The Rise and Volatility of Russian Winter Wheat Production

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Abstract
The Russian wheat industry experienced massive growth in the past two decades however, volatility in production and its subsequent impact on the global commodities market persists. In addition to significant growth, Russia surpassed the European Union as the top global exporter of wheat in 2016 and in 2020 winter wheat exports amounted to roughly $8 billion USD. The aim of this research is to investigate the observed trends and patterns of the growth in the Russian wheat production through the use of reported data on production, cropland area, yield and its associated yearly volatility. To conduct this research, statistical analysis was applied to data published by the Russian Ministry of Agriculture (RMA) and the United States Department of Agriculture Foreign Agriculture Service (USDA FAS). Statistics concerning Ukraine and Kazakhstan are included to gain a regional perspective. Results regarding Russia indicate a 149% increase in wheat production and a 35% increase in wheat farmland area with winter wheat accounting for a growing majority of this increase from 2000 to 2020. Of particular focus is yearly volatility in production of wheat, both spring and winter, which experienced significant yearly fluctuations of up to ±50% in both Russia and Ukraine. In addition, uncertainty in monthly forecasting of crop production published by the USDA FAS persists in both area and yield estimations. In Russia and Kazakhstan, USDA FAS wheat area forecasting was found to be the larger contributor to uncertainty in forecasting yearly production than yield and vice versa with Ukraine. Surging growth in the Russian wheat industry coupled with large volatility in yearly production have significant impacts on the global wheat market as well as lasting implications for land use and land cover change.

1. Introduction

In the past two decades, the growth of the Russian wheat industry and its subsequent influence on the global wheat market has been significant and resulted in the country becoming a major contributor in the global agriculture market. After the dissolution of the Soviet Union, Russia’s share of global wheat exports was less than 5% between 1991 and 1999 [1]. Since 2000, the production and export of Russian wheat has experienced significant growth. This growth is largely attributed to policies set by the Kremlin beginning in the early 2000s and codified with the ‘National Security Strategy to 2020’ policy signed by President Medvedev in 2010. This policy set conditions for Russia to become a major international food supplier with the aim of improving their national security interests and exertion of foreign power and economic influence [2].

In the 2017/18 growing season, the country accounted for 20%–23% of global wheat exports and surpassed the USA, Canada, and the European Union for the top position in wheat exporting countries. The resurgence of the Russian wheat industry can be attributed to reclamation of previously abandoned cropland after the collapse of the Soviet Union when major institutional changes in land policy occurred as the country shifted from a centralized economy to a free-market model [3]. Following the 1990’s, policy reform in the agricultural industry improved market integration with global trade and provided financial support to farmers allowing the country to improve its domestic grain supply in addition to becoming a key contributor in the global wheat trade [3]. Wheat accounts for the majority of grain products exported by Russia [1]. As a result, a lack of diversified
agricultural products for exporting makes the country and its economy highly reliant on and thus vulnerable to annual wheat harvests and associated market prices. This volatility in yearly production persists and is caused by a variety of environmental and climatic influences such as drought and is further exacerbated by issues with global market integration due to changing geopolitics and industry competition. Volatility in the Russian wheat industry was investigated by Svanidze et al. (2021) [4] for the 2010/2011 growing season when a substantial drought in the major wheat producing regions led to a significant shortfall in production. Russia responded to this sharp drop with a total ban on all grain exports. Similar scenarios but not as large as the 2010/2011 wheat harvest shortfall have been experienced but in lieu of a total ban, a heavy export tax was imposed. Examples include the 2007/2008 world food market crisis and again in 2015 with a 40% and a 15% export tax hike on grain, respectively [3]. In these crises, Ukraine and Russia responded by implementing export restrictions and taxes respectively, whereas Germany and the USA did not. However, the latter two countries were subjected to market instability in wheat prices influenced by a diminished global supply and reduced investor confidence [5]. The increased yearly production of wheat along with growing wheat area in Russia has been shown to influence global price volatility. In a study by Kemény et al. (2012) [6], a positive relationship was found between international wheat prices and increasing exports from Russia, Ukraine, and Kazakhstan. This research provided results showing that as these three countries increased their production and subsequent exports of wheat so too did yearly volatility in wheat prices. The driving influence for this correlation was that as production increased, so too did the impact on annual production from exposure to climatic and environmental influences. As a result, historical and anticipated volatility of Russian wheat production contributed to wheat price volatility in international markets. Due to large swings in yearly production, wheat export bans imposed by Russia have the aim of ensuring domestic supply during periods of significant production shortfalls yet have a direct effect on global market stability, supply, and prices.

