Khat chewing, xerostomia, and unstimulated salivary flow among Yemeni adults: a cross-sectional comparative study using sialometry, the Clinical Oral Dryness Score (CODS), and the Summated Xerostomia Inventory (SXI-D)

Mohammed Bin Taja
Sana'a University
Baleegh Al-kadasi
Ibb University
Manal Al-Hajri
Sana'a University
Salah Hafedh
salah.hafedh@gmc-ye.com

Sana'a University

Research Article

Keywords: khat, xerostomia, unstimulated salivary flow, CODS, SXI-D, Yemen

Posted Date: January 6th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8462830/v1

Additional Declarations: No competing interests reported.

Abstract

Objectives

To evaluate the association between khat chewing and oral dryness among Yemeni adults using clinical (Clinical Oral Dryness Score; CODS), symptom-based xerostomia assessment (Summated Xerostomia Inventory–Dutch Version; SXI-D), and unstimulated salivary flow rate (uSFR) outcomes.

Materials and Methods

In this clinic-based cross-sectional comparative study (n = 200), participants were classified as khat chewers (n = 171) or non-chewers (n = 29). CODS (1–10) and xerostomia symptoms (SXI-D; 5–15) were assessed at baseline. Unstimulated saliva was collected by the spitting method over 15 minutes, and uSFR (mL/min) was calculated. Among chewers, uSFR was additionally measured immediately before and after a typical khat session (paired assessment).

Results

Most participants had mild-to-moderate clinical dryness (CODS 1–3: 49.5%; CODS 4–6: 45.5%), with 5.0% classified as severe (CODS 7–10). Mean baseline uSFR was lower in chewers than non-chewers (0.387 vs 0.445 mL/min). Among chewers, mean uSFR decreased from 0.395 mL/min pre-session to 0.229 mL/min post-session ($p < 0.001$). Xerostomia symptoms were common; 39.5% reported a dry mouth on a single-item screen.

Conclusions

Khat chewing was associated with reduced unstimulated salivary flow and frequent oral dryness in this Yemeni adult cohort, and salivary flow decreased substantially after a typical chewing session.

Clinical Relevance: Oral health providers in khat-prevalent settings should screen for xerostomia and counsel chewers on hydration, caries risk mitigation, and symptom management, especially following prolonged sessions.

Introduction

Khat (Catha edulis) chewing remains a widely practiced social habit in Yemen and the Horn of Africa, with surveys indicating high prevalence particularly among men [1–4, 32, 33, 37, 39]. The leaves contain the alkaloids cathinone and cathine, which have amphetamine-like sympathomimetic properties [36–38]. While cultural and social functions of khat sessions are well recognized, accumulating evidence links habitual chewing to a spectrum of oral conditions, including mucosal changes, periodontal disease, and alterations in salivary properties such as pH, viscosity, and flow [5–10].

Xerostomia (subjective dry mouth) and hyposalivation (objectively reduced salivary flow) are related but distinct constructs that substantially impact oral comfort, speech, mastication, taste, swallowing,

denture retention, caries risk, and candidiasis [11–13, 19–23, 40]. Unstimulated whole salivary flow rate (uSFR) thresholds of approximately 0.1–0.2 mL/min are commonly used to operationalize hyposalivation, with values below ≈ 0.1 mL/min associated with markedly increased risk of oral complications [11–13, 21]. The Clinical Oral Dryness Score (CODS) is a 10-item clinician-rated scale (0–10) that captures observable signs of oral dryness and correlates with sialometric findings and symptom inventories [11, 12, 23–26].

Despite Yemen's high burden of khat exposure, contemporary, clinic-based data that quantify the acute impact of chewing on unstimulated secretory function using standardized sialometry, together with a validated clinical dryness index, remain scarce. Moreover, symptom questionnaires can over- or under-estimate xerostomia in populations where beverage intake (tea, coffee) and session-related behaviors may transiently modify oral moisture [13, 34]. To address these gaps, we investigated unstimulated whole salivary flow and CODS findings in working-age adults attending university dental clinics in Sana'a, comparing khat-chewers with non-chewers and characterizing within-chewer pre/post-session changes.

Based on the sympathomimetic profile of cathinone and prior observational reports, we hypothesized that khat sessions would be associated with an immediate reduction in unstimulated salivary flow, and that objective clinical signs of oral dryness would be common among regular chewers [5–10, 36–38].

