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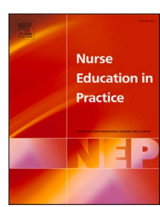

Effectiveness and uptake of WhatsApp-based HIV microlearning for healthcare workers in remote South African clinics: A pragmatic, mixed-methods, cluster-randomised trial

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ABSTRACT

Aim/objective: To design and test the usability of case-based HIV microlearning lessons using WhatsApp groups. This paper reports on effectiveness and uptake.
Background: South Africa has the largest antiretroviral treatment program globally. National guidelines are regularly updated. Ongoing training of healthcare workers is vital but complicated by infrastructural, financial and human resource shortages. Innovative solutions are needed.
Design: A pragmatic, mixed methods, parallel group, cluster randomised trial.
Methods: Nurses and community health workers (CHWs) at 50 clinics in the Eastern Cape were invited to participate. Online questionnaires tested knowledge and retention of knowledge; retrospective folder reviews measured changes in patient care. Patient folders were sampled purposively pre-/post-intervention for clinical points learned. Descriptive and inferential analyses were performed.
Results: Uptake and participation were good: 232 (79 %) nurses and 207 (76 %) CHWs participated. 96 % of nurses and 88 % of CHWs read the lessons within two weeks. There was a significant intervention effect on knowledge, based on the online questionnaires: nurses (0.5 units; 95 % CI 0.11–1.0; $p = 0.0499$) and CHWs (0.7 units; 95 % CI 0.2–1.3; $p = 0.004$).
1083 patient folders were reviewed to compare changes in patient care between the study arms. Adjusting for pre-care differences between the arms, the intervention increased correct patient care by 21 % (95 % CI 10 %-32 %; $p < 0.001$) in the year after the training.
Conclusions: WhatsApp-based microlearning improves knowledge and patient care. This, with the companion paper's data showing that it is well received and accepted, makes it a valuable option for simple, accessible, scalable continuing medical education for HCWs.

1. Introduction

South Africa has the largest antiretroviral treatment (ART) programme in the world (Babatunde et al., 2023), with 5.9 million people on ART in 2023 (UNAIDS, 2023). HIV prevalence was 17.1 % in the same year (UNAIDS, 2023).

Abbreviations: AED, antiepileptic drug; ART, antiretroviral therapy; CHC, community health centre; CI, confidence interval; CHWs, community health workers; COVID-19, Coronavirus Disease of 2019; DTG, dolutegravir; EC, Eastern Cape; GXP, GeneXpert; HCWs, healthcare workers; IQR, interquartile range; HIV, Human Immunodeficiency Virus; HREC, Human Research Ethics Committee; LDL, lower than detectable level; LMIC, low-and middle-income countries; Met, metformin; MLearning, mobile learning; NHLS, National Health Laboratory Services; PHC, primary health clinic; Rif, rifampicin; TPT, TB Preventive Therapy; UNAIDs, Joint United Nations Programme on HIV/AIDS; WOCP, women of childbearing potential.

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ART treatment is guided by national guidelines. Without healthcare worker (HCW) knowledge and use of guidelines, patient care can be compromised (Makhado et al., 2018; Murudi-Manganye et al., 2023). Guidelines are regularly updated as new evidence is published, making ongoing HCW training vital: ensuring knowledge of current guidelines, changes in updated versions, together with an understanding of why recommendations have changed (Nieuwoudt and Manderson, 2018).

In-service training is essential to update HCW knowledge (Motlhaoleng et al., 2023), improve knowledge retention (Kufe et al., 2019) and empower HCWs to do their jobs well (Azad et al., 2020). Ongoing training is challenging in South Africa, which covers 1.2 million km^2, much of it rural. Traditionally, training has either been face-to-face at centralised points or long-form online training. Barriers to this include a lack of financial, human and infrastructural resources (Feldacker et al., 2017; Horwood et al., 2020). There is a need for innovative solutions.

Mobile learning (mLearning) – providing education on mobile devices (Traxler, 2005) – has rapidly gained traction over the past two decades (Asadullah et al., 2023; Chang et al., 2018). Several meta-analyses and reviews on the use of mLearning in nursing education have been conducted with an overall conclusion that it is beneficial (Chen et al., 2021), well accepted (Chan and Leung, 2018) and improves skills and knowledge (Kim and Park, 2019; Yalcinkaya and Cinar Yucel, 2023). A small South African study of nurse educators found that they have a positive attitude to technology-centred education (Ziqubu and Orton, 2023). South Africa has over 100 % mobile phone penetration (Independent Communications Authority of South Africa, 2024).

Time is a limited resource in many clinics with large workloads (Crowley et al., 2021). Microlearning – 'bite-sized' pieces of information transferred via technology, e.g. mobile phones (Hug, 2010) – is a feasible, accessible and flexible teaching strategy for nurses and positive effects on knowledge across health professions have been shown (De Gagne et al., 2019).

