Lung Function Decline and Other Physiological Changes in Health Workers after Working in COVID-19 Isolation Wards: An Observational Study

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Research Article

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Abstract

Background:

Global healthcare systems have been under huge pressure since Coronavirus Disease 2019 (COVID-19) was declared a pandemic. It is critical to prevent further spread of COVID-19 and to protect health workers from infection. This study aims to figure out short-term physiological impact on health workers induced by working in isolation wards for hours with personal protective equipment (PPE), so as to provide insights on reducing physiological impact and infection risk of health workers.

Methods:

Health workers who had worked in COVID-19 isolation wards for at least five weeks in Wuhan, China were recruited. Parameters including lung function, heart rate, oxygen saturation and weight were respectively measured before and after they worked in isolation wards. Comparison and regression analyses were conducted. Correlations between changing levels of measured parameters (lung function and heart rate) and baseline characteristics (body mass index, age, and working duration) were also analyzed.

Results:

After working in isolation wards for four to nine hours, the forced vital capacity (FVC) of health workers (74.32±17.59 versus 81.28±16.35, P<0.001) as well as weight (54.79 (48.50, 61.00) versus 55.50 (48.90, 61.00) P<0.01) showed significant decrease, while HR showed significant increase (110.31±14.65 versus 103.94±16.38, P=0.04). Correlation between BMI and the decline levels of FEV_1/FVC (β=2.87, P=0.02) and correlation between BMI and the decline levels of $FEF_{25\text{-}75}$ % predicted (β=1.80, P<0.05) were reported.

Conclusions:

After working in COVID-19 isolation wards with PPE for four to nine hours, the lung function of health workers declined. The decline levels were associated with BMI. HR increase and weight loss were reported. In order to reduce the potential infection risk of health workers, the balance between working duration and physiological changes should be considered when making shifting schedule.

Background

Over 3,267,184 people (by May 2, 2020) on the world have infected Coronavirus Disease 2019 (COVID–19) and 229,971 patients have died since the first case reported in Wuhan, China in December 2019.[1, 2] The World Health Organization (WHO) has declared COVID–19 a pandemic in March.[3] Patients with COVID–19 mainly showed symptoms such as fever, cough, fatigue, myalgia, and dyspnea. Acute respiratory distress syndrome and multiple organs failure were reported in progressed patients.[1, 4] According to currently available basic reproduction numbers (R_0), the severe acute respiratory coronavirus 2 (SARS-CoV–2), the pathogen of COVID–19, is highly infectious.[5–7] Considering the pandemic of COVID–19 and the shortage of health resource, it is undoubtedly critical to prevent infection spread and

to protect health workers against COVID–19. Although the transmitting way of SARS-CoV–2 is not fully understood yet, contact, respiratory droplet and fomites have been proposed by some scholars.[8, 9] Thus, personal protective equipment (PPE) including N95 filtering facepiece respirator (FFR) or medical mask, gown, goggle and gloves are highly recommended for health workers who work in isolation wards.[4] However, overloading working schedule and side effect of PPE such as skin damage also exerted negative physiological impact on health workers.[10] The exhalation and inhalation resistance of N95 FFR and high-intensity work might contribute to changes of lung function, consequently decreasing working efficiency.[11] Keeping physical function in good status when working in isolation wards might play an important role in preventing health workers from infection. To our best knowledge, there is no similar study concerning the changes of lung function, oxygen saturation, heart rate, and weight of health workers after working in isolation wards. This research aims to show short-term physiological impact of PPE on health workers working under the COVID–19 pandemic and provide reference on formulating work shifting system scientifically.

