

The incidence of leukemia in Saudi Arabia

Descriptive epidemiological analysis of data from the Saudi Cancer Registry (2001-2008)

Ibrahim G. Alghamdi, MPhil, PhD, **Issam I. Hussain**, MPhil, PhD, **Mohamed S. Alghamdi**, MBBS, FFCM, **Ablam A. Dohal**, MSc, PhD, **Mohamed A. El-Sheemy**, FRSM, FRCS.

ABSTRACT

الأهداف: وصف البيانات الوبائية لحالات سرطان اللوكيميا التي تم تشخيصها في المجتمع السعودي من عام 2001م إلى 2008م والمتضمنة عدد الحالات ونسبتها، معدل الوقوع الخام وكذلك معدل الإصابة المضبوط بالعمر والمنطقة وتاريخ التشخيص ونوع اللوكيميا.

الطريقة: تم تطبيق التحليل الوبائي الوصفي الإستباقي لجميع حالات اللوكيميا المسجلة في سجل الأورام السعودي من تاريخ يناير 2001م إلى ديسمبر 2008م. أجريت هذه الدراسة في عام 2013م للتحقق من نمط سرطان اللوكيميا في المجتمع السعودي. تم استخدام التحليل الوصفي والإستدلالي للبيانات عن طريق اختبار التباين، إنحدار بواسون وكذلك الإنحدار الخطي البسيط.

النتائج: تم تسجيل 3852 حالة لسرطان اللوكيميا في المملكة العربية السعودية من تاريخ يناير 2001م حتى ديسمبر 2008م. تعتبر مدينة الرياض الأعلى متوسطا لمعدل الوقوع المضبوط بالعمر لدى الذكور من السعوديين بمقدار (5.2)، يليها المنطقة الشرقية والشمالية من المملكة بمقدار (4.9) لكل 100,000 ألف. علاوة على ذلك، تعتبر مدينة نجران الأعلى متوسطا لمعدل الوقوع المضبوط بالعمر لدى الإناث من السعوديات بمقدار (4.5) لكل 100,000 ألف، في حين تسجل مدينة جازان أدنى متوسط معدلات الوقوع المضبوط بالعمر لسرطان اللوكيميا بالمملكة العربية السعودية.

الخاتمة: تبين وجود زيادة طفيفة في معدلات الإصابة بسرطان اللوكيميا في المملكة العربية السعودية من تاريخ 2001م إلى 2008م. مدينة الرياض والمنطقة الشرقية والشمالية سجلت أعلى المعدلات لسرطان اللوكيميا لدى الذكور بينما مدينة نجران تسجل الأعلى لدى الإناث. وبالنظير الآخر تسجل مدينة جازان أقل المعدلات لسرطان اللوكيميا في المملكة العربية السعودية.

Objectives: To describe the epidemiological data of leukemia cases diagnosed from 2001 to 2008 among male and female Saudis, including the frequency and

percentage of cases, the crude incidence rate (CIR), and the age-standardized incidence rate (ASIR) stratified by leukemia subtype, region, and year of diagnosis.

Methods: This is a retrospective descriptive epidemiological analysis of all Saudi leukemia cases recorded in the Saudi Cancer Registry (SCR) between January 2001 and December 2008. The study was carried out in 2013 to investigate the pattern of leukemia in the Saudi population. Descriptive statistics and Poisson regression model were used.

Results: A total of 3852 leukemia cases were registered in the SCR between January 2001 and December 2008. The region of Riyadh, Saudi Arabia had the highest overall ASIR among Saudi males at 5.2 per 100,000 males, followed by both the Eastern region and Northern region at 4.9 per 100,000 males. Furthermore, the region of Najran recorded the highest overall ASIR among Saudi females at 4.5 per 100,000 females. However, Jazan had the lowest average ASIRs of leukemia in Saudi Arabia.

Conclusion: There was a slight increase in the CIRs and ASIRs of leukemia in Saudi Arabia between 2001 and 2008. Riyadh, the Eastern region, and the Northern region had the highest overall ASIRs of leukemia among Saudi males, and Najran had the highest overall ASIRs of leukemia among Saudi females; while Jazan had the lowest rates among the Saudi population.

Saudi Med J 2014; Vol. 35 (7): 674-683

From the School of Life Sciences (Alghamdi I, Hussain) University of Lincoln, Brayford Pool, Lincoln Hospital (El-Sheemy), Research and Development United Lincolnshire Hospitals NHS Trust, Lincoln, United Kingdom, and the Ministry of Health (Alghamdi M), General Directorate of Health Affairs, Al-Baha, and the King Fahad Specialist Hospital & Research Center (Dohal), Dammam, Kingdom of Saudi Arabia.

Received 3rd February 2014. Accepted 4th May 2014.

Address correspondence and reprint request to: Mr. Ibrahim G. Alghamdi, School of Life Sciences, University of Lincoln, Brayford Pool, Lincoln LN6 7TS, United Kingdom. Tel. +44 (1162) 761913. E-mail: bio-stat@botmail.com

