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Original Research Article

Micro-costing analysis of a digital mental health intervention for adolescents in south India: the AikyaMind mHealth application

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ABSTRACT

Background: Adolescent mental health disorders affect 7.3% of Indian youth, yet treatment remains inaccessible for over 80%. While digital interventions show promise, their economic feasibility in resource-constrained settings remains unexplored. This study conducted a micro-costing analysis of AikyaMind, a comprehensive mHealth application for adolescent mental health in Karnataka, India.
Methods: Using the activity-based costing-ingredients methodology, we analyzed costs from a provider's perspective over a one-year implementation period (2023-24). Data collection employed structured micro-costing tools capturing direct development, meeting, and training costs. Capital items were annualized using a 3% discount rate. Per-user costs were calculated across utilization scenarios (100-10,000 users). Fiscal impact was assessed against Karnataka's District Mental Health Program budget. One-way sensitivity analysis identified cost drivers.
Results: Total costs were ₹74,548 (US$896), comprising direct development (65.73%), meetings (26.84%), and training (7.43%). App development represented the largest component (₹30,000). Per-user costs demonstrated substantial economies of scale, decreasing from ₹745.48 (100 users) to ₹7.45 (10,000 users)- a 99% reduction. Implementation required only 0.07% of the state mental health budget. Sensitivity analysis revealed that app development costs were the primary driver, causing a variation of ±₹6,000 with a 20% change.
Conclusions: The AikyaMind application demonstrates exceptional economic feasibility for addressing adolescent mental health gaps in LMICs. With a total development cost of less than US$900 and a cost of US$0.09 per user at scale, digital mental health interventions offer financially viable solutions for resource-constrained settings. These findings support the integration of mHealth within existing public health programs to achieve universal health coverage goals.

Keywords: Adolescent mental health, Cost-effectiveness, Digital health economics, India, mHealth, Micro-costing

INTRODUCTION

Mental health disorders among adolescents represent a growing global health crisis, with approximately 10-20% of young people worldwide experiencing mental health conditions.[1] In India, the burden is particularly acute, with the National Mental Health Survey reporting that 7.3% of adolescents suffer from mental disorders, yet less than 20% receive adequate treatment.[2] This substantial treatment gap is exacerbated by limited mental health infrastructure, with only 0.75 psychiatrists per 100,000 population compared to the recommended 3 per 100,000.[3]

The COVID-19 pandemic has further intensified these challenges, with studies reporting a 25% increase in anxiety and depression among young people globally.[4]

Digital mental health interventions, particularly mobile health (mHealth) applications, have emerged as promising solutions to bridge this treatment gap. The proliferation of smartphone usage in India, with 750 million users projected for 2023, and significant penetration among adolescents creates unprecedented opportunities for scalable mental health service delivery.[4] Evidence from high-income countries demonstrates that digital interventions can effectively reduce symptoms of depression and anxiety in adolescents, with effect sizes comparable to face-to-face interventions.[5,6] However, the economic feasibility of implementing such interventions in resource-constrained settings remains understudied, particularly in low- and middle-income countries (LMICs), where 90% of adolescents reside.[7]

The economic evaluation of digital health interventions is crucial for informed policy-making and resource allocation; however, systematic reviews reveal significant gaps in costing evidence from low- and middle-income countries (LMICs). Iribarren et al. found that only 26% of mHealth economic evaluations were conducted in low-income settings, with most focusing on communicable diseases rather than mental health.[8] This evidence gap is particularly pronounced for adolescent-focused interventions, where only 18% of digital mental health studies included economic analyses.[9] Furthermore, existing costing studies often lack methodological rigor, with Le et al noting that fewer than half employ comprehensive micro-costing approaches necessary for accurate budget planning and scalability assessment.[10]

The integration of digital mental health interventions within existing health systems presents both opportunities and challenges. India's National Mental Health Program (NMHP) and Ayushman Bharat Digital Mission provide policy frameworks that support digital health adoption; however, implementation remains fragmented due to unclear cost implications and concerns about sustainability.[11] Previous mHealth implementations in India, such as the ReMiND program for maternal health and ImTeCHO for tribal health, demonstrated cost-effectiveness but focused on different populations and health outcomes.[12,13] The specific costs and resource requirements for adolescent mental health applications remain unexplored, hindering evidence-based scale-up decisions.

