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Portfolio Spiking with Cryptocurrency: A Risk-Adjusted Performance Analysis

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Abstract

The objective of this study is to provide empirical documentation on the risk-adjusted performance of portfolios formed by investing in a Cryptocurrency such as Bitcoin and a risk-free asset. The study evaluates the performance of these Bitcoin-spiked portfolios using statistical measures grounded in modern portfolio theory. Market returns are adjusted for the degree of total risk, systematic risk, and downside risk inherent in each portfolio, and the securities are then ranked on the basis of risk-adjusted performance. In addition to standard Sharpe, Jensen, and Treynor performance measures, two newer evaluation metrics, the Modigliani and Sortino measures, are used for ranking the portfolios. We report that these portfolios have varying levels of risk and return. Our key finding is that these portfolios' risk-adjusted returns are not only quite impressive but also exceed that of S&P 500, our benchmark market portfolio. The implication of our results is that investors with higher risk tolerance could earn substantially higher returns by including a larger percentage of Bitcoin in their portfolios. Our results should be informative to individual and institutional investors contemplating investing in cryptocurrencies but aware of their high risk.

Keywords: Cryptocurrencies, Bitcoin, Portfolio Analysis, Performance Measurement

I. Introduction

Investors seek assets to include in their portfolio which would raise the level of expected return with an acceptable increase in level of expected risk. In recent times, cryptocurrencies have received much attention as an asset group that could possibly be included in an investment portfolio. The most commonly traded cryptocurrency is Bitcoin. In fact, as of December 31, 2021, Bitcoin is estimated to have a market cap of about US$ 900 billion, which is worth half the market cap of the entire cryptocurrency universe. At this time, to our knowledge, there is no rigorous study of the increase in return per unit of risk that could be attributed to the inclusion of Bitcoin in a securities portfolio. This study investigates the effect on portfolio return and risk by "spiking" a safe portfolio of U.S. Treasury bills with a speculative volatile asset like Bitcoin. The study examines the risk-return characteristics of 10 portfolios that include Bitcoin and 4-Week US Treasury Bills in varying proportions.

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Bitcoin can be bought on digital currency exchanges. Further, third party exchange brokers, including Bitcoin ATMs and debit cards, will exchange Bitcoin for dollars at a given rate. In 2017, the CBOE (Chicago Board Options Exchange) and the CME (Chicago Mercantile Exchange) started trading Bitcoin Futures as well as Micro Bitcoin Futures. Bitcoin is now legal tender in El Salvador and is increasingly gaining global acceptability as a medium of exchange. Exchange traded funds (ETFs) based on Bitcoin are also available to investors. The most widely traded Bitcoin-based ETF is managed by ProShares (2021) and trades under the ticker symbol BITO.

Prior studies on cryptocurrencies focus on the riskiness and diversification implications of these securities. For example, in their study Brauneis and Mestel (2018) show that there are substantial changes in cryptocurrency prices, with maximum day-to-day fluctuations exceeding 70 percent. Luo et al. (2021) point to "immense price fluctuations" that are persistent in these markets. Malladi (2022) finds that the standard deviations of daily returns of cryptocurrencies are significantly larger than stocks, gold, and bonds. Regarding diversification benefits, Bakry et al. (2021) indicate that cryptocurrencies can hedge safe haven properties and diversify portfolios when the market conditions are normal. Mroua et al. (2022) show that adding cryptocurrencies to commodities and stocks provides a good hedge.

The research problem that this study addresses is to identify an optimal level of Bitcoin that an individual should hold in an investment portfolio, given their comfort level with bearing risk. A unique contribution of this paper is a comparison of the risk level of two different kinds of investment portfolios, one containing a highly risky asset, Bitcoin, held in combination with a risk-free asset (T-Bills) in order to mitigate risk, and another portfolio containing only stocks. Existing literature on the subject has a gap in that, while other studies as we discussed above highlight the risk inherent in holding cryptocurrencies and their ramifications for diversification, to our knowledge, no other study compares this volatility with the risk embedded in holding stocks. This comparison is made with a view to providing some empirical documentation to investors who are contemplating buying Bitcoin, but are not sure of the extent to which they should expose their portfolios to this risky asset. The results of the study should be of great interest to investors, asset managers, and financial planners.

