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Research Paper

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Research Paper

Pulse oximeters market analysis during the COVID-19 pandemic: Kyiv pharmacies' offers and survey of pharmacy faculty students

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ABSTRACT

Objectives: The objective of this study was to study the market of pulse oximeters to select the optimal choice for monitoring health status during the COVID-19 pandemic.

Methods: Pulse oximeter data, presented on the Tabletki.ua website (2021) in Kyiv (Ukraine), were summarized and discussed. A survey about the history of the device purchase among 170 students of the Faculty of Pharmacy (Zaporizhzhia State Medical University, Ukraine) was statistically analysed by Kolmogorov–Smirnov, Shapiro–Wilk, Levene's, Scheffe tests, one-sample *t*-test, Spearman's correlation and one-way ANOVA.

Key findings: The largest part of the Kyiv (Ukraine) pulse oximeter market is occupied by the People's Republic of China (70.97%). The price ranged from UAH 171.50 to UAH 1799.00. The models S6 and Linke LK88 are found to be the best choices according to the fullest provided data, the lowest minimum price and emphasis on the oxygen saturation and pulse rate accuracies. Medical students statistically significant would buy a pulse oximeter for less than UAH 563.40 ($t(76) = -2.884$; $P = 0.005$). The price did not depend on age ($F = 1.104$, $P = 0.372$) or gender ($F = 2.466$, $P = 0.121$), but there was a correlation between price and year of purchase ($F = 2.712$, $P = 0.051$). Students are primarily interested in country of origin, guarantees and pharmacist recommendations. A significantly weak Spearman's correlation was found between price and friend advice ($\rho = 0.275$, Sig. = 0.015).

Conclusions: The same models differ in price by up to 4.2 times and in between them – up to 10. Less than half of the responders bought devices, and even a quarter of them did not use them at all, although they were from a health field. The detailed notifications about accuracy for different patient skin types are required in the device description. More people should be aware of pulse oximeter importance to maintaining health after COVID-19.

Keywords: pulse oximeter; COVID-19; pharmaceutical market; survey analysis

INTRODUCTION

The situation with the COVID-19 pandemic continues to be frightening and must be brought under control. According to Worldometer,[1] from 17 September 2021 to 9 February 2022, the worldwide number of cases has risen from 227 to ~401.5 million. Fortunately, the mortality rate decreased from 2.06% to 1.44%. Also, Ukraine lowered its rank from 8th to 18th among other European countries with a total of 4 380 047 cases and 2.33% of death cases, which is still not so optimistic after almost 2 years of fighting this disease.

The five hygiene rules[2] recommended to maintain health nowadays are as follows: (1) washing hands frequently with soap and water for at least 20 seconds; (2) not touching the face with unwashed hands; (3) coughing or sneezing into a tissue or elbow and carefully discarding the tissue; (4) keeping at a distance of 1.5 metres from others; (5) staying at home if feeling unwell, while contacting the hotline or healthcare professional. But, when feeling unwell and sitting at home, how to understand if hospitalization is vital? Not so long ago, thermometers played this role, but today pulse oximeters have entered our daily life to solve this problem.[3]

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The whole path of pulse oximeter development in Japan and the USA can be found in the latest Miyasaka *et al.*'s[4] paper with touching memories from engineers, scientists, clinicians, academics, business people and clinical practitioners, etc., tributing Dr Takuo Aoyagi with his invention 'Optical Oxygen Measuring Device', registration No. 947 714 in 1974. But only in 1977, the fingertip device OXIMET-Met-1471 by Minolta Camera, Co., Ltd contributed to the initial spread of pulse oximeters, close to those known now. Also, while the idea of pulse oximetry originated in Japan, device development lagged there due to a lack of business, clinical and academic interest. But, awareness of the importance of anesthesia safety in the USA, due to academic foresight and media attention, in combination with excellence in technological innovation, led to widespread use of pulse oximetry around the world. And at the 34th Annual Meeting of the Japan Society of Technology in Anesthesia in commemoration of receiving the 2015 IEEE Medal for Innovations in Healthcare Technology, Dr Aoyagi remarked in a chat with Akio Yamanishi (Former Chief, Medical Equipment Division, Minolta Camera, Co., Ltd): 'You'll go and find pulse oximeters at supermarkets or electronic shops in the not-too distant future'. And his prophecy has come to life during the pandemic of COVID-19. Unfortunately, Dr Aoyagi passed away in 2020 with his final wish to find not a principle, but a theory of pulse oximetry to go beyond its usage limit.

Thus, nowadays pulse oximetry usage is considered to be a standard of care during surgical procedures and is part of a routine set of vital signs.[5] Moreover, Enoch *et al.*[6] found out that when used for children, it can reduce the cases of unrecognized hypoxaemia and mortality rates (when combined with improved oxygen administration), length of emergency department (ED) stay and change physicians' decisions on illness severity, diagnosis and treatment. These devices are also useful in monitoring respiratory and non-respiratory diseases like asthma, chronic obstructive pulmonary disease,[7] congenital heart defects, congestive heart failure, cystic fibrosis, interstitial lung diseases, lung cancer, obstructive sleep apnoea and pneumonia.[3]

Operating principle and measurement parameters

The pulse oximeter is a mini device that can be used to evaluate the level of arterial blood saturation (SpO_2), pulse rate (PR) and perfusion index (PI) fast, easy, non-invasive and non-costly.[4, 8, 9] Its working principle is based on the absorption of light of different wavelengths: while the far-IR light (660 nm) is significantly absorbed by water and non-vascular tissues, the red and near-IR light (940 nm) is absorbed well by tissues. Oxygenated haemoglobin (HbO_2) absorbs more far-IR light and allows more red light to pass through. Deoxygenated haemoglobin (HHb) allows more infrared light to pass through and absorbs more near-IR light. At the start, two types of light come from a pair of diodes that emit light located in one part of a finger probe (Figure 1).[10] Then, they are delivered through the finger and ascertained by a photodiode on the opposite part of the probe.

