

Oral Nicotine Pouches and Public Health: Evidence from an Updated Scoping Review

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Abstract

Introduction: The popularity of oral nicotine pouches (ONPs) is rising in the US and worldwide. This review provides an update on their potential public health impact.

Methods: We searched six electronic databases for ONP-related empirical studies through September 30, 2025, updating an earlier review. Outcomes included ONP product characteristics, use patterns, beliefs, perceptions, toxicity, sales, and marketing.

Results: We identified 73 new studies published since our previous review (majority conducted in the US; 12 industry-funded). Nationally representative US surveys indicate a slow but steady increase in current ONP use prevalence among youth, ranging between 1.8% and 2.6% in 2024. Current use among adults was relatively low in 2022–2023 (0.4%–0.8%), with higher use among ages 18–44 and current tobacco users. US sales have more than tripled between 2021 and 2024. Marketing strategies increasingly emphasize potentially youth-appealing claims, with online and social media as key promotional channels. ONPs generally contain higher levels of freebase nicotine than other oral nicotine/tobacco products, with nicotine delivery increasing proportionally with nicotine strength. Nicotine uptake from higher strength ONPs ($\geq 6\text{mg}$) typically exceeds that from cigarettes in adult smokers, while ONPs consistently score lower in positive subjective ratings than cigarettes. Evidence suggests that ONP use substantially reduces smoking in daily smokers, generally resulting in dual use rather than complete cigarette cessation. ONPs are considerably less toxic than cigarettes, but their long-term health impacts remain understudied.

Conclusions: The review underscores the need for further research on ONP health effects, their efficacy in long-term smoking cessation, and broader public health impact in tobacco-naïve populations.

Implications: This updated review synthesizes the rapidly expanding evidence base on ONPs, providing timely, policy-relevant insights to inform tobacco regulatory bodies as they evaluate ONP product standards, marketing practices, and population-level public health impacts.

Introduction

The popularity of ONPs continues to increase worldwide, with the global market valued at nearly US\$2 billion in 2022 and expected to reach US\$23 billion by 2030.¹ Leading ONP manufacturers report increasing sales, mainly in the US, with an expanding geographic reach into new markets, such as Pakistan and Saudi Arabia.^{2–4} Globally, the regulatory landscape of ONPs is constantly evolving, with many countries still developing legislative proposals.⁵ While ONPs are commercially available without restrictions in many countries (e.g., Pakistan, UK), others either banned (e.g., the Netherlands, Belgium, France), limited ONP sales to pharmacies (e.g., New Zealand, Australia, Canada), or restricted sales of high-dose nicotine strength (e.g., Finland).^{5,6} In the US, while many ONP products are commercially available, only ZYN and on! products have been legally authorized for marketing by the Food and Drug Administration (FDA) as of 2025.^{7,8}

In our previous scoping review, we included studies published through January 2024.⁹ The review concluded that ONPs appear less toxic than cigarettes and may deliver comparable nicotine, presenting an alternative for combustible product users, though most evidence came from industry-funded studies. Furthermore, the review found a high prevalence of ONP awareness (35–42%) and susceptibility to use (9–44%) among US youth and young adults.⁹ These findings, along with increasing sales of ONPs in the past year reported by industry,^{3,4,10} may indicate further growth in ONP use. The present work updates our previous scoping review to reflect the fast-moving research on ONPs and inform regulatory bodies of the current state of evidence.

Materials and Methods

This review adhered to the guidelines for the Preferred Reporting Items for Scoping Reviews (PRISMA-ScR). The preregistered protocol is available on Open Science Framework.^{11,12}

Search Strategy

We used search terms described in our first review.⁹ In addition to MEDLINE, EMBASE, and Web of Science, we included three new clinical trial databases: CENTRAL, clinicaltrials.gov, and the WHO ICTRP. Our updated searches were conducted on September 30, 2025, with searches in MEDLINE, EMBASE, and Web of Science limited to publications from 2023 to exclude evidence already identified in the original review; date restrictions were not used in the other databases. Identified records were combined and deduplicated. Four reviewers independently screened titles and abstracts using Covidence (Veritas Health Innovation, Melbourne, Australia). Two reviewers independently screened full-text articles for eligibility criteria. One reviewer searched the references of eligible papers for additional sources. Disagreements were resolved by consensus. The complete PubMed search strategy is presented in Supplementary File S1.

Eligibility

We included peer-reviewed empirical studies on ONPs within the five outcome categories described in our earlier review.⁹ We excluded studies on non-nicotine pouches (e.g., nicotine analogue pouches) and studies that investigate a wider range of oral nicotine products (e.g., pouches, lozenges, gum) without reporting ONP-specific findings.

Data Extraction

Two reviewers independently extracted key data from the full texts of eligible studies using a standardized data extraction tool in Microsoft Excel (Microsoft Corporation, 2019). Data entries were compared, and any disagreements were resolved by consensus.

Data Synthesis

We synthesized data and presented findings in tables and narration, grouped by outcome categories and, within those, by specific outcomes. Our secondary analysis stratifies findings by population (youth and adults, history of tobacco/nicotine use), country, and source of funding (industry vs. non-industry). This review update focuses on new evidence since our first scoping review. Supplementary Tables 1–4 include studies from both reviews, and the Discussion explicitly assesses whether new evidence reinforces, extends, or contradicts conclusions from the earlier review.

Results

A total of 481 unique titles and abstracts were screened for eligibility, with 181 assessed in full text. Seventy-three studies were eligible for inclusion (including 12 industry-funded) (Figure 1). Supplementary Table 1 presents characteristics of the included studies from both scoping reviews, comprising 135 studies.

