Research Square

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Unilateral chewing training and its associated factors in adults with hemiplegic cerebral palsy: a cross-sectional study

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Research Article

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Abstract

Background

Unilateral chewing training is increasingly used in oral rehabilitation, but its status and associated factors in adults with hemiplegic cerebral palsy (CP) remain unclear. This study aimed to investigate the current status of affected-side chewing ability and its associated factors in adults aged 30–50 years with hemiplegic CP.

Methods

A cross-sectional study was conducted at a tertiary hospital in Xinjiang from April to June 2025. Chewing ability was objectively assessed using color-changeable gum, with grades 1–2 defining decreased function. Other variables included demographic information, cerebral hemorrhage severity, oral motor skills, subjective chewing difficulty, nutritional status, and oral health-related quality of life (OHRQoL). Multivariable logistic regression identified factors independently associated with decreased chewing ability.

Results

A total of 120 adults with hemiplegic CP were included. The prevalence of decreased chewing ability was 32.5% (39/120). Multivariable analysis showed that no regular unilateral chewing training (OR = 4.28, 95% CI: 1.82–10.06, *P* = 0.001), moderate cerebral hemorrhage volume (10–30 mL) (OR = 3.76, 95% CI: 1.51–9.34, *P* = 0.004), low articulatory oral motor skills (OR = 3.92, 95% CI: 1.63–9.44, *P* = 0.002), and malnutrition (OR = 4.15, 95% CI: 1.69–10.18, *P* = 0.002) were independent risk factors for decreased chewing ability.

Conclusions

Decreased chewing ability is common in adults aged 30–50 years with hemiplegic CP. Moderate cerebral hemorrhage volume, poor oral motor skills, severe subjective chewing difficulty, and malnutrition are independently associated with impaired masticatory function. Color-changeable gum can be used for the early detection of chewing dysfunction. Healthcare providers should assess oral motor function, nutritional status, and chewing ability and implement targeted oral rehabilitation strategies for this population.

Introduction

Cerebral palsy (CP) is a nonprogressive neurodevelopmental disorder, and hemiplegic CP accounts for 30–40% of all cases [1–3]. Among adults aged 30–50 years with hemiplegic CP, long-standing unilateral

motor dysfunction leads to disuse atrophy of masticatory muscles on the affected side, impaired neuromuscular coordination, and subsequent deterioration of masticatory function [4, 5]. Clinical manifestations include difficulty chewing hard foods, compensatory unilateral mastication on the unaffected side, and even nutritional deficiencies, which severely compromise dietary quality and social participation [6, 7].

Mastication is a key modulator of brain neuroplasticity. Rhythmic, task-specific chewing activates hippocampal neural activity and promotes functional reorganization in the primary motor cortex [8, 9]. In adults with hemiplegic CP, long-term hemiparesis weakens neural connections within the affected-side masticatory motor pathways, creating a vicious cycle of disuse and neural degradation. Unilateral chewing training on the affected side is hypothesized to selectively stimulate dormant neural pathways, but its real-world application and associated factors have not been well studied.

Chewing ability is usually assessed by three methods: direct objective, indirect, and subjective assessment [10]. Color-changeable chewing gum (masticatory performance evaluating gum xLITOL) is a reliable, objective tool for assessing masticatory function, with simple operation and high reproducibility [11]. Previous studies have shown that the decline in mastication function is related to age, number of teeth, oral motor skills, and nutritional status [12, 13]. However, the main study population of these studies was mostly community-dwelling elderly people or general CP populations, and the epidemiological characteristics of decreased chewing function in adults with hemiplegic CP have not been specifically investigated.

Therefore, this study aims to investigate the current status of chewing ability in adults aged 30–50 years with hemiplegic CP, analyze its influencing factors (including unilateral chewing training status), and provide a reference for the implementation of scientific oral health management by healthcare workers.

Methods

Study population

This was a cross-sectional study and is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) principle. A convenience sampling method was performed to include adults with hemiplegic CP in a tertiary hospital in Xinjiang from April to June 2025.

