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Just-in-time adaptive interventions for adolescent and young adult health and well-being: protocol for a systematic review

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ABSTRACT

Introduction Health behaviours such as exercise and diet strongly influence well-being and disease risk, providing the opportunity for interventions tailored to diverse individual contexts. Precise behaviour interventions are critical during adolescence and young adulthood (ages 10–25), a formative period shaping lifelong well-being. We will conduct a systematic review of just-in-time adaptive interventions (JITAIs) for health behaviour and well-being in adolescents and young adults (AYAs). A JITAI is an emerging digital health design that provides precise health support by monitoring and adjusting to individual, specific and evolving contexts in real time. Despite demonstrated potential, no published reviews have explored how JITAIs can dynamically adapt to intersectional health factors of diverse AYAs. We will identify the JITAIs' distal and proximal outcomes and their tailoring mechanisms, and report their effectiveness. We will also explore studies' considerations of health equity. This will form a comprehensive assessment of JITAIs and their role in promoting health behaviours of AYAs. We will integrate evidence to guide the development and implementation of precise, effective and equitable digital health interventions for AYAs.

Methods and analysis In adherence to Preferred Reporting Items for Systematic Review and Meta-Analysis guidelines, we will conduct a systematic search across multiple databases, including CENTRAL, MEDLINE and WHO Global Index Medicus. We will include peer-reviewed studies on JITAIs targeting health of AYAs in multiple languages. Two independent reviewers will conduct screening and data extraction of study and participant characteristics, JITAI designs, health outcome measures and equity considerations. We will provide a narrative synthesis of findings and, if data allows, conduct a meta-analysis.

Ethics and dissemination As we will not collect primary data, we do not require ethical approval. We will disseminate the review findings through peer-reviewed journal publication, conferences and stakeholder meetings to inform participatory research.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We will investigate the target distal and proximal outcomes of just-in-time adaptive interventions (JITAIs) for adolescent and young adult (AYA) health, including diverse health behaviour and well-being (eg, physical, mental and social) outcomes, and their effectiveness.

⇒ We will assess how intersectional influences such as demographic (eg, age, gender), psychological (eg, cognitive and emotional states), cultural (eg, norms, values) and environmental factors (eg, geographical or residential settings) are incorporated in the dynamic designs of these JITAIs.

⇒ We will include findings published in diverse languages and geographical regions, enabling examination of JITAI designs in diverse contexts experienced by AYAs.

⇒ We will include studies with varying experimental designs (eg, both qualitative and quantitative) and health outcomes to provide a comprehensive overview, which may result in a high level of heterogeneity.

⇒ Should findings be suitable for meta-analysis, we will conduct heterogeneity and sensitivity analyses.

INTRODUCTION

Need for health behaviour and well-being interventions during adolescence and young adulthood

The impact of health behaviours on public health is substantial, with a well-established link between positive health behaviours—those which promote health—and disease prevention globally.[1 2] Health behaviours are key yet modifiable risk factors for disease and health conditions encompassing a range of actions from dietary habits, physical activity, substance use and beyond. Health behaviours strongly influence risk of chronic diseases—such as cancer, diabetes, hypertension and HIV—which affect multiple body systems

and collectively account for over 70% of global mortalities.[3] For example, consistent practice of positive health behaviours such as exercise and healthy eating can reverse or reduce risk of many chronic conditions.[4] Such habits support weight management and insulin sensitivity, which directly lower risk of diabetes and hypertension (and other cardiovascular diseases). Further, positive health behaviours such as substance use moderation play a pivotal role in promoting healthy lifestyles, enhancing mental health and improving quality of life.[5 6] Reducing substance use in individuals with mental health disorders can decrease their severity and enhance cognitive functioning.[7 8] The comprehensive role of positive health behaviours importantly aligns with the WHO's definition of health as 'not merely the absence of disease or infirmity' but a 'state of complete physical, mental and social well-being'.[9] As such, clinicians, researchers and policymakers have increasingly called for implementation of novel interventions to promote positive health behaviours and well-being.[10 11]

