Ecological Momentary Assessment in Suicide Research

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Abstract

[Objective] This paper aims to systematically summarize research findings on ecological momentary assessment in the field of suicide. [Methods] The research design and applicable populations of ecological momentary assessment are introduced, its compliance and influencing factors analyzed, and common safety management strategies elaborated. [Results] Ecological momentary assessment is feasible and safe in suicide research, can predict short-term variability in suicidal ideation and behavior, and improves understanding of suicide risk and its influencing factors. [Limitations] Although it offers advantages such as high ecological validity and reduced recall bias, limitations remain regarding reactivity, dependency, data management, and statistics. [Conclusion] Future efforts should strengthen data privacy protection, integrate digital technology and artificial intelligence, conduct localized research within the Chinese cultural context, and further enhance capabilities for understanding, predicting, and preventing suicide.

Full Text

Preamble

The Application of Ecological Momentary Assessment in Suicide Research

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Abstract:
[Objective] This article aims to systematically summarize the research findings of ecological momentary assessment (EMA) in the field of suicide. [Methods] It introduces the research design and target populations of EMA, analyzes its compliance and influencing factors, and discusses common safety management strategies. [Results] The feasibility and safety of using EMA in suicide research are confirmed. EMA is capable of predicting the short-term variability of suicidal ideation and behavior, thereby enhancing the understanding of suicide risk and its influencing factors. [Limitations] Despite advantages like high ecological validity and reduced recall bias, EMA has limitations regarding reactivity, dependency, data management, and statistics. [Conclusions] Future efforts should focus on strengthening data privacy protection, integrating digital technologies and artificial intelligence, and conducting localized research within the context of Chinese culture to further improve the understanding, prediction, and prevention of suicide.

Keywords: ecological momentary assessment; suicide; risk factors; feasibility; safety

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Suicide represents a major global health and social problem. According to World Health Organization statistics, more than 1 in 100 deaths (1.3%) worldwide are caused by suicide [**?**]. Although global suicide rates declined by 29% between 2000 and 2019, from 13.0 to 9.2 per 100,000 people [**?**], suicide remains the fourth leading cause of death among adolescents and young adults aged 15–29 [**?**]. In China, suicide is the third leading cause of death among individuals aged 10–24, with rates increasing annually with age [**?**]. Consequently, mental health professionals and clinical psychologists must promptly assess individuals at risk for suicidal ideation and behavior, effectively understand the dynamic changes in suicide risk, and monitor suicide-related behaviors in high-risk populations in real time to better comprehend and prevent suicide.

Despite decades of accumulated knowledge about suicide risk and protective factors, challenges persist in accurately assessing suicide risk [**?**]. A meta-analysis by Franklin et al. of literature from 1965–2015 on suicide risk factors revealed

that these factors predict suicide risk only slightly better than chance, with no improvement in predictive power over the past 50 years [?]. Substantial progress remains elusive in understanding suicide risk processes and accurately predicting suicidal behavior. One possible reason is significant methodological limitations in previous suicide risk research [?, ?]. Most traditional studies rely on cross-sectional surveys with large time spans (months or years), providing distal information about suicide [?]. Researchers still lack adequate understanding of many fundamental attributes of suicidal ideation and behavior, as well as time-varying, proximal risk and protective factors [?, ?], thus revealing limited information about "who" is at "high risk" and "when." Research indicates that psychiatric patients show exponential increases in suicidal ideation severity in the days and hours preceding a suicide attempt [?, ?]. In fact, individual suicide risk changes nonlinearly [?], with approximately 25% of suicide attempters denying prior suicidal intent [?, ?] and about one-third reporting acting without any prior planning [?, ?, ?]. Consequently, suicide research experts have called for greater attention to intensive time-sampling methods, conducting finer-grained analyses at more frequent assessment time points to capture short-term dynamic changes in suicidal ideation and their risk factors \cite{15–19}.

Ecological Momentary Assessment (EMA), first proposed by Stone and Shiffman in 1994 and also known as Experience Sampling Method (ESM) or Ambulatory Assessment (AA), is defined as the real-time, repeated collection of participants' current behaviors and experiential data in natural environments [?], aiming to conduct cross-time measurements more frequently and flexibly in more natural settings [?]. Since its introduction, EMA has been applied to study various mental disorders and clinical phenomena, including major depression and affective disorders \cite{22–24}, schizophrenia \cite{25–27}, anxiety disorders [?, ?], obsessive-compulsive disorder [?, ?], and borderline personality disorder \cite{32–34}, gradually becoming an emerging psychological research method and recognized as a major advance in medical research [?].

EMA can repeatedly measure individuals' recurring cognitions, emotions, and behaviors throughout the day, capturing real-time changes in suicide risk while effectively avoiding recall bias [?]. For example, Forkmann et al. conducted a 6-day EMA study with participants, measuring 10 times daily to assess variability in suicidal ideation [?]. Gratch et al. found that among adult patients with major depression, over half of participants reported significantly higher frequency and severity of suicidal ideation through EMA compared to traditional assessment [?]. EMA can capture more accurate and nuanced suicidal thoughts in participants' daily lives, providing information closer to real-world contexts. EMA is not only suitable for examining short-term fluctuations in individual suicidal ideation and behavior but also for identifying risk and protective factors in daily life. For instance, Czyz et al. used daily diaries (a special form of EMA) to evaluate hospitalized adolescents with suicidal ideation and attempts, extracting early signals of suicide crisis [?]. Mournet et al. conducted 6 daily EMA surveys among undergraduate students, finding that seeking social support was unrelated to next-day reported suicidal ideation but positively correlated with

same-day ideation [?]. EMA can capture fine-grained, "real-world" information when suicidal ideation and behavior occur, potentially filling existing research gaps [?].

Due to its substantial potential to supplement traditional suicide prediction research designs [?], EMA has gained widespread application in international suicide research. As of December 2023, a search of the Web of Science database using the following free-text and subject terms: ("ecological momentary assessment" OR EMA OR "experience sampling method" OR ESM OR "Ambulatory Assessment" OR "Daily Diary") AND (suicid*) yielded 796 publications. [Figure 1: see original paper] depicts the annual number of EMA studies published in the suicide field from 2007 to present. A rapid growth trend began in 2018, peaking in 2022 before declining in 2023. This indicates that EMA is receiving increasing attention in suicide research and has become an active research area.

China began conducting EMA research in mental health-related fields in the early 21st century. Feng Danjun and Shi Lin first introduced EMA applications in stress and coping research [?]. Only recently have researchers gradually expanded the scope of EMA research, though primarily limited to perceived stress, clinical care, burden, and motivation, with fewer applications in suicide research. This article attempts to systematically summarize research findings on EMA applications in the suicide field, introducing specific research methods, analyzing feasibility and safety, and exploring EMA' s short-term predictive capacity for suicide risk and proximal factors to provide new ideas for future suicide risk prediction studies using EMA.

2. Methodological Introduction of EMA in Suicide Research

How does EMA collect data in suicide research?
Research tools for EMA constitute an important consideration in study design. Historically, researchers have used paper diaries, Personal Digital Assistants (PDAs), and smartphones [?, ?]. With mobile technology development, smartphones' ubiquity, convenience, and ease of operation offer new possibilities for clinical research and practice. Smartphones integrate functions for sending assessment prompts, collecting data, real-time storage, and secure data transmission, providing new solutions for EMA. For example, Glenn, Kleiman, Kearns, et al. used platforms specifically designed for EMA research, mEMA (www.ilumivu.com) and Metricwire (www.metricwire.com), when investigating high-risk suicidal adolescents [?]. These applications have also been used in other clinical sample studies [?, ?]. Researchers helped adolescents download and register the apps, sent assessment prompts in real time through online platforms, and monitored data to track participant compliance and high-risk status. Additionally, researchers have used platforms or applications such as TelEMA [?], Qualtrics [?], MovisensXS [?, ?], MEmind [?, ?], and Ethica [?] to evaluate and monitor data. Smartphones greatly reduce participant burden, enabling high-frequency data collection across different times and locations to more accu-

rately reveal influencing factors on suicidal ideation and behavior and changes in suicide risk.