Use Patterns of ONPs

Thirty-seven new studies reported on use patterns of ONPs, focused on the US (18), Europe (10), Asia (6), Canada (2), and Australia (1). Five received tobacco industry funding.¹³⁻¹⁷ Supplementary Table 2 summarizes studies on ONP use prevalence.

US Prevalence Estimates

Among nationally representative youth surveys, the Population Assessment of Tobacco and Health (PATH) survey data yielded estimated lifetime (current) ONP use prevalence of 0.9% (0.2%) among adolescents ages 12-17 in 2022-2023.¹⁸ The

National Youth Tobacco Survey (NYTS) indicated an increase in lifetime (current) ONP use from 1.9% (0.8%) to 3.5% (1.8%) among middle and high school students between 2021 and 2024.¹⁹⁻²² Monitoring the Future (MTF) survey indicated an increase in lifetime (current) ONP use among 10th and 12th grade students from 3% (1.3%) in 2023 to 5.4% (2.6%) in 2024, with most reporting dual use with e-cigarettes.²³ Among adolescent current ONP users in 2024, 29% reported frequent use, and 22% reported daily use.^{20,21}

Among adults, nationally representative surveys PATH and Tobacco Use Supplement to the Current Population Survey (TUS-CPS) yielded estimates of 2.7%-3.3% lifetime ONP use, 0.4%-0.8% current use, and 0.2% daily use in 2022-2023.^{18,24-27}

Prevalence Estimates in Other Countries

Lifetime (current) ONP use was estimated at 3.3% (1.2%) among British youth in 2024,²⁸ 3.7% (2.6%) among adolescents in Quebec, Canada in 2024,²⁹ 26% (19%) among youth and adults in Australia in 2023,³⁰ 5.4% among German youth in 2022-2023,³¹ and 17.2% (9.4%) among Pakistani youth and adults in 2022³² (with current use at 3.4% [2.7%] among adolescent boys [girls] in 2023-2024).³² In Finland, lifetime (current) use was 14.4% (3.7%) among youth and adults in 2022,³³ and 17.2% (7.2%) among youth in 2023.³⁴

Among adults, the prevalence of lifetime (current) ONP use in 2024 was 13% in the UK,³⁵ and 5.4% (1%) in Great Britain.²⁸ In England, current use was 0.4% in 2023.³⁶ Lifetime (current) use was 9.2% (4.3%) in Poland in 2024.³⁷ In Saudi Arabia, lifetime use was 14.2% among the general population³⁸ and 21.2% among those with tobacco use history in 2024/2025.³⁹ In Canada, lifetime (current) use was 27% (12%) among adult college students in 2024.⁴⁰ Current use was estimated at 1.4% in Sweden and 0.8% in Denmark in 2019.¹⁴

ONP Consumption Behaviors

Current ONP users reported keeping the pouch in their mouth for ≤ 20 minutes,^{13,15,30} (except for ≤ 60 minutes in Sweden¹³), using them frequently or daily,^{21,32,40} or multiple times a day.⁴¹ The average consumption of pouches per day, often reported in categories, was 5-6 in the US,^{15,16} ≤ 5 in Germany and Switzerland,¹³ between 2-6 in Saudi Arabia,^{39,42} 6-8 in Denmark,^{13,14} and 8 in Sweden.^{13,14}

In the US, the most commonly used brand among youth and young adults (ages 13-24) was ZYN, whereas both ZYN and Lyft (Velo) were commonly used among adults ages 25-40.^{21,43}

The most commonly used ONP flavor in the US, Germany, Switzerland, Sweden, and Denmark was mint, both among youth^{19,21} and adults.^{13,24,25} Both mint/menthol and fruit flavors were commonly used among Australian youth and adult users.³⁰

The most frequently reported nicotine strength used, often reported in categories, was 4mg in the US,¹⁵ 6–15mg in Germany and Switzerland,¹³ 11–15mg in Sweden and Denmark,¹³ ≤ 4 mg in Finland,³³ 5mg in Australia,³⁰ 6-10mg in Saudi Arabia,⁴² and 4-7mg in Canada.⁴⁰

Demographic Characteristics of ONP Users

Supplementary Table 3 presents studies on demographic characteristics of ONP users. Among adolescents, ten new studies from the US, Germany, Finland, Canada (Quebec), Pakistan, and the UK found a higher likelihood of lifetime ONP use in males,^{18,20,23,28,31} older ages,^{18,20,23,31} American Indians/Alaska Natives (AI/AN),²⁰ non-Hispanic white,^{18,20,23} multicultural race,²⁰ rural residents,²³ current^{18,28}, former^{18,28} and lifetime¹⁹ smokers, current,^{18,23,28} former,¹⁸ and lifetime¹⁹ e-cigarette

users, current¹⁸, former¹⁸ and lifetime¹⁹ smokeless tobacco (SLT) users, current tobacco/nicotine product users,³¹ past-year other oral tobacco¹⁸ and cannabis users,^{18,28} and those reporting higher sensation seeking³¹ and lower subjective social status.³¹ Studies of adolescent current user demographics were limited by small sample sizes, but suggest higher use in males,^{18,20,23,29,34,44} older ages,^{18,20,23,29} AI/AN and non-Hispanic white,^{18,20,23} Hispanic,⁴⁵ current^{18,19,28,29,34} and former¹⁸ smokers, current^{18,19,34} and former¹⁸ SLT users, current vapers,^{18,19,23,28,29,34} current multi-product users,⁴⁴ and past-year other oral tobacco¹⁸ and cannabis users.^{18,28}

In adults, twelve new studies from the US, Australia, Canada, Poland, Pakistan, Saudi Arabia, and Great Britain found higher odds of lifetime ONP use among ages 18-25,⁴¹ 18-30,³⁹ 18-34,^{25,28} 18-39,³⁸ 18-60,³⁷ and 18-64,^{18,24} males^{18,24-26,28,30,38-40} (except no association with gender in one Polish study³⁷), and non-Hispanic whites^{18,24-26,40} (except no association with ethnicity in one British study²⁸). Similarly, current ONP use was more likely among adults ages 18-24,²⁷ 18-60,³⁷ 18-64,^{18,24} males,^{18,24-27,30} and non-Hispanic whites.^{18,24-27}