Methods

This observational study was conducted from February to March 2020 in Wuhan, China. The inclusion criteria were as follows: 1) licensed doctors and nurses who have received intense training to manage COVID–19 patients; 2) working in isolation wards with PPE over four hours; 3) not smoking; 4) not pregnant; 5) without any chronic respiratory diseases history including chronic obstructive pulmonary disease (COPD) and asthma; 6) showing no respiratory tract infection symptom within last two weeks. All subjects involved in this study had worked in isolation wards for at least five weeks. The information of any subject infected by COVID–19 within 28 days after they ended working in isolation wards were recorded. All subjects were informed about the procedure and details of this study and signed consents. This study was approved by the Institutional Review Board (IRB) of authors' hospital.

Measurement was conducted under the supervision of a pulmonologist. Lung function parameters including forced vital capacity (FVC) % predicted, forced expiratory volume in one second (FEV_1) % predicted, ratio of FEV_1 to FVC (FEV_1/FVC), peak expiratory flow (PEF) % predicted and mean forced expiratory flow, mid-expiratory phrase (FEF_{25-75}) % predicted were measured and calculated by Ubreath Spirometer System PF680 (e-LinkCare Meditech Co.,Ltd., Hangzhou, China). Blood oxygen saturation measured via pulse oximetry (SpO_2) was obtained by Pulse Oximeter CMS50DL (Heal Force Bio-meditech Holdings Group, Shanghai, China). The information of all subjects including sex, age, height, baseline weight was collected and body mass index (BMI) was calculated. Before these health workers entered and after they left isolation wards, their heart rate, SpO_2, weight, and lung function were measured in less than five minutes without wearing PPE.

When working in isolation wards, all these health workers were equipped with PPE consisting of protective coveralls (*AAMI PB70 level 4)* covered by surgical gowns, N95 FFR (In line with the standard of *GB/T32610–2016 KN95; NIOSH N95; FFP2)* covered by surgical mask (In line with the standard of

GB/T32610–2016 KN90; FFP1),, protective goggles, gloves (double layers), long shoe covers (double layers), and surgical cap. Their work mainly contained managing patients with COVID−19, establishing venous access, sputum induction, ventilators management, nursing, *etc.* Working durations in isolation wards of all subjects were over four hours. The actual working durations could vary, but were recorded and analyzed. Actual working time for four to six hours was defined as short working-duration while more than six hours but less than nine hours was defined as long working-duration.

All the statistics were analyzed using Stata/SE 12.0 (College station, TX) and GraphPad Prism 8 (San Diego, CA). Normally distributed parameters were analyzed using Student's t test and simple linear regression analysis. Non-normally distributed parameters were normalized before analyzing. $P < 0.05$ was regarded significant for all analyses. Normally distributed parameters displayed in this study were as mean ± standard deviation and non-normally distributed parameters were shown as median (25^{th} percentile, 75^{th} percentile).

Results

There were 36 healthy health workers, 34 females and 2 males in one isolation ward involved in this study. The demographic data were shown in Table 1. The mean age was 30.06 years, ranging from 22 to 39. Their BMI ranged from 16.94 to 31.22, averaging 21.69. After working in isolation wards for averaging 6.5 hours, the HR were significantly higher than values measured before working (110.31±14.65 versus 103.94±16.38, $P = 0.04$) while FVC % predicted showed a decline (74.32±17.59 versus 81.28±16.35, $P<0.001$). The after-working means of FEV_1 % predicted, FEV_1/FVC, PEF % predicted and FEF_{25-75} % predicted were also lower than before-working means, but no significant difference was observed ($P = 0.13$, $P = 0.85$, $P = 0.23$, $P = 0.25$, respectively). Comparison was shown in Table 2. The before-working weights of two health workers (one male and one female) were measured in incorrect method (wearing PPE) and were consequently excluded from weight change analysis. After working in isolation wards, the weights of other health workers (n = 34) significantly decreased (54.79 (48.50, 61.00) versus 55.50 (48.90, 61.00) P<0.01). The decreasing level was 0.43±0.71 kg.

Table 1: Demographic characteristics of health workers recruited in this study.

