Research report

Title: Protocol proposal for, and evaluation of, consistency in nicotine delivery from the liquid to the aerosol of electronic cigarettes atomizers: regulatory implications

Running head: Aerosol nicotine delivery from e-cigarettes

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Abstract

Aims. The study aim was to propose a protocol and evaluate the consistency in nicotine delivery to the aerosol of different types of EC atomizers, as required by regulatory authorities.

Design. Three cartomizer and 4 tank-type atomizer products were tested (3 samples per product). The aerosol from 3 20-puff sessions from each sample was collected using a smoke machine. Three cartridges from a nicotine inhaler and 3 tobacco cigarettes were also tested.

Setting. Analytical laboratory in Greece.

Measurements. Aerosol nicotine levels were measured. Relative standard deviation (RSD, i.e. coefficient of variation) was calculated separately for each cartomizer and replacement atomizer head sample (intra-sample RSD) and between different samples (inter-sample RSD). The % difference from the mean, which is used to assess the quality of medicinal nebulizers, was also calculated.

Findings. The aerosol nicotine levels were 1.01-10.61 mg/20 puffs for ECs, 0.12-0.18 mg/20 puffs for the nicotine inhaler and 1.76-2.20mg/cigarette for the tobacco cigarettes. The intra-sample RSDs were 3.7%-12.5% for ECs and 14.3% for the nicotine inhaler, while for the tobacco cigarette it was 11.1%. The inter-sample RSDs were higher in cartomizers (range: 6.9-37.8%) compared to tank systems (range: 6.4-9.3%). All tank-type atomizers and 1 cartomizer were within 75-125% of the mean, as dictated for medicinal nebulizers.

Conclusions. Consistency in nicotine delivery to the aerosol from tank-type atomizers was within the acceptable limits for medicinal nebulizers and similar to the nicotine inhaler. Two out of 3 cartomizers had poor consistency. This protocol could be effectively used for regulatory purposes.

Keywords. Electronic cigarette; nicotine; aerosol; regulation.

Introduction

Electronic cigarettes (ECs) are a recent addition in the tobacco harm reduction strategy of providing alternative, less harmful, products to smokers. Until now they are unregulated, however, the European Union has adopted a new Tobacco Products Directive (TPD) in 2014 [1], which included rules for the marketing of EC products. The regulation will take effect on May 2016, and mandates that products are only placed on the market if they comply with this Directive. Among the requirements, the TPD clearly states that: "*electronic cigarettes deliver the nicotine doses at consistent levels under normal conditions of use*". This is a reasonable concern, not related to the safety but to the efficacy of ECs as smoking substitutes. One of the main expectations is that ECs will provide the amount of nicotine a smoker needs, and this will probably play an important role determining the success of ECs to substitute smoking. Studies have shown that there is a learning curve in EC use, with consumers (vapers) having different puffing patterns compared to smokers [2-4]. Another study found better nicotine absorption from EC use after consumers used the products for 4 weeks compared to baseline [5]. This is related to the different functional and performance characteristics, as well as different nicotine delivery patterns of ECs compared to tobacco cigarettes [3,4,6]. Similar adjustments are seen in smokers when switching from "regular" to "light" cigarettes (compensatory smoking) [7-9]. It is expected that consistency in nicotine delivery would prevent vapers from the need to continuously adjust their EC use patterns to compensate for the inconsistent nicotine delivery when using the same EC products repeatedly.

A previous study examined the nicotine delivery from the liquid to the aerosol using first-generation (cigarette-like) devices [10]. However, that study examined disposable devices equipped with prefilled cartomizers only. Moreover, the results were influenced by differences in the nicotine content of the liquid; thus it could not assess the consistency of the cartomizers only. Finally, the devices were tested at 150 and 300 puffs, evaluating the total nicotine delivery to the aerosol rather than the consistency in nicotine delivery to the aerosol from repeated use sessions, since is highly unlikely for consumers to take 150 or 300 puffs within one session. Newer generation atomizers are refillable, can be used with a large variety of battery devices and can be used long-term by changing the wick-coil head only; thus, a different protocol is needed to determine their consistency in nicotine delivery.

The primary aim of the study was to propose a protocol for regulatory purposes and examine the consistency in nicotine delivery from different EC atomizer products. A secondary objective was to compare the nicotine consistency among the EC products tested and with a medicinal nicotine inhaler and tobacco cigarettes.

