Spatial Accessibility to Cancer Care Facilities in Saudi Arabia

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Abstract

Access to cancer care facilities is recognized as affecting the long-term health and well-being of cancer patients; however, little is known about spatial accessibility to specialized cancer therapy centers in Saudi Arabia. This study has estimated the spatial accessibility to cancer care facilities in Saudi Arabia in terms of travel time, and assessed the associations between the travel time to specialized cancer therapy centers and geographic sectors, demographic characteristics, the diagnosed number of cancer cases (CCs) and the cancer crude incidence rate at the city level. A geographic information system (GIS) and spatial analysis were used to estimate spatial accessibility (i.e., travel time) using street network distance, adjusted by road speed limit. Incidences of diagnosed cancer were obtained from the Saudi Cancer Registry (SCR) from January 1998 to December 2004. The spatial cancer incidence database was designed and developed at the city level based on aggregated individual CCs. Spatial access to specialized cancer care facilities appears to be sufficient for a proportion of the Saudi population. For the total Saudi population during the study period, the median travel time to the closest specialized cancer care facility was 212 min, with an interquartile range (IQR) of 97–315 min. Travel times of 2 h to the closest specialized cancer center were estimated for 57% of the Saudi population in 2004. There were variances in access, and there were population groups in the southern and northern regions that had limited access to these settings. These areas should be the primary targets for the development of regional cancer services.

Keywords: cancer, spatial accessibility, cancer care facilities, GIS, Saudi Arabia

1. Introduction

Cancer is a major health problem in both developed and developing countries, and is a leading cause of death worldwide. Globally, new cases of cancer are estimated to increase from 11.3 million in 2007 to 15.5 million in 2030 [1]. The estimated number of new cases of cancer is expected to continue to rise by 3-4% each year, and 60% of this increase will occur in developing countries, where healthcare facilities and patient care are limited. In the Eastern Mediterranean Region (EMR), cancer incidence is predicted to rise 1.8 times over the next decade [2]. Saudi Arabia has experienced rapid socioeconomic changes in recent years. An increase in wealth has been accompanied by a change in lifestyle, dietary habits, disease patterns and an increase in life expectancy; all of these changes may have influenced the incidence of certain types of cancer in the country. Additionally, considering the growth and aging of the population of Saudi Arabia, the probably rise of cancer rates will add a significant burden to healthcare utilization.

Access to healthcare facilities is commonly recognized as an important goal in meeting the health needs of individuals [3]. For specialized health services such as cancer care that are not broadly or evenly distributed in spatial terms, access may be essentially restricted by spatial accessibility [4]. Spatial access highlights the significance of geographical barriers (i.e., travel distance or time) between patients and health providers [5]. For cancer patients, poor spatial access to cancer care facilities (spatial factor) has been related to an increased risk of developing advanced stage cancer [5-7], a decreased use of cancer therapy [8,9], a lower likelihood of receiving cancer screening [10], lower participation in cancer treatment clinical trials [11] and lower cancer survival [12-14]. Access to cancer healthcare settings also varies among population groups by their socioeconomic status and demographic characteristics (non-spatial factors) such as social class, whether they reside in a rural area, income, insurance status, race and ethnicity, culture, age and gender [15-25]. Screening could reduce the risk of cancer death through early detection [26]. Lengthy or costly travel to a healthcare provider or preventative service facility can hinder patients from being screened, and patients who are screened may not acquire suitable and appropriate follow-up for the screening results [27-29].

