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Systematic Review

Evaluation of temporomandibular disorder self-management apps in Australia: a systematic review to inform clinical use

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Abstract

Background This study aimed to systematically evaluate apps with temporomandibular disorder (TMD) self-management content available in Australia for quality, clinical safety, self-management support functions, and contributors to app development.

Methods A systematic search of the App Store (iOS) and Google Play (Android) was conducted on 18 April 2023 (and updated 26 July 2023) to identify apps that had TMD self-management content. Two raters independently assessed app quality, clinical safety, self-management support, and contributors to app development for the involvement of people living with TMD and clinicians. Quality was evaluated using the Mobile App Rating Scale (MARS) for engagement, functionality, aesthetics, and information quality scored using a 5-point Likert scale. App clinical safety was assessed using MARS functionality (item 6) and information quality items for accuracy/relevance (item 15), scope (item 16), and visual information accuracy/clarity (item 17) (scored on a Likert scale), and the M-Health Index and Navigation Database framework questions: does the app provide any warning for use? Does the app have a crisis management feature? Can the app cause harm? (scored yes/no). Self-management support was evaluated using the Self-Management Support (SMS-14) checklist (scored yes/no). Included apps, app store descriptions, and linked websites were qualitatively evaluated to determine the contributors to app development.

Results Seven apps with TMD self-management content were available in Australia. Overall, the included apps were of acceptable quality (mean = 3.25/5) but scored poorly for engagement (2.71/5) and information (2.92/5). Clinical safety limitations identified were the inability to identify and/or direct users to support services in a crisis and inconsistent TMD information. One app (Do I Grind or Snore) was deemed potentially harmful as sleep sounds suggestive of obstructive sleep apnoea were interpreted as snoring by the app. Overall, the inclusion of self-management support functions was variable (range 1–9; mean = 4.71/14), with pain/TMD education (71%) and self-monitoring (71%) the most common. Only one app had development input from a person with lived experience of TMD.

Conclusion The quality and self-management support of apps with TMD self-management content is variable. TMD apps with activating self-management strategies and higher engagement scores are more likely to be effective. Concerningly, one app was found to be potentially harmful, and overall apps lacked user safeguards. Only one app involved a person with TMD in its development, and the authors recommend using co-design in future TMD app development to improve app quality, clinical safety, and impact.

Keywords: temporomandibular disorder; orofacial pain; app quality; app safety; pain self-management; co-design

Introduction

Temporomandibular disorder (TMD) is an umbrella term for conditions affecting the masticatory muscles, jaw joints, and associated structures [1].Associated symptoms of jaw pain, headache, and restricted opening are common [2]. Approximately 19% of people will be affected by TMD-related pain and functional limitation in their lifetime, impacting their relationships, ability to work, and the broader economy [2]. Patients with TMD are estimated to use 1.6 [3] to 3 times [4] more medical and dental services than people without TMD. Self-management is the mainstay of treatment for chronic pain conditions, such as TMD, and refers to the ability of individuals, with the support of family, friends, and healthcare professionals, to manage chronic pain impacts such as symptoms, treatments, and lifestyle changes [5]. Due to the ubiquitous nature of smartphones, apps are touted increasingly as cost-effective and broad reaching tools to deliver self-management support for chronic pain conditions [6–8]. However, the quality, clinical safety, self-management, and development of TMD apps are unknown, highlighting the need for the present study to provide an evidence-base for clinicians to recommend the use of apps to TMD patients.

Previous appraisals of chronic pain apps, such as for low back pain [9–11], headache and migraine [11, 12], and

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neck pain [13], have evaluated app quality using the Mobile App Rating Scale (MARS). MARS defines indicators of app quality to include engagement (interactive, customizable, targeted to users), functionality (user-friendly app navigation, accurate and fast-working components), aesthetics (graphic design, overall visual appeal), and information quality (accuracy, credibility, well-written, relevant) [14]. Chronic pain apps generally scored highly for functionality and aesthetics but scored poorly for engagement [9, 10, 15–17]. It has been recommended that future app development and related research should determine how app features can be optimized to improve user engagement across diverse populations [11, 15], as low engagement can impact long-term adherence [17] despite app efficacy [15].