Smartphones are ideal platforms for implementing intelligent EMA technology, offering unprecedented opportunities for researchers and clinicians to conduct short-term suicide risk prediction studies. Future research can leverage smartphones' rich sensors and powerful computing capabilities to continuously collect data in daily life to monitor potential dangers in high-risk suicide populations. Simultaneously, researchers can combine self-report data from suicide populations to obtain more comprehensive, accurate, and real-time information, deeply understanding the dynamic characteristics of suicidal ideation and behavior over time and mastering the temporal sequence of suicide-related features. Furthermore, data security standards should be established to protect participant privacy and actively address digital security challenges brought by smartphones in EMA research.

How is research designed for EMA in suicide research?
Mental health professionals and clinical psychologists should select appropriate research designs based on specific research questions and nature [**?**]. EMA generally includes event-contingent design, time-contingent design, and hybrid designs [**?**, **?**, **?**], requiring participants to complete assessment questionnaires in daily life to record naturally occurring events or fill out questionnaires when devices emit signals [**?**, **?**]. In suicide research, study design determines whether researchers can effectively observe variables of interest and precisely capture changes in suicide risk and related factors.

(1) Event-Contingent Design: Exploring Triggers of Suicidal Events
Events can be categorized as discrete or continuous [**?**, **?**]. Event-contingent design is a data collection protocol based on specific discrete events, not aimed at characterizing participants' overall experiences but focusing on preset behaviors or experiences [**?**]. In suicide-related research, researchers have identified some distal factors related to suicide risk, such as sleep disorders [**?**], depression, and borderline personality disorder [**?**]. However, insufficient research exists on proximal triggers of suicidal ideation and behavior, such as the contexts in which they occur and factors predicting the transition from ideation to behavior. EMA' s event-contingent design provides new avenues for measuring suicide risk changes in individuals' daily life contexts. For example, Nock et al. conducted an EMA study with 30 adolescents who had self-harm thoughts in the past week, instructing participants to make event-contingent reports when experiencing self-harm thoughts or behaviors [**?**] to understand contextual circumstances and test proximal predictors of the transition from self-harm thoughts to behaviors. Tian et al. used event-contingent design to investigate suicidal ideation among Chinese working women, assessing changes in ideation within 20 minutes to 2 hours after positive affect [**?**] to test key predictive factors.

In event-contingent EMA studies, participants self-determine when events occur and initiate assessments, completing data reports around preset events to gather contextual information and triggers related to suicide. This event-based

design enables real-time assessment of participants' suicidal ideation and behavior, capturing situational contexts and factors at event occurrence, and directly observing associations between suicide risk assessment and specific events, offering high internal validity. However, in a review of 23 EMA studies in the suicide field, none used event-contingent design alone [**?**]. In another systematic review of self-harm, suicidal ideation, and behavior, only one of 49 included studies used event-contingent design alone [**?**]. Therefore, despite EMA' s potential importance in suicide-related research, event-contingent design is rarely applied alone in practice. First, event-contingent design examines associations between suicidal ideation/behavior and real-world contextual factors, requiring researchers to collect large amounts of data to explore causal relationships, making study design and data analysis more complex. Second, suicide-related events are typically difficult to control, and participants may miss active responses due to emotional distress or forgetfulness during ideation/behavior episodes, making it difficult for researchers to verify whether participants completed all preset event assessments. This can lead to low compliance and even systematic errors due to missed data. Overall, while event-contingent design can provide more contextual information for suicide-related research and promote understanding of transitions in suicidal ideation and behavior, its application is limited by requirements for large datasets, collection difficulties, potential interference with participants' natural states, and need for researcher guidance and supervision.

(2) Time-Contingent Design: Detecting Trends in Suicidal Ideation Changes

Continuous events are stimuli whose intensity, frequency, or other characteristics change over time (e.g., emotions or suicidal ideation), lacking clear start and end points but representing ongoing processes or phenomena [**?**]. Therefore, continuous events may be more suitable for time-contingent research designs [**?**]. Current research has confirmed that suicidal ideation fluctuates significantly in short periods, with intensity and frequency changing markedly over time, making EMA' s time-contingent design appropriate for detecting and capturing this variability. In suicide-related research, time-contingent design emphasizes temporal factors, requiring participants to respond according to preset or random schedules—that is, completing questionnaires based on time "signals" rather than events, also known as signal-contingent sampling [**?**, **?**]. This sampling method focuses more on fluctuations in suicidal ideation, emphasizing observation and collection of participants' suicidal thoughts and ideas at different time points, using either fixed schedules or random (or semi-random) timing [**?**, **?**, **?**]. Notably, when implementing random (or semi-random) sampling, participants can provide input about their daily schedules (including sleep and wake times) [**?**] to optimize EMA prompt windows for each participant. By creating personalized sampling schedules, data can be collected within signal prompt intervals ranging from 30 to 60 minutes [**?**, **?**, **?**] to more comprehensively capture participants' suicide-related features and reveal potential changes and trends in suicide risk.

Comparing the two timing arrangements in time-contingent design, fixed schedules require participants to complete questionnaires at equal time intervals or at

the same time daily [?], facilitating stable collection of suicidal ideation and behavior data and exploring individual suicide risk change trends at identical time points. For example, Van Genugten et al. conducted a 2-week EMA study with affective disorder patients, assessing transient affective states through 5 daily surveys at fixed 3-hour intervals [?]. Hallard et al. sent 7 online questionnaires to participants daily from 8 AM to 10 PM at 2-hour intervals to understand the change process of suicidal ideation [?]. In another exploratory study of suicidal ideation and related factors in hospitalized depression patients, Peters et al. used a fixed schedule for EMA with major depression inpatients, requiring participants to answer questions via mobile app at 9 AM, 3 PM, and 8 PM daily to explore how emotional instability affected suicidal ideation instability [?]. Therefore, in fixed time-contingent design, participants complete questionnaires based on preset time "signals" rather than when suicidal ideation and behavior occur. Through longitudinal statistical analysis of collected equal-interval time series data, researchers can capture short-term fluctuations in suicidal ideation and compare changes in suicide risk at fixed time points. However, this design has two main limitations. First, individual suicide risk changes nonlinearly, and fixed schedules may fail to capture sudden or irregular occurrences of suicidal ideation and behavior. Second, fixed schedules may cause participants to adjust their daily behaviors to accommodate preset assessment times, making it difficult to accurately capture such changes.

Random sampling refers to sending assessment signals to participants at random times throughout the day [?, ?, ?]. For example, Gratch et al. conducted 6 random assessments of suicidal ideation in adult major depression patients within a 12-hour daytime span, with at least 30 minutes between each assessment [?]. Semi-random sampling combines advantages of random and non-random sampling by dividing the 24-hour day into several time blocks and sending prompts randomly within each block to collect more comprehensive and representative data, fully capturing characteristics of suicidal ideation variability [?, ?]. For example, Kleiman et al. sent 4 signal prompts daily at random 4–8 hour intervals to suicidal inpatients [?] to assess psychological and physiological predictors. Oquendo et al. conducted a 7-day EMA study with major depression patients, assessing 6 times daily with random collection of suicidal ideation and stressful events within 2-hour periods [?]. Compared to fully random schedules, semi-random schedules can balance research needs for randomness and control, enabling more fine-grained and uniform investigation of relationships between suicidal ideation and behavior within specific time periods, facilitating exploration of change trends. Second, suicide assessments may induce emotional discomfort, while semi-random schedules can minimize psychological burden and disruption to normal life. Additionally, semi-random scheduling prevents participants from forming fixed expectations or habits about assessment times, reducing potential errors and helping understand more authentic relationships between suicidal ideation and behavior.

