COST-EFFECTIVENESS OF A TECHNOLOGY BASED HEALTH INTERVENTION MODULE ON UNDER-FIVE CHILDHOOD IMMUNIZATION SCHEDULE

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ABSTRACT

Technology based health intervention has seen an increase in use in multiple health programs. Improving non-adherence days ensures that children achieve maximum benefits of the immunization program. Determining the cost-effectiveness of the intervention to improve non-adherence days to the under-five childhood immunization schedule will be beneficial to policy and decision makers. A quasi-experimental study was conducted in nurseries in Putrajaya and Cyberjaya from January 2016 to January 2018. The sample size were 196 respondents with Putrajaya as the intervention group and Cyberjaya as the wait-listed control group. The intervention was a technology based health education module. Intervention groups received the intervention through the messaging service of Whatsapp at pre-determined intervals. Respondents answered a validated, self-administered questionnaire at baseline, immediately post-intervention and 3 months post-intervention. The costs of this program was then calculated to determine its cost-effectiveness. Data was analysed using Statistical Package for Social Science (SPSS) Version 23. The mean non-adherence days were 10 at baseline with no significant difference between both groups. The cost-effectiveness analysis showed that the intervention was cost effective with the cost-effectiveness ratio being less than 1. The technology based health intervention module was cost-effective in improving non-adherence days. The ability to improve non-adherence will greatly benefit children who receive the under-five childhood immunizations and the costs reduction may help policy makers to determine future plans of action.

Keywords

Under-Five Childhood Immunization Schedule, Adherence, Cost-Effectiveness of Health Intervention and Technology based Health Education Module.
1.0 Introduction

Immunization is the process to replace a predicted natural primary contact between the human body and a hostile organism with a much safer artificial contact, in order to allow the build up of antibodies that increase the immunity with subsequent natural contact as stated by the World Health Organization (WHO) (2016). It also explains that immunization as a process where a person through a vaccine administration obtains immunity.

Adherence has been the key major factor for the alarmingly high number of vaccine preventable diseases occurring even with data stating a very good coverage of vaccine. Adherence has multiple definitions according to various literatures with some defining it as defaulters, delay in the immunization schedule or incomplete immunization coverage (Hill et al. 1991; Nyhan et al. 2015; Vassiliki et al. 2014). Even in developed countries such as the United States a worryingly high number of vaccine preventable diseases and outbreaks such as measles has been on the rise with 23 outbreaks reported and the biggest single outbreak involved 383 persons for 2014 alone with factors being attributed to misinformation, anti-vaccine groups and non-compliance to the immunization schedule (Nyhan et al. 2015). The study done by Hill et al. (1991) in the United States of America demonstrated how the Hepatitis B vaccination was recorded as having good coverage (>95%) but still had a high prevalence rate of transmission among the respondents. This was due to the adherence issues of not completing the immunizations on schedule with an average mean delay of 1.3 months. It found the significance of being not being adherent to jeopardizing the effectiveness of a Hepatitis B immunization program in that population. Vassiliki et al. (2014) demonstrated in his prospective study that adherence to the immunization schedule was a key factor in the reduction of immunization coverage in Greece where there was more than 35% drop of immunization coverage from 2011 to 2014 among the under-five population.