According to Penchansky and Thomas [30], spatial accessibility is one of five factors related to healthcare access; the other four are availability, affordability, acceptability and accommodation [28]. Accessibility to healthcare facilities can be described by spatial factors such as travel distance, travel time, region and service supply (type and quality) [4,31]. Several methods have been applied to estimate spatial accessibility to healthcare services [31], including the use of the straight-line distance between population centers and healthcare suppliers [23-34], network-based distances that rely on travel times and road distances to the closest facilities [35-39], service densities that count the number of facilities in a population [40-43], kernel density estimation (KDE) [31], the two-step floating catchment area (2SFCA) method [44], the enhanced two-step floating catchment area (E2SFCA) method [45], and a Gaussian two-step floating catchment area (G2SFCA) method [46]. Although service density has been commonly applied and is not difficult to calculate, the method does not consider the interaction between populations and service facilities across arbitrary neighborhood boundaries. The primary limit of using the KDE technique is that travel obstacles are not considered when a straight line method is used to calculate Euclidean distances. The 2SFCA approach employs physical road-based network distance, which more accurately approximates the real environment; however, the technical limitations of applying the 2SFCA process mean that the method remains underutilized in epidemiological studies [47]. With the development of geographical information systems (GIS), road-network-based travel distance or travel time is considered a common measure of accessibility, although such measures do not consider competition among diverse service facilities [47].

The detection of disparities in the spatial access to specialized cancer care facilities has the advantage of identifying deficient areas that would benefit from better access and would play a role in prevention, screening and treatment, as well as identify inequalities in healthcare utilization [4]. Additionally, characterizing spatial access is the first step in advising cancer control policies, plans, and strategies. The aim of this study is to estimate spatial accessibility to specialized cancer care facilities in Saudi Arabia in terms of travel time. The study also aims to understand the associations between spatial access (i.e., travel time) to healthcare cancer facilities and demographic features, geographic sectors, the

diagnosed number of CCs, and the cancer crude incidence rate (CIR). To our knowledge, no such study has been conducted previously in Saudi Arabia.

2. Material and Methods

2.1. Cancer, Population and Spatial Data

Incidences of cancer have been obtained from the Saudi Cancer Registry (SCR). The SCR is a population-based registry that was established in 1992 and began reporting cancer cases (CCs) on January 1, 1994 [48]. The cancer dataset includes statistics on diagnosed incidences of cancer in Saudi nationals from January 1998 to December 2004. Cancer incidence rates were calculated based on the mid-point population structure for Saudi nationals, which was estimated from the population in 2004 as reported by the Central Department of Statistics and Information (CDSI) of the Ministry of Planning [49]. Age is a recognized covariate for cancer incidence; however, population data by age group was only available at the regional level. Thus, the CIR was used instead of the age-standardized incidence rate (ASR). The CIR for a particular cancer site in the human body is the total number of CCs registered as a proportion of the total population. All rates are expressed as per 100,000 individuals. The CIR per 100,000 can readily be calculated by dividing the total number of cases of a particular cancer type by the population and multiplying the result by 100,000.

The spatial cancer incidence database in Saudi Arabia was designed and developed in the form of an ESRI file geodatabase at the city level. The cancer database for the present study also includes records for individual CCs; however, the location of each CC was not included. To develop a spatial cancer database, the individual CCs were aggregated to the city level. All of the CCs that were located in the same city were grouped and aggregated to be represented in that city. The geographical level of analysis in this study is at the city level and 240 cities are included (N = 240) (Figure 1). To achieve the second objective of the study, the following four datasets were prepared using GIS: geographic sectors (Figure 2), which was prepared by aggregating the 13 administrative regions in Saudi Arabia into five geographic sectors, the distribution of the Saudi population (Figure 3), the distribution of the number of diagnosed CCs (Figure 4) and the distribution of the CIR (Figure 5).

2.2. Cancer Healthcare Facilities

In Saudi Arabia, cancer management is offered free of charge to all Saudi patients, including those who may need advanced treatment abroad, regardless of their place of residency. Yet, specialized cancer care facilities are primarily located in the three major cities: Riyadh, Jeddah, and Dammam (Figure 1). These facilities provide specialized medical cancer care, including opportunistic screening, early detection, therapeutics, rehabilitation, and palliative care. Specialized cancer centers vary in terms of the standard of care, and some centers specialize in certain cancer therapies such as adjuvant treatments and new technologies in radiation therapy. Riyadh city encompasses the King Faisal Specialist Hospital and Research Centre, National Guard Hospital, Armed Forces Hospital, King Fahad Medical City, Security Forces Hospital and King Khalid University Hospital. Jeddah city contains the King Abdulaziz University Hospital, King Abdulaziz Cancer Centre, National Guard Hospital, and Armed Forces Hospital. The Dammam metropolitan area includes the King Fahd Specialist Hospital, Saudi Arabian Oil Company hospital (Saudi ARAMCO Hospital) and King Fahad University Hospital. To develop a spatial database of specialized cancer care facilities, the locations of individual facilities were aggregated to the city level. All of the facilities that were located in the same city were grouped and aggregated to be represented in that city.

