Periodontal treatment needs and workforce requirements: comparisons between the normative and sociodental approaches using different skill mix models


Abstract – Objectives: Assessment of dental treatment needs has predominantly been based on the normative approach, despite its numerous limitations. The sociodental approach is a more rational method of needs assessment as it incorporates broader concepts of health and needs and behavioural propensity. This study compares estimates of periodontal dental treatment needs and workforce requirements for different skill mixes using normative and sociodental approaches among a sample of adults in Malaysia. Methods: A cross-sectional study was carried out on 732 Malaysian adults aged 30–54 years. Subjects’ normative and sociodental needs for periodontal treatment were assessed using WHO criteria, an oral health-related quality of life measure (the Oral Impacts on Daily Performances index), and behavioural propensity measures for toothbrushing and smoking behaviour. The proportion of subjects requiring periodontal treatment and the numbers of dentists and dental therapists required to treat them using the normative and sociodental approach were compared using different skill mix models. Results: The estimates of need for periodontal treatment using the sociodental approach were 90% lower than the respective estimates using the normative need method. Overall, 14.43 dentists would be required per 100 000 people using the normative approach compared to 2.32 for the sociodental approach. When skill mix models were used, the number of dentists required decreased by almost 70% when more periodontal procedures were delegated to dental therapists. Conclusions: Using the sociodental approach resulted in much lower estimates of dental need and workforce requirements for periodontal treatment than using the normative method. Using dental therapists markedly reduced the numbers of dentists needed for periodontal treatment.

Key words: auxiliaries; manpower; periodontal diseases; quality of life

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Numerous workforce models have been used to determine the appropriate numbers and types of current and future health personnel. They include the Health Needs Model (1, 2), the Service Target model (1, 3), the WHO/FDI JW6 model (4, 5). Each model uses different combinations of data or assumptions to derive the estimates. For example, the Health Demands Model (2, 6) uses utilization data, and the Manpower to Population Ratio Model (7) calculates the required health workforce...
based on the size of the targeted population. As different models generate different estimates for the same health scenario, it is important to choose one that more accurately estimates workforce requirements. This is usually influenced by the political, economic and social values of a health system (7) and the method used to assess needs.

In dentistry, various methods have been used when estimating needs for dental personnel. For example, in England (8), Scotland (9) and Australia (10), the Health Demand method was used to predict dental workforce requirements while the WHO/FDI model, which is based on needs weighted by demand, was used in France (11) and Lebanon (12). These models estimate dental workforce requirements by assessing the population’s normative dental treatment need based either on clinical dental conditions or the trends in clinically assessed oral health and patterns and types of dental utilization. The changes in knowledge about the life history of caries and periodontal disease were probably not taken into account. For example, a number of studies have reported a slow progression of dental caries (13) and periodontal diseases (14), and a decline in the prevalence of some common oral diseases (15). The estimation of dental workforce should therefore consider these changes in patterns of oral diseases as they impact on the future roles and types of dental workforce requirements.

In Malaysia, dental disease levels among adults are generally high. The prevalence of caries and periodontal disease was above 88% in 2010 (16). Authorities have employed the ratio method, and the target was to have one dentist per 4000 people by the year 2020. The numerous shortcomings of the ratio method have been discussed (1). A recent review on the Malaysian dental workforce demonstrated that if the Health Needs method is used to predict dental workforce, there will be a possibility of oversupply of dentists in 2020 (17). However, no action has been taken to modify the dentist to population ratio of 1 to 4000.

Another common limitation of most workforce models is that they only use normative or clinical assessments to assess health needs. There are numerous limitations to using clinical measures as the only parameter when assessing treatment need (18). Normative assessments do not capture subjective perceptions in relation to the psychological and social impacts of a health condition, and such perceptions are important determinants for utilizing health services. In addition, normative methods do not consider people’s health behav-
studies have not considered differences in estimates of workforce requirements between these two approaches. A study on a representative adult sample in South Korea (19, 26) found that the need for dentists was significantly lower using SDA compared to NN. However, that study did not use a skill mix approach in deriving dental workforce estimates. Therefore, the objective of this study was to compare estimates of periodontal dental treatment needs and workforce requirements for different skill mix models using normative and sociodental approaches among a sample of adults in Malaysia.