In addressing the issues regarding adherence to immunization, health education is an important aspect in decision-making process on childhood immunization. It goes in tandem with health literacy, which may be defined as the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health (WHO, 2015). Various countries have already in place many health programs that aim to promote and empower populations to adhere to the immunization schedule. Technology based health intervention has been on the rise in the health care invention programs with the broad accessibility of computer and smart phones with penetration rates higher in developed countries but also a very encouraging number in developing and under developed countries as well (Gücin & Berk, 2015). The amount of information, encouragement and support that can be conveyed to individuals during face-to-face consultations or through traditional media such as leaflets is limited, but mobile technologies such as mobile phones and portable computers have the potential to transform the delivery of health messages. These increasingly popular technologies where more than two-thirds of the world's population now owns a smart phone can be used to deliver health messages to people anywhere and at the most relevant times (Feldmann, 2003). Technology is a means for providing individual level support to health care consumers. Technology based health interventions for health care consumers have been designed to increase healthy behaviour such as to remind regarding upcoming appointments, medications timing reminders and also for compliance to immunization schedules (de Fine Olivarius et al. 2001). A very successful program was also demonstrated by Free et al. (2009) in a randomized control trial that showed an increase in the number of successful participants who stopped smoking among...
those who received a technology based health intervention in comparison to those who did not. Similarly in the study by McMahon et al. (2005) utilized a web-based intervention to help improve the HBA1C levels of diabetic patients. Participants receiving web-based care management had lower HBA1C over 12 months when compared with education and usual care. Persistent website users had greater improvement in HBA1C when compared with intermittent users or education and usual care. Technology based health intervention is an important role in the future of health care programs and intervention and must be explored.

However in implementing any health intervention program, the cost and benefits of the program must always be accounted for to ensure sustainability and effectiveness of the program is achieved. Thus incorporating health economic evaluation tools such as cost-effectiveness analysis in a health intervention program will enable the comparison of relative costs and outcomes of two or more courses of action (Russell et al. 1996). This is important for any ministry or health agencies, as they were able to justify the need for a program and also detect programs that are not cost-effective. Cost-effectiveness has been used in multiple health intervention studies such as those by Solberg, Maciosek & Edwards (2008), Windsor et al. (1990) and Barnett & Hui (2000). The studies conducted a cost-effectiveness analysis to determine the most cost effective method of health intervention for the purpose of ensuring sustainability. Cost-effectiveness analysis is an integral part of health care that has often been overlooked mainly due to lack of expertise or budgetary constraints. However by implementing the health economic evaluation in a study, future projects and research will be able to have a more systematic and mathematical referencing material to ensure progressive developments in health intervention programs and research.

2.0 Methods

2.1 Study design and location

A quasi-experimental study design was used for the study. Respondents in Putrajaya were selected to be the intervention group while those in Cyberjaya were selected to be in the control group. The control group was wait-listed and only received the technology based health intervention when the final period of 3 months post-intervention was concluded in Putrajaya. The study was conducted over a period of 2 years from January 2016 to January 2018.

2.2 Recruitment

Recruitment was initiated by approaching all the nurseries listed under the welfare department in both areas. Those that were showed interest and were willing to join the study were then asked to provide the list of all parents and children who were registered in the nurseries. The list was then analyzed and the data gathered was crosschecked to determine if the inclusion and exclusion criteria were fulfilled. All those short-listed were contacted directly to ask for consent to involve them in the study. Those who refused were excluded and this resulted in the recruitment of 196 respondents in total, 98 in the intervention group and 98 for the control group. The participants were then provided with the information that they would now be included in a Whatsapp® chat group and that further instructions will be provided once the group is initiated.
2.3 Participants

Men and women are eligible to participate in the study if they were Malaysian, had a child under 24 months old who had an immunization appointment in 3 months, there were non-adherent to the immunization schedule and if they had more than one child registered in the nursery, the youngest child will be selected. To ensure commitment to the research group, the respondents were allowed to have access to a medical officer from 8am to 10pm daily for any questions pertaining to general health that would be answered as quickly as possible. This is further detailed out in Table 1.

2.4 Setting

The research utilized the chat group and was active daily from 8am to 10pm daily for 3 consecutive months. At the start of the intervention, the participants were given a thorough explanation regarding the rules of communication, what type of materials they are to expect and not to spread or share the information to other friends and family until the end of the study period. Respondents were also told that none of their information will be further recorded where no names needed to be given or introductions among respondents to be necessary. The module was given in a systematic timeline where the respondents would receive information on Mondays, Wednesday, Fridays and Sundays between 8am and 8.30am. The moderator of the group was a trained medical officer well versed in the under-five childhood immunization schedule.

