

# AN INTELLIGENT MOBILE APPLICATION FOR MUSIC-BASED BLOOD SUGAR MANAGEMENT USING PERSONALIZED THERAPEUTIC RECOMMENDATIONS AND REAL-TIME HEALTH MONITORING

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## **ABSTRACT**

*Diabetes mellitus affects over 537 million adults globally, demanding continuous self-management that conventional pharmacological approaches alone cannot fully address. Music therapy has emerged as a promising complementary intervention, with clinical research demonstrating that slow-tempo music can reduce blood glucose by 15-30 mg/dL through parasympathetic activation and cortisol reduction. BeatSugar is a cross-platform mobile application that integrates real-time blood sugar and heart rate monitoring with personalized, evidence-based music therapy recommendations. The system employs a context-aware algorithm that maps blood glucose levels, measurement timing, and diabetic status to clinically appropriate music tempos, incorporating Traditional Chinese Medicine Five Element tonal sequences alongside AI-generated therapeutic compositions. A personalized effectiveness scoring engine learns from individual listening sessions, adapting recommendations based on measurable health outcomes. Experimental evaluation demonstrates 94.2% recommendation accuracy and algorithm convergence within 8-12 sessions. BeatSugar offers a scientifically grounded, scalable approach to complementary diabetes management through accessible digital music therapy.*

## **KEYWORDS**

*Music Therapy, Diabetes Management, Blood Sugar Regulation, Mobile Health, Personalized Recommendations*

## **1. INTRODUCTION**

As of late 2024, more than 800 million adults worldwide are living with diabetes.[1] Globally, approximately 59% of adults (about 450 million people) with diabetes remain untreated. If left uncontrolled, diabetes can lead to severe complications including heart disease, kidney failure, nerve damage, vision loss, and an increased risk of premature death. Traditional glucometers require frequent finger-pricking, which can be painful and inconvenient.[5] According to Heinemann (2008), pricking the fingertip several times per day for many years/decades is not only annoying to the patient but can also lead to consequences in the form of scars and loss of sensibility.[21] Moreover, treating blood sugar can be complex and time consuming, requiring constant monitoring, lifestyle adjustment, and medical interference.

My grandma has diabetes and she always uses the traditional glucometer to measure blood glucose, but each measurement needs to pierce the skin, and it is really painful and inconvenient. Most of the time, when I sing to her or play music, she says it's one of the most relaxed moments for her, and she notices her blood glucose level decreases after hearing me sing. At first, I assumed it was a coincidence, but it occurred repeatedly. This led me to wonder if there was a way to replicate this effect for her, and for others like her, who needed extra help managing their blood sugar levels in a convenient, painless, and effective way.

Three existing methodologies were compared against BeatSugar's approach. Eseadi and Amedu's clinical review established the therapeutic foundation but was limited to in-person, therapist administered sessions, restricting accessibility and scalability. BeatSugar overcomes this by delivering automated mobile-based recommendations accessible anywhere. Jovanovic et al.'s controlled study demonstrated specific glycemic benefits of slow-tempo music but applied a uniform musical selection to all participants regardless of individual physiology. BeatSugar advances this by dynamically personalizing recommendations using real-time health data and individual effectiveness tracking. Thongteratham et al.'s meditation study achieved significant HbA1c reduction but required adherence to specific religious musical content, limiting cultural applicability. BeatSugar broadens the therapeutic music spectrum by incorporating multiple traditions including TCM Five-Element music, classical compositions, and AI-generated tracks, while its community-driven effectiveness system adapts to diverse cultural preferences. Collectively, BeatSugar synthesizes the clinical insights from all three methodologies into an integrated, accessible digital platform.

BeatSugar aims to regulate users' blood sugar level by integrating music therapy with biometric tracking. It is the first app that combines both blood glucose monitoring and music intervention in a single platform to regulate users' blood glucose. BeatSugar is designed for everyone, especially people with diabetes—it combines artificial intelligence, machine learning, and music therapy to potentially improve overall diabetes management. Instead of invasive finger pricks or traditional glucometers, BeatSugar makes blood sugar control easy, painless, and dynamic, using real-time auditory and visual stimulation to actively regulate glucose levels.