Following this introduction, the rest of the paper is structured as follows. Section 2 presents a review of the literature on the theoretical underpinning of cryptocurrencies and summarizes pertinent studies in the area of modern portfolio theory. Section 3 reports the performance of Bitcoin/risk-free asset portfolios on a risk-adjusted basis, using the S&P 500 Index as a benchmark for comparison purposes, and the yield on 4-Week US Treasury Bills as a proxy for the risk-free rate of return. Section 4 presents an analysis of the empirical findings and Section 5 concludes the paper.

II. Literature Review

Satoshi Nakamoto (2008) is credited with conceptualizing Bitcoin as a payment mechanism that does not need the services of a financial intermediary. It needs to be noted that the true identity of the person or group that used this pseudonym is unknown. Cryptocurrencies use encryption to verify and secure transactions. The encryption which serves to secure bitcoin as a payment mechanism is based on Elliptic Curve Cryptography. Technical details on the standards for efficient cryptography are reported in Centicom Corp. (2010). The mathematical foundation of cryptography is the generic elliptical curve:

$$y^2 = x^3 + ax + b$$

The cryptosystem based on this structure is described in Koblitz (1987). An excellent exposition of elliptical curves and their use in cryptography can be found in Seelinger (2021). John, O'Hara, and Saleh (2022) explain the economic significance of using blockchains to create Bitcoin. An excellent summary of the history and meteoric rise of Bitcoin can be found in Chohan (2022).

There are two distinct streams of literature regarding the empirical behavior of cryptocurrencies in investment portfolios: the first group of studies analyze portfolios composed of only cryptocurrencies and the second group of studies focus on portfolios of a variety of securities besides cryptocurrencies. Among the first group of studies, Burggraf (2019) shows that portfolio optimization strategies perform better than equally-weighted portfolios and individual cryptocurrencies. He also shows that the best performing strategy is the long-only minimum variance portfolio. Brauneis and Mestel (2019) utilize the Markowitz mean-variance framework to show that combining cryptocurrencies enhances low-risk investment opportunities. Li et al. (2022) find that modeling the dynamic asymmetric dependence among cryptocurrencies can lead to major economic gains. Culjak et al. (2022) study the optimization of sectoral cryptocurrency classification portfolios. They show that five of the six strategies they test perform better when they include business services, exchange, and financial sectors.

One of the studies that examine portfolios of cryptocurrencies and other assets is Li et al. (2021). The authors show that when cryptocurrencies are added to a portfolio of other assets, the efficient frontier shifts upward. This result holds regardless of whether short selling is restricted. Qarni and Gulzar (2021) indicate that

cryptocurrencies provide major diversification benefits for foreign exchange portfolios. This effect is most significant for Bitcoin trading in Euros. Pho et al. (2021) compare the diversification benefits of gold and cryptocurrencies. They find that while Bitcoin increases both the return and risk, gold is a better diversifier.

Other aspects of cryptocurrencies have also been studied in the literature. For example, Bouri et al. (2018) focus on predicting Bitcoin prices using tangible assets such as gold and commodities. Corbet et al. (2018) examine speculative bubbles in cryptocurrency, particularly Bitcoin. Chan et al. (2019) study the use of Bitcoin as a hedge for various stock indices such as Euro Stoxx, Nikkei, Shanghai and Toronto. Akhtaruzzaman et al. (2020) focus on the use of Bitcoin to hedge risk in the utilities sector. Bouri et al. (2020) examine the correlation between Bitcoin and the downside risk of U.S. stocks and gold.

To the knowledge of the authors, this is the first study of the returns that have accrued to portfolios of risk-free securities spiked with differing proportions of cryptocurrencies. The purpose of injecting Bitcoin into a portfolio of risk-free securities is, of course, to raise the expected return of the portfolio while, at the same time, keeping the expected risk of the portfolio at a level acceptable to the investor. The theoretical underpinning of this study is Modern Portfolio Theory, which has deep roots, going all the way back to research pioneered by Treynor (1965), Sharpe (1966), and Jensen (1968). The performance evaluation metrics of these researchers are still commonly in use. Treynor (1965) evaluated an investment portfolio by adjusting the mean excess return (mean return less the risk-free rate of return) for the degree of market risk. Sharpe (1966) calculated mean excess return adjusted for the degree of total risk in the portfolio. Jensen (1968) created a metric (Jensen's Alpha) to determine whether the deviation of portfolio returns from market returns was statistically significant, and, thereby, to determine whether the excess return should be attributed to an external factor such as superior management, or purely to chance.

