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ASSESSMENT AND EVALUATION OF PULMONARY FUNCTION PARAMETERS IN UNDERGROUND COAL MINERS OF TELANGANA STATE

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ABSTRACT

The purpose of this study is to evaluate the pulmonary function parameters using portable electronic spirometer in underground coal miners and to compare the obtained results with the equal number of general population (Control). The assessed spirometry parameters include Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), Peak Expiratory Flow (PEF) and Forced Expiratory Flow (FEF_{25-75}). Coal miners are more prone to acquire restrictive respiratory diseases such as pulmonary fibrosis and coal worker's pneumoconiosis. The results show that there is a statistical significance for all the pulmonary function parameters among underground coal miners. We noted that 93% underground coal miners had FVC abnormality compared to 4% in general population and 12.5% underground coal miners had severe FVC deficit whereas there was no severe FVC deficit in general population. Among coal miners, factors such as age and work experience lead to a gradual decline in FVC. Our spirometry analysis suggests that the FVC deficit has an impact in inducing deficiency of other pulmonary function parameters such as FEV_1, PEF and FEF_{25-75}.

KEYWORDS: Spirometry, Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), Peak Expiratory Flow (PEF), Forced Expiratory Flow (FEF_{25-75}), Underground coal miners.

INTRODUCTION

Coal is a combustible black or brownish-black sedimentary rock composed of carbon-75%, Ash-9%, Oxygen-8%, Hydrogen-5%, Nitrogen-2%, Sulfur-1%.[1] Underground soft rock mining is a group of underground mining techniques used to extract coal minerals. There are two primary mining techniques used to mine coal: they are underground mining and surface mining.[2]

Pollutants produced by coal dust act on the respiratory system to cause a variety of obstructive and restrictive lung diseases. Coal dust most potently causes restrictive lung diseases. Restrictive disease is a condition marked by a reduction in total lung capacity. A restrictive ventilatory defect may be caused by a pulmonary deficit, such as coal workers pneumoconiosis, pulmonary fibrosis.[3]

Coal Workers Pneumoconiosis (CWP) can be defined as the accumulation of coal dust in the lungs and the tissue's reaction to its presence; it is also known as black lung disease, it is caused by long term exposure to coal dust. It is common in coal miners and others who work with coal. Inhaled coal dust progressively builds up in the lungs and cannot be removed by the body, this leads to inflammation, fibrosis, and in worse cases, necrosis.[4]

MATERIALS AND METHODS

This study was conducted in Collieries located in towns of Godavarikhani and Srirampur, Telangana, India between February - September, 2017. Three hundred underground coal miners were enrolled in this study. Miners above the age of 28 years, having minimum work experience of 5 years were included, because they have sufficient exposure to acquire pulmonary dysfunction. These miners work for at least 8 hours per day and 6 days a week without following any self-protective measures. Miners of age above 60 years, work experience less than 5 years were excluded. Informed consent was obtained from each participant prior to collection of data from each participant. Data was collected through direct personal communication. The type of data collected from each participant includes: demographic data such as age, past medical history, co-morbid conditions, and social habits etc. It must be noted that the study included only male participants. Spirometry analysis was performed using a portable electronic Spirometer (Model- Contec SP 10) to measure the pulmonary function and the readings were noted. The data obtained from the spirometry analysis was then compared to an equal number of unexposed general population (control group).

Smoking pack-years has been calculated based upon the following formula:

Pack-years = No. of cigarettes smoked per day × No. of years smoked ÷ No. of cigarettes in a pack.

RESULTS

The results have been divided into two groups and they are as follows

Group I: Underground coal miners

Group II: Control

Group I: Underground (300).

Table. 1: Severity wise distribution of spirometry parameters.