Methods

Study design and setting: We conducted a clinic-based cross-sectional comparative study with a nested within-subject pre–post assessment among khat chewers. Participants were recruited from Sana'a University dental clinics between July 2019 and December 2021.

Participants: Adults aged 16–50 years attending the university dental clinics were invited to participate. Participants were classified as khat chewers or non-chewers based on self-reported khat use. The sample size reflected a pragmatic clinic-based recruitment target intended to (i) estimate the prevalence of clinical oral dryness and xerostomia symptoms and (ii) detect within-chewer pre–post changes in unstimulated salivary flow; between-group comparisons were considered exploratory given the imbalance between groups.

Ethical considerations: Written informed consent was obtained from all participants. For participants aged 16–17 years, consent procedures followed local regulations and the approving ethics committee requirements. The protocol received institutional ethical approval prior to recruitment and was conducted in accordance with the Declaration of Helsinki.

Measures: Clinical oral dryness was assessed using the Clinical Oral Dryness Score (CODS; 10-item clinical scale; total 0–10, higher scores indicating greater dryness). Subjective xerostomia symptoms were assessed using the Summated Xerostomia Inventory–Dutch Version (SXI-D), a five-item questionnaire with three response categories per item (Never = 1, Occasionally = 2, Ever = 3; total score 5–15). An Arabic version was produced by translation and back-translation of the SXI-D items for use

among Yemeni adults. Unstimulated whole saliva was collected by the spitting method with participants seated upright. Chewers provided samples immediately before and immediately after a typical khat session; non-chewers provided a single baseline sample.

Statistical analysis: Descriptive statistics summarized participant characteristics, khat use, salivary flow, CODS, and xerostomia symptoms. Within-chewer pre–post changes in salivary flow were evaluated using paired tests (paired t-test or Wilcoxon signed-rank, as appropriate). Between-group comparisons at baseline (chewers vs non-chewers) were evaluated using independent-samples tests (Welch's t-test or Mann–Whitney U) for continuous variables and χ^2/Fisher's exact test for categorical variables. We report mean differences (or median differences) and p-values. Multivariable adjustment was not performed because key confounders were not uniformly available in the study dataset.

Results

Participant characteristics: Two hundred adults were enrolled; 148 (74.0%) were male and 52 (26.0%) female, with a mean age of 26.37 years (range 16–50). Khat chewing was reported by 171 participants (85.5%); 125 were daily chewers. Participant characteristics and khat-use patterns are summarized in Table 1.

Table 1
Participant characteristics and khat chewing status

Characteristic	Value
Sample size (n)	200
Mean age (years)	26.37
Age range (years)	16–50
Male n (%)	148 (74.0%)
Female n (%)	52 (26.0%)
Khat chewing: Yes	171 (85.5%)
Khat chewing: No	29 (14.5%)
Daily consumers (subset)	125 (62.5%)

Key study outcomes are summarized in Table 2 (unstimulated salivary flow outcomes) and Table 4 (xerostomia symptom item responses).

Table 2
Unstimulated salivary flow rate (uSFR) outcomes

Comparison	Mean total flow (15 min), mL	Mean uSFR, mL/min	Notes
Baseline (non-chewers)	6.67	0.445	Single baseline collection
Baseline (chewers, pre-session)	5.80	0.387	Before khat session
Chewers (post-session)	3.45	0.230	Immediately after khat session
Chewers: Before Khat chewing	5.93	0.395	Paired comparison p < 0.001 (as reported)
Chewers: After Khat chewing	3.43	0.229	Paired comparison p < 0.001 (as reported)

Table 4
Xerostomia symptoms (SXI-D item responses)

Item	Never n	Never %	Occasionally n	Occasionally %	Ever n	Ever %
My mouth feels dry when eating a meal.	71	38	93	49.7	23	12.3
My mouth feels dry.	35	18.8	129	69.4	22	11.8
I have difficulty in eating dry foods.	39	21	105	56.5	42	22.6
I have difficulties swallowing certain foods.	85	45.9	81	43.8	19	10.3
My lips feel dry.	39	21	103	55.4	44	23.7

Abbreviations: CODS, Clinical Oral Dryness Score; uSFR, unstimulated salivary flow rate; SXI-D, Summated Xerostomia Inventory–Dutch Version.