In 1997, Franco Modigliani and Leah Modigliani did some pioneering work in the area of financial reward and risk. They proposed a new risk-adjusted performance measure (hereafter referred to as M Squared), which is intuitively quite appealing to investors. The idea that underlies their methodology is to adjust the returns of a portfolio to the level of risk in an unmanaged stock market index and then measure the returns on the risk-matched portfolio. Further, academicians and practitioners in finance have shown an interest in downside risk measures for evaluating portfolio performance. The most widely cited performance measure that adjusts for downside risk is the Sortino Ratio (Sortino & Price, 1994). In this paper, we use a modified Sortino Ratio that was introduced by Pedersen and Satchell (2002), who show that this ratio has a sound theoretical foundation.

III. Data and Methodology

Monthly return data for Bitcoin for the five-year period January 2016 - December 2020 are obtained from the Center for Research in Security Prices (CRSP). We then form the following portfolios:

	Name of Portfolio	Portfolio Composition
1.	Bitcoin2	Bitcoin 2%, T-Bills 98%
2.	Bitcoin4	Bitcoin 4%, T-Bills 96%
3.	Bitcoin6	Bitcoin 6%, T-Bills 94%
4.	Bitcoin8	Bitcoin 8%, T-Bills 92%
5.	Bitcoin10	Bitcoin 10% T-Bills 90%
6.	Bitcoin12	Bitcoin 12%, T-Bills 88%
7.	Bitcoin14	Bitcoin 14%, T-Bills 86%
8.	Bitcoin16	Bitcoin 16%, T-Bills 84%
9.	Bitcoin18	Bitcoin 18%, T-Bills 82%
10.	Bitcoin20	Bitcoin 20%, T-Bills 80%

These ten portfolios form the sample used in this study for the performance analysis. The return on U.S. 4-Week Treasury Bills is utilized as the proxy for the risk-free interest rate. The Standard and Poor's 500 Index is used as the market benchmark.

Monthly returns are averaged over the five-year period to obtain the mean return. Risk-free rate of return is subtracted from the mean return to compute the mean excess return, which is divided by its standard deviation to compute the Sharpe (1966) measure:

$$S_i = \frac{R_i - R_f}{\sigma_i} \qquad [1]$$

where

R_i = mean return on portfolio i,

R_f = mean risk-free rate of return
σ_i = standard deviation of returns for portfolio i.

Mean excess return of each portfolio is divided by its beta to obtain the Treynor (1965) measure:

$$T_i = \frac{R_i - R_f}{\beta_i} \quad [2]$$

where β_i is estimated from the market model:

$$R_{it} = \alpha_i + \beta_i R_{mt} + e_{it} \quad [3]$$

where
R_{mt} = market return during period t,
e_{it} = error term.

Expected return of each portfolio is subtracted from its actual mean return to compute Jensen's (1968) Alpha:

$$\alpha_i = R_i - E[R_i] \quad [4]$$

where the expected return for each portfolio is obtained using the Capital Asset Pricing Model:

$$E[R_i] = R_f + \beta_i (R_m - R_f) \quad [5]$$

Jensen's Alphas are then tested for statistical significance.

Mean excess return for each portfolio is divided by the downside deviation of that portfolio's return from the risk-free rate of return to compute the Sortino Ratio (Sortino & Price, 1994; Pedersen & Satchell, 2002):

$$SO_i = \frac{R_i - R_f}{DD_i} \quad [6]$$

where the downside deviation is estimated as follows:

$$DD_i = \left[\frac{1}{n-1}\sum_{j=1}^{n}(\max\{0, R_f - R_{ij}\})^2\right]^{1/2} \quad [7]$$

Here, j is the month index.