Leukemia is considered a cancer of the blood and is the most common malignancy among children in the United States and Canada.^{1,2} The highest incidence rates were observed in developed and industrialized countries.^{1,3} In the United Kingdom, acute and chronic leukemias were estimated at 2.5% of all cancer types among the general population.⁴ According to a report from the Leukemia and Lymphoma Society in 2013,⁵ it is estimated that 48,610 new cases per year of leukemia will be diagnosed, and 23,720 people are expected to die from the disease. In addition, it is estimated that 33% more males are diagnosed with leukemia compared with females.⁵ In Saudi Arabia, the International Agency for Research on Cancer (IARC) estimated that the age-standardized incidence rate (ASIR) for leukemia was 3.0 per 100,000 population in 2008, and the age-standardized mortality rate (ASMR) was 2.6 per 100,000 population.⁶ Furthermore, the registry of King Faisal Specialist Hospital and Research Center (2011) recorded 6216 cases of leukemia admitted to the hospital during the years from 1975 to 2011.⁷ In 2008, the Saudi Cancer Registry (SCR) reported that leukemia ranked third in cancer incidence among the male population, and fifth among females.⁸ The ASIR of leukemia in Saudi Arabia is slightly low in comparison with other Arabian Gulf countries. For example, in 2008, the reported ASIR for Qatar (6.7), Bahrain (5.3), Kuwait (5.1), Oman (4.6), and the United Arab Emirates (3.7) were higher than Saudi Arabia (3.0).⁶ Despite insufficient data on the geographical distribution of leukemia in Saudi males and females, we intended to examine the crude incidence rate (CIR) and ASIR of leukemia cases by conducting an observational descriptive epidemiological study of the disease while considering the spatial/temporal distribution of recorded cases in the SCR from 2001 to 2008.⁹

Methods. We conducted a retrospective, descriptive, epidemiological study of all leukemia cases in the Saudi population diagnosed between January 2001 and December 2008. The data for this study are managed by the Saudi Cancer Registry (SCR), which is a population-based registry that was established in 1994 by the Ministry of Health in Saudi Arabia. However, no data were available from 1994 to 2000, and the most recent available dataset from the SCR was in 2008.

Disclosure. The authors declare no conflicting interests, support or funding from any drug company.

Since 2001, the SCR has been reporting on the pattern of cancer in Saudi Arabia with the main objective of defining the epidemiological distribution of the disease. Based on these data, there are currently comprehensive reports for 13 administrative regions from 2001 to 2008 that provide the frequency with percentage of cases, the CIR and the ASIR, stratified by the provinces of Saudi Arabia, gender of patients, and the years of diagnoses. The percentages of leukemia cases among genders were calculated in the SCR reports by dividing the number of cases by the total number of male and female cancer cases. This study was conducted using these reports to critically gather all of the information from the SCR with the aim of presenting the descriptive epidemiology of leukemia in Saudi Arabia.

For data analysis, we used the Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Corporation, Armonk, NY, USA). The descriptive analysis of the epidemiological data was performed by calculating the overall percentage, the CIR, and the ASIR stratified by the leukemia subtype, gender, region, and year of diagnosis. The percentage was calculated by adding the number of cases of leukemia and then dividing that number by the total number of cancer cases. Furthermore, the Poisson regression model was conducted to calculate the incidence rate ratio (IRR) of leukemia cases in each region of Saudi Arabia.

The overall age-standardized incidence rates are reported as per 100,000 males and females and were calculated for all of the SCR datasets based on the (Segi) Standard for World Population with an intermediate age. The Segi World Standard can be used in a direct method of standardization to calculate the ASIR of leukemia. It allows to control the confounding effects of age when making comparisons between different populations with respect to the age structure.^{10,11}

Results. Leukemia among male Saudis. A total of 2222 leukemia cases were documented in the SCR between January 2001 and December 2008. The frequency of leukemia cases increased slightly from 2001 to 2008. In Figure 1A and B, it is shown that there were 267 cases in 2001 (9.6%, 95% confidence interval [CI]: 7.0 to 12.2%). This figure decreased to 241 by 2004, representing a decline of 2.7%, this was the lowest percentage stated by the SCR (2004). From 2005 to 2008, the number of leukemia cases increased from 250 to 345, representing an increase of 1%. The CIRs of leukemia cases among males in Saudi Arabia, stratified by leukemia subtype and the year of diagnosis from 2001 to 2008 per 100,000 males indicates a slight