Understanding the detailed cost structure of mHealth interventions is essential for multiple stakeholders. For policymakers, accurate costing enables budget allocation and comparison with traditional service delivery models. Program implementers require cost breakdowns to identify efficiency opportunities and plan sustainable financing. For researchers, transparent costing methodology facilitates cross-study comparisons and meta-analyses. The activity-based costing-ingredients (ABC-I) approach, recommended for digital health interventions, provides the granular detail necessary for these diverse applications while enabling sensitivity analyses to identify cost drivers and optimization opportunities.[14]

The present study addressed these critical gaps by conducting a comprehensive micro-costing analysis of the AikyaMind mHealth application, specifically designed for adolescent mental health support in Karnataka, India).[15] This research aimed to determine the total economic costs of developing and implementing the AikyaMind application and to assess its scalability potential by examining cost structures across different user scenarios. By employing rigorous costing methodology and examining integration within existing mental health program budgets, this study provides essential evidence for the economic feasibility of digital mental health interventions in resource-constrained settings. It contributes to the growing body of implementation science literature and offers practical insights for achieving universal health coverage goals by 2030.

METHODS

Study design and setting

A micro-costing analysis using a top-down approach was conducted to determine the economic costs of developing and implementing the AikyaMind mHealth application for adolescent mental health. This approach was selected to capture all resources utilized in the development process, allowing for a detailed examination of cost components and their relative contributions to the total cost. The study was conducted in the Mysore district, Karnataka, India, from 2023 to 2024.

Application development and features

The AikyaMind mobile application was developed using the Flutter framework, with Firebase serving as the backend infrastructure, to provide comprehensive mental health support for adolescents. Key features were: self-screening tools for depression, anxiety, and stress; information, education, and communication (IEC) materials on mental health; online counselling services connecting users with mental health professionals; a meditation tracker for monitoring mindfulness practices; and secure user authentication through phone number and one-time password verification. The application architecture incorporated Firebase authentication for secure login, Cloud Firestore for user data storage, and Firebase real-time database for self-diagnosis scores and progress tracking. The AikyaMind application was designed for and deployed among adolescents residing in the urban and rural Mysore district, Karnataka, where the project was actively implemented.[15] The app aimed to support adolescents in self-managing their mental health

through accessible digital tools and professional guidance.

Costing framework

The current study employed a provider perspective to assess the costs of developing and implementing the AikyaMind application. The time horizon for the analysis encompassed the full development cycle and the initial one-year implementation period. All costs were calculated in Indian Rupees (INR) for the financial year 2023-24, during which the actual development and implementation took place. Cost data were systematically collected and categorized into direct development, meeting, and training costs.

Data collection

Cost data were collected using a microcosting data collection tool adapted from validated digital health costing instruments to capture all direct and indirect costs systematically.[12,13] Primary data sources included project financial records, meeting minutes, purchase receipts, salary information, and semi-structured interviews with key personnel involved in the development process. For shared resources, appropriate apportioning techniques were employed to allocate costs accurately to the AikyaMind project.

Cost categorization and measurement

Direct development costs encompassed app development by the developer team, gap assessment activities, and implementation materials (including printing, as well as information, education, and communication materials). Meeting costs included three key project meetings: project initiation and requirements gathering, pilot testing and changes, and final development and rollout. At each meeting, costs were further categorized into human resources, equipment, furniture, and space. Training costs comprised human resources, furniture and equipment, space, and computer equipment for training sessions. For capital items and durable goods with a lifespan exceeding one year, costs were annualized using a linear depreciation method with a 3% discount rate.

Cost per user analysis

To assess economies of scale and the potential cost-effectiveness of the intervention at different levels of adoption, we calculated the cost per user across various utilization scenarios (100, 500, 1,000, 5,000, and 10,000 users). Total costs were divided by the number of users in each scenario to determine the cost per user.