The oxygen level of arterial blood (SpO_2) correlates to the amount of absorbed red and IR light. The absorption may fluctuate because of the increase in arterial blood volume in the systole state and decrease in the diastole state. From the transmitted light intensity data, the pulsation amplitude – alternating current (AC) and the total intensity – direct current (DC) were obtained, and the ratio, AC/DC, was calculated. This AC/DC ratio was obtained at both wavelengths of red and IR, and their ratio was also calculated. This is the so-called ratio of ratios. At a low level of SpO_2, which means HHb increased, the relative amplitude of the red light is greater than IR absorbance. Conversely, a higher level of SpO_2 results in a lower IR modulation value. It should be mentioned that according to home monitoring protocol,[11] exclusion criteria for patients suspected with COVID-19 after ED discharge include resting SpO_2 <92% and ambulatory SpO_2 <90%.

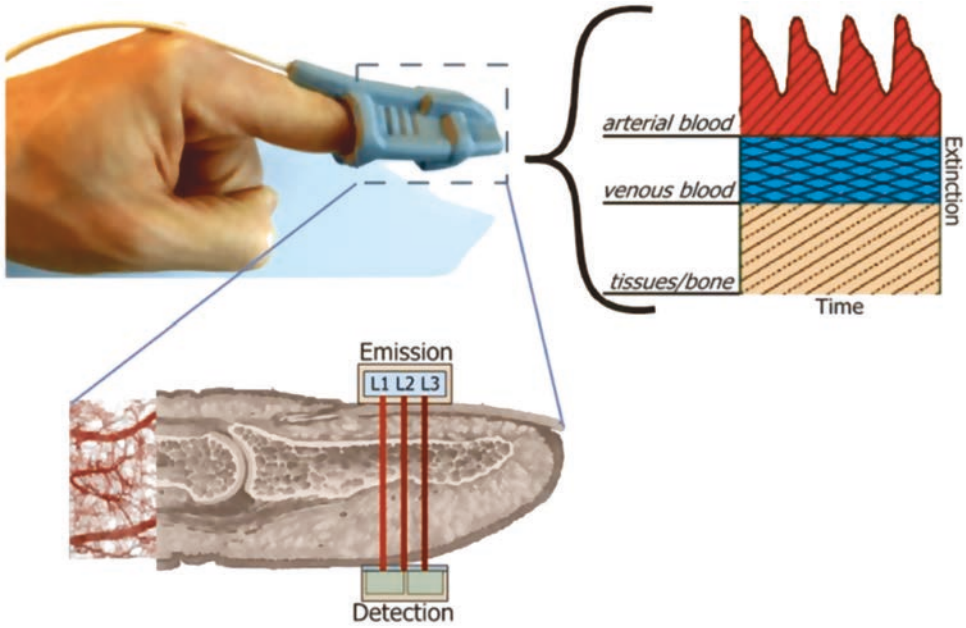

Figure 1 Illustration of the pulse oximeter usage.[10]

The PI shows an analysis of the blood flow intensity at the measurement site, the number of working capillaries and the volume of blood vessels (pulse strength). It has been found to be a reliable indicator of peripheral perfusion.[12] PI is calculated by dividing the pulsatile signal AC by the non-pulsatile signal DC × 100 and is expressed as a percentage ranging from 0.02 to 20. A PI of 4–7% is considered the norm for the correct measurement of saturation. A low value of this parameter (<4%) can distort the results of changes in saturation, and indicates, for example, hypothermia of the finger, the presence of vascular diseases, shock conditions, etc. An indicator of more than 7% indicates excessive perfusion, which also affects the quality of measurements.

A PR is an estimation of the number of times a heart contracts per minute. The normal PR values for adults range from 60 to 100 beats per minute (bpm).[13] This is called resting heart rate. When being active, it's necessary to wait at least 5 min before measuring a pulse. When the heart rate is too fast, it's called tachycardia. For some people, a PR below 60 bpm indicates abnormally slow heart action, also known as bradycardia. In general, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. An irregular pulse is when the heart does not beat in a regular, steady rhythm is called an irregular heart rate or an arrhythmia.

According to the UK National Health Service Protocol of 2021,[14] SpO_2 levels ≥95%, PR <20 and HR ≤ 90 are considered mild conditions with monitoring health at home; SpO_2 ≥93–94%, PR = 21–24 and HR = 91–130 are deemed moderate and need hospital admission, and for patients with SpO_2 ≤92%, PR >25 and HR >131 urgent admission is indicated.

Precautions and accuracy

The most frequent places of pulse oximeter usage are the finger (especially the second one), nose, ear lobe and forehead because the skin of those areas is denser in vascular than any other body parts. Unfortunately, it is often mentioned in the device description that multiple factors can affect the accuracy of a pulse oximeter reading, such as movement of hands, poor perfusion, skin pigmentation, thickness, temperature, current tobacco use and presence of fingernail polish, age, body shape, place of measurement, etc.[15, 16] The US Food and Drug Administration (FDA) reports[15] that its accuracy is highest at saturations of 90–100%, intermediate at 80–90% and lowest below 80%.

A recent study[17] has shown that in two large research groups, patients with black skin had nearly 3 times the frequency of hypoxaemia detected than those of patients with white skin. Moreover, it was found that a pulse oximeter target of 92% ensured a safe SpO_2 >60 mmHg in 91.7% of patients with white skin, but in only 50% of patients with black skin.[18] And managing patients with unreliable measurements of oxygenation is hazardous, partly because dangerously low saturations are missed. But also because low saturations are exaggerated and lead to unnecessary intubation with additional casualties.[19] Besides, Tobin and Jubran[20] suggest that authors in their studies could reverted to the more mundane terminology of mean and standard deviation and refrained from the use of 'bias and precision' terms, as in that case the influence of skin colour is not taken into account.

Also, in the latest review,[21] which included a total of 22 studies, it is reported that only 75% of oximeters are deemed accurate for patients with poor peripheral perfusion, except modern models, utilizing more complex algorithms. The earlobe placement of the oximeters seemed more sensitive, with greater measurement accuracy than on the fingertip. Besides, only one study was found for skin pigmentation control and none strictly followed the FDA recommendations for experiments to determine the oximeter accuracy.