(3) Hybrid Design: Revealing the Overall Mechanism of Suicidal Behavior

When researchers are interested in both target events and their dynamic changes, hybrid designs combining time- and event-contingent approaches can reveal antecedents and consequences of events, providing contextual data for interpreting suicide-related events [?]. For example, Coppersmith et al. assessed adolescents with self-harm history, requiring participants to complete two non-suicidal self-injury (NSSI) reports daily at noon and day' s end [?]. Additionally, participants were required to report when self-harm thoughts or behaviors occurred, helping researchers capture relatively large totals of NSSI behaviors within a timeframe and analyze individual NSSI differences. In another feasibility study on dynamic monitoring of suicidal ideation conducted in Chinese cultural context, Zhu Jiaxin et al. conducted one natural cycle of dynamic monitoring of suicidal ideation and related factors in adult patients with mood disorders [?]. Researchers combined time-contingent and event-contingent designs, conducting 5–8 surveys daily at fixed and random time points while requiring patients to actively report ideation or behavior outside predetermined times, revealing suicide risk change trends while focusing on suicide-related events. Therefore, when researchers are concerned about specific events' impact on suicide risk while also hoping to capture suicide risk change trends through EMA, hybrid designs can be adopted. Hybrid designs can observe and measure influencing factors of suicide-related events, assess associations between events and suicide risk, and reveal temporal sequence relationships. Through evaluation of suicidal ideation and behavior across time spans, trends in suicide risk changes over time can be tracked.

Overall, when conducting EMA research in the suicide field, mental health professionals and clinical psychologists need to balance research purposes, question demands, and feasibility, clarifying whether the focus is on suicidal ideation change trends or specific contexts and motivations during short-term suicide crises, comprehensively considering design advantages and disadvantages, and flexibly using different designs to obtain more comprehensive results. Based on previous research, many EMA studies in the suicide field often use time-varying design schemes to explore short-term fluctuations in suicidal ideation [?, ?, ?, ?], which has been verified in two recent systematic reviews. Time-contingent design is most commonly used in suicide EMA research, followed by hybrid design [?, ?]. Therefore, to fully understand suicidal ideation changes at different moments, researchers can prioritize time-contingent design to capture relationships between suicidal ideation and other variables over time, exploring dynamic characteristics of suicide risk. To comprehensively consider time trends and specific contexts/influencing factors during event occurrence, capturing major events of suicidal ideation and behavior in the short term, hybrid design can be considered, encouraging participants to conduct additional assessments when suicidal ideation occurs to reveal the overall mechanism of suicidal behavior, understand antecedents and consequences of suicide crises, and obtain more comprehensive, in-depth insights to promote understanding and prevention of suicidal behavior.

What populations are suitable for EMA in suicide research?

When conducting EMA research in the suicide field, researchers typically con-

sider which populations this method is suitable for and whether it can be generalized beyond clinical settings; how it applies to different age groups, and what research challenges may be faced. These issues have attracted researchers' attention.

(1) Sample Sources: Applicable to Both Clinical and Community Populations

Most known EMA studies in the suicide field have been conducted with psychiatric outpatients and inpatients [**?**, **?**], as clinical samples often have higher manageability and risk controllability, facilitating timely involvement and supervision by mental health staff throughout the research process, assessing participants' suicidal ideation and behavior change trends, and providing timely intervention for individuals with higher suicide risk. For example, researchers have conducted clinical EMA studies with high-risk populations such as suicide attempt patients in psychiatric emergency departments and recently hospitalized patients with suicidal thoughts [**?**, **?**, **?**, **?**], tracking dynamic development of participants' suicide risk, which helps researchers timely understand change trends and predictive factors of suicidal ideation and behavior. Meanwhile, questions about whether severe clinical mental disorder patients are suitable for EMA research due to psychopathology have also attracted attention. Researchers have used frequently collected EMA data from patients with borderline personality disorder (BPD) [**?**, **?**], major depression [**?**, **?**, **?**], and bipolar disorder [**?**, **?**] to discover that predictive algorithms can more sensitively detect changes in suicidal ideation and behavior, further exploring potential impacts of negative emotion levels on short-term suicide risk prediction. Additionally, some successful studies have been conducted in schizophrenia patients [**?**, **?**].

Subsequently, researchers began extending EMA use to community populations. For example, Nock et al. earlier used EMA in community samples with self-harm and suicide risk to reveal frequencies and intensities of self-harm and suicidal ideation occurrence [**?**]. Rogers et al. conducted longitudinal testing of suicide risk in 237 community-recruited high-risk adults [**?**]. Gratch et al. achieved real-time monitoring of suicidal ideation in adult depression participants through repeated measurements [**?**], also confirming EMA' s applicability in high-risk community populations. Therefore, EMA is applicable not only to psychiatric emergency and inpatient populations but also to community populations outside clinical settings, providing more comprehensive perspectives and tools for suicide risk and influencing factor prediction research.

EMA research shows that suicide results from interactions among multiple risk factors, with significant individual differences in suicide characteristics [**?**]. This highlights the value of exploring different suicidal ideation and behavior subtypes among high-risk populations in both clinical and community settings. For example, Kleiman et al.' s research identified different latent subtypes of suicidal ideation, noting that one subtype is closely related to recent suicide risk, a conclusion validated in both community and clinical samples [**?**]. Therefore, future EMA research in community samples should consider not only demo-

graphic characteristics like age, gender, cultural background, economic status, and education level but also individuals' mental health diagnostic history and suicide-related features. By analyzing different suicidal ideation subtypes, researchers can help identify suicide risk factors in specific populations' daily lives and better understand characteristics and manifestations of different suicide risks. In clinical samples, by examining associations between suicidal ideation development trajectories and future suicide tendencies under different mental disorder characteristics, main predictive factors for suicidal behavior can be identified. Additionally, risk prediction can be based on patients' hospitalization status (length and frequency) and post-suicide attempt behaviors to assist mental health experts and clinicians in evaluating discharge criteria.

(2) Sample Age: Need to Focus on Adolescent and Elderly Populations

Regarding age distribution of research participants, most EMA studies in the suicide field have concentrated on adult samples, with fewer studies on adolescents and elderly populations. In one systematic review of EMA, 17 of 23 included independent studies used adult samples, 6 used adolescent samples, and no elderly samples were found [**?**]. However, previous research has found that suicidal ideation increases rapidly during adolescence, along with suicide risk [**?**], with suicide attempt rates peaking in mid-adolescence [**?**]. Additionally, research shows that elderly populations have higher suicide rates than younger people due to stronger death wishes and more lethal methods [**?**]. Therefore, conducting EMA research on adolescents and elderly populations is important for suicide risk identification and early prevention.

Although EMA research on adolescent suicide is limited, researchers have conducted some successful explorations. Studies have been conducted in adolescents with NSSI, adolescent psychiatric outpatients, inpatients, and community adolescents [**?**, **?**, **?**], finding that EMA can more finely analyze dynamic changes in suicidal ideation and relationships between risk factors at different time points. For example, Hamilton et al. found through EMA research that social media has a subtle and complex relationship with adolescent suicidal ideation [**?**]. Social media experiences have proximal effects on same-day suicidal ideation in adolescents, but ideation does not affect next-day social media experiences. Glenn, Kleiman, Kandlur et al. found in a study of adolescents recently receiving acute mental disorder treatment that interpersonal negative life events during hospitalization were significantly associated with next-day suicidal ideation, with thwarted belongingness mediating this relationship [**?**].