Materials and methods

A cross-sectional study was carried out on a Malaysian adult sample of 30- to 54-year-old employees of a public university in Kuala Lumpur. The age range was chosen because adults of that age have established periodontal disease. The estimated sample size was calculated as 723, based on the predicted differences in proportion between normative needs and sociodental needs (estimated at 40%) and a nonresponse factor of 10%.

The survey contained an oral health examination and a face-to-face interview. The NN for periodontal treatment was assessed using a modified Community Periodontal index (CPI) (27) where the presence of bleeding, calculus and pocketing was recorded for all index teeth. Duplicate periodontal examinations were carried out on 6% of total sample during the survey period, and the intra-examiner agreement was excellent (kappa 0.82).

The SDA assesses oral health needs by identifying people with normative need, then looking at their perceived need using an oral health-related quality of life (OHRQoL) measure and at the propensity to benefit from dental treatment (18). The SDA has been described in detail elsewhere (19, 24, 25). In brief, there are three components of the SDA: (i) normative need (NN), where treatment needs are assessed by professionals, (ii) impact-related need (IRN), where normative needs are combined with OHRQoL and (iii) propensity-related need (PRN), where IRN is combined with the behavioural assessment to determine the type of appropriate treatment. There are two different models of the SDA (18). The first is the dental treatment needs for life-threatening and Chronic Progressive Oral Conditions (DNLP) Model. It is for people with life-threatening health conditions, such as oral cancer, or those with chronic progressive dental conditions. People with such conditions are only normatively assessed, and appropriate dental treatments are provided based on their propensity to benefit. The second model is the Basic Model for Dental Treatment (BMDN). This is for people with nonlife threatening and nonprogressive dental conditions. They are assessed for all the three main components of the SDA.

The OHRQoL and propensity were assessed by interview. The Malaysian version of the Oral Impacts on Daily Performances index (OIDP) (28) was used to evaluate OHRQoL. This widely used OHRQoL measure allows the calculation of a condition-specific score (CS-OIDP), whereby the reported oral impacts are attributed to specific oral conditions or diseases, such as periodontal disease. Respondents were asked whether they experienced difficulties in the following daily life activities and behaviours due to their oral health and related problems in the past 6 months: eating, speaking clearly, cleaning teeth or dentures, going out, performing light activities, performing main role, sleeping, smiling, emotional stability and enjoying contact with people. For each of the oral impacts experienced, respondents provided a frequency (0 = never, 1 = less than once a month, 2 = once or twice a month, 3 = once or twice a week, 4 = three to four times a week and 5 = every day or nearly every day) and severity (0 = no effect, 1 = very little effect, 2 = little effect, 3 = moderate effect, 4 = severe effect and 5 = very severe effect) rating. A performance score was calculated by multiplying the frequency and severity ratings. Participants who reported an oral impact were further asked which oral condition(s) they felt were responsible for that impact. This allows partitioning of the overall OIDP score to scores specific to an oral condition. If they reported an oral impact and attributed the impact to having calculus, loose teeth, bad breath, bleeding gums, swollen, abscessed or receding gums, they were considered to have an impact-related need (IRN) for periodontal treatment.

Propensity-related behaviours for periodontal needs include toothbrushing practices and smoking as they are the main behaviours that affect periodontal health and the success of periodontal interventions. Respondents were asked about the frequency of their toothbrushing and smoking practices. Those who brushed twice daily and never smoked or had quit smoking more than
10 years ago were considered to have a high propensity for periodontal treatment.