So, pulse oximeters have been known for a long time and are widely used in medical practice today. Hence, it was decided to analyse the variety of pulse oximeters in the Ukrainian (Kyiv) pharmaceutical market to choose the best option according to the presented parameters, and additionally to consider the consumer preferences of purchase and its usage.

MATERIALS AND METHODS

Pulse oximeter market analysis

The pulse oximeters, offered at the Tabletki.ua web resource (2021) in Kyiv (Ukraine),[22] were taken as the subjects of the study. The following data were analysed: name and country of the manufacturer, model name, number of seller pharmacies, minimum and maximum prices (UAH 26.73 = $1, September 2021), certification, warranty time, parameters of the model (SpO_2, PR and PI ranges, temperature and humidity of usage, screen colour, batteries, accuracy, critical value alerts and auto-shutdown time).

Questionnaire

A questionnaire about age and gender, bought or not pulse oximeter, year of purchase (before 2019–2021), approximate price, frequency of usage (once a day, a week, if you feel unwell, never used, the device was already broken) was proposed to students of Faculty of Pharmacy, Zaporizhzhia State Medical University, Ukraine. Also, the most important parameters for the purchase (country of the manufacturer, warranty card, battery, pharmacist or friend's advice, USB charging, screen and device colour) were asked.

Sample size

According to Machin *et al.*,[23] the sample size of rules of thumb may be categorized into two categories: flat and stepped. In our case, it is a flat rule of thumb (a single number is suggested for every situation). When it was decided to choose confidence as 0.99 and probability as 0.05, the minimum sample size was calculated as 89.[24] As a result, 170 students took part in the study. Additionally, in the result of data analysis, two groups were formed: 93 persons, who did not buy pulse oximeters, and 77, who bought. If calculate confidence as 0.98, the sample size is 76. So, sample sizes were of a high level of confidence.

Statistical analysis

The data were analysed using the Statistical Package for the Social Sciences software (IBM SPSS for Windows Inc., v. 26.0, Chicago, IL, USA). Each answer was scored according to its own scoring formula. Data were presented as a number, percentage, mean and standard deviation for parametric data. Independent *t*-test was

Table 1 The pulse oximeters presented in the Kyiv pharmacies

Country	Company	Model	Warranty
People's Republic of China	CMICS Medical Instruments Co., Ltd	S6	1 year
		S10	
		S8P	
	IMDK Medical Technology Co., Ltd	FU-YK81C	
	Shandong Yiguang Medical Instruments Co., Ltd	302A	
	Shenzhen Bioeasy Biotechnology Co., Ltd	LK87	
		Linke LK88	6 months
		CY901L	
	Shenzhen IMDK Medical Technology Co., Ltd	C101A3	+[2]
		iMDK C101A2	
	Shenzhen Creative Industry Co., Ltd	Creative Medical PC-60F	
	Shenzhen Aeon Technology Co., Ltd	AEON A310 L	
	Xuzhou Yongkang Electronic Science Tech. Co., Ltd	YK-81C[1]	1 year
	Changzhou Huaang Medical & Health Instruments	OKCI (P-01)[1]	
	Contec Medical Systems Co., Ltd	Contec CMS50D	6 months
	Shanghai Berry Electronic Tech Co., Ltd	BERRY BM1000B	
	Aeras Medical Pte, Ltd	SONOSAT-F02T[1]	
	Dr. Life Ltd	Dr. Life aCurio AS-301[1]	
		Dr. Life aCurio AS-302[1]	
	Shenzhen Yimi Life Technology Co., Ltd	YM101	
		YM103	
		YM201	
Ukraine	Dolphi-Ukraine LLC	Gamma Oxy Scan[1]	2 years
	Medhouse-Ukraine, Ltd	ProMedica XP-20[1]	2 years
	Dopomoga-1, Ltd	Medicare	
Singapore	Little Doctor International (S) Pte, Ltd	Little Doctor MD300C23	+
	Beijing Choice Electronic Technology Co., Ltd	MD300C19	
Great Britain	Heaco Medical Technology	Heaco CMS50B[1]	+[2]
		Heaco CMS50C	6 months
Germany	Beurer GmbH	Beurer PO 40	5 years
Russian Federation	La Med LLC	EximLab P-01[1]	

[1]Monochromic screen.
[2]Warranty mentioned on the website, but the time period was not specified.

used to compare the two quantitative variables. Normality of data was assessed using Kolmogorov–Smirnov and Shapiro–Wilk tests. The Spearman's correlations were done to assess the significance of the relationship between variables. Data were analysed via 2 (group) × 2 (time) mixed-factorial analysis of variance (ANOVA) after Leven's test. Independent samples *t*-test was conducted between groups. Statistical significance was defined as $P < 0.05$ for all tests with data presented as mean and standard deviation unless other. Origin (Pro), Version 2018, OriginLab Corporation, Northampton, MA, USA was used to plot the figures.

RESULTS AND DISCUSSION

Analysis of website data

Companies and warranty

Prescription oximeters, which are reviewed by the FDA,[15] receive 510(k) clearance and are available only with a prescription in the USA. The FDA requires that these pulse oximeters undergo clinical testing to confirm their accuracy. They are most often used in hospitals and doctors' offices, although they may sometimes be prescribed for home health monitoring. But recently, the usage of over-the-counter (OTC) oximeters has increased as a result of the COVID-19 pandemic.[25] They are sold directly to consumers in stores or online and include sometimes even smartphone apps developed to estimate oxygen saturation. These products are sold as either general wellness or sporting/aviation products that are not intended for medical purposes, so they do not undergo FDA review. So, if pulse oximeters are not cleared by the official certification company, they should not be used for medical purposes. Still, the majority of such are found in the pharmaceutical market of Ukraine.

Thus, there were 31 different models found on the Tabletki.ua website[22] (Table 1), which is one of the largest online markets of medical items in Ukraine.

Pulse oximeters were presented by six countries (People's Republic of China, Ukraine, Singapore, Germany, Russian Federation and Great Britain). The largest part of the market

was taken by the People's Republic of China (70.97%) by the number of companies (14) and models (22) (Figure 2).