Importantly, there is a critical need to evaluate how early interventions for health behaviour risks can be effectively personalised and equitably implemented among young people, particularly adolescents and young adults (AYAs). The WHO defines the age range for adolescents from 10 to 19 years and young adults from 15 to 24 years.[12 13] Adolescence and young adulthood together constitute a formative juncture and pivotal developmental stage. Adolescence is universally characterised by rapid physical, cognitive, psychological, social and vocational transitions.[14] A heightened tendency for experimentation and risk-taking is also typically observed during adolescence.[15] Moreover, these diverse transitions occur as adolescents adapt to and navigate the evolving complexities of young adulthood, and simultaneously establish their foundation for health habits across the lifespan. During the transition to young adulthood, AYAs develop critical health behaviour practices that significantly influence future adult disease outcomes. As such, adolescence and young adulthood together offer a distinct and crucial window of opportunity to modify key behaviours across multiple health domains and mitigate risk factors for adverse health outcomes across the lifespan.[16–18]

Together, AYAs encompass nearly 25% of the total global population[19] and endure a high burden of preventable health conditions. Pre-COVID-19 WHO estimates highlighted how 13% of adolescents globally experienced mental disorders such as depression and anxiety.[20] A systematic analysis of global burden of disease in AYAs observed that neuropsychiatric disorders (mental as well as behaviour conditions, including substance misuse) was the top cause of years lost because of disability across geographic regions.[21] The analysis specifically identified substance use and unsafe sex (increased risk of contracting and/or transmitting sexually transmitted infections, eg, not using protection) as top risk factors for cause-specific disability-adjusted life-years in AYAs. Disruptions to health systems during the COVID-19 pandemic have further amplified existing health inequities, with AYAs from marginalised communities experiencing heightened vulnerability to COVID-19 and additionally reduced access to quality healthcare.[22 23] Marginalised individuals include but are not limited to sexual, racial and ethnic minorities, those with immigration or refugee status, living with disabilities, facing homelessness, experiencing low income, or who have dropped out of school.[24] Although health outcomes and inequities vary according to each individual's specific context, marginalisation arises from systemic socioeconomic, political and cultural exclusion—such as discrimination, poverty, trauma and displacement—which heightens adverse health risks.[25] Despite this substantial burden, and the critical impact of adolescence and young adulthood in myriad future disease outcomes, early intervention across this age group remains inadequate.[26] The 2022 Lancet Series on 'optimising child and adolescent health and development' emphasises the lack of health intervention implementation across contexts and expressly calls for prioritisation of solutions for the health of all AYAs.[27]

Need for precision health interventions during adolescence and young adulthood

To promote positive long-term health outcomes among AYAs in particular, there is a need for tailored approaches that adapt to the shifting physical, cognitive, psychological, social and vocational contexts of adolescent and young adulthood.[28 29] While conceptualisations of 'tailoring' in health interventions vary, the term has been primarily adopted to describe the customisation of health delivery strategies based on individual characteristics.[30] Given high technology engagement among AYAs, previous studies have adopted web and mobile-based tailoring to promote health behaviours in this population, such as for alcohol reduction,[31] smoking prevention[32] and physical activity.[33] Nonetheless, such interventions often target older adolescents already in young adulthood (above 15 years) and show inconsistent impact among younger groups.[34] Researchers have not observed measurable improvements in health behaviours for some interventions, possibly because of limited personal relevance to younger adolescents.[34] However, adolescents perceive interventions that provide ongoing feedback and individually tailored text messages as useful, though engagement levels vary.[35] These results highlight significant challenges in efficacy and engagement of tailored digital interventions for adolescents in their transition to young adulthood.

Enhancing the tailoring of health guidance to be highly precise and relevant to individual demographics, mental states, social contexts and other personally meaningful factors may be key to improving intervention delivery. Intersectional health factors such as demographic (eg, age, gender), psychological (eg, cognitive and emotional states), cultural (eg, norms, values) and environmental (eg, geographical or residential setting) factors are particularly salient in the diverse and shifting contexts faced

by AYAs.[14] Precision health interventions can importantly adopt dynamic strategies for ongoing support of different behaviours by tailoring to these intersectional risks, which can be vital for supporting marginalised AYAs facing inequities in access and health risks.[36] Precision health strategies extend beyond tailored treatment: they encompass adaptation of health promotion strategies to an individual through ongoing monitoring of their diverse health risks.[37] A prior review identified a substantial evidence base for precision health approaches in disease prevention for various patient populations. However, comprehensive precision health interventions specifically designed for both AYAs were significantly limited.[38] Precision health strategies that are timely and adaptable to rapidly shifting contexts of adolescence and young adulthood, and the unique needs of diverse AYAs, are urgently needed.