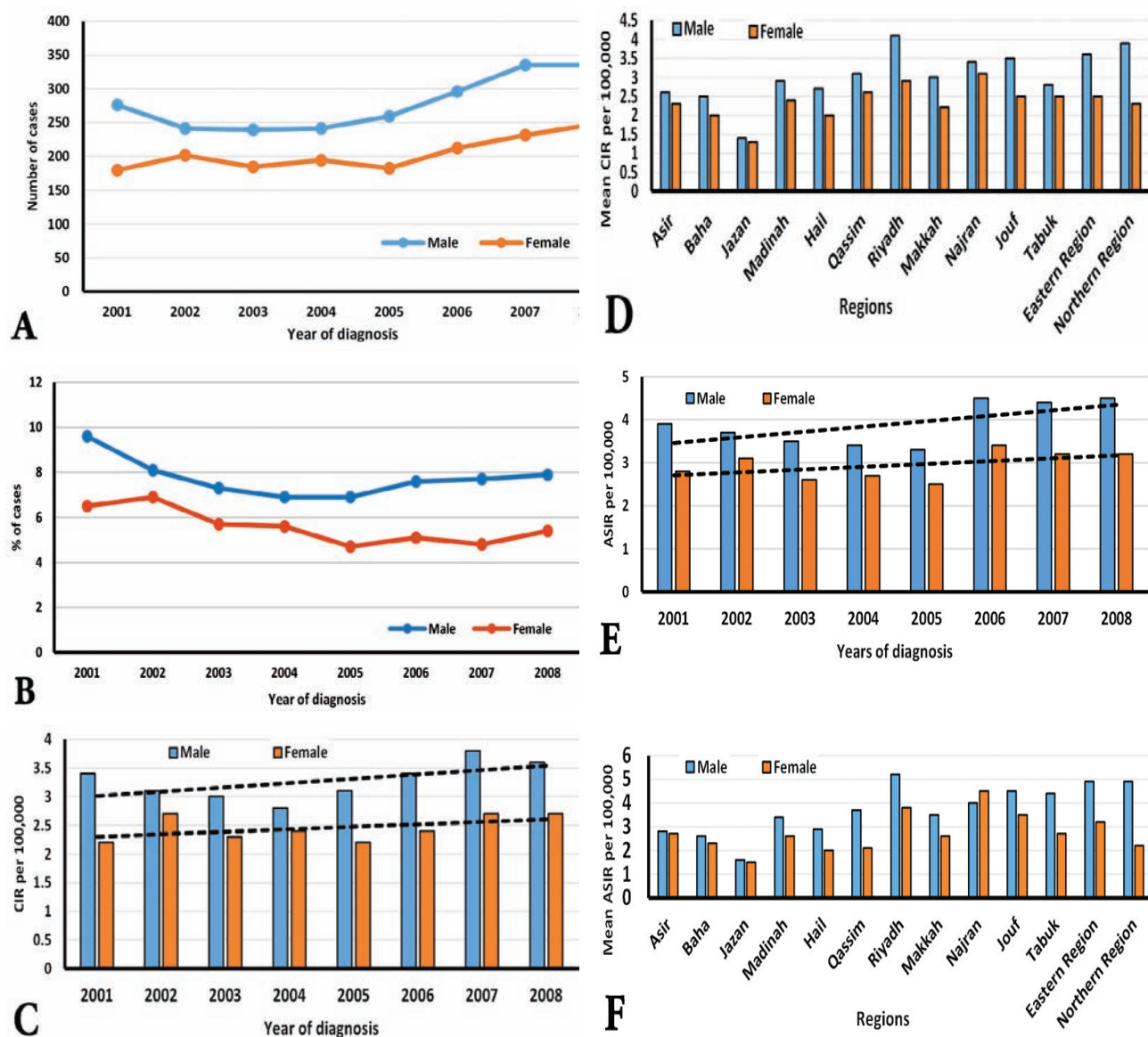


Figure 1 - Graphs showing: A & B) number and percentage of leukemia cases among Saudi males and females between 2001 and 2008; C) crude incidence rate (CIR) of leukemia cases among Saudi males and females between 2001 and 2008; D) overall CIR of leukemia cases among Saudi males and females stratified by regions of Saudi Arabia from 2001-2008; E) age-standardized incidence rate of leukemia cancer cases among Saudi males and females during the year 2001-2008; F) overall age-standardized incidence rate of leukemia cases among Saudi males and females stratified by region of Saudi Arabia from 2001-2008.

decrease from 2001 to 2004, then a steady increase from 2005 to 2008. According to Table 1 and Figure 1C, a CIR of 3.4 (95% CI: -0.6 to 7.4) per 100,000 males was estimated in 2001, and a CIR of 2.8 (95% CI: -0.2 to 5.8) per 100,000 males was estimated in 2004. In 2007, the CIR of 3.8 (95% CI: -0.2 to 7.8) per 100,000 males was the highest rate recorded by SCR. In addition, the overall CIR of leukemia stratified by the region of Saudi Arabia from 2001 to 2008 per

100,000 males was calculated from the SCR, as shown in Table 2 and Figure 1D. The region of Riyadh in Saudi Arabia had the highest overall CIR for leukemia at 4.1 (95% CI: -1.0 to 9.1) per 100,000 males, followed by the Northern region at 3.9 (95% CI: -1.3 to 9.1) and the Eastern region at 3.6 (95% CI: -1.1 to 8.3). The lowest average of CIR was documented in Jazan at 1.4 (95% CI: -0.6 to 3.4), Baha at 2.5 (95% CI: -0.6 to 5.6), and Asir at 2.6 (95% CI: -0.4 to 5.6). The ASIR

Table 1 - Confidence intervals for the crude incidence rate (CIR) and age standardized incidence rate (ASIR) per 100,000/year of leukemia cases among Saudi males and females stratified by years of diagnosis and leukemia subtypes from 2001-2008.

Year	Lymphoid	Myeloid	Unspecified	Total	95% confidence interval	Lymphoid	Myeloid	Unspecified	Total	95% confidence interval
2001										
CIR	1.8	1.5	0.1	3.4	-0.34-2.1	1.0	1.2	0.0	2.2	1.3-3.1
ASIR	1.9	1.8	0.2	3.9	2.8-5.0	1.1	1.6	0.1	2.8	2.1-3.5
2002										
CIR	1.7	1.3	0.1	3.1	-0.78-1.6	1.3	1.2	0.1	2.6	2.0-3.4
ASIR	1.9	1.7	0.1	3.7	2.8-4.6	1.2	1.8	0.1	3.1	2.3-3.9
2003										
CIR	1.9	1.1	0.0	3.0	-1.1-1.3	1.0	1.2	0.1	2.3	1.8-2.8
ASIR	2.0	1.4	0.1	3.5	2.7- 4.3	1.1	1.5	0.0	2.6	2.0-3.2
2004										
CIR	1.5	1.2	0.1	2.8	-1.2-1.4	1.0	1.3	0.1	2.4	1.9-2.9
ASIR	1.7	1.6	0.1	3.4	2.5-4.3	1.0	1.6	0.1	2.7	1.7-3.7
2005										
CIR	1.8	1.1	0.2	3.1	-5.5-1.8	0.9	1.1	0.2	2.2	1.8
ASIR	1.7	1.4	0.2	3.3	2.5-4.1	0.9	1.4	0.2	2.5	1.9-3.1
2006										
CIR	1.8	1.3	0.3	3.4	-0.7-1.6	1.0	1.3	0.1	2.4	1.4-3.4
ASIR	2.3	1.8	0.4	4.5	3.2-5.8	1.2	2.0	0.2	3.4	2.3-4.5
2007										
CIR	2.2	1.3	0.3	3.8	-1.2-1.2	1.3	1.2	0.2	2.7	1.5-3.9
ASIR	2.4	1.6	0.4	4.4	3.0-5.9	1.4	1.5	0.3	3.2	2.0-4.4
2008										
CIR	1.7	1.5	0.4	3.6	-1.6-0.8	1.2	1.2	0.3	2.7	2.1-3.3
ASIR	2.2	1.9	0.4	4.5	3.3-5.7	1.4	1.4	0.4	3.2	2.3-4.1

