Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Analysing the Optimum Number of Cupping Points for Selected Diseases by Utilising Graph Colouring

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ARTICLE INFO

Keywords:
Graph colouring; cupping point; insomnia; stroke; back pain

ABSTRACT

An innovative methodology is proposed in optimizing the cupping points related to stroke, insomnia and back pain diseases through the utilization of a graph colouring. Personalized treatment strategies and patient management heavily rely on the optimization of cupping points. By leveraging the powerful tools of graph theory and by the application of colouring approach, this study aims to provide valuable insights into enhancing the optimum number of cupping points for selected diseases. Based on the observations and analysis, shown that the properties of graph colouring hold.

1. Introduction

Wang *et al.,* [1] state that one of the traditional Chinese medicines (TCM) treatments for reducing chronic pain is cupping therapy. As describe by Aboushanab *et al.,* [2] and Cao *et al.,* [3], medicinal cupping technique involves the use of cups made of various materials, that are applied to the acupoint or painful location using a heating or vacuum device. It is used as a deep-tissue massage and to treat a variety of diseases, including pain, inflammation, poor circulation, pressure in blood vessel, and others as mentioned in Kim *et al.,*[4].

Refer to Al-Bedah et *al.,* [5], wet cupping, movement or massage cupping, dry cupping, flash cupping, and medicinal cupping are just a few of the many varieties of cupping therapy that are available. According to Al-Bedah *et al.,* [6] currently, dry cupping and wet cupping are the two types of frequently used cupping. The specific underlying tissue is simply drawn into the suction cup during dry cupping. The process is the same in wet cupping, yet it incorporates the additional steps of bloodletting and scarification into the overall process. Ghods et *al.,* [7] mention that the medicinal

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https://doi.org/10.37934/araset.65.1.168184

cupping point will be chosen based on the patient's complaint or disease. Specific medicinal cupping points will be used for each different disease. To induce suction, the cup was heated before being put on the body parts. The point will then be cut, causing blood to spill. Al-Bedah et al., [8] and Umar *et al.,* [9] state that the procedure is repeated until there was no more blood flowed from the medicinal cupping points.

Refer to Xu *et al.*, [10] and Aboushanab et *al.*, [11], for over thousands of years, TCM has been developed and is known for its diagnostic and therapeutic benefits for several diseases, including migraines, back pain, stroke, asthma, and diabetes. Numerous studies have been done on a range of diseases to show the effectiveness of medicinal cupping therapy has been shown by Uddin *et al.*, [12]. Back pain, insomnia, and stroke are the three diseases of interest that will be highlighted in this study due to some following justifications. So far, however, there has been little discussion about the exact cupping point for these diseases.

First disease that will be discuss in this paper is chronic back pain leads to physical, psychological, and economical impact, as well as a high consumption of medications and medical services as mention by Sielski *et al.,* [13] and Gore et *al.*, [14]. According to World Health Organization (WHO) [15], in 2020, around 619 million people worldwide had back pain. It is expected to increase to 843 million by 2050 due to more people and an aging population. Sita *et al*., [16] reported that TCM has been used in conjunction with allopathic pain management as part of the movement towards demedicalization. Among these methods, medicinal cupping therapy is suggested and used as one of the TCM approaches that help to alleviate chronic pain as describe by Wang *et al*., [17].

Second disease is the most typical sleeping issue is insomnia. According to Cao *et al.,* [18], middle school students, employees, and soldiers are among the 43.8% of people who report having trouble sleeping, with college students experiencing the worst cases of insomnia. Zhang *et al.,* [19] state that medicinal cupping therapy give positive effect and demonstrating superiority in cases of mild insomnia with fewer treatments and higher rates of improvement and cure. There is a current paucity of studies describing how medicinal cupping, rooted in ancient traditions, emerges as a potential candidate for alleviating insomnia symptoms.

Last disease that will be discussed is stroke. The World Stroke Organization (WSO) [20] has declared that stroke continues to be the second most common cause of death and the third most common cause of death and disability combined (measured in disability-adjusted life-years lost - DALYs) worldwide. Many stroke survivors continue to experience residual disability even though stroke mortality is declining, shown by Feiqin *et al*., [21]. As mentioned in Ovbiagele *et al.,* [22], the prevalence of stroke and the socioeconomic burden are anticipated to be increased as there will be a growing ageing population and a declining number of stroke deaths. Refer to Lee *et al*., [23] and Kim *et al*., [24], few studies have examined how cupping treatments were tested on stroke patients to study the effectiveness of cupping in the rehabilitation of stroke.

According to West *et al.,* [25], graph colouring is a technique used in graph theory. The chromatic number (χ) is the smallest number of colours needed to colour the vertices of a graph in such a way that no adjacent vertices have the same colour. In planar graphs, the Four-Colour Theorem dictates that the chromatic number is at most 4, and bipartite graphs are always 2-colorable stated by Appel *et al.,* [26]. As the applications, scheduling, map colouring, and wireless communication, are some of examples. Determining the chromatic number is NP-complete determined by Garey and Johnson [27], and conflict-free colouring, where adjacent vertices have distinct colours, is relevant in certain contexts. So far, very little attention has been to the role of graph colouring toward to find the specific cupping point in medicinal cupping therapy.

The existing researchers specifically examine the efficacy of medicinal cupping. To date, research on specific cupping points for the treatment of back pain, insomnia and stroke has yet to be explored.

The research is geared towards identifying medicinal cupping points to assist practitioners during medication. This study proposes a graphical methodology that use graph coloring perspectives to determine the optimal number of medicinal cupping points for treating back pain, insomnia, and stroke.

2. Methodology

The human nervous system, which comprised of central and peripheral nervous system, are connected as they are made up of brain and bundles of afferent and efferent nerves fibers. By identifying the medicinal cupping point as the vertices, a basic graph may be constructed, allowing for the use of graph theory. Refer to Al Bedah *et al*., [8], currently, practitioners continually cupping at random points, mostly due to patient's preferences. An increasing of the number of medicinal cupping points cost more time and money. In this regard, using a trustworthy simulation model based on graph colouring gives a more advantageous choice, allowing cupping practitioners to ascertain and effectively explain the appropriate and necessary number of medicinal cupping points. This preliminary investigation used graph colouring as the chosen method due to data accessibility challenges highlighted by Kim *et al.,* [28], despite the existence of alternative approaches such as multi-objective functions and multi-criteria decision-making. Some related definitions that will be used in this article will first being defined.

Definition 1 [29]: Vertex
A vertex, V is a point where two lines intersect or meet.

The vertices of the generated graph are the cupping point employed in medicinal cupping. There must be a specified location and a specific number of cupping points for each disease.

