



Article

# Personal Care Product Use in Pregnancy and the Postpartum Period: Implications for Exposure Assessment

Carly Lang <sup>1</sup>, Mandy Fisher <sup>2,\*</sup>, Angelica Neisa <sup>2</sup>, Leona MacKinnon <sup>2</sup>, Sandra Kuchta <sup>2</sup>, Susan MacPherson <sup>2</sup>, Adam Probert <sup>2</sup> and Tye E. Arbuckle <sup>2</sup>

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<sup>1</sup> Independent Research Nurse Consultant, Ottawa, ON K1A 0K9, Canada; carlylang@gmail.com

<sup>2</sup> Population Studies Division, Environmental Health Science and Research Bureau, Health Canada, 50 Colombyne Dr., AL 0801A, Ottawa, ON K1A 0K9, Canada; angelica.neisa@gmail.com (A.N.); Leona.MacKinnon@hc-sc.gc.ca (L.M.); Sandra.Kuchta@hc-sc.gc.ca (S.K.); Susan.H.MacPherson@hc-sc.gc.ca (S.M.); adam.probert@hc-sc.gc.ca (A.P.); tye.arbuckle@hc-sc.gc.ca (T.E.A.)

\* Correspondence: mandy.fisher@hc-sc.gc.ca; Tel.: +1-613-301-5618

**Abstract:** Concern regarding the potential for developmental health risks associated with certain chemicals (e.g., phthalates, antibacterials) used in personal care products is well documented; however, current exposure data for pregnant women are limited. The objective of this study was to describe the pattern of personal care product use in pregnancy and the post-partum period. Usage patterns of personal care products were collected at six different time points during pregnancy and once in the postpartum period for a cohort of 80 pregnant women in Ottawa, Canada. The pattern of use was then described and groups of personal care product groups commonly used together were identified using hierarchical cluster analysis. The results showed that product use varied by income and country of birth. General hygiene products were the most commonly used products and were consistently used over time while cosmetic product use declined with advancing pregnancy and post-delivery. Hand soaps and baby products were reported as used more frequently after birth. This study is the first to track personal care product use across pregnancy and into the postpartum period, and suggests that pregnant populations may be a unique group of personal care product users. This information will be useful for exposure assessments.

**Keywords:** personal care products; pregnancy; reproductive health; exposure; use patterns; concurrent use

## 1. Introduction

Personal care products (PCPs) are widely used in our daily lives. In this paper, we define PCPs as products which are used for personal hygiene and grooming, (e.g., shampoo, soaps) and beautification (*i.e.*, cosmetics). In Canada, Health Canada has the mandate to protect the health of Canadians by minimizing the risk associated with the use of PCPs marketed in Canada. PCPs may fall into one of three regulatory categories in Canada: cosmetics, drugs or natural health products [1]. Every cosmetic contains a number of ingredients, from preservatives to cleansing agents to fragrances. Health Canada maintains a list of ingredients that present health risks and prohibits or limits the use of ingredients that present health risks. In order to facilitate these exposure assessments, it is important to have information on the PCPs that Canadians are using, especially among potentially more susceptible populations such as pregnant women and their infants. However, few data sets on PCP use are

available [2–4]. Furthermore, to evaluate cumulative exposure of chemicals by various routes, it is also important to have data on which PCPs are used concurrently, by the same consumer [2,5,6].

Cross sectional studies reporting PCP use patterns in the general population have been conducted in the United States [7–10] and in Europe [5,6,11–13]. However, as has been acknowledged, there is great intra- and inter- individual variability in product use [10,14] that can only be captured using data generated from longitudinal studies [4]. At present, data on PCP use patterns in pregnancy are limited. Studies have focused on reporting PCPs that may contain specific chemicals [15–18]. Data on a broad range of PCPs are required in order to undertake a comprehensive assessment of exposure to chemicals and products that are continuously being introduced to the market. To date, no study has examined PCP use patterns across pregnancy and it is not known if pregnant women represent a unique group of PCP users who may be using products differently than the general population.

In this paper, we report the use patterns of PCPs in women across all trimesters of pregnancy and into the postpartum period. Data on prevalence of use, frequency of use, and PCP co-use patterns during pregnancy are determined to support exposure assessments for this particular subpopulation group.

## 2. Methods

Eighty pregnant women in the Ottawa (Ontario, Canada) area were recruited at prenatal clinics to participate in the *Plastics and Personal-care Product use in Pregnancy (P4) Study*. Detailed methods of the P4 Study have been previously published [19,20]. While the P4 Study collected vast quantities of biomonitoring data as well as data on food consumption and activity patterns, only information pertaining to patterns of PCP use is reported in this paper. The study was approved by Health Canada's Research Ethics Board (2008-0045) and the Research Ethics Boards at each of the participating hospitals (2008473-01H).

### 2.1. Study Population

Women presenting to obstetric clinics in Ottawa were approached for participation in the study. In order to be eligible, women were at least 18 years old, planning to deliver in Ottawa, able to speak English or French, and less than 20 weeks pregnant at the time of recruitment. Women were excluded from participation if they were known to have major health conditions or if the fetus was known to have a major congenital anomaly at the time of recruitment. Participants were allowed to continue in the study if these conditions developed or were identified after they were enrolled.

### 2.2. Data Collection

Women who consented to participate were asked to complete detailed diaries describing PCP use during early pregnancy (Early pregnancy: between 6 weeks and 19 weeks plus 6 days gestation) during a weekday (T1A) and weekend day (T1B), as well as during the 2nd (24–28 weeks, T2) and 3rd trimesters (32–36 weeks, T3) of pregnancy, and 2–3 months post-partum (T5). The T4 time period in the P4 Study captured the birth of the child. Because of the busy nature of this time for the participants, no PCP use information was collected at this time point so it is not referenced within the context of this paper. During early pregnancy (T1A, T1B), women completed 48-h diaries on weekdays, weekends, or optionally both. During all other time periods (T2, T3, T5), women completed the diaries for a 24-h period. Participants recorded which PCPs were used, the date and time of use, the activity performed while using the product, and the brand and manufacturer of the product. We did not collect information on the amount of product used per application. Detailed descriptions of what to include in the diaries were given to the participants before the study began, and were provided in print along with contact information for the research coordinator should participants have questions when they returned home. All data collection (T1A, T1B, T2, T3, T5) took place between December 2009 and July 2011. Demographic variables were obtained via questionnaires administered to the women during the first study visit, and updated at subsequent study visits.

### 2.3. Data Analysis

PCPs were recorded by participants free-form in the diaries and were transcribed into a Microsoft Access database and then analyzed in SAS<sup>®</sup> Enterprise Guide<sup>®</sup>, Version 4.2 (SAS-EG) and R software (www.r-project.org). PCPs were initially grouped into 16 categories commonly used by risk assessors at Health Canada (listed in Table 1) using the SAS EG index and trim functions. All product entries were verified by at least two reviewers to confirm reliability of product coding. PCPs that did not fit into these 16 categories were grouped as “other product use” and are excluded from this report. Two product categories, “fragrance and perfumed products”, and “nail polish and remover”, are included in the total number of PCPs used by participants and in the comparison tables for the discussion but were eliminated from further analysis due to low reported use (0–6 uses per time period). The remaining 14 categories were retained for analysis of prevalence and frequency of use. The baby product category was eliminated from the cluster analysis because of its overwhelming use in the postpartum period (T5), giving a total of 13 categories used in this analysis.

