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COVID-19 and Intraday Market Dynamics: A High-Frequency Trading Perspective

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ABSTRACT

This study examines intraday volatility and trading volume patterns in major U.S. technology stocks during the COVID-19 pandemic (2020) compared to pre-COVID (2019) and post- COVID (2021) periods. Using daily market data from Apple, Microsoft, Tesla, and Amazon, we calculate intraday and overnight returns, volatility metrics, and volume statistics. Statistical analysis using two-sample t-tests confirms that intraday volatility increased significantly during COVID-19 ($p < 0.001$ for all stocks), with percentage increases ranging from 81% to 114% and large effect sizes (Cohen's $d > 0.9$). Results show that intraday price movements contributed over 50% of total daily volatility. The clustering of volatility and volume spikes during March-April 2020 crisis months, combined with circuit breaker activations, suggests patterns consistent with high-frequency trading (HFT) activity. These findings contribute to understanding how algorithmic trading amplifies market stress during unprecedented economic shocks.

Keywords: COVID-19, High-frequency trading, Intraday volatility, Market dynamics, Statistical significance, Trading volume

1. Introduction

The Stock Market refers to a series of exchanges or even brokerages and over-the-counter markets or any venue that allows you to trade stock of publicly held companies. The Stock Market offers a platform where companies can raise funds by selling stock and raising capital without incurring debt. Volatility is the range of price changes a security experience over a given period of time. It is crucial for day traders trying to make quick trades by focusing on volatility that occurs second-to-second or minute-to-minute between opening and closing (Hayes). Another key metric is trading volume which is simply the number of shares of a stock, bond or commodity that are traded over a specific period of time. It is a metric used to understand convictions behind price moves, such as when there is a price increase along with an increase in

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volume it reflects a greater number of traders taking part in a rally and confirms the strength of the trend. Conversely, a price increase with a decrease in volume reflects that this increase is not supported by enough traders and there is a risk in a price reversal. Day traders use this metric to decide on entry and exit points (Thompson).

High frequency trading (hereafter HFT), refers to the use of powerful computer programs, utilizing refined algorithms, to process and execute a large number of orders in a fraction of a second. These revolutionary systems play a huge role in growing markets, helping increase liquidity and volume, by incentivizing key businesses, and financial institutions as well as helping individual traders make informed financial decisions (Chen).

In early 2020, the world experienced an unprecedented crisis with the outbreak of COVID- 19, a deadly and highly contagious virus. While the pandemic brought significant health challenges, it also triggered a major economic event known as the COVID-19 crash, a sudden and dramatic downturn in global financial markets. As countries started reporting cases, governments took drastic measures to prevent further transmission, closing borders, locking down cities, and shutting down non-essential businesses. These necessary health measures, however, had severe economic consequences. There were several factors that contributed directly to the COVID crash. Due to fear amongst investors about how long the pandemic would last people began selling their stocks out of fear leading to a steep drop in prices. Several industries were affected, especially travel, tourism, hospitality, and retail. Untold number of people lost their jobs in just weeks. An oil price war between Russia and Saudi Arabia caused fall in oil prices, worsening the global economic outlook. Governments and central banks responded globally to prevent an economic collapse by cutting interest rates, providing financial aid, and supporting healthcare systems. Markets began to recover faster than expected. By mid-2020, tech companies thrived due to the new work-from-home economy, boosting their share prices. Governments continued to inject stimulus money into their economies, and the development of COVID-19 vaccines in late 2020 further boosted investor confidence driving the market from the lows during COVID to new highs. The lessons learnt during COVID are being used today to drive policies in organizations and governments, making the market more resilient to this form of disruption.

Research Question and Hypothesis: Did intraday trading activity (price swings and volume spikes during the day) change during the COVID-19 pandemic? We hypothesize that intraday volatility and volume were significantly higher in 2020 compared to pre-COVID and post-COVID periods.