of leukemia stratified by leukemia subtypes and the year of diagnosis in Saudi Arabia, from 2001 to 2008 per 100,000 males, was calculated from the SCR (Table 1 and Figure 1E). Similarly, there was a slight decrease from 2,001 to 2004, then a stable increase from 2005 to 2008. The highest ASIRs of leukemia were recorded in 2006 and 2008 at 4.5 (95% CI: -0.6 to 9.6). However, the ASIR of lymphoid leukemia was the highest among male Saudis during the year 2001 to 2008. Table 2 and Figure 1F show that the region of Riyadh had the highest overall ASIR for leukemia at 5.2 (95% CI: -0.8 to 11.2) per 100,000 males, followed by the Northern region at 4.9 (95% CI: -1.2 to 8.4) and the Eastern region at 4.9 (95% CI: -1.1 to 10.9). Alternatively, the region of Jazan at 1.6 (95% CI: -0.4 to 3.6), Baha at 2.6 (95% CI: -0.4 to 5.6), and Asir at 2.8 (95% CI: -1.1 to 6.7), had the lowest average ASIRs for leukemia among male Saudis. Poisson regression model was conducted to calculate and compare the incidence rate ratio (IRR) of leukemia cases among males in different regions of Saudi Arabia. The model was statistically significant, LR $X^2(13) = 1618, p < 0.001$. According to Table 3, Jazan was the reference region for making comparisons with other

provinces of Saudi Arabia, the IRRs were significantly higher $p < 0.001$, for the region of Riyadh at 10.2 times (95% CI: 7.4 to 13.9), followed by Makkah at 7.2 times (95% CI: 5.2 to 9.9), and the Eastern region at 6.0 times (95% CI: 4.4 to 8.3). Finally, the differences in the CIR and ASIR between the year 2001 and the year 2008 were calculated from the reports published by SCR, to investigate the pattern of leukemia among male Saudis in different regions (Table 4). The greatest changes in the ASIRs were observed only in the region of Tabuk at 4.5 and Madinah at 4.3.

Leukemia among female Saudis. A total of 1630 leukemia cases were documented in the SCR between January 2001 and December 2008. The frequency of cases with leukemia increased slightly from 2001 to 2008. In Figure 1A and B, it is shown that the highest percentage was recorded in 2002, with 201 cases (6.9%, 95% CI: 5.7-8.1%). This percentage decreased to 4.7% by 2005, and was the lowest percentage stated by the SCR (2005). From 2006 to 2008, the number of leukemia cases increased from 195 to 250, representing an increase of 0.2%. The CIRs of leukemia cases among females in Saudi Arabia, stratified by leukemia subtype

Table 2 - Confidence intervals for the crude incidence rate (CIR) and age standardized incidence rate (ASIR) per 100,000/year of leukemia cases among Saudi males and females stratified by regions and leukemia subtypes from 2001-2008.

