Volume 10, Issue 9, September – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep716

Maximal Voluntary Ventilation in Obese and Non-Obese Rural Adolescents and its Association with Fat Mass Index- Analytical Cross-Sectional Study

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Publication Date: 2025/09/19

Abstract:

- ***Introduction:***

Childhood obesity is a growing public health concern, yet limited research has examined its impact on the cardiopulmonary system, particularly in rural populations and across different age groups. Excess body fat in overweight and obese individuals can lead to a restrictive breathing pattern, reduced lung volumes, and decreased cardiopulmonary endurance, increasing the risk of related diseases. Pulmonary function tests, such as spirometry and maximum voluntary ventilation (MVV), provide valuable insights into respiratory capacity. While BMI is widely used to assess weight status, the Fat Mass Index (FMI) offers a more precise measure of adiposity. However, This study aims to evaluate the effect of obesity and age on pulmonary function measurements among obese and non-obese children and adolescents, and to examine the correlation between fat mass index and respiratory parameters in this population.

- ***Methods:***

This analytical cross-sectional study recruited eighty adolescents (12–19 years) from rural India were classified as obese (n=40) or non-obese (n=40) using WHO BMI-for-age standards. MVV was assessed by spirometry (ATS guidelines) and FMI by validated equations. Data were analyzed using Shapiro–Wilk, Mann–Whitney U, and Spearman's correlation.

- ***Results:***

Obese adolescents showed significantly lower MVV than non-obese peers [72.30 L/min (IQR 63.35–79.70) vs. 96.25 L/min (IQR 86.40–109.75); median difference = 23.95; U = 189.5, $p < 0.01$]. FMI correlated moderately and inversely with MVV in the obese group ($\rho = -0.579$, $p < 0.01$), but no significant association was observed in non-obese participants ($\rho = 0.261$, $p > 0.05$).

- ***Conclusion:***

This study concludes that obesity significantly impairs pulmonary function in adolescents, with lower MVV values in obese participants and a moderate negative correlation between MVV and FMI. FMI assessment may aid early detection of respiratory compromise.

Keywords: *Maximum Voluntary Ventilation (MVV), Fat Mass Index (FMI), Spirometry, Childhood Obesity, Rural Children, Adolescents.*

How to Cite: Aditi Wagh; Dr. Achira Panja (2025) Maximal Voluntary Ventilation in Obese and Non-Obese Rural Adolescents and its Association with Fat Mass Index- Analytical Cross-Sectional Study. *International Journal of Innovative Science and Research Technology*, 10(9), 993-998. https://doi.org/10.38124/ijisrt/25sep716

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I. INTRODUCTION

Obesity is a complex chronic condition characterized by excessive body fat accumulation, leading to adverse metabolic, cardiovascular, and respiratory consequences. [1] Childhood obesity is becoming a serious concern. Numerous studies across the country have focused on assessing the prevalence of childhood overweight and obesity in urban settings, while relatively few have explored this issue in rural populations. [2] The excessive buildup of body fat that poses a significant threat to an individual's well-being. In addition to social stigma, reduced quality of life can also be a consequence of obesity which contribute to mental health issues, such as anxiety and depression. [1] Pulmonary complications associated with Obesity tends to result in more frequent occurrence of illness and death. [3] The global prevalence of adolescent obesity is rising, with estimates suggesting that by 2025, over 167 million individuals will experience health problems related to obesity. [4] Obesity also has profound effects on the respiratory system. Adult obesity reduces lung capacity and expands the lungs in a restrictive manner. However, childhood obesity is often associated with an obstructive pattern, leading to an increase in pulmonary conditions such as obstructive Sleep apnea and reactive airway disease, which adversely affect quality of life and long-term Health outcomes. [5, 6] Recent research indicates that obesity can negatively affect the function of respiratory muscles, impairing both the muscles responsible for inhalation (inspiratory) and exhalation (expiratory), even in individuals who do not have pre-existing interstitial lung diseases. [7] Pulmonary function tests provide valuable insight into lung development and physiological changes in children. [8] Maximal Voluntary Ventilation (MVV), a spirometric measure, used to assess individual’s respiratory endurance essentially how well the lungs and respiratory muscles can sustain rapid, deep breathing over a short period. Several factors influence MVV performance, including the strength of the respiratory muscles, the flexibility and compliance of the lungs and chest wall, as well as how efficiently an individual can control their breathing and manage resistance in air way. [9] In field research, the Fat Mass Index (FMI) is increasingly used to assess body adiposity with greater precision. When compared to BMI, FMI measures fat mass with greater specificity and economic feasibility. [10] While previous studies have examined obesity’s effects on pulmonary function in urban populations, limited research addresses rural adolescents, where socioeconomic and lifestyle factors may differ.