The Sharpe measure is multiplied by the market standard deviation and then the risk-free rate added to calculate the M Squared measure (Modigliani & Modigliani, 1997):

$$M^2_i = \frac{R_i - R_f}{\sigma_i}\sigma_m + R_f \quad [8]$$

Finally, the market standard deviation (σ_m) is divided by the portfolio standard deviation to obtain the Leverage Factor for each portfolio:

$$L_i = \frac{\sigma_m}{\sigma_i} \quad [9]$$

The Leverage Factor compares the total risk in the given portfolio with the total risk in the market portfolio. For example, a Leverage Factor less than one implies that the risk of the portfolio is greater than the risk of the market index. An investor who is not comfortable bearing risk in excess of market risk should consider un-levering the portfolio by selling off part of the holding in the portfolio and investing the proceeds in a risk-free security, such as a Treasury Bill. On the other hand, a Leverage Factor greater than one implies that the standard deviation of the portfolio is less than the standard deviation of the market index, and that the investor should consider levering the portfolio by borrowing money (if possible, at the risk-free rate of return) and investing in that portfolio.

The significance of the Leverage Factor is that it can be used to form a portfolio containing the portfolio and the risk-free asset that has the same total risk (standard deviation) as the market portfolio. By forming this portfolio, risk exposure is limited to market risk and possible return could be more than the market return. These

Leverage Factors are used to compute the adjusted returns in Table 3. First, the mean Monthly Adjusted Return (MAR) is computed using the Leverage Factor:

$$[10] \quad \text{[illegible]}_i = L_i R_i + (1 - L_i) R_f \qquad [10]$$

Then, the mean Annual Adjusted Return (AAR) is calculated by compounding over 12 months:

$$AAR_i = (1 + MAR_i)^{12} - 1 \qquad [11]$$

Finally, the portfolios are ranked by order of magnitude of the mean AAR.

IV. Results and Discussion

The ten portfolios are identified in Table 1 along with their risk, return, and performance statistics. The portfolios are listed in order of Bitcoin weight. Not surprisingly, the portfolio with the highest mean return is Bitcoin20 with an average monthly return of 2.14 percent. In comparison, the monthly mean return of the benchmark S&P 500 Index is 1.18 percent. The portfolio with the highest total risk (measured by the standard deviation of returns) is also Bitcoin20 with a monthly standard deviation of 4.81 percent. In comparison, the standard deviation of the benchmark S&P 500 Index is 4.34 percent. Further, Table 1 reports the numerical values of the Sharpe and Sortino measures, which are used later in Table 2 to rank the portfolios. The highest Sharpe and Sortino measures (0.4328 and 111.24) are obtained by Bitcoin2. In comparison, the Sharpe measure and the Sortino measure of the benchmark S&P 500 Index are 0.2520 and 38.77, respectively.

Table 1. 5-Year Returns and Performance on a Monthly Basis (2016-2020)

Portfolio	Mean	StDev	Sharpe	Sortino	Beta	M2	Jensen'sAlpha	Alpha t_stat	Treynor
Bitcoin2	0.29	0.47	0.4328	111.24	0.02	1.9653	0.18	-1.58	10.86
Bitcoin4	0.50	0.95	0.4295	108.14	0.04	1.9510	0.37	-1.19	10.33
Bitcoin6	0.70	1.44	0.4280	106.85	0.06	1.9442	0.55	-0.81	10.16
Bitcoin8	0.91	1.92	0.4271	106.17	0.08	1.9404	0.73	-0.45	10.08
Bitcoin10	1.11	2.40	0.4265	105.74	0.10	1.9381	0.91	-0.11	10.03
Bitcoin12	1.32	2.88	0.4262	105.46	0.12	1.9364	1.09	0.20	10.00
Bitcoin14	1.52	3.37	0.4259	105.25	0.14	1.9352	1.28	0.48	9.98
Bitcoin16	1.73	3.85	0.4257	105.10	0.16	1.9343	1.46	0.73	9.96
Bitcoin18	1.93	4.33	0.4255	104.97	0.19	1.9336	1.64	0.95	9.95
Bitcoin20	2.14	4.81	0.4254	104.88	0.21	1.9331	1.82	1.14	9.94
S&P 500	1.18	4.34	0.2520	38.77	1.00	1.1812	0.00	0.00	1.09
Bitcoin	10.33	24.12	0.4244	104.16	1.04	1.9288	9.10	2.89	9.86
4W T-BILL	0.09	0.07	0.0000	0.00	0.00	0.0889	0.00	-1.95	0.00