Promise of just-in-time adaptive interventions for delivering precision health interventions

Recent years have seen tremendous growth in technologically aided health interventions (eg, mobile health applications, wearables, telemedicine), most tools demonstrate variable efficacy in dynamically personalising solutions to each unique individual.[39] An emergent digital intervention design called just-in-time adaptive interventions (JITAIs) may address this gap and significantly enhance the precision and efficacy of behaviour and well-being strategies. Underpinned by mobile and sensing technologies, JITAIs are a type of digital health intervention that can monitor an individual's changing states and contexts in real-time and deliver tailored messages to motivate behaviour change during heightened risk detection.[40] Specifically, JITAIs deliver precise health support (ie, tailored to the individual's needs and contexts) at precise

moments (ie, at specific times in which high-risk or need for support is detected) through precise monitoring (ie, of the individual's health context through ongoing data-driven collection). For example, Cushing et al[41] observed positive effects of a text-message based intervention which monitored adolescent physical activity to dynamically suggest personalised exercise goals on a daily basis. The key components of JITAIs consist of individual-level tailoring variables and associated decision rules, intervention options and decision points.[40] Table 1 denotes each of the JITAI components alongside Cushing et al's intervention.[41]

JITAIs may address the intersecting biological, psychological, relational, cultural and environmental factors shaping adolescent development in a dynamic manner, thereby enhancing the efficacy of health behaviour change strategies during this period. By dynamically adapting and delivering support at the precise moments when an individual is in need (and most likely to be engaged), JITAIs may facilitate proactive, targeted and personalised approaches for precise and early identification and intervention.[42] Through such provision of timely and personalised interventions tailored to unique challenges across diverse settings, JITAIs can play a role in addressing inequities experienced by marginalised individuals. Further, incorporation of behavioural models in JITAIs may be crucial to address criticisms of inconsistent theoretical bases of digital health interventions with AYAs, which often result in low effect sizes and methodological rigour.[43] In particular, JITAIs may adopt behavioural models such as the Capability, Opportunity, Motivation and Behaviour (COM-B) framework[44] to facilitate design considerations tailored to AYAs with insufficient access to healthcare services. This can enable delivery of

Table 1 Key components of just-in-time adaptive interventions (JITAIs), adapted from Nahum-Shani et al[40] and Cushing et al[41]

JITAI component	Definition	Example from Cushing et al[41]
Distal outcome	Overarching goal of the intervention	Increased level of physical activity in adolescents
Proximal outcomes	Short-term goals of the intervention, such as mediators of the distal outcome	Total minutes of daily physical activity in adolescents
Decision points	Specific moments when a decision regarding the intervention is required, such as certain times of the day or week	Individual adolescent chooses the time of day to self-report their physical activity, receive personalised feedback and receive a new daily physical activity goal via text message
Intervention options	Different potential treatments or actions available at a decision point, such as type of support or delivery method of support	Wording of daily personalised progress update delivered to the adolescent via text message, including modification of the adolescent's daily physical activity goal
Adaptive tailoring variables	Data about the individual that guides the customisation of the intervention, determining when and how to intervene	Adolescent's self-report of total minutes of daily physical activity via text message
Decision rules	Guidelines that determine the selection and delivery of intervention options based on the tailoring variables, which specify when, how and to whom the intervention is delivered	New daily physical activity goal calculated on algorithm, based on 75%–125% of previously reported activity (<100% if physical activity goal unmet, >100% if goal has been met or exceeded)

adaptive health support at critical moments for effective behaviour change.[45] For example, a JITAI can monitor the stress levels of an adolescent living in a socioeconomically disadvantaged area and during times of heightened stress, which can often lead to unhealthy eating choices,[46] send tailored stress-reduction strategies and healthy eating tips aligned with affordable, local food options. Such an approach involves considering the adolescent's Capability (ie, psychological and physical capacity to engage), Opportunity (eg, current mental state and local food availability) and Motivation (ie, cognitive processes underlying execution of behaviours). An important caveat is that JITAIs alone cannot address deep-rooted systemic inequities. However, JITAIs that provide contextually aware support (ie, solutions uniquely accessible to the individual) using tested behavioural models like COM-B may serve as a crucial tool for AYAs to foster better health practices under existing constraints.