Fiscal impact analysis

The fiscal impact of implementing the AikyaMind application within the existing National Mental Health Program (NMHP) was assessed by comparing the development and maintenance costs to the Karnataka state budget allocation for mental health (₹1083.30 lakhs for District Mental Health Plan implementation in FY 2023-24).[16] This analysis helped determine the budgetary feasibility of integrating the application into the state's mental health program.

Sensitivity analysis

A one-way sensitivity analysis was conducted to assess the robustness of the costing results to variations in key cost parameters. Each cost component (app development, meeting costs, implementation materials, training costs, and gap assessment) was independently varied by ±20% while holding all other parameters constant. Results were presented in a tornado diagram to visually illustrate the relative impact of each parameter on the total cost. This analysis helped identify the most influential cost drivers and assess the stability of the cost estimates under different assumptions.

Data analysis

All costs were calculated in Indian Rupees (INR) for the 2023-24 fiscal year, during which the actual development and implementation took place. Data were analyzed using Microsoft Excel 2019 for cost calculations and Python 3.8 (matplotlib 3.5.1, pandas 1.4.2) for visualizations of sensitivity analysis. Results were reported as total costs and percentages by category, with detailed breakdowns of each cost component to ensure transparency and reproducibility.

Ethical considerations

The study was approved by the Institutional Ethics Committee of JSS Medical College, JSS Academy of Higher Education and Research, Mysuru (IEC reference number: JSSMC/IEC/05012022/36NCT/2021-22). All stakeholders involved in providing cost information gave informed consent for their participation.

RESULTS

The micro-costing analysis of the AikyaMind mHealth application development and implementation revealed a total cost of ₹74,548. As shown in Table 1, this total was distributed across three primary cost categories: direct development costs (65.73%), meeting costs (26.84%), and training costs (7.43%).

Table 1: Total costs of AikyaMind mHealth application development and implementation.

Cost category	Amount (INR)	%
Direct development costs	49,000	65.73
Meeting costs	20,011	26.84
Training costs	5,537	7.43
Total	74,548	100

Direct development costs

Direct development costs constituted the largest portion of the total budget, accounting for ₹49,000 (65.73%). As detailed in Table 2, these costs primarily comprised app development (₹30,000), implementation materials (₹15,000), and gap assessment (₹4,000).

Table 2: Breakdown of direct development costs.

Item	Cost (INR)	Percentage	Description
App development	30,000	61.22	One-time app development cost by the developer team
Gap assessment	4,000	8.16	Travel and per diem for 2 data collectors
Implementation materials	15,000	30.61	Includes all printing and IEC development costs
Total	49,000	100	

Table 3: Breakdown of meeting costs.

Meeting	Purpose	Cost (INR)	Percentage
Meeting 1	Project initiation and requirements gathering	7,045.00	35.21
Meeting 2	Pilot testing and changes	5,920.33	29.59
Meeting 3	Final development and rollout	7,045.33	35.21
Total		20,011	100

Meeting costs

Meeting costs totaled ₹20,011 (26.84% of total costs), distributed across three key project meetings, as shown in Table 3. Project initiation (meeting 1) and final development (meeting 3) represented approximately equal proportions at 35.21% each, while the pilot testing meeting (meeting 2) accounted for 29.59%.

Each meeting's costs included multiple components, with human resources representing the largest proportion. For meeting 1 (project initiation and requirements gathering), human resources accounted for 86.94% (₹6,125) of the total meeting cost, comprising contributions from an IT professor, a professor of community medicine, and a psychologist. The remaining costs were distributed among furniture (6.67%, ₹470), equipment (4.69%, ₹330), and space (1.70%, ₹120), with all capital items appropriately annualized using a 3% discount rate. This cost structure was representative of all three project meetings, highlighting the knowledge-intensive nature of mHealth app development. Detailed component-wise breakdowns for all meetings, including their annualization calculations, are provided as supplementary files.

Training costs comprised ₹5,537 (7.43% of total costs). These costs primarily consisted of human resources (₹4,200), with smaller allocations for furniture and equipment (₹676), space (₹360), and computer equipment (₹300).

Cost per user analysis

We calculated the cost per user across various user volume scenarios to understand the potential for economies of scale. As shown in Table 4, the per-user cost decreased substantially with increased user numbers, from ₹745.48 for 100 users to just ₹7.45 for 10,000 users.