Parameter	Normal	Mild	Moderate	Severe
FVC	21 (7 %)	150 (50 %)	92(30.6 %)	37(12.5 %)
FEV_1	53 (17.6 %)	134 (44.6 %)	71(23.6 %)	42(14 %)
PEF	76 (25.3 %)	77 (25.6 %)	64(21.3 %)	83(27.6 %)
FEF_{25-75}	148 (49.3 %)	65 (21.6 %)	47(15.6 %)	40(13.3 %)

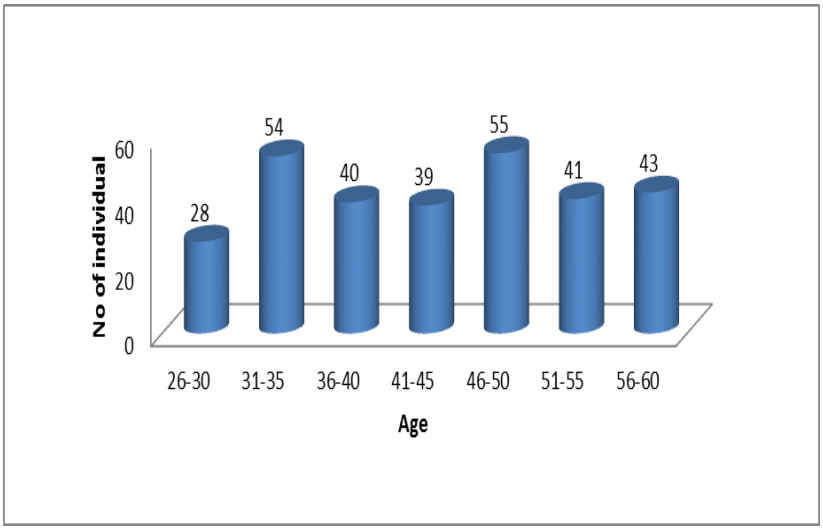

Figure. 1: Age wise distribution.

Table. 2: Age wise distribution of different grades of FVC.

Age group (years)	Normal	Mild	Moderate	Severe
≤30	9	16	2	1
31-35	2	46	5	1
36-40	2	28	10	0
41-45	3	18	12	6
46-50	1	15	36	3
51-55	3	15	15	8
56-60	2	11	12	18

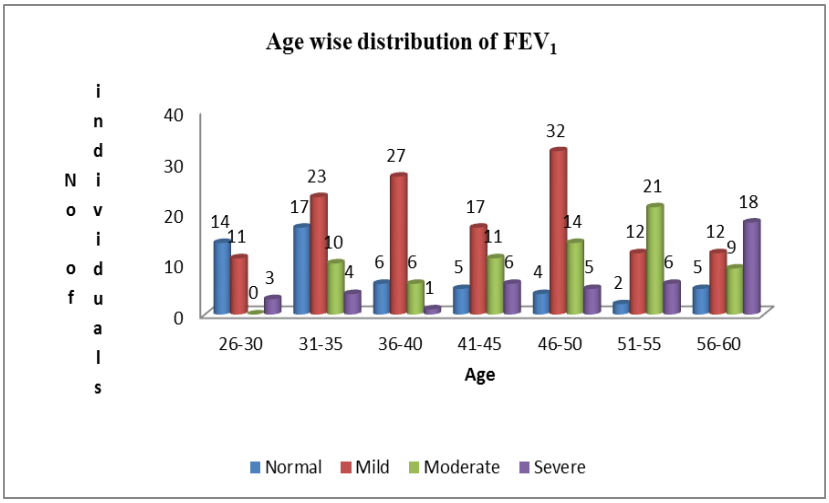

Figure. 2: Age wise distribution of different grades of FEV_1.

Table. 3: Duration of exposure wise distribution.

Exposure duration (years)	Number of individuals
6-10	88
11-15	43
16-20	53
21-25	48
26-30	51
>30	17

Table. 4: Distribution of different grades of FVC according to duration of exposure.

Exposure duration (years)	Normal	Mild	Moderate	Severe
6-10	12	63	11	2
11-15	2	29	12	0
16-20	2	22	21	8
21-25	1	14	25	8
26-30	4	15	20	12
>30	1	6	3	7

