



SPECIAL ARTICLE

Respiratory flows as a method for safely preventing the coronavirus transmission (COVID-19)

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Abstract The spread of CoV-2 occurs mainly by respiratory droplets. Its dispersion depends on several factors: viscoelasticity of fluid, ventilation, evaporation rate, exhalations, sneeze or cough. At moment, the preventive distance to avoid the contamination has been established in 1–2 m. We believe that it is necessary to review this aspect, because the respiratory flows change with the intensity of physical activity.

The ventilatory response can be evaluated in terms of ventilatory demand or ventilatory efficiency. During maximal effort tests, athletes mobilize an extraordinary amount of air arriving to 150/200 L/min. The respiratory volume follows increase in linear progression during the test in function of power developed. When the air volume is increased 10 times, we think that the distance should be around 6–7 m.

Coronavirus disease (COVID-19) is an acute respiratory tract infection that emerged at the end of 2019. It was initiated in China and showed that 13.8% of cases were severe and 6.1% critical. This severe presentation is mainly due to the pulmonary expression of the virus through specific receptors.¹

It is believed that CoV-2 (COVID-19) occurs primarily through respiratory droplets, the same way that influenza.² With droplet transmission, the virus is released into respiratory secretions when an infected person coughs, sneezes, or speaks can infect another person if they come into direct contact with the mucous membranes. Infection can also occur if a person touches a contaminated surface and then

touches their eyes, nose, or mouth. The drops generally do not travel more than 2 meters (m) and do not remain in the air. Regarding the period of infectivity, the interval during which an individual with COVID-19 is infectious is uncertain, it seems that SARS-CoV-2 can be transmitted before the development of symptoms and during the course of the disease.^{2–4} Furthermore, the clinical characteristics of COVID-19 (SARS CoV-2) substantially overlap with influenza and other viral respiratory diseases.⁵

Respiratory flow

Measurements of air flow and lung volume are used to give diagnoses of lung disorders (obstructive and restrictive), to characterize severity, and to control the responses to

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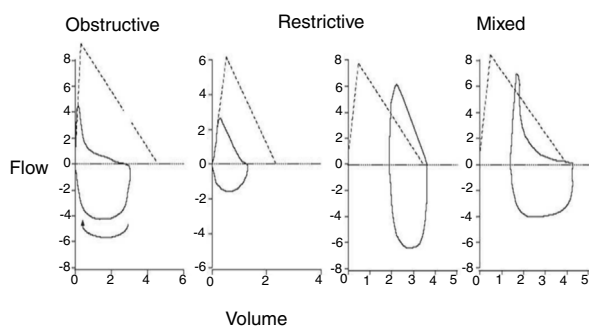


Figure 1 Morphology of flow-volume curve in different respiratory functional patterns.

treatment. The data are reported as absolute flows, volumes and as percentages of expected values.⁶

In expiratory flow test, is recorded the expired volume: forced vital capacity (FVC) and the expired volume in the first second (FEV₁). The modern devices measure only the air flow and integrate the time to estimate the expired volume.^{6,7}

Spirometry and volume flow curve

The forced spirometry includes FEV₁ and FVC measurements as indicators of airway status.^{6,8} The morphology of the flow volume curve is useful for detecting the characteristic the slowdown of expiration at low volumes in obstructive problems and the convexity of curve in restrictive cases. When the FEV₁/VC ratio is less of 70% it is compatible with an obstruction problem⁶⁻¹⁰ (Fig. 1).

In general, in healthy subjects, respiratory function is not usually decisive or limiting the performance in aerobic endurance sports.¹¹ Training programs that include exercising leg muscles as running or cycling are commonly used both in sedentary populations as well in patients with diverse pathology (chronic obstructive pulmonary disease, chronic heart failure, arterial hypertension, etc.) to improve their performance, reduce perception of symptoms and improve the quality of life.¹²

The ventilatory response to exercise can be evaluated in terms of ventilatory demand, ventilatory efficiency and profile of respiration. Ventilatory demand [total ventilation (VE)], can be assessed as the relative contribution of tidal volume (VT) and respiratory rate (RR). The efficiency ventilatory (VE) must increase with the production of carbon dioxide (VCO₂) (that is, the slope and the VE/VCO₂ ratio).¹²⁻¹⁴

Ventilation per minute (VE) is about 5–6 L/min at rest
 $[VT = 0.5 L - 0.1 \text{ (dead space)} \times RF = 12-15 \text{ breaths/min}]$

In sedentary people, the maximum respiratory rate (RRmax) reaches 35–45 breaths/min, however, in elite athletes it reaches 60–70 breaths/min. Also, the maximum tidal volume (VTmax) can reach about 2–2.5 L (VT does not usually exceed 55–65% of the VC, both in sedentary and athletes).^{15,16}

Modifications in VT and RF have influence in alveolar ventilation (VA). This (VA) is the amount of air that go into the alveoli every minute and participates in the respiratory exchange. This fact is fundamental because this respiratory

exchange only occurs in the alveoli and not in the respiratory tract (airways). Di Paco et al.¹⁷ have demonstrated that an improved ventilatory profile response after training, must contributes to increased sports performance, despite the fact there are no significant changes in heart rate (HR) at a determinate rate.