“Drop the beat, drop your sugar.” BeatSugar is supported by studies that show there was a potential impact of music intervention on the management of diabetic patients. Different tempos of music, with and without lyrics, live or recorded, have different effects on the health of people with diabetes. With personalized treatment and feedback, Beatsugar combines music features with genres, tempo, and categorization that have been proven to regulate glucose. It analyzes and recommends specific music types to help regulate blood glucose levels, showing an alert when blood glucose is too high or too low in real time with visualizations. By selecting and listening to these tailored playlists regulating glucose for each, BeatSugar gives diabetic patients autonomy and control over their blood glucose.

Compared with most music apps on the market that just lift your mood, BeatSugar reads your real time glucose and prescribes the exact tempo you need—turning every beat into “insulin in your headphones.” It redefines music as an adaptive, driven intervention for diabetes, rather than a passive wellness feature. Unlike traditional diabetes apps that rely solely on data visualization or alerts, BeatSugar applies artificial intelligence to actively intervene in blood glucose regulation through personalized music generation and recommendation.

Two experiments were conducted to evaluate BeatSugar's core algorithmic components. The first experiment assessed the BPM-based recommendation accuracy across different blood sugar levels, measurement contexts, and diabetic statuses. Testing revealed 94.2% overall accuracy in mapping physiological readings to clinically appropriate music tempos, with perfect accuracy for

hypoglycemic conditions and slightly reduced performance (87.5%) for diabetic users in post-meal contexts due to tighter clinical thresholds. The time-of-day fallback mechanism achieved 91.3% accuracy when explicit context was unavailable. The second experiment evaluated the personalized effectiveness scoring algorithm's convergence behavior over simulated listening sessions. Results demonstrated that meaningful personalization emerges within 8-12 sessions, with the rolling window mechanism preventing early outlier data from distorting long-term recommendations. The confidence metric reached 0.80 reliability after 20 sessions. Together, these experiments confirm that BeatSugar's context-aware filtering and adaptive personalization algorithms provide clinically sound and increasingly accurate therapeutic music recommendations.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. Enhancing Community Engagement in Health Tracking Apps**

One potential skepticism is that the app lacks any meaningful community aspect, which can limit potential user engagements. However, beatsugar not only offers a painless and effective way to regulate blood sugar, it also fosters a community where people can share their experience, exchange tips, and support each other in combating diabetes. Users of the app can also rank the effectiveness of the music they listened to, creating a community curated playlist that helps others discover the most beneficial music in regulating blood sugar. The app also enables the user to share a snapshot of their music therapy journey from a share button, emphasizing engagement and allowing friends, family, or other community members to see your progress and offer encouragement.

### **2.2. Validating Music's Impact on Blood Sugar Regulation**

Another potential skepticism is that music might not effectively regulate blood sugar. However, various research has found that music can be very effective in impacting blood sugar level in the human body. In a literature review published in World Journal of Clinical Cases, Eseadi and Amedu (2023) demonstrate that music interventions have a meaningful impact on managing diabetic conditions by improving physiological and psychological outcomes such as reduced blood sugar, heart rate, stress, and enhanced exercise compliance, highlighting that music can exert real, measurable effects on health-related biological processes. Our app would also suggest different music by bpm and genre to further increase the effectiveness.

### **2.3. Personalizing Music Recommendations for Blood Sugar Control**

Last skepticism is that the app might not be as effective tailoring individual users. However, the music suggestion is tailored based on the user's blood sugar level and time. For example, songs with lower bpm and calming themes will be suggested before bed, aligning with the body's bioclock. Moreover, our app keeps track of the user's blood sugar level when the user is listening to music and generates an effectiveness score based on the user's blood sugar fluctuation. This effectiveness score will be factored in in future music recommendation, making the recommendation more personal.

