MEDS Clinical Medicine (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/medsc.2024.050507
ISSN 2616-1907 Vol. 5 Num. 5

A review of innovative technology in chronic disease

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Keywords: Health utilization, COVID-19, Noncommunicable diseases, Innovative technology

Abstract: The COVID-19 pandemic has posed significant challenges for individuals with chronic non-communicable diseases (NCDs), disrupting traditional healthcare access. This study explores the impact of telemedicine and mobile applications on managing chronic NCDs during the pandemic, focusing on their roles in improving care, reducing exposure risks, and empowering patients. The aim was to evaluate the outcomes of innovative technologies on healthcare utilization, health behavior, disease outcomes, and readmission rates during the early phase of the pandemic. A systematic review was conducted, analyzing studies published after the global spread of the disease, with a focus on telemedicine and remote monitoring technologies. The review included experimental and quasi-experimental studies, following PRISMA guidelines. Out of 664 records, five studies met the inclusion criteria, all showing positive effects on chronic NCD management. The findings suggest that telemedicine and mobile applications significantly enhanced disease control, particularly through remote monitoring. However, disparities in adoption and technical barriers remain, emphasizing the need for targeted efforts to address socio-economic, educational, and geographical inequalities to ensure equitable and effective management of chronic NCDs.

1. Introduction

Chronic non-communicable diseases (NCDs) represent a formidable global health challenge, significantly impacting morbidity and mortality worldwide. The prevalence of NCDs such as heart disease, cancer, diabetes, and chronic respiratory conditions has steadily increased, owing to a complex interplay of genetic, environmental, and lifestyle factors[1]. The global burden of NCDs is staggering. In 2014, NCDs accounted for over two-thirds (38 million) of global deaths. By 2019, this figure had risen to approximately 74% of the 55 million deaths worldwide, underscoring the urgent need for effective prevention and management strategies[2] .

The far-reaching consequences of NCDs extend beyond individual health to impact entire communities, healthcare systems, and societies[3,4]. These conditions lead to long-lasting impairments, diminished quality of life, and substantial financial strain, both for individuals and for healthcare providers[5]. The COVID-19 pandemic has further exacerbated the challenges faced by individuals with NCDs, as disrupted healthcare systems and limited access to essential services have hindered disease management and increased the risk of complications[6-10] .

The COVID-19 pandemic exacerbated the challenges faced by individuals with NCDs. Prior to

the pandemic, effective management of NCDs required continuous and comprehensive care to avoid prospective complications, delay disease progression, and reduce healthcare needs[11]. However, the global health crisis in 2020 disrupted routine care, strained healthcare systems, and disproportionately impacted those with chronic conditions, creating a perfect storm of challenges for these vulnerable populations[5].

Innovative approaches became essential in healthcare delivery, especially for patients with NCDs [12,13]. Telemedicine and digital health emerged as promising solutions, offering enhanced accessibility, improved patient-provider interaction, and streamlined disease management[14]. Telemedicine and digital tools are widely used as common examples. Their popularity has enabled continuous monitoring of chronic conditions even during lockdowns[12,15]. The help of a full remote device provides real-time data, to help adjust the treatment plan and effective management of symptoms[16-18]. In addition, remote medical treatment by allowing remote health platforms and consulting experts, expanded the patients' medical service access to remote or insufficient service areas[19].

However, challenges remain, including limited access to technology, inadequate digital literacy, and technical issues that compromise the effectiveness of telemedicine solutions[19]. Despite these challenges, studies have consistently shown that telemedicine and digital technologies are effective in managing chronic diseases during the pandemic, helping to improve health outcomes such as blood glucose control and hypertension management. Nevertheless, the implementation and long-term impact of these innovative technologies on health management and quality of life require further investigation.

While numerous studies have explored the potential benefits of these technologies, inconsistencies in methodology and application have hindered definitive conclusions. Variations in study design, sample size, patient characteristics, and follow-up periods have contributed to the uncertainty surrounding the overall effectiveness and limitations of innovative technologies in NCD care[16-18,20,21] .

To address these gaps and provide a comprehensive understanding of the impact of innovative technology on NCD management during the pandemic, a systematic review is essential[20,22-24]. By synthesizing the existing evidence, this review will contribute to informed decision-making, guide future research, and ultimately improve the quality of care for individuals with NCDs.

