Griffith UNIVERSITY
Queensland, Australia

SCIENTIFIC REPORT

TESTING AEROSOL SUNSCREEN PRODUCTS: EXPLORING THE IMPACT OF WIND ON THE APPLICATION OF SUNSCREEN.

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November 2021

Acknowledgements

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Dr Hacker is a senior researcher within the Improving Health Outcomes for People (ihop) research program and a senior research fellow within Menzies Health Institute Queensland, Griffith University

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Report Disclaimer

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Executive Summary

Five commercially available aerosol sunscreen products were tested to assess the impact of wind on the ability to apply sunscreen. Experiments were undertaken to determine the percentage of sunscreen loss when wind was applied at velocities of 10 kilometre per hour (kph) and 20 kph. Sunscreen was dispersed from each aerosol product using a calibrated down-force actuator device, which was pressed for 10 seconds and the subsequent output collected. The percentage of sunscreen lost was calculated by comparing the amount of sunscreen collected when no wind was applied with the amount of sunscreen collected when the 10 kph and 20 kph wind conditions were applied. The wind velocities used in this investigation are categorized as light wind (10 kph wind) and moderate wind (20 kph wind) by The Australian Government Bureau of Meteorology. Weather station data collected over summer from 8 Australian beaches showed between 9am-4pm the hourly observation period reported wind gusts greater than 10 kph 95% of the time and 69%-87% of the time for wind gusts greater than 20 kph. The average amount of sunscreen collected per 10 seconds, in triplicate, was determined for each wind condition and the application coverage of 5g of sunscreen per limb and 35g of sunscreen for a whole body was calculated.

Two Banana Boat® (ID-02, ID-03) aerosol products were tested while one product from the brands Neutrogena® (ID-01), Hawaiian Tropic®, (ID-04) Surf Life Saving® (ID-05) were tested.

Key Findings:

- The proportion of sunscreen lost due to the impact of wind varied between products and ranged from 32%-79% for 10 kph and 28-93% for 20 kph wind conditions.
- The amount of sunscreen blown away in the 20 kph wind condition was calculated into a cost using the recommended retail price (RRP) for all products and ranged from $4.70-$16.70.
- The spray time required to provide adequate coverage was similar between products for the no wind condition and ranged from 7-18 seconds per limb.
- The spray-time varied between products for the 10 kph wind condition ranging from 11-83 seconds per limb and 10-250 seconds per limb for the 20 kph wind condition.
- The spray time required for adequate coverage increased for the 10 kph or 20 kph wind conditions from the no wind conditions for all sunscreen products.
- All products tested could adequately provide 2 adult whole body applications of sunscreen in no wind conditions.

- Four of the five sunscreen products tested would require more than one bottle to provide adequate coverage for one whole body application in the 20 kph wind condition.
- The cost of one adult whole body sunscreen application in the 20 kph wind condition for aerosol sunscreen products averaged $42.80 (SEM ±14.61) and ranged from $9.20 to $90.

Whilst this study investigated the impact of wind on aerosol sunscreen products there is still further research required to answer additional questions on the efficacy and safety of these products. Extending the findings from this study to assess the deposition behaviour of these products on human skin is needed. Experiments testing how well a sun protection film can be achieved from aerosol products when wind is present warrants further investigation. Given the impact wind had on the particles dispersed from aerosol products the concept of passive inhalation should be further explored and the inhalation risk from aerosol sunscreen products better characterised by determining the particle size dispensed from products.

Introduction

Skin cancer is the most common cancer in Australia and places a large burden on the health care system as well as our community (1). Frequent overexposure to ultraviolet (UV) radiation from sunlight is a key risk factor for developing melanoma and keratinocyte skin cancers and sunburn is an immediate indicator that sun damage has occurred. Sunburn remains highly prevalent in Australia in the younger age groups and as little as one severe sunburn in childhood can double the risk of developing a melanoma before the age of 40 (2, 3).

Daily sunscreen use at a population level has been shown to prevent keratinocyte cancers, melanoma deaths and to reduce healthcare costs (4). Molecular research has also shown the protective role for sunscreen when applied at the correct concentration of 2mg/cm^2, which blocked the harmful molecular effects of UV radiation (5). However, effectiveness of sunscreen depends on its application at an appropriate thickness (2mg/cm^2) and regular re-application (6). Previous research has shown both adults and children apply far less sunscreen than is recommended, which results in providing less protection (7, 8). An estimated 7220 melanomas in 2010 could have been prevented with effective sun protection in the Australian population, however current sunscreen use has only reduced melanoma incidence by 1729 cases or 14%, illustrating there is substantial opportunity for improvement (9).

Public health campaigns have been communicating how much sunscreen is needed for adequate coverage, such as a teaspoon of lotion per limb. Aerosol sunscreens have been a recent addition to the sunscreen market, gaining popularity due to their novel and convenient application system. However, there has been limited advice or recommendations for the application of aerosol sunscreen products with instructions on the label stating, "to use liberally" while some state "do not apply in windy conditions" and "use in a well ventilated area". The Australian Government Bureau of Meteorology defines wind velocities of 10 kph in the light wind category and can be described as wind felt on the face, leaves rustle and ordinary vanes are moved while the wind velocity of 20 kph is defined as moderate winds and described as raises dust and loose paper; small branches are moved (10). Aerosol sunscreen products can also be difficult to see on the skin when applied, which could lead to areas being missed and there have been reports of serious sunburn incidents following use of some aerosol sunscreen products.

During 2020, we reported the results from testing nine commercial aerosol sunscreen products, which showed the proportion of propellant in aerosol sunscreens varied between products and ranged from

27%-83%. The spray time required to provide adequate coverage varied between the aerosol sunscreen products tested and ranged from 4 -14 seconds per limb.

In this study, we report the results from testing five commercially available aerosol sunscreen products, assessing the impacts of environmental conditions such as wind on the application, efficacy, cost and safety of these products.

Methods

Synopsis

Study Title	Testing and Evaluating the Impact of Wind on Aerosol Sunscreens
Investigators	Dr Elke Hacker
Study site (s)	Griffith University, Nathan Campus, Brisbane, Queensland, Australia
Study Design	Laboratory Testing
Planned Sample Size	Five Aerosol Sunscreens
Study Period	Sept 2021-Nov 2021
Primary Objectives	The aim of this research project is to: i) assess the proportion of sunscreen lost when a crossflow of wind at velocities of 0 kph, 10 kph and 20 kph is applied. ii) determine how long each aerosol sunscreen needs to be sprayed to attain an adequate coverage of sunscreen when a crossflow of wind is applied.
Main Inclusion criteria	• Aerosol sunscreen product commercially available in Australia.
Exclusion criteria	No longer commercially available in Australia
Test Product	• Neutrogena®: Beach Defence Sunscreen Spray • Banana Boat®: Simply Protect Kids Spray • Banana Boat®: Ultra Clear Spray • Hawaiian Tropic®: Tropic Silk Hydration Sunscreen Spray • Surf Life Saving®: Sunscreen Sport Spray
Sponsor	Cancer Council Victoria
Partners	Australian Radiation Protection and Nuclear Safety Agency

Study Design

Five commercially available aerosol sunscreen products underwent testing to assess the amount of sunscreen lost when a crosswind was applied at velocities of 10 kph and 20 kph (Figure 1). The wind velocities used in this investigation are defined in the light and moderate wind category by The Australian Government Bureau of Meteorology. Flow rate experiments were undertaken to determine the amount of sunscreen collected per second for each wind condition. The percentage of sunscreen lost was calculated by comparing the amount of sunscreen collected from the 0 kph series to the amount collected from the 10 kph and 20 kph series. The length of time to spray the aerosol sunscreen product to reach an adequate coverage of 5 g per limb and 35g for a whole body was then calculated for each product.