II. METHOD

➢ *Design*

An analytical cross-sectional study was conducted over six months (January–June 2024) in rural schools in Kopargaon, Maharashtra, India. 80 adolescents aged 12–19 years were recruited via purposive sampling. WHO BMI-for-age growth standards classified participants as obese (> +2 SD) or non-obese (–2 SD to +1 SD). This research utilized a computerized spirometer and FMI equations validated in previous studies to collect information on participants MVV values and FMI values calculated respectively. A total of 80 samples were included in the sample, a size considered sufficient to yield statistically meaningful findings while also considering for possible exclusion. The study was carried out in the rural area of Kopargaon, offering a defined geographic focus that facilitated an understanding of the community’s specific context, ethnic, geographic and contributing factors. All participants were briefed on the study’s objectives, and informed consent the parents was obtained prior to enrolment. Ethical clearance was granted by the appropriate institutional review board before the commencement of data collection.

➢ *Inclusion and Exclusion Criteria:*

The study included adolescents aged 12 to 19 years, both male and female, classified as obese (BMI > +2 SD) or non-obese according to WHO growth standards. All participants led a sedentary lifestyle and voluntarily consented to participate in the study. Whereas, the exclusion criteria for the study included individuals who had undergone any recent surgical procedures, as such interventions could influence respiratory capacity and overall physical performance. Participants with diagnosed neurological disorders were excluded due to the potential impact of these conditions on motor control, coordination, and the ability to perform the required assessments accurately. Similarly, individuals with cardiovascular or respiratory disorders were not considered for participation, as these conditions could directly affect maximum voluntary ventilation and confound study outcomes. Those with cognitive or mental impairments that limited their capacity to understand and follow multi-step instructions were also excluded to ensure the reliability and safety of the testing process. Finally, individuals who were unwilling to provide informed consent or chose not to participate in the study were not included.

III. PROCEDURE

➢ *Maximum Voluntary Ventilation (MVV)*

All the analyzed for spirometry (Clarity Spirotech^{++}). The best of at least three technically acceptable values for Maximum voluntary ventilation (MVV) according to the standards of American Thoracic Society with volunteers in sitting position with back supported, the highest value among three was recorded. Each trial was performed for 15 seconds with a 60-second rest interval between each attempts. Participants were instructed to breathe as quickly and forcefully as possible throughout the test. [11] Consistent verbal encouragement was provided by the physiotherapist during all 15 seconds of each trial.

➢ *Fat Mass Index (FMI)*

FMI was calculated using equation constructed in previous study using reference values obtained from Dexa. In FMI values for each individual were calculated by using their BMI and Age along with the formulas.

- For boys: FMI: $18.655 - 0.007.\ BMI^2 - 293.601.\ BMI^{-1} + 0.112 \times Age - 0.018.\ Age^2$
- For girls: FMI: $18.455 + 0.007.\ BMI^2 - 293.601.\ BMI^{-1}$. [12]

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IV. DATA ANALYSIS

In this study, data collected through spirometry and FMI were organized and analysed using both descriptive and inferential statistical tests. Demographic variables, including age distribution, gender distribution, were summarized through means, standard deviations

The normality of the data was assessed using Shapiro-Wilk test. All parameters were significantly non-normal in at-least one group. MVV values in the obese group were not normally distributed (W=0.929, p=0.015), while those in the non-obese were normally distributed (W=0.975, p=0.512). FMI values were normally distributed in non-obese group (W=0.964, p=0.234), while those in obese were not normally distributed (W=0.881, p=0.0005). As non-parametric distribution was demonstrated, thus data are expressed as Median and IQR, Statistical tests chosen based on Obtained results was non-parametric tests such as Mann Whitney U test was used for the comparison between obese and non-group MVV and Spearman rank correlation for Correlation between MVV and FMI for both the groups.