The organism is continually undergoing changing O₂ demands, that depend on metabolic activity, therefore, ventilation must adapt to this demand by increasing the respiration rhythm and carrying out a more appropriate respiration.¹⁸ Professional and/or recreational athletes respire with greater ventilatory volumes of air and a lower respiratory rate. This fact is due to the constant stimulation of respiratory center and the training of respiratory muscles. Higher thoracopulmonary elasticity improves ventilatory mechanics and alveolar ventilation.^{15,16,18}

Since the respiratory flow are high when are increased the metabolic needs and the physical requirement are increased, this high volume of mobilized air can determine the behavior and the safety measures that should be taken when doing exercise in these circumstances of possible contagion by COVID-19.

What should be the safety distance? Recommendations

Transmission of COVID-19 is not well characterized, but it is likely to be like SARS, spreading by droplets and the air.¹⁹ Also, coronaviruses can persist on inanimate surfaces (metal, glass or plastic) for at least 9 days, and can be inactivated with an efficient disinfection procedures.²⁰

The dispersion of the drops depends on several factors: viscoelasticity of fluid, exhalation, type of ventilation, expiration rate, evaporation rate and turbulent cloud of drops generated during exhalations, sneezes or coughs.²¹ Thus, understanding evaporation and dispersion of droplets is important for developing an effective control method for infectious diseases, because the distance to which the drops can move is related with the distance at which is possible contaminate and transmit the diseases.²¹

Therefore, it is appropriate to review the infection control rule established in 1–2 m³. Now, most horizontal droplet transmission studies show distances of more than 2 m. Bahl et al.²² in their review indicated that there are few studies on horizontal spread of droplets in medical journals. By this, they have reviewed in other sciences such mathematical and engineering disciplines to emit they conclusions. They have concluded that the maximum distance in 8 m. On the other hand, Cui et al.,²³ have indicated that the contamination makes the coronavirus more lethal.

As have indicate Morawska and Cao,²⁴ it is extremely important to recognize the reality that the virus spreads through the air. Also, adequate control measures should be implemented to prevent further spread of the disease by droplets with SARS-CoV-2 through the ventilation system.

Problems of respiratory: volumes and flows in athletes

From the data collected in the numerous stress tests, with ergospirometer that we have carried out over the

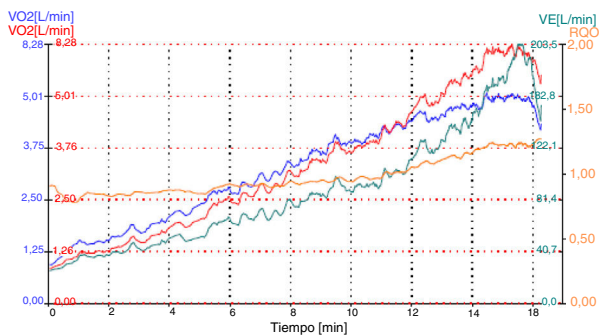


Figure 2 Representation of ergospirometry. Ventilation/min (VE=L/min) in an.

years, we have observed how the respiratory volumes vary throughout the test in athletes. In a maximum incremental test from 1 min per step starting at 125W and ending between 350–400 W (maximum), the athlete moves about 20–30L/min and at the end of maximal test they end up mobilizing volumes between 150/200 L/min. Correspondingly, the respiratory volume increases quite linearly throughout the test (Table 1) (Fig. 2).

In the figure we can observe that the respiratory flows are very important from the beginning. That knowledge determines the safety distance, which helps to avoid contamination among athletes. As shown in the figure, as we increase the power (W), the ventilation (VE) increases, too. In a mathematical model we can establish that the radius of reach (distance) increases with the square root of the increase in power made during the effort.

Therefore, and considering these data, when the air volume is increased by 10 times, the distance (m) should be multiplied by approximately 3, and we would go from 2 m to 6–7 m away. Remember that 2 m is the recommended distance for normal subjects.³

On the other hand, if we analyze the dispersion based on the launch of particles, that is, the “parabolic shot” of the same, the flow also depends on the exit velocity. That is, although we have 10 times greater volume, the respiration frequency also increases, so the exit speed is not 10 times more. In general, the respiratory rate practically doubles at the end of the test, therefore, the exit speed will be 5 times greater. In this case, the reach distance in the worst case would be multiplied by 5, going from 2 to 10 m.

