Implementing the Calculation of the Appropriate Drug Dose for Children Using the Programming Language C#

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5 authors, including:

Sukejna Redžepi
University of Sarajevo

Belma Muftic

Vanja Piljak
University of Sarajevo

Nermina Ziga Smajic
University of Sarajevo

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Sukejna Redžepi, Belma Muftić, Vanja Piljak, Nermina Žiga, and Mirza Dedić

Abstract

Drug dosage is the amount of a drug or medicinal substance, which needs to be administered to a patient in the form of a single dose or in the form of multiple doses, in order to achieve desirable therapeutic effect. Determining the adequate dose for a child represents a challenge, since the drug pharmacokinetics are different in the bodies of children, compared to those in adults, therefore children usually require lower doses of medication compared to adults. There are numerous formulas to calculate the appropriate drug dose for children, based on the child's age, weight, etc. The aim of this project is to design a computer program that will calculate the drug dosage for children quicker, and requiring less effort. Using the programming language C#, a user interface was developed. The application enables calculating the dose for children based on the adult dosage and the age or weight of a child requiring the medication, and it also regards children under the age of one as a special group and enables the calculation of the dose for those children specifically. The application simplifies the work of a pharmacist in a drugstore in terms of dispensing medication for children and it can be also used by paediatricians while prescribing drugs for children.

Keywords

Drug dosage • Child dosage • Dose calculation formulas • C# programming language

1 Introduction

Posology is the study concerned with dosage. Drug dosage implies the determination of the amount of drug or medicinal substance, which needs to be administered to a patient in the form of one single dose or in the form of multiple doses, for the sake of achieving desirable therapeutic effect, considering the fact that the given dose makes the poison or the cure in this case [1]. The quantity of the drug administered to a patient within 24 h in the form of one single dose, or multiple doses for the purpose of treatment is called a dosage [2]. Several types of doses can be differentiated:

- The physiological or ineffective dose (dosis physiologica) is the quantity of drug which has no effect, but is still present in the organism.
- The therapeutic or effective dose (dosis therapeutica) is the optimal quantity of drug with which a therapeutic effect is achieved and is always greater that the ineffective dosage.
- The effective dosage (ED50) is the quantity of drug effective in 50% of the human population [3].
- The toxic dose (dosis toxica) is the quantity of drug which leads to toxic effects in the organism.
- The lethal dosage (dosis letalis) is the quantity of drug which leads to the death of an organism. Minimal lethal dose (dosis letalis minima) is the minimum quantity of drug, which still causes death. Medium lethal dosage (dosis letalis media) is the quantity of drug which usually causes death [2].

In the majority of cases, a single dose of drug is not enough to cure the cause of illness and therefore the dose has to be repeated so that the drug therapeutic concentrations can be maintained at the drug's site of action. The dosage frequency is different for different drugs and therefore two more types of doses can be differentiated:

S. Redžepi (✉) · V. Piljak · N. Žiga · M. Dedić
Faculty of Pharmacy, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
e-mail: sukejnars@gmail.com

B. Muftić
Faculty of Electrical Engineering, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

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- The maximum singular dose (dosis maxima singula) is the largest therapeutic dose of a drug which can be administered all at once without harmful consequences.
- The maximum daily dose (dosis maxima pro die) is the largest quantity of drug, which taken in a time interval of 24 h does not cause toxic effects [2].

Doses which are listed in the pharmacopoeia for certain substances are related to the adult, i.e. normally developed person, therefore when dosing drugs for children, certain adjustments must be made. The differences between the dosage required for children, and the dosage required for adults is due to many factors which include changes in pharmacokinetic parameters, age, body, weight, surface area, and genetic predisposition [4]. There are numerous formulas for calculating the dosage for children from an adult dose, based on weight, age and surface area of the child's body [5].