Unstimulated salivary flow and xerostomia symptoms: Among khat chewers, the 15-minute unstimulated saliva volume decreased from 5.93 mL before a typical khat session to 3.43 mL after the session (0.395 to 0.229 mL/min). Baseline unstimulated saliva volumes were numerically lower in chewers than non-chewers, but period-specific baseline differences were not statistically significant in summary analyses. Xerostomia symptom burden (SXI-D) did not differ between chewers and non-chewers (mean ± SD 9.33 ± 1.96 vs 9.52 ± 1.91; p = 0.638).

Clinical oral dryness: Across the full cohort (n = 200), CODS grading indicated mild dryness in 49.5%, moderate dryness in 45.5%, and severe dryness in 5.0% of participants (Table 3). Symptom questionnaires showed broad endorsement of ‘occasional’ dryness-related items—particularly dryness

during meals and upon waking—consistent with limited diagnostic specificity of symptom-only screening in this population and the value of objective measures.

Table 3
Clinical Oral Dryness Score (CODS) distribution

CODS category	Severity	n	%
1–3	Mild xerostomia	99	49.5
4–6	Moderate xerostomia	91	45.5
7–10	Severe xerostomia	10	5.0

Ancillary observations: Consistent scheduling minimized circadian variability, and unstimulated collections were completed before any procedures that could stimulate flow. Questionnaire data suggested frequent co-consumption of tea/coffee during chewing sessions, which merits attention in future analyses.

Discussion

Limitations

Because participant-level raw data were not retained, analyses are limited to the aggregate results reported in the original thesis (e.g., no multivariable regression or correlation analyses).

Principal findings: In a university-clinic cohort from Sana'a, khat chewing was associated with a large acute reduction in unstimulated salivary flow (≈ 42% decline in uSFR from 0.395 to 0.229 mL/min) and a high prevalence of objective signs of oral dryness as captured by CODS. These results substantiate clinical impressions that regular chewers frequently exhibit salivary hypofunction around sessions and underscore the importance of objective chairside assessment in high-prevalence settings.

Context with prior literature: Reviews and observational studies have linked khat to oral mucosal changes, periodontal inflammation, and altered salivary properties, including decreased pH and modified viscosity [5–10]. Our data complement these findings by quantifying immediate changes in unstimulated secretion using standardized protocols. Given accepted hyposalivation thresholds (≈ 0.1–0.2 mL/min) [11–13, 21], post-session means near 0.23 mL/min approach clinically important ranges, particularly for individuals with comorbid risk factors (polypharmacy, autoimmune disease, diabetes) [19–23].

Physiologic considerations: Cathinone's sympathomimetic activity may influence salivary gland vasculature and acinar function, while session behaviors (prolonged unilateral mastication, reduced water intake, and concurrent caffeine use) may compound dehydrating effects [36–38]. Although stimulated salivary flow may transiently increase with mastication, the observed suppression in unstimulated output post-session aligns with autonomic modulation and behavioral fluid balance shifts.

Time-course studies are warranted to clarify recovery dynamics over several hours and the cumulative impact of daily chewing.

Clinical implications: Routine chairside screening can integrate three steps: [1] brief intake on khat frequency/duration and co-use (tobacco, tea/coffee), [2] CODS scoring (0–10), and [3] a 5–10-minute unstimulated collection to estimate uSFR. Management should focus on etiologic counseling, hydration strategies, sugar-free/xylitol chewing gum or lozenges, topical fluoride and remineralizing agents, high-fluoride toothpaste, and saliva substitutes where needed [19–23]. Medication review is advisable for xerogenic drugs (anticholinergics, antidepressants, antihypertensives), and denture wearers may benefit from fit optimization and nighttime relining regimens. Preventive recall can be individualized for patients whose post-session uSFR suggests elevated caries or candidiasis risk.

Public-health and regional considerations: Yemen's high prevalence of chewing among men and substantial use among women [1–4, 32, 33, 37, 39] imply a large population at risk for xerostomia-related morbidity [40]. Embedding simple UWS protocols and CODS scoring into public and university dental clinics could facilitate early identification and tailored prevention. Health-promotion messaging may integrate oral-health consequences with broader cardiometabolic risks associated with chronic khat use [35–38].

Strengths and limitations: Strengths include use of standardized unstimulated sialometry, a validated clinical dryness index, and pre/post assessment in chewers. Limitations include the single-center design, lack of long-term follow-up, and residual confounding despite exclusions (dietary patterns, fluid intake, unmeasured medications). Symptom questionnaires exhibited broad 'occasional' endorsements, consistent with prior observations that symptoms alone are insufficiently specific in mixed-exposure settings [13, 24–26, 34].