Characteristics	Mean (n=36)	Minimum	Maximum
Age(y)	30.06±4.77	22	39
Working duration(min)	413.50 (315, 432)	277	518
Weight(kg)	55.50 (49.0, 61.5)	45	85
BMI	20.67 (19.47, 23.21)	16.94	31.22

Abbreviation: BMI=Body mass index

Table 2. Changes of parameters after health workers working in isolation wards.

Characteristics	Before working (n=36)	After working (n=36)	P
SpO_2 (%)	98.39±0.69	98.26±0.73	0.42
Heart Rate (/min)	103.94±16.38	110.31±14.65	0.04
Weight (kg)	55.50 (48.90, 61.00) *	54.79 (48.50, 61.00) *	<0.01
FVC (%)	81.28±16.35	74.32±17.59	<0.001
FEV1 (%)	31.05 (23.20, 50.90)	30.55 (20.90, 41.85)	0.13
FEV_1/FVC (%)	37.55 (30.80, 57.55)	44.42±16.88	0.87
PEF (%)	14.75 (11.30, 25.35)	15.60 (10.80, 20.50)	0.23
FEF_{25-75} (%)	21.45 (14.45, 33.35)	19.40 (13.20, 23.90)	0.25

Abbreviation: FVC=Forced vital capacity, FEV_1= Forced expiratory volume in one second, FEV_1/FVC= Ratio of FEV_1 to FVC, PEF= Peak expiratory flow, FEF_{25-75}=Forced expiratory flow, mid-expiratory phrase.

*Parameters of two health workers were measured in incorrect method and were excluded. Therefore, n = 34 for this characteristic.

A significant negative correlation between BMI and the decline levels of FEV_1/FVC (β = 2.87, *P* = 0.02) was observed through linear regression (shown in Figure 1). The correlation between BMI and decline levels of FEF_{25-75} % predicted (β = 1.80, *P*<0.05) also showed significance (shown in Figure 2). However, there was no significant correlation between age and changing levels of any measured parameter.

There were 14 subjects in short working-duration group and 22 in the long one in total. No significant difference was shown in age (30.71±4.58 versus 29.64±4.96, *P* = 0.52) or BMI (22.48±3.84 versus 21.19±2.91, *P* = 0.28). Neither before-working nor after-working lung function in both short working-duration group and long working-duration group showed significant difference (shown in Table 3). None of these recruited health workers were confirmed infected by COVID−19 within 28 days after they ended working in isolation wards.

Table 3: Comparison of characteristic changing levels between different working durations.

	Before working			After working		
Characteristics	4~6 h (n=14)	6~9 h (n=22)	P	4~6 h (n=14)	6~9 h (n=22)	P
SpO_2 (%)	98.50±0.76	98.32±0.65	0.45	98.35±0.74	98.00 (98.00, 99.00)	0.49
Heart Rate (/min)	103.43±17.55	104.27±16.01	0.88	110.57±15.34	110.14±14.56	0.93
Weight (kg)	55.73 (51.00, 60.80)	55.78±8.32*	0.44	54.54 (50.60, 60.80)	55.49±8.27*	0.51
FVC (%)	78.06±18.47	83.33±14.93	0.35	70.04±20.18	73.40 (68.90, 84.30)	0.25
FEV_1 (%)	36.36±23.62	40.63±21.95	0.37	30.55 (17.70, 41.20)	30.45 (21.70, 42.30)	0.78
FEV_1/FVC (%)	31.95 (29.40, 67.50)	38.45 (31.80, 51.80)	0.52	47.01±19.43	42.77±15.29	0.47
PEF (%)	12.15 (10.30, 24.60)	21.80±14.37	0.22	17.80 (9.60,19.40)	14.15 (11.00,20.50)	0.73
$FEF_{25\text{-}75}$ (%)	17.60 (13.30, 37.10)	21.90 (14.70, 29.60)	0.33	19.40 (10.80, 31.80)	19.15 (14.30, 22.80)	0.92

Abbreviation: FVC=Forced vital capacity, FEV_1= Forced expiratory volume in one second, FEV_1/FVC= Ratio of FEV_1 to FVC, PEF= Peak expiratory flow, $FEF_{25\text{-}75}$=Forced expiratory flow, mid-expiratory phrase.