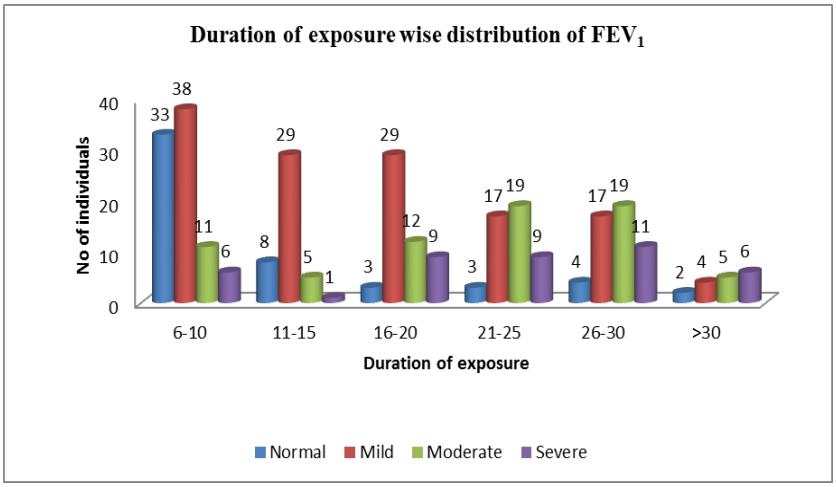

Figure. 3: Distribution of different grades of FEV_1 according to duration of exposure.

Social history wise distribution

Smoking: Total number of smokers = 81 (27 %).

Table. 5: Smoking (pack year) wise distribution of different grades of FVC.

Pack year	Normal	Mild	Moderate	Severe
0-3	3	19	11	2
>3-6	2	9	6	3
>6-9	0	9	8	9

Table. 6: Smoking (pack year) wise distribution of different grades of FEV_1.

Pack year	Normal	Mild	Moderate	Severe
0-3	18	15	8	4
>3-6	1	4	7	8
>6-9	1	5	7	13

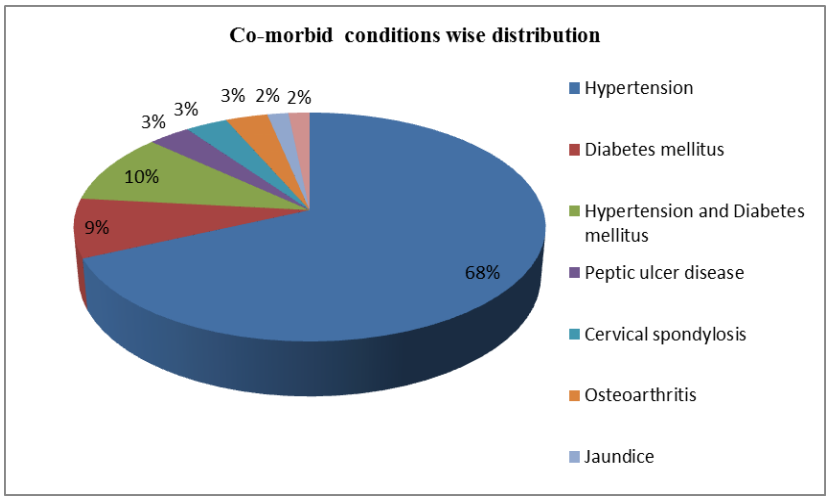

Figure. 4: Co-morbid conditions wise distribution.

FVC wise distribution of other parameters

FVC vs. FEV_1 distribution

Of 300 UG (UnderGround) coal miners, FVC was normal in 22 individuals, among them 8 had abnormal FEV_1. Among 149 individuals with mild FVC, FEV_1 was abnormal in 112 (75.1%). Among 92 individuals with moderate FVC, FEV_1 was abnormal in 90 (97.8%). Among 37 individuals with severe FVC, FEV_1 was abnormal in all individuals (100%).

FVC vs. PEF distribution: Out of 300, FVC was normal in 22 individuals, among them 13 (59%) has abnormal PEF. Among 149 individuals with mild FVC, PEF was abnormal in 96 (64.4%). Among 92 individuals with moderate FVC, PEF was abnormal in 78 (84.7%). Among 37 individuals with severe FVC, PEF was abnormal in 37 (100%) individuals.

FVC vs. FEF_{25-75} distribution

Out of 300, FVC was normal in 22 individuals. Among them 9(40.9 %) has abnormal FEF_{25-75}. Among 149 individuals with mild FVC, FEF_{25-75} was abnormal in 53(35.5 %) individuals. Among 92 individuals with moderate FVC, FEF_{25-75} was abnormal in 55(59.7 %) individuals. Among 37 individuals with severe FVC, FEF_{25-75} was abnormal in 35(94.5 %) individuals.

