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Updating an Electrostatics-Based Perspective in View of the Enhanced Infectivity of SARS-CoV-2 Variants

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Abstract

The static electric field continuously surrounding a human body because it is subject to tribocharge buildup can play a key role in the control of the external viral entry mechanism. This phenomenon could be promoted by the electrostatically induced migration of charge-loaded harmful airborne. On the other side, the same field might be beneficial as a natural means of reducing the spike/host cell affinity, hence, of preventing the adverse effects of infection after the viral entry. The paper draws attention to the above complex phenomenology, the implications of which can be ambivalent, as a further contribution to updating a previous investigation.

Keywords: Airborne; Electrostatics; Grounding; Human body; Patient Care Areas; Sars-CoV-2, Triboelectrification.

1. Preliminary remarks

COVID-19 spreading is the result of different mechanisms involving respiratory droplets disseminated in ambient airspace after being expelled by speaking, coughing, and sneezing. More in general, droplets with aerodynamic diameter of at least 5 μm might be accidentally inhaled, before ballistically settling to the surrounding surfaces (including the ground), by a person who happens to be positioned over a distance of the order of 1 m from the one who expels. The infection can also develop following direct contacts with droplets already deposited on the collecting surfaces at hand. But it must also be taken into due account that there is an amount of hazardous droplet nuclei in the airborne state, thus having a diameter reduced to 1 μm, or thereabout;

see, for example, [1]. Therefore, an overlooked and underestimated transmission of infection through an airborne route might occur especially in response to a natural electrostatic influence surrounding a human body [2]. It cannot but be determined by a pair of actual contributory factors

- airborne droplet nuclei can bear a considerable net (positive or negative) electric charge;
- under ordinary conditions, human bodies are rather perpetually subject to contact electrification by tribocharging, hence, they behave as sources of background electrostatic fields.

The unwanted overall outcome is that a not inconsiderable amount of charge-loaded ambient droplet nuclei staying harmfully airborne can be electrostatically captured or repelled, depending on the combination of all the positive and negative charges brought into play; see the essential representation of (Fig. 1). It has been theoretically proved in [2] that

- the human aptitude to build up tribocharges with insignificant leakage to ground importantly depends on the worn shoes, specifically on their typology, size and materials;
- the consequent flow of the described charge-bearing bioaerosol is set up as a drift under the thrust of Coulombian forces resisting the obstruction of buffer air molecules. Of course, special attention is paid here to the droplet nuclei driven towards the subject’s face;
- important climate-related reasons are expected to especially affect the insulating properties of the shoes, and, in turn, the efficiency of the electrostatic mechanism claimed above.

The adopted theoretical method consists in mimicking a variously postured human body by an articulate assembly of interconnected conducting ellipsoids, individually representing basic anatomical blocks. The model accommodates mutual electrostatic couplings among the involved ellipsoids, without disregarding some external influences, notably, ground plane, walls, nearby furnishings and other people [3]. Given that the contact-separation triboelectric charging due to the steppage gait is the main charging mechanism for standing subjects, the maximum induced electric field in close proximity to the head has been estimated as being in range of 10-100 kV/m, reduced to one-tenth about a meter away. In the case of a seated posture, the reduced charging mechanism caused by the feet is more than offset by rubbing garments against the seat (especially when synthetic materials are involved).

2. Discussion

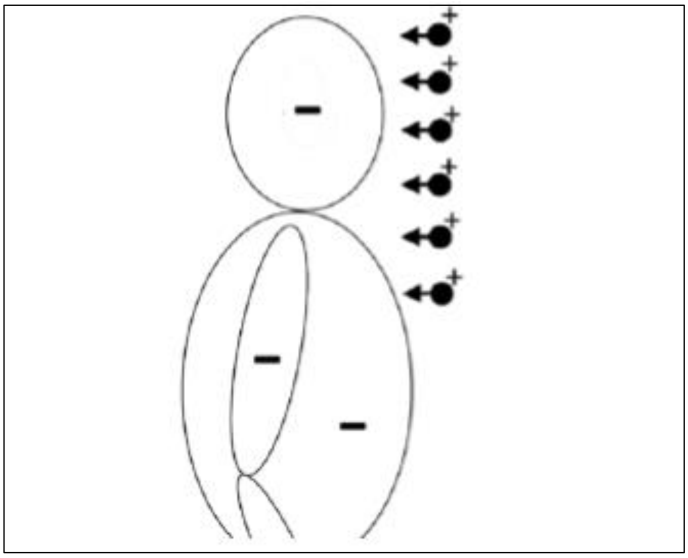
The efficiency of the triboelectric effect for a walking subject largely depends on the type of shoes worn, thus on a pivotal item that is accounted for by the following physical quantities