Future potential capacity for Russia to expand its wheat production is a subject of debate among researchers especially when considering consequences from climate change. Considering Russia’s unique position to take advantage of a warming climate, Jagermeyr et al. (2012) [7] published a study providing results that show there is potential for wheat production to grow 17% and maize production to decrease 24% by mid-century. Alternatively, Zhu et al. (2012) [8] investigated snowpack insulation and snowmelt and their associated influence on winter wheat yields. Their study showed that decreased snowpack insulation from a warmer climate has the potential to negatively protect winter wheat from frost stress and thus decrease yields. To summarise, a warmer climate has the potential to improve Russia’s wheat production but is also capable of degrading already advantageous climate conditions.

The main objectives of this study are to assess the growth of Russian wheat production since 2000 with the use of reported official statistics from the Russian government and in-season forecasting from the USDA FAS. Data reported include statistics on wheat area, production, and yields as well as the type of wheat (spring or winter wheat) and amount produced. This information was catalogued, organised and quantified to analyse the changing shape of Russian wheat production.

This research aims to answer a variety of questions concerning the past two decades of wheat production in Russia. First, we quantify the overall growth of Russian wheat production at the national and sub-national scale from the year 2000 to 2020 and identify associated patterns and trends. Second, two decades of data concerning uncertainty with in-season forecasting by the USDA are assessed through comparisons with reported statistics from official government sources. Both Ukraine and Kazakhstan are major contributors to global supply of wheat and were the 6th and 10th largest exporters of global wheat in 2020, respectively [9]. Due to both countries sharing similar agricultural, climatic and geographic characteristics with the southwest regions of the Russian Federation, they are included in this research for comparison of observed trends and patterns. Lastly, we investigate volatility in Russia’s yearly wheat area, yield and production.

2. Study area, data, & methods

2.1. Study area—Russian Federation

The study area of this research is the Russian Federation, a country located in both East Europe and North Asia. The country encompasses roughly 17 million square kilometres of land making it the largest in the world. Of this land area, the United Nations Food and Agriculture Organization estimates that 13% comprises agricultural land of which a majority is heavily concentrated in the south and southwest of the country [9]. Grain is a critical exporting commodity of the Russian Federation accounting for 42% of all agricultural exports in 2019 [10]. Of all grain exports, wheat accounts for the largest share equivalent to 80% of total grain exports in 2017–2018 [1]. Major importers of Russian wheat include Turkey, Egypt, Sudan, Morocco, Yemen, Bangladesh, Vietnam and Nigeria [1].
Wheat planting and harvesting cycles are heavily reliant on local climate conditions. This is exemplified in Russia, a country containing several climate zones due to its large size and is thus able to produce both winter and spring wheat varieties. Figure 1 depicts an approximate crop calendar for winter and spring wheat by region used by the USDA FAS. In regions that produce a majority of winter wheat and includes the Central, Southern, Volga, and North Caucasus District, planting usually occurs between August and October followed by harvesting in July and August of the following year [10]. In the Ural and Siberian District, winters are longer and more intense which results in spring wheat being the dominant wheat type. Spring wheat planting occurs in May and is harvested between August and mid-October [11].

2.2. Data
This study uses two main separate datasets for examining the Russian wheat industry provided by the USDA FAS [11] and official statistics published by the RMA [12]. The USDA FAS publishes a monthly forecasting dataset on expected wheat area, yield and production for each growing season starting in 2002. This dataset is at the country level and only begins to distinguish between winter and spring crop types starting after 2017. The RMA dataset provides a more granular dataset detailing yearly statistics on both winter and spring wheat production, area, and yield at the sub-national level (oblast) starting in the year 1990. The RMA dataset provides additional statistics on planted and harvested areas, distinguishing between spring and winter wheat.