It is interesting to note that among all these models, only 4 were found to be fully certified in Ukraine, having FDA and European (CE) certificates: Creative Medical PC-60F, MD300C19, C101A3, iMDK C101A2. They all were presented by Shenzhen-named companies, China. Still, all others are also actively distributed through Ukrainian Pharmacy Stores, but surprisingly the certification is not reported.

Among all devices, only eight models (S6, Linke LK88, YK-81C, Contec CMS50D, Gamma Oxy Scan, ProMedica XP-20, Heaco CMS50C and Beurer PO 40) had warranty time mentioned in their description, that is, from 6 months to 5 years (Table 1). And three devices (C101A3, Little Doctor MD300C23, Heaco CMS50B) were just said to have a warranty.

Parameters

It's notable that only for three devices the working wavelengths of red light and infrared light were reported: 660–666 nm and 890–904 nm for Dr. Life aCurio AS-301 and AS-302; 680 nm and 940 nm for Little Doctor MD300C23. Only for the latter, the allowable finger circumference was shown: 20–75 mm.

The battery AAA pack was included for 45% of devices (Table 2) and only two models S8P and S10 had a built-in battery that can be charged via USB. About 68% of the pulse oximeters were going with the colour screen (Table 1), and others were preferably red monochromic. The majority (87%) of studied pulse oximeters had SpO_2 and PR measurements. In Table 2, the devices are grouped according to their SpO_2 (%) measuring ranges: 35 (36)–99 (100), 70–99 (100) and 0~100.

The FDA notifies[15] that if the SpO_2 ≥94% is followed by no chest pain, shortness of breathing or any emergency symptoms, it is a normal state that the patients can continue monitoring themselves. If the SpO_2 ≤94%, it is a sign that patients require to be hospitalized. And if SpO_2 ≤90%, it indicates an emergency state that patients need to treat with intensive care. Besides, accuracy below 80% is intermediate. So, the most useful working range will be 70–99 (100), which is presented by eight models

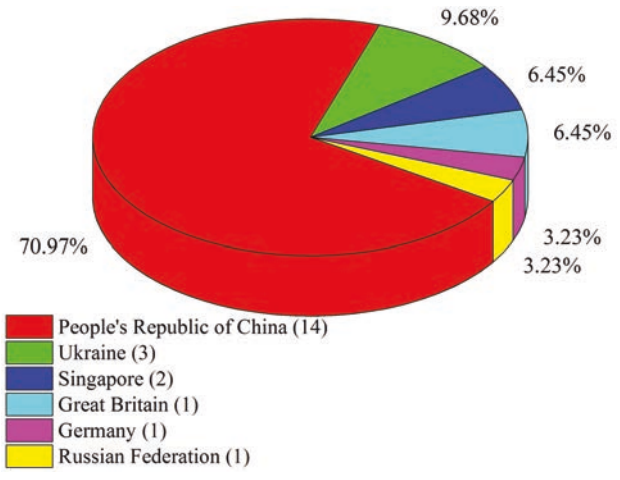

Figure 2 Percentage of the pulse oximeters by the number of models for each country and their corresponding companies' number in the Kyiv pharmacies.

(Table 2), among which S6 and CY901L Little Doctor accuracies are the most truthfully described (2–3%). Unfortunately, there was no found notifications and precautions for customers about accuracy when used with different skin colour or having nail enamel.

Only eight pulse oximeters (Gamma Oxy Scan, iMDK C101A2, Yimi Life YM101, YM103, YM201, SONOSAT-F02T, Creative Medical PC-60F and Beurer PO 40) were equipped with PI positioner which shows an analysis of the blood flow intensity at the measurement site (pulse strength) (Table 2). Practically, all of them measure SpO_2 from 35% to 99%.

Only seven devices had an operating temperature description and humidity to show the most accurate results: models Medicare, S6, CY901L, Little Doctor MD300C23: 4(5)–40°C and 15–80%; Models 302A, YM101, Linke LK88: 10–40°C and ≤75%, respectively. .

Prices

The minimum price on the market is 171.5 hryvnias (UAH) found for LK-87, and a maximum of 1799.0 UAH for Beurer PO 40 (Figure 3). The currency rate at that time was UAH 26.73 = $1. The average minimum price was calculated as UAH 563.40 ± 305.82 for all models or UAH 505.36 ± 223.02 without the last expensive model.

It is noteworthy that monochrome devices were only OKCI (P-01), SONOSAT-F02T, Gamma Oxy Scan, ProMedica XP-20, Heaco CMS50B and EximLab P-01, and their average minimum price was lower: UAH 459.75 ± 162.10, but close to the average one.

Beurer PO 40 stands out separately because its maximum price was UAH 1799. The German origin is considered of top quality (even its warranty is 5 years).

All devices had a wide range of prices: from a minimum of UAH 171.5 for the LK87 model to almost 10 times higher price (UAH 1011) for the Little Doctor MD300C23.

It is noteworthy that for half of the pulse oximeters, the difference between their minimum and maximum price was found from 2 to 4.2 times due to market demand during COVID-19. When checking the price changes over the past year on the Tabletki.ua website (Figure 4) for the most popular Linke LK88 model,[26] there was shown a sharp decrease of almost 5 times due to market saturation.

And it is predictable that the number of drug stores offering the pulse oximeters with the lowest prices would be of the greater amount (Figure 5). Moreover, when analysing the number of pharmacies versus minimum prices, there was found positive correlation with R^2 of 0.3588. And, popular models were sold in 255–559 different pharmacy stores. The average minimum price for such models was UAH 361.04 ± 128.70, which was about UAH 200 lower than the average price of all studied devices.

The less known models appeared to be FU-YK81C, Creative Medical PC-60F, Dr. Life aCurio AS-301 and AS-302, Little Doctor MD300C23 and Beurer PO 40, probably, due to the remaining high price. And EximLab P-01 unpopularity despite its lowest price was reasonable – its country of production was Russian Federation, a country that had strained relations with Ukraine. The models FU-YK81C, OKCI (P-01) and BERRY BM1000B were the least described among all.

