

Spatial accessibility to health care services among children with cerebral palsy in Johor, Peninsular Malaysia

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Abstract

Cerebral palsy (CP) is one of the most common causes of disability in childhood, leading to functional limitations and poor nutritional status. Families with CP children face challenges in providing proper care. Thus, accessibility of CP patients to health facilities is important to ensure that they can maintain regular visits to health facilities for proper treatment and care. The current study aimed to map the spatial distribution of CP in Johor, Malaysia and measure the accessibility of CP patients to nearby hospitals, health clinics and community-based rehabilitation centres. The study is based on CP cases in 2017 obtained from the Department of Social Welfare, Malaysia and analysed using the average nearest neighbour, buffer analysis and Kernel Density Estimation. Results indicate that there is generally good access to health care services for many of the CP children in Johor, but for 25% of those living more than 10 km away from the health clinics

or community-based rehabilitation centres, regular visits can be a problem. This information should be used for targeted intervention and planning for health care strategies. Furthermore, information on hospital accessibility of CP children would allow for planning of proper and regular treatment for these patients. The study has shown that it is possible to improve the understanding of the distribution of CP cases by integrating spatial analysis using geographical information systems without relying on official information about the density of populations.

Introduction

Cerebral palsy (CP) is one of the most common causes of disability in childhood leading to functional limitations and poor nutritional status (Novak, 2014). CP also can be described as a group of disorders in the development of movement and posture in the developing brain (Soleimani *et al.*, 2011; Holmes *et al.*, 2013). It can also be associated with other conditions, including intellectual disability, seizures, impairment of vision, hearing or speech, musculoskeletal disorders and bronchopulmonary disorders (Sankar and Mundkur, 2005). Several factors have been implicated in congenital CP risk including low birth weight, prematurity, infections during pregnancy, maternal steroid use and birth complications (Holmes *et al.*, 2013; Himmelmann and Uvebrant, 2014; Papavasileiou and Petra, 2020). The worldwide incidence of CP has been reported to vary from 1.5 to more than 4 per 1000 live births (Stavsky *et al.*, 2017). Due to movement limitations and the associated co-morbidities, CP children require specific treatments, long-term rehabilitation and other kinds of health and social care support, including access to proper education (Trabacca *et al.*, 2016). However, people with disability, including CP individuals, do not have equal access to these services due to various factors such as gender role and other differences (Ali *et al.*, 2011), inconvenient location of health care facilities due to hilly terrains (Mateen *et al.*, 2013) or long distances from home (Majrooh *et al.*, 2013; WHO, 2015; Panezai *et al.*, 2017) and lack of transportation (Majrooh *et al.* 2013; WHO, 2015; Malik and Ashraf, 2016; Qureshi *et al.*, 2016; Panezai *et al.*, 2017).

Accessibility refers to the physical access a user possesses to a location and this aspect has been widely applied as a scientific method for assessing the distribution of public services (McGrail and Humphrey, 2014). Accessibility can also be referred to the potential for health care use or revealed access that involves interaction between provider and patient (McGrail, 2012). According to Casas *et al.* (2017), revealed accessibility is estimated using the travel time to the health facility where the patient was diagnosed. Access to hospital facilities is defined as the timely use of health services for the best possible health outcome, which amounts to

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the degree of adjustment between certain population characteristics and its health care resources (Institute of Medicine United States, 1993). Access is thus considered a functional relationship between the beneficiaries of health care and medical facilities and the resources available, something which reflects the differential existence of either facilitating factors or those of obstacles, impediments and difficulties. In health care, accessibility has five dimensions: i) affordability of the patients to pay for services; ii) arrangement and organization of resources that meet patients' needs, such as open hours and appointment possibilities; iii) patients' perception of the services and how the providers meet their needs; iv) relation between existing health facilities and needs; and v) the spatial relationship between the location of facilities and the location of patients (Penchansky and Thomas, 1981; Levesque *et al.*, 2013). Among the five dimensions of health care accessibility, geographical accessibility is much easier to measure and determine (Paez *et al.*, 2010) if geographic information systems (GIS) can be used to spatially analyse the specific health data (Hare and Barcus, 2010). For example, the accessibility of cardiovascular hospital facilities was explored by considering the number of beds and residents at different critical distances from each other (Stavsky *et al.*, 2017). Recently, spatial-time analysis of cardiovascular emergency medical requests was utilised for policymakers to design interventions that could improve the response time and reduce cardiovascular-related mortality (Azimi *et al.*, 2021). Revealed access to haemodialysis facilities in Northern Tehran was found to be affected by spatial as well as non-spatial factors that included gender, income and education level, ethnicity and ownership of transport (Kiani *et al.*, 2017). For management of acute diseases, determination of potential spatial accessibility to emergency medical services (EMS) and identification of areas with poor access to EMS would help policymakers to plan and allocate resources to improve provision of these services (Hashtarkhani *et al.*, 2019). Locally in Malaysia, spatial statistical methods have been utilised to gain