Given that the first few months after discharge from acute mental disorder treatment represent a high-risk period for suicide [**?**], adolescents are prone to suicidal behavior, rehospitalization, and persistent suicidal ideation [**?**, **?**, **?**]. Researchers can use daily diaries to reveal development trajectories of suicidal ideation and behavior during critical time windows in acute suicide risk periods to capture day-to-day change trends in suicide risk. When studying triggers of suicide-related events or exploring within-day fluctuations in suicidal ideation

among adolescents, careful consideration must be given to the feasibility of frequent, repeated measurement and potential challenges. For example, adolescents may not independently own phones or have free internet access, face restrictions on electronic device use during school, and have difficulty protecting personal privacy. Meanwhile, adolescents may be under guardianship due to safety management needs, requiring parental involvement and supervision during research. Therefore, future research should strengthen communication and cooperation with schools and parents, coordinating adolescents' electronic device usage permissions and data reporting times. On one hand, data collection can be scheduled during specific time periods (e.g., morning, evening, lunch breaks, and after school) based on adolescents' schedules, with different sensitivity issues investigated during different periods—for instance, assessing suicide risk influencing factors during school hours and suicide-related issues at home. Additionally, different collection frequencies can be used on weekdays versus weekends to obtain more comprehensive information. On the other hand, EMA application usability should be optimized to avoid sending assessment reminders during classes or campus activities to prevent unnecessary impact on adolescents. Researchers should reduce application dependence on networks, allowing adolescents to report in non-network environments with automatic data upload when connected. Simultaneously, attention should be paid to adolescents' privacy protection and safety management, conducting one-on-one assessment interviews in private settings or through encrypted networks, assisting parents with safety management, and addressing common concerns about adolescent participation in EMA research.

The lack of EMA research in elderly populations may stem from researchers' concerns about imposing additional burden on this group. Particularly when EMA studies use electronic devices for data collection, researchers should consider whether elderly participants can or are willing to operate these devices, as this may affect EMA study compliance rates. However, a meta-analysis on patient preferences showed that elderly participants may not particularly prefer traditional paper assessment methods [**?**]. Although concerns have been expressed about using these technologies in groups with low education and socioeconomic status [**?**, **?**], studies have confirmed the feasibility of using EMA technology in elderly populations \cite{91–94}. For example, Jung et al. conducted 7 consecutive days of EMA surveys with 64 adults over 65, randomly assessing daily vitality fluctuations 4 times daily, with an average compliance rate of 79.6% [**?**], slightly higher than another EMA study on emotional changes in elderly populations [**?**]. Future research can further focus on suicidal ideation, non-fatal and fatal suicidal behavior in elderly populations to verify the feasibility of conducting EMA suicide research in this group. On one hand, EMA technology can be used to investigate proximal and distal factors of suicidal ideation in specific elderly populations (e.g., depression patients, community-dwelling elderly living alone) and explore buffering effects of protective factors like positive emotions and social support on suicide risk. On the other hand, considering that physical illness and functional disability in elderly populations are closely related

to depression and suicidal behavior [?], EMA can collect data on chronic diseases, physical pain, and other health conditions in elderly populations, assess frequency and severity of suicidal ideation, and analyze associations between specific physical diseases and suicidal behavior. Additionally, to reduce technical difficulties elderly people may encounter when operating electronic devices, wearable devices can be combined to continuously collect individual physiological, sleep, and activity data unobtrusively, enabling real-time monitoring of suicide risk levels in elderly populations, deepening understanding of suicide feature development changes, and providing clinical practice support for early identification of suicidal ideation and suicide prevention.

3. Feasibility and Safety of EMA in Suicide Research

Although EMA offers advantages in capturing dynamic development of suicidal ideation and behavior and obtaining more nuanced differences in daily life, its feasibility and safety in suicide research remain unclear. For example, what is the completion rate of EMA studies in high-risk suicide populations? What factors affect data quality? Does frequent, repeated assessment of "sensitive" topics cause iatrogenic effects? How should mental health professionals and clinical psychologists respond to individuals' suicide risk and provide necessary support and resources? These issues require further research to determine the feasibility and safety of conducting EMA in high-risk suicide populations.

(1) Compliance Rates of EMA in Suicide Research

Researchers define compliance rate as the percentage of completed measurements by participants who did not drop out during the entire study period [?], also called average response rate [?, ?]. It is a key determinant of whether EMA is implementable and an important indicator affecting the feasibility of frequent, repeated assessment of suicidal ideation and behavior [?]. If overall compliance is low, it weakens EMA research advantages. On one hand, it leads to reduced sample size and decreased data quality and statistical power [?, ?], making it difficult to accurately predict short-term fluctuations in suicidal ideation. On the other hand, systematic missing data can cause bias in captured suicidal ideation and behavior [?], affecting comprehensive assessment of suicide risk and influencing factors.

Overall, EMA feasibility in suicide research has received substantial support, with compliance rates ranging from 44% to 90% and an average completion rate of 68% [?], nearly consistent with two other review studies [?, ?]. Another systematic review based on 16 independent studies reported an average EMA compliance rate of 75% [?], higher than Rabasco and Sheehan' s study [?]. Specifically, EMA compliance in suicide research shows considerable variation. Some studies show compliance rates gradually decreasing over assessment time [?, ?, ?], others show initial increase then decrease and stabilization [?], gradual increase during assessment [?, ?], or even repeated fluctuations [?]. Therefore, it should be recognized that factors affecting compliance in EMA research are complex and may be influenced by assessment questionnaire length, assessment

frequency, incentive measures, and severity of individual suicidal ideation.

(2) Factors Influencing Compliance Rates in EMA Suicide Research
In a 4-week follow-up study of psychiatric inpatients, researchers assessed participants' suicidal ideation and behavior daily with 32 questions, finding that EMA compliance decreased by 20% from week 1 to week 4 [**?**]. In another study of young people recently treated in a psychiatric emergency department, researchers assessed participants 4 times daily for 8 weeks with 16–26 questions related to suicide and risk factors like hopelessness and emotional dysregulation, showing a week-by-week decreasing compliance trend [**?**]. This indicates that longer questionnaires over time may cause participant fatigue and boredom, reducing engagement. Additionally, research notes that longer assessment questionnaires may increase participant burden, leading to more careless responses and lower compliance. Conversely, brief questionnaires do not reduce compliance even with frequent assessment [**?**, **?**] and may even increase it [**?**]. Therefore, future research can prioritize frequent but brief suicide assessment questionnaires or use single-item indicators to assess suicide and related factors to reduce participant burden. For example, Kleiman et al. used single-item indicators to assess hopelessness, burden, and loneliness in two 28-day studies of suicidal ideation and risk factors to reduce measurement burden [**?**]. Forkmann et al. used 2 items from the Beck Scale for Suicide Ideation to measure suicidal ideation fluctuations in clinical samples [**?**]. Although researchers have validated that single-item indicators correlate highly with original assessment questionnaires, future research should further explore differences between single-item indicators and original questionnaires during EMA assessment and test their applicability in suicide-related research.

Regarding longer EMA assessment questionnaires, researchers can consider slightly varying question wording, using different versions of the same scale or reverse-question formats to minimize individual resistance to repeated assessment. For example, Torous et al., in an EMA study of major depression patients, created different versions by slightly adjusting PHQ-9 question wording. The phrase "feeling tired or having little energy" could be adjusted to "I have felt tired, not much energy" and "I have been active, full of energy," randomly using different questionnaire versions across 3 daily assessments [**?**]. This approach can increase participant engagement and alleviate resistance to repeated measurement, but requires ensuring equivalence of different wordings on assessment indicators. Additionally, researchers can adjust presentation order of assessment indicators and specific questions or randomly select individual questions for each assessment to reduce participant habituation responses and maintain focus during assessment, thereby improving compliance.