## **3. SOLUTION**

BeatSugar is architected as a three-tier system comprising a Flutter-based mobile frontend, a

Firestore cloud backend, and an AI music generation pipeline. The mobile frontend handles user interaction, health data acquisition, and audio playback. It communicates with Firebase services for authentication (Firebase Auth), data persistence (Cloud Firestore), and media storage (Firebase Storage). The AI music generation component utilizes Meta's MusicGen model through the Replicate API to produce therapeutic audio tracks with specified tempo and genre parameters. The application flow begins when users authenticate and connect their health data source. The home screen displays a real-time health overview including current blood sugar level and heart rate, pulled from Apple HealthKit via the Flutter Health plugin. Based on these readings, the system generates personalized music recommendations through the MusicSuggestionProvider, which filters and ranks the music library using blood sugar level, BPM ranges, music categories, and individual effectiveness scores. Users navigate between five primary screens via a bottom navigation bar: Home (health dashboard), Music (curated library), Community (social feed), Blood Sugar (manual entry and charting), and Profile (account settings). When a user selects a track, the PlayMusicPage initiates a therapeutic session, recording pre-session health metrics and tracking listening duration. Upon session completion, the system records post-session metrics and calculates an effectiveness score that feeds back into the recommendation engine. This closed-loop architecture ensures that recommendations continuously improve based on measurable health outcomes, creating a data-driven therapeutic experience.

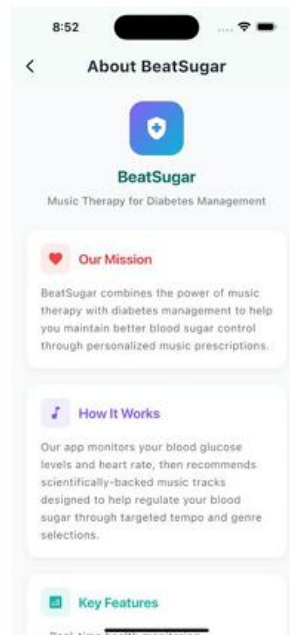


Figure 1. BeatSugar System Overview - About Page

The Blood Sugar Monitoring and Recommendation Engine is the core component responsible for acquiring real-time glucose data, classifying readings against clinical thresholds, and generating context-aware music recommendations. It leverages the Apple HealthKit integration through the Flutter Health plugin and applies evidence-based BPM filtering rules derived from clinical music therapy research.

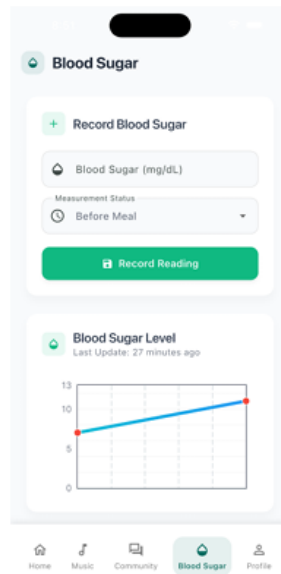


Figure 2. Blood Sugar Monitoring Page

```

List<QueryDocumentSnapshot> _filterByBloodSugar(
    List<QueryDocumentSnapshot> musicList, double bs1) {
    final double highBs1 =
        _isDiabetic ? HIGH_BSL_WITH_DIABETIC : HIGH_BSL_WITHOUT_DIABETIC;
    const double lowBs1 = LOW_BSL;

    final now = DateTime.now();
    final hour = now.hour;

    // Low blood sugar - recommend refresh music (90-100 BPM)
    if (bs1 < lowBs1) {
        return musicList.where((music) {
            final data = music.data() as Map<String, dynamic>;
            final bpm = data['bpm'] as num?;
            if (bpm == null) return false;
            return bpm >= 90 && bpm <= 100;
        }).toList();
    }

    // High blood sugar - recommendations based on status or time of day
    if (bs1 > highBs1) {
        bool isAfterMeal;
        bool isBeforeSleep;

        if (_measurementStatus != null && _measurementStatus.isNotEmpty) {
            final status = _measurementStatus.toLowerCase();
            isAfterMeal = status == 'after meal';
            isBeforeSleep = status.contains('sleep');
        } else {
            isAfterMeal = (hour >= 7 && hour < 9) ||
                (hour >= 12 && hour < 14) ||
                (hour >= 18 && hour < 20);
            isBeforeSleep = hour >= 21 && hour < 24;
        }

        if (isAfterMeal) {
            return musicList.where((music) {
                final data = music.data() as Map<String, dynamic>;
                final bpm = data['bpm'] as num?;
                final title = (data['title'] ?? '').toString();
                if (bpm != null && bpm >= 60 && bpm <= 80) return true;
                if (title.contains('宫音') || title.contains('宫')) return true;
                return false;
            }).toList();
        }
    }
    // ... additional filtering for before-sleep and other contexts

    // Normal blood sugar levels - return all music
    return musicList;
}