Definition 2 [29]: Edge
The edge, E is a link or line between vertices, V.

The human nervous system will be represented by the edges connecting all the relevant cupping points (vertices) to create a basic graph.

Definition 3 [29]: Graph, *G*
A graph $G = (V, E)$ consists of V, a nonempty set of vertices or nodes and E, a set of edges.

In this study, the vertices and edges will be the cupping points and nerves, respectively. The definition of the approach method is then provided.

Definition 4 [30]: Graph colouring
Graph colouring is an assignment of colours to every vertex and if two vertices joined each other by an edge, they must have different colours.

The process will determine the optimal solution where the graph contains the fewest colours to be assigned.

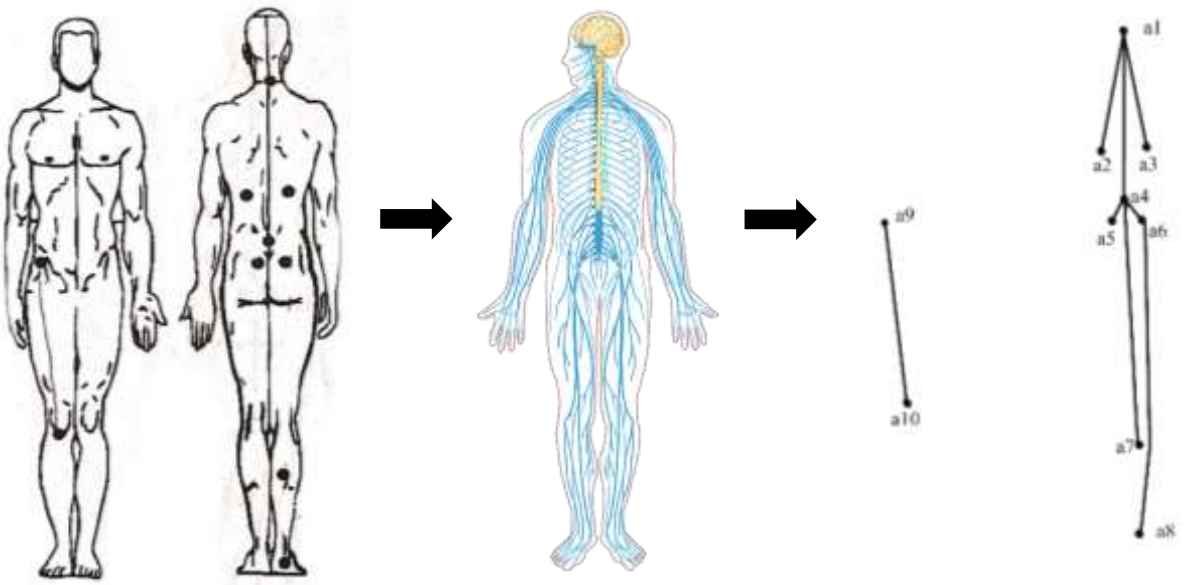
Definition 5 [30]: Chromatic number, χ(*G*)
The chromatic number, χ(G) of the graph is the least number of colours required for colouring a graph.

The chromatic number is determined by counting the total amount of colour utilised after assigning a colour to each vertex. The element with the lowest chromatic number will be selected to make the decision.

Graph colouring has significant practical applications in a variety of domains, and its study has provided several theoretical issues. Graph colouring is widely utilised in practical applications such as compiler design, scheduling, wireless communication, and timetabling that can be seen in review papers by several authors [31-34]. This suggests that graph colouring can be used as a different strategy for streamlining procedures. In this article, the graph colouring approach will be used to determine the ideal number of medicinal cupping sites for back pain, insomnia, and stroke treatment. Since there is no research that use graph colouring towards medicinal cupping, and there exist a relation between medicinal cupping and the basic graph, graph colouring method is chosen as the most suit approach that can be used in this research.

3. Results and Discussions

A recent study by Jie *et al.,* [35] reports that the COVID-19 pandemic caused countries and organizations worldwide to revise their business operations. Some countries, such as Malaysia, imposed Movement Control Orders (MCO) to stop the virus from spreading. Healthcare professionals are faced with circumstances where patients may not be available for physical examinations due to the COVID-19 pandemic's problems. When presented with the situation, this research mainly depends on data obtained exclusively from interviews and medical opinions. According to consultations with specialists, each disease has unique cupping points that lies on the human nervous system. These back pain, insomnia, and stroke cupping points had been applied and practiced by the cupping therapy expert from Pusat Bekam Al-Yakin. The association of cupping point will then be discussed by a human anatomy specialist from International Islamic University Malaysia (IIUM) Kuantan, Pahang, viewed from a medical perspective. After that, a fundamental graph derived will be used to investigate the connection between medicinal cupping points and the human neurological system. A simple graph is developed to illustrate the connections between the cupping points via graph theory. Figure 1 shows the procedure for the basic medicinal cupping point.



Step 1: Basic cupping point are determined (Nerve vertex)

Step 2: Mapped to human nerve body (Nerve edge)

Step 3: Simple graph obtain (Nerve graph)

Fig. 1. Mathematical model process for basic cupping points

As a result, the following definitions for nerve vertex, nerve edge, and nerve graph are presented.

Definition 6 [31]: Nerve Vertex, *NV*
Nerve vertex, NV is a vertex that represents medicinal cupping points for a unique disease based on the peripheral nerves system.

Definition 7 [31]: Nerve Edge, *NE*
Nerve edge, NE is an edge that connects between the nerve vertex, $N\,V$ to form a simple graph based on the peripheral nerves system.

Definition 8 [31]: Nerve Graph, *NG*
A nerve graph, NG consist a set of nerve vertex, NV that connected by nerve edges, NE . In other way, nerve graph represents as NG = (NV , NE).

Definition 9: Nerve Cupping, *NC*:
A nerve cupping, designated as *NC*, represents a specific medicinal cupping point strategically applied to be cupped during medicinal cupping treatment.