While microlearning interventions are usually asynchronous (Flornoy-Guédon et al., 2024; Mollaei et al., 2024; Palmon et al., 2021), many based on 'just-in-time' training (Inker et al., 2021; Messing et al., 2024; Sedaghatkar et al., 2023), a lack of interaction is an often reported disadvantage (Palmon et al., 2021; Tan et al., 2024). For the purposes of this trial, microlearning refers to the bite-sized lessons implicit in its name but delivered synchronously.

WhatsApp offers a free and accessible platform for training, even in the most remote clinics. The platform was used by 94 % of South Africans in 2023 (Statista, 2023). It has been shown to be effective and acceptable to HCWs across several medical fields and training methods in low- and middle-income countries (LMICs) (Elzeky and Shahine, 2022; Jafree et al., 2022; Thorp et al., 2021). Woods et al. (2019) described the use of WhatsApp as an HIV discussion forum for clinicians working in the Eastern Cape and showed that engagement in the group improved self-reported confidence and practical application of knowledge, concluding that WhatsApp is an easy-to-use and implement continuing medical education platform.

There are gaps in the research field. Azad et al. (2020), in their narrative synthesis of continued nursing education in LMICs concluded that, while it is essential and effective in improving knowledge, there is a "profound lack of rigorously designed studies to evaluate the effectiveness of continuing nursing education interventions in LMICs". There is a lack of data involving nurses, with many studies involving only nursing students who are expected, due to their age, to be more familiar with technology than older generations (Kim and Park, 2019). Most studies have been done in developed countries (Yalcinkaya and Cinar Yucel, 2023).

At the microlearning level, there are few rigorous studies of effectiveness, especially exploring more complex outcomes, e.g. changes in patient care (De Gagne et al., 2019; Tennyson et al., 2022). Coleman and O'Connor's (2019) scoping review on WhatsApp-based interventions notes that all except one intervention had only been evaluated up to Level 1 or 2 of Kirkpatrick's Levels of Training Evaluation, the gold standard. Kirkpatrick's levels are: (1) reaction; (2) learning; (3) impact/behaviour change; and (4) results/performance change (Kirkpatrick and Kirkpatrick, 2016).

The aim of this trial was to design and test the usability of WhatsApp group-based HIV microlearning for rural South African healthcare workers, measuring its uptake, acceptability, feasibility and effectiveness. The primary outcome measure was a change in knowledge. In this paper, we report on the effectiveness (knowledge changes and changes in prescribing/patient care) and uptake and participation of/in the intervention. A companion paper [in this issue] reports on the acceptability and feasibility.

2. Material and methods

A comprehensive methodology of this pragmatic, mixed-methods, parallel-group cluster-randomised trial has been published elsewhere (Chisholm et al., 2024). A summary of the methods is provided below. The study design is represented in Fig. 1.

2.1. Study setting

Fifty predominantly nurse-led clinics in four districts in the Eastern Cape province of South Africa were included. The Eastern Cape is a resource-poor area with 58 % of the population living in rural areas (Statistics South Africa, 2024). The overall HIV prevalence is 13.7 %, with a higher prevalence (27.7 %) in younger people, 25–49 years old (Human Sciences Research Council, 2022).

2.2. Sampling and randomisation

Cluster randomisation was done at town level. Fifty clinics were included and clustered by town: 30 for nurses and 28 for community health workers (CHWs). Two clinics had no CHWs who participated. Clusters were stratified into three strata by type of clinic (community health centre [CHC] or primary health clinic [PHC]), number of nurses and number of patients seen, to obtain two equally sized groups and minimise variance between groups (Rutterford et al., 2015).

Prior to the training intervention, the trial statistician randomised the clusters into intervention or control group within each stratum. One stratum had two towns (two CHCs); the second, 18 towns (36 PHCs); and the third, 10 towns (12 PHCs); allowing for randomisation in a 1:1 ratio.

Sampling of the patient folders was purposive, to include folders of patients with conditions that had measurable outcomes from the learning points in the training, e.g., the double dosing of dolutegravir in patients taking rifampicin for tuberculosis (Supplementary Table 1):

Adult (>18 years old) patients living with HIV and:

- initiating ART
- pregnant
- on rifampicin
- on metformin
- on antiepileptic drugs (AEDs)

2.3. Participants and recruitment

All community health workers (CHWs), counsellors and nurses in the facilities were invited to participate in the training during recruitment visits between October and December 2022. One doctor or pharmacist visits multiple sites in the districts, so they were excluded, to minimise the risk of contamination across clusters. Inclusion criteria were:

- CHWs, counsellors and nurses
- Training was conducted in English, so required English comprehension
- Access to a phone with WhatsApp