Methods

Materials

Both first-generation (cigarette-like rechargeable batteries with cartomizers) and new-generation (so called “tank-type atomizers”) were examined in this study. To avoid inconsistencies in nicotine content of the EC liquid, a custom liquid composed of 45% propylene glycol, 45% glycerol, 8% deionized water and 2% nicotine was prepared and used with all products. This represents a common formulation for commercial EC liquids, and was prepared to avoid differences between labelled and true levels of nicotine that have been observed in commercial liquids.

Three brands of first-generation products were acquired from the UK (JacVapour V3i kit and Volcano Magma) and from Czech Republic (Vapour2 cigs). They consisted of a rechargeable lithium battery and a cartomizer. The choice was based on the availability of empty cartomizers from these brands that can be filled with liquid by the consumer. This would allow us to use the prepared liquid, avoiding the possible variability in nicotine concentration in the prefilled cartomizers which would affect consistency. Three samples of cartomizers and battery devices from each brand were obtained. Four brands of tank-type refillable atomizers were obtained from the market, representing 2 of the most popular atomizer manufacturers worldwide (Aspire Nautilus Mini and Aspire Atlantis, Aspire, Shenzhen, China; Kangertech EVOD Mega and Kangertech Subtank, KangerTech, Shenzhen, China). Instead of replacing the whole atomizer, they have replaceable wick-coil heads which need to be regularly (usually every few days) replaced by the vapers. We obtained 3 samples of wick-coil replacement heads for each atomizer. Two new-generation battery devices were used with the tank-type atomizers, depending on the power level setup: Innokin iTaste SVD2.0 and Innokin iTaste MVP3.0 Pro (Innokin, Shenzhen, China). These devices contain a rechargeable lithium battery with a capacity of 2400-2600 mAh and have integrated electronic circuits to adjust power (W) delivery. The former has a power delivery capacity of 5-20 W while the latter has a power delivery capacity of 5-40 W. As a comparator, a pharmaceutical nicotine inhaler (Nicorette, Johnson & Johnson Hellas Consumer, Marousi, Greece) was obtained from a local pharmacy, consisting of a pipette and 42 replacement cartridges. According to the leaflet, each cartridge contained 10mg of nicotine. Finally, 1 pack of tobacco cigarettes (Marlboro regular) was obtained from a local tobacco store.

Protocol design

Our purpose was to evaluate nicotine delivery consistency when the same equipment setup is used in different sessions (intra-sample consistency), as well as when different replacement cartomizers or wick-coil replacement heads of the same product brand are used (inter-sample consistency). Therefore, 3 aerosol samples from 20-puff sessions (with a 5 minute period between sessions) would be collected using the same cartomizer and the same wick-coil replacement head. The comparison between these puff sessions would determine the intra-sample consistency. The same procedure would be followed with 2 more cartomizers and wick-coil replacement heads. The comparison between the 3 cartomizers and between the 3 wick-coil replacement heads would determine the inter-sample consistency.

The cartomizers and tank-type atomizers were filled with the prepared liquid. The nominal capacity of the cartomizers was 1 mL, but we filled them with 0.8 mL to avoid potential overfilling. A preliminary evaluation showed that 0.8mL was enough for performing 3 20-puff sessions. The tank-type atomizers were filled with 1 mL liquid. All products were attached to a custom-made smoke machine, and the aerosol was collected in 44mm-diameter Cambridge filter pads. The batteries of the cartomizers were automatically-activated when the puff was initiated by the machine. The tank-type atomizers were puffed with manually controlled batteries, so one of the researchers was responsible for pressing the button to activate the device for the time the puff was drawn. To facilitate coordination, the researcher manually activated the smoke machine to initiate each puff at the same time of activation of the battery device. All batteries were fully charged before use. For every cartomizer, 20 puffs were obtained, with the smoke machine programmed to a puffing pattern of 4 s puffs, 30 s interpuff interval and 60mL puff volume. There was no possibility to adjust the power with the batteries used with the cartomizers. For every wick-coil replacement head of the tank-type atomizers, 20 puffs were obtained at different power levels. Power levels were chosen based on information from the retailers and preliminary testing by a vaper (member of the research team) who obtained few puffs from all tank-type atomizers at the chosen power settings to make sure there is enough aerosol production. For Aspire Nautilus Mini and KangerTech EVOD Mega, puffs were obtained at 7 W using a puffing pattern of 4 s puffs, 30 s interpuff interval and 60 mL puff volume and at 10 W using a puffing pattern of 3 s puffs, 30 s interpuff interval and 60 mL puff volume. Manufacturer instructions for Aspire Atlantis and KangerTech Subtank recommended that they should be used at 15-30 W power levels. A preliminary test by the vaper verified that there was almost no aerosol production when used at 10 W. Thus, puffs were obtained at 15 W, using a puffing pattern of 4 s puffs, 30 s interpuff interval and 60 mL puff volume, and at 25 W, using a puffing pattern of 3 s puffs, 30 s interpuff interval and 60 mL puff volume. The Innokin SVD2.0 device was used for the aerosol collection at 7 and 10 W while Innokin iTaste MVP3.0 Pro was used at 15 and 25 W. The cartomizers and the tank-type atomizers were weighed with a precision scale before and after the aerosol collection to measure aerosol yield.