Assessment Frequency. In suicide research, EMA sampling frequency determines the precision of sampling suicide risk and related factors. Lower assessment frequency may cause missing or inaccurate information, making it difficult to accurately capture suicide risk change trends, while higher frequency may make tasks time-consuming and burdensome for participants, showing fatigue

effects and ultimately affecting EMA data quality and study compliance [**?**, **?**]. Given that higher assessment frequency causing participant burden is a current consensus and urgent issue in EMA research, researchers have attempted to explore the relationship between assessment frequency and compliance to enhance participation. A meta-analysis found significant compliance differences across different EMA assessment frequencies. In clinical samples, studies with higher assessment frequency (6+ times daily) showed higher compliance, while lower frequency studies (2–3 times daily) showed lower compliance. In non-clinical samples, lower frequency studies had higher compliance [**?**]. This indicates different correlations between assessment frequency and compliance in clinical versus non-clinical settings. Potential reasons may be that in clinical settings, participants prefer frequent assessment due to supervision and support from medical staff, increasing their compliance awareness and motivation. Conversely, in non-clinical settings, participants may focus more on self-management and autonomy, making lower frequency more aligned with their preferences. However, another comparative study on EMA assessment frequency, data quality, and compliance found no correlation between assessment frequency and participant response burden or response quality [**?**]. Meanwhile, a review of 481 EMA studies found that assessment frequency had no effect on compliance [**?**]. Therefore, the relationship between assessment frequency and compliance may be complex, influenced by study design, individual characteristics, incentive measures, and other factors.

Notably, potential negative impacts of assessment frequency on participants cannot be ignored. Rogers et al., in a daily 6-assessment EMA study of community suicide high-risk individuals, found that over one-third of participants believed reducing assessment frequency would correspondingly reduce burden and recommended scheduling assessments according to participants' personal timetables [**?**]. In Forkmann et al.' s study of suicidal ideation in clinical patients, 3 participants dropped out due to feeling that high assessment frequency increased personal burden [**?**]. Therefore, future research can consider creating personalized assessment times, setting EMA assessment start and end times based on participants' daily schedules, or using different assessment frequencies on weekdays versus weekends considering participants' varying schedules and engagement throughout the week to reduce burden. Additionally, extra assessment reminders can be set to improve EMA compliance. For example, Czyz et al. sent text messages to participants daily from 5–7 PM, reminding them to respond within 1–1.5 hours after receiving survey links, with reminder timing based on participants' convenience and preferences [**?**]. Parrish et al., in a suicide risk study of severe mental disorder patients, had research assistants actively contact participants who missed 3+ EMA surveys [**?**]. Researchers can also send messages summarizing and feeding back participants' EMA completion at different stages, allowing participants to understand their participation and motivating continued engagement.

A systematic review of EMA studies in the suicide field found that most studies lasted 1–4 weeks, with 1–10 assessments daily, averaging 5 per day [**?**, **?**, **?**].

Therefore, researchers are recommended to set reasonable assessment periods based on research needs, establishing optimal sampling schedules that balance time coverage and participant burden to improve compliance. When researchers aim to detect day-to-day changes in suicidal ideation, lower frequency assessment can be considered to reduce burden. If within-day change trends need analysis, higher assessment frequency can be considered. Additionally, comparing compliance under different assessment frequencies through research design and deeply exploring interactions between assessment frequency and individual/clinical characteristics can help more comprehensively understand assessment frequency' s impact on compliance, improving EMA data quality and accuracy for more effective support in suicide research.

Incentive Measures. In addition to automatic reminders [**?**], researchers have considered implementing incentive measures to improve compliance. For example, researchers have used monetary rewards [**?**, **?**, **?**, **?**, **?**, **?**], gift cards or vouchers [**?**, **?**, **?**], and portable electronic devices for data collection [**?**, **?**] to improve or maintain compliance. However, the extent to which these measures actually work requires further validation. Reviewing existing empirical studies, most have chosen monetary incentives, even offering additional monetary rewards for achieving certain completion rates [**?**, **?**, **?**]. However, a review of 481 EMA studies found that monetary compensation had almost no effect on increasing compliance [**?**]. Additionally, some studies indicate that over-reliance on monetary incentives may affect participants' true motivation, which does not benefit feasibility exploration of EMA in real-world contexts [**?**]. Moreover, high monetary compensation may be viewed as coercive and raise ethical concerns [**?**]. Some studies note that participants are willing to provide real-time information about their mental health status in EMA research, which helps understand their true selves [**?**, **?**]. Therefore, alternative incentive methods are recommended, such as personalized feedback reports based on EMA data that can help participants understand their suicidal ideation and behavior change trends and potential risk factors in real-world contexts, obtaining more scientific and effective guidance. Such personalized feedback reports can motivate participants, enhance self-awareness and insight, which may be more valuable to participants.

Severity of Suicidal Ideation. Notably, some studies with higher compliance reported lower detection rates of suicidal ideation [**?**, **?**], while studies with lower compliance reported higher ideation [**?**, **?**], consistent with Ammerman and Law' s systematic review finding no significant correlation between participant compliance and suicidal ideation detection rate [**?**]. Earlier research found that individual compliance was not significantly affected by demographic characteristics or mental symptom severity [**?**], and compliance rates were not significantly correlated with suicide attempt history or current suicidal ideation severity [**?**, **?**, **?**, **?**]. However, some studies found different relationships between symptom severity and compliance across samples with different suicide risks. For example, Husky et al. found that patients with suicide attempt history had lower compliance than healthy controls [**?**], possibly because individ-

uals with severe mental symptoms have difficulty tolerating EMA' s repeated measurements and perceive greater burden. Conversely, Czyz et al. found in a daily diary study of high suicide risk populations that adolescents with suicide attempt history had higher compliance than those without [**?**], possibly because they participated in fewer other activities and thus completed assessments more easily. Similar studies suggest that hospitalized patients have higher compliance, possibly because medical staff can supervise assessment completion throughout [**?**], also confirmed in Husky et al.' s study where patients recently hospitalized due to suicide attempts showed higher compliance [**?**]. Therefore, individuals with higher suicide risk may be affected by treatment environment when completing EMA, or may be unable to complete assessments on time due to negative emotions and lack of insight. Future research should further explore relationships between mental disorder severity and compliance in suicide populations, considering impacts of sample source and treatment environment on compliance, distinguishing mental disorder subgroups and suicide risk severity levels, setting different assessment methods for suicidal ideation and behavior (dichotomous and continuous variables), and conducting more detailed analysis of suicidal ideation to explore other potential factors affecting compliance. This will help more comprehensively understand complex factors in suicide risk assessment and provide important references for developing more effective intervention and prevention strategies.

(1) Safety Concerns of EMA in Suicide Research

When conducting EMA research with high-risk suicide populations, whether participants can accept intensive repeated assessment is a question researchers must consider. For a long time, concerns about whether asking about suicide increases suicide possibility have received widespread attention from researchers, healthcare professionals, and the public [**?**, **?**], reflecting concerns about potential negative impacts of asking high-risk populations about suicide risk. However, substantial research indicates that asking about suicide does not trigger suicidal ideation or increase individual suicide behavior likelihood [**?**, **?**]. In fact, it can even reduce individual suicidal ideation and distress [**?**, **?**]. Although EMA shows great potential for short-term suicide risk prediction, it remains unclear whether repeated assessment of suicide "sensitive"topics may have adverse effects or even increase suicide risk.

Research on whether using EMA to ask about suicide increases individual suicidal ideation or behavior typically shows no effect [**?**, **?**, **?**]. For example, Glenn et al. evaluated potential iatrogenic effects of EMA research in high-risk suicidal adolescents treated in psychiatric settings. Results showed that the research process did not increase adolescent suicide risk or cause other negative effects [**?**]. Participants' rehospitalization rates did not significantly differ from other adolescents receiving the same treatment. However, these studies mainly focused on short-term direct investigation, still having limitations in revealing causal relationships and long-term effects of suicide. In a longitudinal randomized controlled study by Law et al., participants were randomly assigned to control assessment and intensive suicide assessment groups. The intensive group

reported negative psychological experiences, suicidal ideation, and behavior 5 times daily, while the control group only reported negative psychological experiences. Results found almost no evidence that EMA caused suicide-related negative outcomes during the 2-week assessment period or 6-month follow-up [**?**]. Study duration and frequent, repeated measurement had no significant effect on any suicide-related outcomes, even in high-risk borderline personality disorder patients.