Ideally, the relation between cupping points and the mathematical model can be depicted as below (Table 1):

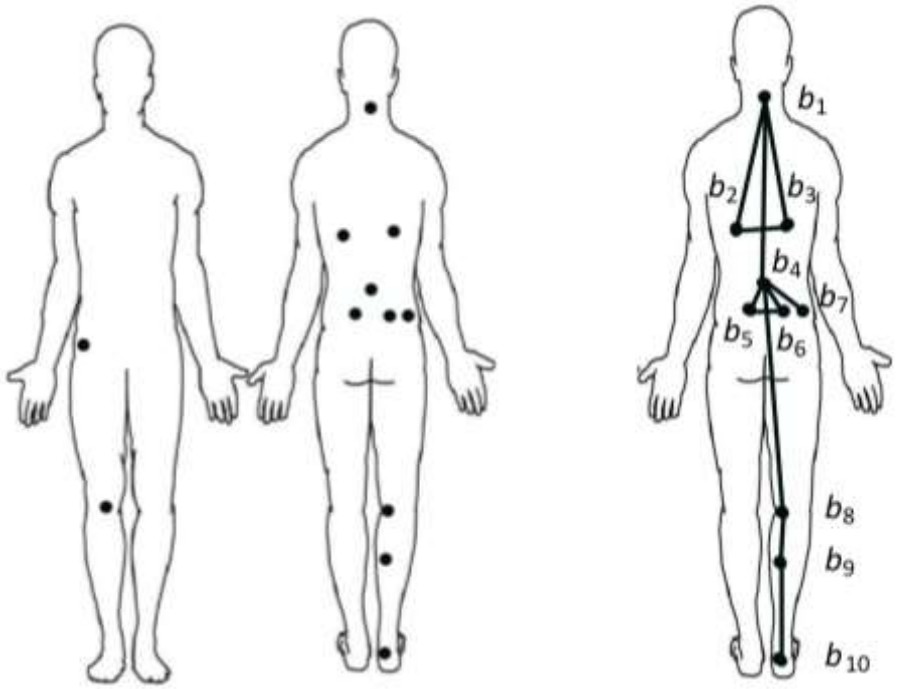
Table 1
The relation between cupping points and the mathematical model

Medicinal cupping	Mathematical model
Medicinal cupping points	Nerve vertex
Peripheral nerve	Nerve edge
Cupping points system	Nerve graph
Set of nerve vertex that will be cupped	Nerve cupping

By leveraging the powerful tools of graph theory and by the application of colouring concepts, the process of mathematical model will be tested toward backpain, insomnia and stroke on finding optimum number of cupping points as discussed in section of 3.1, 3.2 and 3.3.

3.1 Graph Colouring Model for Back Pain

Figure 2 displays the 10 nodes that represent the nerve vertex *(NV)* used by practitioners to treat back pain. The nerve edge *(NE)* of the graph in Figure 2(b) depicts the nerves connections between the 10 nodes of the back pain nerve vertex *(NV),* which are renamed as vertices b_i, $1 \leq i \leq 10$ of a nerve graph *(NG)*. Figure 2(b) can be depicted as a nerve graph *(NG),* as seen in Figure 3.



(a) Nerve vertex for back pain [36] (b) Nerve edge based on human nerve

Fig. 2. Nerve vertices and nerve edge for back pain

Fig. 3. Nerve graph, *NG*, for back pain

Figure 3 is derived from Figure 2(b). Due to the connection at the junction where the nervous system connects, the nerve vertices were found to match to the peripheral nervous system. Using graph theory, the connection of the nerve vertex generates a nerve graph, *NG*. The ideal number of nerve vertex for medicinal purposes is determined by applying the concept of graph colouring to the nerve graph *G*. Figure 4 shows the process of applying graph colouring to the nerve graph, *NG*:

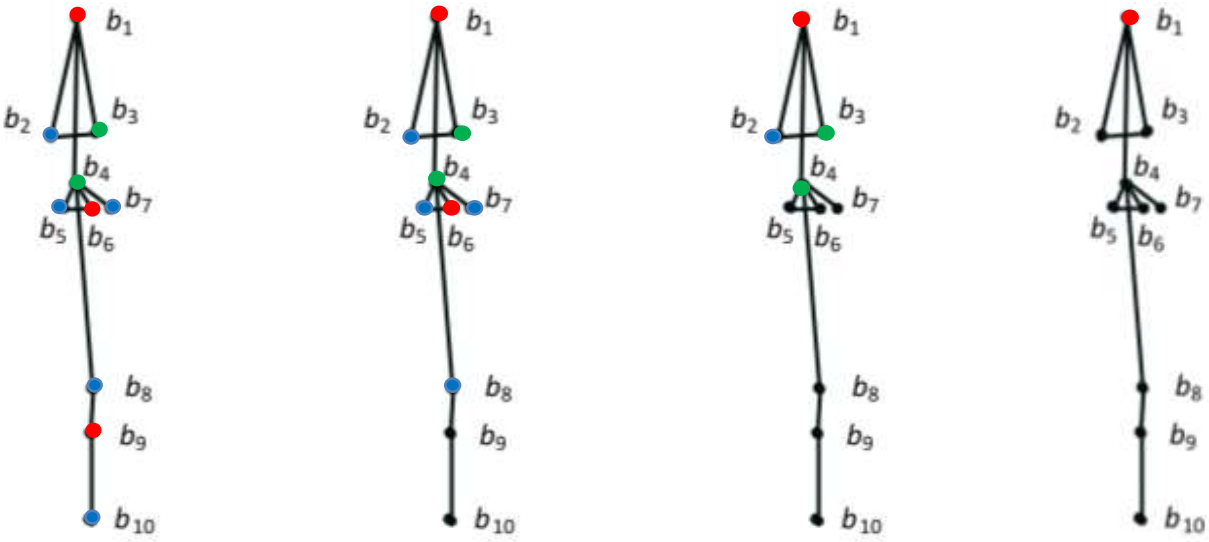


Fig. 4. Steps for colouring the retrieved figure with graph colouring methods for back pain

The process begins by choosing a random nerve vertex and colouring it. Vertex b_1, is, for instance, given the colour red (Step 1). In Step 2, it is discovered that vertices b_2, b_3, and b_4 are adjacent with vertex b_1 and must be coloured with a different colour. Other vertices that are adjacent to b_4 are treated similarly. Reusing colours that satisfy the graph colouring characteristics is strongly advised, as seen in steps 3 and 4. This procedure is repeated until all vertices have been coloured (Step 4). The result of this procedure is the chromatic number χ(*G*) = 3. Using a trial-and-error method, the precise results are obtained during the graph colouring processes. This iterative process is repeated until all vertices are coloured, allowing the chromatic number, χ(*G*), to be calculated. The trial and error method's outcomes are shown in Table 1.