The inclusion criteria were as follows: (1) diagnosis of hemiplegic CP (ICD-11: GB37.1) confirmed by neurologists and rehabilitation physicians; (2) age 30–50 years; (3) definite hemiplegic side; (4) affected upper/lower limb muscle strength ≥ Grade 3 (Manual Muscle Test); (5) ≥ 20 natural teeth (excluding third molars, Grade III mobile teeth, and dentures) with normal occlusal relationships; (6) history of perinatal or early-onset (≤ 3 years) cerebral hemorrhage confirmed by cranial CT/MRI, with a stable condition for ≥ 6 months; and (7) voluntary participation.

The exclusion criteria were as follows: (1) complete denture wearers or severe oral diseases (e.g., severe periodontitis, acute oral ulcers); (2) cerebral hemorrhage > 30 mL or bilateral trigeminal nucleus injury; (3) recurrent cerebral hemorrhage within 1 year; (4) conditions known to affect masticatory function (e.g., Parkinson's disease, temporomandibular joint disorder); and (5) osteoporosis (T score ≤ − 2.5) or severe alveolar bone atrophy.

This study was approved by the Institutional Review Board of The First Affiliated Hospital of Xinjiang Medical University (approval number: 2025HXNK-126). All participants were investigated after providing the relevant informed consent.

Assessment

A color-changeable gum (Masticatory Performance Evaluating Gum XYLITOL, Lotte Co., Ltd., Tokyo, Japan) was used to objectively assess mastication performance. Participants were instructed to chew the gum on the affected side for exactly 60 seconds. The chewed gum was immediately flattened to a 2-mm thickness and compared against a standard 5-grade color chart. A score of 1–2 indicated "decreased chewing ability," while a score of 3–5 indicated "normal chewing ability" [11].

General information included age, sex, hemiplegic side, and duration of cerebral hemorrhage. Cerebral hemorrhage severity was classified as small (< 10 mL) or moderate (10–30 mL) based on cranial CT/MRI [14].

Oral health-related information was collected, including regular unilateral chewing training (defined as structured affected-side chewing training ≥ 5 times per week, 15 minutes per session for ≥ 8 weeks in the past 6 months), oral motor skills, and subjective chewing difficulty [15, 16]. Low articulatory oral motor skills were indicated by a response of "yes" to the self-reported question: "Have you had difficulty in clear pronunciation recently?" [17], combined with a 4-point scale assessment (0–3 points) for buccal inflation, tongue protrusion, and mouth corner closure [18]. Subjective chewing difficulty was assessed using a modified 5-point scale (1 = no difficulty, 5 = completely unable to eat) for hard foods on the affected side.

Nutritional status was assessed by the Malnutrition-Inflammation Score (MIS) [19]. An MIS ≥ 8 was defined as malnutrition. Oral health-related quality of life (OHRQoL) was measured using the Chinese version of the Oral Health Impact Profile-14 (OHIP-14), with lower scores indicating better quality of life [20].

Data collection

Data collection was conducted via face-to-face interviews using a standardized questionnaire. The chewing ability test was conducted by two researchers: one performed the color evaluation, and the other was responsible for timing. All questionnaire content was collected by a single researcher to

maintain consistency. Each questionnaire required 10–15 minutes to complete. The structured questionnaire was developed specifically for this study. The English version is provided as Supplementary Material.

Data analysis

Data analysis was performed using SPSS 26.0 software. Quantitative data are depicted with frequencies (n) and percentages (%). The chi-square test was used to analyze differences between the normal and decreased chewing ability groups. Before multivariable analysis, collinearity diagnostics were performed on independent variables. Variables were retained only if they met the following criteria: variance inflation factor (VIF) < 10 and tolerance > 0.1. To determine variables independently associated with chewing ability, a multivariate logistic regression model (Forward: LR) was performed with selected variables showing a $P < 0.05$ in the univariate analysis. Odds ratios (ORs) and their respective 95% confidence intervals (CIs) were calculated. A $P < 0.05$ was considered significant.