Body Mass Index (BMI) wise distribution

Underground mean BMI was 23.78 ± 1.17

BMI wise distribution of FVC

Out of 300 individuals, 260 (86.6 %) had normal BMI (BMI 18.5 - 25), among them FVC was abnormal in 243 (93.4 %). Of 40 (13.3 %) individuals who were overweight (BMI > 25), 35 (87.5 %) individuals had abnormal FVC.

BMI wise distribution of FEV_1

Out of 300 individuals, 260 (86.6 %) were having normal BMI, among them $FEV_1$was abnormal in 215 (82.6 %). 40 (13.3 %) were overweight, among them $FEV_1$was abnormal in 32 (80 %) individuals.

BMI wise distribution of PEF

Out of 300 individuals, 260 (86.6 %) were having normal BMI, among them PEF was abnormal in 197 (75.7 %). 40 (13.3 %) were overweight, among them PEF was abnormal in 27 (67.5 %) individuals.

BMI wise distribution of FEF_{25-75}

Out of 300 individuals, 260 (86.6 %) were having normal BMI, among them FEF_{25-75} was abnormal in 135 (51.9 %). 40 (13.3 %) were overweight, among them FEF_{25-75} was abnormal in 17 (42.5 %) individuals.

Group II: Control (300)

Table. 7: Severity wise distribution of spirometry parameters.

Parameter	Normal	Mild	Moderate	Severe
FVC	288 (96%)	11 (3.6%)	1 (0.3%)	0 (0%)
FEV_1	295 (98.3%)	4 (1.3%)	1 (0.3%)	0 (0%)
PEF	283 (94.3%)	13 (4.3%)	1 (0.3%)	4 (1.3%)
FEF_{25-75}	296 (98.6%)	0 (0%)	4 (1.3%)	0 (0%)

Table. 8: Statistical analysis of obtained results. (Using Graphpad Prism 7)

Underground vs. Control	P Value	R^2	t	95 % CI
FVC	0.025	0.0083	2.247	-5.436 to -0.3651
FEV_1	<0.0001	0.702	37.53	-1.865 to -1.68
PEF	<0.0001	0.4349	21.45	-3.565 to -2.967
FEF_{25-75}	<0.0001	0.5133	25.11	-2.633 to -2.251

DISCUSSION

Underground coal miners: In a study conducted by Wang *et al* 2013[5], the restrictive impairment in underground coal miners was noted to be 6.4%. In contrast, we found that restrictive lung function was 93 % and obstructive lung function 2.3%. This disparity is due to the enforcement of US Coal Mine Health and Safety Act, which became a law in 1969, establishing an enforceable federal limit on the exposure of underground miners to respirable coal mine dust. In the first 30 years of enforcement of this law, 89% decline was observed in the prevalence of restrictive lung disease and coal worker's pneumoconiosis. Where as in India, there is no such law enforcement to reduce the risk and limit of dust exposure in coal miners. Hence lung function was compromised in 93% of underground coal miners.

a) Forced Vital Capacity (FVC): It is the amount of air which can be forcibly exhaled from the lungs after taking the deepest possible inhalation. FVC is used to determine both the presence and severity of restrictive lung diseases. In this study, 12.5% of the participants were found to have severe FVC deficit, whereas 32% had moderate, and 50% individuals had mild FVC deficits. Various factors which impact pulmonary condition among underground coal miners are as follows.

Duration of exposure: Individuals with work exposure of 21-25 years had 97.9% FVC deficit and the severity was found to be increasing significantly from 16-30 and above years of work exposure (15% to 41.1%). This may be because of exposure tenure and FVC deficit which has a direct proportionality.

Age: In a study conducted by Wang *et al* 2013[5] the mean age was found to be 46.5 years ± 10, with an age range of 18-74 years. Similarly, we noticed that mean age was 43.62 years ± 9.52, age range was ≤ 30-60 years. 98.1% of the underground coal miners had abnormal lung function in the age group of 46-50, which was highest compared to the other age groups. The severity was found to be increasing gradually in the age groups between 46- 60 years. The

above observation reveals that severity was seemed to be increasing with age. Since, age is related to exposure tenure, FVC deficit was increasing proportionately.