In accordance with Definition 4, Results 1 and 3 are the best options out of the three potential outcomes listed in Table 2. Results 1 and 3 are the best options because they achieve the highest number of vertices for blue (which is 5 vertices) and the least number of vertices (which is 2 vertices; displayed in green) for Result 1, and the maximum number of vertices (which is 5 vertices; shown in red) for Result 3. The details are as follows:

Result 1: χ(*G*) = 3
- : 3 nerve vertices, $\{b_1, b_6, b_9\}$
- : 5 nerve vertices, $\{b_2, b_5, b_7, b_8, b_{10}\}$
- : 2 nerve vertices, $\{b_3, b_4, \}$

Table 2
Results of graph colouring for nerve graph *NG* (back pain)

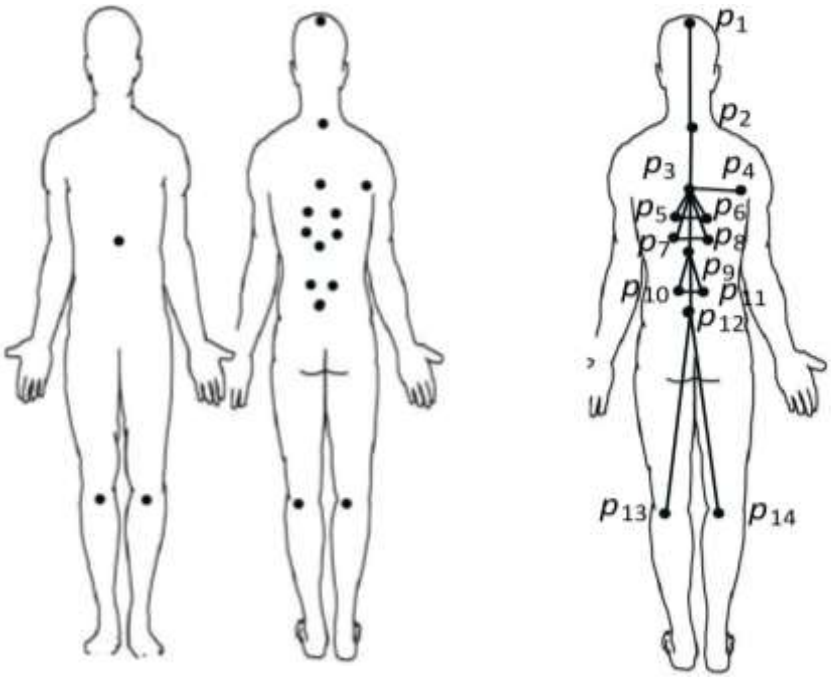
Colour	Result 1	Result 2	Result 3
Red	3	3	5
Blue	5	4	3
Green	2	3	2

Result 1 and 3 shows the optimal colour arrangement on the graph that meets the criteria for graph colouring. The chromatic number χ(*G*) of this configuration is 3, which is the smallest number of colours needed to colour all of the vertices without allowing adjacent vertices to share the same colour. Figure 4 shows that two vertices are the most effective nerve vertex (Result 1 and Result 3) for

the first treatment, which is both sufficient and effective. This is in contrast to the previous method, which consisted of 10 nerve vertices [36]. For Result 1, the green point is the key element that offers the best solution and greatly lowers the quantity of nerve vertex needed for the procedure. The red-marked points will take precedence over the blue ones because there are fewer vertices that need to be cupped if patients need another round of medicinal cupping treatment. While in Result 3, The blue-marked points will take precedence over the red ones because there are fewer vertices that need to be cupped if patients need another round of medicinal cupping treatment.

3.2 Graph Colouring Model for Insomnia

The 14 nodes that correspond to the nerve vertices (*NV*) that practitioners utilize to treat insomnia are shown in Figure 5. The nerve edge (*NE*) in Figure 5(b) displays the nerve connections between the 14 nodes of the insomnia nerve vertices, which are renamed vertices p_i, $1 \leq i \leq 14$, of a nerve graph (*NG*). As seen in Figure 6, Figure 5(b) can be represented as a nerve graph.



(a) Nerve vertices for insomnia [36] (b) Nerve edge based on human nerve

Fig. 5. Medicinal cupping points for insomnia

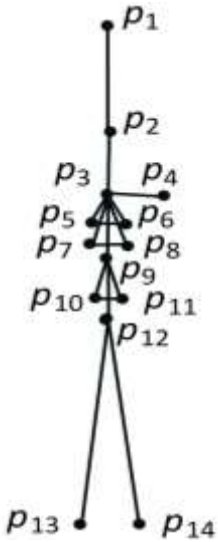
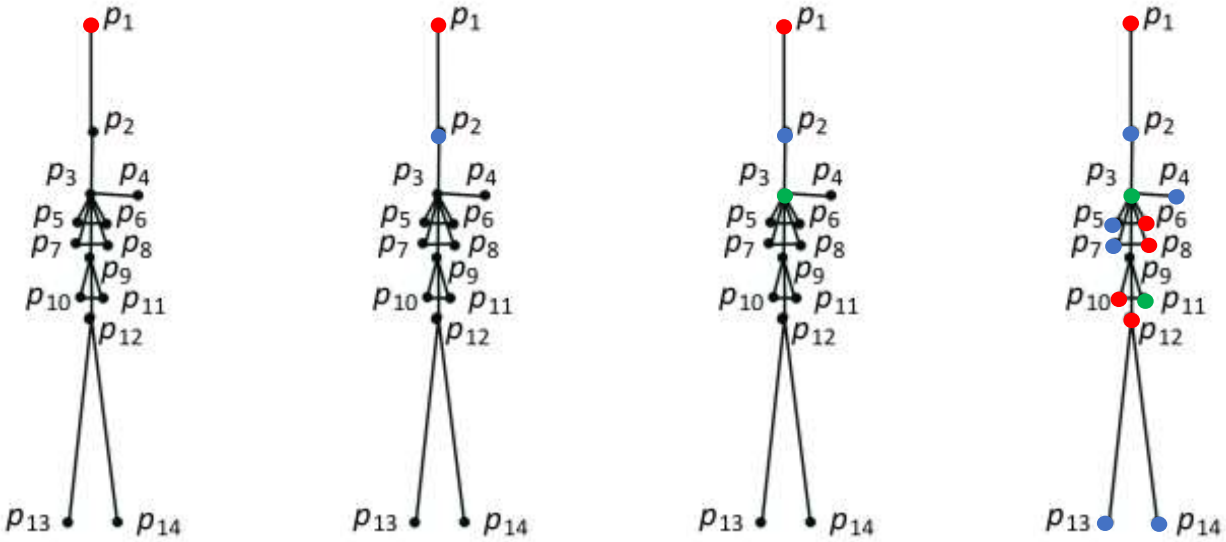


Fig. 6. Simple graph, *G*, for insomnia

Figure 7 shows the process of applying graph colouring to the nerve graph (*NG*):



Step 1 Step 2 Step 3 Step 4

Fig. 7. Steps for colouring the retrieved figure with graph colouring methods for insomnia

As the same steps undergo, the results obtain as follows as in back pain.