2.5 Measurement instruments

The primary outcome is the adherence to the under-five childhood immunization schedule, whereas the secondary outcome was the knowledge, vaccine perception and awareness of the under-five childhood immunization schedule. At baseline, socio-demographic data (respondents, child, maternal and logistic factors) about the participants and the number of adherence days are collected. The research utilized a tested and validated self-administered questionnaire that the respondents had to complete at baseline; immediate post intervention and 3 months post intervention. The cost effectiveness analysis followed the health economic evaluation method.

2.6 Analysis

Data was first analysed descriptively to identify means of the response. Log transformation was performed to reduce skewness and to obtain normal distribution of data, and outliers were then removed by checking the Mahalanobis Difference. For adherence days, paired sample t-test was used to measure adherence days within group, independent t-test for between groups, bivariate analysis of which independent t-test was used for categorical factors and Pearson’s correlation for continuous factors to measure association and was then followed by generalized estimating equations (GEE). The health economic evaluation, in the form of a cost-effectiveness analysis was then performed at this stage.
### Figure 1: Cost-Effectiveness Ratio (CER) Calculation Pathway

\[
TC_I = \frac{x}{a} \\
TC_C = \frac{y}{c} \\
CER = \frac{TC_I}{TC_C}
\]

Where:

- \( x \) = cost of intervention for intervention group.
- \( y \) = cost of intervention for control group.
- \( a \) = number of respondents in intervention group with adherence.
- \( b \) = number of respondents in intervention group without adherence.
- \( c \) = number of respondents in control group with adherence.
- \( d \) = number of respondents in control group without adherence.
- \( TC_I \) = total cost of 1 unit in intervention group.
- \( TC_C \) = total cost of 1 unit in control group.
Table 1: Calculation of cost for labour, consumables and overheads.

<table>
<thead>
<tr>
<th>Labour</th>
<th>Total time of each staff member</th>
<th>Monthly wage rate plus EPF or pension contributions.</th>
<th>=</th>
<th>Total staff cost per intervention.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumables</td>
<td>Number of each consumable item used</td>
<td>Purchase cost for each consumable item</td>
<td>=</td>
<td>Total consumables</td>
</tr>
<tr>
<td>Existing costs</td>
<td>Existing costs of programs</td>
<td>=</td>
<td>1</td>
<td>=</td>
</tr>
<tr>
<td>Overheads</td>
<td>Cost of overheads</td>
<td>X Days used</td>
<td>=</td>
<td>Total overhead cost</td>
</tr>
</tbody>
</table>

Cost of 1 unit of adherence is equal to the total cost of group divided by the total number of adherence of group.

The costs were then calculated according to the time spent with the cost from the salary over a 3-month period, from the commencement of the study to the end of the study. Every role that the researcher underwent was simulated to that of the human resource and other factors that would have cost. This enabled a clear costing calculation and ultimately enabled the researcher to then perform the cost-effectiveness analysis on the study.

Cost-Effectiveness Ratio (CER):

The results of the calculation enabled the researcher to calculate the cost-effectiveness ratio to ascertain between the intervention and control group, which was the most cost-effective. This enabled the researcher to identify if the technology based health intervention module is sustainable to be utilized for future use. Cost-effectiveness of intervention group was obtained using Cost-Effectiveness Ratio (CER) calculation. Both of the groups were measured on the same output that is the adherence to the under-five childhood immunization schedule that is quantified:

\[
CER = \frac{\text{Cost of intervention group to achieve 1 (ONE) unit of adherence}}{\text{Cost of control group to achieve 1 (ONE) unit of adherence}}
\]

If CER < 1, means the intervention IS cost-effective
If CER > 1, means the intervention IS NOT cost-effective
3.0 Results