2.3. Measures of Spatial Accessibility

In the context of health care, spatial accessibility refers to travel impedances or barriers (e.g., travel time, distance, and cost) between a patient's location and health service locations [28]. Depending on the scale of the available data, spatial accessibility is typically measured from a patient's residence or from a population center, such as the geometric centroid of the city of residence [31]. In this study, the patient locations and service locations (specialized cancer care facilities) are represented by the location of cities (Figure 1). Spatial accessibility in terms of travel time was computed using road-network-based travel distances. A value of travel time can be calculated in several ways. One method is to actually measure the average travel times for each street segment; another is to use the speed limit on the street to calculate an approximate travel time by dividing the segment length of the street by the speed limit. The latter method was applied in this study, using average speed limits of 70 km/h on urban streets and 120 km/h on highways. The data

processing and spatial analyses in this study were conducted using ESRI ArcGIS 10.1 (Redlands, CA, USA) and travel distances were computed using Google Earth. Travel times were ascertained using the route with the shortest travel time (travel distance weighted by speed limit) from each city to the closest cancer care facility based on the associated speed limits on national highway roads and street networks within cities. SPSS 13 was used to compute median travel times with interquartile ranges (IQRs) by geographic sector, population, number of diagnosed CCs, and cancer CIRs.

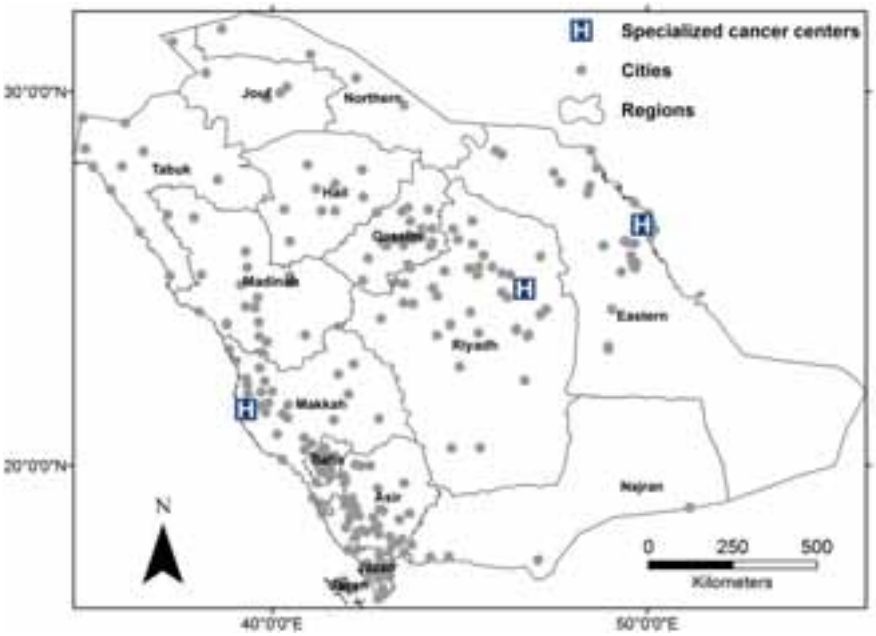

Figure 1: Locations of cities and specialized cancer centers

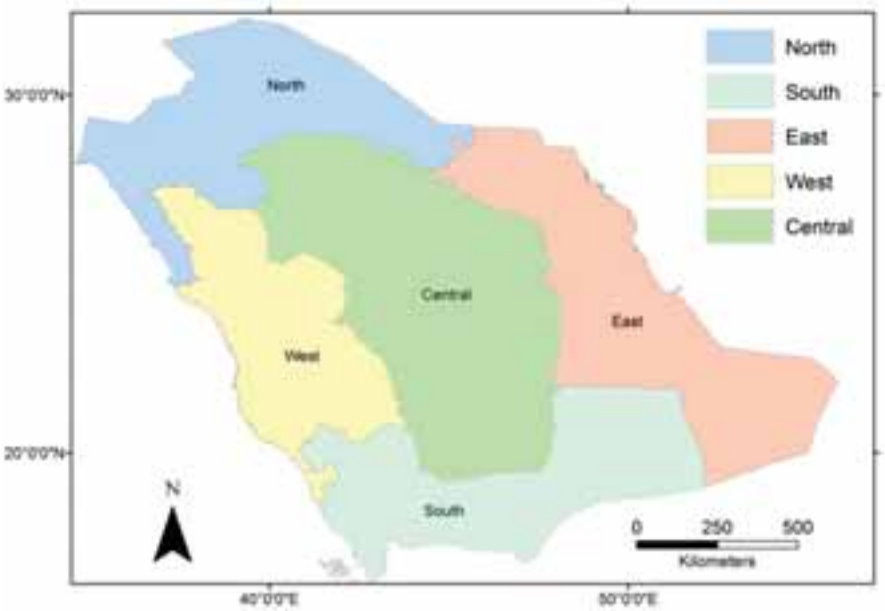

Figure 2: Geographic sectors

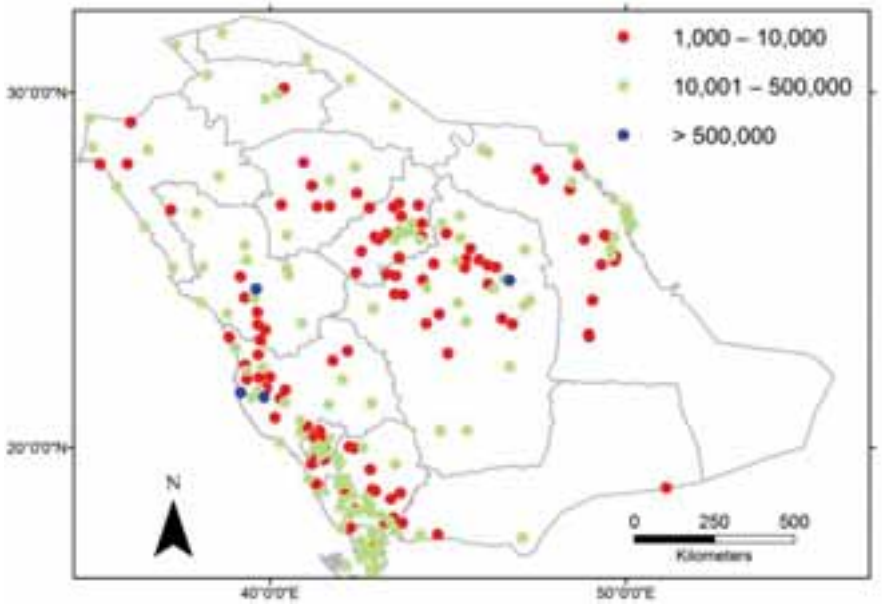

Figure 3: Distribution of the Saudi population, 2004

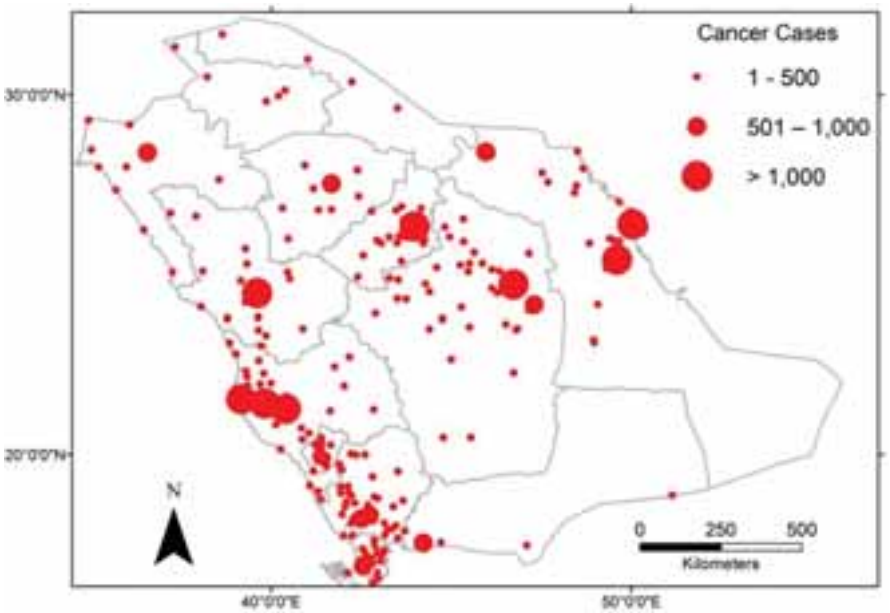

Figure 4: Overall diagnosed cancer cases, 1998-2004

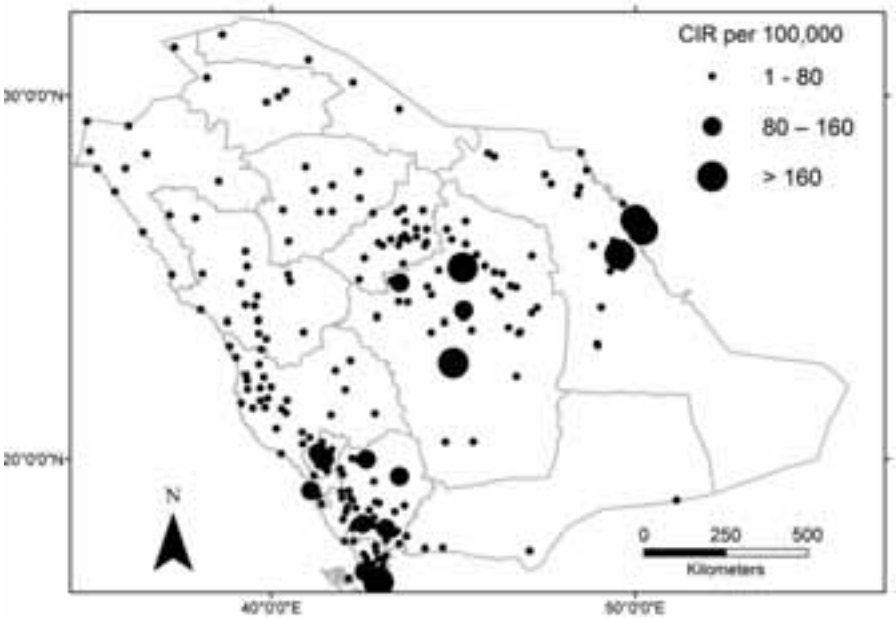

Figure 5: Overall cancer CIR, 1998-2004

3. Results and Discussion

The spatial accessibility analyses in the current study include 240 cities in Saudi Arabia. Three of those cities contain specialized cancer care or academic-based care settings (Figure 1). A total of 45,532 CCs that were diagnosed among Saudi nationals between January 1998 and December 2004 are included in the spatial accessibility analyses. Figure 6 presents spatial accessibility (by travel time) to the closest city that contains specialized cancer centers. The cities that are the closest to Riyadh, Jeddah, and Dammam have travel times of less than 2 h, whereas cities in the southern and northern parts of the country display travel times of more than 5 h. This long travel time was expected, as the current spatial distribution of cancer care facilities in Saudi Arabia creates large gaps between locations. The results indicate that approximately 45% of the targeted Saudi population lives within 1 h of a city that contains specialized cancer care facilities; whereas approximately 28% of the population lives more than 4 h from a city with these amenities (Table 1).

The associations between demographic features and spatial access to specialized cancer care facilities for the total Saudi population indicate that the median travel time to the closest city that contains a specialized cancer center is 212 min (IQR, 97–315 min). However, stratification by geographic sector (Table 2), demographic characteristics (Table 3), the number of diagnosed CCs (Table 4) and the CIR (Table 5) at the city level indicate variations in travel time.