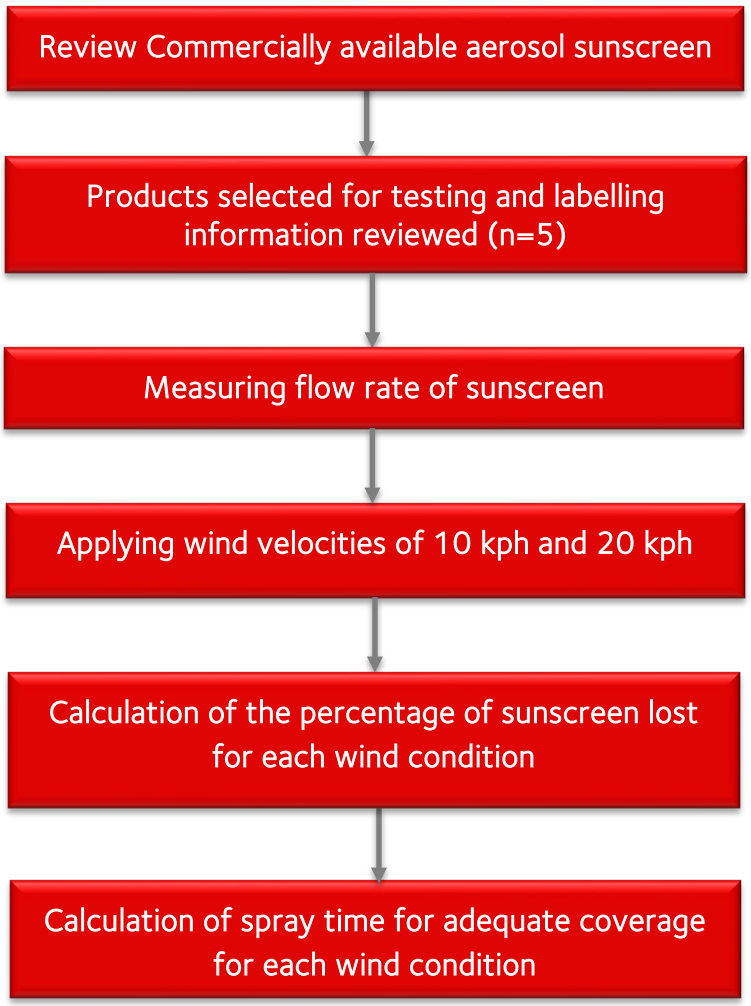

Figure 1. Flow chart of testing procedures.

Flow Rate determination protocol

Data collection was undertaken with a room temperature of 25^0C. Sunscreen was dispersed from each aerosol product using a calibrated down-force actuator device. The downforce actuator device used a horizontal toggle clamp to apply downforce on the aerosol sunscreen bottles (Figure 2). Custom bases were constructed for each product to ensure all products were placed in the actuator device at the same height. The toggle clamp was calibrated to 14.4N using a handheld Digital Force Gage (DILLON GL, China). The down force used was equivalent to the force used by a finger to disperse sunscreen. A jet-spray of sunscreen was dispersed from all products using the actuator device (Figure 2).

Figure 2. The actuator device. The calibrated actuator device dispersing a jet-spray of sunscreen onto an arm 10cm away from the bottle.

Sunscreen dispersed from each product was collected using a 18cm diameter funnel placed 12.5 cm from the nozzle of each product (Figure 3A, 3B). A clamping apparatus held the collection funnel in place and a laser measurement tool (Bosch Pty Ltd, Australia) was used to align the centre of the funnel with the nozzle of the aerosol product (Figure 3C). The flow rate was determined for each aerosol sunscreen product by dispersing sunscreen using the actuator, which was pressed for 10 seconds and the subsequent output collected via a funnel into a container (Appendix Multimedia File 1-5). The collection container and funnel were weighed before testing and 1 hour following testing, which allowed for the propellent to evaporate. The flow rate was calculated for each product and completed in triplicate.