understanding on the distribution of dengue cases in Putrajaya (Hazrin *et al.*, 2016).

Most studies focused on measuring travel time, *e.g.*, based on driving time from the patient's home to the hospital. This includes investigating the spatial distribution of patients, determining hotspots of cases and shortest-path analysis. Network analysis was used to calculate the average shortest distance between residential areas and hospital facilities in China (Yin *et al.*, 2018) and to define areas suitable for the allocation of new health centres in Jeddah City (Murad, 2018). Kiani *et al.* (2018) showed that the generalized two-step floating catchment area (2SFCA) method could be used to measure revealed access time of patients to the haemodialysis facilities. More recently, spatial accessibility to hospital facilities in Kumasi, Ghana has also been investigated using the 2SFCA method (Asera-Akuffo *et al.*, 2020). This study determined real travel time (driving and walking) to understand the impact of different transportation modes on spatial hospital accessibility, and the report included policy suggestion to improve transportation facilities in the rural part of the metropolis. On the other hand, evaluation of spatial accessibility of urban public facilities in Keifeng, China, based on web mapping using an application program interface (API), revealed different levels of inequalities in residents' travel time to hospitals (Zheng *et al.*, 2019).

The most commonly used methods for measuring accessibility of hospital service facilities are network analysis (Samat and Shattar, 2013; Murad, 2018; Rahimi *et al.*, 2018; Yin *et al.*, 2018; Khakh, 2019), average nearest neighbour (ANN) (Samat *et al.*, 2010; Hazrin *et al.*, 2016) origin-destination (OD) cost matrix (Samat *et al.*, 2010; Samat and Shattar, 2013; Asera-Akuffo *et al.*, 2019; Zheng *et al.*, 2019), Moran's *I* (Hazrin *et al.*, 2016; Rahimi *et al.*, 2018), kernel density estimation (KDE) (Hazrin *et al.*, 2016) shortest-path analysis (Zhu *et al.*, 2019), Gaussian function (Asera-Akuffo *et al.*, 2019), multiple ring buffer (Samat and Shattar, 2013; Khakh, 2019) and 2SFCA (McGrail, 2012; Kiani *et al.*, 2018;

