

ONLINE APPLICATION BASED ON KING INTERACTION SYSTEM THEORY TO INCREASE TREATMENT ADHERENCE AND CLINICAL INDICATORS IN TB CHILDREN

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ABSTRACT

Introduction: Non-adherence to treatment among TB children in Indonesia varied 40.5%-57.2%. An innovative method of education might improve treatment adherence and clinical recovery of TB children. The aims of this study were to compare the treatment adherence and clinical indicators of TB children who received an intervention using an online application based on King's theory with a conventional method. **Methods:** This is a quasi-experimental study to educate 55 TB school-age children using a validated online application based on King's interaction system theory, compared with the conventional method in 55 TB children as the control group. The medication regularity and control discipline were observed four times in weeks 2, 4, 6, and 8. Measurements of acid-fast bacilli (AFB) smear sputum examination, TB scoring, chest X-ray examination, level of Hb, and nutritional status were done twice in pre- and post-intervention. Data analysis used chi-square, paired t-test, independent t-test, Mann Whitney, McNemar^b. or Wilcoxon test. **Results:** The results of this study revealed that the intervention group was significantly successful compared to the control group in several indicators, such as increasing treatment adherence ($p=0.001$), controlling discipline ($p=0.001$), reducing AFB positive ($p=0.001$), TB scoring ($p=0.001$), infiltrate in chest X-ray examination ($p=0.013$), and increasing Hb levels ($p=0.001$). Meanwhile, nutritional status could not be compared because, from the beginning of the study, the nutritional status was unbalanced and benefited the intervention group. **Conclusion:** The online application based on King's theory has succeeded in increasing medication adherence and clinical improvement of pulmonary TB in children.

Keywords: TB children, treatment adherence, clinical indicators, online application

INTRODUCTION

Tuberculosis (TB) children are still prevalent; at least 500,000 children suffer from TB every year in the world. In Indonesia, the TB disease prevalence is still elevated, and Indonesia is ranked second after India (Ministry of Health, no date). In East Java in 2019, as recorded by the Statistical Research Agency of the Health Office, it reached 54,863 people. The high cases of tuberculosis also have an impact on the high mortality rate in East Java, which amounted to 1,125 patients from January 2019 to December 2019 (Health Agency of East Java Province, 2019).

There are several risk factors for the transmission of TB in children, including a history of contact with TB sufferers, weak immune system, low social and economic, poverty, low malnutrition, unhealthy homes, population density, family size, and environmental hygiene (Siddalingaiah et al., 2023). The WHO reported that only 71% of the target treatment of TB children were treated in 2018-2022 (WHO, 2023). Many WHO initiatives were taken to manage TB in children, for example, funding for vulnerable populations, including interventions for TB children, formulation of oral regimens for TB treatment that would be loved by the

children, and supporting innovative tools and models of care.

There were variations in the percentage of the outcome of TB treatment in children. Globally, TB treatment in children's outcomes is good overall, 85-91%; however, the proportion of incomplete adherence is still high (WHO, 2023). Research in Mozambique reported that 88% completed the TB treatment in children, in which undernourishment and a history of a refugee mother were risk factors for incomplete treatment (Lopez-Varela et al., 2017). In Indonesia, two studies reported that non-adherence to treatment of tuberculosis among TB children was 40.5%. First, a study in Makassar, city revealed that low knowledge of parents about TB and non-compliance with taking medication are factors that have a substantial risk of treatment failure for pulmonary TB patients in children (Baharuddin, 2019). Second, a study in Jogjakarta also showed that only 59.5% of the respondents with pulmonary tuberculosis were compliant with taking medication, and there was a relationship between scholarship, uphold from family and health workers with the compliance of medication consumption. However, they did not relate to patient encouragement and obstacles of visiting to health services (Rochmawati et al., 2024). Another study in Indonesia reported that in Palembang City the level of noncompliance among TB patients is 57.2% (Diesty et al., 2020).

