 (84.8 %)	.0005*	26 (25.2%)	42 (60.9%)	.0005*
Yes	37 (39.8%)	60 (15.2%)		77 (74.8%)	27 (39.1%)	
No. of MN on back of trunk						
Mean (±SD)	0.62 (1.0)	0.21 (0.6)	.0005‡	2.45 (3.4)	0.67 (1.3)	.0005‡
Median (IQR)	0 (0-1)	0 (0-0)		2 (0-3)	0 (0-1)	
Range	0-7	0-6		0-23	0-9	
Acquired any MN on body						
No	6 (6.3%)	72 (18.3%)	.004*	0 (0%)	5 (7.2%)	.009†
Yes	89 (93.7%)	322 (81.7%)		106 (100%)	64 (92.8%)	

IQR, Interquartile range; *MN*, melanocytic nevi.
*Pearson χ^2 test.
†Fisher exact test.
‡Nonparametric Mann-Whitney test.
§Kruskal-Wallis test.

playing in the water in the warmer months was higher in cohort 2 although this did not reach significance in the 2-year-olds (Table II). A higher proportion of children in cohort 2 went to the beach ($P < .001$) and swam in outdoor pools ($P \leq .03$) (Table II). "Playing in water with back exposed during warmer half of year" was more frequent among the children in cohort 1 (both $P < .001$) (Table II).

By the time they were 2 years old, more than half the children had been sunburned (52.4% in 1991; 55.9% in 1999) (Table II) although there was a higher percentage of 1-year-olds in cohort 2 (51.2%) than in cohort 1 (35.5%) with a recorded sunburn ($P = .007$) (Table II). A lower proportion of children in cohort 2 had ever been sunburned on the back or shoulders (both $P < .001$), acquired MN on the back of trunk (both $P < .001$), or acquired any MN on their bodies ($P < .01$) (Table II).

Multivariate analysis confirmed that children in cohort 2 had spent, on average, more hours outside in the sun on a typical day in the previous year than children in cohort 1 (regression coefficient 0.17; 95% confidence interval 0.04-0.30; $P = .014$; log-transformed outcome) when adjusted for all potential confounders.

Sun-protection measures

Although fewer than half the children almost always used sunscreen when outdoors during summer, this was higher among cohort 2 (1-year-olds, 23.4% vs 48.1%, $P < .001$; 2-year-olds, 20.0% vs 43.3%, $P = .001$) (Table III). Overall the use of sunscreen during the winter months was lower than in summer, and although a higher proportion of children in cohort 2 used this sun-protective measure in winter, the difference between cohorts was not significant among the 2-year-olds (Table III). Significantly more children in cohort 2 almost always wore protective swimwear (a shirt or Lycra [nylon elastane; E. I. du Pont Nemours & C., Inc, Wilmington, DE] suit that protects the trunk) while swimming outdoors (both seasons $P < .001$) (Table III). A Lycra cover-up suit was worn when swimming outdoors by 65.9% of 1-year-olds and 69.6% of 2-year-olds in cohort 2; these data were not available for cohort 1 (Table IV). Hat use data were only collected for cohort 2; a legionnaires hat was the most common hat type worn outdoors (1-year-olds, 44.9%; 2-year-olds, 54.4%). Furthermore, 63.8% of 1-year-olds and 73.5% of 2-year-olds almost always wore a hat when outdoors during summer whereas 53.5% of 1-year-olds and 60.3% of 2-year-olds did so during winter (Table IV).

Multivariate analysis confirmed that children in cohort 2 had, on average, acquired fewer MN than children in cohort 1 (regression coefficient −0.62; 95% confidence interval −0.80 to −0.44; $P < .001$; log-transformed outcome) when adjusted for all potential confounders.