Table 1 also reports the values of Betas, M Squared measures, Jensen's Alphas (and their t-statistics), and Treynor measures, all of which are computed using the benchmark S&P 500 Index. The portfolio with the highest systematic risk (Beta=0.21) is Bitcoin20, as was the case with total risk. In comparison, the Beta of the benchmark S&P 500 Index is, by definition, exactly 1.00. The portfolio with the highest M Squared measure (1.9653) is Bitcoin2. In comparison, the benchmark S&P 500 index has an M Squared measure of 1.1812. The portfolio with the highest Alpha measure is Bitcoin20 with Alpha equal to 1.82. None of the Alphas are significant at the five percent level. The Alpha of the benchmark S&P 500 Index is, by definition, zero. Finally, the portfolio with the highest Treynor measure (10.86) is Bitcoin2. In comparison, the Treynor measure for the S&P 500 Index is 1.09.

Table 2 reports the rankings of all the portfolios. The Sharpe, Sortino, Treynor, and Alpha ranks all indicate that our ten portfolios have returns (adjusted for total risk, downside risk, and systematic risk) that exceed the risk-adjusted returns of the S&P 500 Index. By definition, the ranking based on the M Squared measure is identical to the ranking based on the Sharpe measure. However, the M Squared measure enables us to draw some inferences, which cannot be drawn from the Sharpe measure and these are detailed at the end of this section.

Table 2. Five-Year Ranking (2016-2020)

	Sharpe Rank (M Squared Rank)	Sortino Rank	Treynor Rank	Alpha Rank
Bitcoin2	1	1	1	10
Bitcoin4	2	2	2	9
Bitcoin6	3	3	3	8
Bitcoin8	4	4	4	7
Bitcoin10	5	5	5	6
Bitcoin12	6	6	6	5
Bitcoin14	7	7	7	4
Bitcoin16	8	8	8	3
Bitcoin18	9	9	9	2
Bitcoin20	10	10	10	1
S&P 500	11	11	11	11

Table 3 reports the average returns that accrue to the portfolios with and without risk-adjustment. The risk-adjustment is performed using the Modigliani methodology. The returns are annualized for the convenience of investors. This is done by compounding the monthly mean returns over twelve periods. In that table, Bitcoin20, which ranks second based on unadjusted returns, falls back to rank ten on the basis of returns adjusted for risk. On the other hand, Bitcoin2, which ranks twelfth on an unadjusted basis, ranks first when the returns are adjusted for risk. The leverage factor for a portfolio containing only Bitcoin is 0.18, which implies that an investor, who is comfortable bearing at most the same level of risk as in the benchmark S&P 500 index, could unlever this asset (lend 82 percent of available funds at the risk-free rate of interest and invest the rest in Bitcoin, essentially coming up with the same asset composition as the portfolio named Bitcoin18) and thereby attain an annual return of 25.84 percent which is considerably higher than the 15.13% annualized return on the benchmark index.

Table 3. Five-Year Annualized Performance: Unadjusted and Adjusted for Risk

	Unadjusted Annualized Returns (%)	Unadjusted Rank	Adjusted Annualized Returns (%)	Adjusted Rank	Leverage Factor
Bitcoin2	3.58	12	26.31	1	9.16
Bitcoin4	6.15	11	26.10	2	4.55
Bitcoin6	8.77	10	25.99	3	3.02
Bitcoin8	11.46	9	25.94	4	2.26
Bitcoin10	14.20	8	25.90	5	1.81
Bitcoin12	17.01	6	25.88	6	1.50
Bitcoin14	19.88	5	25.86	7	1.29
Bitcoin16	22.81	4	25.85	8	1.13
Bitcoin18	25.81	3	25.84	9	1.00
Bitcoin20	28.88	2	25.83	10	0.90
Bitcoin	225.25	1	25.77	11	0.18
S&P 500	15.13	7	15.13	12	1.00

To explore this fully, consider an investor who would like to bear only an average level of risk and still earn returns superior to the benchmark index. In this context, the average level of risk is measured by the standard deviation of the benchmark S&P 500 index, which is 4.34 percent on a monthly basis. Now consider the following investment strategy: Suppose that the investor has $1,000 to invest. The investor could lend $820 at the risk-free 4 Week T-Bill rate and invest $180 in Bitcoin. The end of month return from the Bitcoin portion of the portfolio will be $180 x 0.1033 = $18.59. Suppose that the loaned funds were deposited at the monthly risk-free rate of 0.09 percent. In that case, the loaned funds will earn interest of $820 x 0.0009 = $0.74. The portfolio return is $18.59 + $0.74 = $19.33, which is a return of 1.93 percent on a monthly basis or 25.78 percent annualized. This return is considerably higher than the annualized return on the S&P 500 index (15.13 percent). Note that the monthly risk of Bitcoin18 is 0.18 x 24.12 = 4.34 percent, equal to the risk of the S&P 500 index in Table 1. This investment strategy, therefore, enables the investor to earn substantially better returns for an average level of risk.