*Parameters of two health workers were measured in incorrect method and were excluded. Therefore, n = 20 for these characteristics.

Discussion

This is the first study focusing on short-term physiological changes (especially lung function) in health workers who worked in COVID−19 isolation wards for over four hours with PPE including N95 FFR, trying to provide reference on formulating scientific working shift system to protect health workers. SARS-CoV−2 is a new pathogen which is extremely contagious. There were more than 3,000 health workers in China and at least 9,000 in US reported infected.[12, 13] More than 40,000 health workers were infected in Europe according to local media. The importance of protecting health worker from high infection risk has been emphasized by many authors.[14, 15] Since droplet mode is one of the main spreading ways, respiratory protection such as medical mask and respirator plays a role in protecting health workers. However, respiratory protection may also bring discomfort.[16]

Spirometry test is widely applied in evaluating patients' respiratory function. FVC, FEV_1, and FEV_1/FVC are indicators of obstructive ventilation disorder,[17] usually seen decreased among patients with COPD and bronchial asthma. PEF reflects the function of respiratory muscle and airway resistance while FEF_{25-75} acts as an indicator of small airway function.[18, 19] All these parameters can reflect lung function objectively. The result of this study showed significant short-term increase of heart rate and decline of FVC % predicted, which indicated that continuously working for hours in isolation wards was not an easy task. Slight obstructive respiratory was observed. Exhalation and inhalation resistance from respiratory protection and fatigue of respiratory muscles after long-duration working might be the contributing factors. Roberge et al conducted a trial on physiological impact of N95 FFR on health workers working for an hour (average wearing time when there was no pandemic), finding no significant difference.[11] However, N95 FFR was not the only equipment influencing lung function in our study while the second layer of surgical mask as well as protective coveralls may also exert impact on lung function. Moreover, health workers in our study had a much longer working duration (averaging 6.5 hours) and higher working intensity, which was just the actual condition under COVID−19 pandemic. These could lead to more significant short-term lung function decline and increase of heart rate. Mental stress from COVID−19 outbreak and facing heavily illness quarantined patients might also facilitate the changes.[20]

Currently available evidence showed negative correlations between lung volume (especially functional residual capacity and expiratory reserve volume) and BMI among both normal and overweight people.[21] Therefore, this study assessed the association between changing levels of respiratory functions and BMI. Decline of FEV_1/FVC enlarged as BMI increased among subjects were observed in the result. Similar condition was also recorded between changing levels of FEF_{25-75} % predicted and BMI. These finding indicated that health workers with higher BMI tended to suffer larger decline of lung function. A possible explanation by Littleton et al was that some airways start to closed as the BMI increase.[22] But this explanation was mainly based on lung function decline among obese people while the mechanism in normal or mild-overweight people remains further research. Considering all subjects in this study generally have a lower BMI, the decline of lung function among health workers with higher BMI might be more significant.

Other lung function parameters measured in this study such as FEV_1 % predicted, FEV_1/FVC, PEF % predicted, FEF_{25-75} % predicted all showed lower means but the differences were not significant. It could be influenced by sample size while a larger sample might bring differences. There was no significant difference in SpO_2 between before-working and after-working results, which indicated that changes of oxygen diffusion function induced by working in isolation wards with PPE less than nine hours could be compensated or the oxygen diffusion function could not be influenced. However, for those who work in isolation wards repeatedly, whether the acute decline of lung function would exert long-term impact is still unknown. The possibility of conversion from acute to chronic decline should not be ignored. Long-term decline of lung function could be associated with many diseases such as cardiovascular events, restrictive respiratory disorder, COPD, and lead to chronic hypoxemia.[23]