In contrast to the numerous app quality studies available, few studies have appraised app safety [18], self-management support functions [15, 17], and the inclusion of people with lived experience (PWLE) in app development. More primary studies evaluating these areas have been advocated to examine the magnitude of harm from health apps [18], improve the impact of app self-management functions [15, 17], and ensure apps adequately support consumer tasks [18]. App safety is the actual or potential risk of harm to consumers from app use, and has been assessed in terms of the clinical safety [18, 19] and privacy and security safety of users [19, 20]. Clinical safety includes information content accuracy and consistency to support user decision-making [18, 19], and app functional ability to respond appropriately to user data such as correct medication calculators or responding to suicidal ideation [18, 20]. The present study focuses on the clinical safety of TMD apps, of which the potential for harm is not currently known.

Previous studies have found that chronic pain management apps include few self-management support functions [16, 17]. Self-management support interventions vary, and can generally be considered as existing on a continuum ranging from the passive (e.g. information sharing, online courses) towards the activating (e.g. goal setting, symptom/medication tracking, problem-solving) [21]. Self-management programmes that utilize activating interventions are more effective than those that do not [21, 22]. This suggests that delineation between the inclusion of passive and active self-management activities is important to determine the likelihood of a pain app being effective; however, this has not previously been explored in pain app studies.

Partnering with PWLE is recognized by international [23–25] and Australian [26] guidelines to improve quality of care and minimize risks. 'Lived experience' recognizes the expert knowledge of an individual gained from their perspectives and priorities, regardless of education and profession, which gives them insights that can inform and improve systems, research, policies, and practices [25]. Previous studies of pain apps have found a lack of input from PWLE [27–29]. However, TMD apps were not included in these studies and so it is not known if PWLE of TMD (PWLE-TMD) contribute to app development. Identifying the contributors to app development can provide insight into the likelihood that TMD apps will be relevant, user-friendly, and evidence-based.

There is no evidence-base for clinicians and consumers in Australia to make an informed decision about the apps providing TMD self-management support. In this study, we aim to systematically evaluate apps with TMD self-management content currently available in Australia for quality, clinical safety, inclusion of self-management support functions, and contributors to app development.

Method

The preregistration protocol for this study is available on the Open Science Framework (https://osf.io/ewqtj). Minor variations from the protocol are documented in Appendix A. This study is reported in accordance with the PRISMA Protocols checklist (Appendix B) [30]. The authors' institutions do not require Ethics approval for systematic reviews.

Eligibility criteria

Apps were included if they contained content to manage TMD-related symptoms (e.g. information, symptom tracking, exercises, relaxation). Apps were excluded for the following reasons: (i) not available for download on iOS or Android smartphone in Australia; (ii) no TMD-related management content; (iii) used only in conjunction with proprietary products; (iv) restricted use (clinician use only; code or clinic sign-up required); and (v) not in English.

Information sources and search strategy

A search was conducted on 18 April 2023 of the App Store (iOS) and Google Play (Android) in Australia using fnd.io and play.google.com by A.L. The search strategy was focussed on these app stores because as of October 2022, 99.55% of the mobile operating system market share in Australia was held by these two platforms (iOS 59.75%; Android 39.38%) [31]. Search terms were temporomandibular, TMD, TMJ, bruxing, jaw pain, and teeth grinding. Paid and free apps were included in the search. An updated search was conducted on 26 July 2023 on the App Store (iOS) and Google Play using the same search terms to identify any additional apps.

Data selection process

App names and descriptions were screened against the eligibility criteria by A.L. Eligible apps were downloaded on iPhone 13 (iOS 16) and Samsung Galaxy Z Flip4 (Android version 13) for further assessment of eligibility by A.L. Apps found on both platforms were downloaded on iOS only, and the duplicate were excluded. Only the full-featured version of each app was downloaded for assessment.

