Prescription Medicines offered for Sale on the Dark Web: An Observational Study

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Abstract :The phenomenon of counterfeit drugs was widely discussed during the last decades. According to the World Health Organisation (WHO), counterfeit drugs are those that are knowingly mislabelled, and they may contain little or no active ingredient. Indeed, investigators have found toxic and fatal ingredients in some counterfeit drugs. The sale of these products is facilitated by the crypto market, and the products most traded are illicit opiates, stimulants, and prescription drugs. Consumers beside US dollars they use Bitcoin, a digital currency, to buy the products. Silk Road is a popular marketplace that was first discovered in 2011. Users access Silk Road using specialized TOR software.

Objectives: The aim of this observational study is to find the relationship between the prices and weight in grams and strength of tablets in milligrams of the traded counterfeit/falsified prescription drugs in the Silk Road marketplace during a specific period.

Method and setting: The setting of the study was conducted in the dark web at the SilkRoad platform, to open the dark web the steps initially included downloading TOR software, this link was obtained from google. The second step was to create an anonymous account to login into the platform. Data collection was based on drug advertisements data gathered from the website in the period from the 9th of June 2021 until the 24th of June 2021 were analysed by SSP software.

Results: 168 advertisements were analysed in the study. Analysis of 39 cocaine advertisements results were 95% CI (9.95– 48.71) and *p* value< 0.001; heroine analysis includes 44 advertisements resulted in 95%CI (12.1 – 44.21) and *p* value< 0.001, both models were significant. While the other models their results were not significant and have some limitations.

Conclusion: The final finding and results of the study indicate that there are a strong models to be studied and create good results and there are weak models that need further investigations.

Key words: counterfeit drugs; falsified drugs; crypto market; Darknet; Silk Road; marketplace, vendors; dealers; consumers; opioids; stimulants; Benzodiazepines; cocaine; heroin; sildenafil.

Introduction :

Counterfeit medical products are called by many names such as illicit, substandard and falsified. There is no standard definition of the term 'counterfeit medicine'(1, 2) .

The World Health Organisation (WHO) defines substandard drugs as 'authorised medical products that fail to meet either their quality standards or specifications, or both'. The WHO also defines falsified drugs as 'medical products that deliberately/fraudulently misrepresent their identity, composition or source'(3). The WHO adds that counterfeit drugs can imitate both the generic and the branded versions. These products may be deemed counterfeit based on incorrect ingredients, insufficient amount of the active substance, or false packaging (4). The problem of counterfeit drugs has increased in significance over the last two decades in both developed and developing countries , most notably in poorer countries (4, 5). This phenomenon was first identified in 1985 at a conference in Nairobi, Kenya (6). Large numbers of counterfeit drugs sold around the world are manufactured and produced in Asia, particularly in China (7).

In terms of the safety of counterfeit drugs, this kind of products can be extremely harmful to humans due to the discrepancies between these and their authentic counterparts in quality, safety and efficacy (4). According to WHO, the proliferation of counterfeit drugs has been aided by the lack of drug regulations in many countries, the increase in demand compared to supply and the remarkable increase in some drug prices (4) . Combating this problem will require a large-scale public effort. A crucial step in organising such an effort will be to increase public awareness of the dangers of counterfeit drugs and the damage that they can cause.

These drugs can lead to serious disease and even death. For example, more than 500 children died after taking counterfeit paracetamol (Acetaminophen) syrup containing the solvent diethylene glycol, which is a renal toxin substance (8-10). In another case, a high number of patients did not respond to antimalarial treatment because the drug they used did not contain enough of the active substance. In a similar case, antimalarial drugs were found to contain paracetamol (11).

Failure to treat malaria can quickly allow the parasites to become drug-resistant, a risk exacerbated in both of these examples. Beside that , not only are counterfeit drugs biologically hazardous, they are also economically harmful as they waste consumers' money without providing benefits (12). Moreover, patients who did not benefit from the drugs may lose their trust in medicine and the healthcare system (13). Thus, counterfeit and illicit drugs cause both direct and indirect harm to the user and the wider community.

Most counterfeit drugs are sold on online markets on the dark net and through social media (14). Although the terms *darknet* or *crypto market* are unfamiliar to most people, in recent years the use of counterfeit drugs has risen due to the increase in illegal online trading. The crypto market offers everything that consumers need to carry out transactions, including specific services such as escrow and rating system (15).

Darknet websites are not easy to access, and illegal activities are difficult to identify (14). For the most part, the crypto market comprises websites where vendors provide buyers with the illicit products, particularly drugs (16, 17). The recent surge in online trafficking and distribution through the crypto market can be attributed to a range of factors, such as increasingly widespread internet use and ease of access, the consequently wider reach of advertising via social media, and improvements in technology. Indeed, the first ever online trade for illicit drugs was between students at Stanford University in 1971 who used their institution's network to trade marijuana (18); the online drug trade has continued to evolve with the technology upon which it relies. Today, the deep web or darknet offers attractive advances in discretion: buyers' identities are shielded by false locations while drug traffickers are protected from legal liability (19).