Results

A total of 120 adults with hemiplegic CP were included in this study. Among them, 32.5% (39/120) were defined as having decreased chewing ability. The majority of patients were male (56.7%), with a mean age of 41.04 ± 5.49 years. A history of small-volume cerebral hemorrhage (<10 mL) was present in 61.7% (74/120) of patients. Regular unilateral chewing training was reported in 47.5% (57/120). Detailed general information is shown in Table 1.

Univariate analysis with the presence of decreased chewing ability as the dependent variable showed that there were significant differences between the two groups in terms of regular unilateral chewing training, cerebral hemorrhage severity, low articulatory oral motor skills, subjective chewing difficulty, malnutrition, and OHIP-14 score ($P < 0.05$), as shown in Table 2.

Collinearity diagnostics showed that tolerance values were >0.55 and VIFs were <1.82, indicating no significant covariance between the included independent variables for further analysis.

Binary logistic analysis showed that no regular unilateral chewing training (OR = 4.28, 95% CI: 1.82–10.06), moderate cerebral hemorrhage volume (OR = 3.76, 95% CI: 1.51–9.34), low articulatory oral motor skills (OR = 3.92, 95% CI: 1.63–9.44), and malnutrition (OR = 4.15, 95% CI: 1.69–10.18) were the influencing factors of chewing ability in adults with hemiplegic CP, as shown in Table 3.

Discussion

The present study investigated the prevalence and associated factors of decreased chewing ability in adults aged 30–50 years with hemiplegic cerebral palsy using an objective color-changeable chewing gum assessment. The prevalence of decreased chewing ability was 32.5% (39/120), which is considerably higher than that reported in the general adult population (14.1%–20.0%) [12, 21]. This high

prevalence may be attributed to long-term disuse atrophy of masticatory muscles on the affected side, compensatory mastication on the unaffected side, and progressive impairment of neuromuscular coordination [4, 5]. In addition, cerebral hemorrhage–related injury to cortical masticatory pathways further compromises oral motor function, forming a persistent vicious cycle of functional decline [22].

Multivariable logistic regression identified four independent factors associated with decreased chewing ability: lack of regular unilateral chewing training, moderate cerebral hemorrhage volume (10–30 mL), low articulatory oral motor skills, and malnutrition.

Regular unilateral chewing training was the strongest protective factor. Participants who did not engage in structured affected-side chewing training had more than fourfold higher odds of decreased chewing ability (OR = 4.28). Rhythmic, task-specific chewing on the affected side delivers sustained proprioceptive input, activating the trigeminal spinal nucleus and primary motor cortex and promoting synaptic remodeling and functional reorganization of impaired masticatory pathways [8, 9]. Unlike pathological unilateral chewing (which causes asymmetry and overuse injury), structured unilateral chewing training reverses disuse atrophy and improves neuromuscular coordination. This finding has important clinical implications: a simple, home-based chewing training protocol (≥ 5 sessions per week, 15 minutes per session) may serve as an effective oral rehabilitation intervention for this population.

Moderate cerebral hemorrhage volume (10–30 mL) was associated with a 3.76-fold increased risk of decreased chewing ability compared with small-volume hemorrhage (< 10 mL). This dose–response relationship likely reflects more severe structural brain damage, reduced neural plasticity, and poorer residual neuromuscular control of orofacial muscles [14, 22]. Patients with larger hemorrhage volumes may require more intensive and prolonged oral rehabilitation. Early identification of hemorrhage severity can help stratify patients for targeted interventions.

Low articulatory oral motor skills were independently associated with decreased chewing ability (OR = 3.92). Mastication is a complex sensorimotor process reliant on coordinated neuromuscular activity among the lips, tongue, jaw, and other orofacial structures [18, 24]. In adults with hemiplegic CP, long-term hemiparesis weakens neural connections governing these movements, leading to synchronized impairment of both chewing and articulation [5]. Our finding is consistent with previous studies showing that poor oral motor skills predict masticatory dysfunction [24, 25]. Clinicians should routinely assess oral motor function using simple scales (e.g., buccal inflation, tongue protrusion, mouth corner closure) and consider incorporating oral motor exercises into rehabilitation programs.