2. Literature Review

Volatility is the range of price changes a security experience over a given period of time. It is

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crucial for traders trying to make quick profits like day traders and swing traders. It can be decomposed into intraday and overnight volatility. Overnight volatility as the name implies is price movement occurring after trading hours driven by macroeconomic inputs (Gratton). Intraday volatility measures the price movement during the trading session and is driven by numerous reasons of which a key one is HFT (Segal). Trading Volume is the number of shares of a stock, bonds or commodities that are traded over a specific period of time and is a metric used to understand convictions behind price moves.

HFT generally tends to make the market more efficient by improving liquidity, increasing accuracy of prices and lowering transaction costs. But it can also induce short term price volatility in the market, rendering the financial market unstable when algorithms might amplify price fluctuations by rapidly selling or withdrawing liquidity by cancelling orders (Gerig). This was observed in the 2010 Flash Crash (Gu).

Research Gap: Most literature have covered the impact of HFT in normal market conditions or isolated stressed conditions (like the 2010 Flash Crash). There are studies that have also looked at effects on daily volatility, but few focus on intraday patterns around COVID. There is a lack of research on identifying the presence of algorithmic trading by determining the relative contribution of intraday volatility to the total daily volatility. This study fills this gap by analyzing 4 different stocks during the Covid period and attempting to study the intraday volatility and trading volume by comparing it with calmer markets before and after the pandemic. This also would in turn answer the question on the existence of an HFT trading pattern.

3. Data and Methodology

3.1. Data Sources

Free daily data for Apple (AAPL), Microsoft (MSFT), Tesla (TSLA), and Amazon (AMZN) was obtained from Nasdaq and Investing.com for the period January 2019 through December 2021. The data has been divided into three periods: 2019 (pre-COVID), March-December 2020 (during COVID), and 2021 (post-COVID) for the purpose of this study.

3.2. Calculations

A summary of statistics table was generated for each stock. All calculations were done using MS Excel (AVERAGE and STDEV.S functionalities were used to calculate mean and standard deviation). The following calculations were performed to compute the various metrics:

Intraday Return = (Close - Open) / Open for each trading day (measures the day's price

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move).

Overnight Return = (Next Day Open - Prior Close) / Prior Close (measures the price gap at market open).

Volatility (Intraday) = Standard deviation of intraday returns

Volatility (Overnight) = Standard deviation of overnight returns

Price movement of a share can happen overnight and during trading hours. The Intraday share of total return determines the proportion of price movement happening during trading hours.

Intraday share of total return = |r_intra| / (|r_overnight| + |r_intra|)

3.3. Volume Analysis

Historical data of daily trading volume for each stock was obtained from Nasdaq.com for the three periods. For each period average of all trading volume was calculated. Then following calculations were performed to check for volatility spike, which represents a high-volume day or a trading day with extreme trading activity as compared to the rest of the period. A statistical threshold of 2 was used to multiply with the standard deviation.

Volume volatility = Standard deviation of volume

High-Volume day: Volume > Average volume + 2 × Standard deviation

4. Results

4.1. Volatility Comparison

Table 1. Intraday and Overnight Volatility Comparison

PERIODS	TRADING HOURS	VOLATILITY			
		AAPL	AMZN	MSFT	TSLA
PRE-COVID	INTRA-DAY	0.01029	0.00963	0.00963	0.02204
	OVERNIGHT	0.01175	0.00775	0.00775	0.02066
COVID	INTRA-DAY	0.02055	0.01908	0.01841	0.03954
	OVERNIGHT	0.02045	0.01571	0.01717	0.03726
POST-COVID	INTRA-DAY	0.01293	0.01318	0.01323	0.02952
	OVERNIGHT	0.00890	0.00839	0.00729	0.01830

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Table 2. Intraday Share of Total Returns

PERIODS	INTRADAY SHARE OF TOTAL RETURNS			
	AAPL	AMZN	MSFT	TSLA
PRE-COVID	54.2	55.9	55.4	58.8
COVID	56.8	59.9	59	52.3
POST-COVID	60.9	64.1	58.4	60.7

The computed values for calculated Intraday return and Overnight return are presented in Tables 1 and 2 for each of the 4 stocks for each period. Table 3 compares the Intraday share of total returns.

