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Postprint of a Study on the Effects of Health Coaching Technology Combined with Wearable Devices on Glycolipid Metabolism and Self-Management Behaviors in Patients with Type 2 Diabetes

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Abstract

Background: Type 2 diabetes mellitus (T2DM) has become a global public health burden. With the rapid development of internet and digital technologies, intelligent service models play an important role in the management of T2DM patients.

Objective: To investigate the efficacy of wearable devices combined with health coaching technology in patients with T2DM.

Methods: A total of 315 T2DM patients hospitalized at the Second Affiliated Hospital of Nanchang University from June 2020 to June 2021 were enrolled as study participants. Using the random number table method, patients were divided into a control group, intervention group A, and intervention group B. The control group received conventional management based on capillary blood glucose monitoring; intervention group A used wearable devices for conventional management; intervention group B used wearable devices combined with health coaching technology for management. Differences in glycemic control, lipid control, and self-management behavior among the three groups were compared before intervention and at 3, 6, 9, and 12 months after intervention.

Results: During the study period, 15 cases were lost to follow-up, and 300 study subjects were finally included in the analysis, with 100 cases in each of the three groups. There was an interaction effect between intervention method and time on 2-hour postprandial glucose (2 hPG), glycated hemoglobin (HbA1c), frequency of hypoglycemia, high-density lipoprotein cholesterol (HDL-C), Type 2 Diabetes Self-Care Behavior (2-DSCS) and Summary of Diabetes Self-Care

Activities (SDSCA) scores (P<0.05). The main effect of intervention method was significant for the number of hypoglycemia cases, total cholesterol (TC), HDL-C, 2-DSCS and SDSCA scores (P<0.05). Except for the frequency of hypoglycemia, the main effect of time was significant for all indicators (P<0.05). The levels of HbA1c, fasting blood glucose (FBG), 2 hPG, and TC at 3, 6, 9, and 12 months after intervention were lower than pre-intervention levels within the same group, and the 2-DSCS and SDSCA scores were higher than pre-intervention levels within the same group (P<0.05). After 3 months of intervention: the frequency of hypoglycemia in intervention group B was lower than that in intervention group A and the control group; the HDL-C level and SDSCA score in intervention group B were higher than those in the control group (P<0.05). After 6 months of intervention: the 2 hPG and TC levels in intervention group B were lower than those in the control group; the HDL-C levels, 2-DSCS scores, and SDSCA scores in intervention group A and intervention group B were higher than those in the control group; the SDSCA score in intervention group B was higher than that in intervention group A (P<0.05). After 9 months of intervention: the FBG, 2 hPG, and TC levels in intervention group B were lower than those in the control group; the FBG and 2 hPG levels in intervention group B were lower than those in intervention group A; the HDL-C level, 2-DSCS score, and SDSCA score in intervention group B were higher than those in the control group; the 2-DSCS score and SDSCA score in intervention group B were higher than those in intervention group A (P<0.05). After 12 months of intervention: the FBG, 2 hPG, HbA1c, TC, and low-density lipoprotein cholesterol (LDL-C) levels in intervention group B were lower than those in the control group; the FBG, 2 hPG, and HbA1c levels in intervention group B were lower than those in intervention group A; the HDL-C level, 2-DSCS score, and SDSCA score in intervention group B were higher than those in the control group and intervention group A (P<0.05).

Conclusion: Wearable devices combined with health coaching technology have both short-term and long-term effects on improving comprehensive glycemic and lipid control status and enhancing self-management ability in T2DM patients.

Full Text

Effects of Health Coaching Combined with Wearable Devices on Glucose and Lipid Metabolism and Self-Management Behavior in Patients with Type 2 Diabetes Mellitus