Malnutrition was another strong independent risk factor (OR = 4.15). The relationship between malnutrition and decreased chewing ability is likely bidirectional. Impaired mastication reduces dietary intake and food variety, predisposing patients to protein-energy malnutrition [25, 26]. Conversely, malnutrition decreases muscle mass and strength, including masticatory muscles, further exacerbating chewing dysfunction [27]. This vicious cycle is particularly relevant in patients with hemiplegic CP, who may already have reduced nutrient intake due to swallowing difficulties or dependency on caregivers. Quarterly nutritional screening using tools such as the Malnutrition-Inflammation Score (MIS) is

recommended, along with dietary optimization (texture-modified foods, nutrient supplementation) and, when appropriate, chewing training to break the cycle.

Collectively, these findings highlight the clinical phenotype of oral frailty in adults with hemiplegic CP, where masticatory impairment, poor oral motor function, and nutritional risk overlap and reinforce each other [15, 23]. Unlike general oral frailty studied in community-dwelling older adults, the present population has a unique etiological driver (cerebral hemorrhage) and a specific remediable factor (unilateral chewing training), offering a clear target for intervention.

Clinical implications

Based on these results, we recommend routine screening of masticatory function (using color-changeable gum), oral motor skills, and nutritional status for all adults aged 30–50 years with hemiplegic CP. Structured affected-side chewing training (≥ 5 sessions per week, 15 minutes per session) should be incorporated into home-based oral rehabilitation programmes as a simple, low-cost, and feasible intervention. For patients with moderate cerebral hemorrhage volume or low oral motor skills, more intensive supervision and longer training duration may be needed. Healthcare providers in neurology, rehabilitation, and dentistry should collaborate to implement these assessments and interventions.

Limitations

This study has several limitations. First, the cross-sectional design precludes drawing definitive causal conclusions between the identified factors and decreased chewing ability. Longitudinal studies are needed to confirm the directionality of associations. Second, the single-center design and relatively limited sample size (n = 120) may reduce the generalizability of the findings to other regions or populations. Third, we did not assess caregiver support, training adherence, or compliance with unilateral chewing training, which may act as important modifiers of masticatory function. Fourth, although the color-changeable gum method has been validated, the visual interpretation of color grades retains a small degree of subjectivity. Fifth, potential confounders, including socioeconomic status, medication use (e.g., antiepileptics, antihypertensives), and dental status (beyond the inclusion criterion of ≥ 20 teeth), were not included in the analysis. Future multicenter longitudinal studies with larger sample sizes and more comprehensive covariate assessment are warranted to verify the long-term effectiveness of standardized chewing training and to establish causal relationships.

Conclusions

This study revealed a prevalence of decreased chewing ability of 32.5% in adults aged 30–50 years with hemiplegic CP. Lack of regular unilateral chewing training, moderate cerebral hemorrhage volume, low articulatory oral motor skills, and malnutrition were independently associated with decreased chewing

ability. Color-changeable gum provides a convenient and objective tool for early screening. Healthcare providers should assess oral motor function, nutritional status and chewing training status and promote standardized unilateral chewing training as part of home-based oral rehabilitation.

Abbreviations

CP Cerebral palsy

MIS Malnutrition-Inflammation Score

OHIP-14 Oral Health Impact Profile-14

OHRQoL Oral health-related quality of life

OR Odds ratio

CI Confidence interval

STROBE Strengthening the Reporting of Observational Studies in Epidemiology

Declarations

Author Contributions

AM: Conceptualization, Methodology, Project administration, Writing – original

draft. XBW: Data curation, Resources. AS: Validation. JT: Data curation. GYL: Data

collection. ZTY: software. MTT: Supervision, Writing – review & editing, Funding acquisition, Project administration.

Ethics approval and consent to participate

The design and implementation of the present study were conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of The First Affiliated Hospital of Xinjiang Medical University (approval number: 2025HXNK-126). All participants were investigated after providing the relevant informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to potential privacy concerns but are available from the corresponding author upon reasonable request.