➢ *Descriptive Statistics*

Participants ranged in age from 12 to 19 years. In the non-obese group, 27.5% were aged 12–14 years, 40% were 15–17 years, and 32.5% were 18–19 years. In the obese group, 27.5% were aged 12–14 years, 42.5% were 15–17 years, and 30% were 18–19 years. The non-obese group comprised 37.5% females and 62.5% males, whereas the obese group included 47.5% females and 52.5% males.

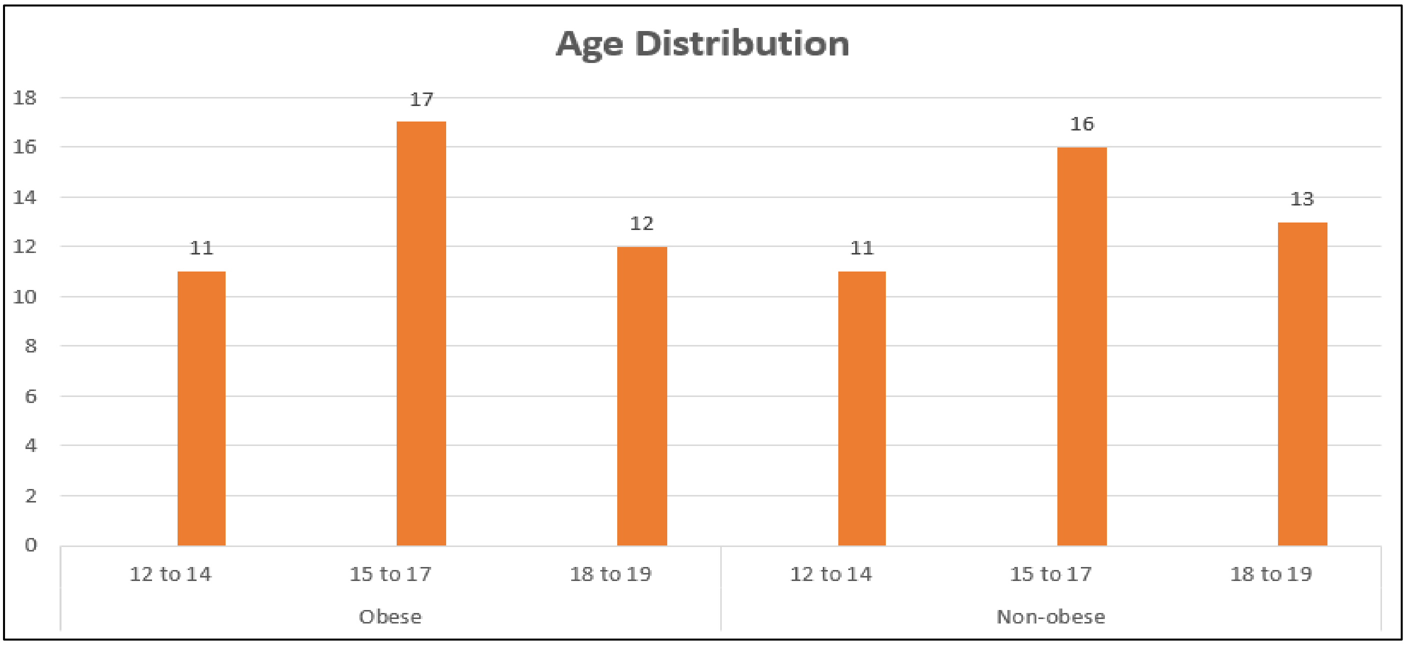

Fig 1 Age Distribution of Obese and Non-Obese Participants

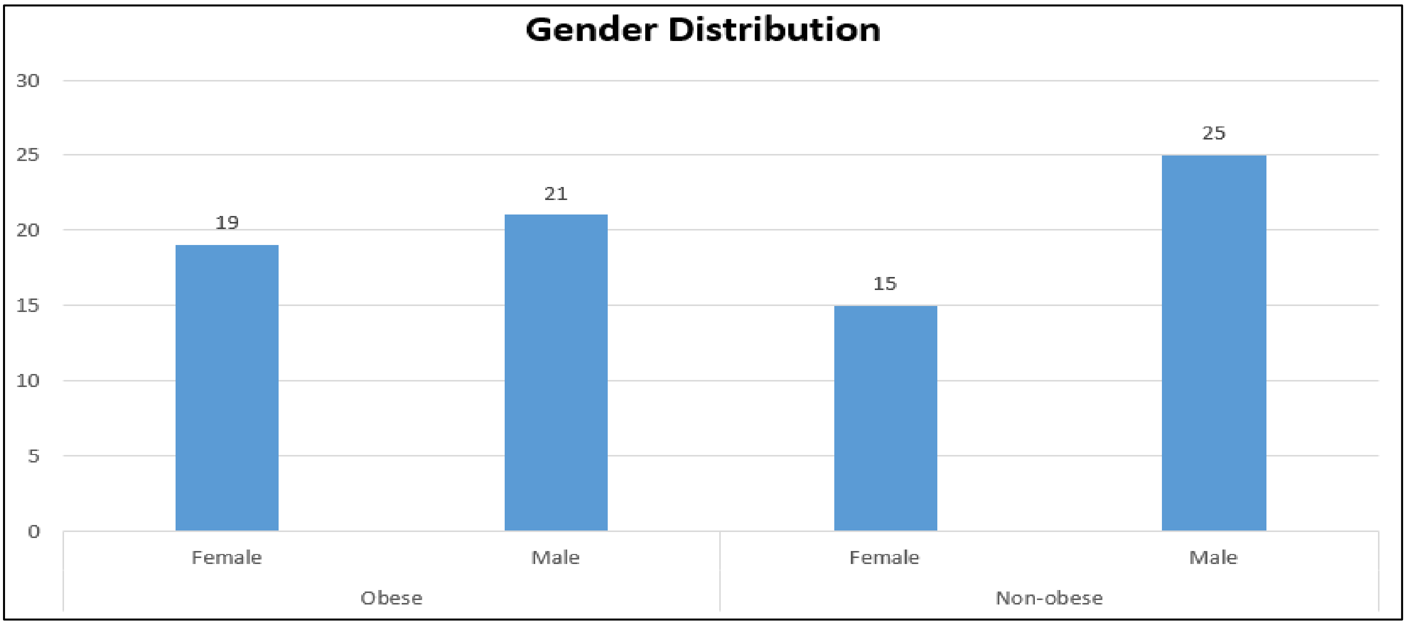

Fig 2 Gender Distribution of Obese and Non-Obese Participants

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25sep716

Table 1 Descriptive Statistics for Maximum Voluntary Ventilation

Group	N	Rank	Median	Q1	Q3	IQR
Obese	40	25.18	72.30	63.35	79.70	16.35
Non-obese	40	55.83	96.25	86.85	109.75	23.35

Table 1. In the non-obese group, the median MVV was 96.25 L/min, with an interquartile range of 86.40 - 109.75 L/min (IQR = 23.35). In contrast, obese participants had a lower median MVV of 72.30 L/min, with an interquartile range of 63.35 - 79.70 L/min (IQR = 16.35) with and median difference of 23.95 L/min.