**Table 1.** Personal care products (PCP) categories used and examples of PCPs within each category.

PCP Category	Examples of PCPs Included	Abbreviated Name	Leave on Category	Rinse off Category
Baby Lotions, Soaps and other Baby Products	Wipes, diaper ointment, baby body wash, petroleum jelly	“babyprod”	NA	NA
General Makeup and Cosmetics	Blush, foundation, concealer	“makeup”	X	
Lip Products	lip balm, lipstick, lip gloss	“lip”	X	
Eye Makeup and Cosmetics	Eye shadow, mascara, brow liner	“eyemakeup”	X	
Hairstyling Products	Hairspray, gel, mousse, hair paste	“hair”	X	
Nail Polish and Remover	nail polish, nail polisher remover	“nail”	X	
Fragrance and Perfumed Products	perfume, bubble bath, body mist, air freshener	“frag”	X	
Deodorant and Antiperspirants	Deodorant, antiperspirant	“anti”	X	
Body Lotions, Creams and Oils	Body butter, belly oil, sunscreen, hand cream	“lotion”	X	
Face Lotions and Creams	Day cream, night lotion, acne cream, eye moisturizer	“face”	X	
Body Soaps	Body wash, body gel, shower soap	“bodysoap”		X
Facial Soaps, Cleansers and Washes	Face cleanser, exfoliator, face masks, eye makeup remover	“skinclea”		X
Toothpaste and Mouthwash	Toothpastes, dental rinse, mouthwash	“oral”		X
Hand Soaps, Sanitizers and Soap Not Otherwise Specified (NOS)	Liquid soap, bar soap, waterless sanitizers *, generic soap	“soap”		X
Shampoo	Shampoo	“shampoo”		X
Conditioner	Rinse-off conditioner, 2-in-1 shampoo and conditioner, leave-in conditioner	“condit”		X

\* waterless sanitizers were not included in the “Rinse off” category and added to “Leave on”; NA is not applicable because the category includes both leave on and rinse off products.

Descriptive statistics were performed to describe the (arithmetic) mean, standard deviation, median, and range of PCPs used by participants as well as the number of different PCP categories used at each time point. The total number of PCP applications by participants was calculated by computing the frequency of PCPs used within each of the 16 different categories (Table 1).

The prevalence of PCP use was determined for each PCP category in order to identify users and non-users. We defined “prevalence of use” (yes/no use) as the use of the PCP category at least once

during the 24 h study period. “Frequency of use” was further described to examine how many times each participant used any product category throughout pregnancy and in the postpartum period. The GLIMMIX procedure in SAS<sup>®</sup> was used to formally test whether or not there were differences in PCP use over time. This procedure used a generalized, linear, mixed model which can be used to study the change in the response variable over time.

In order to determine which PCP categories were commonly used together during pregnancy, R software was used to perform hierarchical cluster analysis. Co-use was defined here as use of two or more PCPs within two 48 h periods in early pregnancy (T1A and T1B). Tables with prevalence of PCP use were created. PCP categories used at any time were coded as “1”, and if they were never used during these times they were coded as “0”. Because of the binary nature of the variables, asymmetrical binary distance was selected as the distance measured. A conservative approach was used to determine the number of clusters ( $k$ ), where  $n$  = the number of PCP categories [21]:

$$k \approx \sqrt{\frac{n}{2}}$$

Baby products were removed from this analysis because of their overwhelming use in T5. These products were also, most likely, used for the baby and not the mother making this category different from the other PCP groups. With  $n = 13$  categories, we had  $k \approx 3$  clusters. The percentage of participants in each cluster was calculated. Co-use combinations were also calculated in order to provide data for aggregate exposure.

Pearson chi-square tests for independence in contingency test tables were used to examine the association between demographic variables (age, parity, education, household income, and country of birth; see Table 2) and PCP use; when contingency table counts were small, Fisher’s Exact test was used instead. When differences were found, bar graphs were used to visualize the association.

**Table 2.** Characteristics of study population ( $n = 80$ ).

Characteristic	$n$ (%)
Age	
<30 years	17 (21.25)
30–34 years	37 (46.25)
35–39 years	19 (23.75)
≥40 years	7 (8.75)
Highest level of Education Completed	
High school diploma	9 (11.15)
College diploma	14 (17.5)
University degree	36 (45)
Advanced degree	21 (26.26)
Marital Status	
Married	63 (78.75)
Other	17 (21.25)
Household Income	
<\$60,000	7 (8.75)
\$60,001–\$80,000	11 (13.75)
\$80,001–\$100,000	13 (16.25)
≥\$100,000	44 (55)
Don’t know or declined	5 (6.25)
Country of Birth	
Canada	63 (78.75)
Other	17 (21.25)

Table 2. Cont.

Characteristic	n (%)
Employed	
Yes	66 (82.5)
No	14 (17.5)
Parity	
0	37 (46.25)
1	34 (42.5)
2+	9 (11.25)
Pre-pregnancy body mass index (BMI)	
Underweight/normal	50 (70.42)
Overweight/Obese	21 (29.58)
	<b>Mean (SD)</b>
Height (cm)	165.4 (7.3)
Pre pregnancy weight (kg)	66.5 (13.2)

### 3. Results

#### 3.1. Demographics

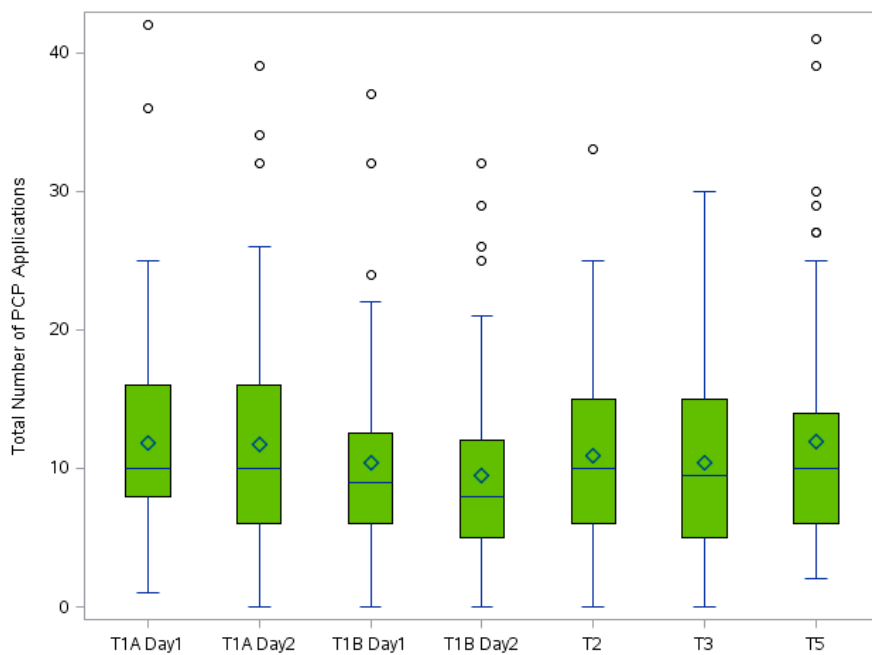
A detailed description of participant characteristics is presented in Table 2. Participants were predominantly Canadian-born, older, and well educated. Most women reported having graduated college or university (89%). Participants were 32.4 years old on average and the mean gestational age at recruitment was 13 weeks. The recruitment rate for the study was low, with an acceptance rate of 11% affecting the generalizability of the study results.

While 80 participants in total were recruited for the study, the number of participants who completed each study time period varied. As participants were required to complete only one early pregnancy time period to enter the study, 63 completed the weekday time period and 67 completed the weekend time period. Some participants were lost to follow up, had early outcomes (*i.e.*, spontaneous abortion), or voluntarily withdrew from the study over time. Reasons for not completing the study included the following: too busy ( $n = 5$ ), medical reasons ( $n = 6$ ), moved out of country ( $n = 2$ ) and inability to be contacted by research staff ( $n = 5$ ).