According to Definition 4, Results 1 is the best choice out of the three possible outcomes listed in Table 3. There are three possible results. Results 1 is the best choice because it produces the most vertices for the colour blue (7 vertices), as well as the fewest number of vertices (2 vertices; indicated in green). The details are as follows:

Result: $\chi(G) = 3$
- : 5 nerve vertices, $\{p_1, p_6, p_8, p_{10}, p_{12}\}$
- : 7 nerve vertices, $\{p_2, p_4, p_5, p_7, p_9, p_{13}, p_{14}\}$
- : 2 nerve vertices, $\{p_3, p_{11}\}$

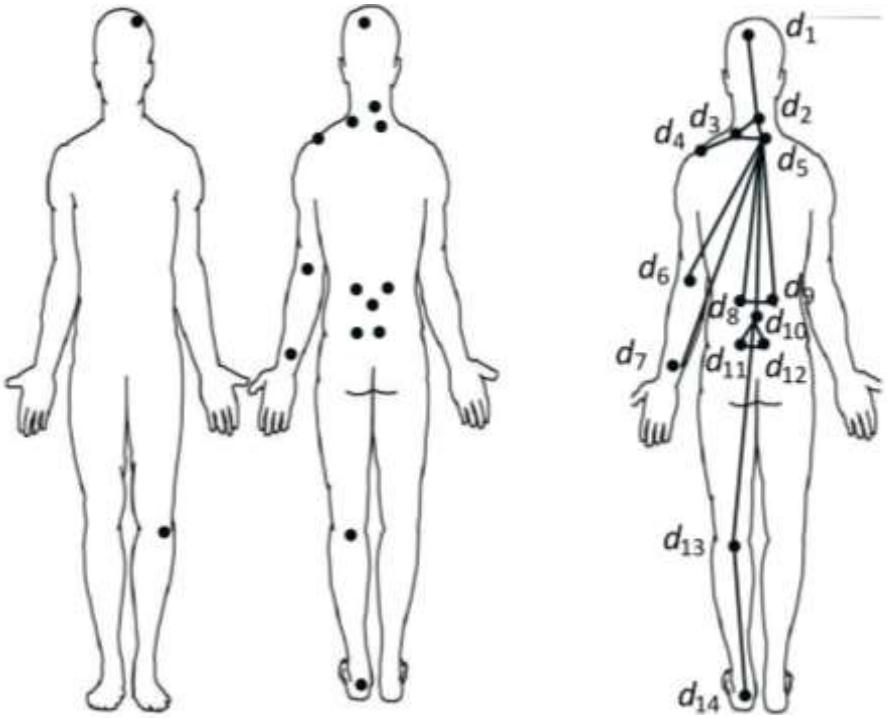
Table 3
Results of graph colouring for nerve graph, *NG* (insomnia)

Colour	Result 1	Result 2	Result 3
Red	5	4	7
Blue	7	7	4
Green	2	3	3

The most optimal colour arrangement on the graph that satisfies the requirements for graph colouring is shown in Result 1. This configuration's chromatic number, or $\chi(G)$, is 3, which is the fewest colours required to colour every vertex without letting adjacent vertices have the same colour. Figure 7 shows that two vertices is the most effective nerve vertex for the first treatment shown in Result 1, which is both sufficient and effective. This differs from the previous approach, which used 14 nerve vertices [36]. The green point is the key element that offers the best solution and greatly lowers the quantity of nerve vertices needed for the procedure. The points with red markings will be given priority over those with blue ones since fewer vertices require cupping in the case that patients require more medicinal cupping therapy slots.

3.3 Graph Colouring Model for Stroke

The 14 nodes that correspond to the nerve vertices (*NV*) that practitioners use to treat stroke are shown in Figure 8. The nerve connections between the 14 nodes of the stroke nerve vertices (*NV*), which are renamed as vertices d_i, $1 \leq i \leq 14$, of a nerve graph (*NG*), are shown by the nerve edge (*NE*) of the graph in Figure 8(b). As shown in Figure 9, Figure 8(b) can be represented as a nerve graph.



(a) Nerve vertices for stroke [36] (b) Nerve edge based on human nerve

Fig. 8. Medicinal cupping points for stroke

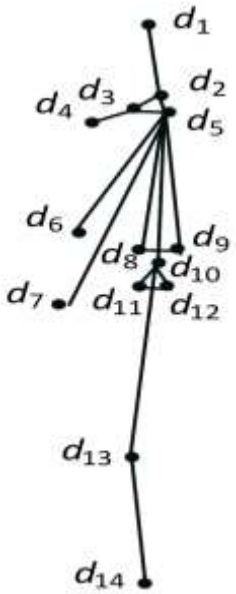


Fig. 9. Simple graph, *G*, for Stroke

The procedure of applying graph colouring to the nerve graph *(NG)* is depicted in Figure 10, as presented below:

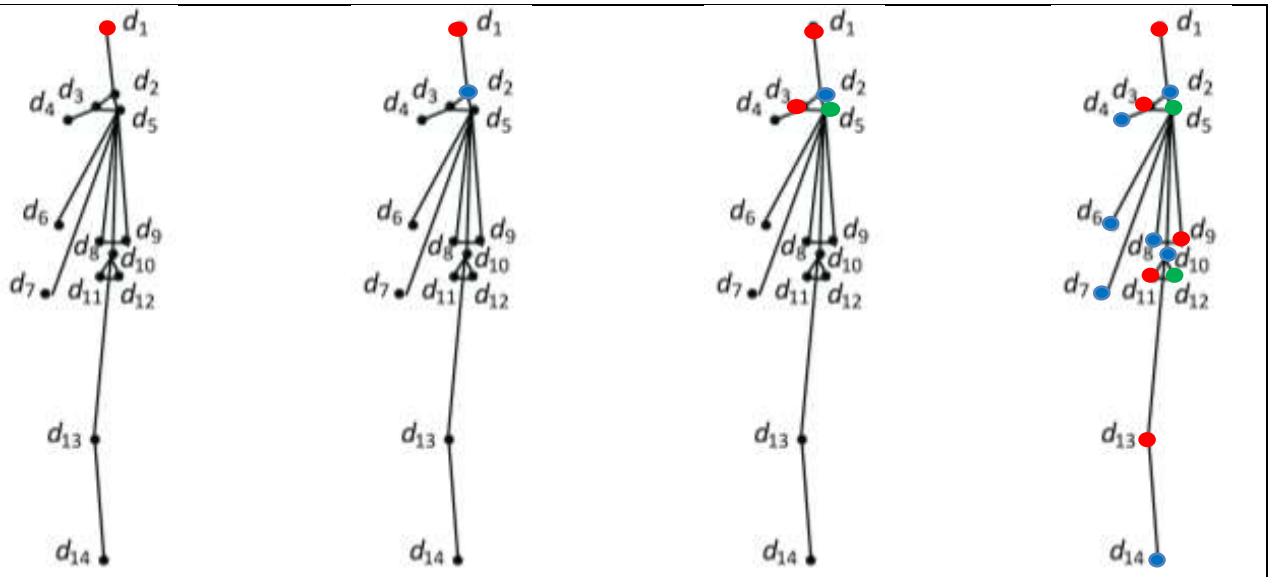


Fig. 10. Steps for colouring the retrieved figure with graph colouring methods for stroke

With the steps implemented as in back pain and insomnia, the following results hold for stroke.