Data on the timings of periodontal procedures were used to estimate numbers of dental personnel needed to treat periodontal disease. An expert committee consisting of six dentists from the Faculty of Dentistry, University of Malaya reviewed periodontal procedures and determined the recommended minimum and maximum time estimates for a dentist to perform different types of periodontal treatment. There were no local data available on the timings for dental therapists performing treatment on adult patients, as they are not currently allowed to treat adults in Malaysia. As the mean time taken by Malaysian dentists and dental therapists to perform amalgam restorations on permanent teeth in school children was comparable (29), we assumed that the dentists’ timings for carrying out periodontal procedures on adults would also apply for dental therapists. The proportion of respondents needing periodontal treatment and the number of dental sextants requiring treatment using the NN and SDA were compared using the McNemar test. In this study, the NN model was compared with the full SDA. Then, the time and the numbers of dentists required to treat periodontal conditions for 100 000 Malaysian adults using the NN and SDA were calculated and compared using the Wilcoxon signed rank test. This calculation was carried out using four estimates of dentists’ annual working hours: 1200, 1500 and 2000 hours based on the WHO (4) estimations and 1760 hours based on Malaysian Oral Health Division estimates (17).

Three different skill mix models were used to assess the differences in workforce requirements when some basic periodontal procedures were delegated to dental therapists. The types of periodontal procedures delegated were based on the results from studies (30–32) and suggestions by Evans et al. (33) and Malaysian dentists (17). Scenario I (Baseline scenario) represents the current situation in Malaysia where only dentists carry out all periodontal treatment for adults. In Scenario 2 (Minimum skill mix), only scaling and polishing procedures are delegated to dental therapists. In Scenario 3 (Maximum skill mix), scaling and polishing and root planing procedures are delegated while dentists carry out periodontal surgery. In the skill mix analysis, only the annual working hours of 1760 was used to highlight the differences in workforce estimates needed to treat periodontal disease between the different scenarios. The working hours are similar for both dentists and dental therapists as Malaysia only allows full time employment in the public sector. Currently in Malaysia, dental therapists are not allowed to work in private practice.

This study was approved by the Ethics Committee of Faculty of Dentistry, University of Malaya and the UCL Research Ethics Committee.

Results

There were 919 employees who fulfilled the inclusion criteria. Of these, 732 agreed to participate in the study, a response rate of 79.6%. The majority were females (66%) and of Malay ethnicity (83.2%). The mean age was 41.2 (SD ±7.9) years. More than half the sample (59.1%) had low educational qualifications and slightly over 70% earned below 3000 Ringgit Malaysia a month. More than 90% brushed their teeth twice or more a day and almost 80% had never smoked. About 40% experienced at least one oral impact in the past 6 months. The mean OIDP score was 2.67 (±6.25) (Table 1).

The most prevalent periodontal condition was presence of calculus only, with no bleeding or periodontal pockets. Forty-six per cent had calculus (without pocketing or bleeding), 27.3% had calculus with bleeding and <8% had calculus with pocketing (Table 2). The prevalence of periodontal pockets was low; 11.9% had pocketing between 4–5 mm, and 2.6% had pocketing of more than 6 mm, with or without bleeding and/or calculus. Overall, less than one dental sextant per sample was affected by a periodontal condition.

About 37% had no normative needs (NN) for any type of periodontal treatment, including oral hygiene instruction (Table 3). The periodontal treatment that was most commonly required was scaling and polishing; 64.1% of the sample required it in on average 1.69 dental sextants. Root planing was needed by 14.9% of the sample while complex periodontal surgery was required by <4%.

Sixty-two per cent of the sample had NN for periodontal treatment. Of those with NN, only 8.3% reported oral impacts due to periodontal conditions. When their propensity for periodontal treatment was assessed, 7.2% had good oral health-related behaviours and were eligible for any recommended periodontal treatment. Those with poor propensity for periodontal treatment (1.1%) needed oral health education to improve their
In terms of the extent of periodontal need, 172.53 sextants required periodontal treatment per 100 people with NN. That decreased to 24.43 for IRN and to 21.78 dental sextants for PRN (Fig. 1). In summary, periodontal treatment need decreased by 88.5% when NN was compared with IRN and by a further 13.2% when PRN was included in SDA. Overall, the difference between NN and SDA was 90% \((P < 0.001)\).

**Workforce requirements**

Table 4 presents the timings for periodontal procedures obtained from the expert review. These timings were converted into hours needed for treatment, and the total minimum and maximum times required for periodontal treatment for 100 000 adults were calculated as the workforce estimates since the study was planned to be applied to the total Malaysian population. When minimum timings were used, the total time needed for periodontal treatment for NN was 25 403 hours per 100 000 adults (Table 5). That decreased to 4087 hours when using the SDA approach. When the maximum treatment time was used (Table 5), the time needed per 100 000 adults was 36 892 hours for NN and 5680 hours for the SDA, a difference of 84% \((P \leq 0.001)\).