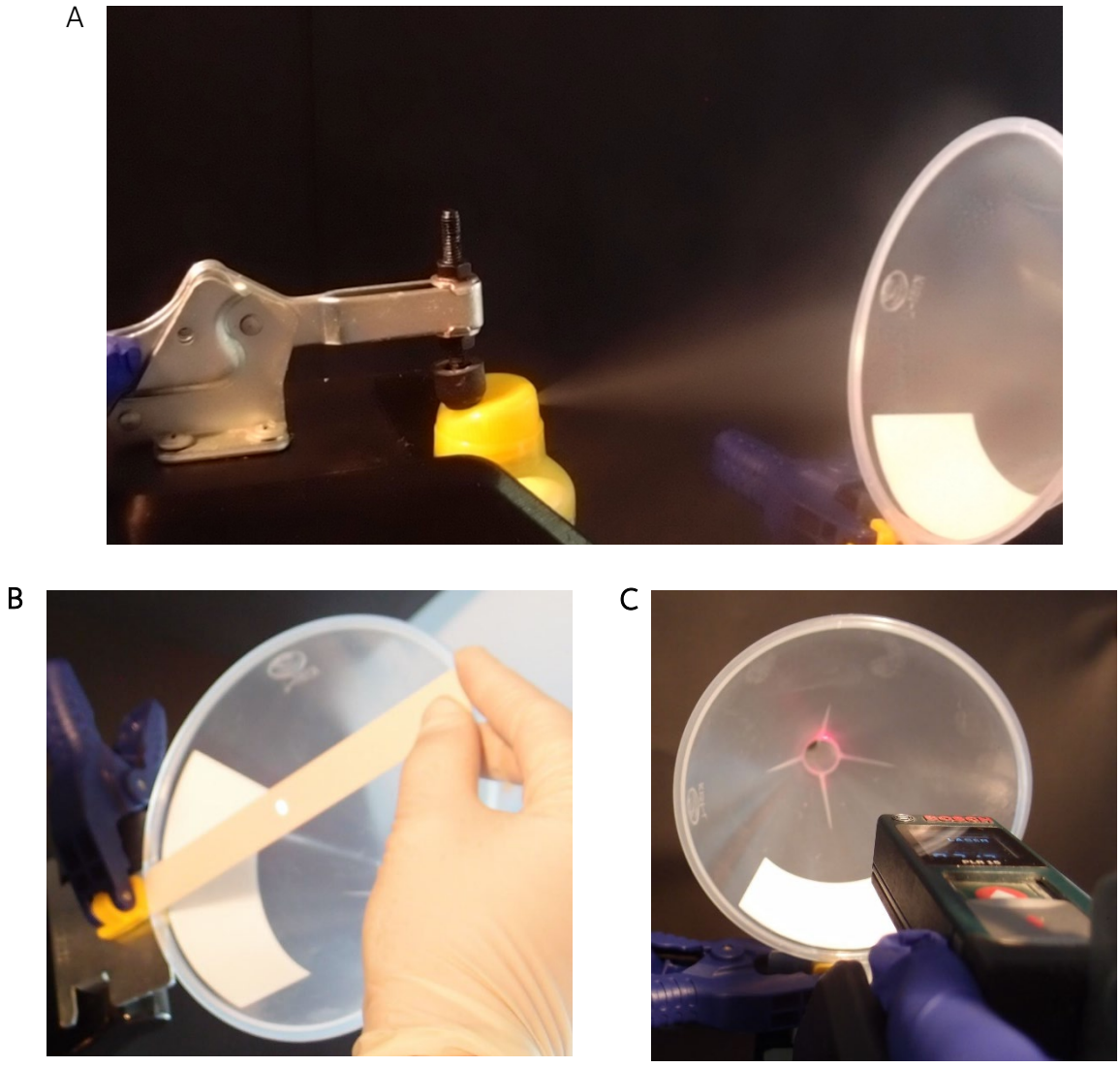

Figure 3. The flow rate experiment. A) The actuator device dispersed sunscreen from the aerosol product into a collection funnel. B) The funnel was placed 12.5 cm away from the product's nozzle, which was measured using a laser distance tool. C) The funnel was aligned with the aerosol product's nozzle using a laser tool to ensure sunscreen dispersed from the product was collected into the centre of the funnel and subsequently flowed into the collection container. Both the funnel and collection container were weighed to determine the amount of sunscreen collected.

Wind determination protocol

A cross flow of wind was generated at velocities of 10 kph and 20 kph. The wind velocity was generated using a fan (Vornado, USA, Model-6303DC) and measured using a hand-held anemometer device (Kestrel, USA). The anemometer device was placed in the centre where sunscreen is projected from the aerosol product and aligned using a laser measurement tool for the wind speed to be measured (Figure 4).

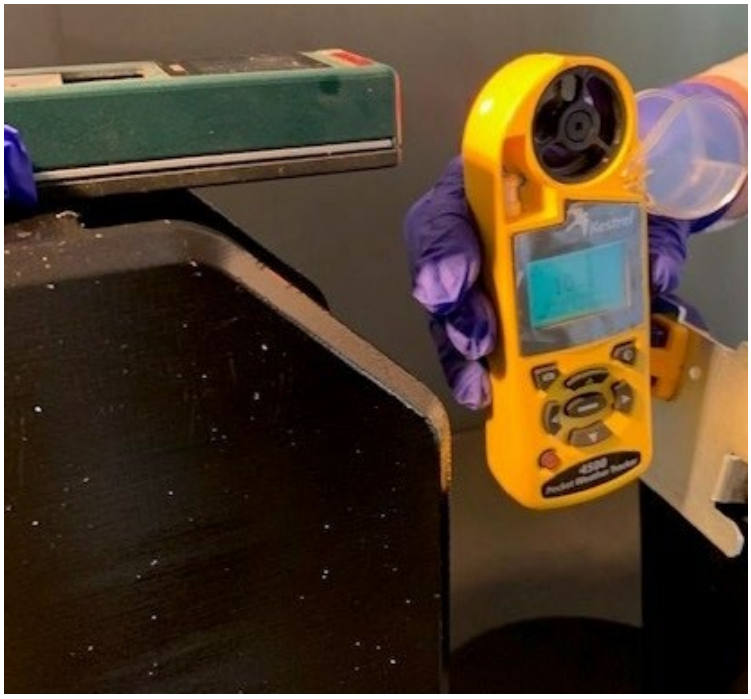

Figure 4. Measuring wind velocities using hand-held anemometer. A cross flow of wind was generated at velocities of 10 kph and 20 kph and measured using a hand-held anemometer.

Results

Sunscreen characteristics

The aerosol sunscreens tested were commercially available in Australia during September and October 2021 and all products had a SPF of 50 or 50+ (Figure 5, Table 1). Two Banana Boat® (ID-02, ID-03) aerosol products were tested while one product from the brands Neutrogena® (ID-01), Hawaiian Tropic® (ID-04), Surf Life Saving® (ID-05) were tested (Table 1).

Figure 5. Aerosol Sunscreen Products tested.

Table 1. Characteristics of Aerosol Sunscreen Products tested.

Brand	Product name	Active Ingredients	Batch number and expiry	Price (RRP)* $	SPF	Product ID number
Neutrogena®	Beach Defence Spray	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane	<B>1098797 EXP SEP 2023	16.99	50	1
Banana Boat®	Simply Protect Kids	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane	20328BF EXP 10/2023	17.99	50+	2
Banana Boat®	Ultra Clear Spray	Homosalate, Octocrylene, Oxybenzone, Octyl Salicylate, Butyl Methoxybidenzoylmethane	21036AF EXP 01/2024	18.00	50+	3
Hawaiian Tropic®	Tropic Silk Hydration	Homosalate, Octocrylene, Octyl Salicylate, Butyl Methoxydibenzoylmethane	21007AF EXP 12/2023	18.00	50+	4
Surf Life Saving®	Sport Sunscreen	Butyl Methoxydibenzoylmethane, 4-Methylbenzylidene Camphor, Octocrylene, Bemotrizinol	<B>1088471 EXP 10 22	16.50	50+	5

*RRP= recommended retail price based on pricing for September 2021 and shown in Australian dollars.

Review of Aerosol sunscreen product Labelling Information

The products purchased for this study were compared with aerosol products from a previous study in 2020 (Multimedia File-6). We observed the ingredient Oxybenzone had been removed from the Hawaiian Tropic® (ID-04) product and the statement reef friendly included on the front of the bottle along with the statement "No Oxybenzone or Octinoxate" (Figure 6A). The Banana Boat® kids (ID-02) product purchased in 2020 and 2021 have the same ingredients and both products state on the front of the bottle "Made without Oxybenzone" (Figure 6B). The Neutrogena® Ultra sheer and Woolworths® kids' aerosol sunscreen products are no longer available for purchase. The Neutrogena® Ultra sheer aerosol product has been removed from the market and a new pump spray Ultra sheer face product is now available, while the Woolworths® product has been removed from the market (Figure 6C, 6D). The Banana Boat® Ultra (ID-03) product has updated instructions for use on the back of the bottle, which now include pictograph instructions (Figure 6E).

The Surf Life Saving® (ID-05) product had similar markings on the 2020 product and the 2021 product including markings on the front of the bottle stating "Lotion spray for better coverage" and "4 HR water Resistant Lotion" (Figure 6F). The directions for use section on the back of the bottle do not state re-apply every 2 hours and instead stated "reapply at regular intervals especially after swimming, exercising or toweling". The Neutrogena® (ID-01) product has similar markings with a "4 HR water Resistant" statement on the front of the product and "reapply frequently" stated on the back of the product. The three Banana Boat® (ID-02, ID-03) products and the Hawaiian Tropic® (ID-04) product all have clear sun safety directions including pictographs on the back of the bottle, which state "Reapply every 2 hours or more often when sweating and immediately after swimming or using a towel". All products except the Surf Life Saving® (ID-05) product stated on the back of the bottle "do not apply in windy conditions'' and "use in a well ventilated area". There is no further guidance provided to consumers on the product for interpreting the terms 'windy conditions' or 'well ventilated area'.