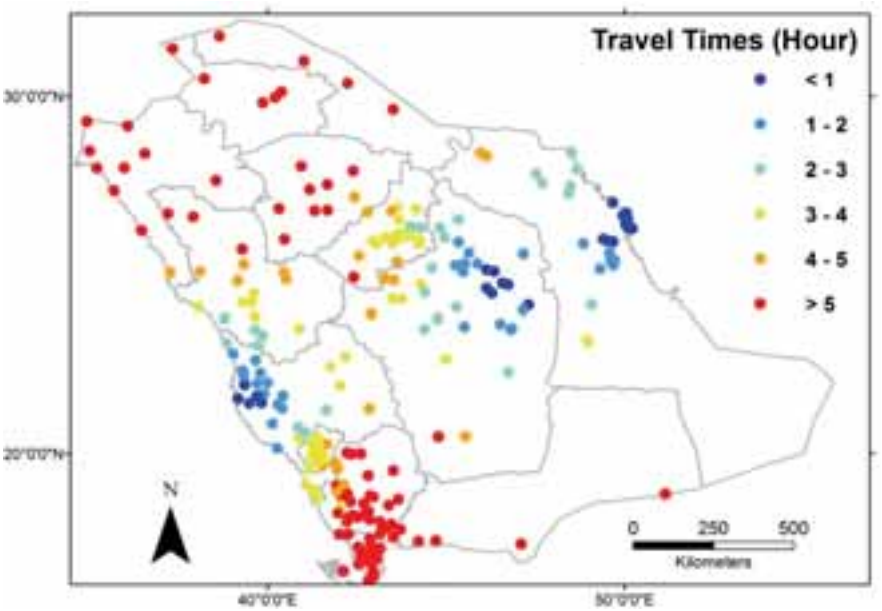

Figure 6: Travel times to specialized cancer centers from Saudi cities.

Table 1: Percentage of the Saudi population displayed in terms of travel time to the closest specialized cancer care facility

< 1 h	1–2 h	2–3 h	3–4 h	4–5 h	>5 h
45	12	3	12	5	23

Table 2: Median travel times to specialized cancer centers stratified by geographic sector

Geographic Sectors	Administrative Regions	Cities N = 240	% of Saudi Population	Median Travel Time (IQR) (min)
North	Tabuk, Jouf, Northern	19	7	497 (432 - 562)
South	Asir, Jazan, Najran, Baha	74	16	358 (267 - 409)
East	Eastern	32	16	82 (47 - 146)
West	Makkah, Madinah	48	29	169 (93 - 220)
Central	Riyadh, Qassim, Hail	67	31	186 (113 - 257)

Table 3: Median travel times to specialized cancer centers stratified by population

Population	Cities N = 240	% of Saudi Population	Median Travel Time (IQR) (min)
1,000 – 10,000	103	4	207 (121 - 308)
10,001 – 500,000	133	57	263 (150 - 380)
> 500,000+	4	39	82 (30 - 195)

Table 4: Median travel times to specialized cancer centers stratified by CCs

No. of Cancer Cases (CC)	Cities N = 240	% of Saudi Population	Median Travel Time (IQR) (min)
1 – 500	222	33	228 (138 - 365)
501 – 1,000	10	15	331 (62 - 424)
> 1,000	8	52	70 (25 - 169)

Table 5: Median travel times to specialized cancer centers stratified by CIR

CIR (Per 100,000)	Cities N = 240	% of Saudi Population	Median Travel Time (IQR) (min)
1 – 80	223	93	226 (131 - 364)
81 – 160	11	4	237 (201 - 394)
> 160	6	3	94 (58 - 250)