DISCUSSION

The major findings from this study were that the sun-protective measures undertaken appeared to

Table III. Changes in sun-protective practices in children of same age in 2 cohorts recruited more than 8 years apart in tropical Australia

	Age 1 y (12-23 mo)			Age 2 y (24-35 mo)		
	Cohort 1 (1991) N = 95	Cohort 2 (1999-2002) N = 394	*P* value*	Cohort 1 (1991) N = 106	Cohort 2 (1999-2002) N = 69	*P* value*
Use of sun protection						
Summer sunscreen use						
Children who almost always wear sunscreen outdoors during summer	22 (23.4%)	188 (48.1%)	.0005	21 (20.0%)	29 (43.3%)	.001
Children who wear sunscreen less often	72 (76.6%)	203 (51.9%)		84 (80.0%)	38 (56.7%)	
Winter sunscreen use						
Children who almost always wear sunscreen outdoors during winter	16 (16.8%)	110 (28.3%)	.023	17 (16.3%)	18 (26.9%)	.096
Children who wear sunscreen less often	79 (83.2%)	279 (71.7%)		87 (83.7%)	49 (73.1%)	
Summer swim-shirt use						
Wears shirt or Lycra suit that protects trunk while swimming outdoors during summer						
Rarely/never	15 (18.8%)	92 (23.7%)	.0005	23 (23.2%)	12 (17.6%)	.0005
Sometimes	24 (30.0%)	29 (7.5%)		31 (31.3%)	3 (4.4%)	
Almost always	41 (51.3%)	268 (68.9%)		45 (45.5%)	53 (77.9%)	
Winter swim-shirt use						
Wears shirt or Lycra suit that protects trunk if swims outdoors during winter						
Rarely/never	11 (19.3%)	73 (27.5%)	.001	23 (28.8%)	7 (17.1%)	.001
Sometimes	16 (28.1%)	26 (9.8%)		22 (27.5%)	2 (4.9%)	
Almost always	30 (52.6%)	166 (62.6%)		35 (43.8%)	32 (78.0%)	

*Pearson χ^2 test.

improve over the study decade, even though time spent in the sun did not decrease. Children in cohort 2 spent more time in the sun on a typical day and playing in water in the warmer months than those in cohort 1. A higher proportion went to the beach and swam in outdoor pools, although children in cohort 1 were more likely to play in water with their backs exposed during the warmer months. By age 2 years, more than half the children in this extreme UV radiation environment[22] had already been sunburned, although a smaller proportion of children in cohort 2 had been sunburned on the back of the trunk or acquired MN.

Although overall sunburn rates did not decrease, the increased popularity of sun-protective swimwear, protecting the torso, reduced the frequency of sunburn on the back of the trunk, and may explain why children in cohort 2 developed fewer MN at this body site. The reduction of this biomarker is promising given MN are the key risk markers for melanoma development.[3] The only other publication reporting a reduction in MN prevalence with increased sun protection involved 7-year-old Swedish children.[23] Overall, there was no reduction in sun exposure over the study decade, despite skin cancer prevention campaigns. Although more children in cohort 2 swam outdoors and went to the beach, most almost always wore swim-shirts, and therefore spent less time playing in water with their back exposed. This suggests that some sun-safe messages are being heeded, although it may be at the cost of increased time spent in the sun, highlighting the importance of emphasizing the multifaceted nature of effective sun protection.

Other studies among infants and toddlers have yielded similar findings.[10] For example, in a survey of participants aged 0 to 45 months from southeast Queensland, Australia, a third had been sunburned by age 11 months and 82% had been burned by age 45 months.[24] Fewer children in our study experienced sunburn, possibly because of: the younger age of our cohorts; different definitions of sunburn; or the difference in geographic location (19°S vs 26°S).

A literature review found sunscreen was the most frequently used sun-protection method in children.[10] In the study reported here, hats and protective swimwear were worn more often than sunscreen. Children aged 1 to 3 years attending child care in Brisbane, Australia (27°S), in 2000 reportedly wore hats more often than children in this study.[25] In contrast, more children in cohort 2 wore legionnaires or wide-brimmed hats than children attending childcare centers across Queensland, Australia, in 2002.[26]

Sun exposure is associated with nevus development,[27] a key determinant of melanoma risk.[3,14]

Table IV. Sun-protective measures used by young children recruited in 1999 through 2002 (cohort 2) in tropical Australia

