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## Original Research

## Sports balls as potential SARS-CoV-2 transmission vectors

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## ABSTRACT

Objects passed from one player to another have not been assessed for their ability to transmit severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). We found that the surface of sport balls, notably a football, tennis ball, golf ball, and cricket ball could not harbour inactivated virus when it was swabbed onto the surface, even for 30 s. However, when high concentrations of 5000 dC/mL and 10,000 dC/mL are directly pipetted onto the balls, it could be detected after for short time periods. Sports objects can only harbour inactivated SARS-CoV-2 under specific, directly transferred conditions, but wiping with a dry tissue or moist 'baby wipe' or dropping and rolling the balls removes all detectable viral traces. This has helpful implications to sporting events.

## 1. Introduction

The transmission potential of the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) includes exposure duration of the virus, the number of viral particles one is exposed to and the route of exposure such as inhalation or skin contact [1,2]. Transmission is facilitated by self-inoculation of mucous membranes by touching one's eyes, nose and/or mouth after having direct contact with infected particles [3] and transmission is observed in numerous settings [4,5]. Longer duration of viral shedding occurs in asymptomatic individuals however, it is not yet proven whether this affects infectivity [6]. It is also well known that younger individuals, typically those active in sporting events, have milder symptoms compared to their adult counterparts, and are often asymptomatic [7].

Environmental contamination has potential as a medium of transmission [8,9]. It is thought that hands can 'pick up' the virus from inanimate surfaces and some data suggests SARS-CoV-2 is stable at a variety of pH values at room temperature as it can be detected on different contaminated surfaces [10,11]. Thus far, the surface stability of SARS-CoV-2 has been analysed on a variety of materials with persistence

for different periods of time, with the greatest stability observed on plastic and stainless steel compared to copper and cardboard [12]. Although these data have shown viral persistence on surfaces that we may come into contact with on a day-to-day basis, its persistence on sports balls has been unstudied.

This has consequences regarding return to sports activities, with its secondary implications including, for example the mental health of different populations deprived of such events, including schoolchildren. While social distancing in sports games and empty stadia have been implemented, there are no data on the infectious potential of objects passed between individuals.

## 2. Materials and methods

SARS-CoV-2 whole pathogen (target concentration of 10,000 dC/mL) from Qnostics Ltd. The virus was transported in frozen conditions, has a 'research use only' status and is inactivated by both heat and gamma irradiation. We used PDI Sani-Cloth® 70 (70% (v/v) Isopropyl alcohol (IPA), COPAN UTM® Universal Transport Medium swabs, Becton Dickson (BD) Sterile Polyester-tipped Swabs, Andrex® Classic

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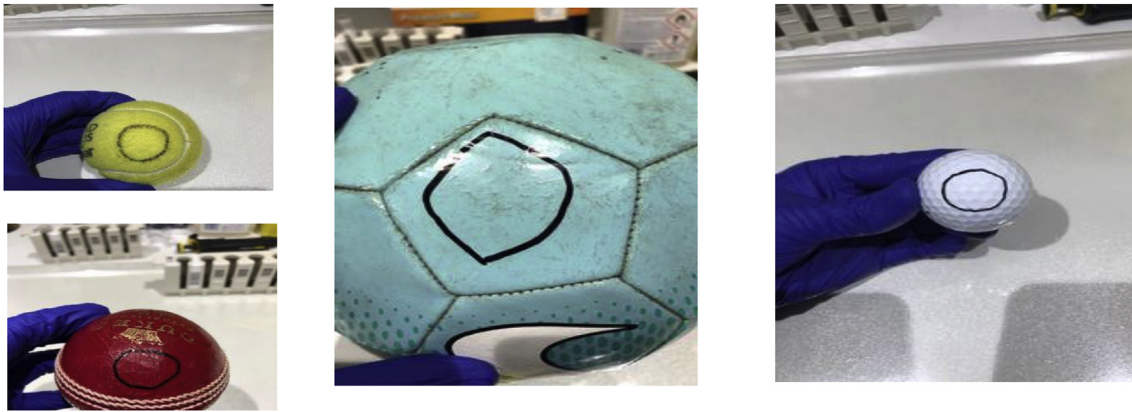


Fig. 1. Shows sports objects with a small patch (identified by a black marker) that has been ‘infected’ with SARS-CoV-2 then swabbed.