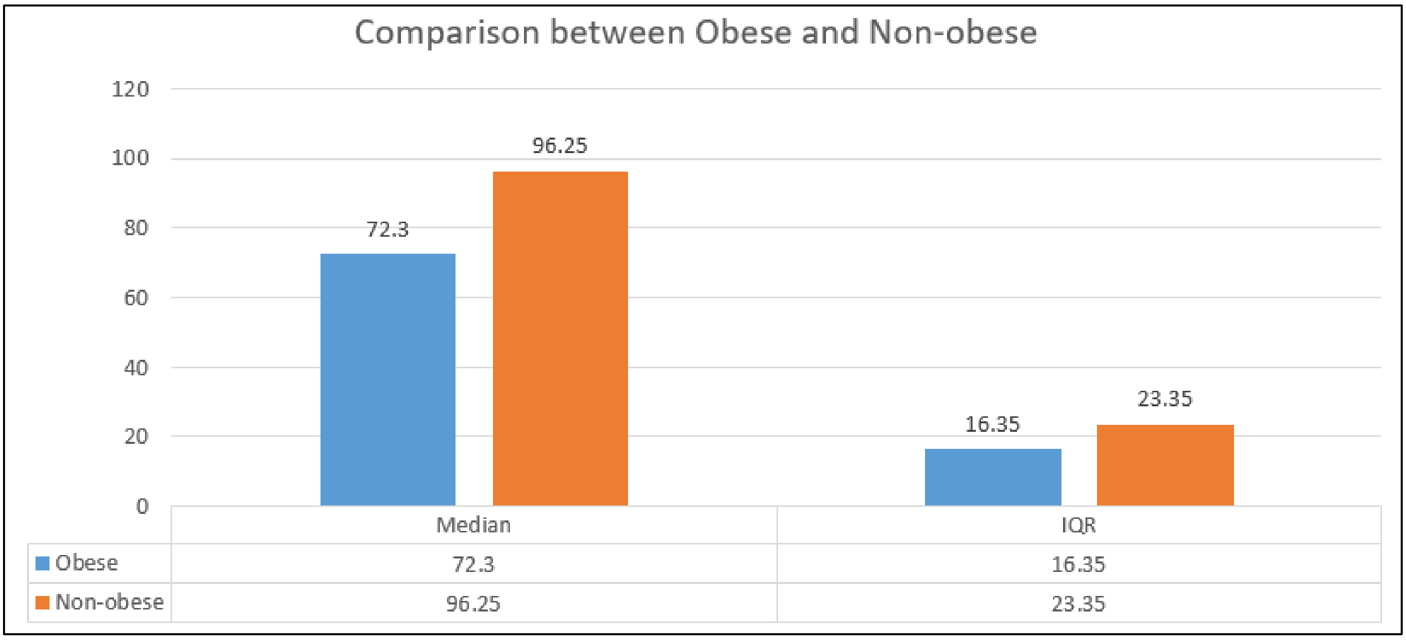

Fig 3 Comparison of Median and IQR Between Obese and Non-Obese.

Table 2 Mann-Whitney U Test

Maximum voluntary ventilation	Obese	Non-obese	Median difference	Effect size(r)	U statistics	P value	Significance
	72.30	96.25	23.95	0.76	189.5	p<0.01	Highly significant

Mann-Whitney U test revealed a statistically significant difference in MVV between two groups (U= 189.5, p < 0.01). Obese group had a lower mean rank (25.18) compared to Non-obese group (55.83), indicating that MVV was significantly lower in Obese. The rank-biserial effect size was r = 0.76, reflecting a very large between-group difference in ranks.

Table 3 Correlation Analysis

Group	Obese	Non-obese
Spearman rank correlation coefficient (rho)	-0.579	0.261
p value	p < 0.01	P > 0.05
Significance	Statistically significant	Not statistically significant

In Obese group the FMI negatively correlated with MVV (ρ = –0.579, p < 0.01), this means as FMI increases, MVV tends to decrease whereas, Non-obese had a weak, non-significant correlation (ρ = 0.261, p > 0.05).

V. RESULTS

A total of 80 adolescents aged between 12 and 19 years were included in the study, with equal distribution between the obese (n = 40) and non-obese (n = 40) groups. The age distribution was comparable across both groups, with a similar proportion of participants aged 12–14 years (27.5%), 15–17 years (42.5% in the obese group vs. 40% in the non-obese group), and 18–19 years (30% vs. 32.5%, respectively). Gender distribution showed a slight female predominance in the obese group (47.5% female, 52.5% male) compared to the non-obese group (37.5% female, 62.5% male). The median Maximum Voluntary Ventilation (MVV) for the obese group was significantly lower at 72.30 L/min (interquartile range [IQR]: 63.35–79.70) compared to 96.25 L/min (IQR: 86.40–109.75) in the non-obese group. The median difference in MVV between the two groups was 23.95 L/min. The Mann-Whitney U test revealed a highly significant difference in MVV values between obese and non-obese participants (U = 189.5, p < 0.01), with a large effect size (r = 0.76), indicating a substantial reduction in ventilatory capacity among obese adolescents.