Based on dentists’ annual working hours of 1760 hours and the findings from this study, the minimum number of dentists needed to perform periodontal treatment per 100 000 people was 14.43 for the NN and 2.32 for the SDA; the respective maximum numbers were 20.96 (NN) and 3.23 (SDA) dentists. When estimates based on annual...
working hours were reduced to 1200 or 1500 hours or increased to 2000 hours, the number of dentists required for periodontal treatment increased or decreased, respectively (Table 6).

The number of dentists needed decreased markedly when more dental procedures were delegated to dental therapists using either NN or SDA. When scaling and polishing were delegated in the NN model, the minimum number of dentists needed for periodontal care per 100,000 people decreased by 65%, from 14.43 (Scenario 1) to 5.04 (Scenario II). If root planing was also delegated in the same model, the minimum number of dentists required decreased further to 4.46 per 100,000 people, a reduction of 69% (Table 7). For Scenarios II and III, the numbers of dentists and dental therapists required decreased by 75% to 88%, respectively when comparing NN with SDA.

Table 3. Normative periodontal treatment need and mean number of dental sextants requiring periodontal treatment in 732 Malaysian adults

<table>
<thead>
<tr>
<th>Type of periodontal treatment required (a)</th>
<th>Percentage of subjects requiring periodontal treatment</th>
<th>Mean number of dental sextants requiring treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment required</td>
<td>(N = 269), 36.8%</td>
<td>–</td>
</tr>
<tr>
<td>Need OHI only</td>
<td>(N = 81), 17.5%</td>
<td>–</td>
</tr>
<tr>
<td>Need SP and OHI</td>
<td>(N = 297), 64.1%</td>
<td>(1.69 (1.42))</td>
</tr>
<tr>
<td>Need SP, RP and OHI</td>
<td>(N = 69), 14.9%</td>
<td>(0.23 (0.57))</td>
</tr>
<tr>
<td>Need SP, CT and OHI</td>
<td>(N = 16), 3.5%</td>
<td>(0.04 (0.25))</td>
</tr>
<tr>
<td>Total number of subjects</td>
<td>(N = 732), 100%</td>
<td>–</td>
</tr>
</tbody>
</table>

OHI, oral hygiene instruction, SP, scaling and polishing, RP, root planning, CT, complex periodontal surgery.

\(a\) The type of periodontal treatment required is based on the worst periodontal condition presence in a subject.

Fig 1. Comparison of the proportion of sample and the number of dental sextants per 100 people with periodontal treatment needs using normative and sociodental approaches \((n = 732)\).
Discussion

There were differences of 90% between normative (NN) and sociodentally (SDA) assessed periodontal needs in our sample of Malaysian adults. These marked differences are consistent with those found in previous studies on populations with differing levels of periodontal disease (24–26). Ryu (26), using the same sociodental approach as in the current study, found that the numbers of dentists needed to treat periodontal disease in a nationally representative sample of South Korean adults decreased from 22.5 (NN) to 2.7 (SDA) per 100 000 adults, a reduction of 88%. That was comparable to the findings in the current Malaysian sample.

Our findings indicate that normative treatment needs assessment yields very high estimates of periodontal treatment needs and workforce requirements. The associated cost of providing dental care based on normative assessment alone will be beyond the financial resources of most countries as they cannot even cover the costs of one dental restoration per child (34). More importantly, and apart from the economic reasons, the sole use of NN assessment is also conceptually inappropriate as it does not incorporate broader factors that determine health and needs.

The current study found that the negative impact of periodontal conditions on the quality of life of the participants was relatively small. Of the 63% people with a normative need for periodontal treatment, only 8.3% reported having an oral impact related to their periodontal condition. This may be partly explained by the weak correlations between normatively assessed and self-reported gingival health (35). People are often unaware of having gingivitis or calculus as they seldom lead to symptoms (36). Having severe periodontal attachment loss with deep periodontal pocket may be associated with loosening of teeth and affect the quality of life. More advanced forms of periodontal disease occur in about 5% to 15% of adults in most countries (37). Such forms were uncommon in the present sample. The prevalence of periodontal pocketing in this study was slightly lower than estimates from national surveys in Malaysia (16). That may be due to the exclusion of older age groups who have a higher prevalence of deep periodontal pockets from the present study.