Figure 6. Review of Aerosol Sunscreen Products labels and markings.

A) Hawaiian Tropic®, B) Banana Boat® kids, C) Neutrogena®, D) Woolworths® kids, E) Banana Boat® Ultra, F) Surf Life Saving®

Determining the amount of Propellant in each Aerosol Sunscreen Product

The amount of alcohol contained within commercially available aerosol sunscreen products was included on the labelling information for three out of the five products tested (Table 2). The proportion of alcohol in the aerosol sunscreen products tested was similar ranging from 41%-59% of the products weight. The Banana Boat® (ID-03) product and the Hawaiian Tropic® (ID-04) product both contained around 50% (Table 2). The Banana Boat® kids protect (ID-02) provided details about the propellant ingredient, which was listed as "hydrocarbon" and the Surf Life Saving® (ID-05) product listed propellant ingredient as "Dimthyl Ehter", however there was no information showing the proportion or amount of these ingredients in the product. The Neutrogena® (ID-01) product tested contained the highest amount of alcohol listed as 59%. The cost of each product (price per 100g) was calculated following adjustment for the amount of alcohol present. The recommended retail price (RRP) shown in Table 1 was used to calculate the price per 100g of sunscreen for each product. There was a range between products with ID-01 $22 per 100g, ID-03 $21 per 100g and ID-04 $17 per 100g. As a comparison measure the price in a supermarket for a tube of sunscreen lotion costs appropriately between $6-$12 per 100g. A limitation when estimating costing for aerosol sunscreen products is the constant variation in price with the purchase price often changing and many retailers selling products at prices cheaper than the RRP.

Table 2. The weight and amount of Alcohol listed on the label for each Aerosol Sunscreen product.

Product ID number	Net weight of Product* (g)	Alcohol Proportion of product^ (%)	Lotion remaining (Sunscreen) Proportion of product (%)	Lotion remaining (Sunscreen) Weight (g)	Sunscreen Cost per 100g adjusted for alcohol component~ ($)
1	184	59.07	40.93	75.31	$22.56
2	175	Propellant hydrocarbon no % on bottle			
3	175	51.20	48.80	85.40	$21.08
4	175	41.40	58.60	102.55	$17.55
5	175	Propellant Dimethyl Ether no % on bottle			

*The net weight for each product is printed on the label and has been transcribed into the table.

^ The percentage of alcohol contained in each product is on the label and has been transcribed into the table.

~The RRP was used to calculate the price per 100g in Australian Dollars for the remaining sunscreen component adjusted for the removal of the alcohol component, which may evaporate when the product is used.

Determining the Flow Rate for each Aerosol Sunscreen Product and exploring the impact of wind.

The flow rate was determined using a 10 second duration and is shown in grams per second in Table 3 and Appendix Multimedia File-1-5. The amount of sunscreen collected when wind was applied at velocities 10 kph and 20 kph is shown in Table 3 and Figure 7, 8. The percentage of sunscreen lost was calculated by comparing the amount of sunscreen collected from the 0 kph series to the amount collected from the 10 kph and 20 kph series and is shown in Table 3. The two Banana Boat® aerosol products ID-02 and ID-03 lost 79% and 72% respectively for the 10 kph wind condition. The 20 kph wind condition saw this amount increase to 93% and 80% respectively for products ID-02 and ID-03. The Hawaiian Tropic® ID-04 product lost 52% and the Neutrogena® ID-01 product lost 32% for the 10 kph wind condition. The Hawaiian Tropic® ID-04 product loss of sunscreen increased to 87% for the 20 kph wind condition with a similar trend for the Neutrogena® ID-01 product losing 64% of sunscreen for the 20 kph wind condition.

The Surf Life Saving® (ID-05) product formed a thick foam during the 10 second dispersion of sunscreen, which was collected in the collection funnel during both the 10 kph wind and 20 kph wind conditions (Figure 9). The Surf Life Saving® (ID-05) product showed similar sunscreen loss for both wind conditions with 34% of sunscreen in 10 kph and 28% of sunscreen in 20 kph.

The amount of sunscreen blown away in the 20 kph windy condition was calculated into a cost using the recommended retail price (RRP) for all products and ranged from $4.68-$16.70 (Table 3).

Table 3. The Impact of Wind on the application of Aerosol Sunscreen.

Product ID	Flow rate Average 0 kph Wind (g/sec)	Collection rate Average 10 kph wind (g/sec)	Sunscreen loss 10 kph wind (%)	Collection rate Average 20 kph wind (g/sec)	Sunscreen loss 20 kph wind (%)	Price RRP* ($)	Cost of sunscreen blown away 20 kph wind ($)*
1	0.50	0.34	32%	0.18	64%	16.99	10.90
2	0.28	0.06	79%	0.02	93%	17.99	16.70
3	0.28	0.08	72%	0.06	80%	18.00	14.35
4	0.31	0.15	52%	0.04	87%	18.00	15.68
5	0.67	0.44	34%	0.48	28%	16.50	4.68

*Cost is based on the Recommended Retail Price (RRP) and shown in Australian dollars