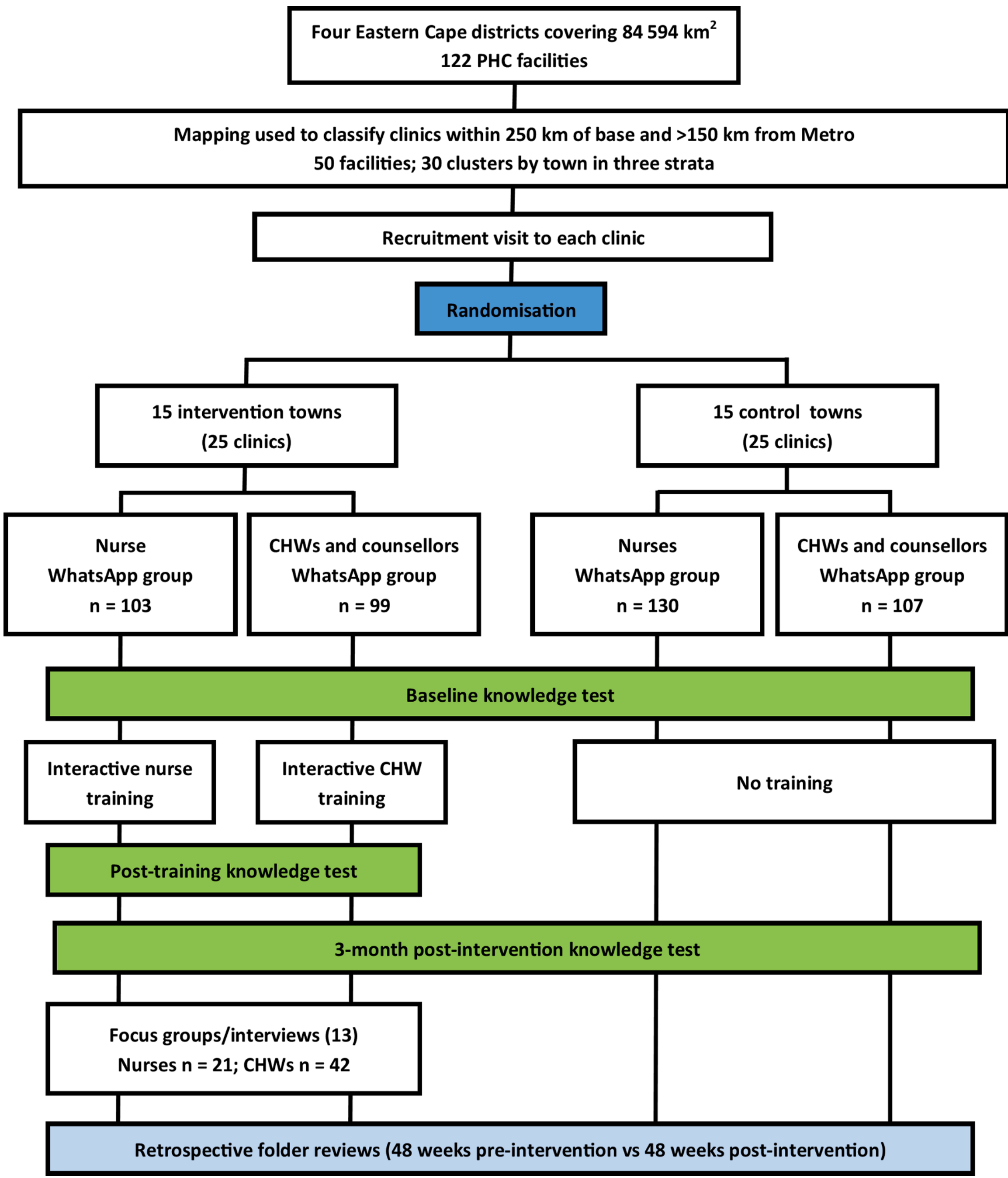

Fig. 1. Study design flowchart.

- Informed consent

Study flyers were left at each clinic and HCWs could sign up at the time of the visit or join via WhatsApp.

2.4. *Training intervention*

WhatsApp groups were made for each of the control and intervention groups, divided by profession: nurses in one group and CHWs and counsellors combined in another group. All four groups received mobile data to cover the data needed to do the online questionnaires and participate in the WhatsApp training. Information messages and links to the baseline online questionnaire were sent between 3 January and 20 January 2023. After the questionnaire closed, participants were informed whether they were in the intervention group (receive training immediately) or control group (receive training at the end of the trial).

The training was conducted 'live' in WhatsApp groups: 10–15-minute, case-based microlearning lessons (Bates, 2019; Corbeil et al., 2021; Crompton, 2013) within the routine lunch break (Supplementary Figure 1). Learning points were based on the National HIV guidelines (South African National Department of Health, 2020) and included lessons on dolutegravir's interactions and how to adjust dosing for nurses and which patients to refer to the nurse, for CHWs (full list of lessons included in Supplementary Table 1). The lessons were produced by the first author, reviewed by a professor of pharmacology and tested in a pilot study.

Six of the learning points covered aspects of patient care that are measurable through folder reviews (Supplementary Table 1). For CHWs, lessons included who to refer to the nurse, in case of interactions. An introduction session was given, followed by six lessons for nurses and

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four lessons for CHWs, considering their scope of practice. Training took place between 23 January and 8 February 2023.