Regions	Lymphoid	Myeloid	Unspecified	Total	95% confidence interval					
						Male			Female	
<i>Asir</i>										
CIR	1.7	0.8	0.1	2.6	1.8-3.4	1.0	1.0	0.3	2.3	1.1-3.4
ASIR	1.7	1.0	0.1	2.8	2.0-3.6	1.0	1.4	0.3	2.7	2.1-3.3
<i>Baha</i>										
CIR	1.5	0.6	0.4	2.5	1.3-3.6	0.9	1.0	0.1	2.0	1.1-2.9
ASIR	1.5	1.0	0.1	2.6	1.8-3.5	0.9	1.2	0.1	2.2	1.6-2.9
<i>Jazan</i>										
CIR	0.8	0.6	0.0	1.4	1.0-1.8	0.5	0.7	0.1	1.3	0.9-1.7
ASIR	0.9	0.7	0.0	1.6	1.1-2.1	0.5	0.8	0.2	1.5	0.9-2.1
<i>Madinah</i>										
CIR	1.4	0.9	0.6	2.9	1.9-3.9	1.1	1.4	0.2	2.4	1.9-3.0
ASIR	1.6	1.1	0.7	3.4	2.1-4.7	0.9	1.6	0.3	2.6	1.5-3.7
<i>Hail</i>										
CIR	1.6	1.0	0.1	2.7	1.6-3.7	0.9	0.9	0.2	2.0	1.2-2.8
ASIR	1.6	1.2	0.1	2.9	1.8-4.0	0.7	1.1	0.2	2.0	1.2-2.8
<i>Qassim</i>										
CIR	1.6	1.5	0.0	3.1	2.3-3.9	1.0	1.4	0.2	2.6	2.0-3.2
ASIR	1.9	1.8	0.0	3.7	2.6-4.7	1.1	1.8	0.2	3.1	2.2-4.0
<i>Riyadh</i>										
CIR	2.2	1.7	0.2	4.1	3.6-4.6	1.3	1.5	0.1	2.9	2.3-3.5
ASIR	2.5	2.4	0.3	5.2	4.5-5.9	1.5	2.2	0.1	3.8	3.2-4.3
<i>Makkah</i>										
CIR	1.7	1.1	0.2	3.0	2.6-3.5	1.1	1.0	0.1	2.2	1.6-2.8
ASIR	1.9	1.4	0.2	3.5	3.0-4.0	1.1	1.4	0.1	2.6	2.0-3.2
<i>Najran</i>										
CIR	1.7	1.5	0.2	3.4	2.1-4.6	1.0	1.8	0.3	3.1	2.0-4.2
ASIR	1.6	2.2	0.2	4.0	3.0-5.0	1.4	2.5	0.6	4.5	3.6-5.4
<i>Jouf</i>										
CIR	1.8	1.5	0.2	3.5	2.0-5.0	1.3	1.1	0.1	2.5	1.4-3.6
ASIR	2.0	1.9	0.6	4.5	2.3-6.6	1.7	1.7	0.1	3.5	1.7-5.3
<i>Tabuk</i>										
CIR	1.4	1.1	0.2	2.8	1.7-3.6	1.3	1.0	0.2	2.5	1.9-3.1
ASIR	2.1	1.5	0.8	4.4	2.7-6.6	1.1	1.4	0.2	2.7	1.4-4.0
<i>Eastern Region</i>										
CIR	1.9	1.5	0.2	3.6	4.0-5.9	1.3	1.1	0.1	2.5	2.0-3.0
ASIR	2.4	2.2	0.3	4.9	4.0-5.9	1.6	1.4	0.2	3.2	2.6-3.8
<i>Northern Region</i>										
CIR	2.2	1.5	0.2	3.9	2.1-5.7	0.6	1.6	0.1	2.3	1.1-3.5
ASIR	2.8	1.7	0.4	4.9	2.9-6.8	0.9	1.9	0.5	2.3	1.1-3.5

and the year of diagnosis from 2001 to 2008 per 100,000 females indicates a steady increase from 2001 to 2008. According to Table 1 and Figure 1C, a CIR of 2.2 (95% CI: -0.8 to 5.2) per 100,000 females was estimated in 2001, and a CIR of 2.4 (95% CI: -0.4 to 5.2) per 100,000 females was estimated in 2004. In 2007 and 2008, the CIR of 2.7 (95% CI: -0.4 to 5.8) per 100,000 females had the highest rate compared

with the other years of diagnosis. However, the CIR of myeloid leukemia was the highest among female Saudis during the years 2001 to 2008. In addition, the overall CIR of leukemia stratified by the region of Saudi Arabia from 2001 to 2008 per 100,000 females was calculated from the SCR, as shown in Table 2 and Figure 1D. Najran had the highest overall CIR for leukemia at 3.1 (95% CI: -1.0 to 7.2) per 100,000 females, followed by

Table 3 - Poisson regression model to calculate the incidence rate ratio (IRR) of leukemia cancer cases among Saudi males and females in the different regions of Saudi Arabia.

Regions	IRR	Male		IRR	Female	
		P-value	95% CI		P-value	95% CI
Asir	2.5	0.001*	1.7-3.7	2.48	0.001*	1.6-3.6
Baha	0.5	0.003*	0.3-0.8	0.5	0.002	0.3-0.7
Jazan	Reference	-	-	-	-	-
Madinah	2.4	0.001*	1.7-3.4	2.1	0.001*	1.4-2.9
Hail	0.8	0.25	0.5-1.2	0.6	0.10	0.4-1.1
Qassim	1.7	0.002*	1.2-2.4	1.5	0.06	1.0-2.1
Riyadh	10.2	0.001*	7.4-13.9	7.6	0.001*	5.3-10.6
Makkah	7.2	0.001*	5.2-9.9	5.7	0.001*	4.0-7.9
Najran	0.8	0.29	0.5-1.2	0.7	0.27	0.5-1.2
Jouf	0.7	0.19	0.5-1.2	0.5	0.01*	0.3-0.9
Tabuk	1.2	0.45	0.8-1.8	1.0	0.93	0.6-1.6
Eastern Region	6.0	0.001*	4.4-8.3	4.8	0.001*	3.5-6.6
Northern Region	0.7	0.06	0.4-1.0	0.5	0.001*	0.3-0.8

Table 4 - The differences in the crude incidence rate and age standardized incidence rate of leukemia cancer cases among Saudi males and females in the different regions of Saudi Arabia from 2001 and 2008.

Regions	Male						Female					
	CIR per 100,000			ASIR per 100,000			CIR per 100,000			ASIR per 100,000		
	2008	2001	Difference	2008	2001	Difference	2008	2001	Difference	2008	2001	Difference
Asir	3.7	1.7	2.0	2.5	1.9	0.6	3.7	0.7	3.0	3.9	0.9	3.0
Baha	1.2	1.0	0.2	1.6	1.5	0.1	3.9	0.0	3.9	4.9	0.0	4.9
Jazan	1.6	1.8	-0.2	1.7	2.0	-0.3	2.0	0.8	1.2	2.1	0.9	1.2
Madinah	5.2	2.0	3.2	6.4	2.1	4.3	3.1	2.8	0.3	3.3	3.1	0.2
Hail	3.4	4.0	-0.6	3.5	3.7	0.2	4.4	1.2	3.2	5.0	1.9	3.1
Qassim	2.4	3.1	-0.7	2.6	3.7	-1.1	2.5	1.7	0.8	3.6	2.0	1.6
Riyadh	3.9	5.1	-1.2	4.6	6.8	-2.2	1.9	3.7	-1.8	2.2	5.1	-2.9
Makkah	3.5	3.3	0.2	4.5	3.8	0.7	3.0	1.9	1.1	3.6	2.3	1.3
Najran	3.5	6.0	-2.5	3.6	6.2	-2.6	3.0	3.0	0.0	4.0	4.6	-0.6
Jouf	5.9	4.7	1.2	7.3	4.9	2.4	1.2	0.7	0.5	1.1	0.4	0.7
Tabuk	3.9	1.6	2.3	6.4	1.9	4.5	4.1	1.1	3.0	4.2	1.6	2.6
Eastern Region	4.0	3.5	0.5	6.0	4.9	1.1	2.5	2.6	-0.1	3.2	3.6	-0.4
Northern Region	4.6	4.0	0.6	7.2	4.9	2.3	3.9	1.7	2.2	4.6	2.4	2.2