The nicotine inhaler was tested with the same smoke machine, using Health Canada Intense puffing patterns (2 s puffs, 30 s interpuff duration, 55 mL puff volume) [11]. Three 20-puff sessions were obtained with each of 3 cartridges. Finally, 3 tobacco cigarettes were puffed in the smoking machine using the same puffing pattern as with the nicotine inhaler.

Nicotine measurements

The aerosol from each session was collected in Cambridge glass-fiber filters. Subsequently they were stored in freezing conditions (-20oC) until analyzed.

The Cambridge filter was transferred in a centrifuge tube of 50 mL volume. 2% quinoline in n-Hexane was used as internal standard; 0.5 mL of internal standard and 19.5ml of n-hexane are added to the centrifuge tube. The filter was well rinsed with the solvent by using a vortex. Finally the mixture was centrifuged for 5 minutes at 3500 rpm. The organic solvent layer was decanted quantitatively in another clean tube and 0.5 mL of the decanted liquid was further diluted with 9.5 mL n-hexane in a stoppered glass tube. Four μL of the diluted solution are injected in a Gas chromatography equipped with a Nitrogen – Phosphorous Detector (NPD). The analytical method was validated by using Cambridge filters spiked with known concentrations of nicotine. The Limit of Quantification of the method was 0.01mg. Five samples of 2 different nicotine concentrations were analyzed. The results of the validation analysis were:

a) Nicotine concentration of 0.2%: Accuracy = 90.5%, Precision = 9.3%.

b) Nicotine concentration of 0.001%: Accuracy = 88.7%, Precision = 9.8%.

c) Average linearity = 0.991 (from 8 calibration curves).

Statistical analysis

Values are reported as mean (SD). The association between aerosol yield and nicotine content in the aerosol was evaluated using Pearson's correlation coefficient. To evaluate consistency in nicotine delivery, the relative standard deviation (RSD, coefficient of variation), expressed in %, was calculated using the equation: RSD = (SD/mean)*100. To evaluate the consistency between the 3 puff sessions of the same cartomizer, wick-coil replacement head and nicotine inhaler cartridge, the intra-sample RSDs were calculated. Each cartomizer and the nicotine inhaler had 3 RSD values, while tank-type atomizers had 6 RSDs (3 per power setting). Comparisons in intra-sample RSDs were performed between products (including nicotine inhaler, 8 products in total) with one-way ANOVA. For tobacco cigarettes, there was only one intra-sample RSD calculated, and it was used for descriptive analysis. To evaluate the consistency between different cartomizers, wick-coil replacement heads and nicotine inhaler cartridges, the inter-sample RSDs were calculated. For cartomizers and the nicotine inhaler, the mean and SD of all measurements were calculated in order to derive the inter-sample RSD. For tank-type atomizers, a separate mean and SD was calculated for each power setting; thus, 2 RSDs per product were derived (one per power setting), and their average was considered as inter-sample RSD. No inter-sample RSD was calculated for tobacco cigarettes. Finally, considering that the medicinal products accuracy for nebulizers requires 9 out of 10 samples to lie between 75% and 125% of the average value (all must lie between 65% and 135%) [10,12], the % difference of each measurement from the mean of all measurements was calculated. A P value of < 0.05 was considered statistically significant and all analyses were performed using commercially-available software (SPSS v22, Chicago, IL, USA).