Dilling-Martinet's rule (dose according to the child's age) [5]

$$\mathit{Child\ dose}\,(CD) = \frac{\mathit{age\ of\ the\ child}}{20} \times \mathit{adult\ dose}\,(AD)$$

Thiemich-Feer's rule (dose according to the child's body weight) [5]

$$\mathit{Child\ dose}\ (CD) = \frac{\mathit{weight\ of\ the\ child}}{70} \times \mathit{adult\ dose}\ (AD)$$

Augsberger's formulas [5]

$$\begin{aligned}\mathit{Child\ dose}\ (CD) &= 4 \times \mathit{age\ of\ the\ child} + 20\\ &= \%\mathit{adult\ dose}\ (AD)\end{aligned}$$

$$\begin{aligned}\mathit{Child\ dose}\ (CD) &= 1.5 \times \mathit{weight\ of\ the\ child} + 10\\ &= \%\,\mathit{adult\ dose}\ (AD)\end{aligned}$$

Young's formula [2]

$$\mathit{Child\,dose}\ (CD) = \frac{\mathit{age\ of\ the\ child}}{\mathit{age\ of\ the\ child} + 12} \times \mathit{adult\ dose}\ (AD)$$

Bolognini's formula [5]

$$\begin{aligned}\mathit{Child\ dose}\ (CD) &= \frac{1}{20 - \mathit{months\ of\ the\ child}}\\ &\quad \times \mathit{adult\ dose}\ (AD)\end{aligned}$$

The main reason age influences the effect of drugs is the fact that the elimination of drugs is less efficient in newborns and older people, therefore the drugs have a stronger and longer effect in those age groups. Glomerular filtration rate (GFR) of infants calculated according to surface area of the body is just around 20% of the adult's value, and the tubular function is decreased as well. Therefore, infants have a longer half-life of drug elimination from the plasma than adults [6]. Immaturity of kidneys of prematurely born children can also have a great effect on the drug elimination. Hence, it is necessary to decrease the dosage or to increase the interval between two consecutive drug doses [7].

In children's practice the drugs need to be prescribed in liquid form, if possible. Insoluble powders need to be mixed with a liquid and pills need to be crushed and administered with a liquid as well. Drugs with an unpleasant taste should not be mixed with food, because they can cause long-term reluctance towards taking that specific food, and hence sugar and syrups should be used to correct the drug's taste and smell. The majority of drugs can be administered in children through the rectum, after a previous enema for cleansing, or in the form of a suppository [5].

The purpose of developing a computer program that can calculate doses for children is to allow paediatricians and pharmacists faster and easier calculation of the accurate dosage for children while prescribing and dispensing drugs. Although computer programs that can calculate paediatric dose are not a new concept in medicine, currently in Bosnia and Herzegovina such a system is not in use in regular clinical practice.

2 Methodology

The programming language C# was used for the development of an application which calculates the right drug dosage for children, where a Windows Forms project was developed as the user interface. Since the calculations for this project do not need any special classes, no particular pattern was used.

The user is required to insert the drug dosage for an average man (where it is indicated that the dosage is in milligrams), after which the user needs to insert one of the following three possibilities:

1. The age of the child (in years)
2. The weight of the child (in kilograms)
3. The age of the child not older than one year (in months).

It is possible to insert decimal numbers for any of the above mentioned values, while characters (except for the dot and the comma) are forbidden. However, if the input field contains more than one comma or dot, a message will pop up notifying that an error occurred with the information where it had occurred, and on that location the resulting value will not be calculated. In case the error is within the field for the dosage of an average adult, no resulting value will be calculated. Furthermore, if there is no value for the dosage for adults, or if all three child values are empty, a message will be shown to notify the user.

When the values are inserted correctly, the resulting field (or fields) where there is an input will calculate the right drug dosage for the child according to the following formulas (according to the previously mentioned options respectively):

$$Child\,dose\,[mg] = \frac{age\,of\,the\,child\,[years]}{20} * adult\,dose\,[mg]$$

$$Child\,dose\,[mg] = \frac{weight\,of\,the\,child\,[kg]}{70} * adult\,dose\,[mg]$$

$$Child\,dose\,[mg] = \frac{1}{20 - age\,of\,child\,[months]} * adult\,dose\,[mg]$$

The field with the resulting child dose cannot be modified, which prevents the possibility of unwanted input. A help button is available in the program, which explains to the user how to use the application. Furthermore, the program offers the resetting of some or all fields with the appropriate button(s). What is important to point out is that the program does not depend on any particular drug, but requires the single dose of the active substance for the given medicament, based on which it calculates the child dose.

3 Results and Discussion

Once the pharmacist starts the application, a window will open on the computer desktop, which represents the starting form of the program. The starting appearance of the program is shown on Fig. 1 in which it can be seen that the application is composed of several spaces in which the corresponding data is entered, necessary for performing the program's function for which it is intended. The program offers the option to change the language from Bosnian to English.