		Age 1 y (12-23 mo)		Age 2 y (24-35 mo)
Usual type of head covering worn outdoors				
Nothing	Not available for cohort 1 (1999)	16 (4.1%)	Not available for cohort 1 (1999)	2 (2.9%)
Cap		72 (18.3%)		8 (11.8%)
Wide-brimmed hat		129 (32.7%)		21 (30.9%)
Legionnaires hat		177 (44.9%)		37 (54.4%)
Hat wearing: frequency during summer				
Never wears hat in summer	Not available for cohort 1 (1999)	16 (4.1%)	Not available for cohort 1 (1999)	2 (2.9%)
Wears hat less than half time		21 (5.4%)		1 (1.5%)
Wears hat about half time		44 (11.2%)		5 (11.2%)
Wears hat more than half time		61 (15.6%)		10 (14.7%)
Almost always		250 (63.8%)		50 (73.5%)
Hat wearing: frequency during winter				
Never wears hat in winter	Not available for cohort 1 (1999)	23 (5.9%)	Not available for cohort 1 (1999)	4 (5.9%)
Wears hat less than half time		44 (11.3%)		6 (8.8%)
Wears hat about half time		67 (17.1%)		9 (13.2%)
Wears hat more than half time		48 (12.3%)		8 (11.8%)
Almost always		209 (53.5%)		41 (60.3%)
Hat-wearing score				
Mean (±SD)	Not available for cohort 1 (1999)	14.5 (7.5)	Not available for cohort 1 (1999)	16.4 (6.9)
Median (IQR)		16 (8-24)		16 (12-24)
Range		0-24		0-24
Usual swimwear worn				
Nothing (naked)	Not available for cohort 1 (1999)	5 (1.3%)	Not available for cohort 1 (1999)	2 (2.9%)
Underpants		15 (3.8%)		3 (4.3%)
Shorts only		4 (1.0%)		0 (0%)
Shorts and shirt		35 (8.9%)		8 (11.6%)
2-Piece swimsuit (bikini) only		23 (5.9%)		2 (2.9%)
Full-piece swimsuit only		44 (11.2%)		5 (7.2%)
Full-piece swimsuit/briefs and shirt		7 (1.8%)		0 (0%)
Lycra cover-up suit		259 (65.9%)		48 (69.6%)

IQR, Interquartile range.

Thus it is particularly relevant that fewer children in cohort 2 than cohort 1 developed MN on the back of the trunk, especially as children raised in Townsville, Australia, develop more MN earlier in life than children raised elsewhere.[5,16]

These data suggest increased sun protection alone (less direct sun exposure) may have slowed MN development without reducing time spent outdoors. The ability to modify the rate of acquisition of MN by sun protection has previously been reported. Sunscreen reduced MN development in 1 study,[28] had no effect in another,[29] and was associated with higher nevus counts in others.[30,31] Wearing sun-protective swimwear has also been shown to be a factor in the prevention of MN,[32,33] whereas legionnaires hats have been associated with lower nevus counts and hat use in general has been associated with fewer MN on the head and neck.[25]

Study limitations include the possibility of information bias in questionnaire data as parents may have altered their responses to overreport sun protection to reflect socially desirable behavior.[34] However, nondifferential bias would have resulted in underestimation rather than overestimation of differences between cohorts. Recruitment of the 2 cohorts differed: cohort 1 was recruited from birth records whereas cohort 2 was recruited from child-care centers. However, nowadays many Australian children attend some formal child care.[35,36] Comparison of the 2 cohorts showed few differences, but children from child-care centers may have been subjected to better sun-protection practices where an established sun-safe policy was in place. It has previously been shown that child-care centers with written sun-protection policies provide better sun protection for young children in their care.[26] The results of this study cannot be generalized to any other group or to the Australian population.

Early childhood is a vulnerable period, not only biologically but also behaviorally, as infants and young children are incapable of deciding about or implementing sun-protection measures.[37] Thus it is important to encourage parents and supervisors to provide sun protection by reinforcing their knowledge[24] and modifying their health-related attitudes and beliefs about sun safety, to lay the foundations for the future sun-safe behavior of the children in their care.[38]

The results of this study suggest the need for a change of approach and continued momentum in public health campaigns, particularly encouraging the use of sun-protective clothing. Assessing the trend in sun-protective practices over time provides some direction for future skin cancer prevention. This study has identified the importance of maintaining the focus of such programs on children.

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