2. Methodology

2.1 Acceptance criteria

Inclusion was based on the following criteria: (1) no restrictions on age or gender, (2) individuals diagnosed with chronic NCDs, (3) an intervention group (IG)utilizing innovative technology and a control group(CG) receiving usual care, (4) randomized controlled trials (RCTs), qualitative analyses, and mixed-method studies, and (5) peer-reviewed journal publications.

The criteria for exclusion were as follows: (1) studies on acute communicable diseases, outdated research, or those lacking technical innovation or focused on traditional medicine; (2) studies reporting increased return rates, re-hospitalizations, or mortality; feasibility studies, case reports, and qualitative inquiries; (3) documents such as policy summaries, research methodologies, reports from organizations, opinion pieces, systematic reviews, and oral presentations.

2.2 Searching strategies

An initial search was conducted across multiple databases, including PubMed, CINAHL, Cochrane, Scopus, ProQuest, Google Scholar, and CNKI, to identify relevant articles. The search

covered publications from the establishment of the databases through December 2019 to 2023, with language restricted to English and Chinese.

We organized the search according to the PICO framework:

(a) Population: The focus was on NCDs, using terms like 'Non-communicable Disease,' 'Chronic Disease,' and specific conditions such as 'heart diseases,' 'Diabetes Mellitus,' 'Neoplasm,' 'cerebrovascular disorders,' 'asthma,' 'pulmonary disease chronic obstructive,' and 'Hypertension.' 'COVID-19' terms were also included for pandemic-related studies.

(b) Intervention: We targeted studies involving innovative technologies, using terms such as 'multimedia,' 'digital,' 'eHealth,' 'mHealth,' and specific platforms like 'social media,' 'mobile devices,' 'smartphones,' 'applications,' 'software,' 'videos,' 'podcasts,' and 'chatbots.'

(c) Comparison: The comparison focused on healthcare services utilization, with terms like 'Health Service,' 'Self-Care,' 'Patient Compliance,' and 'Medication Adherence.'

(d) Outcomes: The outcomes of interest included self-care, patient compliance, medication adherence, health behavior, and overall healthcare service utilization and access.

2.3 Study selection

Titles and abstracts were examined independently by two researchers based on the established criteria. The complete texts of the chosen studies were carefully examined to ensure a comprehensive understanding of their findings. Any differences of opinion among the researchers were addressed through discussion until a consensus was achieved. This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines[25], maintaining rigorous standards for both the systematic review and meta-analysis.

2.4 Data extraction

An Excel sheet was created to facilitate data gathering. Data was extracted from each article by two authors working separately, resolving discrepancies through discussion and consensus. If further clarification was needed, a senior author was consulted to make the final decision. To avoid duplication, data were cross-checked based on recruitment location and year, with only the larger data set included in the final analysis. Data were gathered from various sources, including graphs, tables, text, and supplementary materials.

For each study, details about the intervention were recorded, such as the number of sessions, frequency, follow-up duration, and control protocol. Study characteristics documented included the first author's name, publication year, study design, recruitment period, research area, sample size (overall and per group), and inclusion and exclusion criteria. Additionally, participant characteristics and study outcomes were collected, noting the measurement tools used and the primary and secondary outcome scores at baseline and post-intervention, as shown in appendix 1.

2.5 Assessment of study quality and potential biases

Standardized assessment tools from the Joanna Briggs Institute (JBI) were used to appraise eligible randomized controlled trials (RCTs) and non-randomized experimental studies. Two independent reviewers conducted the assessments. RCTs were required to meet at least 7 out of 13 criteria for a 'yes' response, and non-randomized studies required at least 5 out of 8 criteria. Conflicts were addressed through discussion, and a third reviewer was consulted if needed to achieve agreement.

2.6 Critical Appraisal of Studies

We performed a rigorous evaluation of the selected randomized controlled trials (RCTs) and quasi-experimental studies to assess their quality and dependability.

(a) RCTs

• Pamungkas et al., 2022: 10/13 criteria met.
• Papandreou et al., 2021: 10/13 criteria met.
• Alsaqer et al., 2022: 11/13 criteria met.
• Mahoney et al., 2022: 11/13 criteria met.