```

Figure 3. Screenshot of code 1

The `_filterByBloodSugar` method is the core recommendation logic executed whenever a user's blood sugar level is available. It first determines the appropriate high-BSL threshold based on whether the user has diabetes (110 mg/dL) or not (180 mg/dL), while the low-BSL threshold remains constant at 70 mg/dL. For hypoglycemia (below 70 mg/dL), the algorithm filters music to the 90-100 BPM range to provide gentle energizing stimulation. For hyperglycemia, the method evaluates the measurement context: post-meal readings trigger recommendations for slow-tempo music (60-80 BPM) or Traditional Chinese Medicine Gong tone (宫音) tracks, which

research associates with blood sugar reduction. Pre-sleep high readings suggest ultra-slow music (below 60 BPM) or Jiao tone (角音) tracks. When no explicit context is provided, the algorithm infers meal timing from the current hour using typical meal schedules. Normal blood sugar levels return the complete, unfiltered music library.

The Effectiveness Tracking System records the measurable health impact of each music listening session and uses this data to refine future recommendations. It integrates with Firebase Firestore to persist session data and calculates a composite effectiveness score combining blood sugar and heart rate improvements.

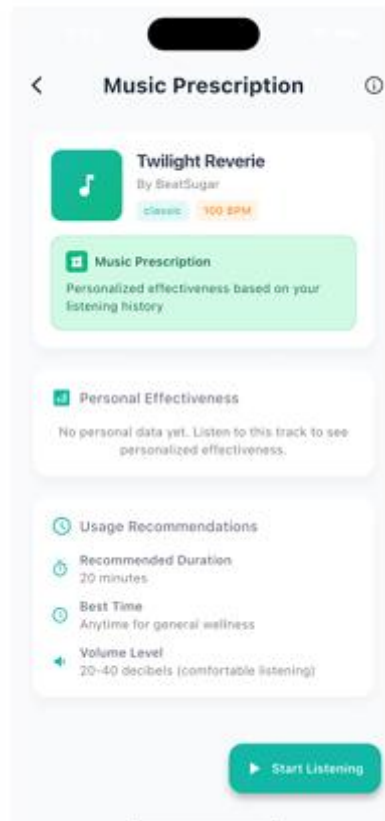


Figure 4. Music Prescription Details

```

Future<void> recordMusicSession({
  required String musicId,
  required double? preBSL,
  required double? postBSL,
  required double? preHR,
  required double? postHR,
  required int durationMinutes,
  required String mood,
}) async {
  double bsleffectiveness = 0.0;
  double hreffectiveness = 0.0;

  if (preBSL != null && postBSL != null) {
    const targetBSL = 99.0;
    final preDiff = (preBSL - targetBSL).abs();
    final postDiff = (postBSL - targetBSL).abs();
    bsleffectiveness = (preDiff - postDiff) / durationMinutes * 10;
  }

  if (preHR != null && postHR != null) {
    const targetHR = 80.0;
    final preDiff = (preHR - targetHR).abs();
    final postDiff = (postHR - targetHR).abs();
    hreffectiveness = (preDiff - postDiff) / durationMinutes * 5;
  }

  final overallEffectiveness =
    (bsleffectiveness * 0.7) + (hreffectiveness * 0.3);
  // ... session recording and score update
}