The first public mention of this problem came from the United Nations Office on Drugs and Crimes (UNODC) in 2014, who predicted that the darknet and other hidden websites would be famous for the widespread sale of controlled drugs (18). Further research into the crypto market found that most of the drugs exchanged were controlled drugs and were bought by a particular group of customers. The researchers termed these products 'party drugs'. The quality and purity of these drugs are unknown, and certainly not reliable (19). To inspire confidence in prospective buyers, dealers occasionally provide details of the quality of their product.

However, due to their obvious vested interest, these dealers cannot be relied upon to objectively inform the consumer. Therefore, some consumers order the same product from different vendors for comparison (20). These consumers then review the quality and price of various product samples to write a reviews for other customers who may purchases from the same vendor (16).

A study conducted in 2017, argued that the price of illicit drugs was higher on the darknet than on the street (16). In contrast, another study observed that the ease of using the websites and low cost were the reason why customers chose to purchase drugs online rather than in person (21). Most of online drug trading is conducted using digital currency Bitcoin (BTC) (22), financial security is ensured through the use of third-party service called escrow services. In this system, a third party holds the funds until the buyer receives the product, then transfers the payment to the dealer (16). Approaches to the problem of illicit drugs differ around the world. For instance, the U.S. Department of Justice, the Food and Drug Administration (FDA) and INTERPOL all target the supply chain. In some countries, the production of falsified drugs is only lightly penalised (10).

There are many websites on the darknet that are known for illicit drug trading. Among the most notorious of these is the Silk Road marketplace, home of a thriving trade in illicit drugs, controlled substances and other illegal commodities. Indeed, the Silk Road marketplace first appeared on the deep web in 2011. The site was built by an anonymous developer under the pseudonym 'Dread
Pirate Roberts'. Silk Road soon became a well-known shop on the deep web, and was said to match Amazon in ease of use (23). The Federal Bureau of Investigation (FBI) closed the Silk Road website in October 2013, but on 6 November, a new version of the website was set up by other hackers (21). This second website and others have been shut down several times, but new versions are created with sufficient speed to largely mitigate any negative effect on the growth of the marketplace or in consumers' interest (24, 25).

Today, using the website is easy and convenient; people can shop on Silk Road and browse anonymously (26, 27). Once the buyer signs into the website, various advertisements for drugs appear on the front page (28). The details of the vendors and buyers on the website are entirely anonymous and the vendors can sell and trade drugs worldwide. Items and services are paid for using BTC (29). As this website is on the deep web, access is possible only through software called The Onion Router, commonly abbreviated to TOR, which encrypts IP addresses. TOR was first used in 2002 (23, 26).

The security of payments is ensured by an escrow system as well as private messages on TOR (23, 30, 31). An advantage of the online drug trade is that vendors and consumers need not meet in person, eliminating the risk of physical violence that has traditionally accompanied illicit trade (22).

Another study has found that most vendors on these websites last around three months before disappearing, but were unable to identify a specific reason for this (30). Although vendors' locations are concealed on the dark web, the shipping origins in advertisements of around 40% of vendors are in the United States (24). The same study showed that most consumers were from the USA, followed by the United Kingdom and Australia (32). In 2005 the United Nations Office on Drugs and Crime (UNODC) found that around $300 billion was spent in the trading of illicit drugs in the USA (22). For this reason, in particular, more global and governmental legal attention should be devoted to these websites.

As there are many counterfeit drugs sold and traded in the Silk Road marketplace, this paper focuses on some of less easily accessible prescription drugs sold on the platform. Eight examples will be considered from the opioid, stimulant and benzodiazepine groups. These will include cocaine, heroin, amphetamine, oxycodone, methamphetamine, alprazolam (Xanax®) and diazepam. Moreover, one study defines drug abuse as "the use of a substance to modify or control mood or state of mind in a manner that is illegal or harmful to oneself or others" (33).

Furthermore, overdose deaths in the United States have doubled since 1999, due in large part to an oversupply of opioid analgesics (34).

Americans are thought to be responsible for 80% of global opioid consumption and two-thirds of global illicit drug consumption. Prescription opioids are used for non-medical purposes by about 20% of Americans (33); Opioid abuse and addiction have a negative impact on attendance and productivity at work.