It may be noted that the above example assumes that the returns on Bitcoin are not correlated with the returns on risk-free US Treasury bills.

Drawing from above results, this study demonstrates how investors can tap into the high return potential of cryptocurrencies while not exposing themselves to all of their risk. This finding is consistent with Brauneis and Mestel (2019) and Li et al. (2022) The analysis shows that adding an optimal quantity of Bitcoin to Treasury bills may result in a portfolio with the same level of expected risk as the stock market benchmark, but with a higher level of expected return. Thus, an investor may be able to expand the frontiers of an efficient portfolio with an optimal asset allocation between Bitcoin and risk-free Treasury bills. This result shows that Li et al. (2021) result holds with the addition of Treasury bills to portfolios. The results of this study would be of interest to investors contemplating investing in cryptocurrencies but aware of their risk.

V. Conclusion and Implications

This study uses the S&P 500 Index to evaluate the risk-adjusted performance of T-Bill portfolios spiked with Bitcoin. Those portfolios with larger proportions of Bitcoin have unadjusted returns which are high, but once risk is factored in, the risk-adjusted returns appear less attractive. On the other hand, portfolios with smaller proportions of Bitcoin have modest unadjusted returns which may become quite attractive to investors, when these returns are adjusted for risk. An investor who is comfortable with the level of risk in the stock market (as proxied by the S&P 500 Index) can attain a return considerably higher than the market rate of return by including a small proportion of Bitcoin (18 percent) in the investment portfolio. Global investors may want to examine each of these portfolios in detail, in order to form an investment strategy that is compatible with their comfort level for market risk. Of course, the contribution of a security to portfolio return and portfolio risk should matter more to global investors than the return and risk of an individual security.

Further, investors who would like to diversify their portfolios would do well to examine investment options with Bitcoin. Portfolios spiked with Bitcoin vary widely in terms of their risk and return, as documented in this study. However, the risk-adjusted returns of these portfolios can be quite attractive and may be superior to the return on a benchmark stock index such as the S&P 500. For investors who seek a level of risk no higher than the benchmark index, this study presents a technique of raising the return on a portfolio by holding Bitcoin in combination with a risk-free security such as a Treasury bill.

Finally, it would be beneficial to update this information on a continuing basis in order to provide ongoing documentation to investors who would like to diversify their holdings to include Bitcoin, but are not sure of how much to hold. Our results could be driven by our choices of cryptocurrency, risk free asset, and market portfolio. Hence, future research should perform similar analyses for other cryptocurrencies using different proxies for the risk-free asset and the market portfolio. Future research should also study the behavior of cryptocurrencies other than Bitcoin, as the different characteristics of these alternative securities may alter the findings. Our study focuses on U.S. markets. As international market structures vary, future research should also study the optimal level of cryptocurrencies in a variety of countries and regions.

The policy implications of this study are twofold. First, despite the potential benefits of cryptocurrencies we identify in our study, they are risky financial instruments. Hence, financial institutions should educate the public on the risks involved in investments involving these securities. Second, policies for cryptocurrency markets are still developing. Government agencies should enhance the regulations regarding the cryptocurrency markets in order to better protect investors, hence allowing them to take advantage of the benefits we identify in our study.

Competing Interest Statement

This research was conducted in the absence of any commercial or financial relationships among authors and they do not have any potential conflict of interest.

Author (s) Contribution Statement

All authors contributed equally to the conception of the model, developing the research ontology and design, acquisition of data, elaborating research design, estimation of methodology, interpretation of results, drafting the manuscript in a scientific academic structure including introduction of study, literature review, discussion, conclusion and implications of study as well as revising and providing the response to reviewers' comments.

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