Non-adherence with the treatment of tuberculosis was primarily due to the length of therapy, quick therapeutic response, and low motivation. A qualitative study reported several reasons, such as low knowledge about the disease, the length of medication, "felt cured," not knowing the duration of standard treatment, and the consequences if they stopped it (Gebreweld et al., 2018). A research in Uzbekistan reported that 44.7% of TB patients had adverse drug reactions (ADR), and females had two times higher compared to male patients. They also reported that the patients

who received the first-line of TB treatment had lower ADR compared to the patients who received the second-line of TB treatment (Abdusalomova et al., 2021). Another problem of TB was relapse, in which a case-control study in Makassar, Indonesia, reported that low education, low knowledge about TB, non-compliance in taking medicine, and low family support caused relapse of TB in children (Baharuddin, 2016).

Treatment in TB children has two stages, namely, the intensive stage and the advanced stage. In the intensive stage (early stages), patients get drugs every day for two months and need to be monitored directly to prevent drug resistance. In this intensive phase, there tends to be disobedience in treatment due to the emergence of drug side effects. Efforts to increase adherence to taking drugs have been carried out through educational information communication programs (IEC). The implementation of IEC programs is provided through education. In this case, health education is provided for parents and children. Therefore, providing and delivering information is necessary to change, foster, or develop positive behavior, not only for parents but also for the TB children (UNICEF, 2022).

Health education for TB children and parents that is widely used today is still conventional, such as using leaflets, booklets, or turning sheets. Along with the times, several studies show that using leaflets, PowerPoint, booklets, and turning sheets is less effective in increasing obedience than using simulations, games, videos, or online applications. A study reported that health education using leaflets and videos equally influences knowledge, but the video is more effective than leaflet media (Anggraeni et al., 2020). This study also concluded that the video is more transparent and takes advantage of the two senses simultaneously, namely vision and hearing. Besides, videos are more flexible in explaining the concept of matter and details of specific skills because they

usually directly describe the information by way of illustration.

Theory of Goal Attainment (TGA) by Imogene King is a nursing theory about nurse-patient connection. A literature study concluded that, according to King's theory of TGA, the absolute requirements of nursing practices were adequate knowledge about relationships and effective communication. The nurse-patient relationship will enhance the quality of care, enhance the patient's condition, and finally enhance the quality of life of the patients (Adib-Hajbaghery and Tahmouresi, 2018).

The development of positive behaviours in health can refer to King's Interaction Systems Theory, which explains an interrelationship between patients and nurses in the hope of achieving goals. Several studies reported success in health education based on this theory. For example, they are increasing the perceptions and self-care behaviour among diabetic patients after implementing nurse-patient transactions based on King's theory (Karota et al., 2020). Another study also proved that education to cadres based on King's theory to implement patient-cadre interaction significantly increased attitudes to prevention, attitudes towards fulfilling nutrition, self-efficacy, and motivation. The training has also proven to increase the cadre's abilities in an effort to prevent TB dropout (Sukartini et al., 2019). Patient noncompliance is the cause of failure in taking the pulmonary TB medicine. The nurse's role is vital in increasing compliance with taking medicine through interaction. Thus, a model of maintenance TB treatment needs to be implemented based on King's theory of interaction system to enhance adherence.

King's interaction system theory enhances compliance by encouraging patients' active participation in decision-making to achieve goals. The results of a study in East Java indicate that implementing King's system increased treatment adherence in lung TB patients.

Thus, King's interaction system becomes a suggested model for the clinical pathway for pulmonary TB patients. Furthermore, King's theory has also succeeded in increasing compliance and motivation of TB patients and preventing TB infections from spreading (Pujiastutik and Sumaningrum, 2019).

Currently, with the advent of the cell phone, most children have mobile phones. Thus, treatment information can be entered through an online application reminder to take medicine, aiming to remind children of drug timings through the ringing system alarm. Based on King's theory, which involved personal, interpersonal, and social systems, the authors have developed online applications and animated videos. This application has been validated by experts in education and psychology so that school-age children easily understand and undergo treatment without feeling pressured. This application focuses on children and parents not forgetting to take medicine on time. It also allows users to set alarms along with terms of date, time, and description of the drug, enabling them to set alarms for the drug at different time intervals.