Table 4. Minimum and maximum times required to perform periodontal treatment

<table>
<thead>
<tr>
<th>Type of periodontal treatment</th>
<th>Minimum time for treatment (minutes)</th>
<th>Maximum time for treatment (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaling and polishing</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Root planing</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Complex periodontal surgery</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 5. Comparison of minimum and maximum time, in hours, needed for periodontal treatment per 100 000 adults between normative and sociodental approaches

<table>
<thead>
<tr>
<th>Minimum treatment time, in hours, needed per 100 000 adults</th>
<th>Maximum treatment time, in hours, needed per 100 000 adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>NN IRN PRN % differences NN-SDA</td>
<td>NN IRN PRN % differences NN-SDA</td>
</tr>
<tr>
<td>25 403 4430.78 4086.97 83.9% P = 0.000</td>
<td>36 892.07 6247.72 5680.77 84.6% P = 0.000</td>
</tr>
</tbody>
</table>

NN, Normative need, IRN, Impact-related need, PRN, Propensity-related need, SDA, Sociodental need.

Table 6. Comparison of the number of dentists required for periodontal treatment per 100 000 adults, by different annual working hours, using minimum and maximum times

<table>
<thead>
<tr>
<th>Annual working hours</th>
<th>Minimum number of dentists needed per 100 000 adults</th>
<th>Maximum number of dentists needed per 100 000 adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NN IRN PRN</td>
<td>PP NN IRN PRN</td>
</tr>
<tr>
<td>1200</td>
<td>21.17 3.69 3.41</td>
<td>30.74 5.21 4.73</td>
</tr>
<tr>
<td>1500</td>
<td>16.94 2.95 2.72</td>
<td>24.59 4.16 3.79</td>
</tr>
<tr>
<td>1760</td>
<td>14.43 2.52 2.32</td>
<td>20.96 3.55 3.23</td>
</tr>
<tr>
<td>2000</td>
<td>12.70 1.22 2.04</td>
<td>18.45 3.12 2.84</td>
</tr>
</tbody>
</table>

NN, Normative need, IRN, Impact-related need, PRN, Propensity-related need.
Due to the low prevalence of severe destructive periodontal disease in the population, related workforce estimates have predominantly been based on the prevalence of gingivitis and calculus. The provision of scaling for those with calculus but without sociodental impacts and/or with low behavioural propensity is questioned as calculus is not a direct cause of periodontal diseases, but a retentive factor (38). The ‘burst theory’ on the progression of periodontal disease indicates that most gingival inflammation does not progress (39), thus further questioning periodic professional removal of dental plaque and calculus. Nevertheless, subjects with gingivitis who did not have oral impacts should be provided with dental health education or oral health promotion to enable them to increase their propensity level and improve their periodontal health. Treatment and oral health education are also required for those with severe periodontitis with deep periodontal pockets, regardless of whether they prevent or not progression of the disease.

As mentioned earlier, there are two models of the SDA: the BMDN model for nonprogressive and the DNLNP model for progressive dental conditions. It is difficult to decide which model to place periodontal disease into because there are different levels of severity involved, and it is not possible to reliably predict progression of the condition. If there is enough evidence to show that moderate periodontal disease is likely to progress to severe forms, or that severe periodontal disease will inevitably progress, then the DNLNP model could be used for people with those conditions. However, there is currently insufficient scientific evidence in relation to the progression of periodontal diseases. This is not a reason to refrain from assessing future needs for periodontal treatment, but the estimates from any relevant method should be viewed with caution. Another more pragmatic approach would be to place all periodontal conditions under the BMDN model and to closely monitor the progression of the disease. This would most likely lead to more modest workforce estimate in the first place, but the monitoring of the disease may well result in additional dental personnel requirements if there is evidence of progression to more severe forms. Further knowledge to determine the progression of periodontal diseases is essential both for our in-depth understanding of the disease but also in terms of important service implications for determining who should get priority in treatment, the type of treatment needed and the appropriate type of personnel to monitor and treat the periodontal condition.