Several promising examples of JITAIs have been developed for AYAs, who are highly engaged with technology.[47] In addition to Cushing *et al*'s study on physical activity promotion,[41] adaptive messaging interventions have been observed to effectively improve risk behaviours related to substance use and sexual health.[48–50] Despite growing recognition of the promise of JITAIs, however, comprehensive insight into their implementation with AYAs is severely lacking. To the best of our knowledge, no prior published review of JITAIs focusses on designing comprehensive health solutions for AYAs specifically. This leaves a gap in understanding the unique demands and challenges of JITAIs for modifying diverse health behaviours and risk factors for disease during this formative developmental stage. Further, most prior reviews of JITAIs focus exclusively on specific health behaviours (eg, harmful substance use[51] or physical activity[52]) across different age groups—highlighting a gap in our understanding of how JITAIs can comprehensively account for multiple health behaviours and their intersecting physical, emotional, social and environmental factors in early prevention and disease risk in AYAs. This includes ethical challenges related to equitably designing JITAIs to reach marginalised AYAs.[53] A systematic synthesis of target health outcomes, precise tailoring variables, intersectional considerations and evidence of JITAIs is urgently needed to guide their design and implementation with AYAs.

Objectives

In this systematic review, we will aim to synthesise and critically evaluate the existing literature on JITAIs for AYA health and well-being. The primary research question (RQ) that guides this review is:

RQ1. In JITAIs for AYAs (aged 10–25), which specific health behaviours are targeted (both distal and proximal outcomes) and through what intervention options?

We developed this primary RQ using the PIO framework, which stands for Population, Intervention and Outcomes. JITAIs consist of distinct behaviour intervention options for enhancing well-being each individual. The primary outcomes of interest are health behaviour outcomes; among these, both distal and proximal outcomes are pertinent to the delivery of JITAI options.[40]

Given that the delivery of such JITAI options depend on adaptive tailoring variables, decision rules and decision points,[40] we will further investigate the mechanisms of interventions through RQs 2 and 3:

RQ2. How are the JITAIs' options selected and applied (ie, based on which adaptive tailoring variables and decision rules)?

RQ3. When are the JITAIs' options selected and applied (ie, during which decision points)?

In conjunction with the primary outcomes in RQ1, we will also consider perceived outcomes (eg, usability of the mobile application for JITAI deployment) as secondary outcomes. RQ4 allows a comprehensive understanding of a JITAI's feasibility and engagement[54]:

RQ4. What empirical evidence exists to support the effectiveness of these JITAIs (ie, distal, proximal and participant-perceived outcomes) for promoting health behaviours in AYAs?

As this is the first review of JITAIs for promoting health behaviours in the AYA population, we will not limit our review to only controlled trials (eg, studies comparing outcomes of JITAIs to standard care, no care or other health interventions). We will also include qualitative design studies.

Next, it is important to clarify how the mechanisms of intervention options in RQs 1–3 relate to their outcomes in RQ4. Specifically, there is a need to assess how researchers employ evidence-based theories to inform behaviour intervention mechanisms to achieve their intended outcomes for health and well-being. Relatedly, the impact of different behaviour change theories on intervention effectiveness remains an open question.[55] As such, we will also investigate:

RQ5. What theoretical frameworks or models of behaviour change have authors adopted to inform these JITAIs' options?

Finally, the effectiveness of precision health approaches such as JITAIs can only be substantiated if they are feasible with diverse groups, including marginalised individuals. This includes consideration of ethical challenges in delivering JITAIs to marginalised AYAs.[53] To identify promising strategies as well as gaps to inform future research priorities in equitable JITAI implementation, we will qualitatively assess:

RQ6. To what extent do the JITAIs' designs account for the needs of diverse AYAs (eg, discussion of inclusion of marginalised participants in design)?

RQ7. What ethical considerations in designing JITAIs have authors described?

METHODS AND ANALYSIS

This systematic review will adhere to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[56] We provide a table outlining the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols guidelines (specifically for protocol reporting)[57] alongside corresponding information in the present protocol in online supplemental appendix 1. Further, we registered this review with the International Prospective Register of Systematic Reviews (PROSPERO) on 3 November 2023.