Overall, the studies generally performed well on most criteria, with high scores in areas such as randomization and follow-up, though some studies had limitations in blinding and treatment delivery.

(b) Quasi-Experimental Studies

• Y. H. Khan et al., 2022: 6/8 criteria met.

This study showed strengths in sample definition, setting description, and measurement validity but lacked in addressing confounding factors.

2.7 Data Synthesis

The findings are presented and discussed narratively, supplemented with tables and figures where relevant to enhance data presentation.

3. Results

3.1 Study Features of Included Research

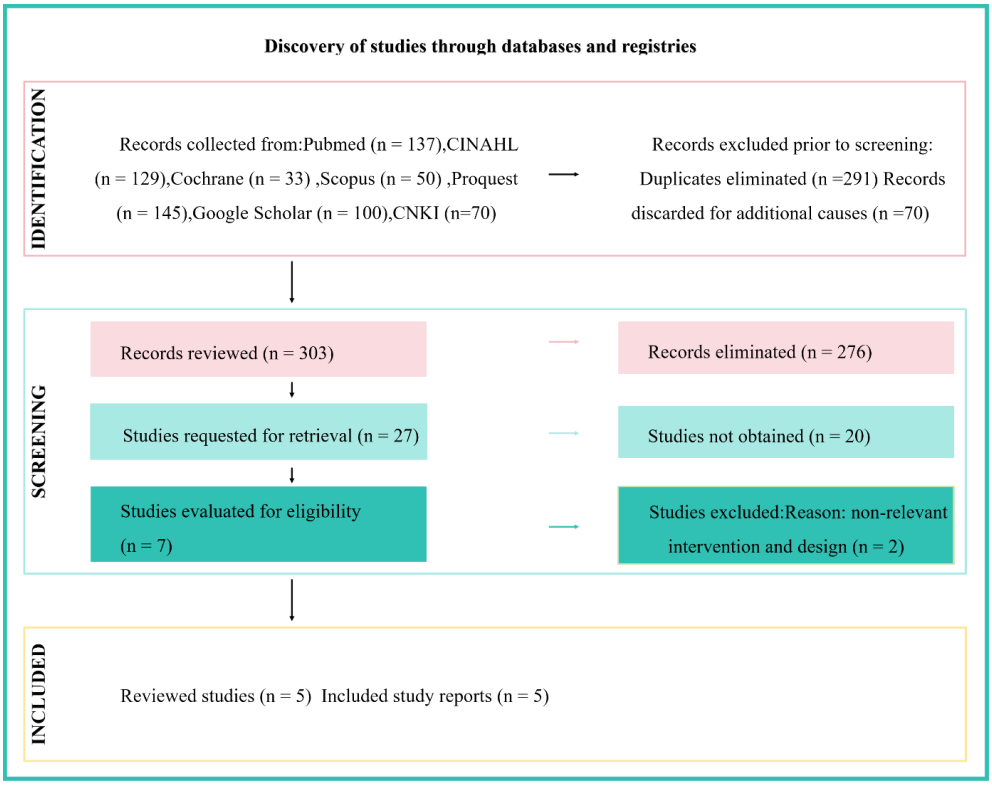

Figure 1: Prisma flow diagram

A comprehensive literature search identified 664 records. After removing duplicates, titles and

abstracts of 303 records were examined. Of these, 276 were excluded. To determine eligibility, 27 full-text articles were reviewed. Out of these, 20 items were excluded as they did not comply with the inclusion criteria. Seven articles passed the methodological quality appraisal and were included in the analysis, while two were excluded after this assessment. Figure 1 shows the search results, study selection process, and inclusion criteria.

The study involved a total of 401 participants, with individual study sample sizes varying between 55 and 120 participants. Among these studies are included, four were randomized controlled trials[16-18,20], and one is a multi-arm pre-post prospective study[23]. In each case, the studies selected patients with chronic NCDs and utilized innovative techniques during the pandemic. These studies involved different religions and governments, with one study in Indonesia[18], one in Greece[20], one in Saudi Arabia[23] , one in Jordan[16], and one in the United States[17]. Three out of the five studies took place in hospitals[16,17,20], while the remaining two were conducted in community settings[18,23]. According to the World Bank Group (2023), these countries are divided into different world economies: lower-middle (Jordan), upper-middle (Indonesia), and high-income tiers (Greece, Saudi Arabia, America).