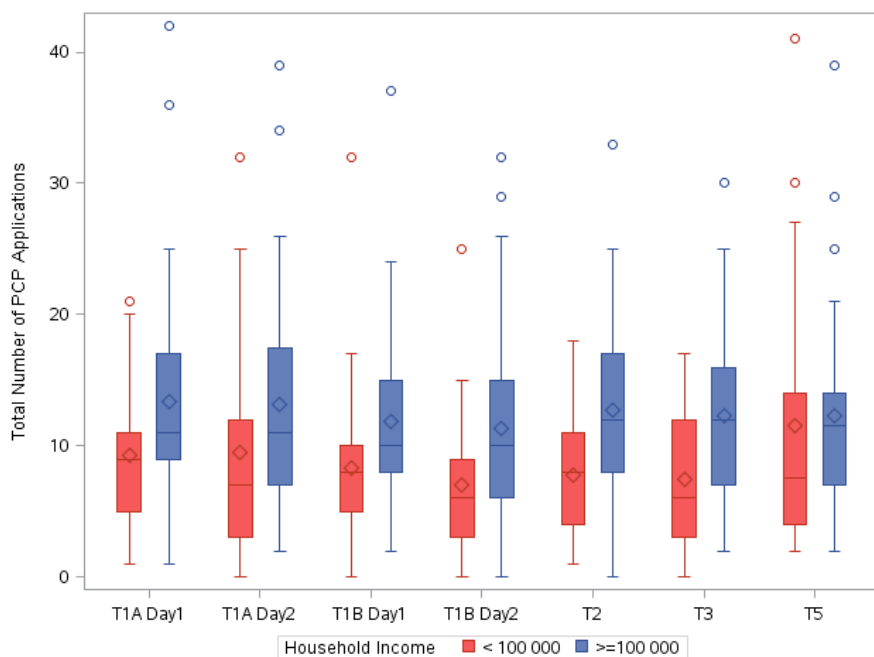
#### 3.2. Personal Care Product Use

##### 3.2.1. Total Number of PCP Applications

Figure 1 shows the total number of PCP applications per participant by study time period. Overall, participants applied PCPs an average of  $10.91 \pm 7.64$  (median of 10) times per day across the study period, ranging from 0–42 PCP applications within a 24 h period. The lower median is reflective of a small number of high users. As shown graphically in Figures 2 and 3 the influence of income was consistent across study time periods. Participants with a household income  $\geq \$100,000$  per year applied PCPs more often than participants with a lower household income at every study time period. Further analyses showed a higher percentage of women in the high income category that had more than one child (16% *vs.* 6% parity = 2+). We found significant correlations between income and education ( $r = 0.26, p = 0.02$ ), age ( $r = 0.32, p = 0.006$ ) and employment status ( $r = 0.34, p = 0.003$ ).



**Figure 1.** The total number of PCP applications with a 24 h period for all participants. The diamond inside the box indicates the mean value and the line inside the box indicates the median value. The bottom and top edges of the box indicate the 25th and 75th percentiles. The vertical lines represent the range of values with outliers indicated by circles.



**Figure 2.** The total number of PCP applications within a 24 h period and household income group. The diamond inside the box indicates the mean value and the line inside the box indicates the median value. The bottom and top edges of the box indicate the 25th and 75th percentiles. The vertical lines represent the range of values with outliers indicated by circles.

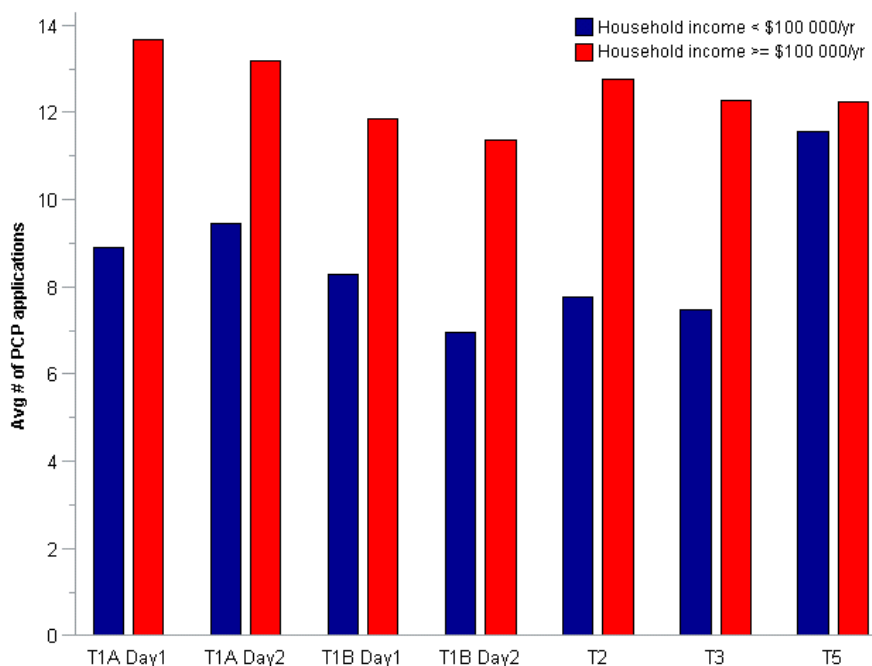


Figure 3. Average number of PCP applications per participant by income and 24 h study period.

### 3.2.2. Prevalence of Use

The prevalence of PCP category use, defined as the number of participants who used a PCP category at least once in a 24 h time period is shown in Figure 4. Prevalence of PCP category use varied greatly between categories, ranging from 9.5% (hairstyling products, T5) to 95.5% (toothpaste and mouthwash, T1A Day 1). Prevalence of general hygiene and skincare products were generally highest, and cosmetic, hair styling, and baby products were generally the lowest.

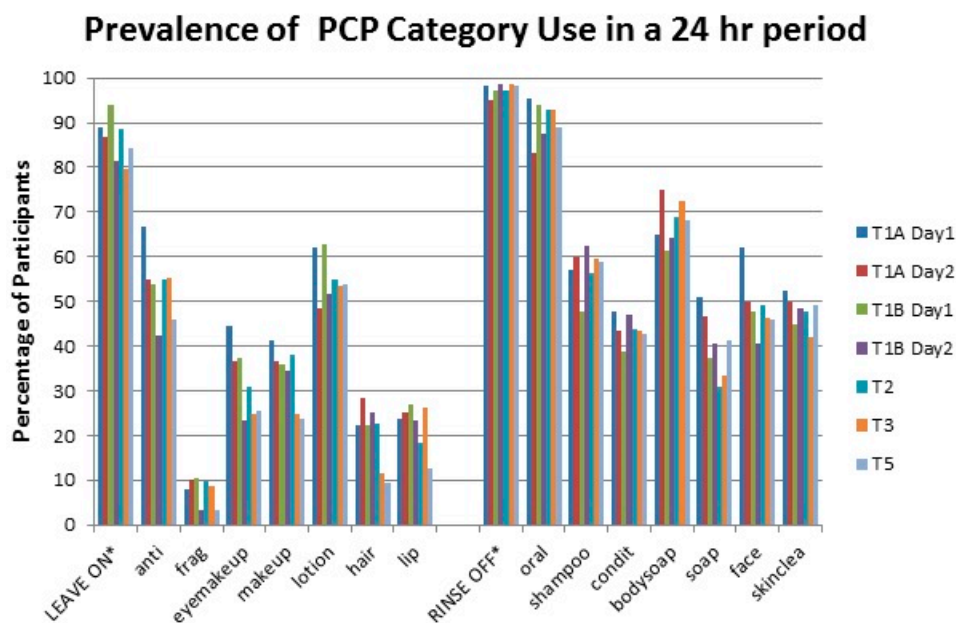


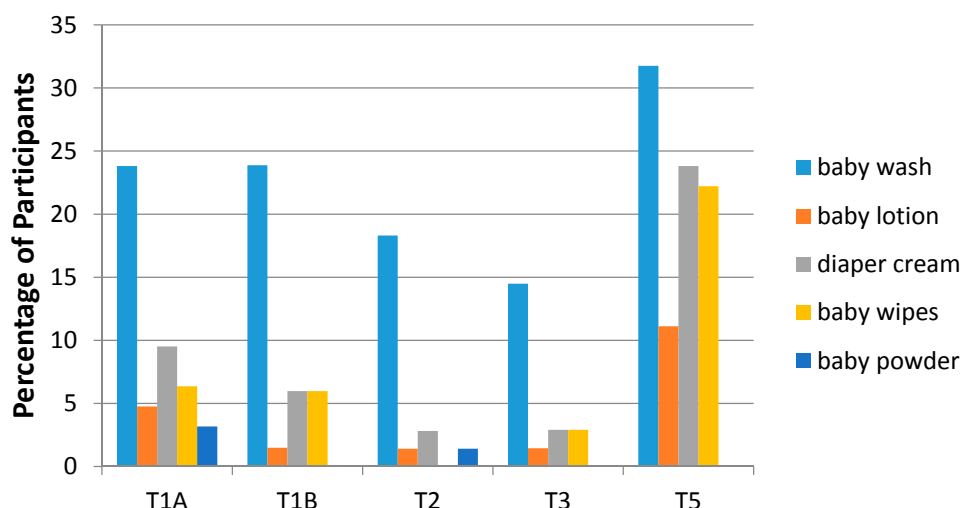
Figure 4. Prevalence of product use categories by study time period. See Table 1 for category definitions.