In the lower right corner of the program there is the option "Help", which essentially gives instructions to the user on what data is sufficient to enter in order to receive the corresponding results, alongside with what requires attention to be paid on. By clicking on the mentioned option, a window is opened, shown on Fig. 2.

The first step, during the dose calculations, is entering the individual dosage for an adult of a specific active substance of drug, i.e. the carrier of pharmacological activity. The dosage is entered in the space marked as "Adult dose" (in milligrams). The next step is entering one of the mandatory data requirements related with the child, e.g. age in the space "Age of child". After entering the data, by clicking on the option "Calculate" (in the lower right corner), in the space

Fig. 1 Display of the starting program appearance

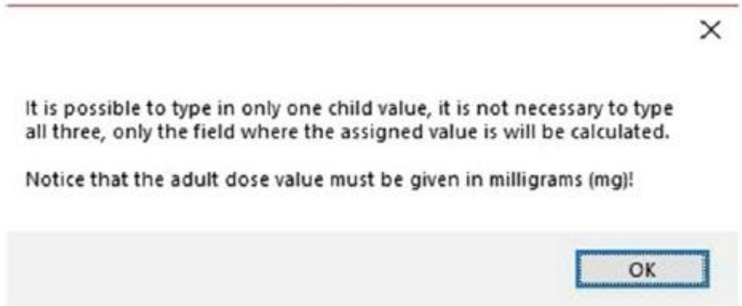

Fig. 2 Display of instructions for opening the program

Fig. 3 Display of entering and calculating the dosage for a child based on the age entered

"Recommended dose" a number is shown representing the suitable drug dosage for the treatment of the child of a specific age. The above-mentioned text is visually shown in Fig. 3.

Also, instead of data based on the child's age, the dosage can be calculated based on the child's weight as well. Calculations are done almost the same, as it was described in the previous example, with the difference that the weight data is entered in the space "Weight of child".

Visual display of this calculation is shown in the Fig. 4.

Children younger than the age of one are going to be regarded as a special group and therefore the program enables dosage calculation specifically for children within this group. The procedure of entering data is the same as in the previous two examples, with the fact that instead of data about the age and the weight of the child, the age of the baby in months, not years, is entered in the space "Children up to 1 year".

Mentioned procedure is shown on the Fig. 5.

The program also allows simultaneously getting data about the recommended drug dosage for a child based on age, weight, as well as number of months. What needs to be done in this case is to enter data of an individual adult's dosage of the drug, then data about age, weight and the age of the infant in months, and click on the option "Calculate", after which in the three fields recommended drug doses are simultaneously presented based on the entered data. It is also important to mention that the entered data for the age, weight and number of months, doesn't have to relate to the same child, i.e. the data can relate respectively to three different

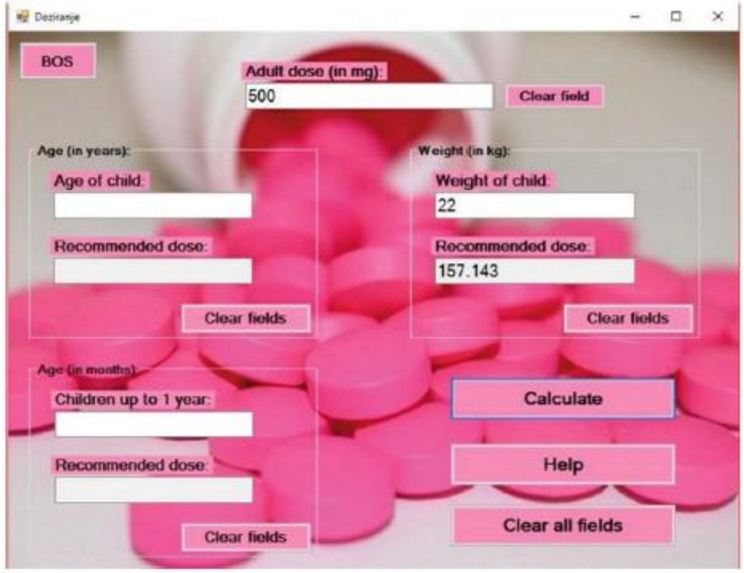

Fig. 4 Display of entering and calculating the dosage for a child based on child's weight data