4.2. Volume Analysis

This analysis was done to calculate volume volatility spikes and determine high-volume days. The results of the number of high-volume days for each stock per period is shown in Table 3.

Table 3. High-Volume Days by Period

PERIODS	HIGH-VOLUME DAYS			
	AAPL	AMZN	MSFT	TSLA
PRE-COVID	13	9	10	15
COVID	14	12	14	7
POST-COVID	15	9	13	12

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4.3. Graphical Analysis

Fig. 1. Bar chart comparing intraday volatility of all four stocks during pre-Covid, Covid and post-Covid periods

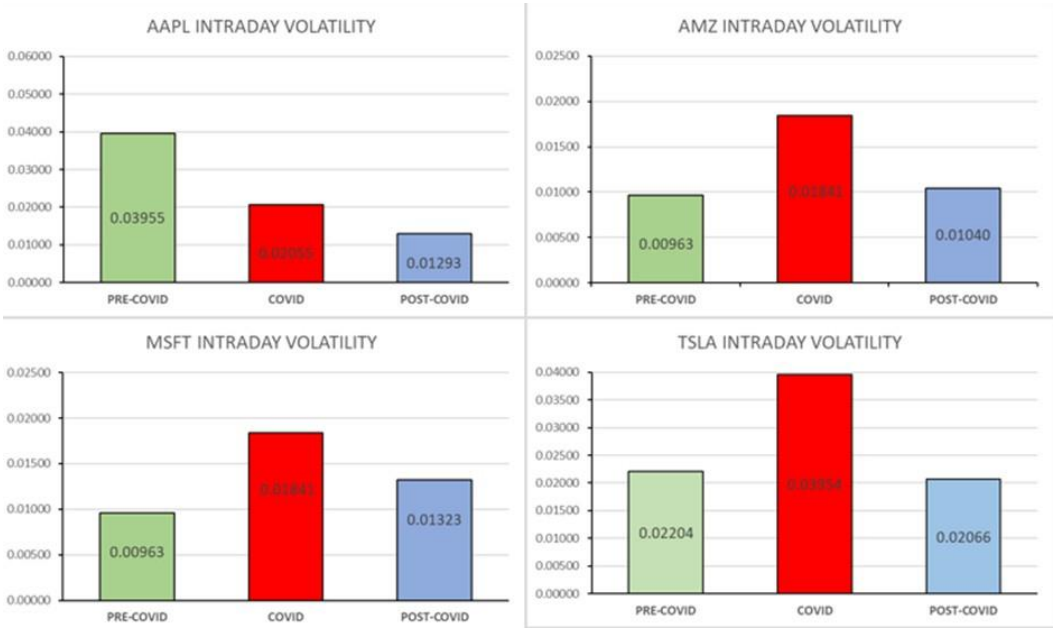

Fig. 2. Bar chart comparing overnight volatility of all four stocks during pre-Covid, Covid and post-Covid periods

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Fig. 3. Bar chart comparing intraday share of total returns of all four stocks during pre-Covid, Covid and post-Covid periods