- insulation resistance (bulk and surface) of the shoe.
- shoe outsole's surface area effectively in contact with the floor. Parenthetically, there is a linear relationship between effective shoe-floor contact area and charge build-up, with the result that the more contact area increases, the more important the static electrification (and related effects) could become.

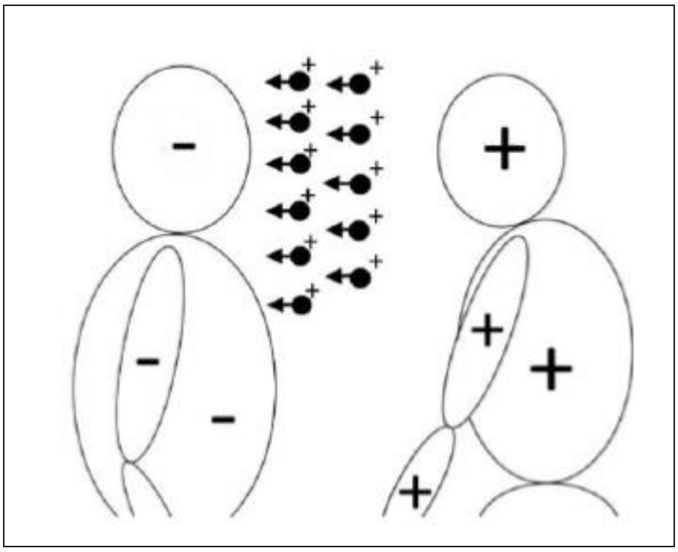
Usual shoe insulation tends to prevent tribocharge building up from leaking to ground, to the extent that closed, unwet and cleaned up footwears are viable candidate that may ultimately lead to the enhancement of the risk of contamination because of electrostatically induced charge-bearing flows.

It was also postulated in [2] the existence of climate-, gender- and age-linked differences in the vulnerability, with reflections on the informational value of epidemiologic data. The rationale behind the climate-dependent risk was fairly linked to the insulation resistance of the shoe through the relative humidity (RH) and, separately, the temperature. In fact, the resistance under examination is prone to decrease significantly as the RH increases (and when it rains, of course); instead, the temperature is involved especially since it is customarily to use precarious footwears (e.g., light sandals), even to walk barefoot, in warm places. Under the circumstances, the foot-ground insulation resistance decays significantly. Additional considerations involving the above pair of bulleted factors regarded the impacts on age- and gender-linked differences because children and, to a lesser extent, women weight less and wear smaller shoes. Concerning this, the tribolelectric charging is in inverse ratio with the human body's weight and shoe size. In addition, women are largely used to wear high-heel shoes, even shoes with stiletto heels, with the result that the charge electrification reduces. Of course, this happens considering that the inner plantar surface that rests on the floor is confined to the forefoot.