Future directions: Prospective, multicenter cohorts should stratify by chewing intensity and duration, beverage co-consumption, baseline hydration, and medication use, while extending observations over 24–48 hours to map recovery of basal secretion. Intervention trials could evaluate the effectiveness of targeted preventive bundles (xylitol + high-fluoride toothpaste + remineralizing agents + hydration counseling) for reducing caries incidence, candidiasis, and patient-reported dry-mouth burden.

Conclusions

Khat chewing among Yemeni adults was associated with a large acute suppression of unstimulated salivary flow and a high prevalence of clinician-observed oral dryness. Objective screening using CODS and brief unstimulated sialometry can be implemented rapidly within routine care to identify at-risk individuals and guide preventive management in high-prevalence communities.

Declarations

Compliance with Ethical Standards

Ethics approval and consent to participate: The study was conducted in accordance with the Declaration of Helsinki and relevant institutional guidelines. The research protocol was reviewed and approved by the Medical Ethics Committee of the Faculty of Dentistry, Sana'a University, Sana'a, Yemen (approval reference OMPR:05/12/2024). All participants were aged 16 years or older; no individuals younger than 16 years were enrolled. All participants were capable of providing informed consent and provided oral and written informed consent before participation.

Consent for publication:

Not applicable (no identifying personal data or images are included).

Funding:

No external funding was received for this study.

Supplementary material: The questionnaire and case-record form are provided as Online Resource 1.

Author Contribution

MBT and BK conceived and designed the study. MBT and MH collected data and performed clinical assessments. SH oversaw analysis and led manuscript drafting. All authors interpreted data, critically revised the manuscript, and approved the final version.

Acknowledgements:

We thank the staff and patients of the Sana'a University dental clinics for their cooperation.

Data Availability

Participant-level raw data are not publicly available. Aggregate summary data used for the figures and tables are provided in the accompanying tables and supplementary files; additional details are available from the corresponding author on reasonable request.

References

1. World Bank. Yemen: Toward Qat Demand Reduction? 2007 (summary article 2014). Available at: https://documents.worldbank.org(accessed 11 Nov 2025)

2. Al-Eryani S Yemen’s Qat Addiction Worsens. World Bank Blogs. 2014 Mar 20. Available at: https://blogs.worldbank.org
3. Nakajima M et al (2012) Gender differences in patterns and correlates of khat and tobacco use. Nicotine Tob Res. ;14[10]:1242–1247. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC3646654/
4. Nakajima M et al (2014) Habitual khat and concurrent khat and tobacco use. Prev Chronic Dis. ;11:E117. Available at: https://www.cdc.gov/pcd/issues/2014/13_0234.htm
5. Al-Maweri SA et al (2018) Khat and oral health: an updated review. Int Dent J. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/idj.12402
6. Al-Alimi A et al (2014) Effects of khat chewing on saliva compositionpHand flow rate. Available at: https://eprints.uob.edu.ly/items/f708103f-6a5b-4245-9711-9ebef6988393/1/ssrn-id2529630%20[1].pdf
7. Badulla W et al (2019) Effect of khat chewing on salivary pH among adults. Evid Based Complement Alternat Med. ;2019:7097972. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC6904976/
8. Silva P et al (2022) Khat: bundle of toxins? Toxins (Basel). ;14[5]:332. Available at: https://www.mdpi.com/2072-6651/14/5/332
9. Al-Akw’a OA et al (2025) Taste thresholds among khat chewers. Oral Surg Oral Med Oral Pathol Oral Radiol. Available at: https://www.oooojournal.net/article/S2212-4403[24]00446-4/fulltext
10. Yarom N et al (2010) Oral manifestations of habitual khat chewing. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 109:e60–e66
11. Osailan SM et al (2012) Clinical assessment of oral dryness: development of a scoring system (CODS). Oral Surg Oral Med Oral Pathol Oral Radiol. ;114:597–603. Available at: https://pubmed.ncbi.nlm.nih.gov/22959491/
12. Jäger DHJ et al (2018) Clinical oral dryness score: evaluation of a screening tool. Clin Oral Investig. ;22:2411–2417. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC6153998/
13. Thomson WM et al (1999) The Xerostomia Inventory. Community Dent Health. ;16:12–17. Available at: https://pubmed.ncbi.nlm.nih.gov/10697349/
14. Navazesh M. Methods for collecting saliva. Ann N Y Acad Sci (1993) ;694:72–77. Available at: https://pubmed.ncbi.nlm.nih.gov/8215087/
15. Navazesh MKumar SK (2008) Measuring salivary flow. J Am Dent Assoc. ;139:35S–40S. Available at: https://jada.ada.org/article/S0002-8177[14]63880-0/pdf
16. Dawes C (1972) Circadian rhythms in human salivary flow. J Physiol. ;220:529–545. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC1331668/
17. Bellagambi FG et al (2020) Saliva sampling: methods and devices. TrAC Trends Anal Chem. ;124:115781. Available at: https://www.sciencedirect.com/science/article/am/pii/S0165993619304182