The objectives of this study were to compare the treatment adherence and clinical indicators of TB children who received an intervention using an online application based on King's theory with a conventional method. The success of this application in increasing TB outcomes might be used as an evidence-based method for routinely conducting health education for TB children.

METHODS

Research design

This study is a quasi-experiment to educate TB children and parents using a validated online application compared with the conventional method in the control group. The online application media was based on King's interaction system theory, with two instruments: online applications and two videos. First, video TB education by the first author, and second a film about

a sick child who finally complies with the treatment. Meanwhile, the control group received education using the conventional methods of nurses using posters.

Place and time

Two community health centres were clustered randomly chosen as intervention and the other two as control groups—data were collected in July-December 2022.

Population and sampling method

Inclusion criteria include children 6-12 years diagnosed with childhood TB in the intensive stage for six months of TB treatment. Based on sample size calculation, comparing two proportions resulted in 55 TB children in each group. The authors used consecutive sampling in each location until all study participants were reached.

Data collection and analyses

The control discipline and medication regularity were observed in the community health centre four times in weeks 2, 4, 6, and 8. Measurements of clinical indicators, including sputum smear examination for acid-fast bacilli (AFB), TB scoring, chest X-ray examination, level of haemoglobin (Hb), and nutritional status, were done twice in pre- and post-intervention. The authors compared the outcome of the two study groups using chi-square, paired t-test, independent t-test,

Mann Whitney, McNemar^b, or Wilcoxon test.

Ethical consideration

All parents of TB children agreed to participate in this study after receiving informed consent. The Ethical Commission of the Faculty of Medicine approved this study with the number: 250/EC/KEPK/FK-UNDIP/VII/2022

RESULT

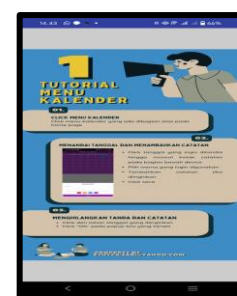
We present images of online applications, consisting of the application's cover, the menu page, user guidance, time to consume medicine, time to control, the booklet menu, the calendar menu, and two educational videos (Figure 1). The age of TB children varies from 6 to 12 years old. Table 1 compares subjects' characteristics in the intervention and control groups. The mean age of TB children (8.09 ± 1.42) years old in the intervention group and no significant differences (p-value of 0.09) compared to the control group with mean age (7.78 ± 1.95) years old. Moreover, the mother's education and their jobs were not significant either. The gender of TB patients and the age of the mother were significant differences. More girls were in the intervention group than the control group and mothers aged 41-50 were significantly less in the control group compared to the intervention group.