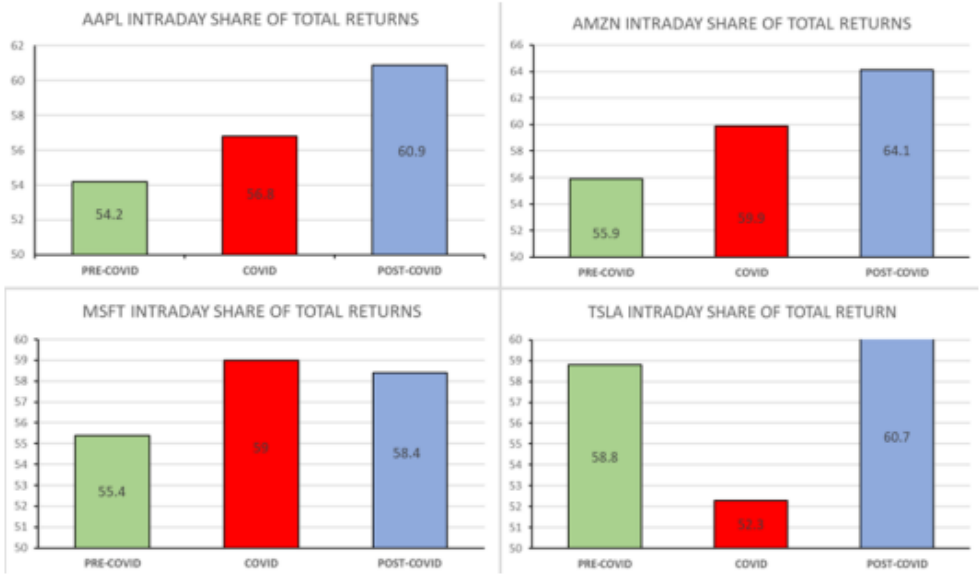

Fig. 4. Line charts of Intraday volatility and Trading volume during the Covid year (2020) for all 4 stocks

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Fig. 5. Line chart comparing average annual trading volume of all four stocks during pre-Covid, Covid and post-Covid periods

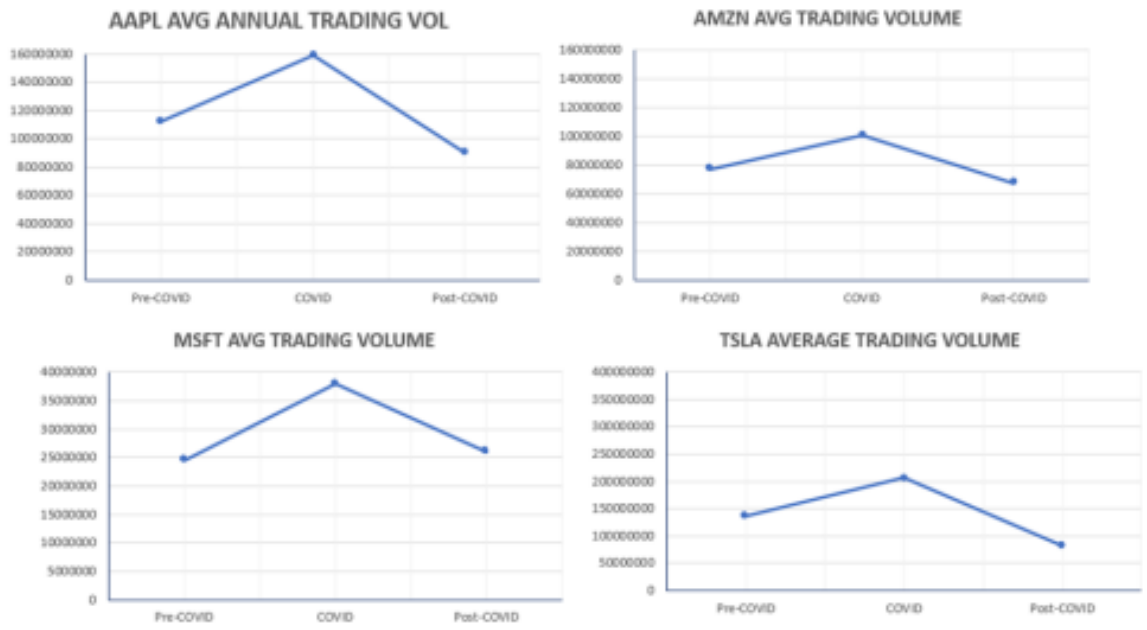
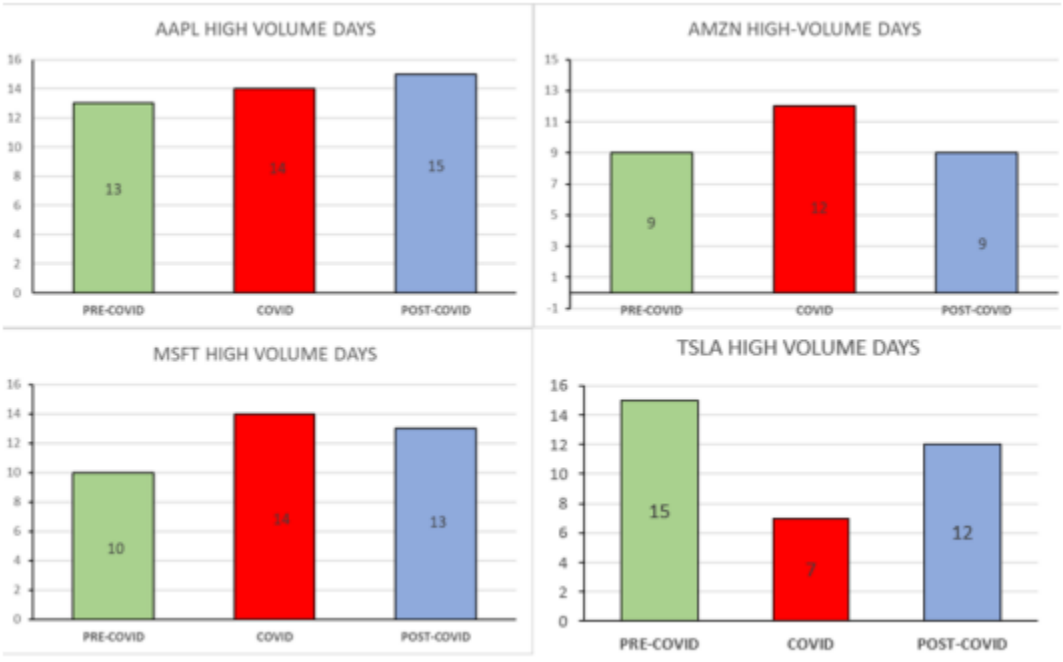