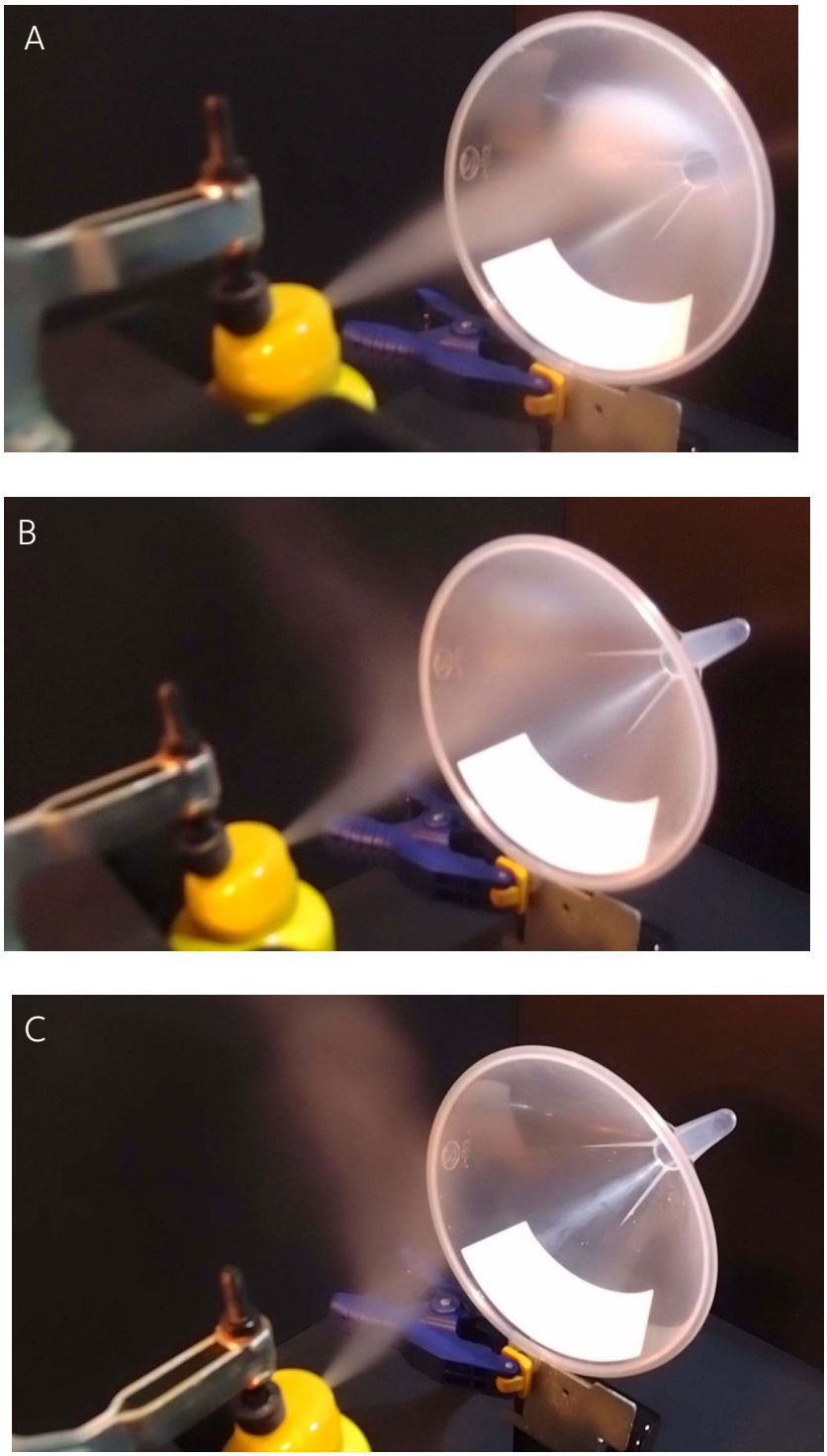

Figure 7. Observations during the cross-wind experiments. A) Sunscreen projected out of the aerosol product in a straight line when no wind was present. B) When wind was applied at a velocity at of 10 kph the sunscreen was blown slightly sideways. C) When wind was applied at a velocity at of 20 kph the sunscreen was blown sideways.

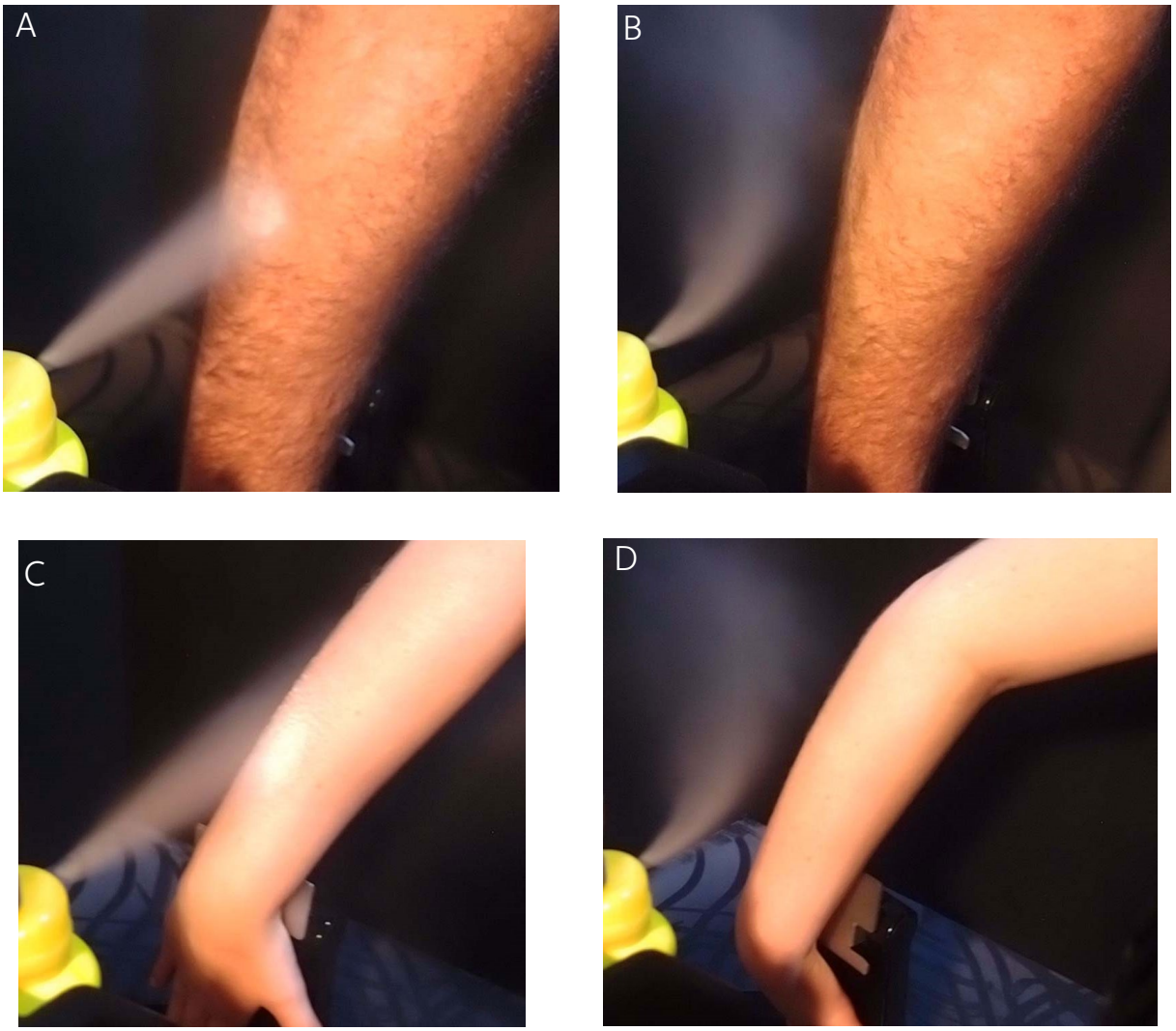

Figure 8. Human arms were used to observe the application of aerosol sunscreen during 20 kph wind conditions. A) An adult arm was placed 10-15 cm from the aerosol sunscreen product with no wind present. B) An adult arm was placed 10-15 cm from the aerosol sunscreen product and wind applied at a velocity of 20 kph. C) A child's arm was placed 10-15 cm from the aerosol sunscreen product with no wind present. D) A child's arm was placed 10-15 cm from the aerosol sunscreen product and wind applied at a velocity at of 20 kph.

