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Abstract
Glucose-6-phosphate dehydrogenase G6PD is a cytoplasmic enzymes that are found in all cells of the human body (Cappellini and Fiorelli, 2008) [8]. NADPH is essential to produce reduced glutathione which is a critical step in protecting the cells from oxidative damage (Figure 1) (Effert et al., 2006, Cunningham et al., 2016) [12, 11]. It plays an essential and vital role in preventing the cellular damage as it catalyzes the rate-limiting reaction and the first step of the pentose phosphate pathway PPP in which NADPH is produced as a result of oxidization of glucose-6-phosphate into 6-phosphogluconolactone i.e. preventing cellular damage from reactive oxygen radicles ROS (Antwi-Baffour et al., 2019, Richardson and O'Malley, 2017, Arese et al., 2012, Al-Ani et al., 2020) [6, 19, 7, 3]. The red blood cells (RBCs) are vulnerable to the formation of reactive oxygen species which is also known as free radicle (Antwi-Baffour et al., 2019, Richardson and O'Malley, 2017) [6, 19].

Fig 1: Role of Glucose-6-phosphate dehydrogenase G6PD in the pentose phosphate pathway PPP (Al-Ani et al., 2020) [3]
Pharmacists are one of the consistently reported source of medication related information in many population (Alani et al., 2020, Hassali et al., 2011) [3,17]. Besides, pharmacists can play an essential role in providing G6PD deficient patients with the useful information about medications that needs to be avoided in such conditions i.e. G6PD (Thompson, 2020) [20]. Pharmacist should be able to identify drugs with definite risk of hemolysis i.e. contraindicated, and drugs with possible risk of hemolysis i.e. used with caution (Table 1). Therefore, we conducted this study to assess the pharmacist knowledge about medications use in G6PD deficient patients.

**Table 1: Drug usage pattern in G6PD deficient patients, adapted from British national formulary BNF (Committee, 2019).**

| Drug                | Definite Risk (Contraindicated) | Possible Risk (Used with caution) |
|---------------------|---------------------------------|-----------------------------------|
| Co-trimoxazole      | √                               | √                                 |
| Ascorbic acid       |                                 | √                                 |
| Aspirin             |                                 | √                                 |
| Chloroquine         |                                 | √                                 |
| Ciprofloxacin       |                                 | √                                 |
| Nitrofurantoin      |                                 | √                                 |
| Dapsone             |                                 | √                                 |
| Probencid           |                                 | √                                 |

**Ethical consideration**
This study was approved from the research committee at The National University. Also, verbal consent were taken from participants prior to the enrollment in the study.

**Methodology**

**Study Design and Population**
This was a cross-sectional descriptive study which was carried out in 2016 in Khartoum, Sudan. A self-administered questionnaire was distributed to 50 community pharmacists in Khartoum, Sudan. Only pharmacist were included in this study. Pharmacist assistants and trainee were excluded from the study. The outcomes of this study were to evaluate the knowledge of community pharmacists about G6PD deficiency and the drugs usage pattern in glucose-6-phosphate-dehydrogenase deficient patients. Convenience sampling method which is defined as following: the researcher have recruited any participants that are easy to get and only participants who are available and have given consent have been recruited as a respondent. Participants have fulfilled the inclusion criteria before being engaged in the study (Gravetter and Forzano, 2018) [15].

**Data collection tool**
Data were collected using a validated semi-structured questionnaire. The questionnaire consisted of 3 main sections: section A concerned with demographic data of participants, section B concerned with knowledge about G6PD and its risk factors. Section C involved questions to assess pharmacist’s knowledge about drug usage pattern in G6PD deficient patients.

**Statistical analysis**
Data were analyzed via the Statistical Package for Social Sciences SPSS, version 23 (Corp, 2016) [10]. Descriptive statistics were used to describe the data; were applicable, continuous data presented as mean ± standard deviation (SD), and categorical data expressed as numbers with percentages.

**Results**

**Participants' demographic data**
Almost half of the participants 48% aged 25-34 years old at the time of data collection. Majority were females 74%. Out of the 50 respondent, forty-four percent of them were senior pharmacists while the rest of them were pharmacists and beginner pharmacists 32%, and 24% respectively (Table 2).

**Table 2: Participants' demographic characteristics**

| Variables                      | Number of respondents, (n) | Percentage of respondents (%) |
|--------------------------------|----------------------------|-------------------------------|
| Age Range (years old)          |                            |                               |
| Less than 24                   | 20                         | 40                            |
| 25-34                          | 24                         | 48                            |
| 35-44                          | 3                          | 6                             |
| 45-54                          | 3                          | 6                             |
| Gender                         |                            |                               |
| Male                           | 13                         | 26                            |
| Female                         | 37                         | 74                            |
| Ministry of health title       |                            |                               |
| Beginner pharmacist            | 12                         | 24                            |
| Pharmacist                     | 16                         | 32                            |
| Senior pharmacist              | 22                         | 44                            |

**Pharmacist’s knowledge about G6PD deficiency as a disease**
When the participants asked about the definition of glucose-6-phosphate-dehydrogenase deficiency, most of them 82% were able to answer it correctly. However, when it comes to the risk factors associated with hemolysis in G6PD deficient patients, less than half 48% were able to correctly identify risk factors (Table 3).