Results

Aerosol nicotine content

Table 1 shows the mean (SD) aerosol nicotine content per 20 puffs from all products tested. There was a wide range of nicotine delivery from different EC products, from 1.01 to 3.01 mg/20 puffs for cartomizers and from 2.72 to 10.61 mg/20 puffs for tank-type atomizers. The nicotine inhaler delivered very low levels of nicotine (0.13-0.15 mg/20 puffs). Tobacco cigarette smoke delivered 1.76 to 2.20 mg/cigarette, which was expected considering that they were puffed using Health Canada Intense puffing regime. A significant correlation was found between aerosol yield and aerosol nicotine content ($r = 0.985$, $P < 0.001$).

[Table 1 here]

RSDs

The intra-sample RSDs for each product are displayed in Figure 1. Statistically significant differences in intra-sample RSDs between products were observed ($F = 2.41$, $P = 0.046$). For tank-type atomizers, the intra-sample RSD ranged from 3.7% to 6.5%, while for cartomizers it ranged from 5.5% to 12.5%. The intra-sample RSD for the nicotine inhaler was 14.3% and for the tobacco cigarette 11.11%.

[Figure 1 here]

The inter-sample RSDs for each product are displayed in Figure 2. For tank-type atomizers, the inter-sample RSD ranged from 6.4% to 9.3%, while for cartomizers it ranged from 6.9% to 37.8%. The high inter-sample RSDs in two of the 3 cartomizers (Vapour 2 and Volcano Magma) were due to 1 of the cartomizer samples delivering significantly lower levels of nicotine to the aerosol compared to the other 2 samples. The inter-sample RSD for the nicotine inhaler was 14.2%.

[Figure 2 here]

Difference from the mean

The % difference of every measurement of aerosol nicotine content from the mean of all measurements is shown in Table 2. For tank-type atomizers, it ranged from a lowest value of 84.5% to the highest value of 112.0% (both for Aspire Atlantis). All tank-type atomizer products complied with the standards for medicinal nebulizers. For cartomizers, only 1 product complied with the nebulizer standards (Jack Vape) while the other 2 products showed significant deviations, which were again associated with 1 of the cartomizer samples delivering lower nicotine levels to the aerosol compared with the other 2 samples.

[Table 2 here]

Discussion

This is the first study evaluating consistency in nicotine delivery from the liquid to the aerosol of ECs. Both first generation (cigarette-like) devices and new-generation (tank-type) atomizers were tested. The main findings were that tank-type atomizers delivered nicotine from the liquid to the aerosol with acceptable consistently, similar to a pharmaceutical nicotine inhaler and to tobacco cigarettes, and within the acceptable limits for medicinal nebulizers. Consistency was observed both when the same setup was used in different sessions and when changing wick-coil replacement heads. Two out of 3 cartomizers had poor performance in inter-sample consistency and in the % difference from the mean, mainly due to lower nicotine delivery with 1 of the cartomizer samples. Of note, nicotine delivery is significantly enhanced with new generation (tank-type) atomizers, especially at high power levels. This protocol could be used for regulatory purposes, considering that there is a requirement by the authorities that ECs should deliver nicotine consistently.

The 2014 TPD is the first regulatory standard for ECs proposed by the European Union [1]. The directive will be enforced in May 2016 and requires that EC products deliver nicotine consistently. However, there is currently no proposal on how this should be determined. There has been a debate, and a letter exchange among scientists and regulators, about the need to perform pharmacokinetic studies to determine consistent nicotine delivery [9]. That would be similar to evaluating a pharmaceutical product and, considering the huge variability of EC battery devices and atomizers, it would be unrealistic, unpractical and expensive. Herein, we propose a protocol which could examine the consistency of cartomizers and newer generation (tank-type) atomizers in nicotine delivery to the aerosol, both when the same equipment is used in multiple sessions and when different cartomizers or wick-coil replacement heads are used. A similar protocol could be used for examining the consistency of battery devices. The protocol is practical, feasible and financially sustainable. Moreover, it provides valuable information about the performance and quality of the products in terms of delivering nicotine from the EC liquid to the aerosol.