Higher lifetime ONP use was associated with current,^{18,24,26,28,30,37,38} former,^{18,24,26,28,30} and lifetime⁴⁰ smoking, current,^{18,26,28,30,38} former,^{18,26,28} and lifetime^{37,40} e-cigarette use, current,¹⁸ former,¹⁸ and lifetime²⁶ SLT use, past-year use of other oral tobacco¹⁸ and cannabis use,^{18,40} quit intentions,²⁴ and past-year smoking quit attempts.²⁴ Higher current ONP use was associated with current^{18,26,28,30,37,41} and former^{18,26,30} smoking, current,^{18,26-28,30,37} former,^{18,26} and lifetime³⁷ e-cigarette use, current,^{18,27} former,¹⁸ and lifetime²⁶ SLT use, and past-year smoking quit attempts²⁴ and cannabis use.²⁸

While active employment was associated with higher lifetime and current ONP use,^{25,37} associations with education level were mixed (ranging from no association^{18,28,39} to both positive²⁵ and negative²⁴ associations). Household income and financial status were not associated with ONP use,^{18,24,27,37,40} except in one US study where income of $\geq \$75,000$ was associated with higher ONP use.²⁵

Impact on Other Tobacco/Nicotine Product Use

Eleven studies (three industry-funded) focused on the association between ONP and other tobacco/nicotine product use.

Non-industry-funded studies

In an 8-week-long three-arm randomized control trial (RCT, n=33), daily smokers with low socioeconomic status and no intention to quit were assigned to either continue smoking, use nicotine-containing e-cigarettes, or use 4mg ONPs instead of cigarettes. By week 8, only one individual completely switched from smoking to ONPs, while three individuals stopped using ONPs, and the majority remained dual ONP/cigarette users. ONP use decreased the baseline average cigarettes per day (CPD) of 15 cigarettes by nearly half.⁴⁶ In another 4-week RCT (n=30), adult daily smokers with no intention to quit were assigned to either 3mg or 6mg ONP use and instructed to switch to ONPs completely. Both ONP strengths reduced CPD, while only 6mg promoted complete smoking cessation in two participants.⁴⁷ A prospective study of Californian adolescents who reported past 6-month e-cigarette use found that current ONP use was associated with a lower likelihood of continued vaping and lower vaping frequency at 6-month follow-up.⁴⁵

In cross-sectional studies, having quit cigarettes was associated with daily ONP use in US adults, while having quit e-cigarettes was associated with current non-daily, but not daily, ONP use.²⁶ Among daily or occasional English smokers attempting to quit smoking, ONPs were used in 3.1% of quit attempts and showed no association with quit success.⁴⁸ Among Pakistani current adult ONP users (most using ONPs >one year), 73% reported dual use with cigarettes while also reporting they would like help quitting ONPs.⁴¹ Youth and adult dual ONP/cigarette users reported no difference in CPD before and after starting ONP use.³² In contrast, 41% of Saudi Arabian adults with a history of tobacco use who tried ONPs reported successful smoking cessation with ONPs; 38% reported a reduction in smoking.³⁹

Industry-funded studies

A 6-month parallel-group RCT (n=100) of adult smokers with no intention to quit assigned participants to either an ad libitum use of 2, 4, and 8mg mint-flavored ONPs of their own choice with instructions to discontinue smoking, or to a control group of continued smoking. Over 90% reduction in CPD was reported in the ONP group at 6 months compared to baseline.¹⁶ In an observational study, adult smokers and /or SLT users with no intention to quit used ad libitum ONPs of various flavors and nicotine strength (1.5-8mg) in a 5-day trial, followed by continued at-home use.¹⁵ At 6 weeks, 27% of smokers and 71% of SLT users reported no cigarette/SLT use, while reporting continued use of ONPs. Among those who continued smoking or SLT use, a 50%-99% reduction in those products used per day was reported by 39% of smokers and 14% of SLT users, compared to baseline. A wider variety of ONP flavors was associated with fewer CPD, independent of nicotine level.¹⁵ In another observational study, young adult daily cigarette smokers used 4mg ONP (mint and citrus flavors) ad libitum for 6 weeks.¹⁷ While only 3% of smokers reported no cigarette use by week 6, 82% reported a reduction in CPD: 48% reduced CPD by 1%-30%, 18% by 30%-50%, and 16% by more than 50%.

Reasons for ONP use

Surveys of Pakistani adults identified peer influence,⁴¹ curiosity to try,³² recreational use,³² ease of use in tobacco-restricted areas,⁴¹ and quitting smoking³² as the main reasons for ONP use. Among Australian adolescents and young adults, common reasons for ONP use were the availability of flavors,³⁰ pleasant taste, and attractive packaging,³⁰ sport performance enhancement,⁴⁹ in nightlife and party settings,⁴⁹ help with nicotine cravings, and vaping and smoking reduction or cessation.^{30,49}

Beliefs and Perceptions

Product Awareness

US

NYTS survey data show that 41% of adolescents reported awareness of ONPs in 2022.¹⁹ Among adults, 45% reported awareness of ONPs in 2021, mainly from stores, the internet/social media, direct mail/ email, and print media ads. Younger, female, Black, and Hispanic (vs. white) adults showed lower odds of ONP awareness.⁵⁰ In a 2021-2022 young adult sample, 20% reported awareness after briefly viewing a Velo ONP ad.⁵¹