18. Forcella L et al (2018) Measurement of unstimulated salivary flow rate. Swiss Dent J. ;128:318–324. Available at: https://www.swissdentaljournal.org/article/view/5581/4179
19. Royal Australian College of General Practitioners. Xerostomia — a clinical update (2016) Available at: https://www.racgp.org.au/afp/2016/december/xerostomia
20. National Cancer Institute PDQ Oral Complications of Cancer Treatment — Xerostomia. Updated 2023. Available at: https://www.cancer.gov/about-cancer/treatment/side-effects/xerostomia-hp-pdq
21. Alvariño JMR et al (2021) Salivary gland flow rates and thresholds revisited. Med Oral Patol Oral Cir Bucal. ;26:e63–e72. Available at: https://pubmed.ncbi.nlm.nih.gov/32755053/
22. Kapourani A et al (2022) Xerostomia and hyposalivation: mechanisms and management. Polymers (Basel). ;14:1434. Available at: https://www.mdpi.com/2073-4360/14/7/1434
23. Hijjaw O et al (2019) Correlation between XICODS and EULAR Sjögren's indices. Open Access Rheumatol. ;11:265–274. Available at: https://www.dovepress.com/correlation-between-xerostomia-index-clinical-oral-dryness-scale-and-e-peer-reviewed-fulltext-article-OARRR
24. Das P et al (2016) Dry mouth and clinical oral dryness scoring systems. Ther Adv Chronic Dis. ;5:192–201. Available at: https://journals.sagepub.com/doi/10.1177/2050168416005001l0
25. Osailan S (2022) Subjective Score for Oral Dryness (SSOD). Med Sci (Basel). ;26[123]:e2302. Available at: https://discoveryjournals.org/medicalscience/current_issue/v26/n123/ms191e2302.pdf
26. RODI validation. Clin Oral Investig (2019) Available at: https://link.springer.com/article/10.1007/s10266-018-0339-4
27. the journal. Preparing your manuscript (sections & data availability). Available at: https://bmcoralhealth.biomedcentral.com/submission-guidelines/preparing-your-manuscript
28. BMC (Springer Nature). Editorial policies (ethicscompeting interests). Available at: https://www.biomedcentral.com/getpublished/editorial-policies
29. BMC. Declarations (ethics approvalconsentdata availability). Available at: https://www.biomedcentral.com/about/declarations
30. Springer Nature. Data Availability Statements—guidance. Available at: https://www.springernature.com/gp/authors/research-data-policy/data-availability-statements
31. Uribe SE et al (2022) Data availability & FAIRness in dental research. J Evid Based Dent Pract. ;22[3]:101727. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC9516597/
32. World Health Organization Bulletin. Khat chewing in Yemen: turning over a new leaf (2008) Available at: https://www.scielosp.org/article/bwho/2008.v86n10/741-742/
33. Wedegaertner F et al (2010) Motives for khat use in Yemen. Subst Abuse Treat Prev Policy. ;5:4. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC3006386/
34. Thomson WM et al (2000) Further testing of the XI. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. ;89:46–50. Available at: https://pubmed.ncbi.nlm.nih.gov/10633939/