Safety distance

For as, is clear that we should increase the safety distance in proportion to the intensity of the athlete’s workload. We consider a linear increase in the safety distance with to the respiratory flow (VE), which would guarantee the optimal distance (Table 2). However, we made the distance calculation with real data, by this we will be more cautious with the recommended distance. It is important for us to consider an increase in distance based on the square root of the increase in respiratory volume (Table 2).

Leuven and Eindhoven,²⁵ though by different methods, have indicated that the rule of social distancing (1–2m) seems effective when standing, but when people go for a walk, run or ride a bicycle, caution must be increased. These authors inform that for example during a race

		Basal	Vo2 máx.	Vo2 máx.	Vth1	Vth1	Vth2	Vth2	Rec. 1'	Rec. 3'
		Medido	Teor	Medido	Medido	% Vo2 máx.	Medido	% Vo2 máx.	Medido	Medido
Tiempo	min	03:22		15:19	10:59	72%	13:15	86%	16:16	
Carga	Watt	0	235	150	150	100%	150	100%	75	
Carga/kg	Watt/kg	0.0		2.1	2.1	100%	2.1	100%	1.1	
VO2	L/min	0.51	3.14	5.07	4.12	81%	4.72	93%	4.33	
VO2/kg	ml/kg	7	45	72	59	81%	67	93%	62	
VCO2	L/min	0.45		6.26	3.97	64%	5.34	85%	5.52	
RQ		0.90		1.23	0.97	78%	1.13	92%	1.27	
Eq O2		30		38	23	60%	29	78%	36	
Eq CO2		34		31	23	76%	26	85%	28	
VE/VCO2		33.67		30.51	23.33	76%	26.03	85%	28.20	
VE	L/min	15.3	146.3	191.0	92.8	46%	139.1	73%	155.6	
VT	L	0.91		2.73	2.93	107%	2.76	101%	2.61	
F.R.	#/min	15.1		62.8	28.9	46%	45.3	72%	53.6	
TA Sis.	mm Hg	0		0	0		0		0	
TA Dias.	mm Hg	0		0	0		0		0	
F.C.	#/min	0	196	0	0		0		0	
Met		2.1		20.6	16.8	81%	19.2	93%	17.6	

Table 1 Ergospirometric values in a stress test starting at 125 W.

Table 2 Example of calculating the safety distance for an athlete at different workloads.

Workload	Heart rate (ppm)	VE (L/min)	Respiratory frequency	Optimal distance, (m)	Minimum distance (m)
Rest	45	7.5	15	2	2
150 W	92	40.2	22	7.3	4.6
300 W	130	85.2	41	8.3	6.7
450 W	171	160	55	11.6	9.2

(competition) someone breathes, sneezes or coughs, these particles remain in the air and therefore the person running behind passes through this cloud of droplets.

The study of Leuven and Eindhoven²⁵ was carried out by simulating the appearance of saliva particles from people during movement (walking and running) and from different positions. They have concluded that when COVID-19 is considered, the recommendation is to stay out of the stream of droplet dispersion, what we call it the “spray.” Likewise, they indicate that the risk of contamination is greater when people go one after the other. They conclude that people moving in the same direction in one line should keep at least 4–5 m distance, and for running and ride in bicycle slow it should be 10 m and for cycling at high intensity, it should be at least 20 m. Also, when passing (advance) someone, it is recommended to be in a different lane and in a considerable distance away.

The difference between the work of Leuven and Eindhoven²⁵ and ours is that they have carried it out by simulation in a special room and our research is based on respiratory flows with real data during an incremental test to maximum. However, both have come to similar conclusions.

Conclusions

Health authorities³ are giving guidelines about the safety distance that people must maintain in order to avoid contagions. These guidelines are made for sedentary people, who do not practice physical activity in general. The problem is in athletes, in whom increase their respiratory flow (quantity and frequency) and thus the distances should be greater. As we have indicated before, in the sports field we must adapt the distance to metabolic requirements, demand more meters, around 10 m when we perform a maximum stress test.

It seems that in Spain, both the Higher Sports Council (CSD) and the Federation of Sports Facilities Entrepreneurs (FNEID) are preparing a proposal to open sports centers and gyms after COVID-19 indicating safety distances (made randomly). That is why, as the safety distance cannot be controlled in confined space, athletes should wear suitable masks to avoid the transmission of particles.

Therefore, as results from our study and the considerations made by the Belgian/Holand group, we believe that the assessment of the secure distance must be more accurate precise specially when we want practice physical activity. Without any doubt we think that is very important to mind the respiratory flows.