Use of the cosmetic and hair styling categories tended to decrease across pregnancy and into the postpartum period. For general hygiene and skincare categories, product prevalence was similar

across time points. The prevalence of “Leave On” products was lower than “Rinse Off” products in general.

Baby products are shown in Figure 5. As would be expected, the prevalence of baby products (baby lotions, baby wash, diaper cream and baby wipes was higher post-partum (T5) compared to during pregnancy (T1, T2 and T3). The highest use was for baby wash followed by diaper creams.

### Baby Product Prevalence of Use



**Figure 5.** Prevalence of baby product use by study time period. Percentage of participants reporting use of the product at least once by study period.

#### 3.2.3. Frequency of Use

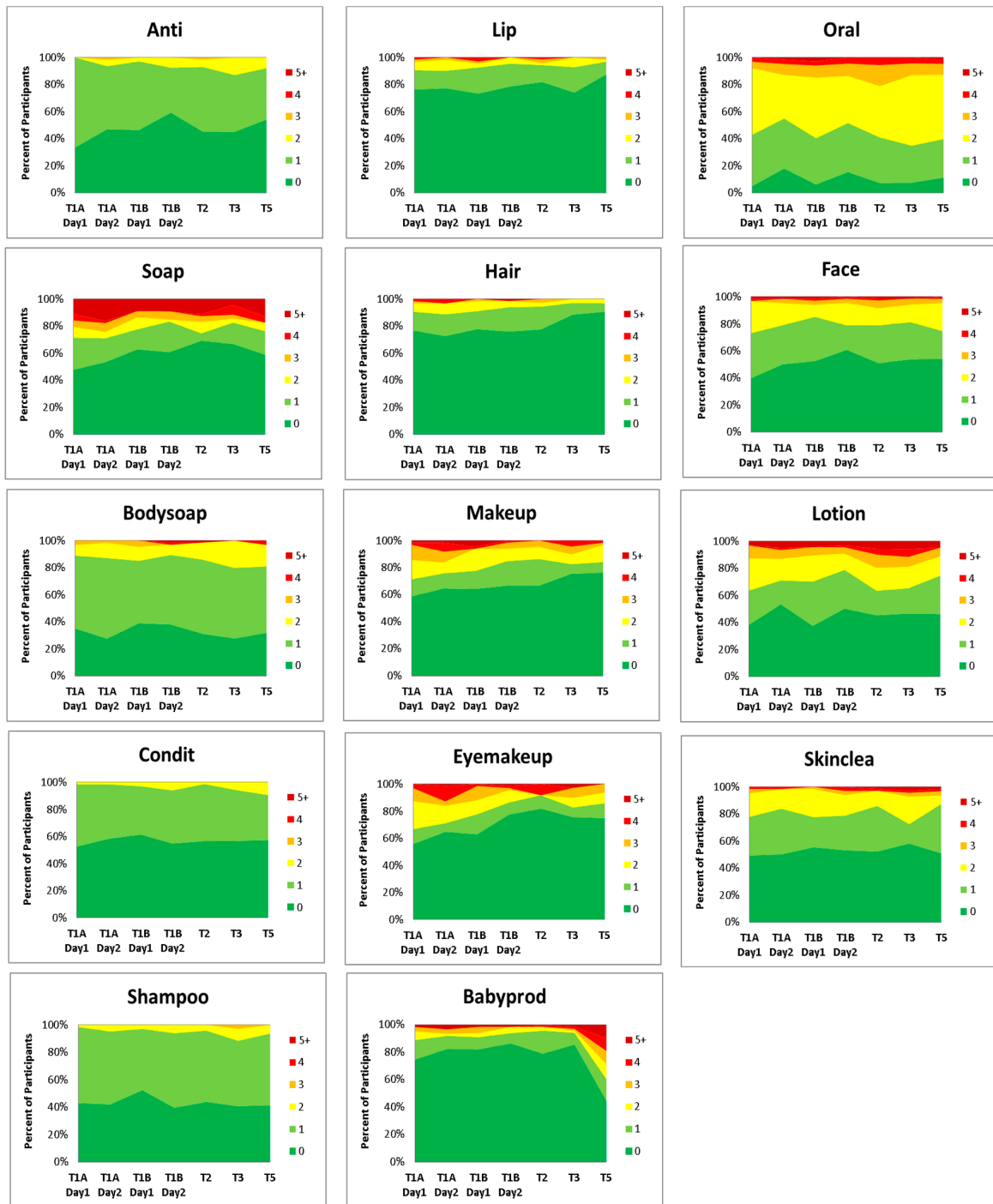
Frequency of use was defined as the number of times a user applied a PCP from a given category within a 24 h period (See Figure 6). The category soap appears to be underreported with up to 60% of participants reporting no use in the last 24 h period. This may be due to the open ended nature of the diary and participants simply forgot to record hand washing and soap use. PCP categories Hand Soaps, Sanitizers and Soap NOS (“soap”) and Baby Lotions, Soaps and Other Baby Products (“babyprod”) and Toothpaste and Mouthwash (oral) had the highest reported mean frequencies of product category use per participant (See Figure 7).

Frequency of use showed little variation over the course of pregnancy and into the postpartum period for general hygiene and skincare products. All time points that differ significantly from the postpartum reference period (T5) are indicated by an \* in Figure 7. The use of the categories “makeup”, “eyemakeup”, Lip Products (“lip”) and Hairstyling products (“hair”) showed a trend toward decreasing frequency of use in the postpartum period. All four categories had significantly higher means in the T1A(weekday) time periods. The categories “lip” and “hair” were also significantly higher in the T1B (weekend) periods compared to postpartum (T5). Baby products (“babyprod”) and Hand Soaps, Sanitizers and Soap NOS (“soap”) showed the greatest variation in frequency of use, with the highest frequencies in the postpartum period (T5), with a maximum of 15 and 23 uses in a 24 h period respectively (data not shown). The category “soap” was used significantly more frequently in T5 than in all other study periods, except T1A. However, this may be due to underreporting of hand soap use during the pregnancy period. Women may have been more aware of their hand washing, and therefore recorded it in the diary, when dealing with a new born baby.