Riyadh at 2.9 (95% CI: -1.2 to 7.0), and Qassim at 2.6 (95% CI: -0.4 to 5.6). However, the lowest overall CIR of leukemia among females was recorded in Jazan at 1.3 (95% CI: -0.7 to 2.3), Baha at 2.0 (95% CI: -1.0 to 3.0), and Hail at 2.0 (95% CI: -1.1 to 5.1). The ASIR of leukemia stratified by leukemia subtype and the year of diagnosis in Saudi Arabia, from 2001 to 2008 per 100,000 females, was calculated from the SCR (Table 1 and Figure 1E). Similarly, there was a steady increase from 2001 to 2008. The highest ASIRs of leukemia were recorded in 2006 at 3.4 (95% CI: -1.2 to 8.0), compared with other years of diagnosis. However, the

ASIR of myeloid leukemia was the highest among female Saudis during the year 2001 to 2008. According to Table 2 and Figure 1F, the region of Najran had the highest overall ASIR of leukemia among Saudi females at 4.5 (95% CI: -0.9 to 9.9) per 100,000 females, followed by Riyadh at 3.8 (95% CI: -0.7 to 8.1) and Jouf at 3.5 (95% CI: -0.6 to 7.1). Alternatively, the lowest overall ASIRs of leukemia among females were recorded in Jazan at 1.5 (95% CI: -0.5 to 3.5), Hail at 2.0 (95% CI: -1.3 to 5.3), and Baha at 2.2 (95% CI: -0.6 to 5.0). Poisson regression model was conducted to calculate and compare the incidence rate ratio (IRR)

Table 5 - The age standardized incidence rate and age standardized mortality rate of leukemia cases in different countries of world. It was estimated by the International Agency for Research on Cancer (IARC) 2012.

Country	Age standardized incidence rate per 100,000		Age standardized mortality rate per 100,000	
	Male	Female	Male	Female
Ireland	12.7	6.5	4.5	2.6
Australia	11.7	7.2	4.5	2.7
United State of America	10.3	7.1	5.4	3.3
United Kingdom	9.3	5.8	4.1	2.4
Jordan	7.8	4.3	6.5	3.6
Kuwait	6.8	6.2	3.0	4.2
Egypt	6.3	5.4	5.5	4.6
Qatar	5.3	3.8	3.7	2.8
Bahrain	5.1	4.6	2.6	1.5
Oman	5.1	4.7	4.3	4.2
China	5.0	3.7	4.2	3.0
Saudi Arabia	4.2	3.5	3.1	2.5
United Arab Emirates	3.7	4.5	2.2	2.8

of leukemia cases among females in different regions of Saudi Arabia. The model was statistically significant, LR $X^2(13) = 980, p < 0.001$. According to Table 3, Jazan was the reference region for making comparison with other provinces of Saudi Arabia, the IRRs were significantly higher $p < 0.001$, for the regions of Riyadh at 7.6 times (95% CI: 5.3 to 10.6), followed by Makkah at 5.7 times (95% CI: 4.0 to 7.9), and the Eastern region at 4.8 times (95% CI: 3.5 to 6.6). Finally, the differences in the CIR and ASIR between the year 2001 and the year 2008 were calculated from the reports published by SCR, to investigate the pattern of leukemia incidences among female Saudis in different regions (Table 4). The greatest changes in the ASIRs were observed only in the region of Baha among females at 4.9 per 100,000.

In this study, we compared the subtypes of leukemia among males and females in different regions of Saudi Arabia. It can be summarized as follows:

A) Male lymphoid and myeloid leukemia. It can be shown in Figure 2A that the overall ASIR of male lymphoid leukemia was higher than male myeloid leukemia in all regions of Saudi Arabia except for Najran. In addition, there was a high correlation between the ASIR of male lymphoid and myeloid leukemia, $R=0.7, p < 0.01$. This finding needs more investigation to explore the reason behind that. We strongly suggest examining the genetics of male lymphoid and myeloid leukemia in the region of Najran.

B) Female lymphoid and myeloid leukemia. It can

be shown in Figure 2B that the overall ASIR of female myeloid leukemia was higher than female lymphoid leukemia in all regions of Saudi Arabia except for the Eastern region. Furthermore, there was a moderate correlation between female myeloid and lymphoid leukemia, $R=0.6, p < 0.01$. This finding also needs more investigation about the genetics of female lymphoid and myeloid leukemia in the Eastern region.

C) Male lymphoid and female lymphoid. It can be shown in Figure 2C that the overall ASIR of male lymphoid leukemia was higher than female lymphoid leukemia in all regions of Saudi Arabia. Furthermore, there was a moderate correlation between male and female lymphoid leukemia, $R=0.5, p < 0.05$.