35. Al-Mawarreb AAl-Motarreb A (2010) Khat chewing and cardiovascular disease. Phytomedicine. ;17:1227–1234. Available at: https://pubmed.ncbi.nlm.nih.gov/20621179/
36. El-Menyar A et al (2015) Khat use: history and heart failure. Oman Med J. ;30:77–82. Available at: https://www.omjournal.org/fultext_PDF.aspx?DetailsID=617&type=fultext
37. EMCDDA/European Union Khat drug profile. Available at: https://www.euda.europa.eu/publications/drug-profiles/khat_en
38. Lo Faro AF et al (2020) Khat pharmacology and toxicology: a review. Front Pharmacol. ;11:558925. Available at: https://www.frontiersin.org/articles/10.3389/fphar.2020.558925/full
39. Astatkie A et al (2015) Prevalence of khat chewing in Ethiopian university students. Subst Abuse Treat Prev Policy. ;10:17. Available at: https://doi.org/10.1186/s13011-015-0018-3
40. Abdullah MJ (2015) Prevalence of xerostomia in adults. J Clin Exp Dent. ;7:e45–e53. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC4349822/
41. van der Thomson WMde Baat CIkebe KMatsuda KEnoki KHopcraft MSLing GY (2011) Shortening the xerostomia inventory. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1123:322–327. 10.1016/j.tripleo.2011.03.024
42. Clinical trial registration: Not applicable (observational study; not a clinical trial)

Figures

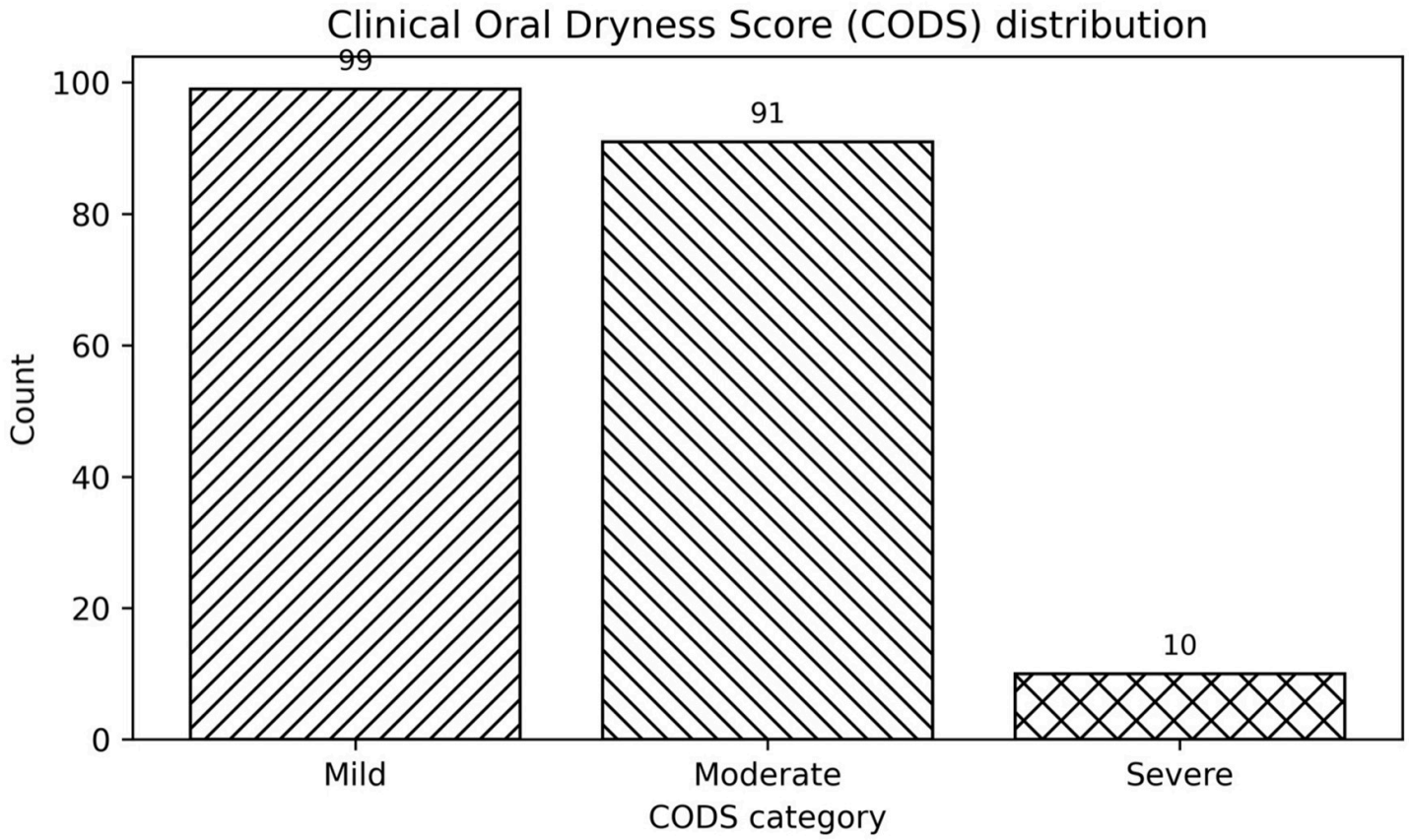

Figure 1

Clinical Oral Dryness Score (CODS) distribution in the study cohort (n=200).