A total of 60 nurseries in Putrajaya and 12 in Cyberjaya were identified. However only 16 nurseries agreed to participate from Putrajaya and 7 from Cyberjaya. These administrators proceeded with sending the immunization records of those registered under their care with a total of 467 immunization cards from Putrajaya and 237 from Cyberjaya being screened for eligibility. The total number of non-adherence obtained from the screening and fulfilled the inclusion and exclusion criteria were 250 for Putrajaya and 151 for Cyberjaya. The final respondents were then selected utilizing simple random sampling using Microsoft Excel spreadsheet and formulating the random generator whereby 98 participants were in the intervention group (Putrajaya) and the control group (Cyberjaya). The response rate was 113% but at the end of the study there was a drop out rate of 16%.

Adherence on under-five childhood immunization schedule was first measured with all the respondents from both the intervention and control group combined. The mean days of non-adherence was 12.46 days or 12 days after being rounded to the nearest number of days at baseline. As for 3 months post intervention the number of non-adherence days reduced to 9.76 or 10 days when rounded to the nearest number of days. The generalized estimating equations (GEE) analysis was used to determine the difference between the intervention group and control group at baseline and 3 months post intervention. Bivariate analysis was first performed on all the variables and those that were significant were included in the GEE analysis and this was child living with mother. The model information demonstrates that it is a linear plot that uses adherence as the dependent variable and takes into account between group effect and within group effect (time). Unstructured working correlation matrix is used as it results in the best model fit.

The goodness of fit model, quasi likelihood under independence criterion (QICC) was 32.356. At tests of model effects, group showed significant (Wald Chi-Square=138.729, df=1, \( p<0.001 \)) as well as time (Wald Chi-Square=27.964, df=1, \( p<0.001 \)) and child living with mother (Wald Chi-Square=47.443, df=1, \( p<0.001 \)).

In the Table 2 below, the results of the GEE analysis are showed. From the analysis result show that those in the intervention group were 75% more likely to have a change in adherence in comparison to the control group (aOR=0.745, 95% CI = 0.701 – 0.793, \( p<0.001 \)). There was also an 82.5% likelihood change in adherence from 3 months post intervention time point in comparison to baseline time point (aOR=0.825, 95% CI = 0.769 – 0.886, \( p<0.001 \)).
Table 2: GEE of adherence to the under-five childhood immunization schedule

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>Adjusted Odds Ratio</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.179</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>-0.313</td>
<td>0.0266</td>
<td>138.73</td>
<td>0.731</td>
<td>0.694</td>
<td>0.770</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.192</td>
<td>0.0363</td>
<td>27.964</td>
<td>0.825</td>
<td>0.769</td>
<td>0.886</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3 months post</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group*Time</td>
<td>-0.187</td>
<td>0.0245</td>
<td>17.786</td>
<td>0.724</td>
<td>0.156</td>
<td>0.972</td>
<td>0.003</td>
</tr>
</tbody>
</table>

*Reference group, *Significant at p < 0.05

Cost effectiveness was calculated by incorporating all costs, from overhead costs, indirect costs, fixed costs and recurrent costs. Average Based Costing (ABC) was performed to determine associated costs. Obtaining the cost of 1 unit of adherence allowed the calculation of the cost-effectiveness ratio (CER) and the incremental cost-effectiveness ratio (ICER).

In Table 4 below the entire costs are shown and the final cost of 1 unit of adherence is obtained for both the intervention group and control group. The overhead costs information was gathered from the accounts department of the health district and aggregated accordingly. Direct cost, indirect costs and the final calculation of the costs for both groups are shown. The final cost for the intervention group was RM 21,491 and for the control group was RM 14,847. The difference in the total sum between both groups was RM 6,644.