Evaluation of app characteristics

App characteristics were appraised using the M-Health Index and Navigation Database Framework (MIND), a publicly available tool characterizing technical specifications, app developer affiliation (i.e. government, non-profit, for profit, academic institute), privacy and security, app inputs and outputs, clinical foundation, features, engagement style and interoperability, and data sharing [32]. Descriptive and dichotomous (yes/no) evaluation was used to score MIND open and closed questions, respectively. A.L. and S.I. reviewed the apps independently and convened to compare findings. Differences were resolved through consensus.

Evaluation of app quality

The Mobile Apps Rating Scale (MARS) was used to evaluate app quality as it has been widely used in health app research

[33], allowing comparison of the included apps with the established literature. Two reviewers (A.L. and S.I.) watched the MARS training video [14] prior to independently assessing the included apps. The MARS criteria for assessing engagement, functionality, aesthetics, and information were used (total 29 items), and each item was scored on a 5-point Likert scale (1 = inadequate, 2 = poor, 3 = acceptable, 4 = good, 5 = excellent) [14]. The reviewers met to discuss differences in individual item scoring. Differences in individual item scoring were accepted as personal preference, for example, for what is engaging and visually pleasing, is subjective. The reviewers' mean scores for each domain were averaged, and the reviewers confirmed agreement of the final score. The interrater reliability was calculated overall using intraclass correlation coefficient (ICC) [34]. ICC estimates and their 95% confidence intervals were calculated using SPSS statistical package version 29.0 based on a mean-rating (k = 2), absolute-agreement, 2-way mixed-effects model.

Evaluation of app clinical safety

There is no single tool accepted for the evaluation of app clinical safety [18, 19]. As the MIND and MARS components overlap with app clinical safety domains of information content quality and software functionality, these tools were used. Information quality was appraised using MARS information quality questions on information accuracy/relevance (item 15), scope (item 16), and visual information accuracy/clarity (item 17). Software functionality was evaluated using MARS functionality (item 6) and MIND questions (Does the app provide any warning for use? Does the app have a crisis management feature? Can the app cause harm?). MARS items were scored as previously described using a 5-point Likert scale. For this section, the scoring was categorically summarized to facilitate meaningful interpretation (i.e. 1 = inadequate, 2 = poor, 3 = acceptable, 4 = good, 5 = excellent). The MIND questions were scored yes/no. Justification for scoring was recorded. Items were scored independently by A.L. and S.I., who convened to resolve any conflicts, as previously described.

Evaluation of self-management support function

Evaluation of self-management support functions was conducted using the Self-Management Support (SMS-14) checklist, an evidence-based tool that assesses app content potential for developing self-management [16]. The 14-item checklist assesses for: pain education; activity pacing; thought and behavioural management; exercises; relaxation; meditation and mindfulness; distraction techniques; self-tailoring (scope for the individuals to incorporate the self-management strategies learnt to fit their individual needs); self-monitoring of symptoms; goal setting (planning meaningful activities to manage pain); problem-solving (a systematic approach to be aware of and developing a plan for dealing with stressful or challenging situations); partnership between patient and clinicians (providing skills for patients to participate in decision-making); access to social support via the app; and culturally tailored information [16]. Each SMS-14 item is scored as a yes/no response, with each positive response scoring one point (maximum 14 points). A.L. and S.I. independently evaluated the included apps against the SMS-14 checklist and convened to compare ratings. Differences in scoring were resolved by consensus.

Evaluation of contributors to app development

A.L. extracted the app store description, in-app 'about' information and information on linked websites, which was tabulated. Two reviewers, A.L. and B.M., independently appraised the information and formed app developer contributor categories using a qualitative descriptive summary approach [35]. The reviewers convened to compare findings and reach consensus.

Results

Systematic search

The initial search identified 97 unique apps on the App Store (iOS) and 153 unique apps on Google Play (Android) (Fig. 1). The secondary search identified one additional new app on the App Store (JawSpace). Following app name and description screening, 15 apps were downloaded for assessment of eligibility. After full app content screening, eight apps were included. One app (TMJ Pro) was removed from Google Play during article preparation, leaving seven apps for data synthesis. The main reason for exclusion was that apps did not include TMD management content (216/251, 86.06%).