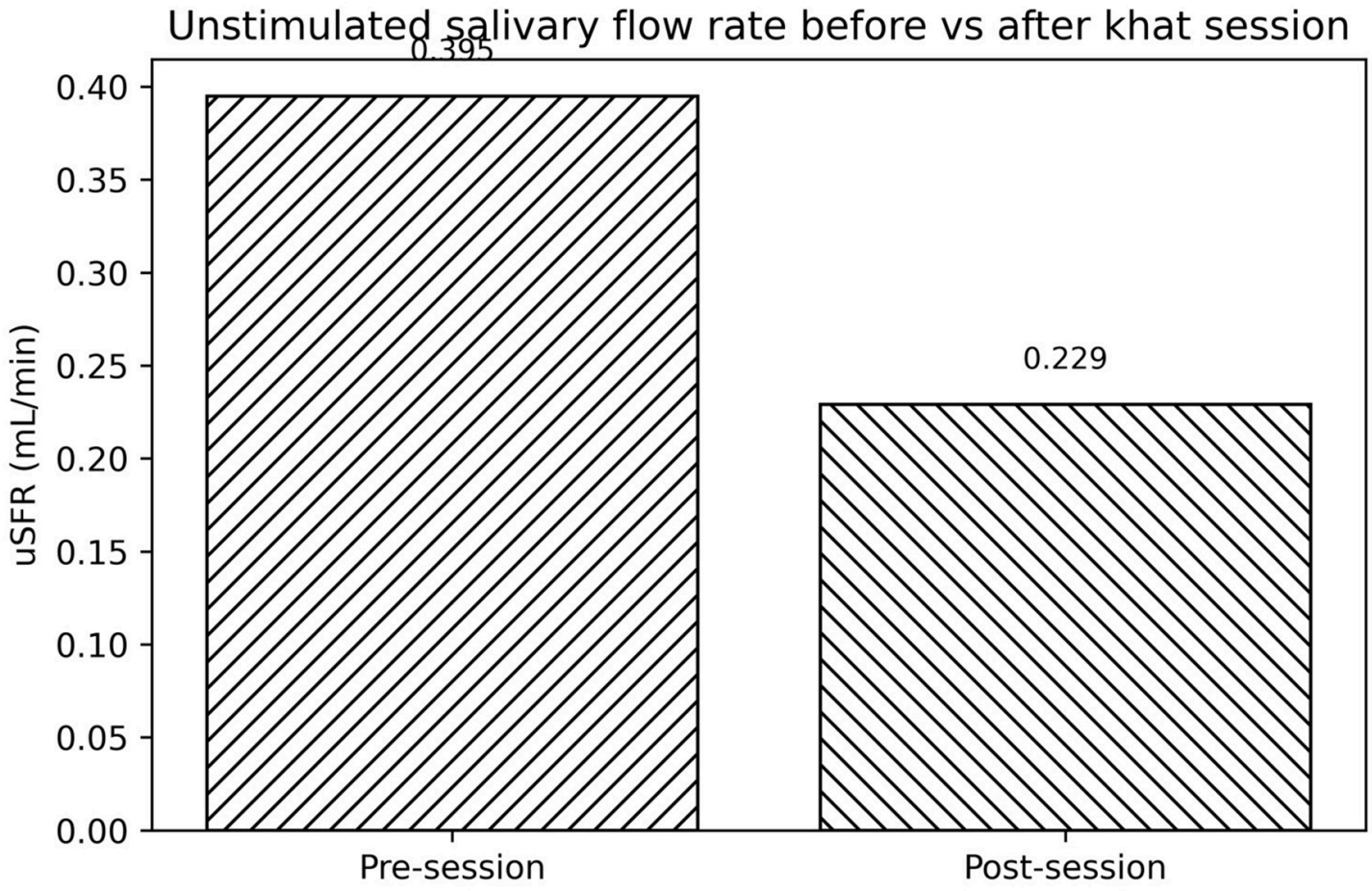

Figure 2

Unstimulated salivary flow rate (uSFR) before and after a khat chewing session among khat chewers (n=171). Bars show mean uSFR (mL/min).