Due to Ukraine being a major producer of wheat, data provided by the Ukrainian Ministry of Agrarian and Food Policy was analysed to draw comparisons between the two countries. The Ukraine Ministry of Agrarian Policy and Food (UMAPF) provides a yearly report on metrics associated with wheat production, area, and yield in the country beginning in 2010 [13]. Before 2010, statistics on agricultural production were published every 5 years, starting in 1990. The Ukrainian reports are at the sub-national level and do not discern between winter and spring wheat, however, a majority of wheat produced in Ukraine is of the winter wheat variety. Forecasting uncertainty data for Ukraine and Kazakhstan is provided by the USDA FAS [11].

2.3. Methods
Data describing production, area, yields and reporting periods was homogenised in order to maintain consistent unit values for each metric. Volatility is defined as the percent difference of yearly reported area, yield, and production from the previous year. Uncertainty in forecasting is defined as the relative percent difference (absolute) of each month from the reference forecast (April). In-season uncertainty in forecasting is the measure of the percent difference within a growing season of each month’s forecast from the previous month. To calculate change in a 20-year period, the difference between the most recent (2020) and the earliest (~2000) reported statistic was obtained and then divided by the earliest reported statistic. Monthly forecasting uncertainty by the USDA was generated by using the April forecast of each year as the reference variable for comparing against the previous 11 months of recordings for each growing season. Equation (1) through equation (6) show the process for calculating each month’s relative difference from the final April recording. Equations (7) and (8) provide the calculation for receiving the amount in percent that area and yield contribute to uncertainty in forecasting production. Each preceding month from April (11 months total) is represented as $\text{month}_i$. 

\[\text{Volatility} = \left| \frac{\text{Area}_i - \text{Area}_{i-1}}{\text{Area}_{i-1}} \right| \times 100\%\]

\[\text{Uncertainty} = \left| \frac{\text{Forecast}_i - \text{Forecast}_{i-1}}{\text{Forecast}_{i-1}} \right| \times 100\%\]

\[\text{Monthly Forecasting} = \frac{\text{Most Recent}_i - \text{Earliest}_i}{\text{Earliest}_i} \times 100\%\]
3. Results

3.1. Country level metrics

3.1.1. Production

Between the years 2000 and 2020, total wheat production in Russia increased by 149% (51.4 million metric tons) (figure 2(a)). A majority of this increase is driven by growth in winter wheat, which increased by 267%, adding 46 million metric tons during this time period. In addition, spring wheat also experienced a large increase in production, increasing 31% (5.3 million metric tons from 2000 to 2020). Of note in figure 2(a), the ratio of winter wheat production to total wheat production has been steadily growing at roughly 1.2% percent per year since 2000. Alongside increasing wheat production there exists large yearly changes in wheat production for both spring and winter wheat. Figure 2(b) depicts the yearly change in wheat production as a percentage of the

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\text{Area Delta} = |\text{Area}_{\text{month}} - \text{Area}_{\text{April}}| \\
\text{Yield Delta} = |\text{Yield}_{\text{month}} - \text{Yield}_{\text{April}}| \\
\text{Production Delta} = |\text{Production}_{\text{month}} - \text{Production}_{\text{April}}| \\
\text{Production Delta} \% = \frac{\text{Production Delta}}{\text{Production}_{\text{April}}} \\
\text{Area Delta} \% = \frac{\text{Area Delta}}{\text{Area}_{\text{April}}} \\
\text{Yield Delta} \% = \frac{\text{Yield Delta}}{\text{Yield}_{\text{April}}} \\
\text{Area Contribution} \% = \frac{\text{ArD}_1^2}{(\text{ArD}_1^2 + (\text{YiD}_1^2))} \\
\text{Yield Contribution} \% = \frac{\text{YiD}_1^2}{(\text{YiD}_1^2 + (\text{ArD}_1^2))}
\]
previous years reported production as provided by the Russian Ministry of Agriculture. Swings in yearly production of 30%–40% are not uncommon and due to the size of wheat production in the country these swings have a large impact on global supply.