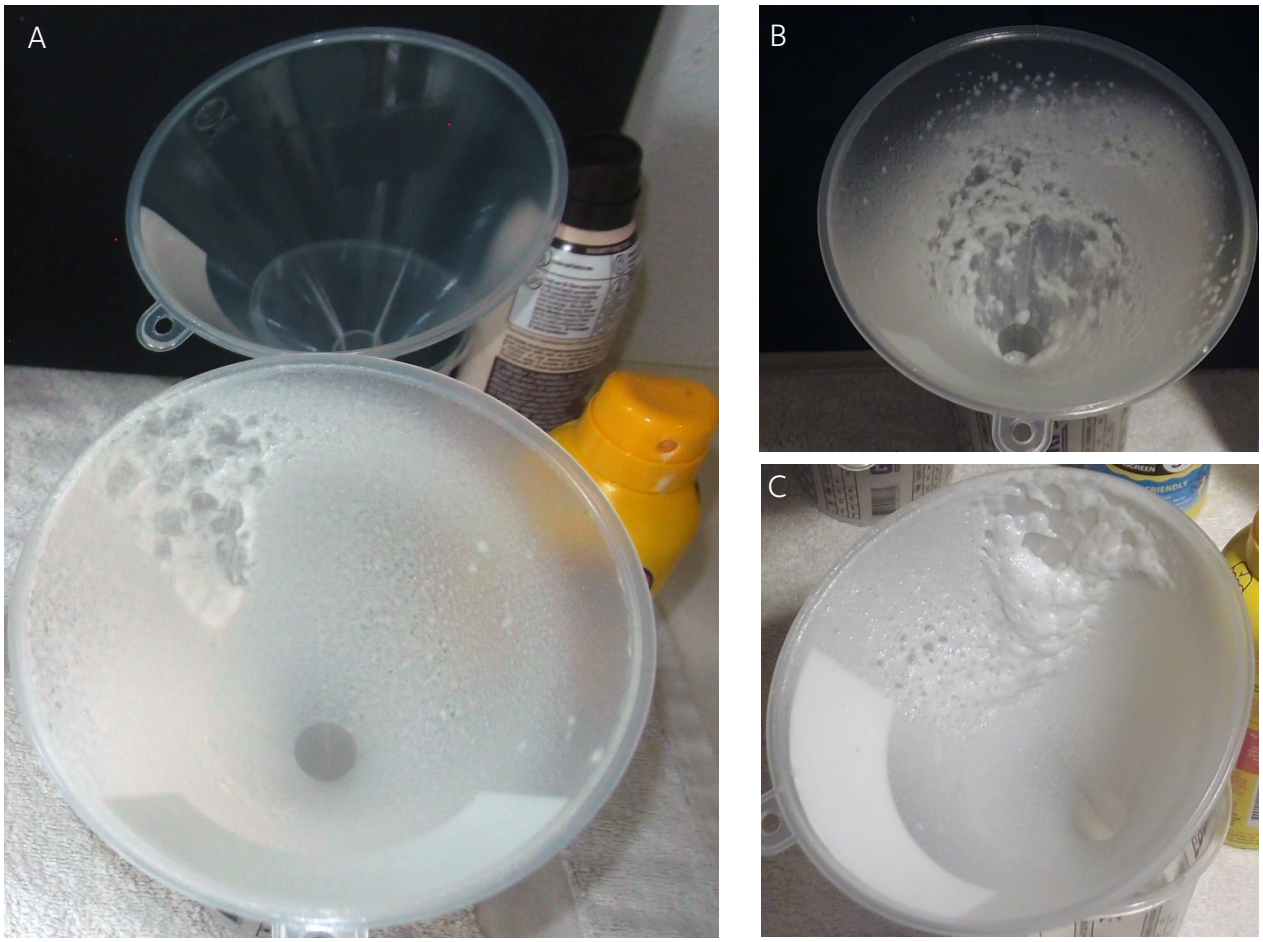

Figure 9. Observations from the cross-wind experiment using the Surf Life Saving® ID-05 product. A) The sunscreen collected from the Surf Life Saving® (ID-05) product was a thick foam like material, which is shown in the front funnel. A clear liquid was collected from the other products and an example of this is shown in the funnel behind for the Hawaiian Tropic® ID-04 product. B) In the no wind condition the Surf Life Saving® ID-05 product produced a foam, which was collected into the center of the funnel. C) In the 20 kph wind condition the Surf Life Saving® ID-05 product produced a thick foam, which was collected on the edge of the funnel.

Determining the length of time each Aerosol Sunscreen Product needs to be applied for adequate sunscreen coverage to be achieved.

The flow rate data was used to calculate the time required to spray a new product and achieve adequate sunscreen coverage including 5g per limb and 35g for a whole body (Table 4). The spray time required to provide adequate coverage varied between the aerosol sunscreen products tested and ranged from 7 -18 seconds per limb. The two Banana Boat® (ID-02, ID-03) products tested were the same with 18 seconds per limb and 125 seconds per whole body application (Table 4). The Neutrogena® (ID-01) product required 10 seconds per limb and 70 seconds per whole body application (Table 4). The Surf Life Saving® (ID-05) product reported the shortest spray time with 7 seconds per limb and 52 seconds per whole body application (Table 4). The Hawaiian Tropic® (ID-04) product required 16 seconds for a limb and 113 seconds per whole body application (Table 4).

The Banana Boat® (ID-02) product and the Hawaiian Tropic® (ID-04) product contained labelling information stating approximately how many applications per can. The Banana Boat® (ID-02) product, which is targeted at children stated "approximately 5 applications per 175g can (for 'big kids'-average sized 10-year-old)" and "approximately 10 applications per 175g can (for "little kids" average sized 3-year-old)". The Hawaiian Tropic® (ID-04) product stated "approximately 4 applications per 175g can (for average size adult)". We calculated how many whole body adult applications would be possible for each product using the standard 35g of sunscreen for adequate sunscreen coverage (Table 4). This calculation is adjusted for the amount of propellent in each product, which from previous studies is regularly observed to be around 50% of the product. The number of whole body adult applications per can ranged between 2.5 -2.6 for the no wind condition (Table 4). The 10 kph wind condition saw the number of whole body adult applications per can decease dramatically with products ID-01, ID-04 and ID-05 yielding one adult application per can and products ID-02 and ID-03 less than one adult application (Table 5). Only product ID-05 would yield one adult application per can for the 20 kph wind condition while all other products provided less than one adult application (Table 6).

Table 4. The Duration of Spray in no wind conditions for adequate sunscreen coverage.

Product ID	Sunscreen collected average 10 sec (g)	Standard Error (SE)	Flow rate Average (g/sec)	Spray Time per limb 5g (sec)	Spray Time per body 35g (sec)	How many adult applications per can*
1	5.0	0.37	0.5	10	70	2.6
2	2.8	0.06	0.28	18	125	2.5
3	2.8	0.19	0.28	18	125	2.5
4	3.1	0.12	0.31	16	113	2.5
5	6.7	0.01	0.67	7	52	2.5

*Calculation based on net weight of product and assuming propellent component is 50% of the product, which is consistent with alcohol volumes listed on products

Table 5. The length of time each Aerosol Sunscreen Product needs to be sprayed when operating in 10 kph wind conditions.