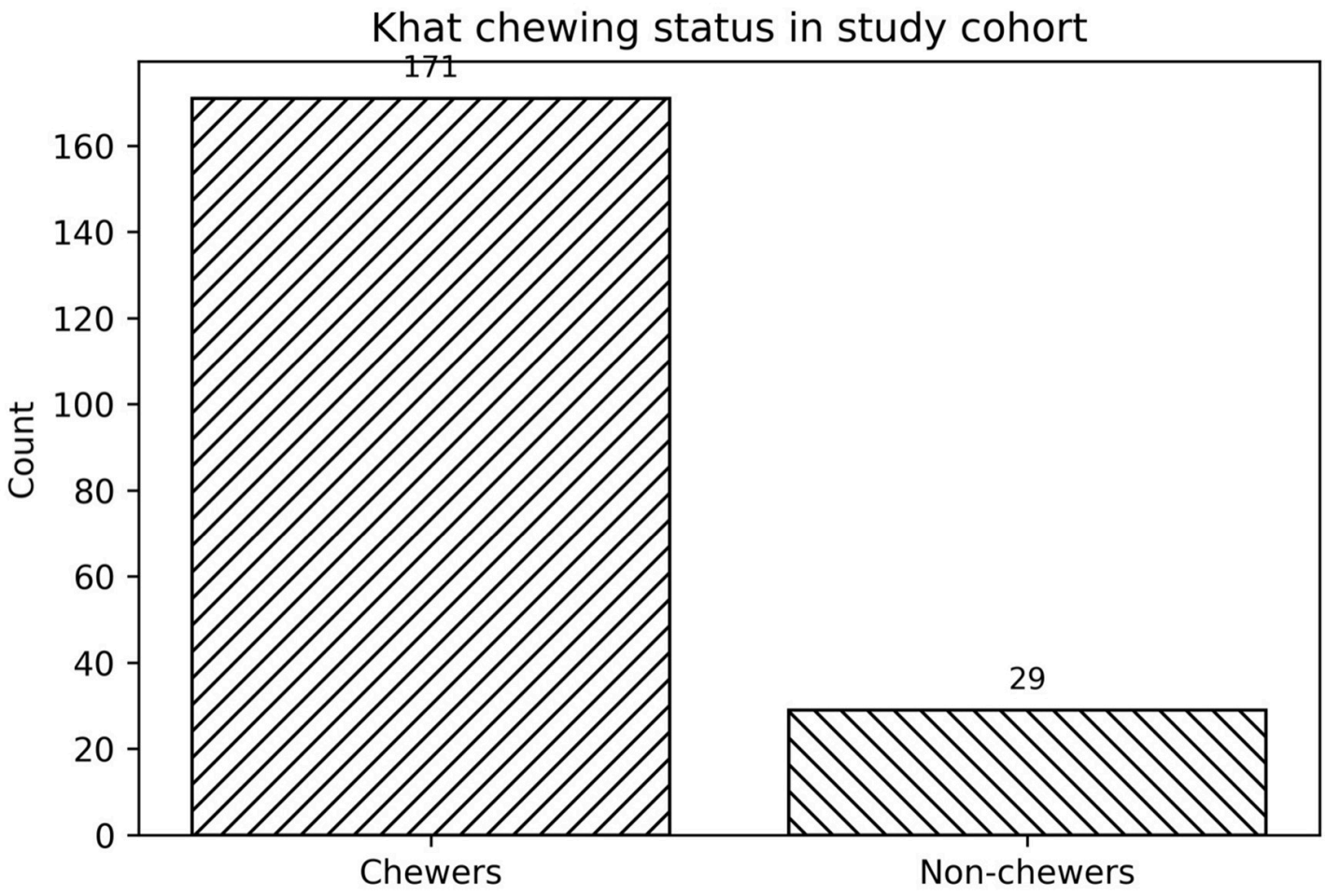

Figure 3

Khat chewing status in the study cohort (n=200).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Questionnaire.pdf
- MedicalEthicsCommitteeApproval.pdf