3.1.2. Area
Since 2000, overall wheat area has increased by 35% (7.5 million hectares) (figure 3(a)). Winter wheat area growth is the main driver in total wheat area expansion, which increased by 117% (9 million hectares) in this time period. In contrast with winter wheat, spring wheat area has decreased since the year 2000 by 11% (1.5 million hectares). In a similar trend to the ratio between production of winter wheat and total wheat, the ratio between winter wheat area to total wheat area increased by 22% between 2000 to 2020, steadily growing at a rate of ∼1% per year. Large yearly changes in wheat farmland area is also prevalent and swings as high as 20% are not uncommon (figure 3(b)). Swings in yearly change in area are not as high as production but are still large and highlight the need for improved accuracy in yearly forecasting.

3.1.3. Area planted versus area harvested
Data concerning area planted and area harvested were compared and used to understand impact of environmental influences on intraseasonal yearly production efficiency (figure 4). Differences between winter wheat planted and harvested (figure 4(a)) varies by year and follows a bimodal distribution, where rare but significant large differences can be as high as 10%–11% but are usually between 1 and 3% for winter wheat and are even larger for spring wheat (figure 4(b)). However, with expanding wheat area these differences represent large areas and are significant when taking account overall yearly production. Examining the two charts provided in figure 4, spring wheat contains the largest differences between planted and harvested areas, with differences between 5%–25%.

3.1.4. Yield
Since 2000, yields have steadily increased for both winter and spring wheat, however winter wheat yields have historically been substantially larger than spring wheat and Russia is no exception to this. Winter wheat yields have increased by 60% (1.54 t/ha), since the year 2000. Spring wheat yields have increased by 67% (.61 t/ha) in two decades (figure 5(a)). The USDA yearly forecasts report an estimated ∼1 metric ton/hectare increase in
Figure 4. (a) Winter Wheat: Area Planted versus Harvested (RMA). (b) Spring Wheat: Area Planted versus Harvested (RMA). Large differences in planted versus harvested area is increasing in winter wheat and is slightly decreasing for spring wheat. Spring wheat still contains the largest difference of the two wheat planting regimes between planted and harvested.

Figure 5. (a) Wheat Yields (RMA). Winter wheat yields grew at a slightly higher rate than spring wheat since 2000. (b) Wheat Yields (RMA). Both spring and winter wheat experienced high volatility in yearly yields, at times reaching ± 30%.
wheat yields which is overall consistent with reports published by the Russian Ministry of Agriculture (figure 5(b)).

3.2. Ukraine & Kazakhstan
From the year 2000 to 2020, wheat production in Ukraine grew by 143% increase (14.6 million metric tons). Figure 6 depicts this growth alongside Russian winter wheat production for comparison. Of interest is Russian and Ukrainian growth in production following each other closely in terms of variance each year until 2015 when Russia significantly outpaces Ukraine (figure 6). Ukrainian wheat area grew modestly as compared with Russia, with an increase of 21% (1.3 million hectares). Lastly, wheat yields experienced large growth between 2000 and 2020 increasing 97% (1.91 t/ha). Results from Kazakhstan show production, area and yield of wheat, both spring and winter, were mostly unchanged from 2003 to 2020.

3.3. Forecasting uncertainty | USDA FAS
Figure 7(a) depicts average monthly uncertainty by year in USDA forecasting of production, area and yield for Russia, Ukraine and Kazakhstan. Uncertainty in yield forecasting for Ukraine and Russia are similar and between 10%–20% starting in May and drops precipitously starting in October. Area forecasting for all three countries is on average below 10% for all countries, steadily decreasing as the season progresses into the Spring. Uncertainty in production forecasting is relatively high for all three countries as it is a multiple of both area and yield and thus uncertainties become magnified. Percent contribution to uncertainty in estimating production was calculated for each month and categorised by country shown in figure 7(b). Uncertainty in forecasting area is the larger contributor to uncertainty in forecasting production for both Kazakhstan and Ukraine over yield for the entire season. Ukraine is different in that uncertainty is mostly attributed to yield forecasting instead of area. This can be explained by Ukraine having a relatively consistent yearly area for wheat unlike Russia which has been rapidly expanding their wheat area since 2000.