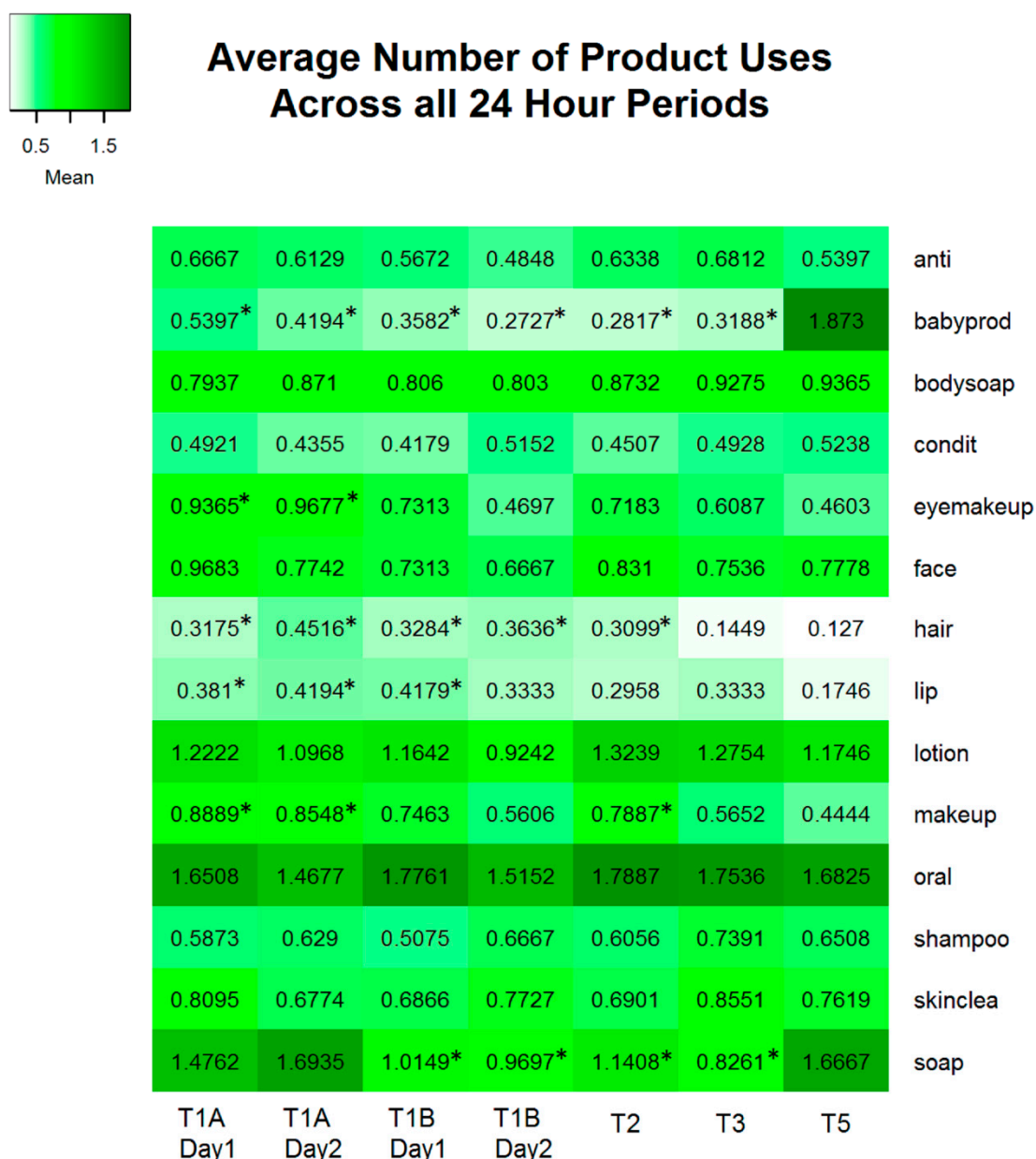
When PCP use frequencies between weekday (T1A) and weekend (T1B) time points were compared, the GLIMMIX procedure revealed that the categories “soap”, “makeup” and “eyemakeup” were all used significantly less frequently during the weekend than during the weekdays. The average



number of Hand Soap uses tended to be 36% ( $p = 0.0116$ ) higher during the weekday than during the weekend. Similarly, the participants tended to use 43% ( $p = 0.0244$ ) more makeup and 62% ( $p = 0.0026$ ) more eye makeup PCPs on the weekdays.



**Figure 6.** Frequency of Use. The percentage of participants who applied a PCP 0, 1, 2, 3, 4 and 5+ times in a 24 h period. The X-axis describes the time period.



**Figure 7.** The average number of product uses in each 24 h period. Results that are significantly different from the postpartum (T5) reference period ( $p \leq 0.05$ ) are indicated with an \*.

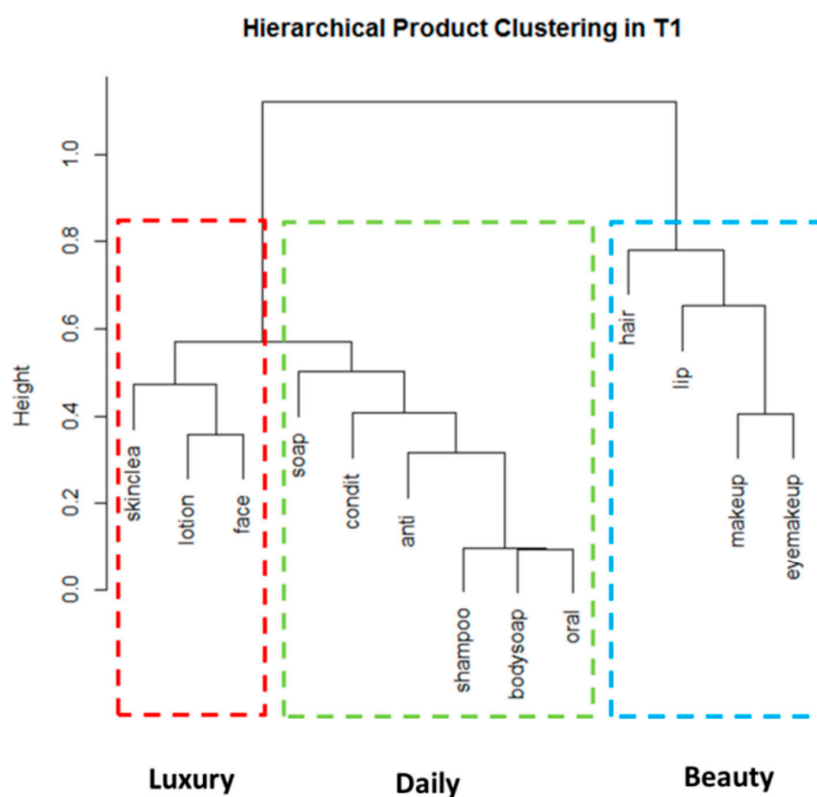
### 3.2.4. Co-Use Patterns

We define PCP co-use here as use of two or more PCPs within a 48 h period. PCP co-use was common in our study, with all but one participant reporting the use of at least two PCPs during T1A ( $n = 62, 98.4\%$ ) and T1B ( $n = 66, 98.5\%$ ). The number of unique PCP co-use patterns was high: in T1A there were 57 ( $n = 63$ ) unique PCP combinations, and 63 ( $n = 67$ ) unique combinations for T1B; that is, most participants used a unique combination of PCP categories within a 48 h period. A complete list of all co-use combinations identified are presented in the Supplementary Tables.

### 3.2.5. Cluster Analysis

The following cluster analysis allowed us to determine groups of PCPs that were commonly used together. The results of a hierarchical cluster analysis with asymmetrical binary distance are shown as

cluster dendrograms for the T1 period (T1A and T1B combined) in Figure 8. Highly related clusters have a height close to zero and are located closer to the bottom of the dendrogram; clusters that are not related have a height close to one and are located near the top of the dendrogram.



**Figure 8.** Dendrogram representing hierarchical clustering from T1. (Three clusters of PCPs that are commonly used together are identified: Cluster 1 (Luxury)—“skinclea”, “lotion” and “face”; Cluster 2 (Daily)—“soap”, “condit”, “anti”, “shampoo”, “bodysoap”, “oral”; Cluster 3 (Beauty)—“hair”, “lip”, “makeup”, “eyemakeup”. PCPs with a height closer to zero are more closely related; PCPs with a height closer to 1 are not related.)