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Abstract

Background Type 2 diabetes mellitus (T2DM) has become a major global public health burden. With the rapid development of internet and digital technologies, intelligent service models play an increasingly important role in T2DM patient management. **Objective** To explore the effectiveness of wearable devices combined with health coaching in patients with T2DM. **Methods** A total of 315 T2DM patients hospitalized at the Second Affiliated Hospital of Nanchang University from June 2020 to June 2021 were enrolled and divided into three groups using a random number table method: a control group receiving routine management based on capillary blood glucose monitoring, an intervention A group managed with wearable devices alone, and an intervention B group managed with wearable devices combined with health coaching. Differences in glycemic control, lipid profiles, and self-management behaviors were compared among the three groups before intervention and at 3, 6, 9, and 12 months post-intervention. **Results** Fifteen patients were lost to follow-up during the study, leaving 300 participants for final analysis (100 per group). Significant intervention method × time interactions were observed for 2-hour postprandial glucose (2 hPG), glycated hemoglobin (HbA1c), number of hypoglycemic episodes, high-density lipoprotein cholesterol (HDL-C), 2-DSCS scores, and SDSCA scores ($P<0.05$). The intervention method showed significant main effects on the number of hypoglycemic episodes, total cholesterol (TC), HDL-C, 2-DSCS scores, and SDSCA scores ($P<0.05$). Time showed significant main effects on all indicators except hypoglycemic episode frequency ($P<0.05$). At 3, 6, 9, and 12 months post-intervention, HbA1c, fasting blood glucose (FBG), 2 hPG, and TC levels were lower than baseline, while 2-DSCS and SDSCA scores were higher than baseline in all groups ($P<0.05$). At 3 months: intervention B group had fewer hypoglycemic episodes than both intervention A and control groups, and higher HDL-C and SDSCA scores than the control group ($P<0.05$). At 6 months: intervention B group showed lower 2 hPG and TC levels than the control group; both intervention A and B groups had higher HDL-C, 2-DSCS, and SDSCA scores than the control group; intervention B group had higher SDSCA scores than intervention A group ($P<0.05$). At 9 months: intervention B group demonstrated lower FBG, 2 hPG, and TC levels than the control group, lower FBG and 2 hPG than intervention A group, and higher HDL-C, 2-DSCS, and SDSCA scores than the control group; intervention B group also had higher 2-DSCS and SDSCA scores than intervention A group ($P<0.05$). At 12 months: intervention B group exhibited lower FBG, 2 hPG, HbA1c, TC, and LDL-C levels than the control group, lower FBG, 2 hPG, and HbA1c than intervention A group, and higher HDL-C, 2-DSCS, and SDSCA scores than both control and intervention A groups ($P<0.05$). **Conclusion** The combination of wearable devices and health coaching demonstrates both short-term and long-term effectiveness in improving comprehensive glycemic and lipid control while

enhancing self-management capabilities in T2DM patients.

Keywords Diabetes mellitus, type 2; Wearable devices; Continuous glucose monitoring; Health coaching; Glucose control; Treatment outcome

Introduction

Currently, China has 164 million people with diabetes, with over 140 million adults suffering from type 2 diabetes mellitus (T2DM) among a population of 1.08 billion adults [1]. Poor glycemic control and high glycemic variability both increase the risk of diabetic microvascular and macrovascular complications, leading to increased economic burden and severely impacting quality of life [2-3]. Continuous glucose monitoring (CGM), as a member of the wearable device family, plays an important role in reducing patient pain and facilitating clinical work by continuously monitoring interstitial fluid glucose and dynamically reflecting glycemic variability and fluctuation amplitude through its characteristic dynamic glucose profiles [4-5].

Health coaching technology refers to an approach conducted within a coach-patient relationship [6] that implements eight fundamental steps including connecting, observing, reinforcing, clarifying, assisting, encouraging, educating, and guiding [7] to enhance patients' self-monitoring behaviors and motivate self-discovery or active learning to achieve individualized goals collaboratively [8]. Health coaching has been widely applied in weight management for overweight and obese patients [9], exercise rehabilitation for cancer patients [10], and remote health guidance for rural veterans [11], all demonstrating positive outcomes. Integrating CGM into health coaching technology to drive knowledge cognition and behavioral change processes offers tremendous potential advantages for creating sustainable behavioral changes and improving self-management capabilities. However, few studies have evaluated whether combining health coaching technology with CGM can improve clinical outcomes in T2DM patients. Therefore, this study aims to assess the effectiveness of CGM combined with health coaching technology in improving glycemic and lipid indicators and self-management capabilities in T2DM patients.

Methods

1.1 Study Participants Using convenience sampling, T2DM patients hospitalized at the Second Affiliated Hospital of Nanchang University from June 2020 to June 2021 were selected as study participants. Inclusion criteria were: (1) patients diagnosed with T2DM according to 1999 WHO classification criteria; (2) disease duration >1 year; and (3) ability to use digital information tools proficiently. Exclusion criteria included: (1) other types of diabetes; (2) severe cardiovascular or cerebrovascular diseases; (3) abnormal renal function; (4) psychiatric disorders; and (5) pregnancy, lactation, or planned pregnancy. Baseline demographic data including gender, age, education level, disease duration, marital status, treatment modality, family monthly income, and occupation were collected before intervention implementation.