In addition to focusing on potential negative effects, researchers also value individuals' experiences during EMA surveys. For example, Czyz et al. conducted daily surveys with hospitalized adolescent mental disorder patients and assessed their feelings. Adolescents described their feelings by selecting "feel better," "feel no change," and "feel worse." Results showed nearly one-quarter of adolescents reported positive emotional changes [**?**]. Additionally, Glenn, Kleiman, Kearns et al. conducted a 28-day EMA survey with high-risk adolescents with suicidal ideation and behavior, finding that adolescents had positive experiences participating in the research [**?**]. Frequent, repeated assessment may enhance individuals' attention to their own psychological states and behaviors, strengthening self-awareness and empowerment [**?**, **?**, **?**, **?**]. Thus, conducting EMA research in the suicide field, whether short-term investigation or long-term tracking, has not found obvious negative effects from repeated, intensive questioning, but instead provides researchers with more comprehensive, in-depth dynamic data about suicidal ideation and behavior. This demonstrates EMA' s safety in suicide research, showing that using EMA in clinical and research fields does not cause iatrogenic effects.

(2) Safety Management in EMA Suicide Research

Although frequent, repeated questioning about suicide-related issues has been confirmed not to cause iatrogenic effects [**?**, **?**, **?**, **?**], suicide-related EMA research still requires strict review by Institutional Review Boards (IRB), with special attention to study safety and privacy issues to ensure ethical standards. This includes reviewing study protocol compliance, participant inclusion criteria, potential risk identification, and informed consent content. Simultaneously, emergency intervention or support measures should be examined, and research teams' crisis management and referral capabilities evaluated to ensure response to potential participant crises. Additionally, researchers face complex ethical considerations, particularly regarding how to act when participants are in imminent suicide crisis [**?**, **?**]. When participants submit survey responses about current or very recent suicidal intent, should the research team intervene? How does the team determine when intervention is needed? What should intervention include? These questions require further discussion within the context of research design and ethical considerations.

Whether to monitor participant data in real time. Nock et al. used the Delphi method to reach consensus on safety monitoring in EMA research. Most experts agreed that participant assessment surveys should be reviewed at least every workday, recommending real-time review when data collection platforms

allow [?]. In cases of high-risk responses, experts believed research teams should contact participants as soon as possible for suicide risk assessment. However, Bentley' s research team, after reviewing 61 independent studies, found that most chose automatic alerts or monitoring participant data at least once every 1–2 days, but about 40% of studies did not monitor or respond to participant suicide risk [?]. Possible reasons include: first, sample type influence—for studies recruiting participants anonymously (e.g., online recruitment), intervention difficulties exist [?]. Second, research scope limitations—researchers worry that real-time data monitoring exceeds original responsibilities, with timely response to participant survey data seeming more appropriate for crisis intervener duties [?]. Third, concerns about potential participant reactions [?, ?]—high-risk suicide populations may receive extra clinical attention, so researchers worry that when participants realize research teams may monitor data, they will reduce reporting of suicide risk-related information or even stop responding [?]. Participants may perceive research team contact for suicide risk assessment as burdensome or useless, even causing unnecessary consequences [?], such as involuntary hospitalization, discomfort, or stigma-related shame. Especially for adolescent populations, to avoid potential contact between researchers and their parents and unnecessary intervention, they may resist EMA assessment [?, ?]. However, for other participants, suicide risk assessment may strengthen their reporting willingness [?]. For example, when participants recognize their responses may trigger potential protective interventions, they may benefit by disclosing more suicidal ideation [?]. Additionally, monitoring real-time data of high-risk suicide populations and taking timely action is also affected by research team capacity, professional training, funding support, and equipment technology. However, from a research ethics perspective, safety of high-risk suicide populations should be researchers' primary concern, as suicidal thoughts are typically intermittent, rapid-onset, short-duration, sudden, and dangerous [?, ?]. Real-time monitoring of EMA data helps researchers more accurately capture changes and development trends in suicide risk for prediction, while also providing timely intervention opportunities for participants to effectively prevent potential suicide risk. Therefore, when designing EMA, careful consideration should be given to balancing participant safety and research purpose. To avoid life-threatening events, researchers should conduct real-time review of participant data and maximize potential benefits to participants. Notably, before monitoring begins, researchers must clearly inform participants in informed consent about confidentiality clauses, including who will access data, monitoring frequency, data use, and confidentiality measures, emphasizing data analysis anonymity to ensure participants' personal identity information is not disclosed. Simultaneously, informed consent should explain circumstances under which confidentiality may be broken, such as legal requirements or when participants' life safety is endangered. This helps participants understand potential risks and researchers' responsibilities.

When intervention is needed. During EMA surveys, researchers often use automatic safety pop-ups for intervention, encouraging participants to contact

crisis hotlines, support persons, or clinicians [?]. Generally, the most common pop-up trigger thresholds include frequency or severity of recent suicidal ideation [?, ?, ?], recent suicide plans [?, ?], recent suicide attempt experiences [?, ?], and recent self-harm behavior and its severity [?, ?, ?]. These thresholds are used to set automatic pop-up triggers and more intensive interventions. Existing studies often use multiple thresholds for safety management [?, ?, ?, ?] and send daily timed messages with crisis intervention resources. For example, in Law et al.' s study, information was proactively sent before each EMA survey, encouraging participants to contact mental health professionals or emergency personnel during crises [?]. Coppersmith et al. automatically sent a crisis hotline and resource list after each survey to ensure safety of this frequent assessment [?]. Some studies did not use safety pop-ups, possibly due to concerns about potential participant habituation, avoiding overly frequent or continuous pop-ups that reduce crisis intervention response [?]. Overall, implementing automatic safety pop-ups based on specific risk thresholds plays a key role in research, helping identify and intervene in potential suicide risk. Future research can set different threshold standards based on participants' suicide risk. For high-risk individuals, stricter standards can be set, such as real-time monitoring of suicidal ideation and behavior in the past 12 or 24 hours and other emergencies (e.g., thoughts of harming others, decreased ability to resist suicide urges). When researchers discover emergency risks in participants' responses, they should immediately contact relevant personnel for assessment and intervention to ensure participant safety. For low-to-medium risk participants, researchers can set more lenient threshold standards and maintain regular attention, providing potential intervention through gentle methods such as pop-up safety tips about mental health support and crisis coping resources. Overall, when conducting EMA research with suicide populations, researchers should more closely monitor and respond to "high-risk" answers, ensuring safety of high-risk suicide groups through rapid assessment and intervention; for "low/medium-risk" answers, more flexible intervention measures can be adopted. Additionally, researchers can create personalized safety notifications to encourage participants to seek appropriate support.

How to use safety management strategies for intervention. Safety management strategies in EMA research include preventive strategies, researcher-initiated support strategies, and other support strategies [?].

Most studies used preventive strategies before initiating suicide assessment. These included previewing EMA survey items related to suicide risk [?], encouraging participants to contact professionals through means outside the study [?]. Additionally, some studies created personalized safety plans [?], provided emergency contact lists [?, ?], informed participants they might experience common emotional distress or suicidal ideation risks during the study, and encouraged them to seek support [?].

Researcher-initiated strategies mainly refer to support measures actively provided by researchers after receiving emergency alerts. These include follow-up

via phone, contacting participants or guardians, and activating safety plans [?]. For example, in Czyz et al.' s study, researchers conducted follow-up calls to assess high-risk adolescents' suicidal ideation or impulses [?]. In another study by Czyz, King, and Biermann, researchers conducted phone interviews with adolescents and parents in week 2 to strengthen connections, encouraging adolescents to use safety plans during crises and encouraging parents to provide support [?]. In Bentley et al.' s study, researchers conducted real-time data monitoring of patients treated in emergency departments or hospitalized for mental disorders [?]. On one hand, safety pop-ups helped patients cope with crises, providing suggestions such as contacting clinicians, emergency numbers, or visiting nearby hospitals, and guiding patients to make choices. On the other hand, researchers conducted detailed risk assessments via phone and encouraged use of personalized safety plans. Currently, safety planning is widely used, with patients and clinicians holding positive attitudes toward it, effectively reducing suicide crisis [?]. Researchers should clarify specific safety plan operations to participants' families, other supporters, and clinicians throughout the study, not just during initial informed consent. By establishing safety manuals, creating personalized safety plans, and finding reliable support sources, individuals' self-management abilities and sense of responsibility when facing suicide crisis can be enhanced.