2.5. Pilot study

Once ethics approval was obtained, a pilot study was conducted with six nurses and six CHWs from a district adjacent to the study district. Participants completed the pre-test questionnaire, received the training lessons and completed the post-intervention questionnaire. Each pilot study participant was phoned, and their input was sought on all aspects of the intervention through semi-structured interview questions. Adjustments were made and amendments submitted to the ethics approval board.

2.6. Data collection and cleaning

The trial aimed to collect data to analyse the intervention at all four levels of Kirkpatrick's Training evaluation – results, behaviour, learning and reaction (Kirkpatrick and Kirkpatrick, 2016). Data were collected using online questionnaires [at baseline (before training), immediately after, and three months after the training intervention]; data from the WhatsApp group interactions; focus groups; and retrospective folder reviews. This paper reports data from these four sources. Additional results, with qualitative data, are reported in the companion paper [in this issue].

The primary outcome to measure the effectiveness of the intervention was a change in HCW knowledge, measured by test scores (counts) from online questionnaires consisting of 10 questions for nurses and seven for CHWs. Secondary outcomes were uptake and participation in the training, acceptability and feasibility and changes in practice. Study definitions can be found in Supplementary Table 2.

2.6.1. Uptake and participation; acceptability and feasibility

Uptake data were collected using the sign-up list from clinic visits, which were transferred into password-protected Excel spreadsheets. HCWs who joined via WhatsApp were added to the lists. Number of HCWs at each clinic was requested during the visit. Participation in the WhatsApp-based training sessions was collected using WhatsApp's two blue ticks which indicate that the message has been opened. The acceptability and feasibility results are reported in the companion paper [in this issue].

2.6.2. Effectiveness: knowledge changes

Healthcare worker knowledge was tested using three online questionnaires, designed on LimeSurvey (Community Edition, Version 5.6.10). The online questionnaires included four sections: demographic information (Appendix A), multiple-choice knowledge questions (Appendices B/C), WhatsApp usability (Appendix D) and mentorship (to be reported in a separate paper). Questionnaire design and administration are fully described in the methodology paper (Chisholm et al., 2024).

2.7. Validity and reliability

The questionnaire was reviewed by both lay people and experienced HIV researchers and clinicians, to evaluate content validity and ensure questions were appropriate, relevant and phrased to minimise bias. The recommended adjustments were made. Three tests were run before the pilot study:

1. **Face validity**: two lay people and six pharmacists checked the survey for face validity, i.e. readability, layout and clarity and required edits were made
2. **Content validity**: six doctors (three HIV experts, three Clinical Pharmacology registrars) and a pharmacist completed a Content Validity Index (CVI), which had an average of 0.8. Questions are considered valid if CVI > 0.78 (Polit and Beck, 2006)
3. **Test-retest for reliability**: the seven HIV hotline pharmacists and five nurses completed the survey twice, two weeks apart, resulting in a Pearson's coefficient of 0.8. Reliability is considered to be good if the correlation coefficient > 0.7 (Litwin, 1995)

2.8. Dissemination of questionnaire

Baseline knowledge was measured before participants were informed whether they were in the control or intervention group. The questionnaire was repeated by the intervention groups immediately after the training and by both groups three months after the training. The control group did not do the immediate post-intervention questionnaire to prevent survey fatigue (North and Giddens, 2013).

Pre-intervention questionnaires were open between 9 and 23 January 2023; post-intervention between 2 February (CHWs) or 9 February (nurses) and 30 March 2023; and 3-month post-intervention questionnaire between 8 and 26 May 2023.

Data collected were exported from LimeSurvey onto Excel and cleaned: those without data on knowledge and usability; and duplicates (first completion – by date stamp – of questionnaire kept) were removed and the data were made anonymous for analysis.

2.8.1. Changes in patient care

Folder reviews were retrospective and data were pulled for the period of 48 weeks before recruitment started (1 November 2021 to 30 September 2022) and 48 weeks from when the training sessions started (23 January 2023 to 22 December 2023). The period of clinic visits for recruitment, prior to the intervention were excluded, to minimise confounding.

Folder reviews were conducted at all 50 clinics by the first author. The researcher was not blinded, as they conducted the training and the folder reviews. A list of the relevant folders was sent via WhatsApp to the managing nurse to organise the visit, 2–4 weeks before the visit. A reminder was sent 1–3 days before the visits. On arrival at the clinics, the list was given to the data capturer, who pulled the relevant folders. Folder review visits took place between January and June 2024.

Data were entered into an Excel spreadsheet and included patient data (age, gender, pregnancy); clinical data (HIV diagnosis date, ART initiation date; co-morbidities); record of GXP; drug data (dolutegravir start date, NRTI backbone, other co-prescribed drugs and relevant drug data) and prescriber (doctor/nurse). Data were cleaned using Excel 365, to ensure all data points fitted within the inclusion criteria and to find any missing data.

2.9. Data analysis

Data were analysed using Microsoft Excel 365 (Version 2410) and Stata Statistical Software: Release 15.1 (College Station, TX: StataCorp LLC).