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Tables

Table 1. Baseline characteristics of participants (N = 120)

Variables	Category	n (%) or mean ± SD
Age (years)	30–40	68 (56.7)
	41–50	52 (43.3)
Gender	Male	68 (56.7)
	female	52 (43.3)
Hemiplegic side (left/right, n)	Left	58 (48.3)
	right	62 (51.7)
Cerebral hemorrhage volume	Small (<10 mL)	74 (61.7)
	Moderate (10–30 mL)	46 (38.3)
Duration of cerebral hemorrhage(years)		32.9 ± 7.6
Regular unilateral chewing training	Yes	57 (47.5)
	No	63 (52.5)
Affected-side masticatory grade		2.25 ± 0.50
Normal (grade 3–5)		81 (67.5)
Decreased (grade 1–2)		39 (32.5)
Masseter muscle strength, kg		16.83 ± 2.83
Low articulatory oral motor skills	Yes	51 (42.5)
	No	69 (57.5)
Oral motor skill score (0–3)		1.56 ± 0.38
Subjective chewing difficulty (1–5)		3.79 ± 0.60
MIS score		3.28 ± 1.08
Malnutrition (MIS ≥ 8)	Yes	8 (6.7)
	No	112 (93.3)
OHIP-14 score		18.83 ± 3.36

MIS: Malnutrition-Inflammation Score; OHIP-14: Oral Health Impact Profile-14.

Univariate analysis (Table 2) showed that cerebral hemorrhage volume, oral motor skill score, subjective chewing difficulty, malnutrition, and OHIP-14 score were significantly associated with decreased chewing ability (all $P < 0.05$). Age, sex, hemiplegic side, and hemorrhage duration were not significant ($P > 0.05$).

Table 2. Univariate analysis of factors associated with decreased chewing ability (n=120)

Variable	Normal (n=81)	Decreased (n=39)	χ^2/t	P value
Regular unilateral chewing training, n (%)			15.36	<0.001
Yes	47 (58.0)	10 (25.6)		
no	34 (42.0)	29 (74.4)		
Cerebral hemorrhage volume, n (%)			12.34	<0.001
Small (<10 mL)	57 (70.4)	17 (43.6)		
Moderate (10–30 mL)	24 (29.6)	22 (56.4)		
Low articulatory oral motor skills, n (%)			17.44	<0.001
Yes	23 (28.4)	28 (71.8)		
No	58 (71.6)	11 (28.2)		
Subjective chewing difficulty (mean ± SD)	3.52 ± 0.51	4.35 ± 0.42	8.75*	<0.001
Malnutrition (MIS ≥ 8), n (%)			7.21	0.007
Yes	2 (2.5)	6 (15.4)		
No	79 (97.5)	33 (84.6)		
OHIP-14 score (mean ± SD)	17.23 ± 2.95	22.15 ± 2.68	8.92*	<0.001

*t-test value (independent samples). For categorical variables, the χ^2 test was used.

Note: Age, sex, hemiplegic side, and hemorrhage duration were not significant (all P > 0.05) and are not shown.

Table 3. Multivariable logistic regression analysis of decreased chewing ability

Variable	β	SE	Wald χ^2	P	OR (95% CI)
Regular unilateral chewing training (ref: Yes)					
NO	1.45	0.44	11.03	0.001	4.28 (1.82–10.06)
Cerebral hemorrhage volume (ref: Small)					
Moderate (10–30 mL)	1.32	0.46	8.17	0.004	3.76 (1.51–9.34)
Low articulatory oral motor skills (ref: No)					
YES	1.37	0.45	9.31	0.002	3.92 (1.63–9.44)
Malnutrition (ref: No)					
YES	1.42	0.46	9.64	0.002	4.15 (1.69–10.18)
Constant	-2.15	0.48	20.12	<0.001	-

* *Hosmer–Lemeshow test: $\chi^2 = 4.23$, P = 0.836; Nagelkerke $R^2 = 0.514$.

Supplementary Files

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

- Englishversionofthequestionnaire.docx