D) Male myeloid and female myeloid. It can be shown in Figure 2D that the overall ASIR of male myeloid leukemia was very similar to female myeloid leukemia in all regions of Saudi Arabia except for the Eastern region. Furthermore, there was very high correlation between male and female myeloid leukemia, $R=0.8, p < 0.01$. This finding also confirms that the Eastern region had a different trend from other regions of Saudi Arabia.

E) Male lymphoid and female myeloid. It can be shown in Figure 2E that the overall ASIR of male lymphoid leukemia was higher than female myeloid leukemia in all regions of Saudi Arabia except Najran. In addition, there was moderate correlation between male lymphoid and female myeloid leukemia, $R=0.5, p < 0.05$. This finding supports the result presented in Figure 2A, that male lymphoid leukemia has an abnormal trend in the region of Najran. Therefore, the genetics of male and female patients with lymphoid and myeloid leukemia should be investigated.

F) Male myeloid and female lymphoid. It can be shown in Figure 2F that the overall ASIR of male myeloid leukemia was higher than female lymphoid leukemia in all regions of Saudi Arabia. In addition, there was a very high correlation between male myeloid and female lymphoid leukemia, $R=0.85, p < 0.01$.

Discussion. The CIRs and ASIRs of leukemia cases among Saudi males and females are very imperative to be studied and updated for all regions in Saudi Arabia. In this study, we concentrated our efforts on the CIR and ASIR of leukemia in Saudi Arabia during the years from 2001 to 2008. Notably, our study is considered the first descriptive epidemiology study on the geographical distribution of leukemia among males and females in different regions of Saudi Arabia, based on the PubMed

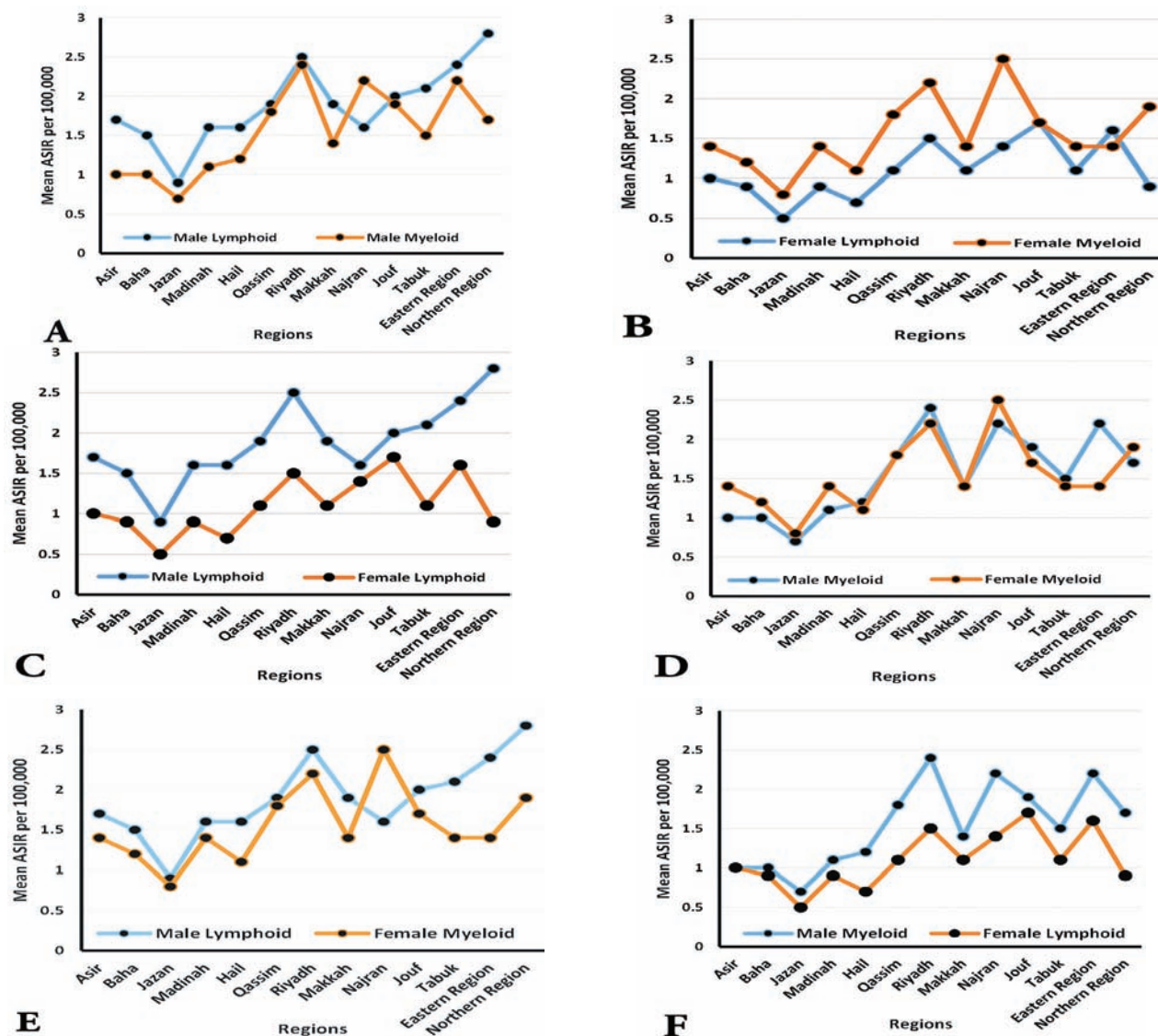


Figure 2 - Graphs showing a comparison of: A) the overall age-standardized incidence rate of lymphoid and myeloid leukemia in Saudi males in different regions of Saudi Arabia during the year 2001-2008; B) overall age-standardized incidence rate of lymphoid and myeloid leukemia in Saudi females; C) overall age-standardized incidence rate of lymphoid leukemia in Saudi males and females; D) overall age-standardized incidence rate of myeloid leukemia in Saudi males and females; E) overall age-standardized incidence rate of lymphoid leukemia in Saudi males and myeloid leukemia in Saudi females; and F) overall age-standardized incidence rate of myeloid leukemia in Saudi males and lymphoid leukemia in Saudi females.