Taking into account medical, economic, social, and criminal consequences, the annual cost of this abuse is approximately half a trillion dollars. Patients who abuse opioids incur annual direct health care costs 8.7 times greater than those who do not (33). Moreover, in terms of stimulants, statistics clearly show that the United States has the highest usage rates. CNS stimulants have also proven popular in the United Kingdom and Australia (35). Alprazolam is the most commonly purchased sedative from vendors in the

United States, and is gaining popularity in the United Kingdom despite the fact that it is not a National Institute for Health and Care Excellence (NICE) recommended medicine and hence is not prescribed by NHS doctors (35).

The last drug presented in our study is sildenafil, known by the brand name Viagra®, is a phosphodiesterase type 5 inhibitor (PDE5i) medication commonly used to treat erectile dysfunction (ED) (36, 37). Sildenafil was first used in the 1980s to treat angina, administered at a dose of 200 mg. By 1993, sildenafil had been overtaken in effectiveness by other antianginal drugs (38). From when sildenafil was first used, many patients appreciated a particular side effect: the drug encouraged penile erection. So, from the early 1990s, sildenafil was used to treat ED (38). As medical intervention for ED became more commonplace, the first treatment approved was sildenafil (Viagra™, Pfizer) (37, 39).

The PDE5i drugs used to treat ED are particularly vulnerable to counterfeiting due to the embarrassment most patients feel requesting them from a doctor (36, 40). To address this problem, Pfizer began selling Viagra® from their own company website in 2013 in an attempt to allow their customers the same degree of anonymity afforded by purchasing on the black market (41). However, in 2014 60% of the sildenafil in Netherland was purchased from illegal sources and was suspected of being counterfeit (42).

The Medicines and Healthcare products Regulatory Agency in UK analysed counterfeit Viagra and found that the samples contained between 0% and 100% of the active ingredient indicated on the label. The counterfeit Viagra® included caffeine, lactose and only 30 mg of sildenafil when there was supposed to be 100 mg. Another sample of counterfeit Viagra® contained paracetamol and metronidazole. Each of these drugs can cause liver damage, and it is prohibited to take metronidazole with alcohol as there serious drug-food interaction (36). Other samples of counterfeit Viagra® were seized in Hungary. These contained only amphetamine and other stimulants (36).

A study of two samples of counterfeit sildenafil found that the active ingredients were different from those in legal Viagra® (42). Moreover, to imitate the blue colour of the authentic Viagra® tablets, some counterfeit versions were coloured with printer ink (36). Without an active ingredient, not only does counterfeit Viagra® convey no health benefit whatsoever, it can also cause antimicrobial resistance (43). For example, a death was reported in Singapore of a man who used an ED drug that contained glyburide (43). To sum up, Viagra® is a legal drug, approved for specific conditions. It provides good outcomes when it is legal and used in appropriate ways. Those who misuse or overuse on a drug can suffer serious side effects and even death.

Objectives:

Therefore, on the bases of the background of misuse and abuse of the counterfeit prescription drugs that traded online, the aim of this piolet observational study is established as to find if there is a relation between the prices differences and the products weight or strength per tablet in a specific time period.

Method and setting:

1-Literature review:

For the first part of this study, papers from several databases were collected and examined to understand the issues at hand. The databases were: PubMed, the University of Brighton library, Google Scholar, and the WHO website.

For this study the main research aim was to investigate counterfeit drugs in general. The focus was then narrowed to consider counterfeit drugs that are traded and sold on the darknet. At this point, the keywords for searches included 'Silk Road; crypto market; illicit drugs; abuse; misuse'. The search was narrowed further to focus on counterfeit prescription drugs traded online. The keywords used were 'counterfeit; stimulants; opioids; benzodiazepines; sildenafil; illegal; sexual; danger'. The date for the search was adjusted to begin in 2000. Filters included journal articles, conference proceedings and e-books – all in the English language.

2-Ethical approval:

The study was ethically approved by Pharmacy and Biomolecular Sciences (PABS) Research Ethics Panel on 13/05/2021 and the reference is: 2021-8305. Approval was granted on receipt of a statement from the researchers detailing how the dark web would be safely accessed during the study period.

3-Study design:

This study is an observational design study in the dark web, the URL link that obtained from google is (http://silkroad6ownowfk.onion).

4-Setting:

The setting for this study is the black market, specifically the Silk Road website. Logging onto the

Silk Road website required several steps. The first of these was to download the TOR browser. Second, the Silk Road URL was taken from Wikipedia.

The third step was to create an anonymous account on Silk Road for the purposes of this study.