Cover of the application



Page of menu



Menu of User Guidance

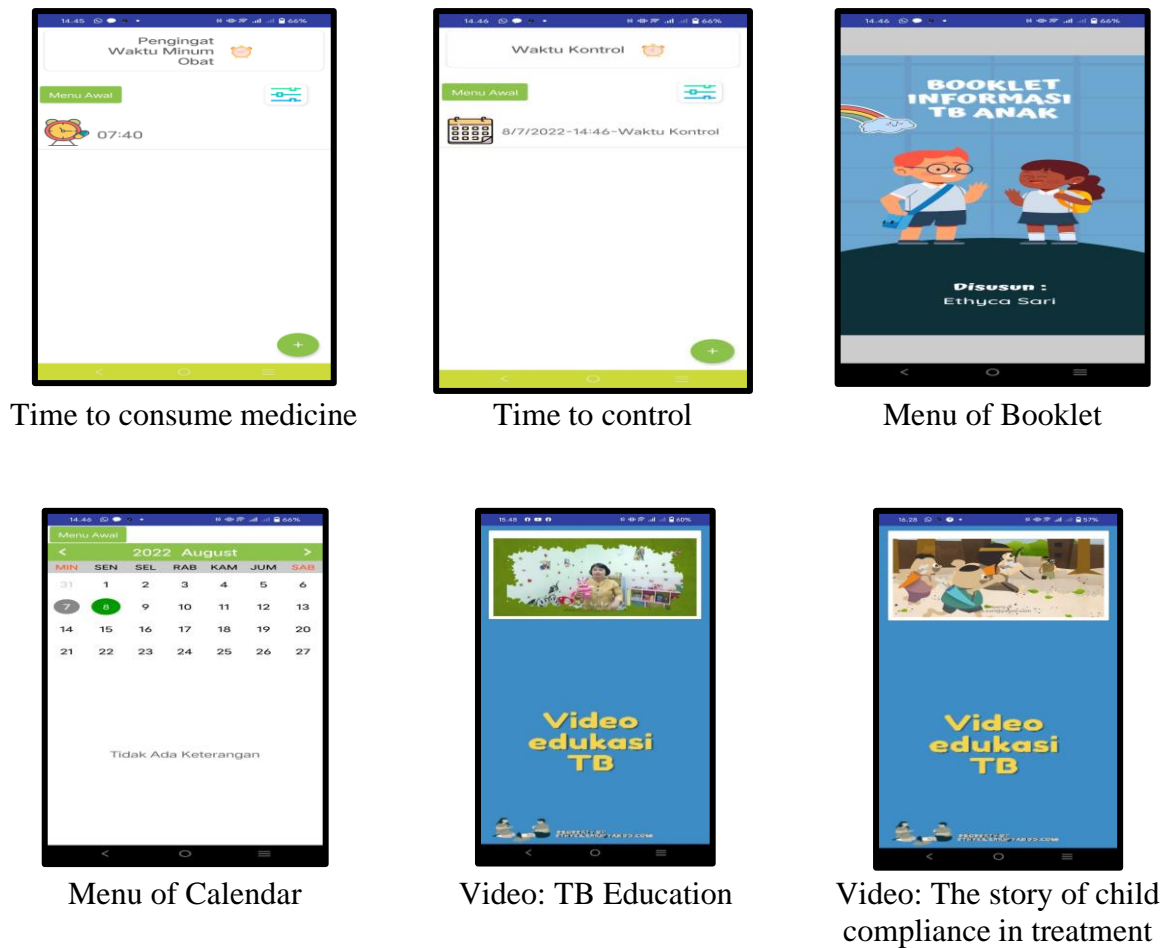


Figure 1. Images of the online application

Table 1. Comparison of characteristics between two groups of study

Subjects' characteristics	Intervention group	Control group	p value
Mean of age ± SD	8.09 ±1.42	7.78 ±1.95	0.09
Gender: - Girl	39 (70.9 %)	30 (54.5 %)	0.01*
- Boy	16 (29.1 %)	25 (45.5 %)	
Age of mother			
Less than 30 years old	10 (18.2 %)	14 (25.5 %)	0.007*
31-40 years old	32 (58.2 %)	38 (69.1 %)	
41-50 years old	13 (23.6 %)	3 (5.5 %)	
Mother's education			
Elementary school	12 (21.8 %)	8 (14.5 %)	0.078
Junior High school	15 (27.3 %)	14 (25.5 %)	
Senior High school	15 (27.3 %)	24 (43.6 %)	
University	13 (23.6 %)	9 (16.4 %)	
Mother's job			
Wife	23 (41.8 %)	35 (63.6 %)	0.47
General employee	14 (25.5 %)	5 (9.1 %)	
Government employee	8 (14.5 %)	5 (9.1 %)	
Private business	10 (18.2 %)	10 (18.2 %)	

* chi-square

Table 2 shows that the intervention group's routine drug consumption and control discipline improved significantly in the comparison with the control group with the p -value= 0.001. The outcome of clinical indicators in all criteria (AFB negative, TB scoring < 6, infiltrate harmful in chest X-ray, and the average of Hb level) in the

intervention group also considerably improved compared to the control group. Clinical indicators of nutrition were also significantly increased in both groups. However, before intervention, malnutrition status in the control group was already more prominent than in the intervention group, or had an imbalance before the study.