Overview of app characteristics

Of the seven included apps, three apps were TMD-specific (JawSpace, TMD Rehab, Tongue Chi TMJ Relief) while the other four were primarily for other conditions (headache, general well-being, sleep, awake bruxism) but included TMD management content. All apps were available on iOS, and three (43%) were available on Android (Table 1). Most apps were paid (86%) and commercially affiliated (86%). A summary of app characteristics is provided in Table 1, and an expanded description in Appendix C.

Evaluation of app quality

MARS was used to assess app quality domains of engagement, functionality, aesthetics, and information. The ICC score for the MARS 29 items was 0.88 (95% CI: 0.83–0.91), indicating good reliability between raters overall [34]. The mean quality score ranged from 1.93 to 4.15 (mean = 3.25) (Table 2). Overall, the highest scoring app was JawSpace (mean = 4.15, good), and most apps (71%) were of acceptable quality (Table 2). Apps had acceptable scores for aesthetics (mean = 3.46) and functionality (mean = 3.89) overall. Scores for engagement (range 1.2–3.60, mean = 2.71) and information (range 1.25–4.0, mean = 2.92) were variable but overall were poor.

Evaluation of app clinical safety

Information accuracy, relevance, and scope of the included apps were variable, ranging from inadequate (Brux App) to good-excellent (JawSpace) (Table 3). Brux App and Tongue Chi TMJ Relief were the lowest rated as they lacked comprehensive information to aid user decision-making. JawSpace and Easeday were the only apps to include information sources. The raters deemed the Do I Snore or Grind app as potentially harmful due to serious functionality issues: when recorded sleep sound data were reviewed, the raters identified that sounds consistent with obstructive sleep apnoea (OSA) were identified by the app as sleep bruxism. Additionally, the