5-Participants:

Participants were included in this observational study if they were presented for sale the items that studied in this study. This study investigated several advertisements involving counterfeit drugs on the Silk Road website. All the cohort are illegal drug sales completed by people on the black market and each sale with all the accompanying data is considered data to be analysed. As the participants enrolled in the study were those making

offers for sales are unknown, each advertisement containing the name, price, and weight of each drug (along with any other information supplied) is discussed from here and forward. Hence, the number of advertisements for each drug will vary according to the number of sales:

- Cocaine has 39 advertisements
- Heroine has 44 advertisements
- Amphetamine has 21 advertisements
- Benzodiazepines has 21 advertisements
- Oxycodone has 19 advertisements
- Methamphetamine has 16 advertisements
- Viagra® has 8 advertisements

This is a cross-sectional study and meets all the relevant eligibility criteria. All sales were completed between 9 June 2021 and 24 June 2021.

6-Variables:

- The outcome variables are number of grams and milligrams of each drug.
- Exposures is availability of each drug for sale.
- Predictors are currency of the sales.
- Potential confounders are unknown; this study and analysis seek to identify them.

As the study is a pilot scoping study, we do not have potential confounders, effect modifiers or diagnostic criteria.

7-Data source and measurement:

The main point of interest was to define the weight and strength in grams and milligrams for drugs, quantity of sales and the price range. All the measurement was done in Statical Package for the Social Sciences (SPSS) software.

8-Bias:

Researcher has been chosen only one platform to collect the data from, which could be a source of bias in our study.

9-Statical methods:

During this study, SPSS software was chosen to perform different types of analysis on data. The results are presented in different types of tables and graphs. For each drug we have used descriptive analysis followed by linear regression analysis. The purpose of linear regression analysis was to find the regression equation and *p* value significance. From the regression analysis was plotted charts for the data.

10-Data collection:

For the data collection part, the data in the time series was manually collected from the Silk Road website. Next, conducting a search in the Silk Road website with the keywords Cocaine, Heroin, Amphetamine, Oxycodone, Methamphetamine, Benzodiazepines (Xanax®- Diazepam) and Viagra®. The data were then tabulated using Microsoft Excel for analysis using the SPSS software.

Data was collected daily from the 9th of June to the 24th of June. Initially the intention was to use RStudio software to import the data from the website directly but were precluded by compatibility issues with dark web platforms, meaning that this stage of the study had to be done manually.

11-Sample size:

As the study is a pilot study, therefore the sample size not subject to any requirements regarding sample size.

Results:

Total number of 168 advertisements were studied in this study. The results present the relationship between the price of drugs sold on the Silk Road website in BTC and United State Dollars (USD) currency and the strength of tablets or weight of these drugs at a specific time. The participants are the people who trade on the black market, and each sale with all relevant data counts for one participant. Because the identity of the second party in any of these transactions cannot be done, each advertisement comprises the name of the drug, the price, the weight, and any other information for each drug was studied in this study. To focus on the study's aim, the products' names and shipping locations were excluded from the analysis.

1- Stimulants:

The first stimulant drug investigated was cocaine. Table 1 shows the results of descriptive analysis of 39 samples (advertisements) obtained from Silk Road website. The mean is 27.11g and the confidence interval (CI) of 95% (9.95– 48.71) with *p* value< 0.001 (table 3 in appendix). The mean monetary value of all Cocaine purchases is 0.035 BTC and 1352.97 USD. Moreover, the regression linear equation (Y= a+bX) for every 1g of Cocaine in BTC is Y= 803.585 + 0.984 (table 1 in appendix). In addition, the regression linear equation in USD is Y= 0.021 + 0.984. The histogram in (figure1) shows the data presented in table 1. The y-axis presents grams purchased, which is the dependent value, while the x-axis presents the price in BTC. From the chart, it can be seen that the most frequently purchased quantity is 16-18g. In table 1 the grams range of purchased Cocaine on the website is between 0-250g.

The next drug in the stimulants group is amphetamine paste. The total advertisements for sale on the platform were 21, and the mean =243 g, 95%CI (58.22 – 521.07).

The BTC currency mean is 0.005 BTC and the USD mean = 202.24 USD (table 1). The *p* value <.001 (table 3 in appendix). The regression equation of BTC is Y= 42347.926 + 0.819; for USD, Y= 1.234+ 0.819 (table 1 in appendix). Furthermore, from the histogram chart (Figure 2) it is clearly that the highest demand is for orders of amphetamine paste weighing 8 – 10 g.

The last stimulant sample in the study is methamphetamine. Table 1 shows that there are 16 methamphetamine samples; the mean= 9.88mg, of 95%CI (3.81 – 17.69); and the *p* value =0.058 (table 3 in appendix). The mean of BTC currency = 0.009 BTC and the mean of USD is 335.25USD (table 1). The regression linear equation for methamphetamine in BTC is Y= 562.668+ 0.482, and in USD Y=0.017+ 0.507 (table 1 in appendix).