Other Countries

In 2024, 41% of British youth ages 11-18 and between 55%-71% of adults had heard of ONPs.^{28,35} In Poland, 24% of adults were aware of ONPs, with higher awareness among current smokers and lifetime e-cigarette or heated tobacco product (HTP) users.³⁷ Among Australian youth and adults, 77% reported awareness, with higher odds in men and current tobacco and e-cigarette users.³⁰ Among Saudi Arabian adults, 59% reported awareness, higher among males and those ages 18-39.³⁸ In 2022, 77% of Pakistani youth and adults were aware of ONPs.^{32,41}

General Opinions

Adult current smokers in North Carolina perceived ONP discreteness, flavors, and packaging as the main appealing factors to youth and young adults, while also perceiving ONPs as a product to supplement rather than replace smoking.⁵²

Product Interest/ Susceptibility

In the US, ONP-related health concerns negatively impacted susceptibility to ONP use in adult current smokers.⁵² Lower education (high-school diploma or less) was positively correlated with intentions to try ONPs among young adults.⁵¹

Nearly 21% of Pakistani tobacco-naïve adolescents were susceptible to trying ONPs, with 15% intending to try them within a year.⁴⁴ Among Australian adolescents and younger adults aware of ONPs, 70% were susceptible to trying them. Susceptibility was driven by having positive attitudes towards ONPs, lower addictiveness perceptions, and current or former use of e-cigarettes, but not tobacco.⁵³ Among Saudi Arabian adults, nearly 60% were susceptible to trying ONPs.³⁸

Risk Perception

Among US adolescents and younger adults, cigarettes were perceived as most harmful, followed by nicotine e-cigarettes, ONPs, nicotine lozenges, tablets, gum, THC e-cigarettes, toothpicks, patches, and non-nicotine e-cigarettes.⁵⁴ Nearly 25% of UK adults perceived ONPs (ZYN) as harmful; 57% perceived them to be less harmful than cigarettes.³⁵ In Poland, 61% of adults perceived ONPs as harmful as cigarettes.³⁷ Among Pakistani youth and adults, 27% perceived ONPs as equally harmful, 31% as more harmful, and 42% as less harmful than cigarettes.³²

Current ONP users were more likely to have low harm perceptions of ONPs,^{54,55} and to perceive them as less harmful than cigarettes.^{37,41} In an industry-funded survey, 34% of adult regular ONP users in Germany, 34% in Switzerland, 37% in Denmark, and 8% in Sweden perceived ONPs as harmful as cigarettes.¹³ Among Australian adolescents and adults aware of ONPs, 68% perceived them as harmful to health, while 38% perceived their harm as comparable to nicotine replacement therapy (NRT).⁵⁵ In Quebec adolescents, those perceiving ONPs as low-risk were 10 times more likely to use them currently than those perceiving them as high-risk.²⁹

Subjective Ratings

Nine new randomized trials (three industry-funded) examined product appeal and subjective ratings after ONP use.

Non-Industry-Funded Studies

In a three-visit study, adult daily smokers were randomized to use wintergreen-flavored 3mg ONPs containing either tobacco-derived or tobacco-free (synthetic) nicotine for 30 minutes. Both ONPs received moderate product liking scores and comparable withdrawal and craving relief. Those using tobacco-derived ONP reported more unfavorable sensory effects, such as tingling and burning sensations.⁵⁶ Among adult daily SLT users assigned to two 30-minute ONP use sessions, 2mg ONP use was associated with smaller reductions in cravings compared to 8mg ONP and own-brand SLT use.⁵⁷ In a single-visit study of young adult past 30-day e-cigarette and dual e-cigarette/cigarette users, 5-minute use of nicotine gum received higher appeal in terms of sensory attributes than 4mg fruit or mint ONP use.⁵⁸ In a three-visit study, adult daily moist snuff users rated both 6mg ONPs with a lower vs. higher portion of freebase nicotine as moderately appealing, with comparable scores for withdrawal symptoms, craving relief, subjective effects, and aversion. Own-brand moist snuff received the highest scores for product appeal and craving relief.⁵⁹

A five-arm study with adult daily smokers randomized to 20-minute use of either mint-flavored 6mg, 20mg, 30mg ONPs, nicotine-free oral pouches, or cigarettes, found that all products, including nicotine-free pouches, reduced acute cigarette craving.⁶⁰ In a 30-minute single-use study, exclusive daily Swedish snus users (≥ 8 mg/pouch) were randomized to each of five products (6mg and 9mg mint-flavored ONP, 11.2 mg spearmint-flavored ONP, 11.2mg bergamot-flavored Swedish snus, 4mg mint-flavored NRT nicotine gum) on separate days for 5 days. ONPs and snus received comparable scores for positive sensations (e.g., satisfaction, craving reduction) and negative sensations (e.g., aversion). NRT received the lowest scores for

positive sensations and intention to use the product again, and the highest score for aversion. Both 9mg and 11.2mg ONPs and snus received comparable scores for intention to use again, while the 6mg ONP scored lower.⁶¹

Industry-Funded Studies

In a series of in-clinic confinement studies, adult daily smokers were randomized to daily use of 5 different flavors of 4-12mg ONPs for 30 minutes (followed by either NRT gum or cigarette use) for 6-8 days. Positive product effects, product liking, intentions to use again, and reduction in urges to smoke were consistently lower for ONPs than cigarettes, and comparable to the NRT gum. Higher nicotine strength ONPs showed greater reductions in urges to smoke, but elicited lower product liking and intent to use again, and higher negative product effects compared to lower nicotine strength ONPs, indicating less favorable subjective experiences.⁶² In another in-clinic confinement study, adult daily snus or ONP users were randomized to a single use of 11mg or 20mg ONPs for 10, 20, or 30 minutes daily for 7 days. All arms reported similar scores for product liking and intent to use again, while the 30-minute use of 20mg ONP received the lowest scores.⁶³ In adult daily smokers, product liking scores were neutral and comparable between 4mg and 7mg ONPs, regardless of flavors, after a single 45-minute daily use of one ONP during a 10-day confinement.⁶⁴