**Table 3: Pharmacists' knowledge about G6PD deficiency**

| Variables                      | Number of respondents, (n) | Percentage of respondents (%) |
|--------------------------------|----------------------------|-------------------------------|
| G6PD deficiency                |                            |                               |
| True                           | 41                         | 82                            |
| False                          | 9                          | 18                            |
| Risk factors for hemolysis     |                            |                               |
| True                           | 24                         | 48                            |
| False                          | 26                         | 52                            |

Pharmacists’ knowledge about medication usage pattern in G6PD deficient patients
Table 4 shows that the majority of current study participants identified that the use of co-trimoxazole, chloroquine, ciprofloxacin, nitrofurantoin, and dapsone 70%, 66%, 68%, 56%, and 78% respectively are contraindicated in glucose-6-phosphate-dehydrogenase deficient patients. On the other hand, most of them stated that ascorbic acid, aspirin, and probenecid 80%, 66%, and 74% respectively as medications that can be used with caution in G6PD deficient patients.
Discussion
There are few studies that assessed the pharmacists’ knowledge about G6PD deficiency. Most of the studies were conducted to evaluate the prevalence, public awareness, and awareness of pregnant women about G6PD deficiency (Al Arrayed and Al Hajeri, 2011, Almuhaini et al., 2018, Almuhaini et al., 2017, Hasan, 2018, Kaseny et al., 2020) [12, 4, 5, 16, 18].

Most of the current study participants aged 25-34 years, this explains why 44% were senior pharmacist i.e. had 5 or more years of practical experience as a pharmacists. Moreover most of the respondents were females 77% this is in accordance with a study conducted by Elhag and colleagues among community pharmacists in Khartoum which also showed that the majority of community pharmacist in Khartoum were females (Elhag and Sulaiman, 2020) [14].

When it comes to the pharmacists’ knowledge about G6PD deficiency as a disease, Most of the pharmacists were able to define G6PD deficiency correctly. However, majority were not able to identify risk factors for hemolysis correctly. With regards to the pharmacists’ knowledge about drug usage pattern in G6PD deficient patients, they showed an overall good knowledge as they were able to correctly identify the contraindicated and used with caution medication. This counteract with a study done by Ahmed Elgamal and colleagues in Khartoum (2013) [13] that was conducted through a prescription containing (Cotrimoxazole) that was given to 70 pharmacist, only 7 pharmacist was able to identify the drug as contraindicated, this shows that pharmacists awareness in Khartoum has been improved since 2013 (Elgamal et al., 2013) [13].

It is worth mentioning that that there are lack of concerted evidence that supports the association with drug-induced hemolysis for many medications and lots of medications that have been prohibited maybe safe to be administered in therapeutic dosages G6PD deficient population. This shows the need for an evidence-based international consensus guideline regarding medication use in G6PD-deficient patients (Youngster et al., 2010) [21].

The current study has provided an insight about the knowledge of community pharmacist in Khartoum, Sudan about medication usage pattern in G6PD deficient patients. However, there are several limitations several limitations including the relatively small sample size, the close-ended questions in the questionnaire which may have restricted the participants’ capacity to explain the underlying reason for a certain outcome and the capacity of the study’s finding to be generalized to other geographical areas. Therefore, it is recommended that future studies should include a larger sample size, and to be conducted in various geographical regions.

Conclusion
The current study has provided an insight about the knowledge of community pharmacist. Overall, pharmacists expressed a good knowledge regarding the medication usage pattern in glucose-6-phosphate dehydrogenase G6PD deficient patients. Pharmacists should use continuous pharmaceutical education to keep up with updated evidence-based information regarding medication use in specific population such as G6PD deficient individuals especially in G6PD prevalent regions.

Conflict of interests
The authors have no conflicts of interest to declare

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Table 4: Pharmacists’ response about medication usage pattern in G6PD deficient patients

| Variables     | Number of respondents, (n) | Percentage of respondents (%) |
|--------------|-----------------------------|-------------------------------|
| Co-trimoxazole |                             |                               |
| Contraindicated | 35                          | 70                            |
| Used with caution | 15                          | 30                            |
| Ascorbic acid  |                             |                               |
| Contraindicated | 10                          | 20                            |
| Used with caution | 40                          | 80                            |
| Aspirin       |                             |                               |
| Contraindicated | 17                          | 34                            |
| Used with caution | 33                          | 66                            |
| Chloroquine   |                             |                               |
| Contraindicated | 33                          | 66                            |
| Used with caution | 17                          | 34                            |
| Ciprofloxacin |                             |                               |
| Contraindicated | 34                          | 68                            |
| Used with caution | 16                          | 32                            |
| Nitrofurantoin|                             |                               |
| Contraindicated | 28                          | 56                            |
| Used with caution | 22                          | 44                            |
| Dapsone       |                             |                               |
| Contraindicated | 39                          | 78                            |
| Used with caution | 11                          | 22                            |
| Probencid     |                             |                               |
| Contraindicated | 13                          | 26                            |
| Used with caution | 37                          | 74                            |
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