Table 4: Cost per user at different utilization levels.

Number of users	Total cost (INR)	Cost per user (INR)
100	74,548	745.48
500	74,548	149.10
1,000	74,548	74.55
5,000	74,548	14.91
10,000	74,548	7.45

Fiscal impact analysis

Implementing the AikyaMind mHealth application aligns with the National Mental Health Program (NMHP) objectives and could be efficiently integrated within its existing budgetary framework. Based on the current Karnataka state budget allocation for mental health (₹1083.30 lakhs for District Mental Health Plan implementation in FY 2023-24), the total development cost of AikyaMind (₹74,548) would represent merely 0.07% of the annual budget, with subsequent annual maintenance costs (₹15,000) accounting for only 0.01%. If implemented through the state-specific initiatives and innovations component (allocated ₹103.45 lakhs), the application could achieve the program target of a 5% annual increase in mental health service coverage while requiring minimal financial resources.

Sensitivity analysis

A one-way sensitivity analysis was conducted using a tornado diagram (Figure 1) to assess the robustness of the cost estimates and identify cost drivers with the highest

potential impact. A uniform variation of ±20% was applied to each key cost input. This range was chosen based on standard practice in economic evaluations when empirical uncertainty bounds or confidence intervals are unavailable. The ±20% threshold represents a conservative estimate commonly used in public health cost studies and micro-costing analyses, especially when the costing is retrospective or expert-driven.

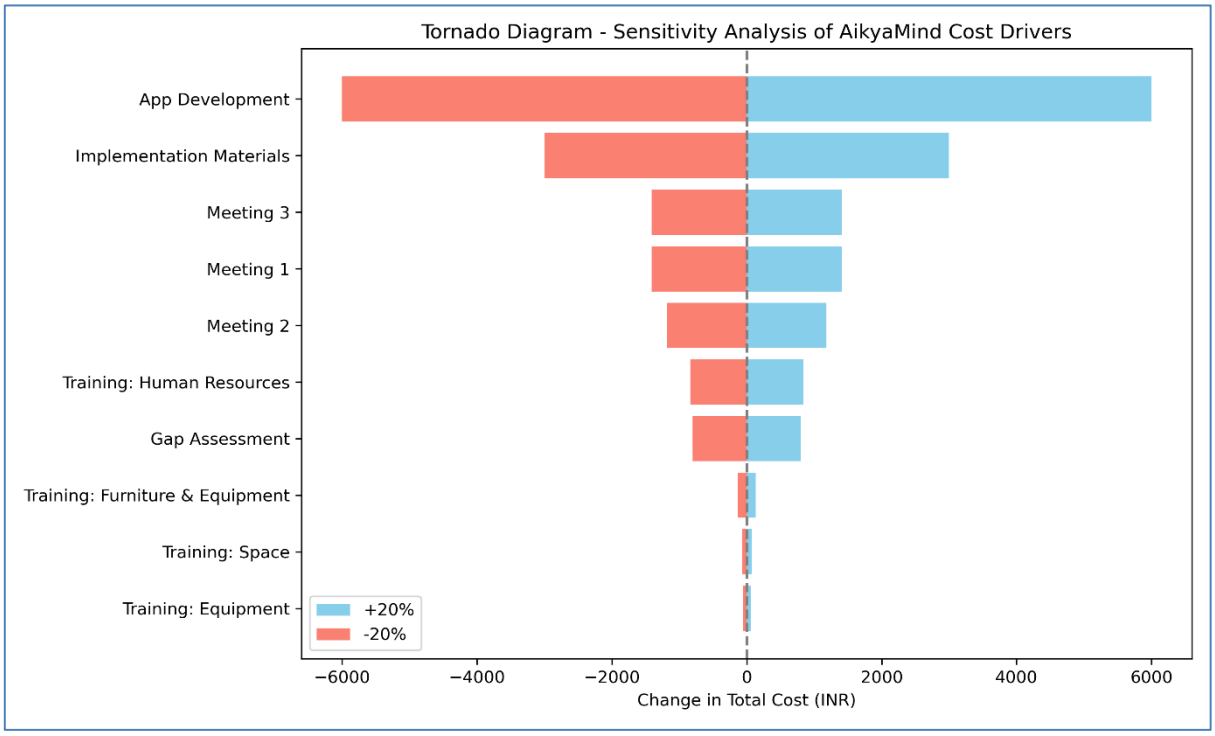

Figure 1: Tornado diagram showing the results of one-way sensitivity analysis for the AikyaMind mHealth application cost components.