Conflict of interest

The authors declare that they don't have any conflict of interests.

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References

1. Wölfel R, Corman VM, Guggemos W, Seilmaier M, Zange S, Müller MA, et al. Virological assessment of hospitalized patients with COVID-2019. *Nature*. 2020.
2. Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, et al. SARS-CoV-2 viral load in upper respiratory specimens of infected patients. *N Engl J Med*. 2020;382:1177.
3. Ministry of Health of Spain. Scientific and technical information: Coronavirus disease COVID-19; 2020. [www.mscbs.gob.es >ccayes> 20200404.ITCoronavirus](http://www.mscbs.gob.es/ccayes/20200404.ITCoronavirus).
4. Kannan S, Shaik-Syed-Ali P, Sheeza A, Hemalatha K. COVID-19 (Novel coronavirus 2019) – recent trends. *Eur Rev Med Pharmacol Sci*. 2020;24:2006–11.
5. Lai C-C, Shih T-P, Ko W-C, Tang H-J, Hsueh P-R. Severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) and Coronavirus disease-2019 (COVID-19): the epidemic and the challenges. *Int J Antimicrob Agents*. 2020;55:105924.
6. Puente L, García de Pedro J. Functional respiratory tests in clinical decisions. *Arch Bronconeumol*. 2012;48:161–9.
7. Puente L, Marín JM, Burgos F, Cobos N, Casanova C, Cueto A, et al. SEPAR 2011 [Lung function assessment procedures]. Madrid: Luzan: Ed. Manual SEPAR; 2011.
8. Glindmeyer HW, Lefante JJ, McColloster C, Jones RN, Weill H. Blue-collar normative spirometric values for Caucasian and African-American men and women aged 18 to 65. *Am J Respir Crit Care Med*. 1995;151:412–22.
9. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, et al. Interpretative strategies for lung function tests. *Eur Respir J*. 2005;26:948–68.
10. Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. *Am J Respir Crit Care Med*. 1999;159:179–87.
11. Salinero JJ, Soriano ML, Lara B, Gallo-Salazar C, Areces F, Ruiz-Vicente D, et al. Predicting race time in male amateur marathon runners. *J Sports Med Phys Fitness*. 2017;57:1169–77.
12. Pescatello LS, Riebe D, Thompson PD. ACSM's guidelines for exercise testing and prescription. Philadelphia: Ed. Wolters Kluwer Health; 2014.
13. Hey EN, Lloyd BB, Cunningham DJC, Jukes MGM, Bolton DPG. Effects of various respiratory stimuli on the depth and frequency of breathing in man. *Respir Physiol*. 1966;1:193–205.
14. Di Paco A, Dubé BP, Laveneziana P. Changes in ventilatory response to exertion in trained athletes: beneficial effects on respiratory physiology beyond performance. *Arch Bronconeumol*. 2017;53:237–44.
15. Belman MJ. Ventilatory muscle training improves exercise capacity in COPD patients. *Am Rev Respir Dis*. 1980;121:273.
16. Robinson EP. Improvement in ventilatory muscle functions with running. *J Appl Physiol*. 1982;52:1982.

17. Cordova A. Sports physiology. Ed. Síntesis Madrid; 2013.
18. Yu ITS, Li Y, Wong TW, Tam W, Chan AT. Evidence of airborne transmission of the severe acute respiratory syndrome virus. *N Engl J Med.* 2004;350:1731–9.
19. Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J Hosp Infect.* 2020;104:246–51.
20. Xie X, Li Y, Chwang AT, Ho PL, Seto WH. How far droplets can move in indoor environments—revisiting the Wells evaporation-falling curve. *Indoor Air.* 2007;17:211–25.
21. Bourouiba L. Turbulent gas clouds and respiratory pathogen emissions potential implications for reducing transmission of COVID-19. *JAMA.* 2020.
22. Bahl P, Doolan C, de Silva C, Chughtai AA, Bourouiba L, MacIntyre CR. Airborne or droplet precautions for health workers treating COVID-19? *J Infect Dis.* 2020. JIAA 189.
23. Cui Y, Zhang ZF, Zhao F, Wang H, Shun-Zhang Y, Detels R. Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study. *Environ Health.* 2003;20:15.
24. Morawska L, Cao J. Airborne transmission of SARS-CoV-2: the world should face the reality. *Environ Int.* 2020;10:105730.
25. Leuven KU, Eindhoven TU. Belgian-Dutch Study: Why in times of COVID-19 you should not walk/run/bike close behind each other. <https://medium.com/@jurgenthoelel/why-in-times-of-covid-19-you-should-not-walk-run-bike-close-behind-each-other-follow-up-with-q-a-ca44e12cc54d>.