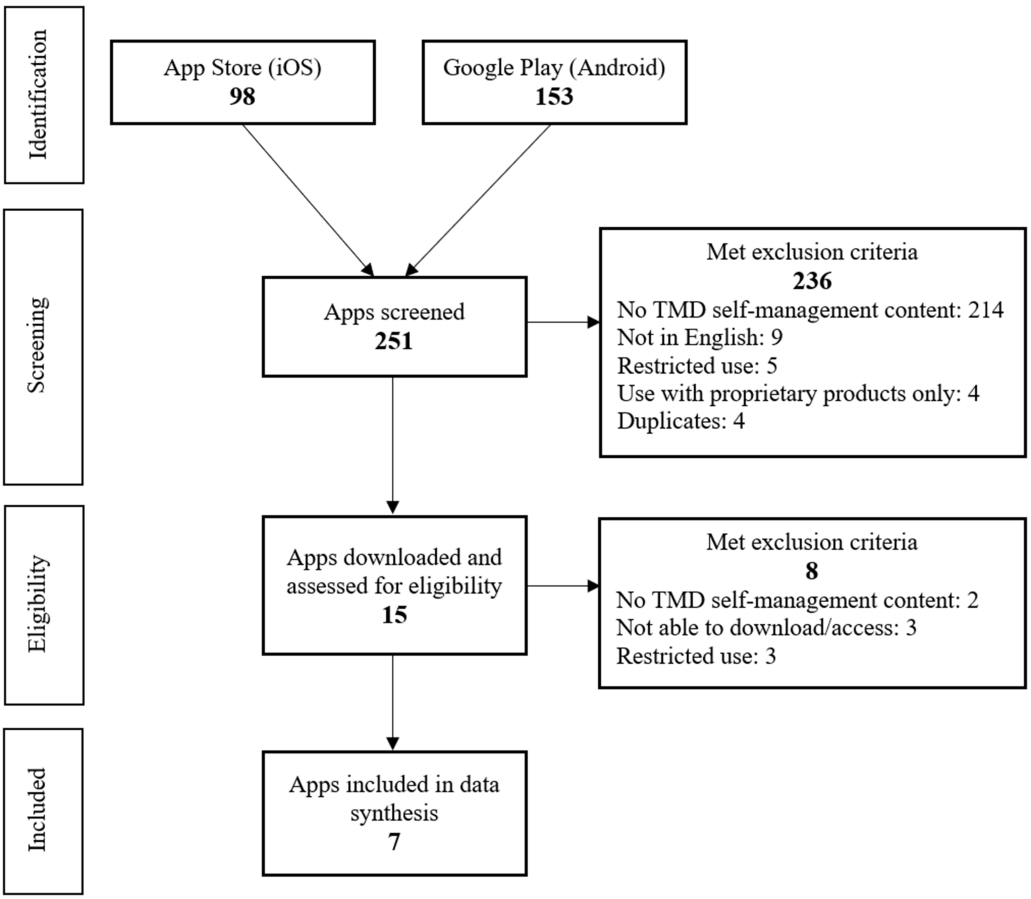

Figure 1 Flowchart for systematic app search from App Store (iOS) and Google Play (Android)

Table 1. Characteristics of included apps

	App						
	JawSpace: Your TMD Journey	**The Tapping Solution**	**Easeday: Headache and Migraine**	**TMJ Rehab**	**Do I Snore or Grind**	**BruxApp**	**Tongue Chi TMJ Relief**
Developer	JawSpace Pty Limited	The Tapping Solution LLC	BioTrack Health Inc.	TMJ Seminars LLC	SleepSnore Labs	Chiara Bonanni	Whynoceros?
Affiliation	Com[a]	Com[a]	Com[a]	Com[a]	Com[a]	NGO[b]	Com[a]
Apple iOS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Android	No	Yes	No	Yes	No	Yes	No
Compatibility	iOS 16.0+	iOS 14+	iOS 12.0+	iOS 11.0+	iOS 10.0+	iOS 12.0+	iOS 9.0+
Fully free	No	No	No	No	Yes	No	No
Free trial	14 days	14 days	7 days	Module 1	N/A	No	No
Cost	14.99/ month[c]119.00/ year[c]	19.49/ month154.00/year 599.99/ lifetime	14.49/mont93.99/year	29.99	N/A	5.99	2.99
Age classification	17+	4+	12+	17+	17+	17+	12+
Last update	26 July 2023	18 July 2023	July 2022[d]	Oct 2022	July 2019[d]	July 2021[d]	July 2018
Size	155.6 MB	235.8 MB	44.7 MB	17.2 MB	52.5 MB	156.6 MB	8.8 MB
Version tested	1.0.4	3.14	2.7.3	1.0.8	1.2.4	2.5.8	4.0

[a]Commercial; [b] NGO = non-government organization; [c] App was free at time of testing; fees stated as per app website on 13 August 2023; [d] Estimated based on App Store (iOS) data as of July 2023, based on App Store reporting last update as 'months/years ago'.
App cost is in Australian Dollars.

app did not have an advisory warning to users to seek medical advice in conjunction with app use. Therefore, users who do not seek medical advice for their sleep issues while using the app are at risk of undiagnosed and untreated OSA. One app (Easeday) directed users to seek prompt medical attention if their headache was sudden, severe, and new. No apps were able to identify escalating symptoms from user data to prompt users to contact crisis support services.

Table 2. MARS assessment of app quality

MARS[a] section	App							Mean score
	JawSpace: Your TMD Journey	The Tapping Solution	Easeday: Headache and Migraine	TMJ Rehab	Do I Snore or Grind	BruxApp	Tongue Chi TMJ Relief	
Section A: Engagement	3.60	3.50	3.50	2.20	3.00	2.00	1.20	2.71
Section B: Functionality	4.50	4.50	4.00	4.25	3.00	3.00	4.00	3.89
Section C: Aesthetics	4.50	4.50	3.50	4.00	3.00	3.50	1.25	3.46
Section D: Information	4.00	2.70	3.50	3.70	2.50	2.80	1.25	2.92
Mean objective quality score[b]	**4.15**	**3.80**	**3.63**	**3.54**	**2.88**	**2.83**	**1.93**	**3.25**

[a]Mobile App Rating Scale.
[b]Mean objective quality score calculated from the mean of the mean scores for MARS sections A-D [25].