Correlation analysis demonstrated a moderate, statistically significant negative association between Fat Mass Index (FMI) and MVV in the obese group (Spearman's rho = –0.579, $p < 0.01$), suggesting that higher fat mass is linked to lower respiratory function. In contrast, the non-obese group showed no significant correlation between FMI and MVV (Spearman's rho = 0.261, $p > 0.05$).

These findings indicate that obesity is strongly associated with impaired pulmonary function in adolescents, particularly as measured by MVV, and that FMI may serve as a valuable marker for predicting respiratory compromise in this population.

VI. DISCUSSION

The present study explored the impact of obesity on pulmonary function among adolescents, with a particular focus on Maximal Voluntary Ventilation (MVV) and its association with Fat Mass Index (FMI). A total of 80 school-aged participants were evaluated 40 categorized as obese and 40 as non-obese. MVV was used as the primary indicator of ventilatory performance, and FMI provided a more accurate representation of adiposity compared to traditional anthropometric indices such as Body Mass Index (BMI). The findings revealed a statistically significant reduction in MVV among obese participants compared to their non-obese counterparts. Median values reflected this difference, with 72.30 L/min with IQR range of 63.35-79.70 L/min (IQR = 15.78) in obese group and 96.25 L/min with IQR range of 86.40-109.75 L/min (IQR = 23.35) in Non-obese group. The Mann-Whitney U test confirmed the significance of this difference ($U = 189.5$, $p < 0.01$). with a large effect size of 0.76. The study also explored the association between Fat Mass Index (FMI) and Maximum Voluntary Ventilation (MVV) through Spearman’s rank correlation analysis. In the obese group, a statistically significant moderate negative correlation ($\rho = -0.579$, $p < 0.01$) was observed, suggesting that an increase in fat mass is associated with a measurable decline in MVV. In contrast, among non-obese participants, no significant correlation between FMI and MVV was found ($\rho = 0.261$, $p > 0.05$).

This supports existing evidence that obesity and anthropometric parameters negatively affects the lung function parameters. The large magnitude of difference in MVV between groups indicates that reduced ventilatory capacity in obese adolescents is not merely a statistical finding but a clinically relevant concern. Physiotherapists and other healthcare providers should consider routine pulmonary function screening in adolescents with obesity, even if no overt respiratory symptoms are present. Early screening for subclinical pulmonary dysfunction using MVV or other spirometric measures could enable early intervention. School-based health programs might consider integrating respiratory assessments, particularly for overweight or obese children, to identify those at risk and provide referrals for further evaluation or physical conditioning programs

Our findings align with earlier studies reporting that obesity in adolescents is associated with reduced lung volumes and ventilator capacity, likely due to mechanical restriction of chest wall movement and increased respiratory workload (Zerah et al., 1993). Similar reductions in MVV have been documented in obese adults (Paralikar et al., 2012; Malini M et al., 2017), but fewer studies have focused specifically on adolescents, particularly in rural populations.

VII. STRENGTHS AND LIMITATIONS

A strength of this study is the focus on a rural adolescent population, which is underrepresented in respiratory health research. The use of FMI provides a more precise measure of adiposity than BMI alone. However, the cross-sectional design precludes causal inference, and the study did not assess other lung function parameters such as forced vital capacity (FVC) or diffusion capacity, which could provide a more comprehensive picture. Future longitudinal studies could clarify the temporal relationship between obesity and MVV decline, gender specific study was not done.

VIII. CONCLUSION

This study concludes that obesity has a significant and measurable negative impact on pulmonary function in adolescents, as indicated by reduced Maximal Voluntary Ventilation (MVV) values. MVV values in obese group was significantly lower in comparison with their non-obese counterparts. A statistically significant moderate negative correlation was observed between MVV and Fat Mass Index (FMI) in the obese group, suggesting that greater fat mass is associated with poorer ventilatory performance. These findings underscore the importance of early screening and targeted interventions in obese youth to preserve and enhance respiratory health. The use of FMI as a diagnostic tool provides a more accurate representation of body composition-related respiratory risk than BMI alone. The integration of pulmonary function assessments into school health programs and paediatric clinical evaluations could lead to earlier identification of subclinical impairments and more effective preventive strategies.

ABBREVIATIONS

- (MVV- Maximum Voluntary Ventilation)
- (FMI – Fat Mass Index)

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