Product ID	Sunscreen collected average 10 sec (g)	Standard Error (SE)	Flow rate Average (g/sec)	Spray Time per limb 5g (sec)	Spray Time per body 35g (sec)	How many adult applications per bottle*
1	3.4	0.32	0.34	15	103	1.8
2	0.6	0.19	0.06	83	583	0.5
3	0.8	0.08	0.08	64	449	0.7
4	1.5	0.12	0.15	33	233	1.2
5	4.4	0.64	0.44	11	80	1.6

*Calculation based on net weight of product and assuming propellent component is 50% of the product, which is consistent with alcohol volumes listed on products

Table 6. The length of time each Aerosol Sunscreen Product needs to be sprayed when operating in 20 kph wind conditions.

Product ID	Sunscreen collected average 10 sec (g)	Standard Error (SE)	Flow rate Average (g/sec)	Spray Time per limb 5g (sec)	Spray Time per body 35g (sec)	How many adult applications per bottle*
1	1.8	0.35	0.18	28	194	0.9
2	0.2	0.10	0.02	250	1750	0.2
3	0.6	0.10	0.06	88	614	0.5
4	0.4	0.10	0.04	125	875	0.3
5	4.8	0.70	0.48	10	73	1.8

*Calculation based on net weight of product and assuming propellent component is 50% of the product, which is consistent with alcohol volumes listed on products

The impact of wind on the spray time required to provide adequate coverage varied greatly between the aerosol sunscreen products tested and ranged from 11 - 83 seconds per limb for the 10 kph wind condition (Table 5). The Neutrogena® product (ID-01) and Surf Life Saving® product (ID-05) reported the shortest spray times for the 10 kph wind condition with 15 seconds and 11 seconds per limb respectively (Table 5). The longest spray time for the 10 kph wind condition was observed for the Banana Boat® product (ID-02) with 83 seconds per limb (Table 5). The 20 kph wind condition saw the spray time per limb increase for the Banana Boat® product (ID-02) to 250 seconds per limb (Table 6). The Neutrogena® product (ID-01) also increased to 28 seconds per limb for the 20 kph wind condition (Table 6). The Surf Life Saving® product (ID-05) reported the shortest spray time with 10 seconds per limb for the 20 kph wind condition (Table 6, Figure 9).

The cost to obtain a whole body 35g application of sunscreen was calculated for the no wind, 10 kph and 20 kph wind conditions. The cost per whole body adult application for the no wind condition for product ID-01 was $6.50 and for product ID-02, ID-03, ID-04 was $7.20 and $6.60 for product ID-05 (Table 7). The cost per whole body adult application in 10 kph wind conditions increased and was $9.40 for product ID-01 and $36.0 for ID-02, $25.70 for ID-03, $15.0 for ID-04 and $10.30 ID-05 (Table 7). The cost per whole body adult application in 20 kph wind conditions was $18.90 for product ID-01, $90.0 for ID-02, $36.0 for ID-03, $60.0 for ID-04 and $9.20 ID-05 (Table 7). The average cost for a whole body adult application was $6.90 (SEM ±0.16) for the no wind condition, $19.30 (SEM ±5.09) for the 10 kph wind condition and $42.80 (SEM ±14.61) for the 20 kph wind condition.

Table 7. The cost of one adult whole body sunscreen application for Aerosol Sunscreen Products.

Product ID	Price (RRP)* ($)	Cost per adult application no wind ($)	Cost per adult application 10 kph wind ($)	Cost per adult application 20 kph wind ($)	Number of bottles# required per adult application 20 kph wind
1	16.99	6.50	9.40	18.90	1
2	17.99	7.20	36.00	90.00	5
3	18.00	7.20	25.70	36.00	2
4	18.00	7.20	15.00	60.00	3
5	16.50	6.60	10.30	9.20	Half a bottle

*Cost is based on the Recommended Retail Price (RRP) and shown in Australian dollars
#Number of bottles required were calculated in increments of half a bottle and rounded to the nearest value
Adequate adult application= whole body application of 35g of sunscreen

Wind Conditions recorded at Beach Locations around Australia.

Wind velocities of 10 kph are defined in the light wind category and wind velocity of 20 kph are defined as moderate winds by The Australian Government Bureau of Meteorology, which are below the 'fresh' or 'strong' wind categories.

To explore the frequency of these wind conditions weather station data was collected between 2010 and 2020 from beach locations including Cottesloe in Western Australia, Glenelg in South Australia, Gold Coast and Noosa in Queensland, Byron Bay, Newcastle and Bondi in New South Wales and Lorne in Victoria. The data was analysed for average wind speed and wind gusts above 10 kph and 20 kph between 9am-4pm during summer months. This timespan was chosen to represent when sunscreen applications would occur at these locations.

A wind gust greater than 10 kph was recorded during an hour observation period 95% of the time at these beaches (Table 8). These results illustrate wind gusts are commonly recorded at beach locations above 10 kph during summer.

Wind speeds are recorded over a 10-minute period to generate an average wind speed and during each hour a wind speed greater than 10 kph was observed 94% of the time at Cottesloe, 91% at Glenelg, 96% at Gold Coast, 89% at Noosa, 93% at Byron Bay, 89% at Newcastle, 87% at Bondi and 79% at Lorne (Table 8). Wind gusts greater than 20 kph were also regularly observed between 9am-4pm during summer at these locations including 87% of the time at Cottesloe, 78% at Glenelg, 80% at Gold Coast, 79% at Noosa, 82% at Byron Bay, 69% at Newcastle, 69% at Bondi and 67% at Lorne (Table 8).

Table 8. Wind Conditions recorded between 9am-4pm at Beach Locations around Australia during summers between 2010 and 2020.

	Total hours[1] 9am-4pm hours (%)	Percentage of time Average wind speed[2] >10 kph	Percentage of time Average wind speed[2] >20 kph	Percentage of time Wind Gust[3] >10 kph	Percentage of time Wind Gust[3] >20 kph
Cottesloe	8384 (99.6%)	94%	52%	99%	87%
Glenelg	8412 (100%)	91%	57%	97%	78%
Gold Coast	8308 (98.7%)	96%	68%	99%	80%
Noosa	8372 (99.5%)	89%	22%	98%	79%
Bryon bay	8298 (98.6%)	93%	64%	98%	82%
Newcastle	8256 (98.1%)	89%	55%	95%	69%
Bondi Beach	8334 (99.0%)	87%	46%	95%	69%
Lorne	8411 (99.9%)	79%	33%	95%	67%

[1]Total hours during the 2010-2020 summer periods with wind data available. Value in parentheses represents the percentage of data availability for the station.

[2]Wind speed averaged over 10 minutes prior to observation time

[3] Highest wind speed recorded over the observation period

Conclusion

In Summary, five commercially available aerosol sunscreen products were tested and the amount of sunscreen lost when wind was applied at velocities of 10 kph and 20 kph was determined (Figure 10). The proportion of sunscreen lost due to the impact of wind varied between products and ranged from 32%-79% for 10 kph and 28-93% for 20 kph. The Banana Boat® range (ID-02, ID-03) lost 79% and 72% of sunscreen in 10 kph wind conditions and 93% and 80% of sunscreen in 20 kph wind conditions. The Neutrogena® (ID-01) product tested lost 32% of sunscreen in 10 kph wind and 64% of sunscreen in 20 kph while the Hawaiian Tropic® (ID-04) product lost 52% of sunscreen in 10 kph wind and 87% of sunscreen in 20 kph. The Surf Life Saving® (ID-05) product formed a thick foam during the 10 second dispersion of sunscreen, which was collected in the collection funnel during both the 10 kph wind and 20 kph wind conditions. The Surf Life Saving® (ID-05) product showed similar sunscreen lost for both wind conditions with 34% of sunscreen in 10 kph and 28% of sunscreen in 20 kph wind. The amount of sunscreen blown away in the 20 kph wind condition was calculated into a cost using the recommended retail price (RRP) for all products and ranged from $4.70-$16.70. The wind velocities used in this study are commonly observed during summer between 9am-4pm with wind gusts great than 10 kph observed 95% of the time at eight popular beaches in Australia and 69%-87% of the time for wind gusts greater than 20 kph.