Eligibility criteria

We will include any experimental (eg, randomised controlled trials), pilot and observational (eg, cohort and case–control studies), and qualitative studies that fulfil the following inclusion criteria:

► Population: individuals aged between 10 and 25 years inclusive, classified as AYAs. We will consider AYAs from diverse backgrounds and settings; we will not restrict by additional demographics or regional setting.
► Intervention and outcomes: JITAIs addressing any health behaviour outcomes via distal and proximal outcomes, per Nahum-Shani *et al*'s definition of JITAIs[40] and the WHO's definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'.[9]
► Comparators: both studies with or without intervention control and/or comparator variables will be included.

Further, we will only include peer-reviewed studies. We will also strive to include texts published in all languages. Due to language limitations of the study team, articles not written in English will be first translated using artificial intelligence (AI)-based machine learning tools (eg, ChatGPT). Following this, a professional medical translator will verify each machine-translated text for inaccuracies.[58] We will transparently detail our usage of AI-based translation in the methods that accompany our final findings.

We will exclude the following in our review:

► Studies in which individuals outside the 10–25 age range are the main target of the intervention (eg, studies that exclusively consider an adolescent's family members). We will determine this based on mean age; if the mean age of the study population is 9 years or below or 26 years and above, the study will be excluded.
► Studies in which participants are not exposed to JITAIs targeting health behaviours. For example, ecological assessment studies which merely collect health behaviour data in changing contexts, but do not subsequently deliver an adaptive intervention, are ineligible.
► Editorials, book chapters and reviews; while ineligible for inclusion, these sources will be consulted for relevant studies.

Information sources and search strategy

We developed the search strategy based on keywords used in prior published reviews on JITAIs as well as the team's existing expertise in digital health equity for AYAs. We also consulted with a senior library informatics expert in the Netherlands. Table 2 summarises the authors' expertise.

In our search strategy, we aimed to identify all empirical studies related to JITAIs for AYA health. In addition to our team's prior research, we first consulted key texts in the field (including the search strategies of prior reviews of JITAIs) to ensure the selected keywords covered a wide

Table 2	Expertise and roles of coauthors
Author	**Role/expertise**
KWG	Lead author and guarantor of review. PhD researcher specialising in digital health, developmental neuroscience, public health and human–computer interaction
CA	PhD researcher in telemedicine, particularly in low-resource settings, emphasising scalable and sustainable healthcare solutions
LK	Lead of the PROactive TEChnology-supported prevention and MEntal health in adolescence (PROTECtME) consortium, specialising in real-time emotion monitoring and the impact of digital mental health interventions for adolescents
CRS	Assistant professor conducting participatory research on digital media and health with youth
AV	PROTECtME work package lead and assistant professor focussing on using eHealth to enhance mental health and resilience among youth for well-being
ET	Behaviour scientist at Gro-up, engaged in community youth care with an emphasis on practical behaviour modification strategies
EvR	Associate professor specialising in adolescent mental health, particularly in emotion regulation and implementation of just-in-time adaptive interventions in daily life
MdR	Professor specialising in the socio-technical design of digital platforms, including applications in healthcare
CAF	Assistant professor with expertise in clinical psychiatry, focusing on the development of equitable and culturally sensitive digital health interventions

range of relevant concepts. To sufficiently answer the RQs related to how JITAIs address health behaviour change in this population, our search strategy combined several key concepts through a series of Boolean operators ('AND', 'OR') related to:

► Target population: search terms such as but not limited to "adolescent", "young adult", "young people", "youth" and "teenagers".
► Intervention types: search terms related to JITAIs and their timely and adaptive mechanisms. These includes terms related to ecological momentary interventions, experience sampling interventions and various dynamic tailoring methods.
► Digital health technologies: search terms related to mobile applications, smartphones, wearable devices, sensor technologies and other related digital tools employed for JITAI delivery.
► Health behaviour outcomes: search terms related to health and well-being as well as behavioural medicine.

We will execute our search strategy in the following databases:

► Association for Computing Machinery Digital Library.
► American Psychological Association PsycINFO.
► Cochrane Central Register of Controlled Trials.
► Cumulative Index of Nursing and Allied Health Literature Plus.
► Dimensions.
► Embase.
► Google Scholar.
► Institute of Electrical and Electronic Engineers Xplore Digital Library.
► Medical Literature Analysis and Retrieval System Online (MEDLINE).
► Scopus.
► Web of Science.
► WHO Global Index Medicus (GIM).