Table 3. Evaluation of app clinical safety

	App						
	JawSpace: Your TMD Journey	The Tapping Solution	Easeday: Headache and Migraine	TMJ Rehab	Do I Snore or Grind	Brux App	Tongue Chi TMJ Relief
Information quality							
Accuracy/relevance	Excellent	Poor	Acceptable	Acceptable	Acceptable	Inadequate	Poor
Scope	Good	Acceptable	Good	Good	Acceptable	Inadequate	Inadequate
Visual information accuracy/clarity	Good	Acceptable	Acceptable	Excellent	Acceptable	Acceptable	N/A
Software functionality							
Does the app provide any warning for use?	Yes	Yes	Yes	No	No	Yes	No
Does the app have a crisis management feature?	No	No	No	No	No	No	No
Can the app cause harm?	No	No	No	No	Yes	No	No
Age appropriate?	Yes	No	No	Yes	No	Yes	Yes
Performance issues?	No	No	No	No	Yes	No	No

Tongue Chi TMJ Relief was not assessed (N/A) on visual information accuracy and clarity as TMD/pain education or user data was not presented visually.

Evaluation of app self-management support

The number of SMS-14 items ranged from 1 to 9 (mean = 4.71) (Table 4). Easeday had the most self-management support functions (9/14). The most common self-management support functions were pain/TMD education (71%) and self-monitoring (71%). None of the included apps allowed users to set personalized activity goals or incorporated culturally sensitive information.

Evaluation of contributors to app development

Development of the included apps involved clinicians (86%), PWLE (43%), and non-clinical contributors (29%) (Appendix D). Only one app (Tongue Chi TMD Relief) had input from a person with TMD, who was also the developer and a dentist. The category 'PWLE' included single individuals who self-identified as having migraine (Easeday), pain (Tapping Solution), and TMD (Tongue Chi TMD Relief). The category 'clinicians' included medical doctors, neuroscientist, neurologist, psychologists, dentists, and physiotherapists. 'Non-clinical' contributors included those working in research and population health. The involvement of patients or advocacy groups was not identified. The level of participation during app development by clinicians and non-clinical contributors could not be determined.

Discussion

Statement of principle findings

Our findings highlight that apps with TMD self-management content available in Australia are generally well-functioning and aesthetically pleasing but lacked engaging features, consistent with previous chronic pain app studies [9, 10, 15–17]. Information quality overall was poor and could be improved by including referenced information to provide user reassurance that app information was evidence-based to support decision-making, further enhancing clinical safety. Major clinical safety concerns included identification that the Do I Snore or Grind app was potentially harmful due to serious sleep sound diagnostic functionality issues, and that overall apps lacked the ability to identify and/or direct users to support services in a crisis. The inclusion of self-management support functions was variable, and apps included multiple passive self-management activities but lacked activating strategies. Only one app had development input from a PWLE-TMD, and the overall low involvement of PWLE is consistent with other studies [27–29]. The 'double-hatting' of PWLE in design/development roles risks their involvement being tokenistic in the absence of input from broader groups of patients or future app users. The involvement of clinicians in the development of the included apps was high compared to other studies [27–29]. This may provide reassurance that these

Table 4. Self-management support functions of apps

Self-management function	App: Easeday: Headache and Migraine	The Tapping Solution	TMJ Rehab	JawSpace: Your TMD Journey	Do I Snore or Grind	Tongue Chi TMJ Relief	BruxApp	SMS-14[a] count all apps
Pain education	✓	✓	✓	✓	✓			5
Activity pacing			✓	✓				2
Thought and behavioural management	✓	✓	✓					3
Exercises			✓	✓				2
Relaxation and breathing	✓	✓	✓			✓		4
Meditation and mindfulness	✓	✓	✓			✓		4
Distraction techniques	✓	✓						2
Self-tailoring	✓	✓		✓				3
Self-monitoring of symptoms	✓	✓		✓	✓		✓	5
Goal setting								0
Problem solving	✓							1
Partnership between views of patient and clinicians	✓							1
Social support		✓						1
Cultural relevance								0
App count	9	8	6	5	2	2	1	-

[a]Self-management support checklist.

apps are clinically 'sound'; however, there lacked transparency regarding clinician involvement.