It was believed in [2] that both the reductions in the shoe's insulation resistance and contact area with the floor were deemed beneficial, precisely because those reductions allowed to understand why the previous infection less affected children and, maybe in more muted form, women, in addition to clearly explain the sensitivity to the climate. Over time, the ever-increasing general infectivity dissolved the above-mentioned early gender- and age-linked differences. This could be the case for the latest outbreak of the SARS-CoV-2 variant Omicron in relation to the previous Delta variant [4], although the enhanced infection (even outdoors) would seem to be accompanied by minor changes in the viral burden [5]. The fact that the virus is prone to replicate faster than previous variants, is quite sufficient reason to suspect that the human body's static electricity



(A)



(B)

Figure 1 (A), (B): Two different scenarios in still air for, say, a negatively charged human body (the host). Case (A), infection of the host in isolation: a partial amount of positively charged droplet nuclei in the airborne state is electrostatically attracted towards the face. Case (B), host-to-host progression: in the presence of a nearby counterpart, a larger amount of positively charged droplet nuclei is electrostatically attracted towards the face of the former host (on the left). The additional quantity of droplet nuclei is put in an equally oriented motion in response to the repulsive electrostatic thrust from the positively charged host (on the right).

existing in real situations continues to play a key role, but conversely attenuating - in a paradoxical manner -, the adverse health effects of the infection as the tribocharge accumulation increases. As an aside, it has been proved elsewhere [6] that a background static electric field spanning the range of 10÷10e+4 kV/m activates irreversible conformational changes in the spike protein, thus decreasing the spike binding to the receptor of the host cell. Therefore, it is admissible that the electric field continuously surrounding an individual, for just bearing a tribocharge that fluctuates slowly and only episodically undergoes truly short breaks (the so-called ESD, an acronym that stand for electrostatic discharge [2,3]), may obviously have a protective effect in line with [6]. The described situation is reflected in lowering the viral burden, as it is especially the case for the latest variant, in the sense that the strengthening of the infection spread could be partially compensated, or even overcompensated, by the reduced ability of the viral agents to ultimately bring disease. The fact that the exposed human body can electrostatically collect fast viruses in the airborne state, see again the graphic view in Fig. 1, would not go to reduce the raised protection. This is because the minute conformational changes mentioned above develop within a few sub-microseconds [6], thus very quickly in comparison to the drift velocity of the charge-bearing viral airborne subject to electrostatic attraction (see details in [2]). However with the possible view of future variants carrying net charge and resistant to the conformational changes mentioned above - on this challenging issue, very promising predictive means of viral evolution over time are underway [7] -, electrostatically driven viral agents towards human targets, via their static electricity, may indeed definitively become a dangerous additional accident. This prudent and precautionary remark projected to a futuristic scenario can be taken into account by usual engineering control as set out below.

As is known, the mitigation of infection by viral attack is typically performed in shared areas, means of travel included, by using mechanical ventilation. But, if appropriate, subsidiary static-free measures can be adopted. Whilst the first of the two control types are largely put in use, the second is popular only in a restricted field of the electromagnetic compatibility, notably the one that takes care of the electrostatic discharge (ESD) (see, for example, [8]). In this last regard, simplest safeguards include static-free boots supplemented, as far as possible, by fabrics and coveralls with similarly antistatic attributes. Especially recommended is the use of grounded floor covering and wrist straps connected to a separate ground terminal. These mitigating measures are typically for indoor use, even though the one indicated first is also applicable outdoor, subject of course to a broader and quite feasible creation of commercially available static-free footwear.

3. Conclusions

As it stands, the described model is inherently robust and provides reliable speculation since based on physical laws. In fact, electrostatics, fluid-dynamics, and electromagnetic compatibility (EMC) are the sole and only theoretical sources adopted in the implementation, which takes for granted that the airborne pathogens are treated as generic charge-bearing particulates. Updated biomedical considerations, notably those involving the notions of infectivity, virulence, pathogenicity, etc., exceed the bounds of this investigation in relation to the critical analysis. Anyway, there is a need to explore some avenues, as those provided here, with a view to find definitive or at least long-term integrated solutions, given some concrete expectation that the ongoing pandemic outbreak may eventually turn into a more stable form. Whether it is appropriate to recommend implementation of the discussed special static-free solutions in patient care areas or not, strongly depends, respectively, on the adverse or mitigating action of tribocharge-originated electric fields surrounding human bodies, provided they are exposed to viral airborne. In this perspective, the theoretical foundation adopted for the human model turns out to be also suitable for implementing targeted experiments by means of dummies. In any case, extra efforts on a transdisciplinary basis may be required in a future, hopefully, not so far away.

4. References

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