2.9.1. Uptake and participation

Descriptive data were calculated for uptake and participation. Uptake of the intervention was calculated using the proportion:

$$Uptake = \frac{HCWs\ who\ signed\ the\ list\ during\ clinic\ visits\ or\ joined\ via\ WhatsApp}{Number\ of\ HCWs\ working\ at\ the\ clinic}$$

Proportions of participants immediately after the session (those who were present during the 'live' session); one hour and 24 hours after the session; and at two weeks after the session, were calculated. Record was kept of participants dropping out – leaving the WhatsApp group – during the training period.

To quantify participation, transcripts from each WhatsApp session were uploaded onto NVivo (Version 14, released 2023) and coded to text

(greetings, answers to questions on case and thank you) or emoji groups, while doing the qualitative analysis through template analysis (see companion paper in this issue). Proportions of interaction within the training sessions were calculated using matrix queries of counts in NVivo.

2.9.2. Knowledge change

Descriptive analyses were performed to calculate proportions of HCWs who answered each learning point correctly on the questionnaires and of total scores, at each follow-up time point.

To analyse differences in changes in HCW total knowledge at the individual level, an expanded multilevel linear mixed-effects regression model of knowledge score on intervention, time, time and intervention interaction and stratification was done with cluster as the first random effect and participant as the second random effect nested within cluster. This model was also adjusted for age, gender and years of experience. Mean differences were estimated with their respective 95 % confidence intervals.

2.9.3. Change in patient care

Descriptive analyses were performed to calculate proportions of patient folders where the treatment was correct for each measurable learning point for the 48-week periods before and after the intervention. The folders from the period before the trial and the period after were mainly not from the same patients, as many of the learning points were for acute conditions, e.g. TB. Also, some folders could have two measurable outcomes, e.g., a pregnant woman with TB.

A summary measure for outcome variables for each cluster was calculated. All ten learning points for nurses in each cluster were combined to obtain a 'knowledge' summary measure (proportion correct). The measurable treatment outcomes (Supplementary Table 1) from the folder reviews in each cluster were combined for the patient care summary measure, using the following formula:

$$Proportion\ of correct\ care = \frac{Number\ of\ folders\ with\ correct\ treatment}{Number\ of\ folders}$$

As the summary measure for each cluster at the two time points represented a repeated measures design, a mixed effects linear regression model for the proportion correct patient care on intervention, time and their interaction was run with cluster as the random effect. The test for a significant interaction was used to test the hypothesis of an intervention effect. The final intervention effect was based in the difference in differences, to account for the significant pre-care difference between the arms. For this, the change (post-pre) within each arm was compared between the arms and the mean difference was estimated and reported with 95 % confidence intervals.

2.10. Ethical considerations

Ethical approval was obtained from the University of Cape Town's Human Research Ethics Committee (HREC 491/2022) and the Eastern Cape Health Research Committee (EC_202209_003).

Participants were invited to participate and either signed up during recruitment visits or via WhatsApp. They received mobile phone data to cover the cost of accessing the online questionnaires and the WhatsApp training.

Patient-level consent for folder reviews was not feasible and there was no risk to patients, as no personal identifiers are included in the reporting. Approval at provincial level to conduct folder reviews was obtained, in accordance with the Ottawa Statement (Taljaard et al., 2013).

All data collected were stored in password-protected files to which only the researcher had access. Anonymised data were given to the statistician for analysis and used for reporting.

3. Results

3.1. Uptake

232/293 (79 %) of nurses and 207/271 (76 %) of CHWs agreed to participate in the trial. After randomisation, 101 nurses were in the intervention WhatsApp group, 131 in the control group. For the CHW groups, 99 were in the intervention WhatsApp group and 108 in control. Tests for demographic variables confirmed that randomisation was successful ($p > 0.05$) and the groups were not different (Table 1).

Uptake of the online questionnaires was 62 % and the demographics of those who completed the baseline questionnaire are listed in Table 1. Participants were predominantly female, reflecting professional norms. At baseline, the mean age for nurses was 40 years (SD 11) and for CHWs, 40 years (SD 9). Mean experience working as a HCW was 11 years (SD 10) in the nurse group; and 11 years (SD 7) in the CHW group. The predominant home language was isiXhosa.

3.2. Participation

One nurse and three CHWs left the WhatsApp groups during the training. In the intervention group, nurses' attendance of the 'live' sessions ranged from 27/101 (27 %) to 51/101 (51 %); CHWs 27/97 (28 %) to 53/99 (54 %) (Fig. 2). By two weeks after the lessons, 97/101 (96 %) of nurses and 86/98 (88 %) of CHWs had read them.

Using NVivo coding and counts, 1295 participant interactions occurred (718 text, 72 emoji) during the seven nurse WhatsApp training group sessions; and in the five CHW group sessions, 475 (213 text, 49 emoji). The spread of the interactions is presented figuratively in Supplementary Figure 2.