There was a large range of nicotine delivery potential among products. Cartomizers delivered less nicotine to the aerosol than tobacco cigarettes (on a puff by puff basis), but some tank-type atomizers exceeded tobacco cigarettes in nicotine delivery.. This is related to different design characteristics of the products and power delivery potential of the battery device.

Cartomizers are composed of an absorbent material surrounding a wick-coil setup [13], while tank-type atomizers are composed of a chamber which contains the liquid, and a wick-coil head which gets liquid from the chamber through holes. Moreover, cartomizers are used with low-capacity batteries which reduce power delivery to the cartomizer as they are discharged and do not have electronic circuits to adjust power levels. On the contrary, tank-type atomizers can be used with more advanced battery devices, as the ones used in this protocol, which maintain stable power levels throughout their working period. Such differences in design and characteristics could contribute to the lower consistency observed in 2 of the 3 cartomizers, which was mainly due to one cartomizer sample having poor performance in nicotine delivery. Among tank-type atomizers tested, there was a large range of nicotine delivery potential, which again could be related to different design, wicking material, coil characteristics (thickness and length) and higher power settings. As expected, power levels correlated with aerosol nicotine content, despite the lower puff duration; similar findings were reported in a study by Talih et al. [14]. Such variability in performance may be important in order to satisfy the different needs and preferences of consumers [15]. Moreover, the high levels of nicotine in the aerosol from new-generation tank-type atomizers could enhance nicotine absorption, considering that several studies using older atomizers have found that plasma nicotine levels are lower from EC use compared to smoking tobacco cigarettes [4,6,16-18], or could satisfy nicotine craving without the need to obtain prolonged or more frequent puffs. This is even more important considering that the European Union TPD will limit the availability of nicotine concentration to a maximum of 20 mg/mL. Although some concerns have been raised about the delivery of high nicotine levels from ECs [19], nicotine intoxication through inhalation is highly unlikely (due to self-titration) and any improvement in the nicotine delivery potential of ECs may enhance their efficacy as smoking substitutes [15]. Finally, the tank-type atomizers tested herein delivered nicotine from the liquid to the aerosol with consistency similar to medicinal nebulizers. This ensures that the consumers can experience similar and consistent effects on repetitive use of the equipment. Of note, all tank-type atomizers tested were made in China. There is some (anecdotal) controversy about the quality of equipment made in China. Our findings show that Chinese products can be of high quality in terms of nicotine delivery.

Some limitations apply to this study. A limited number of EC products were evaluated; therefore, our findings cannot be extrapolated to all products. This protocol could be used not only for regulatory purposes but also by the manufacturing companies to examine the production quality. The very strong correlation between aerosol yield and aerosol nicotine content implies that the potential of the atomizer to deliver nicotine could be calculated by measuring aerosol yield. However, this needs to be verified by measuring aerosol nicotine content using liquids with different nicotine concentrations. For tank-type atomizers, the battery devices were activated manually. This could affect reproducibility if coordination with the puffing machine was not accomplished during the aerosol collection. We did our best to avoid this by activating the smoke machine manually at the same time of activation of the device. Improvements should be made, by integrating of an automatic mechanism which will push the EC device button when the smoke machine takes a puff. The amount of nicotine delivery to the aerosol from tank-type atomizers should be interpreted with caution because the use conditions were not verified by experienced consumers. It is possible that the puff duration was too high for the power levels selected. However, there is no reason to believe that different puff durations would alter the consistency in nicotine delivery. Finally, the protocol did not assess the effect of aging of the atomizers. Use of the same wick-coil atomizer head for several days could affect performance and consistency in nicotine delivery. However, some compromise is needed when addressing testing for regulatory purposes, since it is impossible to replicate all potential use conditions and patterns.

Conclusions

Nicotine delivery to the aerosol from the tank-type atomizers tested was consistent and within the acceptable limits for medicinal nebulizers. Two of the three cartomizer products had low inter-sample consistency, probably related to design and battery limitations. . There is a large range of nicotine delivery potential among different products, with some products capable of delivering higher levels of nicotine compared to tobacco cigarettes. The protocol designed to test the nicotine delivery consistency could be used for regulatory purposes because, unlike pharmacokinetic studies, it is feasible, practical and financially sustainable.