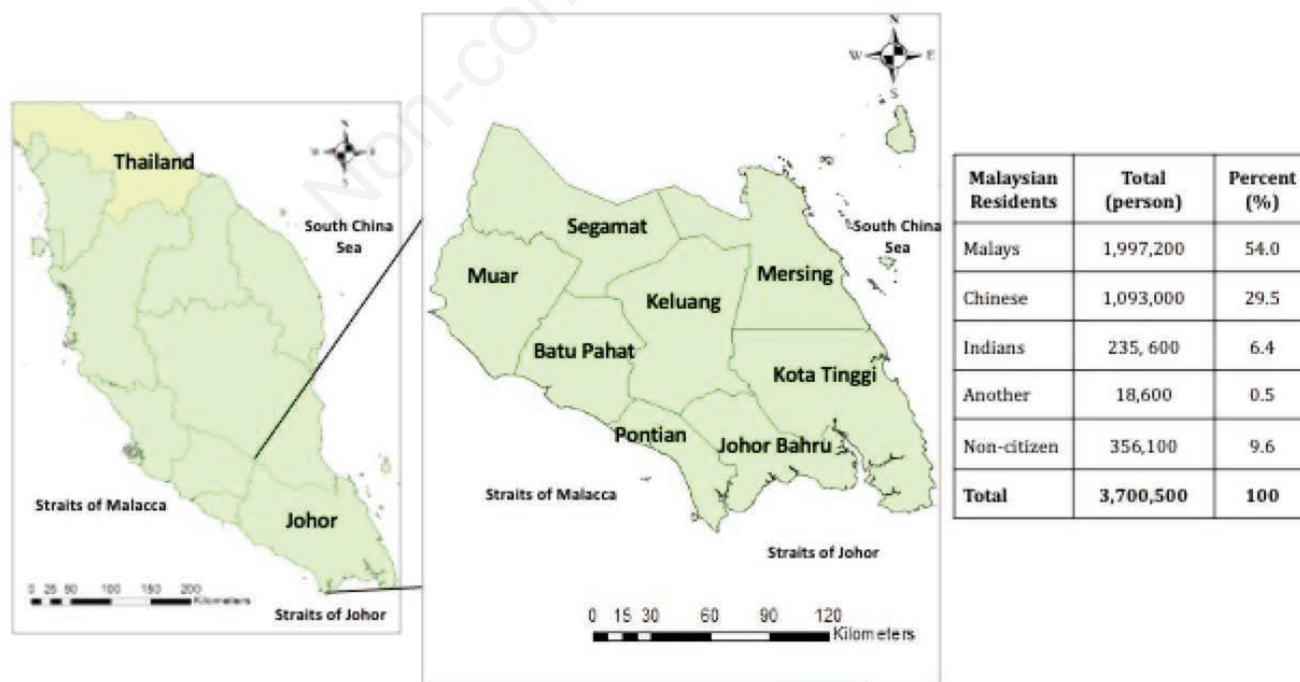


Figure 1. Map of Johor, Peninsular Malaysia showing its eight districts. The population distribution of Johor is indicated.

Asera-Akuffo *et al.*, 2019; Hashtarkhani *et al.*, 2019). Multiple methods and combinations of the methods have been developed to derive an effective spatial measure by using the GIS, the utilisation of which allows simultaneous observation of both attribute and geographical relations in different types of maps (Samat *et al.*, 2010). This assists policy decisions and public communication on the complex information in an easily interpretable format.

Information obtained from GIS studies is used by providers of health care services for disease diagnosis, improvement of health care programmes, evaluation of service effectiveness and identification of outcomes and prognosis (Johns 2002; McNeil, 2009). GIS has also been adopted locally to study the incidence or distribution of diseases such as cancer (Samat *et al.*, 2010) and dengue (Hazrin *et al.*, 2016). However, local data with respect to CP are lacking and no reports on spatial accessibility to health facilities for these patients are available. Early identification and effective rehabilitation are important for improvement of quality of life of children suffering from CP (Dimitrijevic and Jakubi, 2005).

The current study was undertaken to determine the geographical access of CP children in Johor, Peninsular Malaysia to existing health care facilities. GIS was utilised to map the spatial distribution of cases, buffer distances to the hospitals, health clinics and community-based rehabilitation centres (CBRs) and clustering of the hotspot areas determined. The GIS mapping of CP cases in this study can potentially assist in improving population health and health care especially for these children in Malaysia.

Materials and methods

Research area and data collection

Johor State in Peninsular Malaysia was selected as the study area. As seen in Figure 1, it is surrounded by the South China Sea to the East, the Straits of Johor to the South and the Straits of Malacca to the West. The total land area is nearly 19,102 km² (Department of Statistics Malaysia, 2018). The Malaysian Census (2017) reported the population of Johor at 3,700,500, the third-most populous state in Malaysia, with a 9.6% non-citizen population. The Malaysian residents consist of Malays, Chinese, Indians and ethnic minorities (Department of Statistics Malaysia, 2020).

According to the Malaysian Statistics Department (2017), the total number of children in Malaysia was 9,431,600 and Johor has a total children population of 1,076,600. For the current spatial analysis, data on CP cases were obtained from the Department of Social Welfare, Ministry of Women, Family and Community Development in Malaysia. Data collection using GPS was undertaken to ensure that all addresses were captured in the GIS

Table 1. Number of cerebral palsy children in Johor, Malaysia.

Age (years of age)	Male	Female
2-4	22	12
5-7	75	43
8-12	110	84
13-18	92	65
Total	299	204

Source: Department of Social Welfare, 2018.

database. Other data collected for the analysis were the locations of all hospitals, health clinics and CBR centres in Johor. This study is part of a larger project approved by the Universiti Sains Malaysia Human Research Ethics Committee (Approval No. USM/JEPeM/16100411).