database. It describes the real situation of the trend and explores the significance of the disease in Saudi Arabia. Our findings indicate that Riyadh, the Eastern region and Northern region were the highest overall ASIRs for leukemia among males in Saudi Arabia. Alternatively, the region of Jazan, Baha, and Asir had the lowest overall ASIRs of leukemia among male Saudis from 2001 to 2008. In addition, the IRRs of leukemia cases among male Saudis were significantly higher in the region of Riyadh followed by Makkah and the Eastern region

compared with the reference region of Jazan. According to the overall ASIR of leukemia cases among females, the region of Najran, Riyadh, and Qassim recorded the highest rates, while, Jazan, Hail, and Baha recorded the lowest. Similarly, the IRRs of leukemia cases among female Saudis were significantly higher in the region of Riyadh, Makkah, and the Eastern region compared with Jazan.

The regions of Jazan, Baha, and Asir recorded the lowest ASIR of leukemia compared with Riyadh, the

Eastern region and the Northern region. The reasons for the difference between these regions might be environmental life factors, lifestyle habits, and genetic risk factors.¹² Jazan, Baha, and Asir might be sharing some related risk factors for leukemia. This low incidence should be investigated further. In addition, the highest affected areas with leukemia should be investigated like other regions that have lower incidence rates. However, the researchers in the field of hematology may also observe the similarities of the risk factors in Riyadh, the Eastern region, Northern region, Najran, and Jouf, which contribute to the increase in the incidence of leukemia in Saudi Arabia.

In this study, we analyzed the changes in the CIR and ASIR of leukemia among males and females in different regions of Saudi Arabia from 2001 to 2008. Tabuk and Madinah had the highest differences in the ASIR of leukemia among males between the years 2001 and the year 2008, while, Baha had the greatest changes among leukemia in the female population. However, the likely explanation for the differences in ASIR suggests that the population in Tabuk, Madinah, and Baha are affected more by leukemia over an 8-year period (2001-2008).

In 2012, the latest ASIRs of leukemia cases were reported in Saudi Arabia among males at 4.2 per 100,000 and considered slightly low in comparison with Arabian Gulf countries and other world countries (Table 5). The country of Ireland had the highest ASIR of leukemia among males at 12.7 per 100,000 males, this figure was 3-folds higher than Saudi Arabia. In addition, Saudi Arabia recorded the lowest ASIR of leukemia among females at 3.5 per 100,000, compared with the assessment group, while, Australia and the United States of America had the highest ASIR of leukemia among females at 7.2 and 7.1 per 100,000.¹³ In 2012, the most recent ASMRs of leukemia cases were also registered in Saudi Arabia among males at 3.1 per 100,000. This rate was relatively low when compared to Arabian Gulf countries and other world countries (Table 5). The country of Jordan had the highest ASMR of leukemia among males at 6.5 per 100,000, followed by Egypt at 5.5, and the United States of America at 5.4. In addition, the Kingdom of Saudi Arabia documented the third lowest ASMR of leukemia among females at 2.5 per 100,000, while, Egypt, Kuwait, and Oman had the highest ASMR of leukemia among females at 4.6, 4.2, and 4.2 per 100,000. However, the pattern and trend of leukemia among Saudi males and females should be monitored and not neglected because of the low ASIRs and ASMRs.¹³

The important factors and limitations for this study include the impact of socio-economic status, improvement in technology, and awareness among Saudi males and females on the burden of cancer and its incidence rate. The more technologically developed and affluent areas exhibited a higher incidence of cancer. This suggests that people in higher socio-economic areas receive treatment more often, resulting in a larger number of cases being diagnosed and reported, than that in areas with lower socio-economic status where the numbers may be underestimated due to the undetected cases. However, we suspect that the false impact of socio-economic status on the incidence rate of cancer, can only be observed in different regions during a short studied period (months), and that with longer surveyed time (years), all cases should eventually be detected; resulting in a more accurate reported incidence rate. The period of time from case diagnosis may be considered a potential bias for studying the real effect of socioeconomic status on cancer. However, it is challenging to study the relationship between the above factors and incidence rate of cancer because the SCR does not collect data on these factors for different regions in Saudi Arabia. Despite unavailable data related to the geographic distribution of leukemia among males and females in Saudi Arabia, except for the SCR reports, we intended to determine the real patterns and trends of leukemia in different regions during the years from 2001 to 2008. Therefore, the findings of our study are very significant to the researchers and decision makers in Saudi Arabia.

In conclusion, this study revealed that the CIR and ASIR of leukemia among the Saudi population are increasing slightly. Riyadh, the Eastern region, and the Northern region had the highest overall CIRs and ASIRs among males in Saudi Arabia, while Jazan, Baha, and Asir recorded the lowest rates. In regards to the female Saudi population, the region of Najran, Riyadh, and Jouf recorded the highest overall ASIR of leukemia during the years from 2001 to 2008. Further analytical studies are needed to identify the potential risk factors for leukemia among the Saudi population.

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