Out of the three possible outcomes stated in Table 4, Results 1 is the best option, according to Definition 4. Table 4 illustrates the three possible results. Results 1 is the best option since it achieves the most vertices for blue (which is 7 vertices) and the fewest vertices (which is 2 vertices; depicted in green). The details are as follows:

Result: $\chi(G) = 3$

- : 5 nerve vertices, $\{d_1, d_3, d_9, d_{11}, d_{13}\}$
- : 7 nerve vertices, $\{d_2, d_4, d_6, d_7, d_8, d_{10}, d_{14}, \}$
- : 2 nerve vertices, $\{d_5, d_{12}\}$

Table 4
Results of graph colouring for nerve graph, *NG* (stroke)

Colour	Result 1	Result 2	Result 3
Red	5	5	6
Blue	7	6	5
Green	2	3	3

The best colour arrangement on the graph that satisfies the requirements for graph colouring is shown in Result 1. The chromatic number $\chi(G)$, of this configuration is 3, which is the minimum number of colours required to colour every vertex without allowing adjacent vertices to share the same colour. The results presented in Figure 10 indicate that two vertices are the most effective nerve vertex for the first therapy shown in Result 1, which is both sufficient and effective. This is not the case with the previous approach, which used 14 nerve vertices [36]. The green point is the crucial factor that provides the optimal solution and significantly reduces the number of nerve vertices required for the method. The points with red markings will be given priority over those with blue ones since fewer vertices require cupping in the event that patients require more medicinal cupping therapy slots.

3.4 Algorithm

The model is currently undergoing real-world trials in partnership with an industrial partner, Pusat Bekam Al-Yakin. Actual samples must be used during this trial process to confirm the model's efficacy. Researchers created an algorithm that was implemented in the C# programming language, as shown in Figure 11, to guarantee the authenticity of the results. This algorithm is essential for verifying the results produced by the graph colouring procedure. The model can handle the validation process effectively by using C#, enabling precise evaluations and insights. The algorithm plays a key role in assessing the model's effectiveness, enabling relevant inferences to be derived from the trial, and enabling additional model improvements as necessary.

```
Begin
Read matrices from .txt file, M = NxN (V[x,y]),
For all node pairs [x,y] ∈ NxN do
if V[x, y] = 1, then colour x ≠ y; Colour 1, Colour 2, … Colour n
if V[x, y] = 0, then colour x = y;
χ(G) = ∑ Colour
Display ∑ Colour 1, ∑ Colour 2, … ∑ Colour n
End
```

Fig. 11. Algorithm on finding nerve vertex for selected diseases

The adjacency matrix M is first read by the algorithm from a text file (.txt). As the study involves *n* vertices, the matrix M comprises elements of $V[x,y]$, where $1 \leq (x, y) \leq n$. In the algorithm, if vertices $[V_x][V_y] = 1$, it signifies that vertices *x* and *y* are connected, while a value of 0 indicates that the two vertices are not connected. The number of nerve vertices for treating back pain, insomnia and stroke are represented by the algorithm's output, which is shown in Figure 12, 13, 14.

First, this algorithm will be verifying the results produced by the graph colouring procedure for back pain. The number of nerve vertices for treating back pain are represented by the algorithm's output, which is shown in Figure 12.

3.4.1 Back pain

As demonstrated in Figure 11, it is evident that the optimal number of nerve vertices for the treatment of back pain is represented by two vertices, as indicated in green colour. Additionally, blue corresponds to five vertices, while red corresponds to three vertices. This output serves as validation for the results obtained through the application of graph colouring and the concept of the chromatic number. The graph colouring process has successfully identified the most efficient distribution of nerve vertices, supporting the optimal treatment approach for back pain based on the chromatic number concept.

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
b_1	0	1	1	1	0	0	0	0	0	0
b_2	1	0	1	0	0	0	0	0	0	0
b_3	1	1	0	0	0	0	0	0	0	0
b_4	1	0	0	0	1	1	1	1	0	0
b_5	0	0	0	1	0	1	0	0	0	0
b_6	0	0	0	1	1	0	0	0	0	0
b_7	0	0	0	1	0	0	0	0	0	0
b_8	0	0	0	1	0	0	0	0	1	0
b_9	0	0	0	0	0	0	0	1	0	1
b_{10}	0	0	0	0	0	0	0	0	1	0

Fig. 12. Simulation result from algorithm constructed for backpain

Next, this algorithm verifying the results produced by the graph colouring procedure for insomnia disease. The number of nerve vertices for treating insomnia are represented by the algorithm's output, which is shown in Figure 13.

3.4.2 Insomnia

Figure 11 shows that two nerve vertices, which are shown in green, are the best number of nerve vertices for treating insomnia. Furthermore, there are seven vertices for the colour blue and five vertices for the colour red. This result validates the findings from the chromatic number concept and

graph colouring. Based on the chromatic number concept, the graph colouring procedure has successfully determined the most effective nerve vertex distribution, hence enabling the best possible treatment plan for insomnia.

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}
p_1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
p_2	1	0	1	0	0	0	0	0	0	0	0	0	0	0
p_3	0	1	0	1	1	1	1	1	1	0	0	0	0	0
p_4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
p_5	0	0	1	0	0	1	0	0	0	0	0	0	0	0
p_6	0	0	1	0	1	0	0	0	0	0	0	0	0	0
p_7	0	0	1	0	0	0	0	1	0	0	0	0	0	0
p_8	0	0	1	0	0	0	1	0	0	0	0	0	0	0
p_9	0	0	1	0	0	0	0	0	0	1	1	1	0	0
p_{10}	0	0	0	0	0	0	0	0	1	0	1	0	0	0
p_{11}	0	0	0	0	0	0	0	0	1	1	0	0	0	0
p_{12}	0	0	0	0	0	0	0	0	1	0	0	0	1	1
p_{13}	0	0	0	0	0	0	0	0	0	0	0	1	0	0
p_{14}	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Fig. 13. Simulation result from algorithm constructed for insomnia

Lastly, the same process will go through with stroke. The number of nerve vertices for treating stroke are represented by the algorithm's output, which is shown in Figure 13.