Patients were divided into three groups using a random number table method: a control group receiving routine management based on capillary blood glucose monitoring, an intervention A group managed with wearable devices, and an intervention B group managed with wearable devices combined with health coaching technology. The study was approved by the Ethics Committee of the Second Affiliated Hospital of Nanchang University (2nd NCU 2023-04-13).

1.2 Intervention Measures **1.2.1 Control Group:** Capillary blood glucose monitoring was performed $ $5 times daily, with researchers recording each measurement.

1.2.2 Intervention Groups: In intervention group A, research staff installed CGM for patients. The CGM automatically recorded glucose values every 15 minutes, and researchers obtained real-time readings by scanning a sensor worn on the patient' s upper arm using a scanning detector. In intervention group B, patients received CGM installation for glucose monitoring plus health coaching-based glucose management. The health coaching implementation steps were as follows: (1) **Connecting:** Team members communicated with diabetic patients, introduced the study content and objectives, comprehensively understood patients' general information and current diabetes-related cognitive behaviors, informed patients about the close relationship between diabetes knowledge/behaviors and disease progression, and awakened health management awareness. (2) **Observing:** Detailed patient information was collected to construct patient profiles, analyze weak links in disease knowledge mastery and unhealthy behavioral patterns. A WeChat group was established requiring patients to upload daily glucose information, diet, and exercise status. (3) **Reinforcing:** Face-to-face or voice guidance was used to reinforce behavioral management. Diabetes disease knowledge, diet, exercise, and medication information were pushed to patients via WeChat, encouraging them to establish disease management goals and develop management plans. (4) **Clarifying:** Researchers closely monitored patients'daily uploaded glucose, diet, and exercise information to promptly identify potential health problems. When significant deviations from target glucose values, unreasonable dietary structures, inadequate exercise behaviors, or medication non-compliance occurred, timely communication was conducted face-to-face or online to understand problems in glucose management and provide health guidance. (5) **Assisting:** The power of team members including endocrine treatment specialists and specialist nurses was fully utilized to integrate social resources and provide help for patients. If severe diabetic complications or hypoglycemia and other critical situations occurred, family members could directly seek help from health coaches by phone. (6) **Encouraging:** Positive behavioral changes achieved by patients were promptly affirmed, patients were encouraged to express emotions and feelings, and they were guided to experience the benefits brought by behavioral changes and knowledge improvement. (7) **Educating:** Regular online and offline diabetes knowledge and skill education sessions were conducted, supplemented by distribution of diabetes educational videos in WeChat groups. Additionally, mental health lectures were actively conducted to promote patients' psychological well-being. (8) **Guiding:** Individualized health plans were formulated, patients were contacted regularly, and they were guided to realize that only by improving disease knowledge and enhancing behavioral management could better glycemic control be achieved.

1.3 Outcome Measures **1.3.1 Primary Outcomes:** Fasting blood glucose (FBG), 2-hour postprandial glucose (2 hPG), glycated hemoglobin (HbA1c), and number of hypoglycemic episodes were measured at baseline (T0), 3 months (T1), 6 months (T2), 9 months (T3), and 12 months (T4) post-intervention.

1.3.2 Secondary Outcomes: (1) Lipid indicators including total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). (2) 2-DSCS score: This scale evaluates patients' self-management level across six dimensions including diet, exercise, medication, blood glucose monitoring, foot care, and hyperglycemia management, comprising 26 items [12]. A 5-point Likert scale was used (1-5 points), with scores ranging from 26-130. Higher scores indicate better self-management. The scale had good validity (content validity = 0.89) and reliability (Cronbach' s $\alpha = 0.80$). (3) SDSCA score: The SDSCA scale developed by TOOBERT et al. [13] has been widely used. The Chinese version used in this study was translated by WAN Qiaoqin et al. [14], including six dimensions (general diet, special diet, exercise, blood glucose monitoring, foot care, and medication) with 11 items. Scores of 0-7 represent the number of days or average days these items were completed within one week, with total scores ranging from 0-77. Higher scores indicate better self-management capability. The overall Cronbach' s α coefficient was 0.62, sub-dimension coefficients ranged from 0.70-0.89, and scale validity was 0.92.