Population group studied

Department of Statistics Malaysia reported 5840 cases of CP in Malaysia in 2017, and 568 CP children (9.7%) were recorded in the state of Johor. A total of 503 CP cases registered in Johor with the Department of Social Welfare, Ministry of Women, Family and Community Development were analysed (Table 1), accounting for 88.6% of the total reported cases in Johor (Department of Social Welfare, 2018). The highest incidence of CP cases was among children of 8-12 age group. The majority of all registered CP cases were males. The spatial distribution of the cases was also mapped to show the number of CP children in each district (Figure 2). Johor Bahru District recorded the highest population of CP children (262) followed by Batu Pahat (55) Muar (49) and Segamat (42). Only 6 cases were reported in Mersing.

Spatial analysis

The study was based on the spatial analysis functions available in ArcGIS 10.3 (ESRI, 2015). After the preparation of initial data coordinates, the information was added to the map of Johor in ArcGIS. The first analysis was undertaken using ANN that measures the distance between each spatial feature and its nearest neighbour centroids, for example, from the CP cases to the health

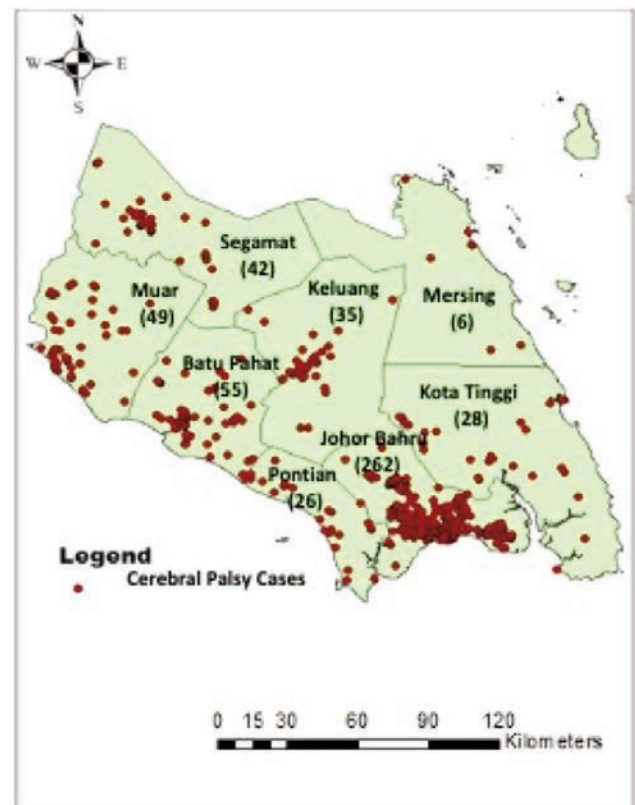


Figure 2. Spatial distribution of cerebral palsy children in Johor districts.



facilities such as hospitals, CBR centres and health clinics.

The value of the ANN ratio (R value) is calculated as the observed average distance divided by the expected average distance (based on a hypothetical random distribution with the same number of features covering the same total area). If the index (ANN ratio) is less than 1, the pattern exhibits clustering. If the index is greater than 1, the trend is towards dispersion:

$$ANN = \frac{\bar{D}_O}{\bar{D}_E} \tag{1}$$

where \bar{D}_O is the observed mean distance between each feature and their nearest neighbour:

$$\bar{D}_O = \frac{\sum_{i=1}^n di}{n} \tag{1a}$$

and \bar{D}_E the expected mean distance for the features given a random pattern:

$$\bar{D}_E = \frac{0.5}{\sqrt{n/A}} \tag{1b}$$

In the equations above (Eq. 1a and Eq. 1b), di equals the distance between feature i and its nearest element; n corresponds to the total number of features; and A is the whole study area. The score can be calculated as:

$$Z_{ANN} = \frac{\bar{D}_O - \bar{D}_E}{SE} \tag{2}$$

where,

$$SE = \frac{0.26136}{\sqrt{n^2/A}} \tag{2a}$$

The second analysis performed was multiple ring buffer analysis to generate a specified distance around the health care service points. Buffers with 5-km intervals were drawn surrounding each hospital, health clinic and CBR centre in Johor. The third analysis was based on KDE (Silverman, 1986; Samat *et al.*, 2010; Hazrin *et al.*, 2016; Rekha *et al.*, 2017; Zhu *et al.*, 2019) to determine whether there would be significant clustering (CP hotspots) in particular areas in Johor state. This interpolation technique was used to calculate the density of point features around each output raster cell by the formula:

$$Density = \frac{1}{(radius)^2} \sum_{i=1}^n \left[\frac{3}{\pi} \cdot pop_i \left(1 - \left(\frac{dist_i}{radius} \right)^2 \right)^2 \right] \tag{3}$$