ONP advertising

In the US, self-reported past exposure to tobacco product ads was positively associated with lifetime and current ONP use among adolescents.¹⁹ Exposure to ONP marketing, discounts, and coupons increased the risk of current ONP use among adults and was associated with ONP experimentation among adult current and former tobacco users.^{27,50}

Brief exposure to an ONP ad featuring content appealing to youth was followed by more favorable ONP perceptions and greater intentions to use by young adults, particularly among prior tobacco users, females, and Black respondents.⁵¹ In an industry-funded study, adult current tobacco experimenters reported the highest purchase intent and product appeal ratings after viewing an ONP ad, followed by current tobacco users and current non-tobacco users. Former and never-users of tobacco reported the lowest scores.⁶⁵ In a tobacco-naïve population ages 15+ in the European Union, past exposure to ONP marketing was associated with higher product appeal, particularly in males and ages 15-24.⁶⁶ In contrast, prior exposure to ONP ads was not associated with increased susceptibility to ONP use among Australian adolescents and young adults.⁵³

Product Characteristics

Nicotine Content and Release from Pouches

A US content analysis of 70 oral tobacco-free nicotine products found that ONPs contained the highest levels of total nicotine (5.71 –31.5mg/g), followed by loose leaf, toothpicks, lozenges, and gum. ONPs contained the highest total nicotine per product (1.41–8.11mg/pouch) and highest freebase nicotine (2.15–16.8mg/g). The proportion of freebase nicotine increased with increasing labelled nicotine strength and varied across ONP brands.⁶⁷ Another content analysis of 50 ONPs showed that despite containing nearly 50% less nicotine than traditional tobacco pouches (6.4 ± 3.5 vs. 12.3 ± 8.2 mg/pouch), ONPs contained a higher portion of freebase nicotine than tobacco pouches ($63.4\% \pm 25.2\%$ vs. $47.2\% \pm 34.4\%$), resulting in a similar, but more rapid, nicotine release profile.⁶⁸ Among 31 ONPs commercially available in Germany, the total measured nicotine ranged between 2.20 and 56mg/pouch.⁶⁹ The measured total nicotine levels in ONPs were generally the same or less than those reported on the label.^{67,69} In an industry-funded study, the extraction of nicotine from ONPs increased with higher nicotine strength and longer duration of use, with the fastest rate of extraction within the first 10 minutes of use.⁶³

Pharmacokinetics

Four of eight new RCTs on ONPs' pharmacokinetic properties were industry-funded (Supplementary Table 4).

Non-Industry-Funded Studies

Among ONPs available in Germany, 30mg ONP showed the highest overall (AUC) and maximum plasma nicotine concentration (C_{max}) in adult daily smokers during a 4-hour assessment period, followed by cigarette, 20mg ONP, and 6mg ONP. Time to reach maximum concentration (T_{max}) was shortest for the cigarette (5 minutes) and longest for 6mg ONP (20 minutes).⁶⁰ Compared to ONPs with synthetic nicotine, ONPs with tobacco-derived nicotine of the same strength and flavor (3mg, wintergreen) showed a higher C_{max} in adult daily smokers at 30 minutes post-use.⁵⁶ In adult daily SLT users, the mean nicotine concentration measured in plasma samples after 30-minute use sessions of 2mg, 4mg, and 8mg ONPs increased in a nicotine content-dependent manner, with 8mg ONPs delivering comparable or greater nicotine than SLT following the same use duration.⁵⁷ Among adult daily moist snuff users, mean plasma nicotine concentration at 30 minutes of use, C_{max} , and AUC were twice as high for the ONP with a higher vs. lower proportion of freebase nicotine of the same strength (6mg), and comparable to moist snuff. T_{max} was comparable across products (36-42 minutes).⁵⁹

Industry-Funded-Studies

Nicotine uptake from ONPs in adult daily smokers generally increased with higher nicotine strength and did not differ by flavor.^{62,64} Compared to cigarettes, AUC within 15 minutes and 4 hours post-use, and C_{max} were lower from 4mg and 8mg ONPs, but comparable or higher from the 12mg and 8mg 'mini' ONPs. The pharmacokinetic profile of the 4mg 'mini' was similar to that of 4mg NRT gum. T_{max} was comparable across all ONPs and the NRT gum (35-40 minutes), and slower than that of a cigarette (5-7 minutes).⁶² Nicotine uptake (C_{max} and AUC within 4 hours post-use) from 11mg and 20mg ONPs in adult daily snus or ONP users increased with nicotine strength and duration of use. The C_{max} for the 20mg ONP was higher than any previously reported values for ONPs and substantially greater than values reported for cigarettes.⁶³ The trend for dose proportionality between nicotine strength of 6, 9, and 11.2mg ONPs and nicotine uptake was observed among adult exclusive and daily Swedish snus users. C_{max} and AUC within 60 minutes post-use for all ONPs were higher than for 11.2mg snus and 4mg NRT gum, and twice as high for 11.2mg ONP as for the 11.2mg snus. ONPs delivered nicotine slightly faster than snus and NRT.⁶¹