The clustering algorithm used here orders the clusters from left to right, based on how closely the clusters are related. Three clusters, as suggested by Mardia’s (1979) [21] conservative approach, can be seen in each of the dendrograms and are summarized in Table 3, along with the co-use combinations. When looked at separately the clusters identified in T1A and T1B are very similar (see supplementary tables): they differ only in the cluster assignment of the product categories “soap” and “condit” (conditioner), and the precise positioning of the PCPs. When combining T1A and T1B we see 3 Clusters. Cluster 1 identified “Luxury” items and includes the categories “skinclea” (e.g., face cleanser, exfoliator, face masks, eye makeup remover), “lotion” (e.g., body butter, belly oil, sunscreen, hand cream) and “face” (eg. day cream, night lotion, acne cream, eye moisturizer); Cluster 2 identified “Daily” products and includes the categories “soap”, “condit” (conditioner), “anti” (deodorant and antiperspirant), “shampoo”, “bodysoap”, “oral” (toothpaste, mouthwash); and Cluster 3 identified “Beauty” products and includes the categories “hair”, “lip”, “makeup”, “eyemakeup”.

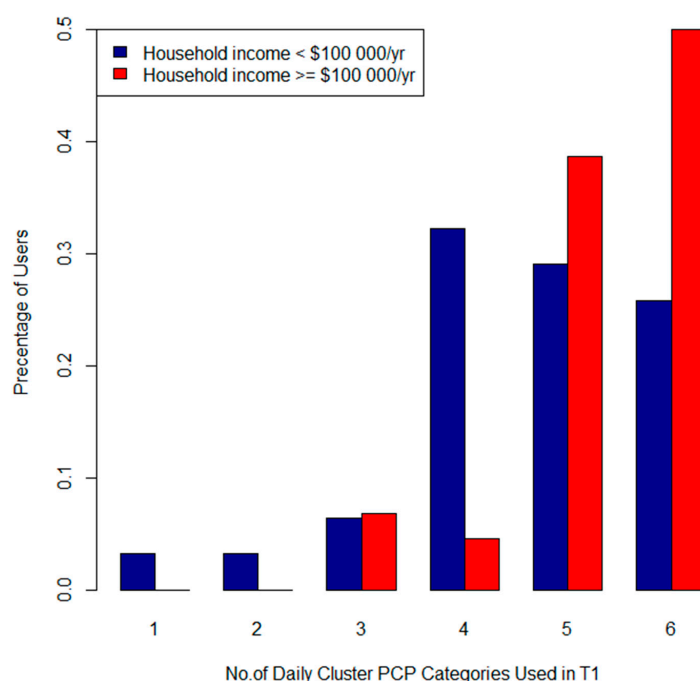
Groups found lower on the dendrogram are more commonly used and provide additional information on co-use, as shown in Table 3. For example, all of the Cluster 1 (“Luxury”) PCP categories were used by 42.5% of participants. For the “Daily” category (Cluster 2), 40% of participants reported use of all categories and in Cluster 3 (“Beauty” products) 15% reported use of all the categories.

**Table 3.** Co-use combinations by Cluster. Co-use combinations are shown for clusters identified in Figure 8.

Combinations		N (80)	%
Daily	SH + O	73	91.3
	SH + O + BS	68	85.0
	SH + O + BS + A	56	70.0
	SH + O + BS + A + C	45	56.25
	SH + O + BS + A + C + SO	32	40.0
Luxury	F + LO	46	57.5
	F + LO + SK	34	42.5
Daily + Luxury	SH + O + BS + A + C + SO + F + LO + SK	18	22.5
Beauty	M + EM	30	37.5
	M + EM + LI	18	22.5
	M + EM + LI + H	12	15.0
All product categories	SH + O + BS + A + S + F + C + LO + SK	7	8.75
	M + EM + LI + H		

SH (shampoo); O(oral); BS (bodysoap); A (anti); SO (soap); F (face); C (condit); LO (lotion); SK (skinclea); M (makeup); EM (eyemakeup); LI (lip); H (hair).

In T1 income was significantly associated with the product categories “skinclea” ( $p = 0.03$ ), “lotion” (0.05), “conditioner” ( $p = 0.01$ ) and the “Daily” ( $p = 0.004$ ) and “Luxury” ( $p = 0.01$ ) clusters. Figures 9 and 10 describe the total number of applications of “Luxury” (Cluster 1) and “Daily” (Cluster 2) products by income category. Figure 9 shows that 50% of participants in the high household income category used “Daily” PCPs 6 times per day, compared to only 25% in the lower income category. The high income group had more frequent applications of “Luxury” items (Figure 10) as well. Age was significantly associated with the “Daily” cluster ( $p = 0.04$ ). Women in the 30–34 age group used this cluster of PCPs more frequently than older and younger participants (See Figure 11). Canadian born *versus* foreign born participants were more likely to use both “shampoo” ( $p = 0.03$ ) and “conditioner” ( $p = 0.0009$ ). We did not find any associations with parity, education, marital status, pre-pregnancy or BMI and PCP categories or clusters.

**Figure 9.** Total number of Daily PCPs (Cluster 2) used per participant by income category in T1.

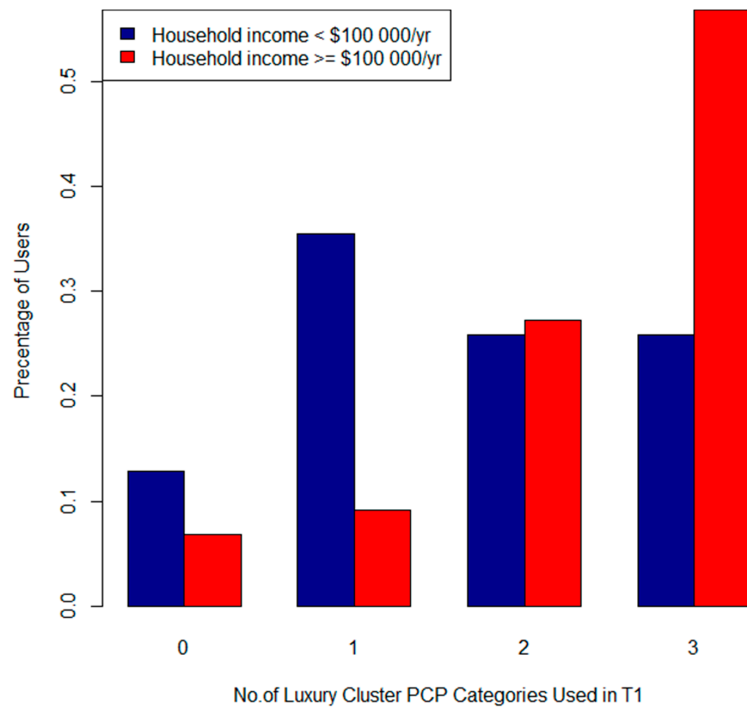


Figure 10. Total number of Cluster 1 (Luxury) PCPs used by income for T1.

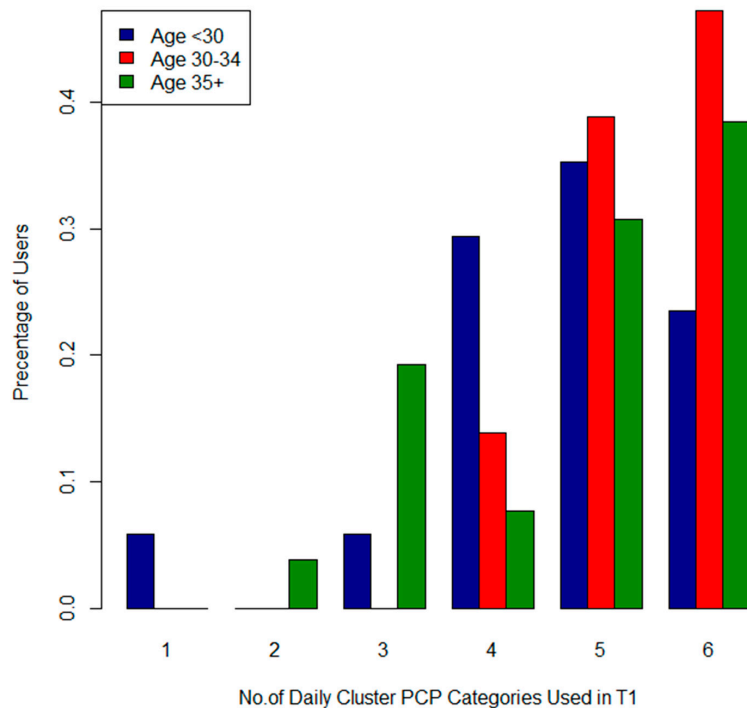


Figure 11. Total number of Cluster 2 (Daily) PCPs used by age for T1.