The spray time required to provide adequate coverage varied slightly between products for the 0 kph wind condition and ranged from 7 -18 seconds per limb. The spray-time varied greatly between products for the 10 kph and 20 kph wind conditions ranging from 11 -83 seconds per limb and 10 - 250 seconds per limb respectively. The increase in spray time for a limb was reported for the Neutrogena® (ID-01) product from 10 seconds for no wind conditions to 15 seconds for 10 kph winds and 28 seconds for 20 kph wind. The spray time for adequate coverage of a limb increased from 18 seconds for no wind conditions to 83 seconds for 10 kph wind conditions and 250 seconds for 20 kph wind conditions as well for the Banana Boat® (ID-02) product. The increase in spray time for a limb was also reported for the Banana Boat® (ID-03) product from 18 seconds for no wind conditions to 64 seconds for 10 kph winds and 88 seconds for 20 kph wind. The increase in spray time for a limb was also reported for the Hawaiian Tropic ® (ID-04) product from 16 seconds for no wind conditions to 33 seconds for 10 kph winds and 125 seconds for 20 kph wind. The spray time for adequate coverage of a limb increased from 7 seconds for no wind conditions to 11 seconds for 10 kph wind conditions and 10 seconds for 20 kph wind conditions for the Surf Life Saving® (ID-05) product.

The proportion of alcohol in the aerosol sunscreen products tested was similar ranging from 41%-59% of the products weight. All products tested could adequately provide 2 adult whole body applications of sunscreen in no wind conditions. This was reduced to less than 1 whole body application per can in the 20 kph wind condition for all products except the Surf Life Saving® (ID-05) product. The cost of an adult whole body sunscreen application in the 20 kph wind condition for aerosol sunscreen products ranged from $9 to $90.

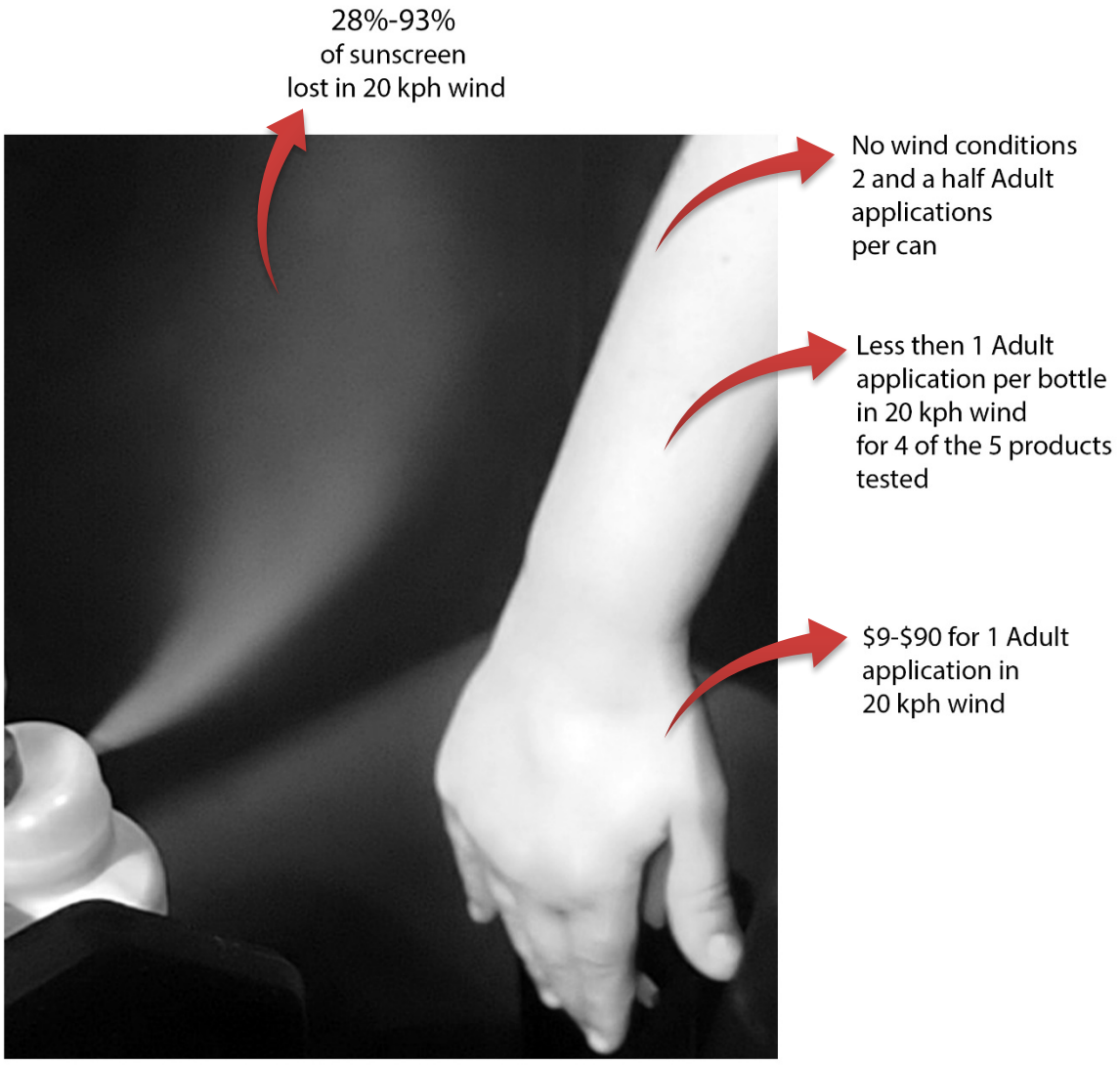

Figure 10. Summary of the findings from the experiments testing Aerosol sunscreen products.

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Appendices

Multimedia File 1-5. The Flow Rate experiment for each Aerosol Sunscreen Product and the impact of wind.

[File name- FILE1_ID01_sprayrate.mp4]

[File name- FILE2_ID02_sprayrate.mp4]

[File name- FILE3_ID03_sprayrate.mp4]

[File name- FILE4_ID04_sprayrate.mp4]

[File name- FILE5_ID05_sprayrate.mp4]

Multimedia File 6. Images of Labelling Information for Aerosol Sunscreen Products.

[Folder name- FILE6_labelling images]

Multimedia File 7. Observational images of Aerosol Sunscreen Products being used to apply sunscreen to Forearms.

[Folder name- FILE7_arm images]