Table 2 The reported parameters (oxygen saturation [SpO_2], accuracy, pulse rate [PR], perfusion index [PI], auto-shutdown time [AST], battery pack and USB) of studied pulse oximeters

Model name	SpO_2, %	Accuracy, %	PR, bpm	Accuracy, bpm	PI, %	AST, s
C101A3[1]	35–99		30–240			8
Gamma Oxy Scan	35–99		30–250		+[2]	
ProMedica XP-20	35–99		30–250			
Yimi Life YM101	35–99		30–250		0–30	5–15
Yimi Life YM103	35–99		30–250		0–30	
Yimi Life YM201	35–99		30–250		0–30	8
SONOSAT-F02T[1]	35–99		30–250		0–30	
S8P[3]	35–99		30–254			8
MD300C19	35–99	±2 (80–99) ±3 (70–80) ≤70 unstudied	30–254	±2 ±2% (30–235)		8
Dr. Life aCurio AS-301[1]	36–99	±2 (70–99)	30–250	±1		
Dr. Life aCurio AS-302[1]	36–99	±2 (70–99)	30–250	±1		
Creative Medical PC-60F[1]	35–100	±2 (70–100)	30–240	±2	0–20	
LK87	35–100		30–250			
AEON A310 L	35–100		30–250			
EximLab P-01[1]	35–100	±2 (70–100)	30–250	±2		
302A	70–99	±2	30–240	±2		
YK-81C[1]	70–99		30–240			8
S10[3]	70–99		30–240			8
S6[1]	70–99	±2–3	30–240	±2–3		8
iMDK C101A2[1]	70–99		30–240		+[2]	8
CY901L[1]	70–99	±2 (70–99)	30–240	±1		8
Little Doctor MD300C23[1]	70–99	±2 (81–99) ±3 (70–80)	30–235	±2 (30–99) ±2% (100–235)		
Medicare	70–100	±2 (70–99)	25–250	±1		8
Linke LK88	0~100	±2	30–250	±2		
Heaco CMS50B[1]	0~100		30–250			5
Heaco CMS50C[1]	0~100		30–250			5
Contec CMS50D[1]	0~100	±2 (70–100)	30–250	±2		8

[1]Batteries AAA pack included.
[2]Mentioned on the Tabletki.ua website (2021) but was not specified.
[3]USB charge.
There were no data mentioned for FU-YK81C, OKCI (P-01), BERRY BM1000B and Beurer PO 40 except the last one has PI function and 10 s of auto-shutdown time.

Best choice

All information provided has been summarized in the following Table 3 to find the most described device.

Hence, about 87.1% of pulse oximeters that had available descriptions on the Tabletki.ua website[22] had SpO_2 and PR specifications. The majority possessed colourful screens (67.7%) and practically half of them had auto-shutdown (45.2%) and battery pack included (48.4%). And, unfortunately, only 38.7% had descriptions of accuracy.

Thus, pulse oximeter S6 appeared to be the best choice according to the fullest information given, lowest minimum price, with a focus on the more detailed accuracies for SpO_2 and PR (the main reason to buy such a device). Also, Linke LK88 was at the top among all listed parameters, following with iMDK C101A2 due to PI detector presence. Considering more expensive ones, Creative Medical PC-60F, Medicare and Little Doctor MD300C23 were the best ones. The majority of the mentioned models were reported to be from the People's Republic of China and only two last ones were from Ukraine and Singapore companies.

Analysis of questionnaire

General data

Moreover, it was interesting to investigate the customers' point of view on the pulse oximeters purchase. Hence, 170 students from the Faculty of Pharmacy agreed to take part in the survey.

In the result, as can be seen from Table 4, the majority of respondents were women (91.2%). And only 45.3% of students bought a pulse oximeter, among which 96.1% were also women. So, one of the limitations of this study was gender inequality. But this was due to the peculiarities of the Faculty of Pharmacy in Ukraine.

The maximum number of purchases was made in 2021 (22.9% of all asked or 50.7% of those who bought it). And

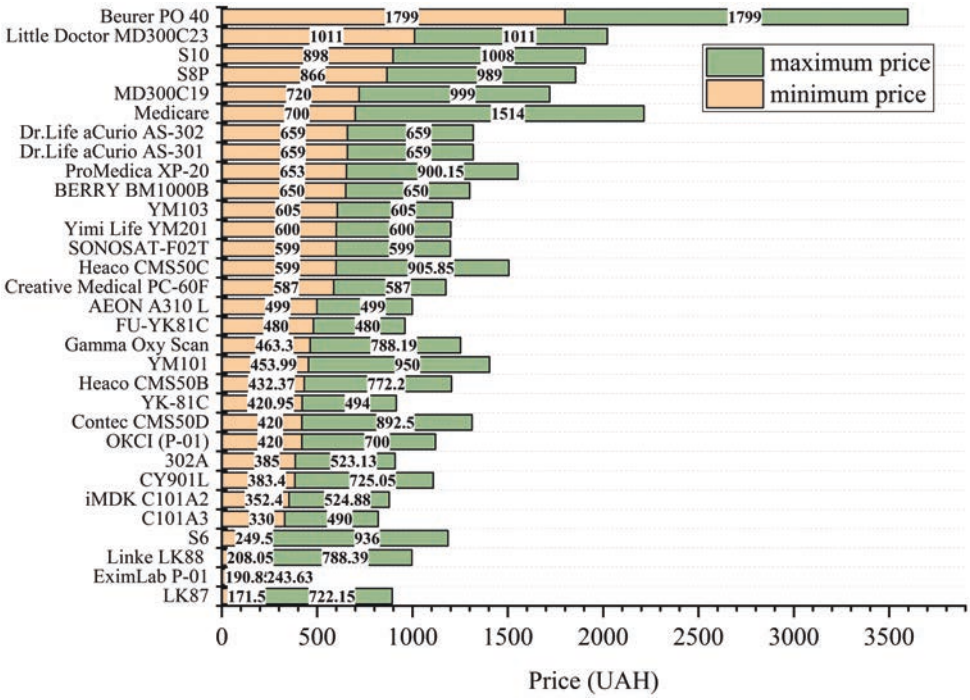

Figure 3 Pulse oximeter prices range from minimum to maximum in hryvnia (UAH).