Description of the Interventions: Innovative technologies were reported in this systematic review mentioned in these studies include smartphone applications[16-18,20] and the pharmacist-based diabetes intervention model and received specific tele pharmacy services[23].

3.2 Outcomes and Effectiveness of Innovative Technologies

3.2.1 Health Services Utilization

This systematic review revealed that throughout the COVID-19 surge, communication tools, and innovative technologies played a crucial role in delivering health services for the management of chronic NCDs. Through video calls, remote diagnosis, and monitoring technologies, healthcare personnel can communicate with patients without the need for them to travel to the hospital in person[16-18]. Many healthcare apps can be used to track a patient's condition and provide medication reminders, and health advice[20,23]. Furthermore, we found that the long-term impact and sustainability of these technologies in healthcare delivery will depend on factors like policy changes[16], infrastructure[16,20], and continued patient[23] and provider acceptance[18].

3.2.2 Health behaviors: self-care, self-management, medication adherence

All five studies evaluated the significant benefits of innovative technology-based interventions on the health behaviors of individuals living with chronic NCDs)[16–18,20,23].

According to Khan et al[23], Mahoney et al[17], and Pamungkas et al[18], interventions led to significant improvements in diabetes self-management and adherence to a Mediterranean diet among individuals with diabetes.

In addition, self-care for hypertension was assessed using the Self Care of Hypertension Inventory (SC-HI). Alsaqer & Bebis[16] found that, after a three-month period, all groups-interventional, apps-only, and standard-showed notable improvements in self-care maintenance scores.

Innovative technologies showed improvement in self-management and self-care behaviours. These include taking medicine regularly[17,18,23], following doctors' recommendations[16,20,23], maintaining a healthy lifestyle[16,18,20,23], such as a balanced diet and moderate exercise, and regular examination and monitoring of disease progression.

3.2.3 Complications related to health outcomes: poor disease control, readmission

Three of the five studies focused on reducing complications associated with diabetes[17,22,23]. The study by Pamungkas et al[18] demonstrated that all clinical outcomes-such as glycosylated hemoglobin

level, blood pressure, and cholesterol level-were significantly improved compared to the CG, with the exception of BMI status.

These findings confirm that dietary control and regular physical exercise positively impact health outcomes in individuals with diabetes mellitus.

4. Discussion

Our comprehensive review emphasizes the pivotal role of innovative technologies in managing chronic NCDs, particularly during the COVID-19 pandemic. These technologies facilitated remote healthcare services, ensured continuous patient care, and reduced the risk of coronavirus exposure by reducing the necessity for physical visits. The uptake of telemedicine and remote monitoring technologies surged throughout the pandemic, offering essential support to healthcare providers and patients alike.

Key innovations identified in our review include smartphone applications[16–18,20] and pharmacist-based diabetes intervention models with telepharmacy services[23]. These technologies have been pivotal in managing chronic NCDs during the pandemic by offering remote healthcare services and ensuring continuity of care[15]. Their impact has been profound, helping healthcare facilities and patients manage chronic NCDs more effectively and providing critical support throughout the pandemic.

Our review aligns with the existing literature. Bhaskar et al[13] noted that technology became essential for ongoing patient care during the pandemic, facilitating remote consultations, continuous monitoring, and education through telephone and video conferencing[13]. The swift adoption of telemedicine has enhanced healthcare delivery and access, particularly for patients with chronic NCDs, while mitigating the risk of virus transmission. Similar findings are echoed by Dusetzina et al [26], who observed increased access to telemedicine and improvements in continuity of care for chronic NCD patients during the pandemic. Innovations such as electronic measurement devices, Internet-connected technologies, and large-scale data analysis have created new opportunities for optimizing healthcare delivery, where remote monitoring systems are vital for increasing patient access and care[12].