The results indicate that the total cost of the AikyaMind mHealth application is most sensitive to variations in app development costs, which caused a fluctuation of over ₹6,000 in either direction from the base case estimate of ₹74,548. Implementation material costs and meeting-related expenses (particularly meeting 1 and meeting 3) were also influential, while training-related expenses (e.g., equipment, space, furniture) had minimal impact on overall cost variation. These findings suggest that targeted development and material procurement process optimization could lead to the greatest potential cost savings. In contrast, financial planning can deprioritize minor components without substantially affecting the total cost. This sensitivity analysis supports more strategic budgeting and informs decision-makers considering scale-up or replication of the intervention in similar settings.

DISCUSSION

This micro-costing analysis of the AikyaMind mHealth application development and implementation revealed a total cost of ₹74,548 (approximately US $896), with direct development costs comprising the largest proportion (65.73%), followed by meeting costs (26.84%) and training costs (7.43%). The per-user cost demonstrated substantial economies of scale, decreasing from ₹745.48 for 100 users to ₹7.45 for 10,000 users. These findings offer crucial insights into the economic viability of implementing digital mental health interventions for adolescents in resource-constrained settings.

The AikyaMind application represents a comprehensive digital mental health platform that incorporates self-screening tools, educational materials, online counselling, and meditation tracking features specifically designed for adolescents. This multi-component approach aligns with emerging evidence on effective digital mental health interventions. Lehtimäki et al found that interventions incorporating human support elements were more effective than fully automated systems, supporting our design choice to include online counselling services that connect users with mental health professionals.[17] Similarly, Zhou et al demonstrated that 64% of online mental health interventions effectively managed depression, anxiety, and stress among youth, particularly when delivered through integrated platforms combining multiple therapeutic modalities.[18]

Our application's use of Firebase infrastructure and Flutter framework reflects current best practices in mHealth development. The emphasis on secure authentication and data protection addresses critical concerns raised by Jones et al, who highlighted data security as a major challenge in adolescent digital mental

health implementations.[19] Furthermore, the inclusion of culturally adapted content and local language support responds to limitations identified by Madonsela et al. in their review of adolescent mental health interventions in low- and middle-income countries (LMICs).[20]

Our total development cost of ₹74,548 (approximately US $896) is substantially lower than that of comparable mHealth interventions reported in the literature. Joshi et al reported development costs of US$208,814 for a digital training program for community health workers in rural India, with human resources accounting for 61% of the total costs. In contrast, our human resources costs, primarily reflected in meeting expenses, represented only 26.84% of total costs, suggesting a more efficient development process.[21]

The cost structure differs markedly from that of Tully et al., who found that mHealth approaches for pediatric weight management cost €722 per adolescent, compared to €142 for usual care. Our per-user costs, even at the lowest utilization scenario (₹745.48 for 100 users), translate to approximately €8.20, representing a 98% reduction in cost. This dramatic difference likely reflects our focus on preventive mental health support rather than intensive clinical intervention, as well as the lower cost base in India.[22]

Prinja et al. conducted a micro-costing analysis of the ReMiND mHealth program in Uttar Pradesh, reporting annual implementation costs of INR 12.1 million for maternal and child health services. Their per-capita cost of INR 31.4 is higher than our projected cost of INR 7.45 per user at scale despite serving a different population.[13] This comparison highlights the cost-effectiveness potential of adolescent-focused mental health interventions, which require less intensive monitoring than maternal health programs.

Our analysis demonstrates significant economies of scale, with per-user costs decreasing by 99% from 100 to 10,000 users. This finding aligns with that of Larsen-Cooper et al, who demonstrated a 48% potential reduction in cost per user at full capacity for a mHealth intervention in Malawi.[23] However, our projected cost reductions are more substantial, likely due to the predominantly fixed nature of app development costs and minimal variable costs associated with digital mental health delivery.