#### 4. Discussion

This study provides information on current usage patterns for 14 categories of PCPs for a cohort of pregnant women in Ottawa, Canada. PCP use patterns were investigated with minimum disturbance to the daily habits of study participants. Unlike most PCP use studies, this study was longitudinal and allowed us to capture differences in product use across pregnancy and into the postpartum period.

Additionally, diaries were used so that our report is not limited to users of certain PCPs, and the study captures actual PCP reported use as opposed to purchase frequency or use of “test” products, as is commonly reported in the literature. We were therefore able to report information on the prevalence and frequency of PCP use as well as PCP co-use in this population, data which can serve as important input to exposure assessment for this unique and susceptible population.

The total number of PCP applications is difficult to compare across studies because of the differing time periods studied and the types of PCPs assessed. For example, Manova *et al.* [6] report that women used an average of 6 of the 8 PCPs examined within the preceding year, and Just *et al.* [17] report that participants used an average of 3 of the 7 PCP types that were assessed in the previous 48 h. Because our study requested information on all PCPs used by participants in an open-ended format, we hope that our dataset can provide useful information for exposure assessment not only for current chemicals of concern, but as new chemicals on the market emerge as potential concerns requiring similar evaluation.

Close to half of the pregnant women in our study used the category “face” (face lotions and creams) and “lotions” (body lotions and creams) at least once per day (See Figure 6). In comparison, Manova *et al.* [6] reported that close to 80% of Swiss-German women aged 18–42 reported use of face creams at least once per day based on a retrospective questionnaire. However, the percentage of women who used the category “face” 2–3 times per day (40%) in the P4 study is similar to that found by Manova *et al.* [6]. For the category “lotion” (body lotions, creams and oils), the prevalence of use (40%–50%) was similar in the P4 study *versus* approximately 50% in the Manova *et al.* [6]. Our study showed a low percentage of women using lip products (lip balm, lipstick, lip gloss) in the last 24 h (20%–25% across time periods). Swiss-German women aged 18–42 reported 50% using lip care products and 20% using lipstick at least once per day in their study [6]. About 30%–40% of the P4 women reported using eye makeup at least once in a 24 h period across all study time points, similar to the Swiss-German study [6].

We found trends in PCP use as pregnancy progressed. Cosmetic and hair styling product use decreased as pregnancy progressed, with less use in the postpartum period (T5), whereas general hygiene and skincare product use was consistent across time periods. Baby product use, as well as hand soap use, increased in the postpartum period. These results suggest that product use datasets representing the general population may be similar for some product categories, but that pregnant and postpartum women may be a unique group of product users for other product categories, which has implications for exposure assessment.

We had hypothesized that PCP use patterns may differ between weekdays and weekends due to different patterns of activity and, while we found no differences in prevalence, hand soap, makeup, and eye makeup were used with a greater frequency during the weekdays than on weekends. Frequent hand soap use could be related to hygiene requirements in certain professions (such as healthcare or food service) and differences in frequency for cosmetics could show a desire to appear well groomed in professional life. However, this study was not powered to link PCP use to specific careers.

We found similar PCPs to be somewhat clustered together suggesting use of similar PCPs occurs at the same time. For example, different types of cosmetics were clustered together, and different types of lotions were clustered together. This finding is particularly relevant since co-use of PCPs containing the same ingredients would result in aggregate exposure, as similar PCPs may contain similar ingredients [2]. For example, participants were likely to use face lotion (“face”) and body lotion (“lotion”) together, in early pregnancy. If a particular chemical of concern was found in lotion-type PCPs, women could be exposed to this chemical via two or more PCPs concurrently.

There are limited published data available addressing use patterns of PCPs in pregnant women. Three biomonitoring studies examined the prevalence of PCP use in relation to urinary phthalates levels in pregnant women. Just *et al.* [17] gathered questionnaire data on the use of seven PCP categories on 186 inner-city women during their third trimester of pregnancy using 48 h recall. Buckley *et al.* [16] sampled 50 women in their second trimester using mailed questionnaires and the same 48 h recall

period. Meeker *et al.* [18] gathered questionnaire data from 105 pregnant women in Puerto Rico during the second trimester, again using a 48 h recall period. Although the PCP categories varied across studies, as well as gestational ages at time of sampling and socio-demographic variables, the results are nevertheless compared in Table 4.

The percentage of users in individual PCP categories varied considerably across studies, with nearly all reported uses higher in the Buckley *et al.* [16], Just *et al.* [17] and Meeker *et al.* [18] studies than in our P4 study, with the exception of baby products, where use in the present study was comparable to the Buckley study. Most notably, the women in the P4 study reported using very few nail polish and fragrance PCPs, whereas the Meeker *et al.* [18] study reported most women used these PCPs within the past 48 h. These differences might be explained by methodological differences in questionnaire *vs.* diary-based data, *i.e.*, recall bias. Poor compliance with the diary may also have occurred within the P4 study, especially for those commonly used items such as hand soap. Another possible explanation is that the targeted populations as well as observation period varied across studies. Furthermore, all of the studies have relatively small sample sizes, which may limit the generalizability of the results.

We also endeavoured to compare the P4 study results to product use information in the general, non-pregnant population. While Wu *et al.* [10] used telephone interviews to recall PCP use estimations over a period of one year, frequency of use information was presented as mean frequency of uses per month for both users and non-users, which was not comparable to our methodology. A series of studies published by Loretz *et al.* [7–9] recruited adult women who regularly used products of interest. Subjects identified the brand of product that they normally use, for the products of interest, and that brand was then purchased, weighed and provided to them for use over a 2 week period. Participants were asked to record daily information on their use of each test product in a diary that was provided to them. The product categories used were somewhat different from the P4 study categories, but we compared use frequencies with similar categories in Table 5. Although the data available for comparison were limited, no notable differences were found between studies, suggesting similar use frequencies among product users despite pregnancy. This comparison is limited due to differences in methodology between studies and small sample size and should be further investigated with additional product use information before drawing conclusions.

An interesting finding in this study is the low reported use of fragrances and perfumed products as well as nail polish and remover, which are often of interest in studies of exposure to environmental chemicals. Possible explanations could include study population characteristics, or simply small sample sizes. Another possible explanation is that participants were asked specifically if they used nail polishes in a questionnaire during each study time period, which may have led them to believe that they should not be using these products during pregnancy. In the questionnaire, only 7% of women said that they always or often wear nail polish while 30% said they sometimes wear it.

To the best of our knowledge, the cluster analysis presented here is unique from other published reports of product use. However, Wu *et al.* [10] did report on Spearman's correlations for product categories in a general population, and also found that PCPs within similar categories (*i.e.* General hygiene/skincare/cosmetics) were likely to be correlated with each other, while PCPs in different categories were not.

We consistently found in our study that women with household incomes  $\geq$ \$100,000 were more likely to use more PCPs than women with lower household incomes. This finding was true for nearly all PCP categories at every time point across the study. While the association was less strong, Canadian-born participants were found to more commonly use specific PCPs or clusters than participants born outside of Canada. In comparative studies, income differences have not been identified a notable association in PCP use patterns, although Wu *et al.* [10] and Just *et al.* [17] report race and country of origin as important variables in PCP use. Manova *et al.* [6] compared PCP use across three European countries and found PCP use patterns to be substantially different, or due to different countries of residence, warning that surrogate PCP use from other countries must be used with caution.

**Table 4.** Comparison of PCP prevalence in four studies of pregnant populations. The number and percentage of users in each study are shown.