Table 4: Financial costs of intervention and control group

<table>
<thead>
<tr>
<th>Overhead Costs (RM)</th>
<th>Yearly (220 days)</th>
<th>Daily</th>
<th>Units Used</th>
<th>Final Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>I C I C</td>
<td></td>
</tr>
<tr>
<td>Administration</td>
<td>1,360,000</td>
<td>6,181.8</td>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>44,000</td>
<td>200</td>
<td>30 30</td>
<td>6,000 6,000</td>
</tr>
<tr>
<td>Transport</td>
<td>12,000</td>
<td>54.5</td>
<td>9 3</td>
<td>490.5 163.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Direct Costs (RM)</th>
<th>Total Cost</th>
<th>Daily Cost</th>
<th>Units Used</th>
<th>Final Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I C I C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health promotion staff</td>
<td>55,000</td>
<td>250</td>
<td>10 5</td>
<td>2,500 1,250</td>
</tr>
<tr>
<td>Staff nurse</td>
<td>46,000</td>
<td>209.1</td>
<td>15 8</td>
<td>3,136.5 1,672.8</td>
</tr>
<tr>
<td>Community nurse</td>
<td>22,800</td>
<td>103.6</td>
<td>30 15</td>
<td>3,108 1,554</td>
</tr>
<tr>
<td>Driver</td>
<td>19,200</td>
<td>87.3</td>
<td>9 3</td>
<td>785.7 261.9</td>
</tr>
<tr>
<td>Health promotion materials</td>
<td>76,000</td>
<td>345.5</td>
<td>10 10</td>
<td>3,455 3,455</td>
</tr>
<tr>
<td>Intervention materials</td>
<td>1,000</td>
<td>-</td>
<td>1 0</td>
<td>1,000 0</td>
</tr>
<tr>
<td>Smart phone</td>
<td>400</td>
<td>-</td>
<td>1 0</td>
<td>400 0</td>
</tr>
<tr>
<td>Data plan</td>
<td>1,200</td>
<td>5.5</td>
<td>55 0</td>
<td>302.5 0</td>
</tr>
<tr>
<td>Gift token</td>
<td>490</td>
<td>-</td>
<td>1 1</td>
<td>490 490</td>
</tr>
<tr>
<td>Indirect Costs (RM)</td>
<td>Total Cost</td>
<td>Daily Cost</td>
<td>Units Used</td>
<td>Final Cost</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>Train the trainer course</td>
<td>100</td>
<td>-</td>
<td>1 0</td>
<td>100 0</td>
</tr>
<tr>
<td>Call-centre training</td>
<td>50</td>
<td>-</td>
<td>1 0</td>
<td>50 0</td>
</tr>
<tr>
<td><strong>Total Sum</strong></td>
<td><strong>21,491</strong></td>
<td><strong>14,847</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I = Intervention group, C = Control group

The adherence cost is calculated by utilising the difference in the number of days to obtain adherence unit. 1 unit of change in number of days from baseline is added or subtracted, to show the final number 3 months post intervention.

![Figure 2: Adherence difference from baseline and 3 months post-intervention](image)

Cost of 1 unit of adherence for Intervention Group:
= 7 units costs 21,491
= RM 3070 cost per unit

Cost of 1 unit of adherence for Control Group:
= -4 units costs 14,847
= RM -3712 cost per unit
As we have already obtained the final cost per unit for both groups the cost-effectiveness ratio can now be calculated. Utilizing the cost per unit of the intervention group we divide it with the cost per unit of the control group to obtain the CER.

\[ \text{CER} = \frac{3070}{3712} \]

\[ \text{CER} = 0.82 \]

Thus if CER is <1 it is therefore cost-effective.

The calculation represents that the intervention module is almost 182 times more cost-effective than the control module in obtaining 1 unit of change in adherence.