Toxicity

Chemical Content

Four new studies provided evidence on the constituents of ONPs. An elemental analysis of six ONPs of various nicotine strengths and flavors confirmed the presence (not quantified) of aluminum, barium, calcium, chromium, copper, iron, manganese, sodium, scandium, strontium, and titanium.⁷⁰ In ONPs of various flavors, high levels of a Xylitol sweetener (nearly 16mg/pouch) and the total presence of 48 flavor compounds were reported.⁷¹ A content analysis of common flavorings used in tobacco products found that ONPs generally contained more flavorings than traditional tobacco pouches, with large variations across and within ONP brands. Menthol was most frequently present, even in fruit-flavored ONPs, especially in those with higher freebase nicotine.⁶⁸ In a chemical analysis of ONPs of various flavors and nicotine strengths, all contained significant amounts of artificial sweeteners (0.3-1.2mg/pouch), even those marketed as "unflavored."⁷² In the VELO ONP brand, the sweetener content was higher in products with higher nicotine levels. Sweeteners at these levels reduced aversion, increased preference, and facilitated nicotine consumption in mice.⁷²

In-vitro Toxicity

An independent assessment of ONPs found that 24-hour exposure of human monocyte leukemia cell lines to ONPs increased several pro-inflammatory cytokines beyond those observed with a pure nicotine solution control.⁷³ In an industry-funded study, seven out of eight own-brand ONPs were deemed non-cytotoxic, non-mutagenic, and non-genotoxic after a 24-hour exposure in hamster ovary cells, while one (8mg; spice flavor) was found cytotoxic and genotoxic at high nicotine equivalent concentrations exceeding those of a cigarette. The comparator ONP (6mg, wintergreen) and snus (8mg, mint) were found non-cytotoxic, non-mutagenic, and non-genotoxic, whereas cigarettes were positive in all three assays.⁷⁴ An industry-funded assessment of seven nicotine degradants and impurities in ONPs concluded that five did not exceed health risks of nicotine itself, while two exceeded levels of toxicity compared to pure nicotine.⁷⁵

Human Studies

Four new studies (one industry-funded) assessed biomarkers in humans. A study using PATH data found higher levels of nicotine metabolites in current exclusive ONP users than in exclusive vapers, and comparable to cigarette smokers, albeit based on a small sample size.⁷⁶ Levels of minor tobacco alkaloids, cadmium, and uranium were lower in ONP users compared to smokers, and comparable to vapers. Lead levels were lower in ONP users compared to users of cigarettes and vapers, and comparable to no tobacco use.⁷⁶ In a 4-week RCT, despite reducing smoking in adult daily smokers, dual use with ONPs did not reduce tobacco-specific nitrosamine levels.⁴⁷ A 20-minute use of ONPs (6mg, 20mg, 30mg) showed a dose-dependent increase in adult daily smokers' heart rate, with the highest increase observed for 30mg ONP and cigarette. The 20mg and 30mg ONPs elevated peripheral and central systolic blood pressure and arterial stiffness, comparable to cigarette.⁶⁰ In an industry-funded RCT, a reduction in gingivitis and enamel staining at 24 weeks was observed in adult current daily smokers who switched to ONPs compared to continued smoking.¹⁶

Marketing and Sales

Market Share and Sales Data

An analysis of US Nielsen sales data (excluding online and specialty shops) found that ONP sales have more than tripled from 327 million units in July 2021 to 1,046 million in May 2024, with sales revenue rising from US\$61 million to US\$232 million. ZYN, on!, Rogue, and VELO brands accounted for 99.8% of total sales, with ZYN leading the sales. Overall, sales were dominated by mint and wintergreen flavors (63%) and 3mg and 6mg strengths (67%), with faster growth in higher-strength (>4mg) ONPs.⁷⁷

Advertising Expenditures and Industry Marketing Strategies

From 2016 to 2023, Velo (BAT) ad expenditures in the US were mostly through TV (60%) and radio (30%), whereas ZYN (Swedish Match) spent most on online display and videos (79%). Of total ONP brand ad expenditures, Velo spent substantially more (89.8%, \$26.3 million) than ZYN (5.7%, \$1.7 million). Since 2022, ad expenditures for Velo dropped to \$0 and ZYN became the leader in ad expenditures.⁷⁸

A content analysis of Nordic Spirit Instagram ads between 2019 and 2023 identified four major themes that target young people, including "fun and freedom", "Nordic happiness", "fuss-free and discreet use", and "healthy and scientifically rational".⁷⁹ Among Instagram posts promoting synthetic nicotine products in 2020-2022, most featured ONPs (52.9%), followed by e-cigarettes (30.6%) and flavored e-liquids (14.1%).⁸⁰

From 2016 to 2022, US business-facing ONP ads focused on convenience (24%), retailer profitability (36%), product popularity and growing sales (24%), individual freedom (24%), and circumventing tobacco product restrictions (6%).⁸¹ A content analysis

of major US ONP brand ads between 2021 and 2023 indicated a decline in marketing terms like 'smoke-free', 'tobacco-free', and 'spit-free', and an increase in claims of discrete and convenient use, and availability of coupons/discounts. Over 84% of ads were posted on brands' social media accounts, with ZYN ads accounting for 55% of all platform ads.⁸² An analysis of US ZYN ads (excluding social media) identified digital media as the primary marketing channel between 2019 and 2023, with increased promotion of reward programs and "spit-free claims", and decreased use of "tobacco-free" claims following PMI's acquisition of ZYN in November 2022.⁸³

Retail Availability

In 2023, nearly 30% of licensed tobacco retailers in three major US cities sold ONPs, mainly through chain convenience stores and smoke/vape shops. Greater availability of ONPs was observed in predominantly White and higher-income neighborhoods, and in neighborhoods with fewer youth residents.⁸⁴ In Pakistan, nearly 8% of surveyed retailers in 2023 sold ONPs, with wider availability and variety in urban areas.^{41,85}

Discussion

Despite the growing popularity of ONPs, the prevalence of current ONP use among the US adult general population remained below 1% through 2023. However, use is higher among those with a tobacco use history, consistent with findings from our previous review.⁹ Among US youth, nationally representative surveys indicate a slow but steady increase in ONP use prevalence, doubling between 2021 and 2024. Notably, the prevalence of current youth ONP use is comparable to that of young adults (0.7%-1.5% in adults ages 18-24 vs. 1-1.5% in middle and high school students in 2022/2023). US sales of ONPs in this period have more than tripled. Disproportionately higher ONP use in some subpopulations, e.g., current tobacco and e-cigarette users, males, youth, and young adults, may be partially driving the increasing sales. Consistent with our previous review, awareness of ONPs in the US remains high, and is more common among youth and younger adults, and those with a tobacco use history.