P4 Study <sup>1</sup>	T1A (n = 63)		T1B (n = 67)		Buckley <i>et al.</i> [16] (n = 50) <sup>2</sup>			Just <i>et al.</i> [17] (n = 186) <sup>3</sup>			Meeker <i>et al.</i> [18] (n = 105) <sup>4</sup>		
	N	%	N	%	Product Category	N	%	Product Category	N	%	Product Category	N	%
Lip Products	20	31.8	23	34.3	Lip Products	42	84	-	-	-	Colored Cosmetics	95	90.5
Eye Makeup and Cosmetics	30	47.6	28	14.9	Eye cosmetics	33	66	-	-	-	-	-	-
Hair Styling Products	24	38.1	22	32.8	Hair styling products <sup>5</sup>	33	66	Hair gel	-	25	-	-	-
-					Hairspray	26	56	Hairspray	-	10	Hairspray	47	44.8
Shampoo	55	87.3	56	83.6	-	-	-	-	-	-	Shampoo	97	92.3
Conditioner	44	69.8	45	67.2	Hair Conditioner	29	58	-	-	-	Conditioner	97	92.3
Body soap	54	85.7	53	79.1	-	-	-	-	-	-	Bar soap	99	94.2
Hand Soaps, Sanitizers and Soap NOS	42	66.7	37	55.2	-	-	-	Liquid hand soap	-	29	Liquid soap <sup>6</sup>	103	98.1
Deodorant and Antiperspirants	49	77.8	42	62.7	-	-	-	Deodorant	-	98	-	-	-
Body Lotions, Creams and Oils	41	65.1	50	74.6	Hand cream or lotion	43	86	Lotion	-	82	Hand and Body Lotion	95	90.5
-					Other cream or lotion	33	66	-	-	-	-	-	-
Baby Products	21	33.3	17	25.4	Baby products	18	36	-	-	-	-	-	-
Fragrances and Perfumed Products	9	14.3	7	10.5	Perfume or cologne	28	56	Perfume	-	41	Perfume/Cologne	93	88.6
Nail Polish or Remover	0	0	1	1.5	Nail polish or remover	8	16	Nail polish or remover	-	10	Nail polish	58	55.2

<sup>1</sup> Based on a 48 h diary; Participants were less than 20 weeks pregnant; Weekday use (T1A) is differentiated from weekend (T1B) use; <sup>2</sup> Based on a 48 h recall period; Participants were in their second trimester of pregnancy; <sup>3</sup> Based on a 48 h recall period; Participants were in their third trimester of pregnancy; <sup>4</sup> Based on a 48 h recall period; Participants were in their second trimester of pregnancy; <sup>5</sup> Does not include hairspray; <sup>6</sup> May include body soap.



**Table 5.** Comparison of the use frequency (per day) of PCPs between an adult female US population Loretz *et al.* [7–9] and the P4 Study during the second trimester of pregnancy. **Only category “users”** were included for both studies.

Product Category	Loretz <i>et al.</i> [7–9]						Product Category	P4 Study T2					
	N <sup>1</sup>	Mean	SD	Med	Min	Max		N <sup>1</sup>	Mean	SD	Med	Min	Max
Lipstick	311	2.4	1.8	2	-	-	Lip Products	13	1.6	1.0	1	1	4
Eye Shadow	299	1.2	0.3	1.1	1	2.7	Eye Makeup and Cosmetics	22	2.3	1.1	2	1	4
Shampoo	340	1.1	0.2	1.0	1	2.1	Shampoo	40	1.1	0.3	1	1	2
Hair Conditioner	297	1.1	0.2	1.0	1	2.4	Conditioner	31	1.0	0.2	1	1	2
Body Wash	340	1.4	0.6	1.13	1	6.4	Body Soaps	49	1.3	0.7	1	1	5
Facial Cleanser	295	1.6	0.5	1.7	1	3.2	Facial Soaps, Cleansers and Washes	34	1.4	0.9	1	1	5
Solid Antiperspirant	340	1.3	0.4	1.1	1	4	Deodorant and Antiperspirants	39	1.2	0.4	1	1	3
Body Lotion, applied to hands <sup>2</sup>	308	2.1	1.6	2	-	-	Body Lotion, Creams and Oils	39	2.4	1.6	2	1	7
Face Cream	308	1.8	1.2	2	-	-	Face Lotions and Creams	35	1.7	1.0	1	1	5

<sup>1</sup> As only PCP users are compared here, sample size differs by PCP category (Zero users are excluded); <sup>2</sup> Use of body lotion was reported by the areas to which it was applied, and it was not possible to deduce total number of applications. Lotion applied to hands is used here as the area with the most frequently reported application.

A major limitation of this study, unfortunately common to most prospective pregnancy cohort studies, is potential selection bias, as participants tended to be older and of a higher socio-economic status than the general population. We cannot rule out that our participants might be women who use fewer PCPs or who use PCPs less frequently than an average pregnant Canadian population, as they may be more health-conscious people who were willing to spend the time participating in this study. Given the small sample size of this study, we may have been unable to detect some differences in PCP use by socio-economic characteristics of the women. As a result, these results are not generalizable to all pregnant women. Another concern is information bias, as the study required participants to self-report the names and types of PCPs used and when they were used. While this data collection was done prospectively, as opposed to being asked to recall what they use and how frequently, some women may have been more diligent in reporting than others, resulting in some misclassification and/or underreporting of product use. There could also have been participant fatigue in reporting of PCPs over time; however, as reports of use of hygienic products were consistent throughout pregnancy, this may not have been a problem. Classification error is another possible limitation; for example, it is interesting that the mean number of PCPs used in early pregnancy (T1) was slightly higher for day 1 than day 2 in both the weekend and weekday time periods. PCP use on day 2 was determined as PCPs used 21 h or more after starting the diary, in order to account for instances where participants may have woken up earlier the second day. However, if a participant woke up and got ready more than three hours earlier on day 2 than day 1, than those PCPs used early in the morning may have been misclassified as day 1 instead of day 2.

## 5. Conclusions

In summary, this study provides data on use patterns for commonly used PCPs in a pregnant and postpartum population, which provides valuable input for exposure modelling of this susceptible group. Studies have shown PCPs to be one of several sources of exposure to environmental chemicals [22]. Compared to previously collected data, prevalence of use may be lower than in other published studies of pregnant women, but use frequencies and co-use patterns between product categories were similar to a non-pregnant population. This study is the first to track product use across pregnancy and into the postpartum period, and suggests that pregnant populations may be a unique group of product users as their use of cosmetic products may decline with advancing pregnancy and post-delivery, however further studies are needed to confirm this finding.

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**Author Contributions:** Carly Lang contributed to the data collection in the study, statistical analysis and the writing of the manuscript; Mandy Fisher was involved in the original design and development of the study, study management, data analysis and manuscript writing; Angelica Neisa analyzed the data; , Leona MacKinnon contributed to the manuscript writing; Sandra Kuchta contributed to the manuscript writing; Susan MacPherson analyzed data and contributed to the writing of the manuscript; Adam Probert analyzed data; Tye E. Arbuckle was involved in the original design, protocol development and writing of manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations/Definitions

PCP	personal care product
T1A	early pregnancy (prior to 20 weeks gestation) study period, weekday
T1B	early pregnancy (prior to 20 weeks gestation) study period, weekend
T1	early pregnancy (prior to 20 weeks gestation) (weekday or weekend)
T2	second trimester (24–28 weeks) study period
T3	third trimester (32–36 weeks gestation) study period
T5	2–3 months postpartum study period

makeup	general makeup and cosmetics
lip	lip products
eyemakeup	eye makeup and cosmetics
hair	hairstyling products
condit	conditioner
bodysoap	body soaps
skincea	facial soaps, cleansers and washes
oral	toothpaste and mouthwash
soap	hand soaps, sanitizers and soap not otherwise specified
anti	deodorant and antiperspirants
lotion	body lotions, creams and oils
face	face lotions and creams
babyprod	Baby lotions, soaps, and other baby products
frag	fragrance and perfumed products
nail	nail polish and remover
face	face lotions and creams

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