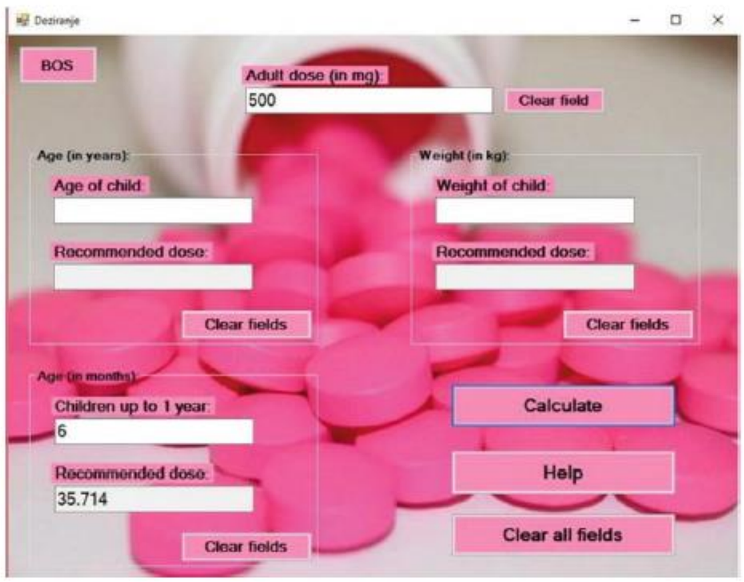

Fig. 5 Display of entering and calculating the dosage of a child under the age of one, based on the age in number of months

Fig. 6 Display of the simultaneously entered and calculated dosage for a child based on data for age, weight and number of months

children. What is important is that the calculations for these three children are done for the same drug and the same individual dose.

Visual representation of the simultaneous calculations for all three cases is shown in Fig. 6.

It is important to state that the program cannot calculate the dosage for a child over one year of age by using Bolognini's formula (field "Age (in months)") which is intended entirely for calculations of the dosage for the children younger than one year.

The research conducted in Singapore examining the effect of computer calculated doses on medication error rates showed that the medication error rate decreased by 15.6% when the dose was calculated by a computer. The research showed that the medication error was quite common in outpatient, emergency department and discharge prescriptions and that the computer calculated doses can significantly reduce errors [8]. The developed program for calculation of drug dose for children can be implemented in various parts of the healthcare system in Bosnia and Herzegovina, such as hospitals, family practices, and pharmacies. The program would enable paediatricians and pharmacists easier and faster calculation of the drug dose for children, allowing more efficient process of prescribing and dispensing medications to children.

4 Conclusion

Based on the application's working principle stated above, it can be seen that its main purpose is to simplify the work of a pharmacist in a drugstore in terms of dispensing medicine for children, in accordance with their, still insufficiently developed, capability to metabolize the medicine. Of course, besides pharmacists, the application would be beneficial to paediatricians, making it much easier for them to prescribe drugs for children. Information, necessary for the application's functioning (age, weight or months of a child), is very easily accessible, taking into account that the doctor needs to state them in the prescription.

The main characteristic of this application is that it allows dosage calculation for children based only on the data of a singular dose of a specific medicine and on the information about age or weight of a child, or the baby's age in months. In other words, in order for a child's dosage to be calculated, it is not necessary to know the trade name of the medicine, but only the singular dose. What may be a disadvantage of the application is that it requires the manual insertion of the singular dose necessary for the calculations. However, if integrated with an e-register, it would be possible to select the wanted drug, and the program would retrieve the data for that drug in order to perform the calculations. In that case, access to the database of the e-register would be needed. Another possibility is to send an API (Application Programming Interface) request; however, both ways would get the needed data, but also minimize the possibility of an ignorance error due to the lack of knowledge of the right dosage.

It is important to emphasize the project is in early stages of the development, and that the currently developed application will be further evaluated in a pilot study to determine its practicality, accuracy and efficiency in clinical practice.

Conflict of Interest Declaration The authors whose names are listed right below certify that they have no affiliation with or involvement in any organization or entity with any financial interests (such as honoraria, educational grants, membership, employment, stock ownership or other equity interest), or non-financial interest (such as personal or professional relationship) in the subject matter or materials discussed in this work.

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