For $dist_i < radius$

where n is the number of input points (included only if within the radius distance of the (x, y) location); pop_i the population field value of point i , which is an optional parameter; and $dist_i$ the distance between point i and the (x, y) location. The calculated density is then multiplied by n , or the sum of the population field if one were provided. This correction makes the spatial integral equal to

n (or sum of population field) rather than always being equal to 1 (ESRI, 2015). This implementation uses a Quartic kernel (Silverman, 1986).

The formula was calculated for every location where we wished to estimate the density. Since a raster was created, the calculation was applied to the centre of every cell in the output raster. The algorithm used to determine the default search radius, also known as the bandwidth, was the following:

$$Search\ radius = 0.9 * \min \left(SD, \sqrt{\frac{1}{1n(2)}} * Dm \right) * n^{-0.2} \tag{4}$$

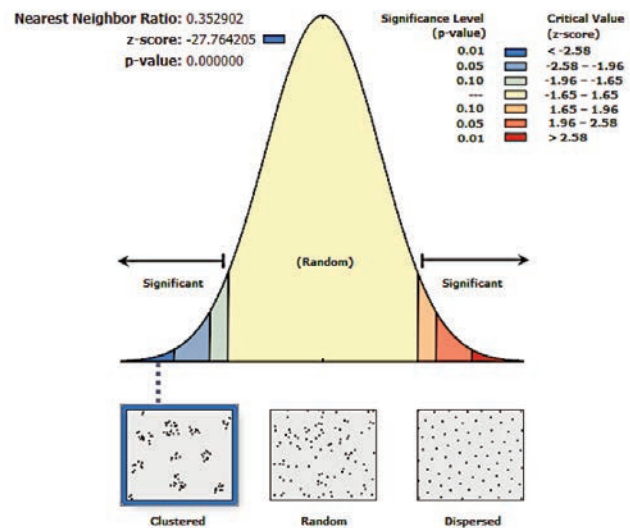
where Dm is the median distance from mean centre; n either the number of points (if no population field is used), or the sum of the population field values (if a population field is supplied); and SD the standard distance. The latter was calculated using the formula:

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - X)^2}{n} + \frac{\sum_{i=1}^n (y_i - Y)^2}{n} + \frac{\sum_{i=1}^n (z_i - Z)^2}{n}} \tag{5}$$

where x_i, y_i and z_i are the coordinates for feature i ; and X, Y and Z the coordinates for the mean centre for the features; and n equal to the total number of features.

Results

ANN analysis produced three types of values that were nearest neighbour ratio (R), z-score and P-value (Figure 3). The z-score is a test of statistical significance to reject or accept the null hypothesis. For the current study, the null hypothesis was that there was no spatial pattern among the CP cases studied. Our analysis indi-



Given the z-score of -27.76, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Figure 3. Average nearest neighbour analysis of cerebral palsy cases in Johor.

cated that the distribution of CP children in Johor was spatially clustered with R-value of less than 1 ($R=0.35$; z -score -27.76 ; $P<0.000$). With a small z -score < -2.58 or $> +2.58$ (standard deviation), it is too unusual for the observed spatial pattern to be the result of random chance, and the P-value will be small to reflect the result (ESRI, 2015). The distribution of CP children in Johor State therefore, can be classified as clustered. Statistically significant clusters were found around Johor Bahru, Batu Pahat, Segamat and Muar districts.

Location of higher density or hotspots of CP children within Johor was further confirmed by KDE analysis. Figure 4 shows the results divided into five categories from minimum (bright colour areas) to maximum (dark colour areas). The highest incidence of CP was observed in Johor Bahru District (0.81-1.00) while the Batu Pahat, Keluang and Segamat districts showed middle medium incidence of CP cases (0.41-0.80). The lowest frequency of CP cases was in the Muar and Kota Tinggi districts (0.21-0.40).