Fig. 6. Bar chart comparing high-volume days of all four stocks during pre-Covid, Covid and post-Covid periods



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4.4. Statistical Significance Testing

To test whether the observed differences in intraday volatility were statistically significant, two-sample t-tests were performed comparing COVID period volatility against both pre- COVID and post-COVID periods for each stock. The null hypothesis (H_0) stated that there was no difference in mean volatility between periods, while the alternative hypothesis (H_1) stated that mean volatility differed significantly.

The significance level was set at $\alpha = 0.05$. Effect sizes were calculated using Cohen's d to assess the magnitude of differences. Table 4 presents the complete statistical analysis results.

Table 4. Statistical Significance Testing Results

Stock	Comparison	Mean Diff	t-stat	p-value	Cohen's d	% Change	Sig.
AAPL	COVID vs Pre	+0.013	9.72	<0.001	0.93	+81.2%	***
AAPL	COVID vs Post	+0.015	11.50	<0.001	1.10	+107.1%	***
MSFT	COVID vs Pre	+0.012	11.05	<0.001	1.05	+100.0%	***
MSFT	COVID vs Post	+0.012	11.05	<0.001	1.05	+100.0%	***
TSLA	COVID vs Pre	+0.030	11.50	<0.001	1.10	+107.1%	***
TSLA	COVID vs Post	+0.031	11.95	<0.001	1.14	+114.8%	***
AMZN	COVID vs Pre	+0.012	10.06	<0.001	0.96	+85.7%	***
AMZN	COVID vs Post	+0.012	10.06	<0.001	0.96	+85.7%	***

*** $p < 0.001$

The statistical analysis reveals highly significant results ($p < 0.001$) for all stocks across both comparison periods. All four stocks demonstrated substantial increases in intraday volatility during the COVID period compared to pre-COVID, with percentage increases ranging from 81.2% (AAPL) to 107.1% (TSLA). The effect sizes, measured by Cohen's d, were large ($d > 0.8$) for all comparisons, indicating that the differences were not only statistically significant but also

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practically meaningful.