The weight loss of health workers after working in COVID−19 isolation wards was the consequence of dehydration because they could not drink water or urinate during working. The PPE including double layers of protective clothing (protective coveralls covered by surgical gown), double layers of respiratory protection (N95 FFR covered by surgical mask) and double layers of shoe covers would quickly made health workers sweaty and tired. Severe dehydration could lead to various health events such as falls, delirium, renal failure and even deaths.[24] Respiratory infection is also strongly associated with dehydrations.[24] In this study, no health workers showed any symptom of dehydration except for fatigue. No infection of COVID−19 was reported afterwards. Hence, the short-term dehydration induced by working in isolation wards could be compensated but long-term impact on those who worked in isolation wards repeatedly is still unknown.

There was no significant difference between age and changing levels of each parameter. It was deduced that young health workers (ranging from 22 to 39) involved in this study show same impact on physiological function. It was hypothesized that longer working duration would induce more significant changes both in lung function and heart rate. Huang et al recommended a working shift system of continuously working for six hours because working for longer duration made workers feel exhausted and even dizzy.[12] Thus, health workers involved in this study were divided into two groups according to different working duration (less than or over six hours) in isolation wards. No significant difference was observed between these two groups. Therefore, continuous working in isolation wards for six to nine hours would not exacerbate the short-term lung function decline or exert more severe physiological impact comparing to working for four to six hours.

Considering the lung function decline and other physiological impact on health workers and the valid using duration of PPE, the balance between protecting health workers and helping more patients should be kept. First, the application scope of respiratory protection should be carefully evaluated. N95 FFR is recommended consistently in aerosol generating procedure such as endotracheal intubation and collecting respiratory specimens while it is still conflicting whether N95 FFR is necessary in non-aerosol generating procedure.[25–27] Surgical mask is recommended to be worn all times in healthcare facilities.[25] Second, the constant working duration of PPE required limitation. There is no consistent recommendation for constant working duration with PPE in isolation wards. The valid using duration of N95 FFR used to be recommended for eight hours by Centers for Disease Control and Prevention of United States while WHO suggested that using a respirator for more than four hours should be avoided.[27, 28] Working with medical mask or N95 FFR constantly could increase infection risk and induce discomfort such as fascial heat and pain.[16] In this study, no health worker was confirmed infection afterwards, which was a testament of the efficacy of protection when working in isolation wards within nine hours. But six-hours duration might be recommended considering working fatigue.

There are limitations in this study. The imbalance of sex proportion could contribute bias, although it was literally independent when recruiting health workers. There might be more persuasive result if more male health workers could be recruited, because sex distribution was reported in association between lung function and obesity.[22] Age distribution is another disadvantage. Although age in this study was

normally distributed, there was no health workers older than 40 years old recruited. The impact of working with PPE in isolation wards within nine hours on elder health workers were still unknown. Moreover, because of the maximum working stress of COVID−19 and the shortage of rest, only 36 health workers in one isolation ward could spent their precious resting time to complete the lung function test in authors' institution. Large sample study is literally better for more convincing result, but prospective and empty controlled group was not feasible considering the infection risk. After working in COVID−19 isolation wards for certain period such as two or more months, significant decline of lung function might be observed. Mid-term and long-term follow up were absence and some potential impact might be consequently ignored.

Conclusions

This study revealed the short-term lung function declined of health workers after working in COVID−19 isolation wards with PPE for four to nine hours. The decline levels were associated with BMI. Heart rate increase and weight loss were reported. No harmful impact on young health workers under 40 years old was found in this short-term observational study. Six-hour working duration could be recommended considering the physiological impact on health workers and the valid using duration of PPE when formulating working shift system. In order to reveal further impact of working in COVID−19 isolation wards on health workers, long-term follow up is required.