Moreover, the graph in (figure 3) shows that methamphetamine is most frequently purchased in quantities of around 11g. Table 1 shows that the range in weight in grams among the samples was 1-50g.

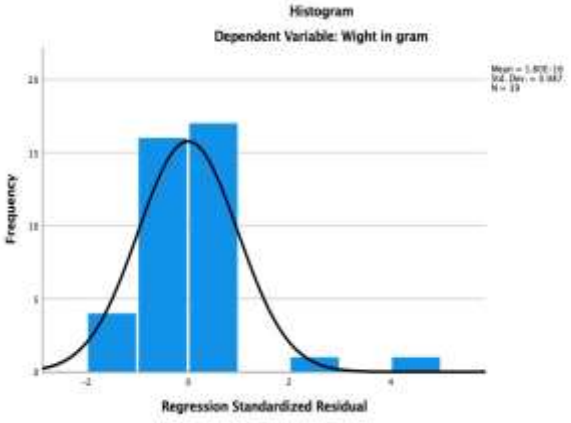

Figure (1): Cocaine Model

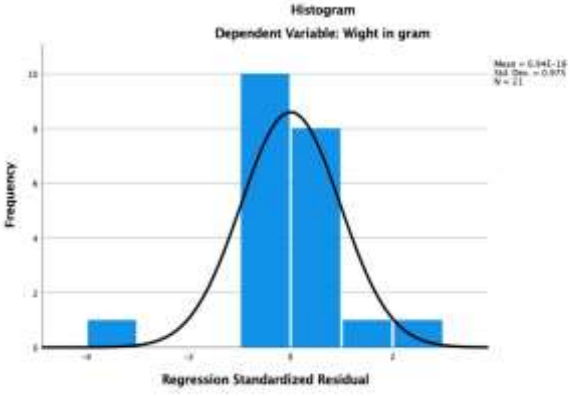

Figure (2): Amphetamine Model

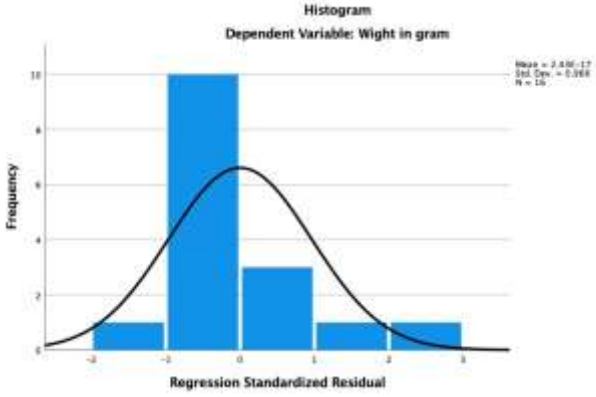

Figure (3): Methamphetamine Model

2- Opioids:

Table 2 shows the results of descriptive analysis of 19 oxycodone samples obtained from the Silk
Road website. The mean strength is 168.42mg, 95%CI (37.38 – 398.14), and the *p* value 0.012
(table 3 in appendix). The mean currency value from all oxycodone purchases is 0.009 BTC and 381.37 USD (table 2). The regression linear equation for oxycodone in BTC is Y= 28924.909 + 0.562, and in USD Y= 0.755 + 0.562 (table 1 in appendix). Figure 4 shows that the strength of formulation most frequently purchased was 30mg per tablet.

In contrast with these findings are the results for heroin. In Table 1, the mean weight in grams of
44 total sales is 26.73g, 95%CI (12.1 – 44.21). The mean values for currency are 0.035 BTC and 588.44 USD. The *p* value for heroin is reported as <.001 (table 3 in appendix). In addition, the linear regression equation for heroin is Y= 1802.234 + 0.988 in BTC, and in USD Y = 0.053 +
0.988 (table 1 in appendix). The histogram shows that the most frequently purchased quantity of heroin was 25-27g.

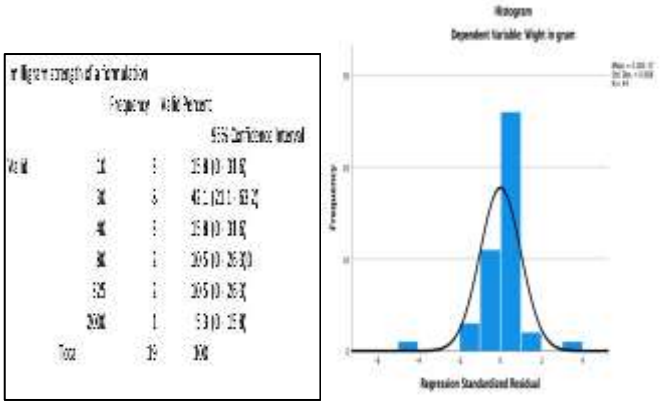

Figure (4): Oxycodone Model

Figure (5): Heroin Model

3- ***Benzodiazepines***:

In this group the analysis includes data on two drugs, Xanax® and Diazepam. Including both drugs, the sample size was 21; the mean strength in milligrams was 3.9 mg, CI95% (2.6 – 5.21). The mean values for currency are 0.015 BTC and 582.62 USD (table 2). As displayed in table 2 and in table 1 in the appendix, the regression equation in BTC is Y= -10.199 + (-0.137); in USD Y= 0.000+ (-0.137). The *p* value is reported as = 0.554 (table 3 in appendix). The histogram chart (figure 6) reports that the most frequently purchased strength in milligrams per tablet was 2mg.