Table 2. Comparison of the outcome of the two groups of study

Outcome variables		Intervention	Control	<i>p</i> value
Routinely drug consumption	Unregular	2 (3.6 %)	38 (69.1 %)	0.001 ^a
	Regular	53 (96.4 %)	17 (30.9 %)	
Control discipline	Not discipline	2 (3.6 %)	37 (67.3 %)	0.001 ^a
	Discipline	53 (96.4 %)	18 (32.7 %)	
Before Intervention	AFB (+)	34 (61.8 %)	25 (45.5%)	0.087 ^a
	AFB (-)	21 (38.2 %)	30 (54.5 %)	
After Intervention	AFB (+)	6 (10.9 %)	24 (23.6 %)	0.001 ^a
	AFB (-)	49 (89.1 %)	31 (56.4 %)	
<i>p</i> value		<0.001 ^b	1.00 ^b	
Before Intervention	TB Scoring \geq 6	54 (98.2 %)	54 (98.2 %)	0.312 ^a
	TB Scoring < 6	1 (1.8 %)	1 (1.8 %)	
After Intervention	TB scoring \geq 6	7 (12.7 %)	28 (50.9 %)	0.001 ^a
	TB scoring < 6	48 (87.3 %)	27 (49.1 %)	
<i>p</i> value		<0.001 ^c	<0.001 ^c	
Before Intervention Chest X-ray	Infiltrate (+)	48 (87.3 %)	52 (94.5 %)	0.187 ^a
	Infiltrate (-)	7 (12.7 %)	3 (9.1 %)	
After Intervention Chest X-ray	Infiltrate (+)	3 (5.5 %)	43 (78.2%)	0.013 ^a
	Infiltrate (-)	52 (94.5 %)	12 (21.8 %)	
<i>p</i> value		<0.001 ^b	<0.001 ^b	
Before Intervention Haemoglobin level	Low	39 (70.9 %)	30 (54.5 %)	0.557 ^c
	Normal	16 (29.1 %)	25 (45.5 %)	
After Intervention Haemoglobin level	Low	7(12.7 %)	12 (21,8 %)	0.001 ^c
	Normal	48 (87.3 %)	43 (78.2 %)	
<i>p</i> value		<0.001 ^d	<0.001 ^d	
Before Intervention Nutrition status	Severe Malnutrition	1 (1.8 %)	12 (21.8 %)	<0.001 ^c
	Moderate Malnutrition	0 (0.0 %)	7 (12.7 %)	
	Normal	20 (36.4 %)	23 (41.8 %)	
	Overweigh	22 (40.0 %)	7 (12.7 %)	
	Obesity	12 (21.8 %)	6 (10.9 %)	

Outcome variables		Intervention	Control	<i>p value</i>
After Intervention Nutrition status	Severe Malnutrition	0 (0.0 %)	11 (20.0 %)	<0.001 ^c
	Moderate Malnutrition	1 (1.8 %)	3 (5.5 %)	
	Normal	11 (20.0 %)	25 (45.5 %)	
	Overweigh	23 (41.8 %)	8 (14.5 %)	
	Obesity	20 (36.4 %)	8 (14.5 %)	
	<i>p value</i>	<0.001 ^d	<0.001 ^d	

^aMann Whitney, ^bMcNemar, ^cIndependent t-test, ^dPaired t-test, ^eWilcoxon U

Sensitive analyses of Hb levels and TB scoring are performed in Tables 3 and 4. Table 3 displays that the Hb levels before treatment were not different in the two study groups. In contrast, the Hb levels in both study groups increased significantly after treatment (<.000^b). However, the mean delta of Hb level increased 2.10 ± 0.99 in the intervention group, whereas the control group only increased 1.01 ± 0.61.

Table 4 presents the median TB scoring of the two study groups during the pre-test, and there were no significant differences between the two study groups. In the post-test, there was a significant decrease in TB scoring from a median of 8 to 5 among the treatment group. Meanwhile, there was only a decrease from a median of 8 to 7 among the control group.

Thus, there was no significant difference in decreasing the TB scoring among the control group.