1.4 Statistical Analysis Data were analyzed using SPSS 26.0 statistical software. Normality tests were performed. Normally distributed continuous data were described as ($\bar{x}\pm s$), otherwise as M(QR). Baseline differences among the three groups were compared using one-way ANOVA, with LSD-t tests for multiple comparisons. Multivariate repeated measures ANOVA and generalized estimating equations with covariates were used for repeated measures analysis to explore group differences and time differences in outcome variables. $P<0.05$ was considered statistically significant.

Results

2.1 Baseline Characteristics Fifteen patients were lost to follow-up during the study, with 300 participants ultimately included in the analysis (100 per group). There were no statistically significant differences among the three groups in gender, age, disease duration, occupation, education level, treatment modality, marital status, or family monthly income ($P>0.05$) .

2.2 Primary Outcomes No significant intervention method × time interaction was found for FBG ($P>0.05$), and the main effect of intervention method on FBG was not significant ($P>0.05$), while the main effect of time on FBG was significant ($P<0.001$). At T3 and T4, the FBG level in intervention group B was lower than in intervention group A and the control group ($P<0.05$) .

A significant intervention method × time interaction was observed for 2 hPG ($P<0.05$), while the main effect of intervention method on 2 hPG was not significant ($P>0.05$), and the main effect of time was significant ($P<0.001$). At T2, T3, and T4, 2 hPG levels in intervention group B were lower than the control group; at T3 and T4, 2 hPG in intervention group B was lower than intervention group A ($P<0.05$) .

A significant intervention method × time interaction was found for HbA1c ($P<0.05$), while the main effect of intervention method was not significant ($P>0.05$), and the main effect of time was significant ($P<0.001$). At T3, HbA1c in intervention group B was higher than intervention group A; at T4, HbA1c in intervention group B was lower than both intervention group A and the control group, while intervention group A had lower HbA1c than the control group ($P<0.05$) .

A significant intervention method × time interaction was observed for hypoglycemia frequency ($P<0.05$), while the main effects of intervention method and time were not significant ($P>0.05$). At T1, hypoglycemia episodes in intervention group B were lower than in intervention group A and the control group; at T4, hypoglycemia episodes in intervention group B were higher than the control group ($P<0.05$) .

2.3 Secondary Outcomes **2.3.1 Lipid Indicators:** No significant intervention method × time interaction was found for TC ($P>0.05$), while the main effect of intervention method on TC was significant ($P<0.05$) and the main effect of time was significant ($P<0.001$). At T2, TC levels in intervention group B were lower than the control group; at T3 and T4, TC levels in both intervention groups A and B were lower than the control group ($P<0.05$) .

No significant intervention method × time interaction was observed for TG ($P>0.05$), with no significant main effect of intervention method ($P>0.05$) but a significant main effect of time ($P<0.001$) .

No significant intervention method × time interaction was found for LDL-C ($P>0.05$), with no significant main effect of intervention method ($P>0.05$) but a significant main effect of time ($P<0.001$). At T4, LDL-C levels in intervention group B were lower than the control group ($P<0.05$) .

A significant intervention method × time interaction was observed for HDL-C ($P<0.05$), with significant main effects of both intervention method ($P<0.05$) and time ($P<0.001$). At T1, HDL-C in intervention group B was higher than the control group; at T2, T3, and T4, HDL-C in both intervention groups A and B were higher than the control group; at T4, HDL-C in intervention group B was higher than intervention group A ($P<0.05$) .

2.3.2 Scale Scores: A significant intervention method × time interaction was found for 2-DSCS scores ($P<0.05$), with significant main effects of both intervention method ($P<0.001$) and time ($P<0.001$). At T2, T3, and T4, 2-DSCS scores in both intervention groups A and B were higher than the control group; at T3 and T4, 2-DSCS scores in intervention group B were higher than intervention group A ($P<0.05$) .

A significant intervention method × time interaction was observed for SDSCA scores ($P<0.05$), with significant main effects of both intervention method ($P<0.001$) and time ($P<0.001$). At T1 and T2, SDSCA scores in intervention group A were higher than the control group ($P<0.05$). At T1, T2, T3, and T4, SDSCA scores in intervention group B were higher than the control group; at T2, T3, and T4, SDSCA scores in intervention group B were higher than intervention group A ($P<0.05$) .