As part of safety management, some studies have used strategies involving family members or other support persons, especially in adolescent research. For example, Esposito et al. obtained consent from adolescent patients' current outpatient psychotherapists to contact them timely when adolescents experienced suicide crisis to assess self-harm thoughts and behaviors [?]. In another study monitoring high-risk adolescents after discharge from acute mental disorder care, Glenn, Kleiman, Kearns et al. established cooperative relationships with adolescents' parents and clinicians, communicating clearly about adolescents' suicide risk and providing parents with necessary support and resources to address adolescent suicide crisis [?].

To achieve "appropriate intervention at the right time" [?], future research can develop diverse safety management strategies. Before assessment begins, preventive strategies are recommended to ensure participants and their families fully understand study nature, safety procedures, and potential risks and benefits. Additionally, researchers can conduct focus group discussions with participants, parents, and clinicians to understand how they wish to receive crisis alerts and provide participants with guidance on crisis coping. During frequent, repeated suicide assessment, participants' data should be monitored in real time. When high-risk data is discovered during monitoring, research teams should strictly follow safety procedures, activate safety plans, adopt automated strategies and researcher-initiated support strategies, thereby realizing EMA' s great value while protecting participant safety.

4. EMA' s Prediction of Suicide Risk

Why can EMA predict suicide risk?

Due to real-time repeated sampling, EMA can precisely capture individuals' current suicidal ideation and behavior. Research indicates that many suicide-related events and risk factors typically rely on participants' retrospective subjective reports, which have low reliability [**?**]. Reasons include: first, retrospective reports can only reflect past situations, cannot capture future development trends of suicidal ideation and behavior, limiting timely examination and prediction of suicide-related events. Second, memory may be biased by individuals' current states [**?**]. For example, individuals with suicidal ideation, affected by rumination, tend to focus on negative information and process it negatively [**?**]. Additionally, memory is biased by peak-end effects [**?**]. Specifically, when individuals are asked to report behaviors or states from the previous week or month, recall is influenced by more salient events within that interval. Therefore, substantial evidence supports the view that "memory is reconstructive and recall is heuristic" [**?**]. When individuals recall suicide-related events through subjective self-reports, "source reconstruction" may occur, introducing systematic rather than random errors. EMA can reduce recall bias and individual subjectivity effects through real-time assessment of high-risk suicide populations, obtaining data that changes over time. It compensates for traditional retrospective reports' limitations in providing objective, accurate suicide information, helping precisely capture suicide-related features and conduct longitudinal, dynamic examination of suicide risk.

Due to its high ecological validity, EMA can accurately describe real changes in suicide risk and influencing factors. Although researchers can eliminate memory bias through experimental methods or laboratory observation, achieving good ecological validity is difficult [**?**]. Research shows that negative life events and daily hassles are common stressors in high-risk suicide populations that can directly predict suicidal ideation and behavior [**?**, **?**]. Therefore, recording and analyzing suicide-related events at different time points and occasions in individuals' daily life environments is crucial. EMA can collect life data from high-risk suicide groups, testing relationships between suicide risk and situational factors in real environments, more accurately understanding causal relationships of suicide events. Compared to traditional research methods, EMA can more effectively describe contextual information of suicide events and predict suicide risk factors.

(1) EMA Enables Finer-Grained Analysis of Short-Term Fluctuations in Suicide Risk

In suicide research, researchers focus more on short-term changes in suicidal ideation and behavior, with follow-up intervals as short as hours or minutes. However, previous suicide risk research typically used low sampling frequency, with less than 1% of studies sampling participants more than once monthly [**?**]. These sampling methods contrast with suicidal ideation and related risk factors that change within hours. Witte et al. proposed that variability in suicidal

ideation may predict suicide risk better than severity or duration of ideation [?]. This suggests that previous cross-sectional or long-term longitudinal studies may inadequately assess dynamic changes in suicidal ideation and behavior. Therefore, suicide prevention requires finer examination of real-time changes in suicide risk. Multiple EMA studies have confirmed that suicidal ideation shows significant variability over time, potentially increasing or decreasing dramatically within finer time granularities (hours) [?, ?, ?, ?]. For example, Czyz, Horwitz et al. found that among adolescent inpatients, all participants' daily suicidal ideation severity changed by at least one standard deviation [?]. In Kleiman et al.' s two studies examining real-time fluctuations in suicidal ideation, they found that almost all participants showed variability in suicidal ideation, with nearly one-third scoring more than one standard deviation higher or lower than 4–8 hours previously [?]. In a domestic study on short-term fluctuations in suicidal ideation, Liu Yixin et al. further refined time granularity (using 3–6 hour intervals), finding that almost all college students with suicidal ideation showed score differences greater than one standard deviation between consecutive time points [?]. EMA' s advantage in suicide research lies in its ability to timely identify the instantaneous nature of suicide crisis and capture richer variation characteristics of suicide risk, which has been verified in comparisons between EMA and traditional retrospective reports.

When exploring relationships between EMA and retrospective reports in suicidal ideation, researchers found that EMA can obtain more accurate suicidal ideation reports [?]. For example, Czyz et al. conducted a one-month EMA feasibility study with adolescents recently discharged after acute mental disorder treatment for suicidal ideation or attempts. The study found that EMA reported more suicidal ideation compared to retrospective self-report using the gold standard clinical assessment (Scale for Suicide Ideation) [?]. Esposito et al. conducted EMA surveys with adolescents at suicide risk and used a modified Columbia-Suicide Severity Rating Scale (C-SSRS) for semi-structured interviews. Results showed that adolescents who denied suicidal ideation in interviews reported at least one relatively severe suicidal ideation in EMA [?]. EMA can capture suicidal ideation more frequently, providing more insights for adolescent suicide research, consistent with other EMA study results [?, ?]. Therefore, compared to traditional retrospective reports, individuals report higher severity of suicidal ideation in EMA. EMA enables finer-grained analysis of short-term fluctuations in suicide risk, emphasizing that EMA not only avoids bias from traditional retrospective reports but also captures participants' real experiences and emotional reactions at specific moments, helping more accurately assess individuals' suicidal intent and risk.

(2) EMA Enables More Comprehensive Assessment of Proximal Factors for Suicide Risk

EMA also allows more comprehensive assessment of proximal risk factors for suicidal ideation and behavior. Husky et al. tested the predictive effects of daily life-related variables on suicidal ideation in recently discharged adult suicide attempters. The study found that after controlling for baseline suicidal ideation,

being at home and working might increase individuals' probability of suicidal ideation, while being with close others, during holidays, or in leisure environments decreased this probability [**?**]. These findings provide preliminary results on proximal environmental and behavioral factors related to suicidal ideation in high-risk samples. Rizk et al. found that emotional instability predicted variability in suicidal ideation in BPD suicide attempters independent of depression severity [**?**], validating that suicide subgroups have different clinical features and risk factors. Hallard et al. found that worry, self-punishment, and rumination were important independent predictors of suicide, while distraction strategies, social control, and cognitive reappraisal negatively predicted suicidal ideation, providing important evidence for the role of thought control strategies in suicidal ideation development [**?**]. Peters et al. used EMA to explore how emotional instability affected suicidal ideation instability in major depression inpatients, finding that suicidal ideation instability was associated with more severe suicidal behavior and depression emotional instability during hospitalization [**?**]. In fact, no single risk factor can highly accurately predict suicidal ideation and behavior [**?**].