DISCUSSION

Various studies on adherence to TB treatment in paediatric patients have been widely conducted, with the results obtained having high variations. Educational media, through online applications and videos, is a channel to convey health information because these tools make it easier for the public to receive health messages. Android smartphones, the most widely used mobile communication device today, can help disseminate information and communication by utilising notification features.

Table 3. Hb level between groups

Hb level	Intervention group Mean ± SD	Control group Mean ± SD	<i>p value</i>
Pre-Intervention	11.54 ± 1.10	11.39 ± 0.86	0.557 ^a
Post-Intervention	13.61 ± 1.15	12.40 ± 0.90	0.000 ^a
<i>p value</i>	<0.000 ^b	<0.000 ^b	
Delta of Hb level	2.10±0.99	1.01±0.61	0.000 ^a

^aIndependent t-test, ^bPaired t-test

Table 4. Comparison of TB scoring between intervention and control group

TB scoring	Intervention group Median (Min-Max)	Control group Median (Min-Max)	<i>p value</i>
Pre-Intervention	8.00 (6-11)	8.00 (5-12)	0.312 ^a
Post-Intervention	5.00 (4-8)	7.00 (4-9)	0.001 ^a
<i>p value</i>	<0.000 ^b	<0.000 ^b	
Delta scoring TB	3.00 (1-6)	2.00 (0-4)	0.001 ^a

^aMann Whitney, ^bWilcoxon

Online applications and animated videos are vision and hearing aids that help stimulate the sense of sight (visual aids) and the sense of hearing (audio-visual aids) during counselling so that parents and children can easily perceive what nurses mean. In this case, researchers have not found the development of online applications and videos pertaining to the theory of Interaction System from King, which is used to conduct health education for TB children and parents by increasing the observance of taking drugs for TB children.

Routine drug consumption and control discipline

This study showed that after using an online application and video to consume medication based on King's theory, the intervention group had a significantly higher regularity of drug consumption than the control group. This study's results are in line with a study that approved King's theory of goal attainment as an effective approach to enhance patient adherence, enhance life satisfaction, and lowering difficulty of therapy (Balasi et al, 2020). Most research states that control indiscipline is influenced by a lack of enthusiasm and obedience in taking medicine. Adherence to TB treatment is a complex phenomenon in which many factors influence the patients' behaviour in taking TB medicine. The study of systematic reviews reported that patient-centred interventions succeeded in addressing several barriers to treatment adherence (Munro et al, 2007).

An intervention study compared community DOTS with family-member DOTS revealed that both methods succeeded in attaining international targets. The indicator used was the proportion of patients who were cured or finished the treatment (Newell et al', 2006). Intervention in regard to King's theory in this research strengthens nurses and patients connection, making patients more trusting and obedient to treatment. Besides, the

online application also allows for increasing the active involvement of the patients in their treatment, which might improve their control compliance. This study revealed that the control discipline in the experimental group was remarkably better than that of the control group, and the number of visits was also higher in the experimental group than in the control group. However, most TB children in the experimental group were girls and notably different from the control group. Therefore, the gender difference might influence the result of this study. Moreover, there was a significant mean difference between the mothers' ages, with the mothers in the experimental group were younger than those in the control group. These confounding variables might also impact the outcome of this research.

Clinical outcomes

The positive rate of AFB

This study decreased AFB in the intervention group, in contrast with the control group, which only occurred in a few patients. Aspects of medication regularity were also significantly better in the intervention group than in the control group, possibly affecting a significant decrease in the number of AFB results in the intervention group. Timely treatment of pulmonary TB is in the early stages to prevent drug resistance, and if the initial treatment is given appropriately, the potential for transmission usually decreases within two weeks after undergoing early-stage treatment; most AFB positive patients become negative (Yew et al., 2011). An observational study reported that 97.6% of patients who received the first-line anti tuberculosis drug who were cured externally transform to second-line anti-tuberculosis drug. Thus, smear-positive sputum after standard anti-TB treatment is mostly due to nonviable *M. tuberculosis* bacilli (MTB) or Non-Tuberculosis Mycobacterium (NTM) (Kang et al., 2016).