Strengths and limitations

To our knowledge, this is the first study systematically identifying and evaluating currently available apps for TMD management. A limitation of the study's design is that only iOS App Store and Android Google Play were systematically searched. A search of other apps stores (e.g. Amazon, Samsung) was not undertaken and additional TMD apps may not have been identified. Additionally, this study is limited to apps available in Australia released prior to 26 July 2023 and updated prior to 13 August 2023, and does not reflect more recent app updates or new apps that may be available or apps available in other countries. A further limitation of this study's design is that the apps were not reviewed by PWLE-TMD and therefore does not account for the variation in design, aesthetic, and engagement preferences due to user age, education, social, and cultural background. App evaluation by clinicians is a common limitation in many studies [8–13, 15–17, 27–29] highlighting the need for greater representation of PWLE in app evaluation research.

Interpretation within the context of the wider literature

Self-management support and health app engagement both aim to enable user collaboration, activation, and decision-making in one's own health [20]. Utilization of high activation self-management strategies, such as goal setting and tailored feedback, has been shown to incentivize app engagement and adherence to positive health behaviours, particularly in users that self-identify as having poor health or low capability [36, 37]. The lack of these persuasive design features means that TMD apps are unlikely to be used long-term and/or promote healthy behaviour. The under-representation of PWLE-TMD in the development of TMD apps is concerning as the factors that influence the success of self-management support and interactive features are nuanced [38, 39]. Consumers' varied attitudes and values underpin the importance of embedding lived experience at every stage in app development. For example, co-design approaches that partner designers and PWLE expertise in the development process have been shown to produce innovative design solutions that effectively meet users' needs, improve product delivery, and increase user satisfaction [40, 41]. Previous research has raised the question of how app features can be optimized to improve user engagement across diverse populations [15]. Indeed, co-design is one evidence-based method to ensure that TMD self-management apps are relevant, engaging, and effective for its users.

Implications for policy, practice, and research

Due to the inconsistencies in TMD information, clinicians must familiarize themselves with app content to warn patients about misleading or potentially harmful information. As apps lack guided self-help and incentivization/gamification, clinicians will likely need to help patients interpret their data, e.g. to identify aggravating and relieving factors, and encourage app use. As there is no single comprehensive TMD self-management app, careful consideration is required to match the needs of the patient with the most appropriate app.

Future research is needed to evaluate TMD app user satisfaction and clinical efficacy using prospective longitudinal study design, and identify how TMD self-management apps can be integrated into healthcare systems to improve care pathways. As PWLE are under-represented in app development, the authors advocate that co-design approaches are used to ensure TMD apps meet the needs of users and are impactful.

Conclusion

The quality and self-management support of apps with TMD self-management content is variable. Concerningly, one app was found to be potentially harmful, and apps lacked safeguards for users. The authors recommend co-design be used in future app development to improve TMD app quality, clinical safety, and impact. Future research is needed to evaluate TMD self-management apps for user satisfaction and clinical efficacy, and to identify how TMD self-management apps can be integrated into healthcare systems to improve care.

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Author contributions

Anita Lim (Conceptualization, Methodology, Formal Analysis [lead], Investigation [lead], Data Curation, Writing—Original Draft, Writing—Review & Editing [lead], Visualization, Project Administration), Bronwen Merner (Investigation, Formal Analysis, Writing—Review & Editing, Supervision), Srividya Iyer (Investigation, Formal Analysis, Writing—Review & Editing), Michael McCullough (Writing—Review & Editing, Supervision [lead]).

Supplementary data

Supplementary data is available at *IJQHC* online.

Conflict of interests

A.L., B.M., S.I., and M.M. declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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