The analysis of the disparity in spatial access to specialized cancer centers across geographic sectors indicates that the median travel time was six times longer in the north sector compared with the east sector (497 min [IQR, 432–562 min] vs. 82 min [IQR, 47–146 min], respectively), nearly three times longer for the west sector (169 min [IQR, 93–220 min]), over 2.7 times longer for the central sector (186 min [IQR, 113–257 min]) and nearly 1.4 times longer for the south sector (358 min [IQR, 267–409 min]) (Table 2). The demographic characteristics were inversely correlated with travel time, as larger populations had shorter travel times to the nearest specialized cancer centers. The median travel time for low-population cities was approximately 2.5 times longer than that for high-population cities (207 min [IQR, 121–308 min] vs. 82 min [IQR, 30–195 min], respectively) and approximately three times longer than for medium-population cities (263 min [IQR, 150–380 min]) (Table 3). The analysis of spatial access to specialized cancer centers by the number of diagnosed CCs indicates that cities with a high number of CCs (> 1,000) have the shortest travel times (70 min [IQR, 25–169 min]), and cities with a medium number of CCs (501 – 1,000) have the longest travel times (331 min [IQR, 62–424 min]) (Table 4). Regarding the CIR, the median travel times to the nearest specialized cancer centers were 226 min (IQR, 131–364 min), 237 min (IQR, 201–394 min), and 94 min (IQR, 58–250 min) for cities with low (1 – 80), medium (81 – 160), and high (> 160) CIRs, respectively (Table 5).

The present study demonstrates that specialized cancer care settings are spatially reachable by a percentage of the Saudi population, since 45% lives within 1 h of a city that contains these facilities. In the U.S., nearly 70% of the population lives within 1 h of a National Cancer Institute (NCI), cancer care center and/or an academic-based cancer care center [4]. However, because of the vast size (approximately 2 million km^2, or approximately 80% of the Arabian Peninsula) and diverse geographical distribution of population in Saudi Arabia, the extent of spatial access to cancer care settings is not uniform. For this reason, the regionalization of cancer care service planning has become essential for expanding services to distant and rural areas. Inequalities in spatial access are observed in the north and south geographic sectors, cities with low- and medium-sized populations, cities with a medium number of CCs and cities with low and medium cancer CIRs. Variances in the median travel time to the nearest specialized cancer care center by geographic sector and population

primarily reveal the rural-urban distribution and spatial distribution of cities in these sectors. The northern and southern administrative regions are the most lacking in terms of travel time. For instance, the southern cities in the Jazan and Najran regions and the northern cities in the Tabuk, Northern, and Jouf regions have the longest median travel times (greater than 5 h). These findings are consistent with previous studies that identify larger distances and travel times to cancer care services in less urbanized, less developed, and rural areas [4,50]. Comparing median travel times with the number of diagnosed CCs, it is found that cities with a high number of CCs have the highest spatial access to specialized cancer care centers (70 min). This result can be attributed to the high proportion (52%) of the Saudi population that resides in these cities. Furthermore, the specialized cancer care centers in Saudi Arabia are located in the largest cities. Thus, the large number of diagnosed CCs may be due to the large population that is in close proximity to these facilities. Regarding cancer CIR, the shortest median travel times (94 min) are found in cities with the highest CIR (161 – 242 per 100,000). However, the IQR is 58 to 257 min, which indicates relatively high travel times.

4. Conclusions

Spatial access to specialized cancer centers appears to be sufficient for a proportion of the Saudi population. For the total Saudi population during the study period, the median travel time to the closest specialized cancer care facility was 212 min (IQR, 97–315 min). Travel times of 2 h or less to the closest specialized cancer care facility were estimated for 57% of the Saudi population. Residents in the northern and southern geographic sectors and people living in cities with low population sizes had the longest travel times to the closest facilities. These two geographic sectors should be the primary targets for the development of regional cancer services. Additional specialized centers must be established in the southern and northern regions to minimize the travel burden on cancer patients. Inequalities in spatial access to specialized cancer care facilities for cities with low populations (i.e. non-urban or rural settings) warrant additional investigation. Because these facilities vary in the level of their standard of care, travel time must be adjusted according to the type of cancer and the required cancer care. This study has primarily assessed spatial access to cancer care facilities in Saudi Arabia. However, healthcare access could also be constrained by non-spatial factors

such as socioeconomic status and demographic characteristics that should be modeled in combination with spatial factors [4]. One shortcoming of this spatial accessibility analysis is the lack of consideration of urban traffic volumes and congestion when estimating travel times. This study did not attempt to investigate the associations between spatial access and attendance, although it provides the basis for future studies that identify causality.

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