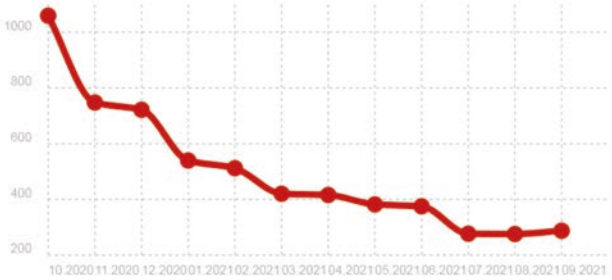

Figure 4 The dynamics of price changes for the Linke LK88 model on Tabletki.ua.[26]

usually, people used it when they were feeling unwell (67.5%). And interesting that a quarter of people (24.7%), of those who purchased the device, did not even use it at all.

Among all the participants, no one used it once a week, and no one had yet broken the device.

When analysing the age, the average value among all participants was 22.98 ± 5.06 years, and for those who had not bought – 22.34 ± 4.11 years (Table 5). The people who purchased pulse oximeters were a bit older: aged 23.74 ± 5.94 years. And the mean price of purchased pulse oximeters was UAH 482.01 ± 247.59 between the minimum UAH 100 and the maximum UAH 1200, according to the approximate price given by the students.

Also, criteria that were most valuable when purchasing or before purchasing a device were evaluated. The lower the number in Table 6, the more valuable was the requested criteria. Price priority was excluded from the questionnaire as the most obvious answer. And two separate groups' answers (who bought, 77 and did not, 93) were analysed.

So, for people who bought a pulse oximeter, the most important thing was the country of origin, and afterwards the guarantee. For those who did not buy, preferences had remained practically the same, but warranty preferences were slightly higher. Next by the importance were pharmacist advice and battery packs, which were also reversed for people who did not buy a pulse oximeter. Those who bought it preferably would ask a friend for their advice before looking for a USB charger or choosing a screen colour. But for others, the friend's opinion was not so important, and the USB charging and the screen colour took higher place in Table 6. The colour of the device was practically irrelevant to everyone.

When comparing the means of gender, age, price, purchase, year and usage (Table 7), the following results were found. The questioned men were younger than women (21.00 vs. 23.17). In 2019, the oldest participants have bought the devices. Women bought more often than men. However, there was great gender inequality (74 vs. 3 persons).

The lowest average price was recorded in the period until 2019 (UAH 270.00), and the highest – in 2020 (UAH 568.59), when COVID-19 was in the period of the greatest escalation.

The highest amount of devices was bought by 20- to 23-year-old students, namely, at the age of 22 years: 18 for mean price UAH 474.44 and at the age of 21 years: 17 for mean price UAH 525.88 (Supplementary Material).

It is interesting to note that the average purchase price for women was lower (UAH 439.64) than for men – UAH 700.00. Those who bought a more expensive device (UAH 524.83) used it more often than others who bought a cheaper one (UAH 473.60). Women in the group of those who did not buy a pulse oximeter were almost 2 years older (22.58) than men (20.75).

Statistical tests

The next step of the study was calculation of the distribution normality by Kolmogorov–Smirnov and Shapiro–Wilk tests

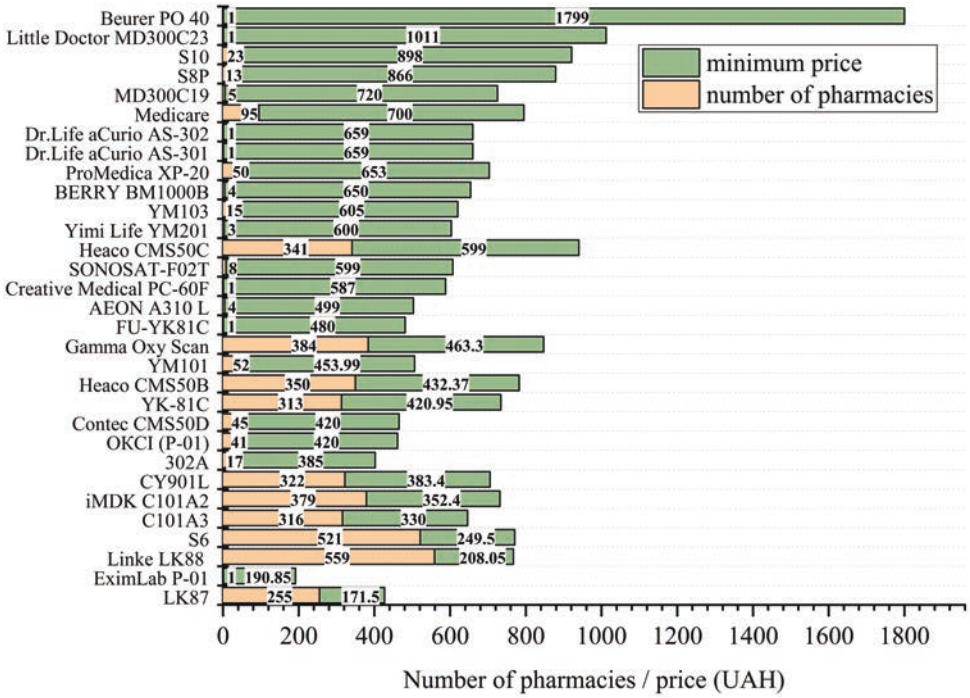

Figure 5 Number of pharmacies selling pulse oximeters versus their minimum prices.

for those, who bought pulse oximeters (77 responders), which showed that it was not normal (Sig. = 0). So, non-parametric Spearman's correlation was done. It was found that between almost all parameters of purchase, the correlation was positive and significant at the 0.01 level (two-tailed) (Supplementary Material). A moderate correlation was found between Pharmacist advice/Friend advice (ρ = 0.652, Sig. = 0), USB charge/Pharmacist advice (ρ = 0.647, Sig. = 0), Screen colour/Pharmacist advice (ρ = 0.632, Sig. = 0) and USB charge/Screen colour (ρ = 0.602, Sig. = 0).