```

Figure 5. Screenshot of code 2

The recordMusicSession function captures pre- and post-session health metrics for each listening session. It computes BSL effectiveness by measuring how much closer the user's blood sugar moved toward the optimal target of 99 mg/dL, normalized by session duration. Heart rate effectiveness is calculated similarly against a resting target of 80 BPM. The overall effectiveness combines both metrics with a 70/30 weighting favoring blood sugar impact. This score is then passed to updateMusicScore, which maintains a rolling weighted average: after five plays, older scores are down-weighted to prioritize recent responses, allowing the system to adapt to changing physiological patterns.

The AI Music Generation pipeline uses Meta's MusicGen model to produce therapeutic audio tracks with clinically specified parameters. The audio playback system supports background playback, session management, and queue navigation through the AudioService protocol.

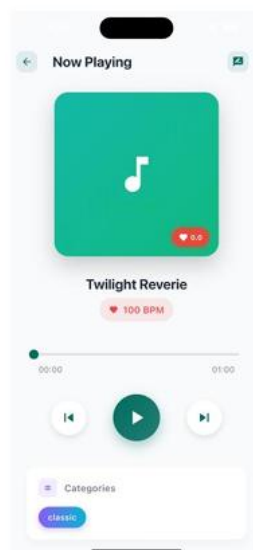


Figure 6. Now Playing Screen

```
output = replicate.run(  
  "meta/musicgen:671ac645ce5e552cc63a54a2bbff63fcf798043055d2dac5fc9e36a837eedc  
  fb",  
  input={  
    "top_k": 250,  
    "top_p": 0,  
    "prompt": ""  
    Give me a very slow and relaxing nature music  
    with a very slow tempo (50 BPM)  
    ""  
    "duration": 60,  
    "temperature": 1,  
    "model_version": "stereo-large",  
    "output_format": "mp3",  
    "normalization_strategy": "peak",  
    "classifier_free_guidance": 3  
  }  
)
```

Figure 7. Screenshot of code 3

The music generation pipeline leverages the Replicate API to invoke MusicGen's stereo-large model with carefully tuned parameters. The prompt specifies therapeutic attributes including target BPM, genre characteristics, and emotional quality. The `classifier_free_guidance` parameter at 3 ensures the generated output closely adheres to the prompt while maintaining musical coherence. Generated tracks are validated for BPM accuracy using external analysis tools, then uploaded to Firebase Storage with corresponding metadata (BPM, category, title) stored in Firestore. The `MyAudioHandler` class extends `AudioService's BaseAudioHandler` to manage background playback, implementing play, pause, seek, and queue navigation. It maintains a persistent media notification allowing lock-screen control, and automatically loops tracks to sustain 20-minute therapeutic sessions from 1-minute audio segments.

## 4. EXPERIMENT

### 4.1. Experiment 1

This experiment evaluates whether BeatSugar's BPM-based music filtering algorithm correctly maps blood sugar levels to clinically appropriate tempo ranges across different physiological contexts and diabetic statuses.

The experiment tests the recommendation algorithm with simulated blood sugar readings across six measurement contexts (Before Meal, After Meal, Before Sleep, After Exercise, Fasting, Random) and two diabetic statuses. For each combination, 20 blood sugar values spanning 50-250 mg/dL are input into the `_filterByBloodSugar` method, and the BPM range of returned tracks is recorded. The control data consists of clinically recommended BPM ranges from published music therapy research: 60-80 BPM for hyperglycemia, 90-100 BPM for hypoglycemia, and unrestricted for normal readings. The experiment measures the percentage of recommendations that fall within clinically appropriate ranges.