3.4.3 Stroke

Two vertices, as shown in green in Figure 11, are the ideal number of nerve vertices for the treatment of stroke. Furthermore, there are seven vertices for the colour blue and five vertices for the colour red. This conclusion serves as confirmation of the results obtained by applying the chromatic number concept and graph colouring. The graph colouring procedure successfully found the most efficient distribution of nerve vertices, supporting the best stroke therapy approach based on the chromatic number concept.

	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}
d_1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
d_2	1	0	1	0	1	0	0	0	0	0	0	0	0	0
d_3	0	1	0	1	1	0	0	0	0	0	0	0	0	0
d_4	0	0	1	0	0	0	0	0	0	0	0	0	0	0
d_5	0	1	1	0	0	1	1	1	1	1	0	0	0	0
d_6	0	0	0	0	1	0	0	0	0	0	0	0	0	0
d_7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
d_8	0	0	0	1	1	0	0	0	1	0	0	0	0	0
d_9	0	0	0	0	1	0	0	1	0	0	0	0	0	0
d_{10}	0	0	0	0	1	0	0	0	0	0	1	1	0	0
d_{11}	0	0	0	0	0	0	0	0	0	1	0	1	0	0
d_{12}	0	0	0	0	0	0	0	0	0	1	1	0	0	0
d_{13}	0	0	0	0	0	0	0	0	0	0	0	0	0	1
d_{14}	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Fig. 14. Simulation result from algorithm constructed for stroke

4. Conclusions

According to the graphical model utilised in this study, this technique also saves time and money because it's imperative to acknowledge that utilizing two vertices as the most effective nerve point for initial treatment is not only sufficient but also highly efficient. This differs significantly from previous methods that required the use of 10 nerve vertices for back pain, 14 for insomnia, and 14 for stroke treatment. The generated C# code also facilitates the validation of this particular outcome. This discovery aids society at large in deciding where to cup as well as researchers and practitioners in the field of medical cupping. Although more research and clinical trials are required to confirm this finding and its applicability in real-world, it's important to acknowledge that this discovery is significant for further development of cupping therapy. It could have a profound impact on patients' well being, as well as various fields and industries. Based on the observations and analysis, shown that the properties of graph colouring hold.

Acknowledgement

The authors would like to thank the Ministry of Higher Education for providing financial support under Fundamental Research Grant Scheme (FRGS) No. FRGS/1/2021/STG06/UMP/02/1 (University reference RDU210107).

References

[1] Wang, Yun-Ting, Yong Qi, Fu-Yong Tang, Fei-Meng Li, Qi-Huo Li, Chang-Peng Xu, Guo-Ping Xie, and Hong-Tao Sun. "The effect of cupping therapy for low back pain: A meta-analysis based on existing randomized controlled trials." *Journal of back and musculoskeletal rehabilitation* 30, no. 6 (2017): 1187-1195. https://doi.org/10.3233/BMR-169736

[2] Aboushanab, Tamer S., and Saud AlSanad. "Cupping therapy: an overview from a modern medicine perspective." *Journal of acupuncture and meridian studies* 11, no. 3 (2018): 83-87. https://doi.org/10.1016/j.jams.2018.02.001

[3] Cao, Huijuan, Xun Li, Xue Yan, Nissi S. Wang, Alan Bensoussan, and Jianping Liu. "Cupping therapy for acute and chronic pain management: a systematic review of randomized clinical trials." *Journal of Traditional Chinese Medical Sciences* 1, no. 1 (2014): 49-61. https://doi.org/10.1016/j.jtcms.2014.11.003

[4] Kim, Jong-In, Myeong Soo Lee, Dong-Hyo Lee, Kate Boddy, and Edzard Ernst. "Cupping for treating pain: a systematic review." *Evidence Based Complementary and AlternativeMedicine* 2011 (2009): 18. https://doi.org/10.1093/ecam/nep035

[5] Al-Bedah, Abdullah, Tamer Shaban, Amen Suhaibani, Ibrahim Gazzaffi, Mohammed Khalil, and Naseem Qureshi. "Safety of cupping therapy in studies conducted in twenty one century: a review of literature." *British Journal of Medicine and Medical Research* 15, no. 8 (2016): 1-12. https://doi.org/10.9734/BJMMR/2016/26285

[6] Al-Bedah, Abdullah, Tamer Shaban Aboushanab, Meshari Alqaed, Naseem Qureshi, Imen Suhaibani, Gazzaffi Ibrahim, and Mohammed Khalil. "Classification of cupping therapy: a tool for modernization and standardization." *Journal of Complementary and Alternative Medical Research* 1, no. 1 (2016): 1-10. https://doi.org/10.9734/JOCAMR/2016/27222

[7] Ghods, Roshanak, Nasrin Sayfouri, and Mohammad Hossein Ayati. "Anatomical features of the interscapular area where wet cupping therapy is done and its possible relation to acupuncture meridians." *Journal of acupuncture and meridian studies* 9, no. 6 (2016): 290-296. https://doi.org/10.1016/j.jams.2016.06.004

[8] Al-Bedah, Abdullah MN, Ibrahim S. Elsubai, Naseem Akhtar Qureshi, Tamer Shaban Aboushanab, Gazzaffi IM Ali, Ahmed Tawfik El-Olemy, Asim AH Khalil, Mohamed KM Khalil, and Meshari Saleh Alqaed. "The medical perspective of cupping therapy: Effects and mechanisms of action." *Journal of traditional and complementary medicine* 9, no. 2 (2019): 90-97. https://doi.org/10.1016/j.jtcme.2018.03.003

[9] Umar, Nafisa K., Sherali Tursunbadalov, Serdar Surgun, Menizibeya O. Welcome, and Senol Dane. "The effects of wet cupping therapy on the blood levels of some heavy metals: a pilot study." *Journal of acupuncture and meridian studies* 11, no. 6 (2018): 375-379. https://doi.org/10.1016/j.jams.2018.06.005

[10] Xu, Judy, and Yue Yang. "Traditional Chinese medicine in the Chinese health care system." *Health policy* 90, no. 2-3 (2009): 133-139. https://doi.org/10.1016/j.healthpol.2008.09.003