Besides, a weak significance at the 0.05 level (two-tailed) correlation was found between price and friend's advice (ρ = 0.275, Sig. = 0.015).

But when calculating Spearman's rho for the entire sample size (170), the correlations significant at the 0.01 level (two-tailed) were lower due to the inclusion of data from people who had no true intent to buy pulse oximeters. So, correlations USB charge/Pharmacist advice (ρ = 0.459, Sig. = 0), Screen colour/Friend advice (ρ = 0.410, Sig. = 0), USB charge/Friend advice (ρ = 0.388, Sig. = 0) and Batteries/Device colour (ρ = 0.385, Sig. = 0) were among the top ones, still with moderate rate.

In the analysis of the one-sample *t*-test, the average price (UAH 482.01) of bought pulse oximeters obtained from responders' answers was compared with the mean minimum price (UAH 563.40), calculated as above. The following values were found: $t(76) = -2.884$; $P = 0.005$; mean difference = −81.387; 95% confidence interval of the difference with lower of −137.58 and upper of −25.19 values. So, people statistically significant would buy pulse oximeters at price lower than UAH 563.40.

Moreover, based on the results of the Levene's test, it was found that the variances of the compared groups of price and age did not differ statistically significantly by median (Levene's statistic (W) = 1.252, $P = 0.293$; Supplementary Material). So, a one-way ANOVA could be performed. As a result, it was revealed that prices in groups of different ages did not differ statistically significantly ($F = 1.104$, $P = 0.372$). Thus, the purchase price did not depend on age in this study. Also, when analysing the dependence of gender on price choice, the variances were also not statistically different by median (W = 0.942, $P = 0.335$), and the ANOVA test showed $F = 2.446$, $P = 0.121$. Thus, the price was not dependent on gender, but its F was of higher value than that of the price–age pair, so its correlation was 3 times more likely to occur. Analysis of the price-to-year ratio showed that the variances did not differ statistically significantly in terms of the mean (W = 1.295, $P = 0.283$). And the average price differs from the year of purchase ($F = 2.712$, $P = 0.051$) at the verge of significance ($P = 0.05$). However, as a result of multiple pairwise comparisons using the Scheffe test, it was found that there were no statistically significant differences between the studied years (Supplementary Material).

Limitations

Website data analysis

The level of reliability of the materials of each pulse oximeter presented on the Tabletki.ua website was a limitation of the presented data.

Questionnaire data analysis

Among limitations of the study were age, occupation and gender of participants. The majority were aged 19–23 (80.0%) of all those aged 19–48. The respondents were students of the Faculty of Pharmacy, so they were more knowledgeable about maintaining health than people in other professions. There was a significant gender inequality; women (91.2%) prevailed over men, which is due to the historical peculiarities of the gender ratio in medical university. Also during the study period in the

Table 3 All parameters reported for pulse oximeters

Model name	1[1]	2	3	4	5	6	7	8	9	10	11	Σ
S6	+	+	+	+		+	+	+	+	+	+	10
CY901L	+	+	+	+		+	+	+	+	+		9
Little Doctor MD300C23	+	+	+	+			+	+	+	+	+	9
Linke LK88	+	+	+	+				+	+	+	+	8
Creative Medical PC-60F	+	+	+	+	+		+	+				7
Medicare	+	+	+	+		+		+	+			7
C101A3	+		+			+	+	+			+	6
iMDK C101A2	+		+		+	+	+	+				6
302A	+	+	+	+				+	+			6
Contec CMS50D	+	+	+	+				+			+	6
YM101	+		+		+	+		+	+			6
Heaco CMS50C	+		+			+	+	+			+	6
MD300C19	+	+	+	+		+		+				6
EximLab P-01	+	+	+	+			+					5
YK-81C	+		+			+	+				+	5
Heaco CMS50B	+		+			+	+				+	5
Yimi Life YM201	+		+		+	+		+				5
Dr. Life aCurio AS-301	+	+	+	+			+					5
S8P	+		+			+	+	+				5
S10	+		+			+	+	+				5
Gamma Oxy Scan	+		+		+						+	4
SONOSAT-F02T	+		+		+		+					4
YM103	+		+		+			+				4
Dr. Life aCurio AS-302	+	+	+	+								4
LK87	+		+					+				3
AEON A310 L	+		+					+				3
ProMedica XP-20	+		+				+					3
BERRY BM1000B						+		+				2
Beurer PO 40					+			+				2
OKCI (P-01)												0
FU-YK81C												0
Σ	27	12	27	12	8	14	15	21	7	4	9	
%	87.1	38.7	87.1	38.7	25.8	45.2	48.4	67.7	22.6	13.0	29.0	

[1]1 – oxygen saturation (SpO_2), 2 – accuracy of SpO_2, 3 – pulse rate (PR), 4 – accuracy of PR, 5 – perfusion index (PI), 6 – auto-shutdown time, 7 – batteries AAA, 8 – colourful screen, 9 – temperature, 10 – humidity of usage, 11 – warranty.

Table 4 Summary of survey data

All participants				Who bought pulse oximeter			
Title	**Subtitle**	**Count**	**%**	**Title**	**Subtitle**	**Count**	**%**
Gender	Women	155	91.2	Gender	Women	74	96.1
	Men	15	8.8		Men	3	3.9
Purchase	No	93	54.7	Usage	Feeling unwell	52	67.5
	Yes	77	45.3		Each day	6	7.8
Year of purchase	Before 2019	4	2.4		Each week	0	0
	2019	5	2.9		Don't use	19	24.7
	2020	29	17.1				
	2021	39	22.9				
Overall		170	100.0	Overall		77	100.0

Table 5 Descriptive statistics of age (years) and price (UAH)

#	Age of all, *N* = 170	Age, who bought, *N* = 77	Age, who did not buy, *N* = 93	Price, UAH
Minimum	19	19	19	100.00
Maximum	48	48	43	1200.00
Mean	22.98	23.74	22.34	482.01
SE	0.388	0.677	0.427	28.215
SD	5.058	5.944	4.114	247.589
Range	29	29	24	1100.00