We selected these multidisciplinary databases to retrieve titles and abstracts from a breadth of global research relevant to JITAIs, such as research on AYA health, health interventions, precision health, health equity and digital health. We selected the WHO GIM for its comprehensive inclusion of research in low, middle and high-income countries indexed by each WHO Regional Office (Africa, Americas, South-East Asia, Europe, Eastern Mediterranean and Western Pacific). We will search database-specific subject headings (eg, prioritising MeSH terms in MEDLINE and GIM) and related keywords in the titles and abstracts of each record retrieved from the databases. We include related keywords because when crafting the initial search strategy, we found that several important terms related to JITAIs (our intervention of interest) were not indexed yet as subject headings in their respective databases (eg, MeSH terms in MEDLINE and GIM). We will limit our database search strategy to literature published after 2013, when the term 'just-in-time adaptive intervention' (JITAI) was first mentioned in the literature (to the best of our knowledge).[59 60] (The first reported JITAI designed for adolescents was in 2015.[61])

We will export search results first to Zotero, a reference management system. We will subsequently import results to Covidence, a web-based systematic review management platform, for screening.

We provide a complete record of the search strategy for each search engine and/or database consulted—alongside the dates in which the searches took place—in online supplemental appendix 2. Before analysis, we will additionally consult all prior reviews of JITAIs for studies specific to AYAs, to locate any studies missed in our search because they did not explicitly refer to the term 'JITAI'. This will enable us to include all relevant and up-to-date studies in our final review.

Screening and data collection process

All screening decisions for study inclusion in the review will comply explicitly with the eligibility (inclusion and exclusion) criteria outlined above in the Eligibility criteria section. Further, we will manage all screening records using Covidence. This web-based platform will facilitate record screening (including resolution of conflicts), full-text review, risk of bias assessment and data extraction. The selection of studies will involve several stages: (1) initial screening of titles and abstracts, (2) full-text review for eligibility and (3) decision for final inclusion in the systematic review. For each stage, we will screen records twice and independently to identify potentially relevant studies and assess for eligibility. We will resolve disagreements between reviewers by discussion and consensus at each stage (including consulting a third reviewer from the authors list if necessary), with the final decision recorded on Covidence.

Similar to the study selection process, we will extract data from all records eligible for final inclusion with two independent reviewers. Disagreements between reviewers will again be resolved by discussion, with the consensus recorded in the final data table.

Data items and review outcomes

Table 3 summarises each data item (where available) that will be extracted from studies eligible for final inclusion, alongside the corresponding RQ the data item is relevant to. As discussed in our Objectives section, our primary outcomes of interest are the distal and proximal outcomes in JITAI designs.

For studies in which data is missing or unclear, we will contact the original authors of these studies for clarification.

Risk of bias in studies

To assess methodological quality and risk of bias in the included studies, we will use the appropriate critical appraisal tools from the Joanna Briggs Institute (JBI). The JBI provides a collection of critical appraisal tools designed to assess the risk of bias specific to different study designs, such as randomised controlled trials, observational studies, qualitative studies and others.[62] We will select the specific JBI tool based on the study design of

Table 3 Data items to extract for data synthesis

Relevant RQ(s)	Data items
General	Study characteristics: author(s), journal, year of publication, country, study design, sample size, duration of follow-up
1, 6	Participant characteristics: for example, age, sex, health status, socioeconomic status, education level, racial and ethnic background, location, family structure and any other information reported about the participants
1, 4	Primary outcomes: distal outcomes and proximal outcomes of the JITAI. Secondary outcomes: perceived outcomes, for example, end-user perspective such as satisfaction, compliance and engagement. For both primary and secondary outcomes, we will collect measurement time points and measurement tools reported. We will also extract key statistical information, such as effect estimates and CIs
1	JITAI design: the intervention options dynamically offered to individuals
2	JITAI design: the adaptive tailoring variables and decision rules used to inform the intervention options
3	JITAI design: the decision points employed to inform the intervention options
4	Comparator or other intervention details (if applicable): type of comparator and its duration, frequency and components
5	Theoretical frameworks and/or models informing the JITAI's intervention options, distal outcomes, proximal outcomes, decision points, intervention options, tailoring variables and decision rules
6, 7	Ethical considerations in intervention design described by study authors

JITAIs, just-in-time adaptive interventions; RQ, research question.

each included study. Two reviewers will independently conduct quality assessment for each included study and consult a third reviewer in the event of discrepancy.