3.3. Effectiveness: knowledge change

The baseline mean individual knowledge scores (based on 10 questions for nurses; seven for CHWs) were the same in both control and intervention groups: nurses, control 7 (range 1–10); intervention 7 (range 3–10); and CHWs, control 4 (range 1–7) and intervention 4 (range 0–7). Immediately post-intervention, both nurse and CHW intervention groups' median knowledge improved by one point. At three months post-intervention, both intervention groups showed slightly better knowledge scores than the control, but these were not significant (Supplementary Figure 3).

When looking at scores across individual knowledge questions, they differed largely (Supplementary Table 3), with low baseline knowledge of dolutegravir interactions, except for rifampicin. Post-intervention knowledge improved on all learning items, except in the case of the magnesium/aluminium interaction knowledge of the nurses.

For the inferential analysis, summary scores were calculated at cluster level. There was no difference between arms at baseline of both the nurse and CHW cohorts ($p = 0.270$; $p = 0.933$) (Fig. 3).

Expanded linear mixed effects modelling was done, adjusting for age, gender, years of experience, stratification, clustering and repeated measures. Three-months post-intervention, there was a significant intervention effect for both nurses (0.5 points; 95 % CI 0.1–1.0; $p = 0.049$) and CHWs (0.7 points; 95 % CI 0.2–1.36; $p = 0.004$) (Table 2).

Mean baseline knowledge score was positively associated with the final score in both groups. In the nurse group, age was negatively associated with total knowledge score and years of experience was positively associated, but this was not mimicked in the CHW group (Lowess graph, Supplementary Figure 4).

3.4. Change in patient care

1158 folders were reviewed at the clinics. During data cleaning, 16 data points were removed because the patient was < 18 years old at the

Table 1
Characteristics of HCWs at baseline knowledge questionnaire.

Characteristic	Nurses			CHWs		
	Intervention	Control	p-value	Intervention	Control	p-value
Healthcare workers, n (%)	84 (43)	110 (57)		70 (46)	83 (54)	
Gender, n (%)						
Female	67 (80)	96 (87)	0.232†	62 (89)	76 (92)	0.555†
Male	17 (20)	14 (13)		8 (11)	7 (8)	
Age (yrs), mean (SD)	40 (10)	39 (11)	0.622#	39 (10)	41 (8)	0.425#
Experience (yrs), mean (SD)	9 (10)	9 (10)	0.780#	10 (6)	12 (7)	0.312#
Home language, n (%)						
isiXhosa	47 (56)	58 (53)	0.588*	47 (67)	47 (57)	0.365*
Afrikaans	25 (30)	43 (39)		19 (27)	32 (38)	
English	9 (11)	7 (6)		2 (3)	4 (5)	
Other	3 (3)	2 (2)		2 (3)	0 (0)	
Highest level of education, n (%)						
Primary school	0 (0)	0 (0)	0.304*	0 (0)	3 (3)	0.483*
High school	4 (5)	10 (9)		55 (79)	66 (80)	
Tertiary	80 (95)	100 (91)		15 (21)	14 (17)	
Profession, n (%)						
Nurse	84 (100)	110 (100)		0 (0)	0 (0)	
CHW	0 (0)	0 (0)		39 (56)	59 (71)	
Counsellor	0 (0)	0 (0)		31 (44)	24 (29)	

Abbreviations: CHW, Community health worker; SD, standard deviation
†Chi-squared test of association; Mann-Whitney test of association; *Fisher's exact test

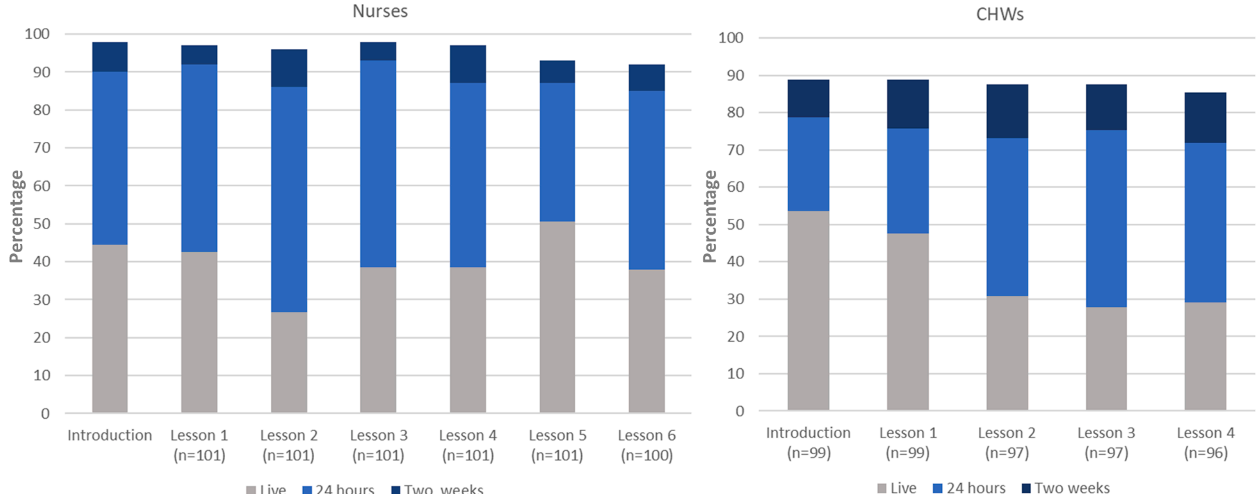
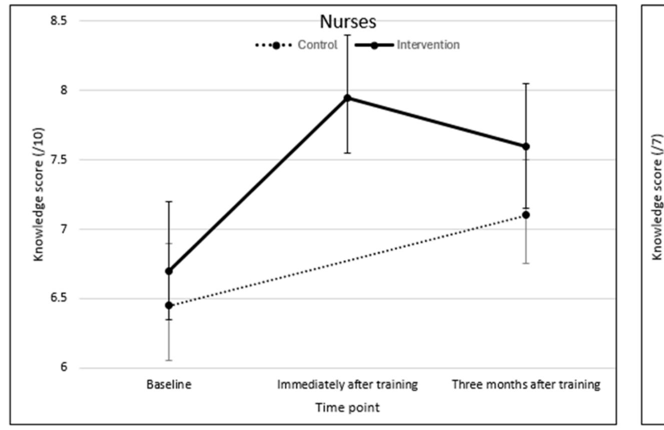