[11] Aboushanab, Tamer S., and Saud AlSanad. "Cupping therapy: an overview from a modern medicine perspective." *Journal of acupuncture and meridian studies* 11, no. 3 (2018): 83-87. https://doi.org/10.1016/j.jams.2018.02.001

[12] Uddin, Syed Mohammad Mazhar, Aatera Haq, and Haris Sheikh. "The use of Hijama (Wet Cupping) in alternative and complementary medicine: efficacious or perilous?." *Journal of Acupuncture & Meridian Studies* 9, no. 6 (2016): 285-286. https://doi.org/10.1016/j.jams.2016.09.002

[13] Sielski, Robert, Winfried Rief, and Julia Anna Glombiewski. "Efficacy of biofeedback in chronic back pain: a meta-analysis." *International journal of behavioral medicine* 24 (2017): 25-41. https://doi.org/10.1007/s12529-016-9572-9

[14] Gore, Mugdha, Alesia Sadosky, Brett R. Stacey, Kei-Sing Tai, and Douglas Leslie. "The burden of chronic low back pain: clinical comorbidities, treatment patterns, and health care costs in usual care settings." *Spine* 37, no. 11 (2012): E668-E677. https://doi.org/10.1097/BRS.0b013e318241e5de

[15] World Health Organization. (2023, June, 19). "Low back pain" Retrieved from https://www.who.int/news-room/fact-sheets/detail/low-back-pain

[16] Sita Ananth, M. "Complementary Alternative Medicine Survey of Hospitals-Summary of Results.[Internet]. Alexandria, VA: Samueli Institute; 2011 [cited May 13, 2018]." (2010).

[17] Wang, Yun-Ting, Yong Qi, Fu-Yong Tang, Fei-Meng Li, Qi-Huo Li, Chang-Peng Xu, Guo-Ping Xie, and Hong-Tao Sun. "The effect of cupping therapy for low back pain: A meta-analysis based on existing randomized controlled trials." *Journal of back and musculoskeletal rehabilitation* 30, no. 6 (2017): 1187-1195. https://doi.org/10.3233/BMR-169736

[18] Cao, Xiao-Lan, Shi-Bin Wang, Bao-Liang Zhong, Ling Zhang, Gabor S. Ungvari, Chee H. Ng, Lu Li et al. "The prevalence of insomnia in the general population in China: a meta-analysis." *PloS one* 12, no. 2 (2017): e0170772. https://doi.org/10.1371/journal.pone.0170772

[19] Zhang, Yue-Feng, Gui-Fang Ren, and Xiu-Chun Zhang. "Acupuncture plus cupping for treating insomnia in college students." *Journal of Traditional Chinese Medicine* 30, no. 3 (2010): 185-189. https://doi.org/10.1016/S0254-6272(10)60038-6

[20] World Stroke Organization (WSO). (2022, January). "Global Stroke Fact Sheet 2022" .

[21] Feigin, Valery L., Michael Brainin, Bo Norrving, Sheila Martins, Ralph L. Sacco, Werner Hacke, Marc Fisher, Jeyaraj Pandian, and Patrice Lindsay. "World Stroke Organization (WSO): global stroke fact sheet 2022." *International Journal of Stroke* 17, no. 1 (2022): 18-29. https://doi.org/10.1177/17474930211065917
[22] Ovbiagele, Bruce, Larry B. Goldstein, Randall T. Higashida, Virginia J. Howard, S. Claiborne Johnston, Olga A. Khavjou, Daniel T. Lackland et al. "Forecasting the future of stroke in the United States: a policy statement from the American Heart Association and American Stroke Association." *Stroke* 44, no. 8 (2013): 2361-2375. https://doi.org/10.1161/STR.0b013e31829734f2
[23] Lee, Myeong Soo, Jong-In Kim, and Edzard Ernst. "Is cupping an effective treatment? An overview of systematic reviews." *Journal of acupuncture and meridian studies* 4, no. 1 (2011): 1-4. https://doi.org/10.1016/S2005-2901(11)60001-0
[24] Kim, Mikyung, Chang-ho Han, Mikyung Kim, and Chang-ho Han. "The effectiveness and safety of cupping therapy for stroke survivors: A systematic review and meta-analysis of randomized controlled trials." *Journal of Korean Medicine* 42, no. 4 (2021): 75-101. https://doi.org/10.13048/jkm.21039
[25] West, Douglas Brent. *Introduction to graph theory*. Vol. 2. Upper Saddle River: Prentice hall, 2001.
[26] Appel, Kenneth, Wolfgang Haken, and John Koch. "Every planar map is four colorable. Part II: Reducibility." *Illinois Journal of Mathematics* 21, no. 3 (1977): 491-567. https://doi.org/10.1215/ijm/1256049012
[27] Garey, Michael R., and David S. Johnson. "Computers and intractability." *A Guide to the* (1979).
[28] Mobbs, R. J., S. Nair, and P. Blum. "Peripheral nerve stimulation for the treatment of chronic pain." *Journal of clinical neuroscience* 14, no. 3 (2007): 216-221. https://doi.org/10.1016/j.jocn.2005.11.007
[29] Satish, "Introduction to graph theory," International Journal of Research in Engineering & Applied Sciences, vol. 3 , no. 6, pp. 35–43, 2013
[30] Rosen, Kenneth H. *Discrete mathematics and its applications*. The McGraw Hill Companies,, 2007.
[[31] Hanafi, N. M., Y. Yusof, M. S. Mohamad, M. F. A. Bakar, and M. A. Ibrahim. "Medicinal cupping in the eyes of graph theory." *Data Analytics and Applied Mathematics (DAAM)* 1, no. 1 (2020): 44-49. https://doi.org/10.15282/daam.v1i01.5325
[32] Brélaz, Daniel. "New methods to color the vertices of a graph." *Communications of the ACM* 22, no. 4 (1979): 251-256. https://doi.org/10.1145/359094.359101
[33] Aslan, Murat, and Nurdan Akhan Baykan. "A performance comparison of graph coloring algorithms." *International Journal of Intelligent Systems and Applications in Engineering* 4, no. Special Issue-1 (2016): 1-7. https://doi.org/10.18201/ijisae.273053
[34] Burke, and Hellier, "Graph coloring and timetabling. In Handbook of Graph Theory", 2002, pp. 445-474.
[35] Jie, C. Y., and N. Mat Ali. "COVID-19: What are the challenges of online learning? A literature review." *International Journal of Advanced Research in Future Ready Learning and Education* 23, no. 1 (2021): 23-29.
[35] Yasin, Penyembuhan Penyakit Kaedah Bekam Cara Rasulullah SAW, Al-Hidayah Publications, 2014, p.102-139.