Globally, higher ONP use prevalence, including among youth, was reported in countries both with a permissive regulatory approach, like Pakistan, and with restrictive ONP regulations, like Finland, Australia, and Canada. In the US and Pakistan, ONPs became the second most used product among youth after e-cigarettes, signaling their increasing popularity in younger segments.^{20,21,44} Further analysis of the impact of different regulatory regimes is warranted to inform future regulations.

The role of ONPs in the initiation and cessation of cigarettes and other nicotine delivery products remains unclear, lacking population-level longitudinal data on transition patterns.^{86,87} Consistent with our previous review, the present review of cross-sectional studies finds that current ONP use was more often associated with current cigarette and e-cigarette use than with former or never use. These findings might indicate supplemental use of ONPs among tobacco users, particularly in places where tobacco product use is prohibited. Indeed, ONPs are increasingly marketed as convenient and discrete products, and are commonly used by school-attending youth^{20,21,29,39,40} and employed adults.^{25,37} Dual use may also reflect a transitional stage to a complete cessation of the initial tobacco product, but, to date, there is insufficient evidence on ONP as a smoking cessation aid. Both independent and industry-funded RCTs found that ONP use for up to 6 months, regardless of nicotine strength, significantly decreased cigarette and SLT consumption in adult daily smokers or SLT users, with minimal impact on smoking cessation. Independent, well-designed research on the longitudinal transitions of ONPs and other tobacco/nicotine products and randomized studies of the efficacy of ONP use as a smoking and e-cigarette cessation aid are needed to understand the substitutional and supplementary effects of ONPs. Future studies should consider multiple ONP use measures (e.g., everyday vs someday, frequency, intensity) to better distinguish transitions by extent of use.

Our earlier scoping review concluded that ONPs contained fewer harmful/potentially harmful constituents at lower levels than traditional tobacco products.⁹ Updated evidence suggests that ONPs also contain substantial amounts of flavorings and artificial sweeteners. We note substantial variations in ONP flavorings within and across brands, with some manufacturers

increasing their content with higher nicotine strengths and freebase nicotine content, likely to reduce aversion and facilitate nicotine consumption. With flavored ONPs commonly used by both youth and adults, the role of flavors in ONP initiation and in the reduction or cessation of tobacco use remains unclear and merits further research. Further, collective findings from the present and earlier scoping reviews suggest that although ONPs are substantially less cytotoxic than cigarettes, ONP constituents beyond nicotine appear to induce inflammatory responses, oxidative stress, and cytotoxicity in short-term assays. Further independent research is needed to assess whether flavorings and sweeteners contribute to these cellular responses.

High levels of total and freebase nicotine in some ONPs raise further concerns. In some countries, nicotine content reaches 56 mg/pouch, while often not stated on the packaging.⁶⁹ High proportions of freebase nicotine in ONPs facilitate faster and greater nicotine absorption through buccal mucosa, potentially increasing nicotine dependence. Yet, ONPs with a high proportion of freebase nicotine (vs. low) do not appear to be superior in relieving cravings in SLT users,^{56,59,60} and their advantage in substitutability for cigarettes and other tobacco/nicotine products is unknown. In line with our previous review, new studies confirm that the nicotine uptake of ONPs increases proportionally with nicotine dose, and the nicotine delivery of higher strength ONPs (≥ 6 mg) generally exceeds that of cigarettes in adult smokers. While this may suggest that ONPs could substitute for smoking, studies in our present and earlier review consistently found a lack of appeal compared to cigarettes, suggesting that smokers may seek behavioral and sensory attributes beyond nicotine delivery. Further, the delayed nicotine delivery time with ONPs compared to cigarettes may not provide immediate craving relief and lead to the use of multiple ONPs in a short time, also referred to as “stacking.”⁸⁸ Such use, particularly of high nicotine strength ONPs, may result in an inadvertent overdose of nicotine and acute nicotine toxicity.⁸⁹ Sales of high-nicotine strength ONPs have been on the rise,^{77,90} and are widely used by adolescents and young adults.^{33,40} The commonly reported lack of users’ knowledge about the ONP nicotine strength further contributes to this concern.^{30,32,33}

The health impacts of ONP use remain largely understudied. Collectively, findings from our previous and present reviews indicate limited, mainly industry-funded evidence of short-term health benefits of switching to ONPs in adult smokers. Emerging evidence in the present and other reviews⁹¹ suggests that acute and regular use—especially at higher nicotine doses—may result in clinically relevant changes of specific markers of cardiovascular health. Similar effects were previously reported from the systemic nicotine absorption from smokeless tobacco.⁹² More research is needed to determine the short and long-term health effects of regular ONP use relative to traditional combustible and smokeless tobacco products, e-cigarettes, HTP, NRT, and no use.

Industry marketing strategies have evolved in recent years, increasingly prioritizing social media to promote ONPs and emphasizing potentially youth-appealing claims about flavors, discreetness, and convenience. The industry widely employs celebrity endorsements, sponsorships of major sporting events, and targeted marketing to specific populations (e.g., athletes) to promote ONPs.⁹³⁻⁹⁶ These marketing tactics are reflected in the commonly reported reasons for ONP use identified in this review, with sport performance enhancement emerging as a new common reason. Furthermore, the industry appears to be moving away from the “tobacco-free” descriptor as a marketing tactic, possibly to mitigate complications with FDA authorization.^{82,83} Meanwhile, a heavily advertised variety of flavors and increasing promotion of coupons and reward programs may attract tobacco-naïve youth.^{82,97} Continuous monitoring of industry marketing strategies is essential, as exposure to ONP marketing was found to be associated with ONP use and product appeal among youth and adults. More research is needed on the effects of ONP marketing on tobacco-naïve populations and how these effects vary across countries with different marketing regulations.