Fig. 2. Proportion of participants that were in the live sessions and had read the lessons by 24 hours and two weeks after.



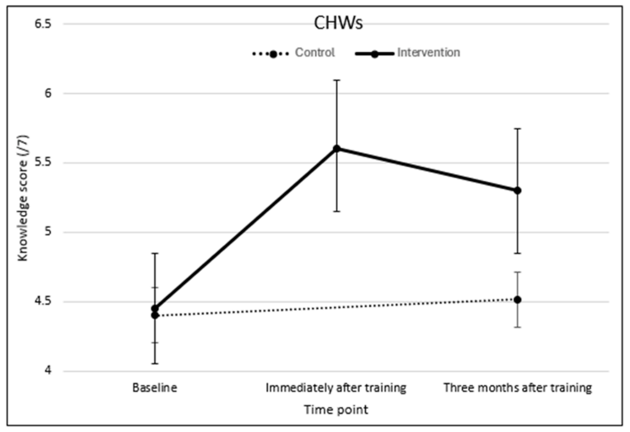


Fig. 3. Summary mean scores at baseline, immediately after intervention, and three months after intervention.

Table 2
Estimated intervention effects for the knowledge score at three months, based on a linear mixed effects model.

Participant group	Intervention mean (SD)	Control mean (SD)	Mean difference	95 % CI	p-value	ICC
Nurses	7.6 (1.4)	7.1 (1.9)	0.5	0.1–1.0	0.049†	0.001
CHWs	5.3 (0.9)	4.6 (1.2)	0.7	0.2–1.3	0.004†	0.115

Abbreviations: SD, standard deviation; CI, confidence interval
†Wald test

relevant data point; and 33 were removed because the relevant data point was not within the trial period. The original trial plan was to access missing laboratory data through LabTrak, the National Health Laboratory Services (NHLS). In June 2024, the NHLS was the victim of a cyber-attack, causing the system to be shutdown (National Health Laboratory Service, 2024) and no access was possible. We excluded 26 data points due to this. 1083 data points from the folders were analysed.

Demographics, concomitant diseases and latest CD4 and viral load results are listed in Supplementary Table 4. Two thirds were female, with a mean age of 37 years old (SD 12). Of those that had the data in the folders, the median CD4 count was 313cells/mm^3 (IQR 150–508) and 53.6 % had a VL $<$ 50 copies/mL (279/521).

There were almost double the number of data points for the 'after' 48 weeks. This is most likely due to the 'before' 48 weeks being during the COVID-19 pandemic, during which clinic visits were kept to a minimum, with many patients only attending the clinic 3-monthly.

Descriptive data and mixed logistic regression analyses of each measurable learning point at the individual level are reported in Supplementary Tables 5a and 5b. The estimated intervention effects for correct patient care are listed in Tables 3a and 3b. The change between pre-intervention and post-intervention care percentages were significantly different between the arms, $p < 0.001$, indicating a significant intervention effect (Table 3a). Conditional on arm, the mixed effects linear regressions showed a positive change in the intervention arm of 20 % (95 %CI 13 %-28 %), compared with a drop of 1 % (95 %CI −8.0 %-8.0 %) in the control arm (Table 3b). A difference-in-differences analysis, accounting for the unbalanced pre-intervention means (intervention 62 %; control 75 %), showed a statistically significant improvement in correct patient care of 21 % (95 %CI 10 %- 32 %; $p < 0.001$) in the intervention arm (Table 3b).

4. Discussion

Our cluster-randomised trial of WhatsApp-based HIV training for HCWs showed that uptake of the training intervention was good, with close to 80 % of invited staff participating. Knowledge of ART and drug interactions improved significantly after the WhatsApp intervention in both nurses and CHWs. This translated into improved patient care in the intervention arm as evidenced by changes in prescribing practice noted through folder reviews. These results and those in the companion paper (insert companion paper) show positive effects of the intervention at all four levels of Kirkpatrick's Levels of Training Evaluation (Kirkpatrick and Kirkpatrick, 2016).