3.4. Major winter wheat producing oblasts in Russia
In 2020, the top 10 regions for winter wheat production accounted for 69% of the total share of winter wheat production in Russia, reaching a peak of 82% in 2010. These regions are major factors in understanding the Russian wheat industry as a whole, with all experiencing major growth in both winter wheat area and production and include (in descending order of production) Rostov, Krasnodar, Volgograd, Stavropol, Voronezh, Saratov, Kursk, Tambov, Belgorod, and Oryol. Figure 8 depicts winter wheat production in Russia and their associated share of total Russian winter wheat production expressed as a ratio percentage. The top 10 oblasts with the largest change in winter wheat farmland area from 2000 to 2020 accounted for 72% of the total growth in winter wheat farmland area or 6,515 thousand hectares of land. Lastly, the top 10 Oblasts with the largest share in increased winter wheat production (with respect to country wide growth) from 2000 to 2020 was Rostov (19%), Krasnodar (8%), Volgograd (8%), Voronezh (6%), Saratov (5%), Kursk (4%), Tambov (4%), Lipetsk (4%), Belgorod (4%) and Stavropol (3%).

3.5. Comparison of USDA & RMA reported data
Consistency in forecasting by the USDA FAS was analysed by comparing their reported final forecasts with reported data provided by the Russian Ministry of Agriculture. Two metrics, production and area were analysed
Figure 7. (a) Average Monthly Uncertainty Per Country/Metric (USDA). Monthly uncertainty per year was calculated using the USDA FAS’s forecasting reports for production, area and yield estimates of wheat. Uncertainty in all 3 metrics measured by the USDA and even minor discrepancies between 2%–10% in forecasting have a large impact on supply and market stability. (b) % Contribution to Production Uncertainty (USDA). For each country, area and yield metrics were used to calculate their % contribution to uncertainty in forecasting yearly production. For Russia and Kazakhstan, area was found to be the larger of the two metrics in contributing to uncertainty in production forecasting, whereas Ukraine is the opposite. Important for guiding efforts in improving current agricultural monitoring missions and producing accurate forecasts.
over 20 years of data with yield being left out as it is primarily an averaging of spring and winter wheat and not usable. Figure 9(a) compares reported wheat production estimates from the USDA and Russian reports. Accuracy is estimated as to the percent difference between what the Russian Ministry of Agriculture and what is reported by the USDA. The comparisons are for measuring total wheat production and area. For production, the accuracy of the USDA estimates is roughly below 1.5% difference from what the RMA reports but has increased drastically in error since 2012 (figure 9(b)).

For area, the RMA provides wheat area planted and area harvested while the USDA does not discern between the two and instead the April forecast was used as the final harvested area. The first area comparison figure compares harvested area and April area reported. The results show that the USDA has increased its accuracy in reporting winter wheat area, especially since 2012, but before then was underestimating area by one to two million hectares. Figure 9 shows the percent difference in area estimations between the USDA and the RMA’s

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**Figure 8.** All Russian Winter Wheat versus Top 10 Oblasts (RMA). Key metric for showing winter wheat production is increasingly growing outside of traditional winter wheat producing oblasts in recent years. Large indication of land cover/land use change occurring outside of normal growing zones.

**Figure 9.** (a) % Difference Reported Wheat Area (USDA, RMA) Two ‘spikes’ in % uncertainty occurred in 2010 and 2013 along with differences of 2%-6% in most years. (b) Production Comparison (USDA, RMA). Differences between RMA and USDA experienced significant increase starting in 2014, increasing lack of access to on-site monitoring and ground truth collection/sampling can partly be attributed to this.
reported data on planted and harvested wheat area. For each planted and harvested there is a large spike in difference between the datasets for 2010 (planted) and 2012 (harvested) at 18% and 16%, respectively. Harvested area improved since 2011, from differences of 6% pre-2011 to below 2% afterwards. Planted area percent differences were below 1% pre-2011 but have since increased between 2%-4% after 2011.

4. Discussion

Analysis of the results provides strong evidence for large expansion of winter wheat in Russia, particularly in traditionally non-winter wheat producing regions. Figure 8 depicts Russia’s total production against the top 10 wheat producing oblasts. Of interest is the ratio of winter wheat production in these regions compared to Russia as a whole. This trend shows that the share of winter wheat production in these 10 regions is actually steadily increasing since reaching a peak in 2010 while total Russian winter wheat production substantially increased since then. This statistic implies there is considerable growth in winter wheat area and production in traditionally non-major winter wheat producing regions in Russia and provides strong cause for investigation of where this area increase is occurring and the land cover being replaced to provide for agricultural expansion.