Our review has several limitations. As a scoping review, we did not conduct a risk-of-bias assessment of the included studies or perform statistical analyses of the included data. Future work should focus on targeted systematic reviews, where the certainty and quality of the evidence can be assessed. The associations with current ONP use should be interpreted with caution due to generally low sample sizes.

Conclusion

ONPs may be a less hazardous alternative to traditional tobacco, but they are not risk-free. Co-use with other tobacco/nicotine products is high, and thus far, the effect of ONPs on smoking cessation remains unclear. Commercially available high-strength ONPs raise public health concerns and may increase nicotine dependence. Health effects of ONPs remain understudied. Future studies should evaluate their efficacy in long-term smoking cessation and their broader public health impact in tobacco-naïve populations.

Declarations

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Figures

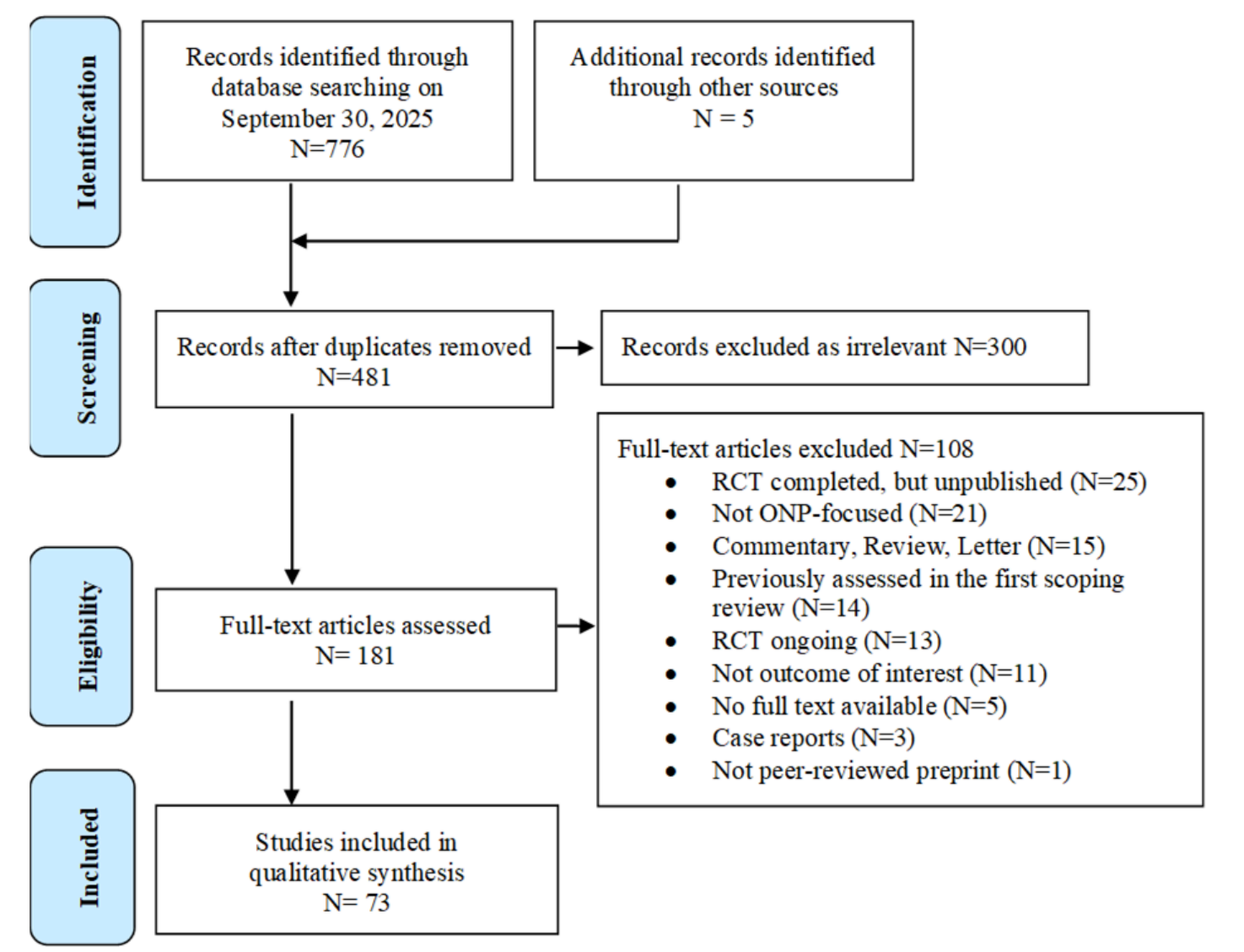


Figure 1
PRISMA Flow-chart of eligibility screening.

Supplementary Files

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- [SupplementaryFileS1.SearchstrategyforthePubMedDatabase.docx](#)
- [SupplementaryTableS1.Characteristicsofallincludedstudies.docx](#)

- [SupplementaryTableS2.PrevalenceestimatesoflifetimeandcurrentONPusebysurveyyearcountryandtobaccousestatus.docx](#)
- [SupplementaryTableS3.DemographiccharacteristicsoflifetimeandcurrentONPusers.docx](#)
- [SupplementaryTableS4.Pharmacokineticprofiles of ONPs compared to other tobacco and nicotine products.docx](#)