Smoking: In a study conducted by Wang *et al* 2013[5], total number of smokers was found to be 22 %. In comparison, our study had 27% smokers. Among these, highest degree of FVC abnormality was noted in > 6-9 pack year interval individuals. Of which 34.6%, 30.7%, 34.6% had a mild, moderate and severe deficit in FVC respectively. This deficit in FVC was may be due to combined effect of smoking accompanied with underground coal mining. Other social habits such as alcohol intake and tobacco chewing have no conclusive evidence in the incidence of deficit in pulmonary function.

BMI: In a study conducted by Blackley *et al* 2014[6], they found that the BMI of underground coal miners was 30.1 ± 5.1. In our study, we observed BMI as 23.78 ± 1.17. Of 300 individuals, 260 had normal BMI. Among them, FVC was abnormal in 93.4%. Of 40 individuals who were overweight, 87.5% had abnormal FVC. There was a slight difference noticed in FVC abnormality among the individuals with normal and abnormal BMI. Our study suggests that the effect of BMI in inducing FVC deficit is unclear in coal miners.

b) Forced Expiratory Volume in 1st second (FEV_1): It is the volume of air forcefully exhaled in the 1st second of total expiratory time.

A study conducted by Blackley *et al* 2014[6], found 13.5 % of underground coal miners had abnormal spirometry in large mines and 40 % abnormality in small mines. In contrast, we noticed that 82.3% underground coal miners had FEV_1 abnormality. Among the total, 44.6%, 23.6% and 14% had mild, moderate and severe FEV_1 deficit respectively. As stated previously, this dissimilarity is due to the enforcement of US Coal Mine Health and Safety Act 1969, establishing an enforceable federal limit on the exposure of underground miners to respirable coal mine dust. Where as in India, there is no such law enforcement to limit the dust exposure in coal miners. Hence lung function was compromised in 82.3% of underground coal miners.

Duration of exposure: Individuals with work exposure of 16-20 years had 94.3% FEV_1 deficit and the severity was found to be increasing significantly from 11- 30 years and above of work exposure (2.3% to 35.2%). This may be due to the direct proportionality between degree of exposure and FEV1 deficit.

Age: In a study conducted by A E Raju *et al* 2014[7], the mean age was observed to be 40 years. Similarly, we observed the mean age as 43.62 ± 9.52. 95.1% underground coal miners had abnormal FEV_1 in the age group of 51-55 years. The severity was found to be increasing gradually from 9% to 39.5 % in the age groups between 46-60 years. The above observation reveals that severity seemed to be increasing with age. Since, age is associated to exposure tenure, FEV1 deficit was increasing proportionately.

Smoking: In a study conducted by Soutar and Hurley *et al* 1986[8], total number of smokers in their study were found to be 63% and average estimated effect of smoking was to reduce FEV_1 more than FVC and to reduce FEV_1/FVC ratio. In comparison, our study had 27% smokers. Among these, highest abnormality was noted in > 6-9 pack year interval as 96.1%, of which 20%, 28%, 52% had a mild, moderate and severe deficit in FEV_1 respectively. This observation reveals that smoking induces a deficit in FEV_1 more than other parameters.

BMI: A study conducted by Guangxing Xu *et al* 2012[9], found that the BMI of coal miners was 24.1 ± 4.1. In our study, we observed BMI as 23.78 ± 1.17. Of total individuals, 260 had normal BMI, among them FEV_1 was abnormal in 82.6%. Of the 40 overweight individuals FEV_1 was abnormal in 80%. Our study suggests that there is an unclear association between BMI and FEV_1 deficit.

c) Peak Expiratory Flow (PEF): It is the maximal flow/peak (or speed) achieved during the maximal forced expiration. It is mostly dependent on person's force of exhalation.

In this study, out of 300 underground coal miners, 74.6% had abnormal PEF. Of all the participants tested, 25.6%, 21.3% and 27.6% had mild, moderate and severe PEF deficit respectively. PEF depends upon the individual force of expiration; hence it could not be used as an absolute determinant in governing the lung function.

d) Forced Expiratory Flow (FEF_{25-75}): Forced expiratory flow (FEF) is the flow of air coming out of the lung during the middle portion of a forced expiration. The usual intervals are 25% and 75% of FVC.