Limitations: Several limitations in this systematic review may impact the applicability and comprehensiveness of our findings. Firstly, by restricting the review to English and Chinese publications, we may have missed important studies published in other languages. Additionally, focusing on international journals and online sources might have led to overlooking high-quality studies published in non-international journals or offline formats, potentially introducing publication bias. Our search was limited to six specific databases, which could have excluded relevant studies indexed elsewhere and affected the scope of the review. Furthermore, categorizing outcomes into three broad groups may have oversimplified the data and missed nuanced results that could have emerged from more detailed classifications. Lastly, some studies had low scores in the Joanna Briggs Institute (JBI) evaluation, indicating potential bias due to lack of full blinding, which could affect the methodological rigor of our review.

5. Conclusions

The beneficial role of innovative technologies, such as telemedicine platforms and mobile apps, in managing chronic NCDs-especially during challenging times like the COVID-19 pandemic-has been well-documented. Multiple studies have demonstrated that these technologies improve self-management behaviors, clinical outcomes, and overall well-being for individuals with conditions like diabetes and breast cancer. However, challenges such as disparities in access and utilization, technical barriers, and concerns about privacy and data security hinder widespread adoption. To overcome

these issues, promoting inclusivity, digital literacy, and equitable access is essential. Addressing disparities in technology usage among different populations is crucial for the successful integration and effectiveness of these technologies in chronic NCD management.

Acknowledgments

The authors appreciate the librarian (Mrs. Kritsana Klangphaow) of the Faculty of Nursing, Khon Kaen University for the valuable literature search advice.

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Appendix

Appendix 1: Summary tables of demographic characteristics and key details of the study

No.	First author year(s)	Type of study	Participants	Demographic Characteristics	Data Collection Details	Findings
1	Pamungkas et al., 2022a [18]	RCT	T2DM	60 T2DM patients from 3 community health centers.	Inclusion Criteria: Uncontrolled Type 2 Diabetes Mellitus (T2DM) Age: 35-59 years Diabetes duration: Over 2 years Language: Proficient in Indonesian Exclusion Criteria: Serious complications Foot ulcers Chronic renal diseases Retinopathy	The diabetes coaching intervention using a smartphone application significantly improved self-care practices and health outcomes in individuals with T2DM in Indonesia. 1. Enhanced all aspects of Diabetes Self-Management (DSM): Participants who engaged in a 12-week diabetes coaching program via a smartphone application demonstrated notable improvements in every component of DSM compared to those in the baseline group who underwent standard treatment at community health centers. The areas of improvement included dietary control, physical exercise, self-monitoring of blood glucose (SMBG), adherence to medication, and screening for diabetes-related complications. 2. Enhanced clinical results: Decreases in HbA1c levels, blood pressure (systolic and diastolic), LDL cholesterol, and rises in HDL cholesterol levels.
				Participants were randomly allocated to the IG (n=30) or the CG (n=30)	Two sub-phases of data collection. Informed consent was obtained after random allocation.	
2	Papandreou et al., 2021[20]	RCT	Breast cancer	Adult breast cancer outpatients at IASO HOSPITAL in Athens, Greece.	Inclusion: Females 18 years and older with a confirmed histological diagnosis of invasive BC (stages I to IIIA). Exclusion: History of other cancers in the last 5 years, severe illnesses, autoimmune diseases, psychiatric disorders.	The tailored dietary plan, rooted in the Mediterranean diet and accompanied by physical activity recommendations, resulted in enhanced dietary habits, body composition, life quality, and psychological well-being among BC patients in Greece. 1. Enhanced adherence to the Mediterranean diet (MD): Participants who followed the intervention, which included a 3-month personalized MD-based dietary plan coupled with physical activity guidelines, showed improved adherence to the MD. This was demonstrated by a rise in monounsaturated fatty acids (MUFAs) consumption, an increase in fiber intake, a decrease in saturated fatty acids (SFAs) intake, and a higher intake of antioxidant vitamin C, when compared to both the initial baseline and the CG. 2. Decreased body weight and improved body composition: The IG experienced decreases in