Suicide risk has cumulative effects, with suicide crisis gradually increasing as risk factors accumulate [**?**]. For example, Czyz et al. used EMA to conduct early prediction research on suicide risk in high-risk adolescent populations, selecting 6 risk factors including hopelessness, perceived burdensomeness, emotional pain, and suicidal ideation duration to construct different combination prediction models. Results showed that combination models demonstrated higher accuracy compared to single-risk-factor prediction models [**?**]. That is, when comprehensively considering risk factors, the model' s predictive ability for suicide risk significantly improved. This emphasizes that different suicide risk factors may interact, and considering multiple risk factors enables more comprehensive assessment of individual suicide risk and more accurate early prediction. Therefore, preventing suicide crisis requires finer examination of dynamic changes in antecedents of suicide risk and related factors. From a prevention perspective, understanding what factors influence suicidal thoughts in the minutes or hours before occurrence is crucial for predicting these thoughts and intentions. Future research can expand this work by considering broader features, risk factors, and time scales. For example, testing relationships between different risk factors and suicidal ideation variability, analyzing how variables interact with suicidal ideation at different time points, conducting prospective comparisons of different combination prediction models with future suicide tendencies, testing stability of suicide risk prediction over longer time spans to optimize prediction sensitivity and specificity. Additionally, long-term EMA tracking can be conducted for individual suicide subgroup models under different mental disorders and suicide features to test changes in different suicidal ideation and behavior development trajectories.

Over the past 20 years, EMA applications in suicide research have grown exponentially. This method has attracted great interest from mental health professionals and clinical psychologists because it allows repeated assessment of

individuals, longitudinally and dynamically studying relationships between variables, effectively reducing recall bias, and having high ecological validity. From a clinical perspective, EMA using real-time, high-density repeated assessment can better capture short-term fluctuations in suicidal ideation, identify proximal risk and protective factors for suicide in real environments, and promote more accurate causal understanding of events. EMA provides researchers with new tools to examine daily suicidal ideation and short-term fluctuations, promising to accurately capture suicide risk change characteristics and issue early warning signals at critical moments.

Suicide risk prediction involves complexity and particularity, encompassing ethical, predictive accuracy, time sensitivity, statistical analysis, and other challenges requiring further research to explore how suicide risk and influencing factors interact over time. Future improvements in short-term suicide risk prediction should involve EMA innovating methods and technologies to precisely predict individual suicidal ideation and behavior change trends and reduce life loss from suicide.

5.1 Strengthening Localization Research of EMA in the Suicide Field

Cross-cultural research shows that cultural factors' influence on suicidal ideation and behavior cannot be ignored [**?**]. A study on risk factors for suicidal ideation in Chinese people found that sociocultural factors had far greater impact than socioeconomic and demographic characteristics [**?**]. This indicates that understanding and addressing suicide in China requires greater attention to how traditional culture, social norms, interpersonal relationships, and other sociocultural factors affect suicide tendencies. For example, in Chinese cultural context, group hierarchy emphasizes collectivism, with individuals tending to obey group norms and seek group support. Therefore, group hierarchy may have protective effects in China [**?**], while social support may hinder professional help-seeking behavior in suicidal individuals [**?**]. Additionally, intergenerational cultural value conflicts may become risk factors for suicide.

Therefore, researchers should emphasize conducting EMA research in local cultural contexts to explore sociocultural risk and protective factors affecting suicidal ideation and behavior development. Meanwhile, when conducting EMA suicide research with adolescents, families should be included in suicide prevention work to obtain parental understanding and support and avoid unnecessary family conflicts triggering potential suicide risk. Additionally, conducting localization research in Chinese cultural context can enrich EMA cultural diversity research but may face challenges from traditional cultural concepts and individual privacy and confidentiality issues. For example, an international suicide screening study found that Chinese suicide populations are more likely to deny suicide-related screening questions, possibly due to strong stigma around suicide in Chinese culture or different cultural expressions [**?**]. In the future, EMA tools more aligned with Chinese cultural background can be developed, using expres-

sions closer to Chinese culture to guide individuals to express true emotional states. Combining wearable devices for more covert data collection can help reduce traditional cultural concepts' impact on suicide research data. Additionally, "face" culture and "collectivism" concepts can be cleverly integrated into research design to improve participation and data quality. For example, highlighting research' s public welfare and social value, emphasizing participants' contributions and importance. Arranging staff for one-on-one reminders during the research process may also increase participants' enthusiasm. These measures will help more deeply and comprehensively understand and address suicide issues in Chinese cultural context, providing more targeted support for suicide prevention work.

5.2 Using Digital Technology and Artificial Intelligence to Conduct EMA Research on Suicide Risk

Multiple studies have found that sleep-wake activity, heart rate (HR), and heart rate variability (HRV) are effective predictors of suicide risk, but further research is still needed to identify specific variables related to acute suicide risk and these variables' temporal change patterns \cite{145–147}. Wearable Artificial Intelligence provides new tools and methods for better real-time monitoring and early warning of suicide [**?**]. It can use sensors to collect individual vital sign data such as heart rate activity, respiratory rate, skin conductance, and body temperature, record social interaction frequency and daily behavior activity types, and monitor sleep duration, quality, and nighttime awakenings. This continuous, uninterrupted data collection provides objective, real information, enabling more accurate real-time monitoring of suicide risk and identifying variations and temporal relationships related to acute suicide.

Furthermore, future research can use artificial intelligence technology to design smarter, more personalized sampling methods. For example, adjusting sampling schedules according to individuals' daily routines integrates assessment into daily life, minimizing impact on participants' normal lives and achieving ecologically valid measurement. Simultaneously, AI can dynamically adjust sampling strategies based on real-time data, timely identifying potential signals of suicide risk and increasing sampling frequency during high-risk moments. In suicide risk prediction, artificial intelligence technology is gradually showing unique prospects due to its ability to process large and complex datasets [**?**]. For example, Chen et al. used multiple machine learning algorithms to develop suicide risk prediction models to predict risk in patients attempting suicide after psychiatric visits, showing good discrimination and calibration [**?**]. Shen et al. used individual and clinical features to build a random forest model, successfully predicting suicide attempts among Chinese medical students with 90.1% accuracy [**?**]. Future research can integrate EMA self-reported psychological indicator data with objective data from wearable AI-collected individual physiological signals, behavioral states, and environmental information to develop personalized algorithms, construct prediction models for short-term changes in

suicidal ideation and behavior, and identify potential high-risk moments. Using AI to process data and compare machine learning strategies can improve accuracy of suicide risk factor identification. Digital technology and AI are expected to improve abilities to understand, predict, and prevent suicide.

5.3 Addressing Legal and Ethical Issues of EMA Data in the Suicide Field

Smartphones and wearable devices can collect large amounts of data, providing detailed information about research processes. By combining participant data with publicly available spatial datasets, it is relatively easy to reconstruct individuals' detailed daily activities in their environments [**?**], while using network sharing methods like cloud storage to save or transmit EMA data poses leakage risks, potentially revealing when and where suicidal individuals are at risk. Therefore, in future research using smartphones and wearable devices as EMA data collection methods, researchers need to comply with relevant legal regulations and take appropriate measures to ensure data security and participant privacy when sharing data. For example, informed consent should clearly state that all participant responses and data will be confidentially processed and only accessible to research team members. Regarding data use, encryption should be applied to data storage and transmission, with more advanced confidentiality measures for sensitive data related to suicidal ideation and behavior. Strict data access mechanisms should be implemented, prohibiting access and processing by unauthorized parties. Participant identity information and sensitive data should be anonymized or obfuscated to avoid potential re-identification risks, while balancing anonymized data availability with research needs. Additionally, participants must be ensured to understand during informed consent what information these data may disclose and potential privacy risks, as well as researchers' ability to protect information anonymity.

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WU Caizhi: Conceptualized the article, organized structure, revised manuscript;
YUN Yun: Organized research background and development, drafted manuscript, correspondence;
XIAO Zhihua: Reviewed existing research on topic, organized materials chronologically;
ZHOU Zhongying, TONG Ting: Summarized future development directions of research topic;
REN Zhihong: Revised final manuscript version.

Note: Figure translations are in progress. See original paper for figures.