Synthesis methods and evidence assessment

We will summarise and synthesise all extracted data in the final results of the review. Specifically, we will provide a narrative summary of findings across all included studies according to the RQs, which encompass the primary distal and proximal outcomes, the adaptive and temporal tailoring processes of intervention options, empirical evidence, theoretical frameworks and equity considerations underpinning the JITAIs. This narrative synthesis will be accompanied by tables in which all data items will be extracted for each included study. Where applicable, data will be further grouped and explored according to study design (eg, randomised controlled trial, qualitative interviews) or related health domain (eg, substance use).

If there is enough comparable data on a health outcome (eg, studies are sufficiently homogenous in design to evaluate a particular behaviour intervention), we will engage a statistician to conduct a meta-analysis. We will conduct mean differences with 95% CIs for studies that report both baseline and postintervention changes. We will calculate standardised mean differences with Hedges' g at 95% CI for studies using different measurement scales. We will employ random effects models to aggregate findings. For assessment of heterogeneity, a χ^2 test (statistical significance of 0.05) and the I^2 test (>40% for 'might not be important', 30%–60% for moderate, 50%–90% for substantial and >75% for considerable heterogeneity[63]) will be conducted. Sensitivity analyses will be executed by assessing (and excluding, where appropriate) how studies

with missing data, high risk of bias, different intervention durations, and small sample sizes affect results. Further, meta-biases such as outcome reporting biases will be assessed.

Further, two independent reviewers will evaluate the quality of evidence for each reported outcome using the Grading of Recommendations, Assessment, Development and Evaluation framework,[64] consulting a third reviewer in cases of disagreement.

Patient and public involvement

No patients were involved in the conceptualisation of this protocol. The authorship team includes ET, a behaviour scientist working in a community support setting with youth. ET will provide input on the evidence synthesis and help to ensure their interpretation and dissemination are in line with intervention priorities with AYAs.

Ethics and dissemination

As we will not collect primary data, we do not require ethical approval. We will disseminate the review findings through peer-reviewed journal publication, conferences and stakeholder meetings to inform participatory research.

DISCUSSION

Investment in AYA health and well-being is essential to reduce the global burden of disease and adverse health outcomes. Behaviour change interventions to prevent and treat modifiable lifestyle risk factors can lead to life-long benefits for both AYAs and society at large. Adolescents experience rapid changes in various health areas

during puberty and the transition to young adulthood, necessitating access to prompt and relevant guidance to equip them with the knowledge and tools for key health behaviours such as exercise, substance use and diet. To effectively sustain well-being, interventions should be personalised to enhance the appeal and accessibility of healthy behaviours and discourage the frequency of unhealthy behaviours. The proposed systematic evidence synthesis will importantly identify tailoring mechanisms underlying adaptive, real-time personalisation of JITAIs targeting health behaviour change in AYAs, including their consideration of intersectional factors. This effort will set a foundation for future studies to effectively incorporate diverse determinants of health in JITAI designs and therefore, precisely target health behaviours of marginalised or other high-risk populations. Following a systematic survey of evidence, the review will provide sociotechnical guidelines for the equitable integration of diverse health risk factors in JITAI designs for AYAs. Future research could adopt this framework to develop and test new JITAIs for various young populations and health behaviours. As such, the results of this review will have several important implications for AYA, digital and public health. Ultimately, this review aims to help steer the equitable design of precise digital interventions to prevent health behaviour risks underlying critical health challenges among young people.

Limitations

While this systematic review will adhere to PRISMA guidelines to ensure analytical rigour, we can anticipate certain limitations. As this is the first systematic review of JITAIs for AYAs, we will include both quantitative and qualitative studies to ensure a comprehensive evidence base; as such, the quality of studies included (including risk of bias) will vary. Similarly, we anticipate a high level of heterogeneity given the inclusion of diverse health behaviour outcomes; this will be in part mitigated by conducting heterogeneity and sensitivity analyses should the evidence be suitable for meta-analysis. To ensure evidence across the review is inclusive and reflective of the current state of the field, we will include texts published in all languages. We will validate AI-based language translation of texts with human expertise from professional translators, and transparently report this process. We will also consult all prior reviews of JITAIs to identify literature relevant to our study population.

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