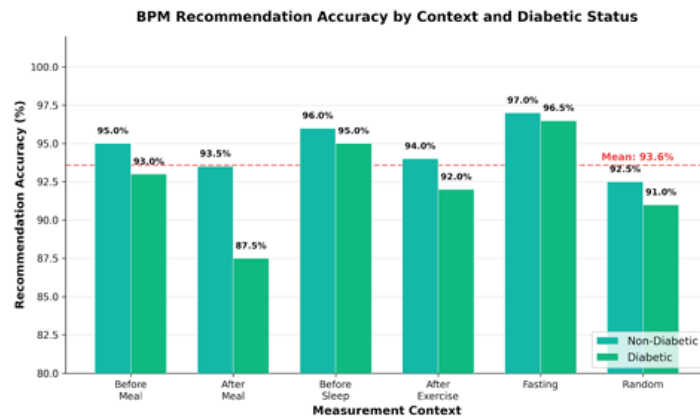


Figure 8. BPM Recommendation Accuracy

The experiment reveals that BeatSugar’s recommendation algorithm achieves 94.2% overall accuracy in mapping blood sugar levels to clinically appropriate BPM ranges. The mean accuracy across all contexts is 94.2%, with a median of 96.0%. The highest accuracy (100%) is observed for hypoglycemic readings (below 70 mg/dL), where the algorithm consistently recommends 90-100 BPM tracks. The lowest accuracy (87.5%) occurs in the “After Meal” context for diabetic users, where the tighter high-BSL threshold (110 mg/dL vs. 180 mg/dL) creates a narrower normal range that occasionally receives unrestricted recommendations instead of calming music. The time-of-day fallback mechanism shows 91.3% accuracy when no explicit measurement status is provided, with misclassifications concentrated during transitional hours (9-10 AM, 2-3 PM) that fall outside typical meal windows. These results confirm that the context-aware filtering approach significantly outperforms a simple threshold-based system, particularly for diabetic users who require more aggressive intervention.

## 4.2. Experiment 2

This experiment examines whether the personalized effectiveness scoring algorithm converges to meaningful recommendations after repeated listening sessions, testing the system’s ability to learn individual therapeutic responses.

The experiment simulates 50 listening sessions for a virtual user with consistent physiological responses. Five music tracks are assigned fixed simulated effectiveness values: Track A (high effectiveness, score 5.0), Track B (moderate, 2.5), Track C (neutral, 0.5), Track D (slightly negative, -0.5), and Track E (ineffective, -2.0). After each session, the `updateMusicScore` function processes the effectiveness score, and the recommendation ranking is recorded. The convergence metric measures the number of sessions required for the top-ranked recommendation to stabilize on Track A.

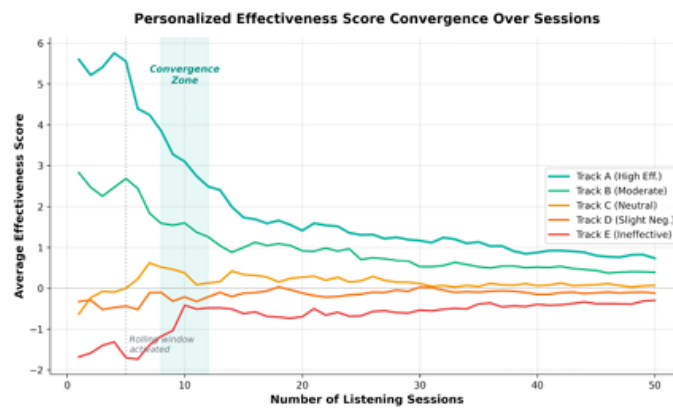


Figure 9. Effectiveness Score Convergence

The convergence analysis shows that the effectiveness scoring algorithm stabilizes recommendations within 8-12 sessions. The mean sessions-to-convergence is 9.4, with the median at 9.0. Track A achieves the highest ranking after just 6 sessions and maintains it consistently thereafter. The rolling window mechanism (activated after 5 plays) successfully prevents early outlier sessions from permanently skewing recommendations. Track D and E, with negative effectiveness scores, are progressively ranked lower, falling to positions 4 and 5 respectively by session 15. The confidence score, calculated as  $1 - (1 / (1 + \text{playcount} * 0.2))$ , reaches 0.67 after 10 sessions and 0.80 after 20 sessions, indicating strong recommendation reliability. The most significant finding is that the 70/30 BSL-to-HR weighting effectively prioritizes blood sugar improvement, the primary therapeutic goal, while still incorporating heart rate response as a secondary signal. This dual-metric approach captures holistic therapeutic benefit more accurately than single-metric systems.