Abbreviations

Coronavirus Disease 2019 (COVID−19); World Health Organization (WHO); severe acute respiratory coronavirus 2 (SARS-CoV−2); personal protective equipment (PPE); filtering facepiece respirator (FFR); forced vital capacity (FVC); forced expiratory volume in one second (FEV_1); peak expiratory flow (PEF); mean forced expiratory flow; mid-expiratory phrase (FEF_{25-75}); Blood oxygen saturation measured via pulse oximetry (SpO_2); heart rate (HR); body mass index (BMI); forced vital capacity (FVC).

Declarations

Ethic approval and consent to participate

The Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No: IORG0003571) gave a final APPROVAL for this study. All subjects signed written informed consent for participate.

Consent for publication

Not applicable

Availability of data and materials

All data could be achieved through emailing Dr. Xin Tang.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contribution

KLC, PPZ and XT drafted and finalized the manuscript. XT and FW were responsible for literature search and study design. LYW, STZ, CPW, YH, and YSW performed data collection. The manuscript has been read and approved by all authors, and all author believe that the manuscript represents honest work.

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Figures

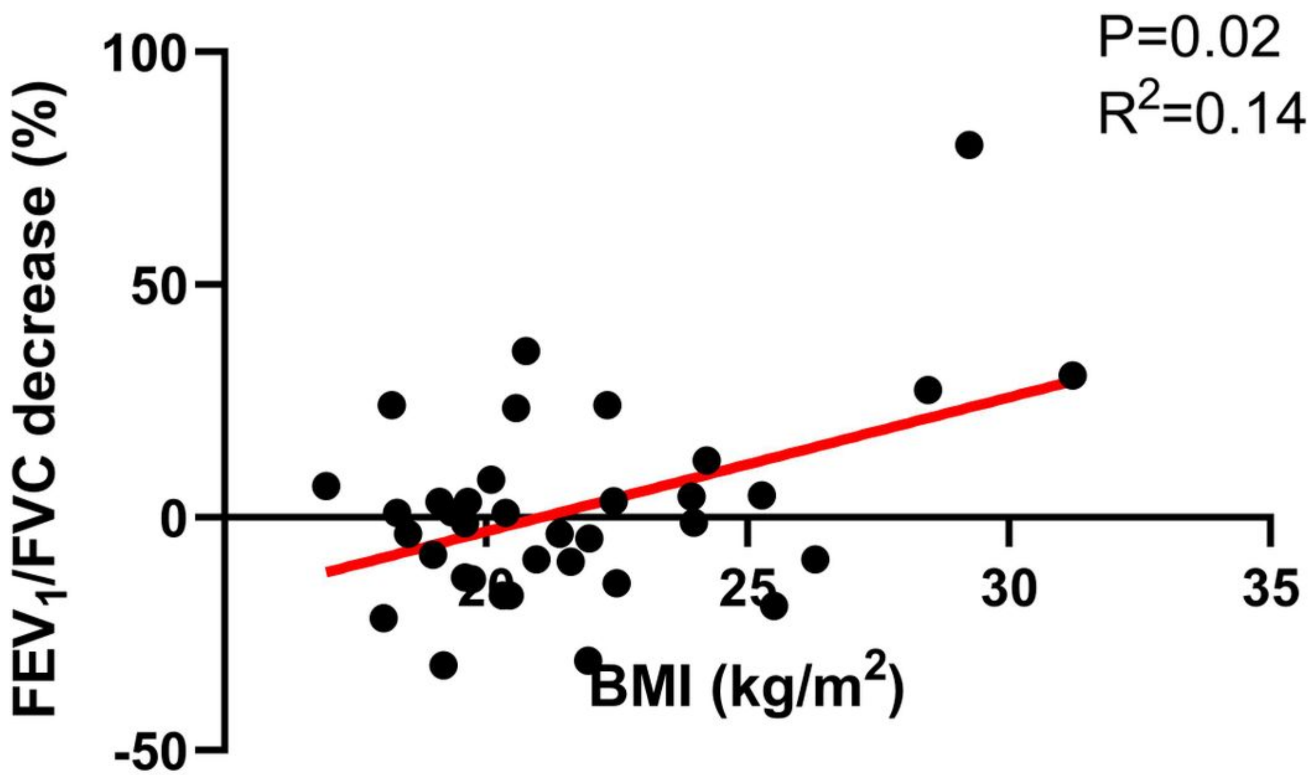

Figure 1

As BMI increases, decreasing levels of FEV1/FVC (β=2.87) enlarges.