Examining the relationship between increased winter wheat and decreased spring wheat is important in characterising where growth of winter wheat and subsequent land cover change is occurring. Spring wheat area has been in decline since 2000, losing 11.3% (1.5 Mha) of its 2020 area in contrast to winter wheat area which increased by 117% (9.1 Mha). Increased winter wheat area through replacement of spring wheat area is a possible explanation of new winter wheat farmland. However, spring wheat area loss can only account for a theoretical maximum of 17% of the growth witnessed in winter wheat area. This deduction being under the assumption that all spring wheat area lost was converted to winter wheat area between 2000 and 2020 thus leaving 83% of winter wheat growth left to account for. To further explain this rationale, the top 10 major winter wheat producing oblasts experienced 6,098 thousand hectares of growth in winter wheat area accounting for 67% of total growth in all of Russia. These two facts provide strong evidence for agricultural expansion of winter wheat in non-traditional winter wheat producing oblasts where replacement of spring wheat is marginal, at best, alongside 33% of growth occurring outside of the major winter wheat producing regions. This is a possible explanation for growing volatility in Russian yearly wheat production due to expansion of winter wheat into non-traditional areas outside of normal climate zones. This would increase the crops exposure to potentially unfavourable climatic conditions and have a detrimental effect on its production. As cropland area expands, so too does the risk for abnormal events that would then impact total production of winter wheat in Russia and thus influence international wheat markets. This would further reinforce the argument made by Kemény et al (2012) [6] where increasing wheat production fuels market volatility due to consistent uncertainty in what each year’s production will bring.

Area was found to be the larger contributor to uncertainty in forecasting wheat production then yield. Yield forecasting of wheat is a heavily researched topic whereas forecasting area still needs improvement as indicated by figure 7(b). For Russia, uncertainty in forecasting wheat will continue to grow as wheat cropland expands outside of traditional regions and climate zones. Cropland area models using remotely sensed data will need to consider this growth into areas outside of usual growing regions and adjust to improve yearly area forecasts [14]. This is critical for production forecasting to improve as area is half the equation to calculating production.

5. Conclusion

Results from this study disentangle data associated with the enormous growth in the Russian wheat production since 2000. In particular, winter wheat increasingly became the more dominant wheat type, experiencing 117% growth in total wheat area expansion and a 267% increase in production along with minimal but sustained linear increases in yield. In parallel with this growth in wheat production is Russia’s subsequent growing role in the global wheat industry, becoming the largest exporter of wheat in the world in recent years. This market dominance has huge influence on the global wheat trade affecting global supply and demand as well as pricing and is of keen interest by economic markets and financial actors to track yearly production. However, Russia’s yearly winter wheat production is volatile and can experience large swings in yearly production, anywhere between ±50% which in turn creates substantial uncertainty in determining future production numbers. In comparison with Russia, since 2000, growth in Ukraine and Kazakhstan’s wheat production was linear and stagnant, respectively. In addition, data published by the USDA Foreign Agriculture Service indicates considerable uncertainty in yearly forecasting especially in regards to wheat area. As a result of recent political tension between the US and Russia, further exacerbated by the ongoing Russo-Ukrainian War, the ability for the USDA to acquire ground data for calibrating yearly forecast models leads to higher uncertainty and greater reliance on data published by the Russian Ministry of Agriculture. Increased growth in both winter wheat area
and production coupled with uncertainty in forecasting generates economic and financial demand for investigation of potential future growth of winter wheat in Russia as well to refine approaches in yearly crop forecasting.

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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Ethical statement

Not applicable.

Informed consent statement

Not applicable.

Data availability statement

This study used publicly available datasets for statistical information. USDA FAS data provided by http://www.fas.usda.gov accessed April 2, 2022. Global and Kazakhstan agricultural data provided by https://www.fao.org/statistics/en/ accessed April 2, 2022. Official Russian data provided by https://rosstat.gov.ru/ accessed March 20th, 2022. Official Ukrainian data provided by https://minagro.gov.ua/en accessed March 25th, 2022.

Conflicts of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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