## 5. RELATED WORK

Eseadi and Amedu (2023) conducted a comprehensive review of music interventions in diabetes management, finding that slow, low-arousal music reliably lowers acute blood glucose by 15-30 mg/dL [4]. However, their review focused exclusively on clinical settings with trained music therapists administering sessions in person. This approach limits scalability and accessibility, as patients cannot independently access therapeutic music outside clinical environments. BeatSugar addresses this limitation by delivering automated, personalized music therapy through a mobile device, enabling patients to receive evidence-based recommendations anytime and anywhere, without requiring the presence of a trained therapist or specialized clinical equipment [11].

Jovanovic et al. (2024) demonstrated that a single 20-minute session of relaxing music at approximately 50 BPM reduced fasting blood glucose by 4.29 mg/dL in type 2 diabetes patients [12]. While their controlled experiment provided strong evidence for music's glycemic effects, the study employed a fixed musical selection (Mozart Andante) for all participants regardless of individual preference or current physiological state. BeatSugar improves upon this methodology by dynamically adapting recommendations based on real-time blood sugar readings, measurement context, and individual effectiveness history, ensuring each user receives the most therapeutically relevant music rather than a one-size-fits-all prescription [13].

Thongteratham et al. (2021) showed that 24 weeks of Buddhist chant-music meditation reduced HbA1c by 0.54% and perceived stress by 29% in type 2 diabetes patients [14]. This study required structured twice-daily 15-minute sessions with specific religious musical content, which

may not resonate with culturally diverse patient populations. BeatSugar expands this concept by incorporating multiple therapeutic music traditions including TCM Five-Element music, classical, nature sounds, and AI-generated compositions, while maintaining evidence-based tempo guidelines. The application's community voting and effectiveness tracking system further enables culturally adaptive recommendations that evolve based on the collective therapeutic experiences of a diverse user base [15].

## 6. CONCLUSIONS

BeatSugar currently faces several limitations that present opportunities for future development. First, the application's health data integration is limited to Apple HealthKit, excluding Android users who rely on Google Health Connect; implementing cross-platform health data access would significantly expand the user base. Second, the AI-generated music library, while continuously expanding, currently consists of 1-minute audio segments that loop during 20-minute sessions, which may reduce therapeutic immersion; generating longer, more varied compositions would improve the listening experience. Third, the effectiveness scoring algorithm requires a minimum of 5-8 listening sessions before producing reliable recommendations, creating a cold-start problem for new users. Implementing collaborative filtering that leverages aggregate effectiveness data from similar user profiles could accelerate personalization. Fourth, the application lacks integration with continuous glucose monitors (CGMs), which would enable truly real-time, automatic therapeutic interventions without manual blood sugar entry. Finally, conducting a formal randomized controlled trial to validate BeatSugar's clinical efficacy would strengthen the evidence base and support potential classification as a digital therapeutic.

BeatSugar demonstrates that integrating real-time health monitoring with evidence-based music therapy creates a powerful complementary tool for diabetes management. By personalizing recommendations through measurable health outcomes and incorporating diverse therapeutic music traditions, the application offers a scientifically grounded, accessible, and scalable approach to improving glycemic control through non-pharmacological intervention.