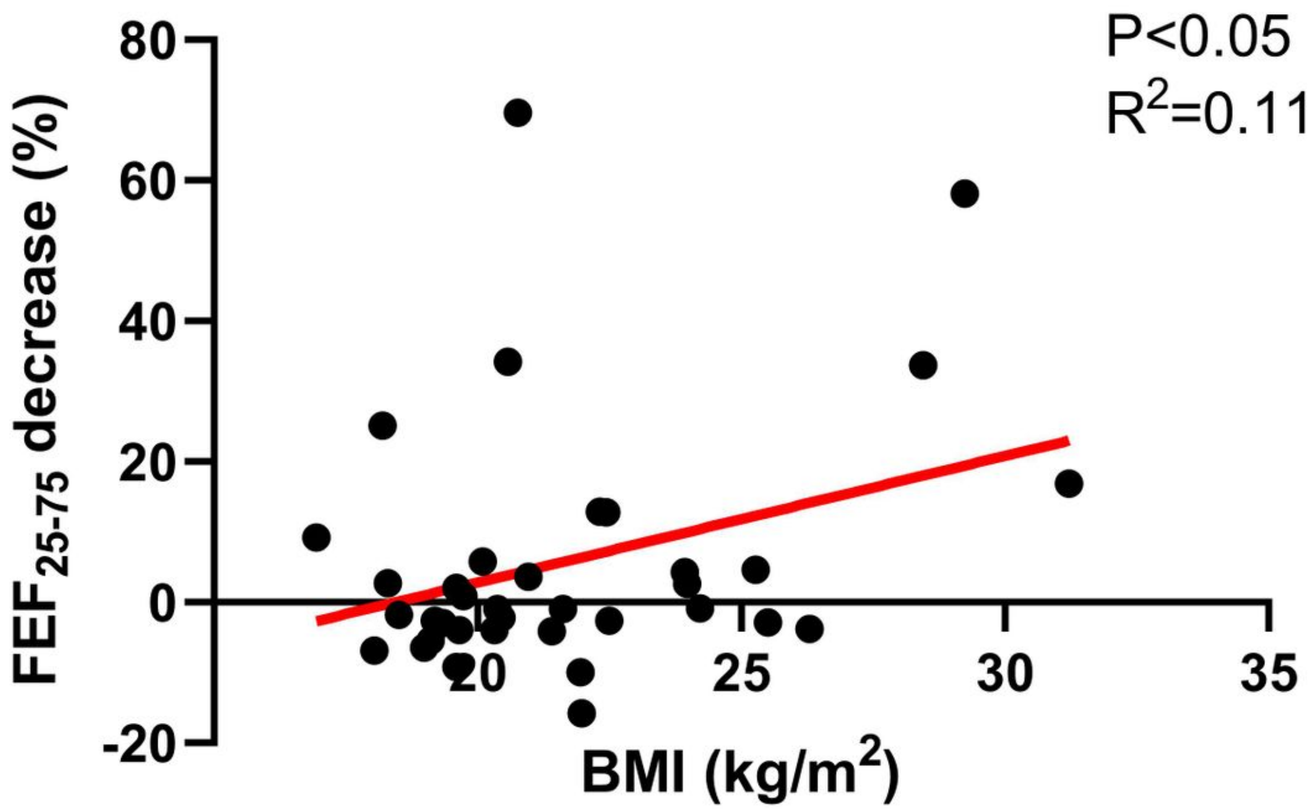

Figure 2

As BMI increases, decreasing levels of FEF25-75 (β=1.80) enlarges.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- datasupplement.csv