While participation levels in the live WhatsApp groups were relatively low (40 % for nurses; 38 % for CHWs), probably due to network and electricity issues (companion paper); by two weeks later, almost all participants (96 % of nurses; 88 % of CHWs) had read the lessons. This highlights the accessibility of WhatsApp as a training platform, allowing both live sessions and 'catch up' after live sessions.

Our participation rates, of 40–96 %, were higher than those reported in other South African studies on mLearning. Chamane et al. (2021) had a nurse participation rate of 64 % in their study of an app to teach HIV testing; and Woods et al. (2019) reported a 50 % participation rate in their WhatsApp-based clinical discussion forum for Eastern Cape clinicians. Our training period was short, so sustainability of high participation rates would require further research.

There was low baseline knowledge of dolutegravir's interactions, echoing data from a previous survey of South African HCWs (Chisholm and Swart, 2022). After WhatsApp training, both knowledge and patient care improved significantly in the intervention arm. While knowledge improvement has been shown in previous mLearning studies e.g. using WhatsApp for blood pressure (BP) monitoring training (Elzeky and Shahine, 2022), Telegram for disaster preparedness training (Najafi Ghezeljeh et al., 2019) and a Moodle app for HIV testing training (Chamane et al., 2021); studies in WhatsApp-based medical education reporting on Kirkpatrick's Level 4 outcomes, i.e. results/performance change (Kirkpatrick and Kirkpatrick, 2016) are lacking (Coleman and O'Connor, 2019).

The trial has several limitations. Firstly, it was pragmatic, so some participants answered only one questionnaire, despite multiple reminders each time. Non-responders may have skewed results and influenced the validity due to sampling bias. Baseline knowledge scores were high (means of 7/10 and 5/7), leaving less room for improvement. The same questions were asked in the pre- and post-intervention questionnaires, which may have resulted in improved knowledge in the control group by familiarity. The pre-intervention period fell during the COVID-19 pandemic. The massive diversion of attention to COVID-19 and less frequent patient visits may have skewed the results. The intervention was short, so may under-represent the effect that sustained training may have. There may also have been movement of staff between clinics, introducing a potential point of bias. Finally, the trial lead completed the folder reviews and was not blinded, which may have introduced further bias.

Strengths of the trial includes its robustness, covering all four Kirkpatrick's levels and using a wide range of data collection to enable triangulation, giving a more accurate overview of the training method's usability. The trial was conducted in a resource-poor province of South Africa which, it is hoped, allows generalisability across South Africa and to other LMICs. Scale-up and implementation studies are needed to confirm this.

Table 3a
Estimated intervention effects on correct patient care.

Correct care before and after the intervention					
	Intervention, n = 15		Control, n = 15		p-value
	Mean proportion correct	SD	Mean proportion correct	SD	
Pre-intervention	0.62	0.20	0.75	0.18	
Post-intervention	0.82	0.11	0.75	0.11	
Difference	**0.20**	**0.23**	**0.00**	**0.21**	**< 0.001***

Abbreviations: SD, standard deviation. *Two-sample *t*-test

Table 3b
Estimated main intervention effects on correct patient care, using mixed effects linear regression model for the proportion correct care with cluster as the random effect.

	Main effects					
	Time		Test for main effect	Intervention		Test for main effect
	Mean difference	95 %CI	p-value	Mean difference	95 %CI	p-value
Intervention	0.20	0.13–0.28	< 0.001[†]			
Control	−0.01	−0.08–0.08	0.975[†]			
Pre-intervention				−0.14	−0.24-−0.03	0.014[†]
Post-intervention				0.07	−0.04–0.18	0.208[†]
Difference-in-differences analysis, accounting for unbalanced pre-intervention means				**0.21**	**0.10–0.32**	**< 0.001**[†]

Abbreviations: CI, confidence interval. [†]Wald test

5. Conclusion

WhatsApp-based microlearning improves knowledge and correct patient care. This, with the companion paper's data showing that it is well received and accepted, makes it a valuable option for simple, accessible, scalable continuing medical education for HCWs. Further research on comparison between this training method and others, the effect of ongoing, regular training on patient care, large-scale implementation, sustainability and cost-effectiveness is recommended.

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CRediT authorship contribution statement

Chisholm Briony Sue: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mapahla Lovemore:** Writing – review & editing, Methodology, Formal analysis. **Lombard Carl:** Writing – review & editing, Methodology, Formal analysis. **Blockman Marc:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Conceptualization. **Orrell Catherine:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Briony Chisholm reports financial support was provided by SAMRC (Bongani Mayosi National Health Scholars Programme). Briony Chisholm reports financial support was provided by an educational grant from Aspen (research costs). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.nepr.2025.104326.

Data availability statement

Anonymised data is available on the University of Cape Town's online repository, ZivaHub Open Data UCT.

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