Table 6 Descriptive statistics of priorities when buying a pulse oximeter

#	Who bought, *N* = 77			#	Who did not buy, *N* = 93		
	Mean[1]	SE	SD		Mean[1]	SE	SD
Country	2.16	0.136	1.193	Warranty	2.23	0.134	1.295
Warranty	2.31	0.141	1.238	Country	2.29	0.124	1.194
Pharmacist	2.64	0.153	1.347	Batteries	2.45	0.129	1.247
Batteries	2.75	0.137	1.205	Pharmacist	2.55	0.131	1.264
Friend advice	2.86	0.144	1.264	USB charge	2.77	0.124	1.199
USB charge	2.92	0.139	1.222	Screen colour	2.87	0.131	1.262
Screen colour	2.92	0.134	1.178	Friend advice	2.90	0.134	1.294
Device colour	3.06	0.135	1.185	Device colour	3.11	0.122	1.175

[1]1 – the most important, 2 – less important, 3 – even less important, 4 – unimportant.

Table 7 Statistics summary of participants' number, mean of age (years) and price (UAH)

Participants		*N*	Mean, age	SD	Those, who bought		*N*	Mean, price	SD
Total	All	170	22.98	5.058	Gender	Women	74	473.18	246.913
Gender all	Women	155	23.17	5.233		Men	3	700.00	173.205
	Men	15	21.00	1.732	Total	All	77	482.01	247.589
Gender, who bought	Women	74	23.81	6.045					
	Men	3	22.00	2.000	Purchase	Before 2019	4	270.00	161.038
Total	Bought	77	23.74	5.944		2019	5	480.00	277.489
Gender, who did not buy	Women	81	22.58	4.318		2020	29	568.59	275.323
	Men	12	20.75	1.658		2021	39	439.64	210.473
Total	Didn't buy	93	22.34	4.114					
Purchase	Before 2019	4	21.75	0.957	Usage[1]	Feeling unwell	52	473.60	236.540
	2019	5	26.40	12.095		Don't use	19	491.53	242.707
	2020	29	23.07	4.765		Each day	6	524.83	381.733
	2021	39	24.10	6.052					

[1]Once a week or has already broken device – nobody.

fall of 2021, people were already used to the COVID-19 pandemic and were not as frightened as they were in early 2019. However, the main purpose of our survey was to see whether students in Ukraine buy and use pulse oximeters in their daily lives and to what extent.

Prospects

The protocol of pulse oximeter usage given by Gootenberg *et al.*[11] provides a feasible and safe framework of identification of the 'silent hypoxia' in the post-discharge period from the hospital. It would be good to develop such a protocol in Ukraine, too. Moreover, there is a new up-to-date Ukrainian governmental program,[27] namely gifting free smartphones to all vaccinated people aged above 60 years old. So, it will be valuable to provide them not only with a low mobile tariff, installed social or administrative programs. But also with health application with 24/365 online help or/and connection to their family physician or nurse to monitor their health, especially after COVID-19 positive test, with free certified pulse oximeter.[3, 28] Moreover, the introduction into the daily lives of patients, who stay at home, the Internet of Things (IoT)-based health monitoring system,[29, 30] which monitors body temperature, PR and oxygen saturation in real time and easily synchronizes with a mobile application for instant access, makes the analysis and

forecast of health status more accurate and timely, therefore, it can be a promising measure to combat the consequences of COVID-19 and beyond.

CONCLUSIONS

The pharmacy market of pulse oximeters, presented on the Tabletki.ua web resource (2021) in Kyiv (Ukraine), was analysed. It turned out that most of the models were made in the People's Republic of China. The number of pharmacies proposing the same model varied by about 500 times. The price of 31 different devices varied by about 10 times. The price of the same model could differ up to 4.2 times. Over the past year, Linke LK88 price has dropped almost 5 times due to market saturation. Among all studied models, S6, Linke LK88, iMDK C101A2 and Creative Medical PC-60F were chosen to be the most optimal for purchase. Despite a fairly good description of the devices, all manufacturers should provide more detailed information on the accuracy of pulse oximeters when used by patients with different skin colours.

According to the questionnaire, only 45.3% of respondents from the Faculty of Pharmacy with an average age of 22.98 ± 5.06 years have bought a pulse oximeter. They used it preferably only when they were not feeling well. And even a quarter of those who purchased the device did not use it at all. The lowest average price was found during the period until 2019 (UAH 270.00), and the highest – in 2020 (UAH 568.59), during COVID-19 greatest escalation. Students from medical university statistically significant would buy pulse oximeters for less than UAH 563.40. The average price of women's choice was 1.6 times lower than that of men. The older people bought the device earlier, more often and for a lower price. Still, due to limitations of the survey, the price did not depend on age ($F = 1.104$, $P = 0.372$) and gender ($F = 2.466$, $P = 0.121$), but there was a correlation between price and year of purchase ($F = 2.712$, $P = 0.051$). Participants were interested preferably in the quality of the device, its country of origin, warranty card and professional opinion of pharmacist. The choice of price was dependent significant on the advice of a friend, who also could be a pharmacist in this particular study.

Therefore, it is recommended that people of all professions pay more attention to the importance of monitoring oxygen levels and heart parameters. It is necessary to teach them how to use pulse oximeters more often and more correctly through television, the Internet or during a visit to the doctor in order to stay safe and sound as long as possible.

SUPPLEMENTARY MATERIAL

Supplementary data are available at *Journal of Pharmaceutical Health Services Research* online.

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Ethics Approval and Consent to ParticipateAll the procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 2008. Ethical approval (protocol №7 of 2 September 2021) from the Bioethics Committee of Zaporizhzhia State Medical University (Zaporizhzhia, Ukraine) was obtained before starting the study. The authors have received clear permission from all participants and respect their privacy.

Consent for PublicationAll authors agreed to submit to the *Journal of Pharmaceutical Health Services Research* for publication.

Data AvailabilityThe data that support the findings of this study are available from the corresponding author, L.A., upon reasonable request.

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