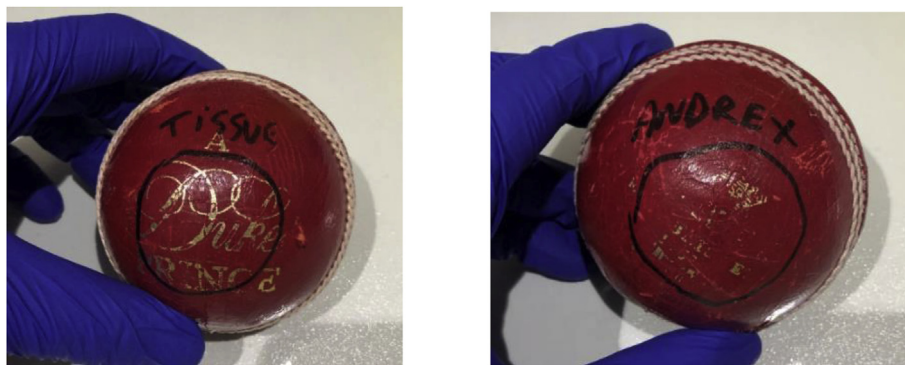


Fig. 2. Shows sports objects with a small patch (identified by a black marker) that has been ‘infected’ with SARS-CoV-2 then wiped with tissue paper or Andrex washlets, then swabbed.

Clean washlets (lightly moist toilet tissue wipes) and sterile gauze.

2.1. Non-SARS viruses’ experiment

At first, we wished to test a range of non-SARS respiratory viruses transmitted intentionally from man onto sports balls, but in 18 individuals tested by commercially available polymerase chain reaction (PCR) from nasopharyngeal swabs, none were positive. The viruses tested included influenza A and B, parainfluenza types 1,2, 3 and 4, metapneumovirus, adenovirus, rhinovirus, parechovirus and enterovirus.

No individuals tested were positive for any virus and the experiment was terminated at this pilot stage.

2.2. Testing the balls for SARS-CoV-2 before experiments

A used football, used cricket balls, a used tennis ball and brand-new golf ball were wiped throughout for 2 min with Sani-Cloth, then rinsed with distilled water and paper dried. The objects were left to stand at room temperature for 2 h and the surface of the balls was swabbed using COPAN swabs and tested for the virus.

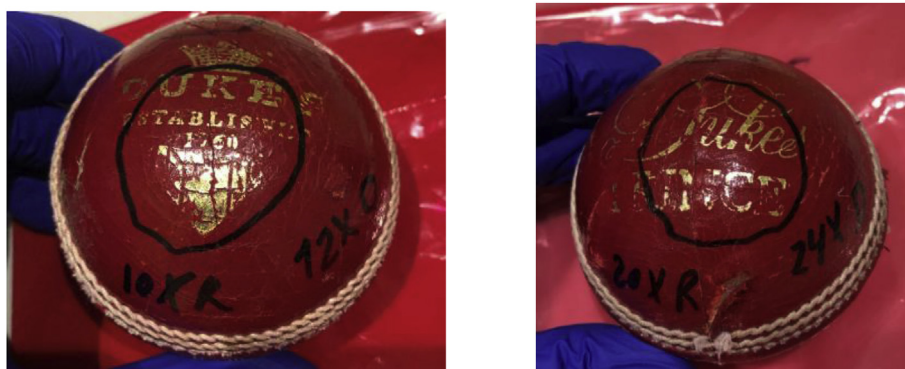


Fig. 3. Shows sports objects with a small patch (identified by a black marker) that has been ‘infected’ with SARS-CoV-2 then wiped with tissue paper or Andrex washlets, then swabbed.