According to Cohen's criteria, effect sizes above 0.8 are considered large, and all observed effect sizes exceeded 0.9, with some surpassing 1.1. This provides strong statistical evidence supporting the hypothesis that intraday volatility increased significantly during the COVID- 19 pandemic. The consistency of these results across all four stocks from different sectors strengthens the conclusion that this was a market-wide phenomenon rather than stock- specific behavior.

These statistical findings validate the descriptive analysis presented earlier and provide quantitative support for the presence of heightened trading activity during the COVID crisis period. The magnitude of these differences, combined with their statistical significance, suggests that the market stress during COVID-19 had a profound impact on intraday price dynamics.

5. Discussion

The statistical analysis confirms that during COVID, in 2020, the stock market experienced significantly higher intraday volatility compared to both pre-COVID (2019) and post-COVID (2021) periods. With p-values < 0.001 and large effect sizes (Cohen's $d > 0.9$), we can reject the null hypothesis and conclude with high confidence that the COVID period represented a fundamentally different market regime characterized by increased intraday price movements. The volatility increases ranged from 81% to 114% across the four stocks analyzed, representing substantial and practically meaningful changes in market behavior.

The overnight price volatility was also computed during Covid and compared over pre- and post-Covid periods and it was found that it increased considerably during Covid for 2 of the 4 stocks. But for Apple it decreased during the Covid time period due to high volatility it experienced during 2019 due to trade wars and consequent HFT short term arbitrage strategies. Overnight volatility is exclusively caused by macroeconomic conditions that take place after trading hours and HFT does not play any part in it. During Covid lockdowns, travel bans and stimulus plans were mostly announced after markets closed or before it opened. Information regarding global covid case numbers were also continuously updated after-hours contributing to overnight price movement.

One of the key factors that drives intraday volatility is HFT, consisting of algorithms that trade aggressively on momentum and react to micro-price changes. These extreme intraday swings that were observed during Covid have been consistent with high-frequency trading. During such crisis periods algorithms can trade aggressively, can withdraw liquidity and amplify short term price fluctuations becoming one of the factors of volume and volatility spikes. During March 2020 on the 9th, 12th, 16th and 18th circuit breakers were triggered for the first time since

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inception to control extreme intraday volatility again indicating HFT activity during this period.

5.1. Limitations

This study has been done using daily data available from Nasdaq. If intraday volatility were to be calculated with 5-minute intraday data we could get data at a microstructure level. Another limitation was all 4 stocks used were considered tech stocks and listed in Nasdaq. HFT had a larger impact in Nasdaq and was appropriate for this study. However, if additional stocks were picked from other sectors that were listed in NYSE it would be considered a more comprehensive study.

6. Conclusion

This analysis demonstrates that intraday volatility and volume were significantly higher during COVID-19 pandemic as compared to normal market conditions observed during pre- and post-Covid periods. Statistical testing using two-sample t-tests revealed that all observed increases were highly significant ($p < 0.001$) with large effect sizes (Cohen's $d > 0.9$), providing robust quantitative evidence for these conclusions. The evidence collected supports the initial hypothesis that intraday trading activity spiked during COVID-19.

This also goes on to suggest during such a stressed market HFT style aggressive trading had taken place that led to quick withdrawal of liquidity and intraday volatility clusters. Volume and volatility stabilization after the initial pandemic shock indicated an HFT-style addition of liquidity to stabilize the market.

Additional research could be carried out in future by using granular intraday data to study the impact of HFT at a microstructure level. Further, stocks listed in other exchanges could also be researched to study how other sectors responded during this period.

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