In this study, of 300 underground coal miners, 50.6% had FEF_{25-75} abnormality. Among the total 21.6%, 15.6 % and 13.3% had mild, moderate and severe FEF_{25-75} deficit respectively. We observed a decline in FEF_{25-75} which might be due to a greater decline in FVC.

Co-morbid conditions: In a study conducted by Zheng *et al* 2017[10], 60.8% were Hypertensive, 14% were Diabetic with a mean age of 65.15 ± 8.86. In our study, we found that 20% underground coal miners had past medical history. Hypertension was the most observed co-morbidity which constituted up to 13.6%, followed by Diabetes mellitus. Hypertension and Diabetes mellitus are most frequently seen co-morbidities globally. The higher percentage in their study was due to variance in the mean age, as the age increases the chance of developing these diseases increases.

FVC vs. Other parameters: (Underground coal miners)

FVC vs. FEV_1: FVC was normal in 22 and abnormal in 278 individuals. Among the individuals with abnormal FVC, 88.8% individuals had abnormal FEV_1, of these 46.7% had mild FEV_1 deficit, 24.8% had moderate FEV_1 deficit and 14.3% individuals had severe deficit in FEV_1. Among the individuals with normal FVC, 36.3% had abnormal FEV_1. We observed that FEV_1 deficit was more in the individuals with abnormal FVC. This might be due to the longitudinal decline in FVC for a prolonged time which may have caused a decline in FEV_1.

FVC vs. PEF: FVC was normal in 22 and abnormal in 278 individuals. Among the individuals with abnormal FVC, 75.8% individuals had abnormal PEF, out of these 26.6%, 20.8% and 28.4% individuals had a mild, moderate and severe decline in PEF respectively. Among individuals with normal FVC, 59% had abnormal PEF. We observed that PEF deficit was more in individuals with abnormal FVC. The relation between FVC and PEF is insignificant as the PEF varies from person to person based on individual force of expiration.

FVC vs. FEF_{25-75}: FVC was normal in 22 and abnormal in 278 individuals. Among the individuals with abnormal FVC, 51.4% individuals had abnormal FEF_{25-75}, out of these 21.5% had mild FEF_{25-75} deficit, 16.1% had moderate FEF_{25-75} deficit and 13.6% had severe deficit in FEF_{25-75}. Among the individuals with normal FVC, 40.9% had abnormal FEF_{25-75}. We observed that FEF_{25-75} deficit was more in the individuals with abnormal FVC. The observed decline in FEF_{25-75} is due to a greater decline in FVC.

Control group

Among 300 control group 4% had restrictive lung function and 1.3% had obstructive lung function. Deficit in lung function is very mild in control group because they are general population who has almost no exposure to occupational dust pollution.

Underground coal miners – Control

Wide difference was observed in the lung function between underground coal miners and control group. 93% underground coal miners had abnormal FVC compared to 4% in the control group. 82.3% underground coal miners had abnormal FEV_1 compared to 1.6% in the control group. 74.6% underground coal miners had abnormal PEF compared to 5.3% in the control group. 50.6% underground coal miners had abnormal FEF_{25-75} compared to 1.3% in the control group. This difference is due to negligible dust exposure among the control group which is insignificant compared to mammoth coal dust exposure among underground coal miners.

CONCLUSION

Our study indicates that underground coal miners have extreme risk of acquiring restrictive lung diseases. The conclusion is based on evidence gathered during the study wherein we noted that as the age and experience of the miners who participated in the study increased, the observed FVC levels decreased. Results of our study do not align with those of other studies conducted in other parts of the world, perhaps because of the preventable measures enforced by the respective governments where the studies were conducted in order to limit coal miners' exposure to dust and reduce the overall risk of lung diseases.

Given the fact that restrictive lung disease cannot be reversed and that they can only be treated symptomatically, coal miners need to take extreme precautions so that they don't acquire the disease. Measures such as use of dust preventive face masks, lifestyle modifications etc. are highly recommended. Additionally, regular analysis of pulmonary function and early detection of restrictive lung disease can go a long way in not only reducing the progression of the disease, but also improving its prognosis. A clinical pharmacist can play a crucial role in regard to counseling these individuals concerning the use of different preventive measures which can aid in prevention and progression of the disease.

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