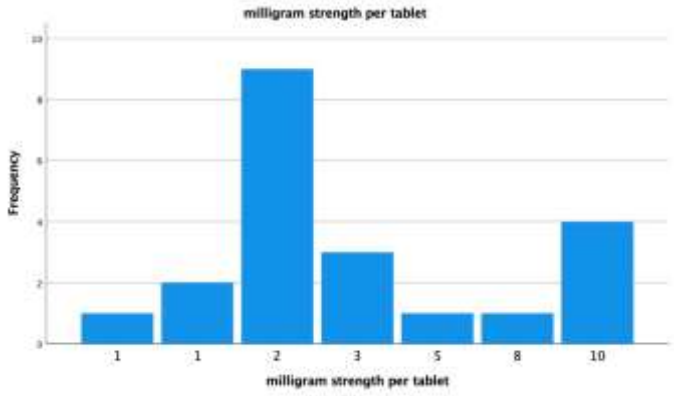

Figure (6): Benzodiazepines Model

4- Viagra:

Globally, the most counterfeited drugs in the world are antibiotics; in Europe, however, this title is claimed by PDE-5i

medications (39). It is for this reason that Viagra® is included in data collection and analysis. As shown in table 2, the sample size is very small (8 samples) but the analysis of the data was available. The mean strength in milligrams per tablet =93.75mg, 95%CI (81.25 – 100). The currency mean is 0.001 BTC, and 40.88 USD. As presented in table 1 in the appendix, the regression equation is Y= -1733.275 + -0.077 in BTC, and the USD regression equation is Y= (-0.051) + (-0.077).

Table 3 in appendix presents *p* value = 0.856. Lastly, the histogram in figure 7 shows that the milligram strength per tablet for almost all sales was 7mg.

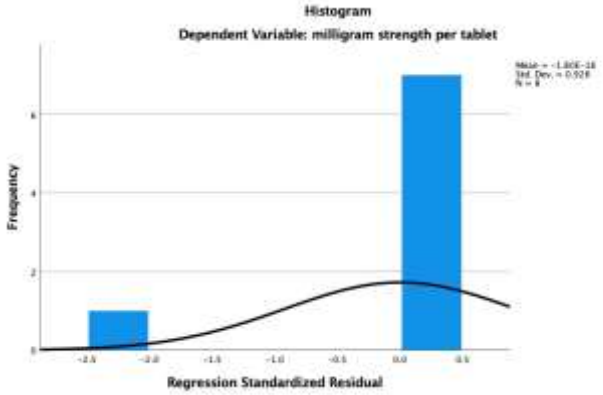

Figure (7): Viagra Model

Table 1

Prescription drugs		Powder/paste weight in g			Price in BTC		Price in USD	
		Mean N		Std. Deviation	Mean	Std. Deviation	Mean	St. Deviation
Cocaine	Min-Max weight in g (0 – 250g)	39	27.11g, CI 95% (9.95 - 48.71)	61.376	0.035BTC, CI 95% (0.014 - 0.061)	0.075	1352.97 USD, CI95% 2255.98)	2867.435
Heroin	Min-Max weight in g (0 – 250g)	44	26.73g, CI 95% (12.1 - 44.21)	55.719	0.017BTC, CI 95% (0.009 - 0.027)	0.030	588.41USD, CI95% (319.71 – 957.63)	1048.884
Amphetamine	Min-Max weight in g (1-2500g)	21	243g, CI 95% (58.22- 521.07)	574.092	0.005BTC, CI 95% (0.001-0.011)	0.011	202.24USD, CI95% 380.02)	380.916
Methamphetamine	Min-Max weight in g (1-50g)	16	9.88g, CI 95% (3.81 - 17.69)	14.332	0.009BTC, CI 95% (0.004-0.015)	0.012	335.25USD, CI95% 556.11)	422.424