This study has demonstrated the potential effect on workforce estimates when a skill mix approach was used. Time gained by dentists through delegation of care could be used to provide complex dental treatment or activities that will maximize their use of skills as team leaders. As in the current study, previous studies have shown a decrease of between 45% and 58% in the requirements for dentists if appropriate dental care is delegated to dental therapists (33, 40). The results reported here are based on the assumption that dental therapists are allowed to perform all care delegated to them. Such an assumption can be questioned as there will be medically compromised patients with simple periodontal treatment needs or patients with a combination of simple and complex periodontal treatment needs that are outside the range of clinical roles of dental therapists. Nevertheless, this study provides a rough estimate of the proportion of dental care within the scope of dental therapists and the number of dental therapists needed to

<table>
<thead>
<tr>
<th>Type of model</th>
<th>Dentist</th>
<th>Dental therapists</th>
<th>Dentist</th>
<th>Dental therapists</th>
<th>Dentist</th>
<th>Dental therapists</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The minimum number of dentists or dental therapists needed for periodontal care per 100 000 people</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normative Need</td>
<td>14.43</td>
<td>0</td>
<td>5.04</td>
<td>9.39</td>
<td>4.46</td>
<td>9.97</td>
</tr>
<tr>
<td>Sociodental Need</td>
<td>2.32</td>
<td>0</td>
<td>1.16</td>
<td>1.16</td>
<td>1.16</td>
<td>1.16</td>
</tr>
<tr>
<td><strong>The maximum number of dentists or dental therapists needed for periodontal care per 100 000 people</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normative Need</td>
<td>20.96</td>
<td>0</td>
<td>5.72</td>
<td>15.24</td>
<td>4.46</td>
<td>16.50</td>
</tr>
<tr>
<td>Sociodental Need</td>
<td>3.23</td>
<td>0</td>
<td>0.91</td>
<td>2.32</td>
<td>0.91</td>
<td>2.32</td>
</tr>
</tbody>
</table>

*Scenario I: only dentists carry out all periodontal treatment; Scenario II: only scaling and polishing procedures were delegated to dental therapists; Scenario III: dental therapists carry out scaling and polishing and root planing procedures while dentists carry out periodontal surgery.*
carry out the care. We acknowledge that this may be a slight overestimate of the actual figure.

Estimation of dental workforce requirements should reflect the populations’ actual needs and ability to achieve maximum health gain. This is facilitated using the sociodental needs assessment approach. Furthermore, the use of skill mix in determining workforce requirements ensures that the skills and competencies of all members of the dental team are maximized.

This study has some limitations. It was conducted on an adult population that is not representative of the population of Malaysia. Different findings could be obtained if nonworking adults or adults living in rural areas were included as less educated, and lower income individuals are more likely to have more needs for treatment and to report impacts from their oral conditions. The samples did not include adults aged above 55 years old and hence, there could be an underestimation of the overall prevalence of periodontal disease. In addition, this study did not compare the time needed for dental health education (DHE) between NN and SDA because there is limited evidence of dentists’ time to provide DHE to their patients. That made it difficult to estimate the time required for DHE under the NN model. If the time for DHE was taken into account, the number of dentists and dental therapists required would be higher than what has been presented here.

In conclusion, using the sociodental approach resulted in much lower estimates of dental need and workforce requirements for periodontal treatment than using the normative method in this sample of University employees aged 30–54 years in Malaysia. Furthermore, using dental therapists markedly reduced the numbers of dentists needed for periodontal treatment. Future studies using the sociodental approach on nationally representative samples should provide relevant information for policymakers and planners at national level.

Acknowledgements
This study was funded by University of Malaya Research Grant (RG 191/10HTM).

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
All authors contributed to the conception and design of the study. NAM conducted the research, collected, analysed and interpreted the data. NAM drafted the paper and AS, GT and RW reviewed the draft critically and contributed substantially to all redrafts. All authors read and approved the final manuscript.

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