The scalability potential is further supported by Modi et al, who demonstrated the cost-effectiveness of the ImTeCHO mHealth intervention, with an incremental cost of US$ 74 per life-year saved. While a direct comparison is challenging due to the different health outcomes, both studies highlight the favourable economics of digital health interventions at scale. Importantly, our sensitivity analysis revealed that app development costs were the primary cost driver, suggesting that investments in robust initial development yield greater returns as user numbers increase.[12]

The fiscal impact analysis demonstrates exceptional alignment with existing health system budgets. At 0.07% of Karnataka's District Mental Health Plan budget, the AikyaMind application represents a minimal financial burden while potentially achieving the National Mental Health Program's target of a 5% annual increase in service coverage. This finding aligns with Prinja et al, who demonstrated the cost-effectiveness of integrating mHealth within existing health systems, reporting cost savings from a societal perspective.[13]

The low maintenance costs (₹15,000 annually, representing 0.01% of the state mental health budget) compare favourably with traditional mental health service delivery models. Ben-Zeev et al found that mHealth interventions for serious mental illness cost approximately half as much as clinic-based treatment while producing comparable outcomes.[24] Our even lower cost structure, combined with the preventive focus on adolescent mental health, suggests the potential for substantial long-term cost savings through early intervention.

Our sensitivity analysis identified app development as the primary cost driver, consistent with Shukla et al, who found that 55% of the total costs for large-scale mHealth interventions were device-related in the first year.[14] However, our infrastructure costs were substantially lower due to cloud-based deployment rather than device distribution. This methodological difference highlights the importance of technology choices in determining intervention costs.

The use of the activity-based costing-ingredients (ABC-I) methodology, as recommended by Shukla et al, enabled detailed cost attribution.[14] Our approach of annualising capital costs using a 3% discount rate aligns with standard health economic evaluation practices.[25] The transparency in cost reporting, with detailed breakdowns of all components, addresses quality concerns raised by Iribarren et al, who found that only 79.6% of CHEERS checklist items were typically reported in mHealth economic evaluations.[26]

The AikyaMind study provides crucial evidence for the implementation of digital mental health in LMICs, addressing a significant gap identified by Stanić et al, who found a lack of economic evaluations from low-resource settings.[9] Our costs are orders of magnitude lower than those reported from high-income countries while maintaining comprehensive functionality. This finding challenges the assumption that effective digital health interventions require substantial investment.

The predominance of development costs (65.73%) over operational costs suggests a favourable model for resource-constrained settings, where initial donor funding or government investment can lead to sustainable interventions with minimal ongoing expenses. This contrasts with Connolly et al, who highlighted ongoing

support costs as a significant barrier to the implementation of digital mental health in clinical settings.[27]

While our study provides comprehensive cost data, several limitations merit consideration. First, we did not include costs associated with user acquisition, marketing, or long-term technical support, which may be necessary for sustained implementation. Second, our analysis focused on provider perspective costs, excluding potential user-side costs such as data charges or device requirements, which Feroz et al identified as significant barriers in low- and middle-income countries (LMICs).[28]

The one-year implementation timeframe may not capture all relevant costs, particularly those related to content updates, platform modifications, or scaling challenges. Future studies should incorporate longer follow-up periods and include effectiveness data to enable full cost-effectiveness analysis, as recommended by Le et al for mental health prevention interventions.[10]

CONCLUSION

This micro-costing analysis demonstrates that comprehensive digital mental health interventions for adolescents can be developed and implemented at remarkably low costs in low- and middle-income country (LMIC) settings. The AikyaMind application, with a total development cost of less than US $900 and a cost of US $0.09 per user at scale, represents a financially viable approach to addressing the substantial mental health treatment gap among adolescents. The favourable comparison with existing interventions, combined with the potential for seamless integration within current health system budgets, supports the scalability and sustainability of this approach. These findings provide essential evidence for policymakers and program planners considering digital mental health investments, particularly in resource-constrained settings where traditional mental health services remain inaccessible to most adolescents.

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