The various distances from the residential areas, where many of the CP children live, to the main roads are depicted in Figure 5. In determining accessibility to the main roads, four distance levels of proximity were used, *i.e.* 0.5, 1, 3 and >5 km. The majority of the CP children (83%) were found to live within 1 km from the main roads, whereas as many as 314 CP children (62%) lived in residential within 500 m from the main road. Only two CP children lived in residential areas >5 km away from the main road. Based on proximity analysis alone, these data suggest that there is reasonable road access for most of the CP children.

The results of multiple ring buffer analysis of the reported CP cases in Johor are based on the proximity of their homes to hospitals, health clinics and CBR centres (Figure 6). The residential areas of 261 (51.9%) of the CP cases were found within 10 km away from the hospitals while 56 of them (11.1%) were situated

outside the 20 km radius. The majority of the CP children (340 cases or 67.6%) were also found to be less than 10 km away from nearby health clinics or the CBR centres (381 or 75.7%). A small number of the CP children (11 or 2.2%) were more than 20 km away from the CBR centres (Figure 6).

Discussion

The distance between residential area and health care facilities such as hospitals and health clinics, is very important for health promotion and maintenance, disease management or prevention, to reduce unnecessary disability or premature death, as well as for achieving social stability. For CP children in particular, accessibility to health clinics is essential and thus, living in close proximity to health facilities offers much advantage as they regularly need rehabilitation for their disability and other health services that would also manage their comorbidities. The ideal distance between health care facilities and the patients has been suggested to be less than 12 km or approximately 50 min driving time at a medium speed while another report suggested that the hospital should be accessible within 2 km buffer from the surrounding population (Jordon *et al.*, 2004). Only around 50% of the CP children in Johor are within close proximity (10 km) to the government hospitals. In the current health care system, government-run health clinics are placed in various districts in Malaysia to help provide free primary care services, especially to under-served rural areas. However, more than 30% of the CP children in our study were found to live more than 10 km away from the health clinics. For some families without own transportation, this could be a great hurdle. Families with bedridden children would also be more impacted. The private sector also caters for health services, but the private clinics are

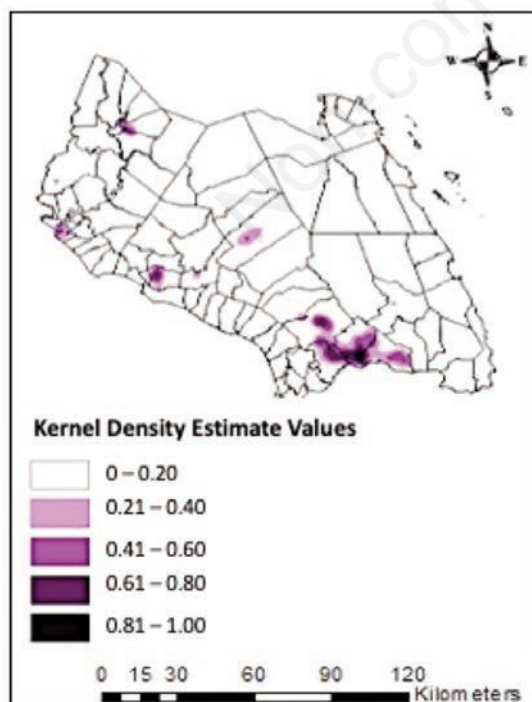


Figure 4. Kernel density estimate of cerebral palsy cases.

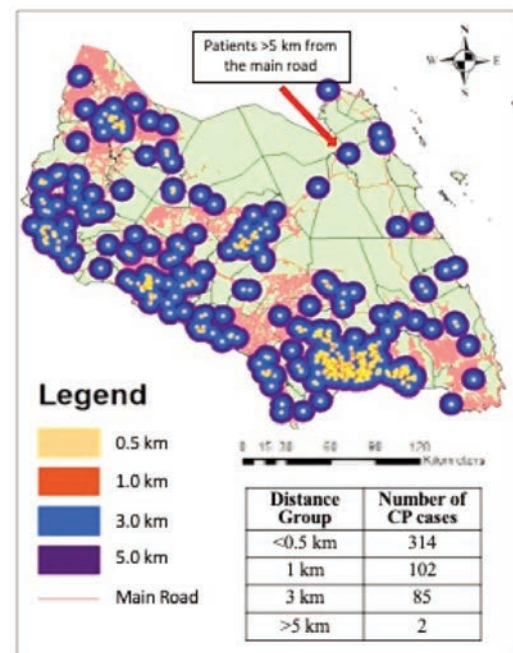


Figure 5. Proximity of cerebral palsy cases (CP) to the main roads. Red arrow indicates the location of two CP children living >5 km away.