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Table 1. Aerosol nicotine levels per puff session for the products tested

	Aerosol nicotine levels (mg)		
Product	Puff session 1	Puff session 2	Puff session 3
Aspire Nautilus Mini (7 W)			
wick-coil head 1	3.13	3.07	3.12
wick-coil head 2	3.11	3.09	3.12
wick-coil head 3	3.02	2.72	2.90
Aspire Nautilus Mini (10 W)			
wick-coil head 1	4.18	4.40	4.21
wick-coil head 2	3.99	4.54	4.26
wick-coil head 3	3.42	3.80	3.98
Aspire Atlantis (15 W)			
wick-coil head 1	3.88	3.68	3.74
wick-coil head 2	3.66	3.74	3.97
wick-coil head 3	3.11	3.26	4.12
Aspire Atlantis (25 W)			
wick-coil head 1	5.83	6.15	6.32
wick-coil head 2	6.94	6.22	5.74
wick-coil head 3	6.24	6.14	6.45
KangerTech EVOD Mega (7 W)			
wick-coil head 1	3.69	3.45	3.56
wick-coil head 2	3.20	3.17	3.15
wick-coil head 3	3.36	3.41	3.25
KangerTech EVOD Mega (10 W)			
wick-coil head 1	4.42	3.98	4.16
wick-coil head 2	3.75	3.38	4.04
wick-coil head 3	4.02	4.14	4.09
KangerTech Subtank (15 W)			
wick-coil head 1	8.02	8.28	8.13
wick-coil head 2	8.95	8.73	8.49
wick-coil head 3	8.76	7.79	7.35
KangerTech Subtank (25 W)			
wick-coil head 1	8.34	7.26	8.36
wick-coil head 2	10.33	10.37	10.61
wick-coil head 3	10.11	9.59	10.09
Volcano Magma			
cartomizer 1	3.00	2.61	2.16
cartomizer 2	1.14	1.10	1.10
cartomizer 3	3.01	2.23	2.13

Vapour 2 cigs			
cartomizer 1	2.08	2.23	2.30
cartomizer 2	2.02	2.02	2.21
cartomizer 3	1.38	1.64	1.01
Jack Vape i3 kit			
cartomizer 1	2.13	2.05	2.15
cartomizer 2	2.02	2.46	2.32
cartomizer 3	2.31	2.40	2.20
Nicotine inhaler			
cartridge 1	0.15	0.12	0.13
cartridge 2	0.18	0.14	0.13
cartridge 3	0.14	0.12	0.12
Tobacco cigarette	1.76	2.20	2.03

Table 2. Mean aerosol nicotine levels and % deviation from the mean for the products tested.

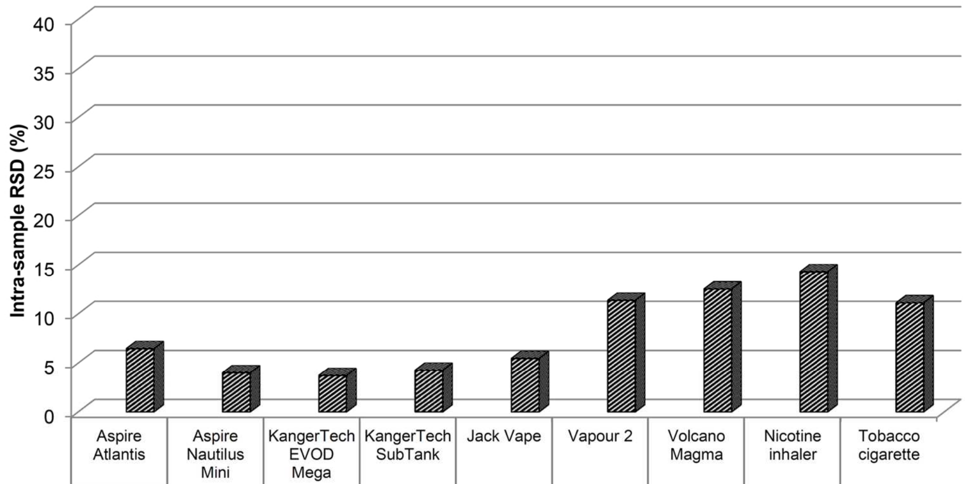
Product	Mean (SD) aerosol nicotine content (mg/20 puffs)	% difference from the mean [a]
Aspire Nautilus Mini (7 W)	3.03 (0.14)	89.8-103.3
Aspire Nautilus Mini (10 W)	4.09 (0.34)	92.9-107.6
Aspire Atlantis (15 W)	3.68 (0.62)	84.5-112.0
Aspire Atlantis (25 W)	6.31 (0.31)	92.4-110.0
KangerTech EVOD Mega (7 W)	3.36 (0.19)	93.8-109.8
KangerTech EVOD Mega (10 W)	4.0 (0.29)	93.8-110.5
KangerTech Subtank (15 W)	8.28 (0.51)	94.1-108.1
KangerTech Subtank (25 W)	9.45 (1.18)	76.8-112.3
Volcano Magma	2.05 (0.78)	53.6-146.8
Vapour 2 cigs	1.88 (0.44)	53.7-118.6
Jack Vape i3 kit	2.23 (0.15)	90.6-110.3
Nicotine inhaler	0.14 (0.02)	85.7-128.6
Tobacco cigarette	2.00 (0.22) [b]	88.0-110.0