The ICER is the difference in costs between the intervention group and control group modules, and divide by difference in their effects (adherence). It shows the average incremental cost associated with an additional unit of the effect measured.

\[
\text{ICER} = \frac{(C_1 - C_0)}{(E_1 - E_0)}
\]

*\(C_1\) and \(E_1\) are the cost and effect in the intervention group and where \(C_0\) and \(E_0\) are the cost and effect in the control care group

\[ \text{ICER} = \frac{21,491 - 14,847}{7 - (-4)} \]

\[ \text{ICER} = 604/\text{Adherence day} \]

**Figure 3:** Cost effectiveness plane for intervention compared with control

For the intervention group, both the incremental cost and incremental effect are positive, the determining of whether the intervention is cost-effective depends on a threshold value \(\lambda\) – of which society is willing to pay for an incremental health gain or equivalently the minimum that society will be willing to accept to forego an incremental health gain. The intervention is regarded as cost-effective when its incremental cost-effectiveness ratio is lower than the set threshold.
4.0 Discussion

The actual cost of the intervention group was calculated to be RM 21,491 and the control group to be RM 14,847. The researcher utilized this number to calculate the cost of 1 unit of adherence. This is important because in determining 1 unit of adherence the researcher was able to formulate the ratio. At baseline both the groups recorded a 10 days to be the non-adherence days. The researcher formulated that 10 days would be the baseline and either added or subtracted the difference in the number of days.

The cost for 1 unit of adherence for the intervention group was 3070 whereas the control group was -3712. This showed that the control group was completely not cost effective. The intervention group was 181 times more cost effective than the control group. The stark difference in the results show that the technology based health intervention is effective in improving adherence days. This result was expected as the systematic enforcement of the module ensured continuous line of communication between the researcher and the respondents. As for the control group, this previously unknown analysis shows a major fault in the current existing health program as the results portray a loss making and ineffective health program. Although conclusions can be drawn from the analysis, a more thorough micro costing needs to be conducted to clarify the results.

Due to the negative impact of the control group, any comparison to the intervention group would be redundant. In all circumstances the result would always show a favourable outcome to the intervention group.

As the incremental cost of the control group is positive and the incremental effect is negative, the current programme for the control group is unequivocally not cost effective. This data also shows that there is absolutely no cost benefit of the current health module to the intervention group. This shows that the money spent on the current health program is not cost effective, but is also a liability as it worsens the number of adherence days.

The main function of the ICER was to enable the researcher to conclude if the health intervention would be cost-effectively applicable on a larger scale such as nationwide implementation. This may enable policy makers and decision makers to enforce and implement technology based health intervention nationwide for the benefit of the population. Respondents must however possess a smartphone and the application installed to be able to join the program, and the costs for purchasing or ensuring that entire populations have this is not accounted for.

5.0 Conclusion and recommendation

The intervention was successful in improving the number of non-adherence days of respondents in the intervention group and was found to be significant from ten days to three days, as opposed to the control group that also showed significant difference but where the number of non-adherence days worsens from ten days at baseline to fourteen days after three months. In comparison between the two groups at baseline it was found to have no significant difference but at three months post intervention analysis showed a significance difference between the intervention group and control group on number of non-adherence days. Health
economic analysis conducted showed that the intervention was cost effective after calculating the cost effectiveness ratio. As for the control group, the existing standard health care was unequivocally not cost effective. Following an intensive three months intervention to improve the non-adherence days of respondents, it was found that the technology based health intervention module was effective.

As the research has shown that the intervention is highly effective and cost effective, that it be integrated and implemented by the Ministry of Health Malaysia. As the results show that the current standard of health promotion program is not cost effective, adapting and launching the technology based health intervention module will be very beneficial. Change in public behaviour, knowledge, vaccine perception and awareness is achievable with the proper utilization of a technology based health intervention module. This may enable the systematic decline of vaccine preventable disease and avoid outbreaks in the future. A higher attainable goal is to achieve total immunity that is a step up from herd immunity.

Declarations

Authors declare this is no conflict of interest in publishing this paper.

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Authors’ contributions

MFR made contributions to the writing of the manuscript, data collection and analysis. MHJ provided idea of the study design and the direction of the study process as well as the re-evaluation of the entire analysis. NAMZ gave insight on the study design as well as the critical revisions of the research.
References