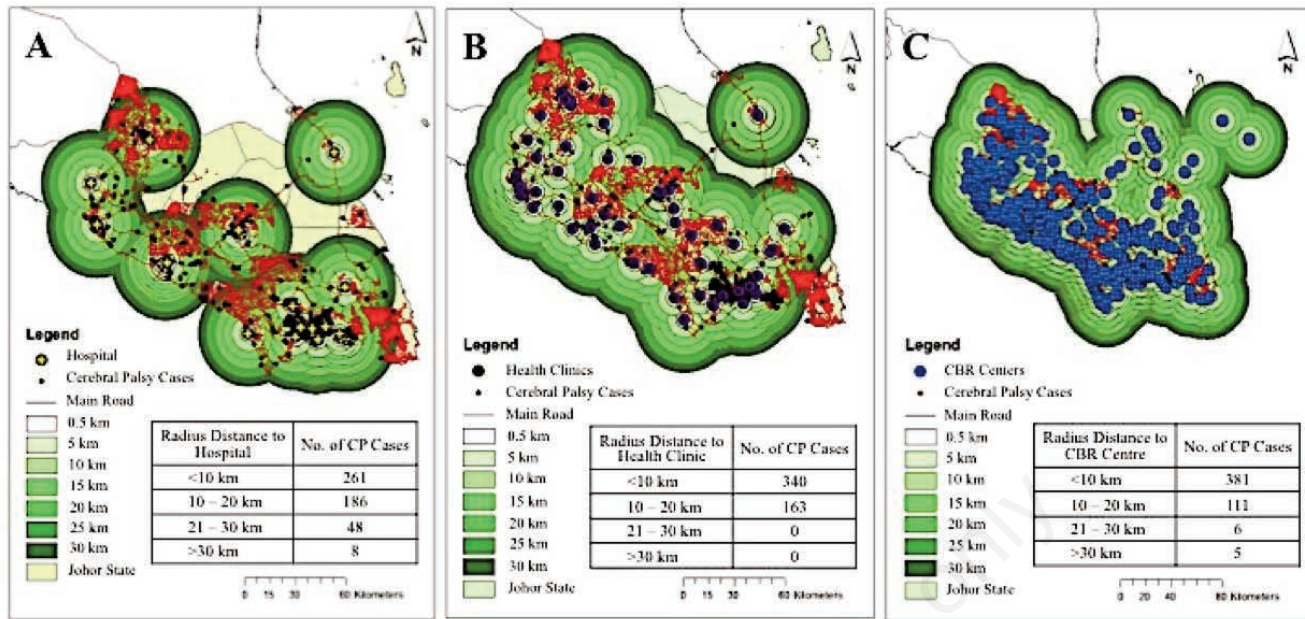


Figure 6. Multiple ring buffer distances of cerebral palsy (CP) cases to health care facilities.

mainly located in urban areas.

The majority of CP children in our study were found to have good access to government-based health care services. However, for nearly 25% of them, *i.e.* those living more than 10 km from the health clinics or CBR centres, access would be difficult. Proximity analysis has further provided information on the road accessibility of the CP children's residential areas. From a health perspective, proximity to main roads plays an important role in connecting patients with nearby health facilities for treatment. Our findings suggest that most of these children have good road access, but the two children situated far away from the main road, would have problems obtaining health care services, especially since transportation is not readily available. Ring buffer analysis further determined how many of the CP children live within the radius of existing health care facilities. Based on this approach, identification of areas short of health care providers could serve as a useful measure for local policy makers in allocating new health services. Suitable locations for health facilities are critically important for example, when availability of transport facilities is limited or long distances exist between scattered villages, and also in situations of uneven landscape (Mateen *et al.*, 2013).