No.	First author year(s)	Type of study	Participants	Demographic Characteristics	Data Collection Details	Findings
						weight, BMI, BFM%, and waist circumference (WC) at the study's endpoint, in comparison to the CG. They also showed enhanced levels of physical activity relative to both their baseline measures and the CG. 3. Enhanced quality of life: The IG saw reductions in weight, BMI, BFM%, and WC by the end of the study, compared to the CG. Additionally, they demonstrated improved physical activity levels when compared to their baseline measurements and the CG. They reported better scores in the global health quality of life scale, role functioning subscale, and emotional functioning subscale compared to their baseline and the CG. 4. Reduced depression and anxiety: The IG showed reductions in emotional distress and anxiety. 5. Consistent fasting blood glucose and lipid levels: In the IG, fasting glucose and lipid levels remained stable, whereas the control group experienced increases.
				Recruitment from March to June 2020.	Personal meetings, written informed consent, and a study information leaflet provided to patients.	
3	Y. H. Khan et al., 2022 [21]	A multi-arm pre-post prospective study	Type 2 DM	Patients with inadequately managed Type 2 diabetes mellitus, aged over 30 years.	Inclusion: Confirmed diagnosis of inadequately controlled Type 2 diabetes mellitus. Exclusion: Serious renal or hepatic dysfunction, pregnancy, sensory impairments, psychological problems, Type 1 DM, gestational diabetes.	The pharmacist-based diabetes intervention model combined with specific telepharmacy services led to improvements in knowledge about diabetes, self-care practices, prescription adherence, and HbA1c levels among individuals with T2DM in Saudi Arabia.
					Patients were recruited during visits to a community pharmacy.	1. Improved knowledge about diabetes: Participants who received the pharmacist-based diabetes intervention model along with specific telepharmacy services demonstrated significantly higher knowledge scores compared to those receiving routine care. The IG had a mean knowledge score of 16.89 ± 2.01, whereas the CG had a lower score of 15.24 ± 2.03 (p-value < 0.001). 2.Improved self-care routines: The IG showed improved self-care practices compared to the CG. Individuals in the IG achieved a higher average score for self-care practices (4.39 ± 1.10) compared to those in the CG, who had a lower score (3.16 ± 0.97), with a statistically significant difference (p-value < 0.001). 3. Improved medication compliance and HbA1c levels: Analysis between the groups showed improvements in medication adherence and reductions in HbA1c levels among participants within the IG compared to the CG. These improvements were statistically significant ($p < 0.05$).
4	Alsaqer & Bebis, 2022[16]	RCT	HTN	Recruited patients (n=443) from a larger population.	Inclusion: Capable of using smartphones. Exclusion: Not meeting study aim.	The intervention consisting of initial education, four free apps, and subsequent public health nurse interventions led to improvements in SBP, self-care practices, and certain aspects of quality of life among individuals with hypertension in Jordan. However, it did not significantly affect DBP, physical functioning, or general quality of life.

No.	First author year(s)	Type of study	Participants	Demographic Characteristics	Data Collection Details	Findings
						1.Decreased systolic blood pressure (SBP): Participants (IG) experienced a notable reduction in SBP of 14 mmHg at the 3-month follow-up compared to baseline ($F = 16.74$, $p = 0.001$). 2.Improved self-care practices: The IG demonstrated improvements in self-care maintenance, monitoring, and confidence compared to both CGs (CG1 and CG2). These improvements were statistically significant ($p < 0.01$). 3. Enhanced quality of life: The IG reported significant improvements in several life quality domains compared to the standard care group (CG2). Significant improvements were observed in role limitations due to physical and emotional issues, pain, fatigue, emotional well-being, and social functioning ($p < 0.05$).
				Systematic random sampling to select 120 participants.	Participants selected via telephone interviews after ensuring eligibility.	
5	Mahoney et al., 2022[17]	RCT	T2DM	Participants ≥22 years old with a diagnosis of T2DM on MDI insulin therapy.	Inclusion: MDI insulin therapy for >6 months, HbA1c of 8.0–11.0%, using specified smartphones.	Using of the BD Diabetes Care App along with personalized nutrition interventions may lead to a trend towards reduced glycemic variability in individuals with type 2 diabetes mellitus. 1.Reduced glycemic variability: Participants in the IG demonstrated a trend towards reduced glycemic variability, as indicated by a reduction in the mean amplitude of the glycemic excursions (MAGE), compared to the CG. However, this reduction did not reach statistical significance ($p = 0.06$). 2. App and PN satisfaction: Both groups reported satisfaction with both the app and personalized nutrition interventions, indicating that participants in the IG were satisfied with the BD Diabetes Care App and the personalized nutrition program.
					Participants selected via systematic random sampling.	