2.3. SARS-CoV-2 control preparation and method detectability

The quality control vials were for single use, defrosted at room temperature, shortly vortex at low speed for 5 s, centrifuged at 5000 RPM for 30 s and used immediately. To test the SARS-CoV-2 positive control and method detectability of the Altona diagnostics assay with the Kingfisher extraction platform and Quantstudio 7, a COPAN swab was dipped in an aliquot of the control material at concentration of 10,000 dC/mL and tested for SARS-CoV-2. Serial dilutions (1:10, 1:4 and 1:2) representing 1000 dC/mL, 2500 dC/mL 5000 dC/mL respectively were also tested.

2.4. Experiment 1

A fresh 1:10 dilution of the quality control was made, and BD polyester swabs were used to smear the diluted material onto the whole surface of the sport balls. Post application, the items were left to stand for 30 s, swabbed thoroughly with COPAN swabs and tested for the virus. Next, we wiped the objects thoroughly for 2 min with Andrex washlets, swabbed the entire surface of the balls with COPAN swabs and tested for the virus. One of the cricket balls was polished with a sterile gaze instead of being wiped with Andrex washlets and tested for the virus. The balls were wiped throughout for 2 min with Sani-Cloth, then rinsed with distilled water, paper dried and left to stand at room temperature for 2 h.

2.5. Experiment 2

A fresh 1:2 dilution of the quality control was made, and BD polyester swabs were used to smear the diluted material onto a small patch of each of the balls [Fig. 1]. Subsequently, the patch areas were swabbed at 30 s post application using with COPAN swabs. Next, the balls were 'played with' in grass field for 5 min and the same patch area was re-swabbed and tested. Balls were wiped throughout for 2 min with Sani-Cloth, then rinsed with distilled water, paper dried and left to stand at room temperature for 2 h.

2.6. Experiment 3

We dispensed 50 µL of undiluted positive quality control (10,000 dC/mL) using a pipette directly in a small patch area of one of the cricket balls. The patch was swabbed at 30 s, 5 min and 1 h using COPAN swabs

Concentration	Swab used to smear the virus in the balls	Time and condition	Cricket ball 1	Tennis ball	Golf ball	Football
1000 dC/mL	polyester	30 s then re-swabbed with COPAN swabs	negative	negative	negative	negative
		Post wiping with Andrex washlets then re-swabbed with COPAN swabs	negative	negative	negative	negative

Concentration	Swab used to smear the virus in the balls	Time and condition	Cricket ball 2
1000 dC/mL	Polyester	30 s then re-swabbed with COPAN swabs re-swabbed with COPAN swabs post polishing with sterile gaze	negative negative

and tested for the virus. The same experiment was repeated with another cricket ball with a fresh 1:2 dilution (5000 dC/mL) and swabbed at 30 s and 5 min. Balls were wiped throughout for 2 min with Sani-Cloth, then

Concentration	Swab used to smear the virus in the balls	Time and condition	Cricket ball	Tennis ball	Golf ball	Football
5000 dC/mL	Polyester	30 s then re-swabbed with COPAN swabs	negative	negative	negative	negative
		Post playing in grass field for 5 min	negative	negative	negative	negative

rinsed with distilled water, paper dried and left to stand at room temperature for 2 h.

2.7. Experiment 4

We dispensed 50 µL of a fresh 1:2 dilution (5000 dC/mL) of the positive quality control using a pipette directly in a small patch area of two cricket balls [Fig. 2]. The patch of one cricket ball was wiped with Andrex washlets, the patch was left to air dry for 5 s and then we swabbed the area with COPAN swabs and tested for the virus. The same experiment was repeated but instead of using the Andrex washlets, we used paper tissue.

2.8. Experiment 5

We dispensed 50 µL of a fresh 1:2 dilution (5000 dC/mL) of the positive quality control using a pipette directly in a small patch area of two cricket balls [Fig. 3]. One of the balls was submitted to 10 rolls in the grass field (at least 1 m each roll) following by dropping the ball 12 times onto the grass field. The same experiment was repeated with 20 rolls and 24 drops.