Prescription drugs			Tablet/Capsules strength in mg		Price in BTC		Price in USD	
		N	Mean	Std. Deviation	Mean		Std. Deviation	Mean	Std. Deviation
Benzodiazepines	Min-Max strength in mg (1-10mg)	21	3.9mg, CI 95% (2.6 - 5.21)	3.364	0.015 BTC, CI 95% (- 0.036)	0.003	0.045	582.62USD, CI95% (138.39-1366.99)	1713.597
Oxycodone	Min-Max strength in mg (10-2000mg)	19	168.42 mg, CI 95% (36.33-392.36)	453.223	0.009 BTC, (0.006-0.013)	95 %	0.008	381.37USD, CI95% (247.60-533.01)	337.274
Viagra	Min-Max strength in mg (50-100mg)	8	93.75 mg, CI 95% (81.25-100)	17.678	0.001BTC, (0.000-0.001)		0.000	40.88USD, CI95% 62.25)	26.920

Table 2

Discussion:

According to WHO, counterfeit and illicit drugs have inspired increasing public health concern worldwide, and around 10-15% of drugs sold worldwide are counterfeit (44). Moreover, the FDA reported that the most counterfeit drugs traded in the US are prescription drugs (45) and the drugs counterfeited most often are controlled substances, sedatives, hypnotics and drugs that enhance sexual dysfunction (46). Patients in developed countries such as the United States (US), the United Kingdom (UK), Japan, Australia and Canada are exposed to the harm caused by these types of drugs (47). Therefore, the falsified medicines directive (FMD) which developed by the European Parliament in 2011 is applied in European Union countries to ensure patients safety (48). The professional obligation of all pharmacists across all the world to provide medicines that are high quality and standard for patients. Regarding the most famous drugs sold on Silk Road, are cannabis, drugs that enhance sexual activity and various stimulants such as cocaine (49). Many counterfeit products have very high-quality packaging and a convincing appearance; this puts the consumer at increased risk of unwittingly consuming a counterfeit substance and suffering the resultant health complications (39, 50).

Since this is a pilot study, expectations could not be informed by previous research completed by this team or any other researcher. And did not know what to expect. So, Silk Road was chosen, a famous darknet platform, and picked different prescription drugs from the website to analyse.

1-Stimulants:

Darknet platforms attract attention to the trade of illicit drugs and controlled substances that need legal and medical supervision (20). To begin with, the results of the cocaine analysis indicate that the CI is a narrow window, which is highly significant with *p* value. From the regression linear equation for both currencies, it is clearly that the regression number is high and prescribe good model. The price is not shown in the chart (Fig 1), but the spread of the data is depicted in standardised plots. The mean is set at 0 and std. dev at 1, following standard normal distribution. Table 2 in the appendix reports the R square number = 0.967. This is a high value indicative of a good model. The prediction of coefficient number is high and efficient but limited to the weight range 0-250g; it is not possible to know whether the model can be applied out with this range. Nonetheless, the R value is very high in this model, indicating that weight can reliably predict the price for each gram. These results are similar to those obtained in analysing the second stimulant drug, amphetamine, where again it is presented high *p* value significance. The limitation in regression equation analysis is that the data were not homogeneous, making it difficult to compare different types, formulations and strengths. The prices in USD varied significantly, so this is not a reliable regression (figure 1 in appendix).

On the other hand, we can see that the methamphetamine results are very different from the cocaine and amphetamine results. Methamphetamine results show that *p* value is not significant and that the linear regression equation and R square= 0.233 (table 2 in appendix), too low to be an efficient model.

2-Opioids:

Moving to the opioids group, the analysis of oxycodone that covered different brands and formulations of the product (pills, powder). This meant that the regression number (table 2 in appendix) was low and unreliable, as it could not take into account the differences in formulations. In addition, the results of the oxycodone analysis indicate that the 95%CI is a very wide range, and not significant because the *p* value is not <0.001. Based on these results, oxycodone is not as useful a model as cocaine. However, separate analyses of each formulation of oxycodone may yield more promising results, and future studies should investigate this. In contrast to earlier findings, however, the heroin results present a good model with high regression number = 0.988 (table 2 in appendix), and narrow 95%CI window with significant *p* value. All of these findings make the heroin model more interesting and reliable more than the oxycodone model in the opioids category.

3-Benzodiazepines:

From the results of the benzodiazepine analysis, it is obvious that the *p* value is not significant. Likewise, the R square value of 0.019 is too low and unreliable to be the used as a model. The sample included different brands and formulation such as pills or bars, which may have affected the reliability of the results.

1- ***Viagra:***

In 2004 around 10.6 million counterfeit sildenafil tablets were detected, and between 2004 and 2008, 35.8 million counterfeit tablets were produced (39, 42). In addition, the most counterfeited drugs in the world are antibiotics, but in Europe more PDE-5i medications are fake (39). Finally, the results of Viagra: analysis are neither significant nor safe to study.