Discussion

This study demonstrates that the intervention combining health coaching technology with CGM was significantly more effective than both the control group and the CGM-only group, consistent with previous research findings [15]. WADA et al. [16] reported in a 24-week multicenter randomized controlled study that compared with self-monitoring of blood glucose (SMBG), the CGM group showed significantly reduced mean glucose levels, mean amplitude of glycemic excursions, and duration of hyperglycemia. These results relate to CGM' s ability to directly visualize patients' glycemic control and variability, analyze treatment intervention effectiveness, and promote behavioral changes in T2DM patients. This aligns with our observation that at follow-up conclusion, the CGM-only group had lower HbA1c levels than the control group, while the health coaching plus CGM group showed significantly better glycemic control than the CGM-only group. However, HAAK et al. [17] conducted a 6-month randomized controlled trial showing that CGM could significantly reduce hypoglycemia incidence but did not significantly improve HbA1c levels. Our results differ, but the significant improvements in intervention group B are directly attributable to the application of health coaching technology. Through detailed data interpretation by health coaches and support provided when patients encounter personal difficulties, health coaches play an equally important role in generating positive self-management outcomes [23]. The dual incentive mechanism created by CGM combined with health coaching technology for patients may produce more significant positive effects than single approaches in motivating patients to set goals, observe data, and adjust lifestyle plans.

T2DM patients often have lipid metabolism disorders and dyslipidemia, leading to pancreatic β-cell damage and exacerbating insulin resistance. This study shows that HDL-C and LDL-C levels improved significantly across all three groups, with clinically valuable results, as reducing lipid levels in T2DM patients is associated with decreased risks of microvascular and macrovascular complications and mortality [19]. Dietary adjustment is an indispensable component of lipid control in T2DM patients. Implementing health coaching technology-based interventions can effectively guide patients to consume high-fiber, low-saturated-fat, and low-cholesterol foods, while health coaches also encourage physical exercise for weight control under safe conditions [20]. Additionally, CGM dynamic data can demonstrate how food intake with different glycemic loads affects glucose responses, which helps improve nutrition and physical activity behaviors [21]. Our results also confirm that individualized interventions using data captured by CGM monitoring devices are more effective than conventional interventions using patient-reported data [22]. Therefore, integrating health coaching technology with CGM technology greatly improves lipid control status in T2DM patients with long-term effectiveness.

This study also confirms the innovative model of CGM combined with health coaching technology demonstrates significant effectiveness in improving self-management capabilities and promoting changes in self-management behaviors in T2DM patients, with self-management scores increasing significantly over time post-intervention. These findings align with YOUNG et al. [23], who reported that health coaching combined with mobile health technology improved self-efficacy and increased physical activity days in T2DM patients. CGM's real-time glucose data observation and Ambulatory Glucose Profile (AGP) reporting provide objective views of daily activities [24], triggering behavior change and goal achievement motivation through observing immediate glucose changes and feedback following physical activity and behavioral patterns. Interveners can provide reinforced behavioral change interventions based on health data feedback loops to improve health outcomes in T2DM patients. Furthermore, the relationship between health coaches and participants plays a crucial role, as health coach-led diabetes education enables patients to clearly recognize specific behaviors that lead to diabetes deterioration and poor health outcomes, and empowers them to choose to avoid risky behaviors under health coach guidance [18].

Study limitations include the use of convenience sampling, lack of blinding, and self-reported secondary outcome scores, which may introduce selection bias, social desirability bias, and Hawthorne effects. In summary, wearable devices combined with health coaching technology demonstrate both short-term and long-term effectiveness in improving comprehensive glycemic and lipid control status and enhancing self-management capabilities in T2DM patients, providing a foundation for further achieving lifelong health for T2DM patients.

Author Contributions: GAO Yuan was responsible for literature search, study conception and design, statistical analysis, results interpretation, and drafting the manuscript. ZHOU Min was responsible for study conception and design, quality control and review, and overall responsibility for the article. QIN Manfen and XU Xuan were responsible for data collection and statistical analysis. YANG Liping, FU Yahong, HUANG Ying, and WANG Wei were responsible for data collection and organization.

Conflict of Interest: The authors declare no conflict of interest.

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