[a] Range of % difference from the mean of all puffs performed by the particular product. For medicinal nebulizers, the acceptable deviation from the mean is 75-125% [10].
[b] Amount per 1 cigarette using Health Canada Intense puffing regime.

FIGURE LEGENDS

Figure 1. Intra-sample relative standard deviation (RSD) in aerosol nicotine content of all products. The table provides the one-way ANOVA post-hoc results for differences between individual products (asterisk indicates $P < 0.05$).

Figure 2. Inter-sample relative standard deviation (RSD) in aerosol nicotine content of all products.



	Aspire Atlantis	Aspire Nautilus Mini	KangerTech EVOD Mega	KangerTech SubTank	Jack Vape	Vapour 2	Volcano Magma	Nicotine inhaler
Aspire Nautilus Mini								
KangerTech EVOD Mega								
KangerTech Subtank								
Jack Vape								
Vapour 2								
Volcano Magma		*	*	*				
Nicotine inhaler	*	*	*	*				

Figure 1. Intra-sample relative standard deviation (RSD) in aerosol nicotine content of all products. The table provides the one-way ANOVA post-hoc results for differences between individual products (asterisk indicates P < 0.05).
138x105mm (300 x 300 DPI)

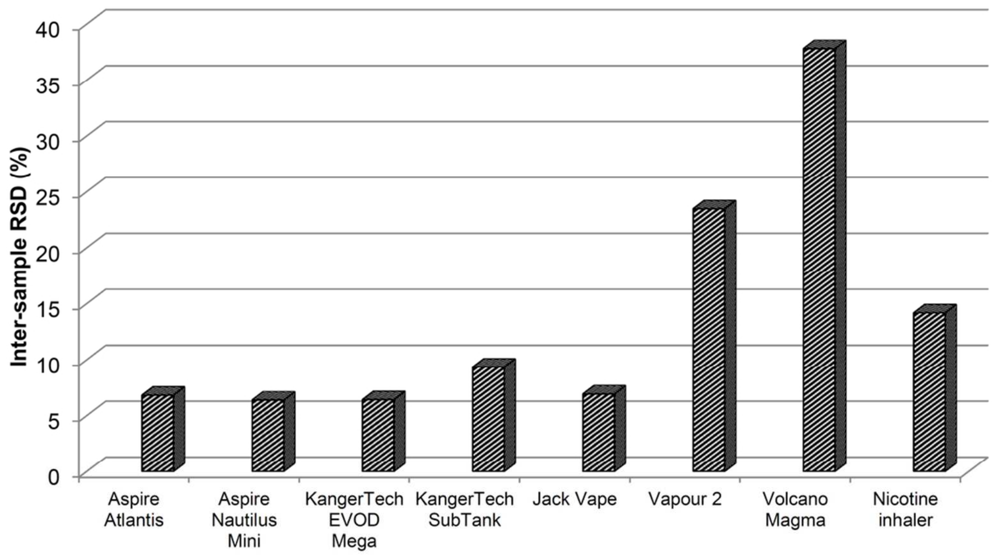


Figure 2. Inter-sample relative standard deviation (RSD) in aerosol nicotine content of all products.
96x54mm (300 x 300 DPI)