Our study found that a higher percentage of CP children are living within 10 km to the CBR centres (75.7%) compared to the health clinics (67.6%). CBR facilities, established by the Department of Social Welfare at the Ministry of Women, Family and Community Development in all states in Malaysia, provide programmes and free services for the care and development of children with various types of disability including CP (Department of Social Welfare, 2018). Children with CP require continuous long-term rehabilitation treatment and other health and social care support. This means that for nearly 25% of the CP children in our study (living >10 km away), regular reach to CBR facilities is difficult without proper and regular transportation, particularly for bedridden children, or because of financial constraints. For such cases, other health support services such as mobile clinics or home

visits by health practitioners could be a solution. This problem may not be unique to far-away families. Based on a health screening camp conducted in Johor Bahru (capital city of Johor State) in 2017, about 85% of the CP children who attended the camp were registered with the Department of Social Welfare. However, only 40% of these children were actually attending the CBR centres on a regular basis (unpublished data). The camp was attended by children and their family living within 6.5 km vicinity of the camp site, so travel impedance and reduced mobility or co-morbidity of some CP children could be contributing factors. Other non-spatial factors such as affordability, gender and education level have also been reported as significant factors for health care access (Kiani *et al.*, 2017; Hoseini *et al.*, 2018). In order to reduce inequities in access to health facilities or services, a more generic and comprehensive approach to organizing the health care system is required (Munoz and Kallestal, 2012). Accessibility to health facilities has a multi-dimensional concept that involves financial accessibility, availability, acceptability and geographical accessibility (Panzai *et al.*, 2017). While geographical aspect of accessibility considers distance of the nearest health facility to citizens either by car or on foot, the social aspect might take into consideration social class of the patients, ethnicity, income and age of health demand (Jordan *et al.*, 2004; Paez *et al.*, 2010; Panzai *et al.*, 2017). Therefore, for future studies, understanding of cultural and social barrier that limit utilisation of available health care services by the CP children should be a major consideration.

KDE is an effective tool to identify high-risk areas within point pattern of disease incidence by producing a smooth, continuous surface that defines the level of risk for that area (Samat *et al.*, 2010). It is also a spatial analysis technique that accounts for the location of features (destination) relative to each other and has been applied to the examination of various aspects of the environment, such as park access (Rekha *et al.*, 2017; Zhu *et al.*, 2019) and health resources (Smiley *et al.*, 2010). A number of studies have successfully implemented KDE to estimate the distribution and

high-risk area for dengue incidence (Hazrin *et al.*, 2016), high cancer incidence (Samat *et al.*, 2010), density of doctors and nurses (Zhu *et al.*, 2019) and accessibility of health care facilities (Rekha *et al.*, 2017). So, KDE is useful in identifying accurate location, spatial extent and intensity of cases. There are currently no reports on the implementation of KDE for CP incidence. The current study thus utilised KDE to show CP incidence levels in different Johor districts which have important implications for the local government in their planning for better care and management of this disability.

There are a few limitations to the current study. This field study suggests that spatial aggregation error in spatial accessibility studies is dependent on the study area and the spatial properties of the amenity being examined (Smiley *et al.*, 2010). To that point, our case study only examined a single study area (Johor State) and access to hospital facilities, CBR centres and health clinics. As such, the results may not be generalized across all states in Malaysia or to other service facilities. Additionally, our analyses were performed using multiple ring buffer, ANN and KDE only, which focus on the near function, such as the distance from residential areas of CP children to available health facilities. These analyses did not consider any potential barriers such as the traffic flow, availability of transportation, and sociocultural issues in evaluating accessibility (Majrooh *et al.*, 2013; Malik and Ashraf, 2016; Qureshi *et al.*, 2016).

For further analysis, we recommend the application of network analysis, service area analysis and OD cost matrix to determine patients' travel time to health facilities and identify new health facilities to ensure optimal use. Future studies on health accessibility should also include private health facilities and the influence of non-geographic barriers or non-spatial factors. Study locations could also be expanded to other states in Malaysia for an overall comparison.

Conclusions

This study has shown that it is possible to improve the understanding of the distribution of CP cases within a particular region by integrating spatial analysis using GIS, which can be done without relying on information about the density of populations. There is generally good access for many of the CP children to obtain health care services, but some level of inequality in geographic accessibility exists for other CP children in the study, hence regular visits to the facilities would be a problem. The spatial information gathered could assist relevant stakeholders and policy makers not only in improving access, quality and utilisation of health facilities and health care services but also to review available access to proper education and social support for these special group of children as well as their caregivers in order to help improve their overall quality of life.

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