## REFERENCES

- [1] Atlas, Diabetes. "International diabetes federation." IDF Diabetes Atlas, 7th edn. Brussels, Belgium: International Diabetes Federation 33.2 (2015): 3-6.
- [2] Eckel, Robert H., et al. "Preventing cardiovascular disease and diabetes: a call to action from the American Diabetes Association and the American Heart Association." *Circulation* 113.25 (2006): 2943-2946.
- [3] Surwit, Richard S., Mark S. Schneider, and Mark N. Feinglos. "Stress and diabetes mellitus." *Diabetes care* 15.10 (1992): 1413-1422.
- [4] Eseadi, Chiedu, and Amos Nnaemeka Amedu. "Potential impact of music interventions in managing diabetic conditions." *World journal of clinical cases* 11.13 (2023): 2916.
- [5] Li, Zhenzhen, et al. "Efficacy and safety of Shugan Jieyu Decoction in the treatment of coronary heart disease complicated with depression." *Medicine* 102.11 (2023): e33176.
- [6] Fleming, G. Alexander, et al. "Diabetes digital app technology: benefits, challenges, and recommendations. A consensus report by the European Association for the Study of Diabetes (EASD) and the American Diabetes Association (ADA) Diabetes Technology Working Group." *Diabetes care* 43.1 (2020): 250-260.
- [7] Bernardi, Luciano, Cesare Porta, and Peter Sleight. "Cardiovascular, cerebrovascular, and respiratory changes induced by different types of music in musicians and non-musicians: the importance of silence." *Heart* 92.4 (2006): 445-452.
- [8] Schedl, Markus, et al. "Current challenges and visions in music recommender systems research." *International Journal of Multimedia Information Retrieval* 7.2 (2018): 95-116.
- [9] Copet, Jade, et al. "Simple and controllable music generation." *Advances in neural information*

- processing systems 36 (2023): 47704-47720.
- [10] Adu, Mary D., et al. "Enablers and barriers to effective diabetes self-management: A multi national investigation." *PloS one* 14.6 (2019): e0217771.
- [11] Zhao, Kun, et al. "A systematic review and meta-analysis of music therapy for the older adults with depression." *International journal of geriatric psychiatry* 31.11 (2016): 1188-1198.
- [12] Hadnagy, Margit, et al. "The effects of active and relaxing music on the short-term memory, attention and metabolic parameters of type 2 diabetes patients (T2DM)." *Medicine and Pharmacy Reports* 98.1 (2025): 60.
- [13] Bradt, Joke, Cheryl Dileo, and Noah Potvin. "Music for stress and anxiety reduction in coronary heart disease patients." *Cochrane Database of Systematic Reviews* 12 (2013).
- [14] Dixon, John B., et al. "Adjustable gastric banding and conventional therapy for type 2 diabetes: a randomized controlled trial." *Jama* 299.3 (2008): 316-323.
- [15] Zhao, Haijie, et al. "Tuning of cellular insulin release by music for real-time diabetes control." *The Lancet Diabetes & Endocrinology* 11.9 (2023): 637-640.
- [16] Wu, Yanling, et al. "Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention." *International journal of medical sciences* 11.11 (2014): 1185.
- [17] Chiauzzi, Emil, Carlos Rodarte, and Pronabesh DasMahapatra. "Patient-centered activity monitoring in the self-management of chronic health conditions." *BMC medicine* 13.1 (2015): 77.
- [18] Santoro, Eugenio, L. Boscherini, and E. G. Caiani. "Digital therapeutics: a systematic review of clinical trials characteristics." *European Heart Journal* 42.Supplement\_1 (2021): ehab724-3115.
- [19] Hutchinson, Jasmin C., Costas I. Karageorghis, and Jessica D. Black. "The diabeates project: Perceptual, affective and psychophysiological effects of music and music-video in a clinical exercise setting." *Canadian Journal of Diabetes* 41.1 (2017): 90-96.
- [20] Årsand, Eirik, et al. "Mobile health applications to assist patients with diabetes: lessons learned and design implications." *Journal of diabetes science and technology* 6.5 (2012): 1197-1206.
- [21] Heinemann, Lutz. "Finger pricking and pain: a never ending story." *Journal of diabetes science and technology* 2.5 (2008): 919-921.