TB scoring

Based on TB scoring, this study showed that TB positive in both study groups reduced significantly. Nevertheless, reducing of TB scoring in the intervention group was remarkably better than the control group. The scoring system is proper to help establish the diagnosis of TB in children and reduce misperceptions of health workers in establishing TB diagnosis. Usually, clinical TB scoring is performed using an interview-based questionnaire and clinical examination. The paediatric TB scoring system was developed and recommended by the Indonesian Paediatrician Association, the WHO, and the Indonesian Ministry of Health to make it easier to establish the diagnosis of TB in children in community healthcare settings (Nurwanti et al., 2017). A literature review of paediatric TB reported differences and similarities in scoring items. Nevertheless, the scoring system is a foundation for pulmonary TB diagnosis in youngsters. Therefore, the TB scoring system can be used by health workers, including in limited facilities (Lusiana, 2019).

The infiltrate on radiological examination

This study showed that the infiltrate on radiological examination in both the intervention and control groups decreased significantly. However, the intervention group also performed significantly better than the control group. Infiltrates are often found as early lesions in people with pulmonary TB and which indicate an active disease process. A study that investigated radiological findings in TB children found that the prevailing lesion found in TB probable and confirmed cases was air space opacification and subsequently soft tissue density incidence of lymphadenopathy, pleural effusion, and airway compression. The most frequent location of soft tissue density suggestive of lymphadenopathy among TB cases was in the upper right lobe

of the mediastinal region, subsequently the middle right lobe and area of the anterior paratracheal. The opacification is mainly in the middle right lobe, subsequently left lobe and lower right (García-Basteiro et al., 2015)

The level of Hb

The study results showed a remarkable increase in Hb levels in both the study groups. However, the increase in Hb levels was more critical in the intervention group than in the control group. This study aligns with a study that reported stepped increases in Hb levels on days 30 and 60 among TB patients after therapy anti-tuberculosis (Gil-Santana et al., 2019). Anaemia is the typical co-existing present in patients with TB. A study reported that 31.9% of patients with TB had anaemia, with 5% less than ten g/dL. The predictive factors for the resolution of anaemia were good treatment response and initial high Hb. Usually, TB-associated anaemia resolves with anti-TB treatment. Therefore, close observation is needed for patients with TB-associated anaemia (Lee et al., 2006).

Nutritional status

The pre-test results of this study showed poor and deficient nutritional status in the control group, and was notably different than in the intervention group. The post-test results revealed a slight decrease in malnourished individuals and less in the control group. Unlike the intervention group which had a very remarkably increase in nutritional status. Nevertheless, in this study, clinical improvements in the intervention group regarding nutritional status could not be compared with the control group because, from the beginning of the study, the nutritional status was unbalanced and benefited the intervention group. A cross-sectional survey in China showed that children with TB affected their nutritional status. The incidence rates of malnutrition were excessive among TB children aged 0.5–2 years and 10–16 years,

respectively. Therefore, monitoring anthropometric and biochemical indicators should be carried out as soon as possible (Gao et al., 2023).

Limitations of the study

The limitation of this study is due to the quasi-experimental design, in which cluster randomisation was only done for the community health centre as the study location. Thus, there was no random allocation for each intervention or control group participant. One of the consequences was a nutrition status imbalance between the intervention (experimental) and the control group before starting the study. Therefore, increasing nutritional status was exempt from the success of this intervention. Besides, no blindness in the outcome measurement might influence the objectivity, including the possibility of the Hawthorn effect in the intervention group.

CONCLUSION

An interactive online application and animated videos about adherence to taking medication in children with TB disease has been proven successful in increasing adherence to treatment, control discipline, and clinical improvement with indicators: AFB examination results (-), TB scoring < 6, infiltrate images (-) on radiological examination, and increased HB levels. Clinical improvement in this study indicates successful treatment, supported by adherence to medication and consistent control discipline. The implication of this study in nursing practices is to enrich the education method, which empowers TB children to be active in increasing their motivation to be cured.

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