Conclusion:

To conclude the thesis, prices of different prescription drugs sold on the darknet can be correlated to the strength or weight of the drugs in a specific period during the COVID-19 pandemic. From the results, we can see that the cocaine and heroin models' analysis provide clear linear association between price and strength or weight, contrary to all other models generated as part of this study. The successful linear regression equation that can predict how much every gram or milligram will cost is a powerful finding that merits further investigation and application. Overall, more need to be done by regulators and policies setters to protect the people who consume these drugs.

Limitations:

Certain limitations happened throughout conducting this study. Firstly, due to the nature of the study as a pilot study, one limitation is that the study data collected from one platform and the sample size is not large. In addition, another limitation to mention is that the successful models based on the cocaine and heroin data have only been tested within a certain weight range, beyond which their reliability remains unproven.

Future Studies:

Further research can endeavour to correct the unreliability of the oxycodone and amphetamine models by analysing each product alone as proposed above. The limitations for this study should provide new hypothesis for future research. A new study could build on this research by compare the darknet prices of the drugs analysed here with their legal and original prices. Finally, this study should alert us to the need to limit the trading of these drugs by generating strict regulations and restrictions on the platforms, vendors and buyers.

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Appendix:

Coefficient table

		Unstandardised Coefficients	Standardised Coefficients	95.0% Confidence Interval for B
		B	Beta	
Cocaine model	(Constant)	-1.38		(-5.416 - 2.656)
	Price in BTC	803.585	0.984	(754.48 - 852.689)
	Price in USD	0.021	0.984	(0.020 - 0.022)

Dependent Variable: Weight in g

Dependent Variable: Weight in g

Heroin model (Constant)	**-4.163**		**(-7.153, -1.174)**
Price in BTC	**1802.234**	**0.988**	**(1716.169 - 1888.3)**
Price in USD	**0.053**	**0.988**	**(0,050 – 0.55)**
Dependent Variable: Weight in g			
Amphetamine (Constant) model	**-6.516**		**(-182.407 - 169.375)**
Price in BTC	**42347.926**	**0.819**	**(28081.751 - 56614.102)**
Price in USD	**1.234**	**0.819**	**(0.818- 1.649)**

Dependent Variable: Weight in g

Benzodiazepines (Constant) model	**4.061**		**(2.408-5.715)**
Price in BTC	-10.1	-0.137	(-45.631-25.233)
Price in USD	0.0	-0.137	(-0.001 – 0.001)
Dependent Variable: Tablet/capsules strength in mg			
Oxycodone model			(-405.847-166.459)
Price in BTC	28924	0.562	(7152.266-50697.551)
Price in USD	0.7	0.562	(0.187- 1.324)

Dependent Variable: Tablet/Powder strength in mg

Coefficient table

Methamphetamine model	(Constant)	4.332	(-4.715-13.378)
Price in BTC	562.668	0.482	(-22.978-1148.313)
Price in USD	0.017	0.507	(0.000-0.034)
Dependent Variable: W			
Viagra model	95.814		(64.415-127.213)
Price in BTC	-1733.275	-0.077	(-24183.49-20716.94)
Price in USD	-0.051	-0.077	(-0.705 – 0.604)

Dependent Variable: Tablet/capsules strength in mg

Table (1) appendix

Model summary

	R Square	Adjusted R Square
Cocaine model	0.967	0.967
Dependent Variable: Weight in g		
Heroin model	0.977	0.976
Dependent Variable: Weight in g		
Amphetamine model	0.670	0.653
Dependent Variable: Weight in g		
Benzodiazepines model	0.019	-0.033
Dependent Variable: Tablet/capsules strength in mg		
Oxycodone model	0.316	0.276
Dependent Variable: Tablet/capsules strength in mg		
Methamphetamine model	0.233	0.178
Dependent Variable: Weight in g		
Viagra model	0.006	-0.16
Dependent Variable: Tablet/capsules strength in mg		

Predictors for all drugs: (Constant), Price in BTC and USD

Table (2) in appendix

	P value Sig.
Cocaine model	<.001
Heroin model	<.001
Amphetamine model	<.001
Benzodiazepines model	0.554
Oxycodone model	0.012
Methamphetamine model	0.058
Viagra model	0.856

Table (3) in appendix

Price in USD			
		Frequency	Percent
Valid	6	1	4.3
	10	4	17.4
	15	1	4.3
	19	2	8.7
	21	1	4.3
	22	1	4.3
	34	1	4.3
	55	1	4.3
	60	2	8.7
	75	1	4.3
	90	1	4.3
	135	1	4.3
	157	1	4.3
	220	1	4.3
	260	1	4.3
	440	1	4.3
	1250	1	4.3
	1350	1	4.3
	Total	23	100

Figure (1) in appendix