3. Results and discussion

As expected, all sport balls tested negative for SARS-CoV-2 before the experiment began. The swabs used to test the quality control material and method detectability tested positive for SARS-CoV-2.

The results for method detectability are shown below:

Concentration	Swab used	Result
1000 dC/mL	COPAN	Positive
2500 dC/mL	COPAN	Positive
5000 dC/mL	COPAN	Positive
10,000 dC/mL	COPAN	Positive

The results for experiment 1 are shown below:

The results for experiment 2 are shown below:



The results for experiment 3 are shown below:

Concentration	Condition	Time	Cricket ball 1
10,000 dC/mL	Virus directly pipetted to the surface of balls (mimicking a cough, spitting or squeeze)	30 s	Positive
		5 min	Positive
		1 h	Positive
Concentration	Condition	Time	Cricket ball 2
5000 dC/mL	Virus directly pipetted to the surface of balls (mimicking a cough, spitting or squeeze)	30 s	Positive
		5 min	Positive

The results for experiment 4 are shown below:

Concentration	Condition	Time and wipes	Cricket balls
5000 dC/mL	Virus directly pipetted to the surface of balls (mimicking a cough, spitting or squeeze)	5 min then wiped with Andrex washlets	Negative
		5 min then wiped with paper tissue	Negative

The results for experiment 5 are shown below:

Concentration	Condition	Time and wipes	Cricket balls
5000 dC/mL	Virus directly pipetted to the surface of balls (mimicking a cough, spitting or squeeze)	5 min then 10 rolls and 12 drops in grass field	Negative
		5 min then 20 rolls and 24 drops in grass field	Negative

The method detectability results show evidence that the quality control material used contained detectable levels of the pathogen and that the method could detect the levels of the virus concentration in the range used in all experiments (1000 to 10,000 dC/mL).

It is notable that our initial experiments (1 and 2) failed. When SARS-CoV-2 positive control materials at 1000 and 5000 dC/mL concentrations are applied onto the whole surface of sport balls using BD polyester swabs, there was no detectable levels of the virus when observing the variables imposed in the experiment, including very short term testing after 30 s. One can speculate that using polyester swabs to apply the virus to the surface of balls may be sub-optimal as polyester may significantly absorb the quality control material and the concentration of the virus in the surface of sports balls will be lower than the method's detectable threshold. The pressure applied by the swab and its material are also variables to consider but they do not fully reflect a human user in the game. Certainly, experiments (1 and 2) do not reflect real-world settings.

On the other hand, when positive control at 5000 copies/mL and 10,000 copies/mL concentrations are directly applied to the surface of cricket ball there are detectable levels of the virus at 30 s, 5 min and 1 h (experiment 3). This experiment may potentially mimic a sneeze, a cough or players spitting on balls where visible liquid droplets are expected, but high volume (50 µL) of high viral concentrations applied directly to a single area are invariably required to detect levels of the virus. It is thought that viral levels of 5000 dC/mL represent a highly 'infectious' sample. This experiment also does not fully reflect real-world setting due to significant experimental variation.

The results of experiment 4 and 5 suggest that if a highly concentrated viral load (5000 dC/mL) is in contact with a cricket ball, followed by a 5 min wait (the drops will dry up) and then wiping the surface of the ball with either Andrex washlets or paper tissue, the transmission to another player is unlikely following these conditions, in that we could not detect

any viral genetic material. Similarly, dropping and rolling the ball led to no evidence of viral contamination either, which could be because of motion or friction, potentially amplified by the shape of the ball.

Interestingly, a previous study from an intensive care unit in Pavia, Italy examined Continuous Positive Airway Pressure helmets from staff and found only 2 out of 26 curved helmets positive for low-level SARS-CoV-2 RNA [2]. Paradoxically, another study found that half of the shoe sole samples from ICU medical staff tested positive for the virus [13], and the reality here is that viral load in sputum is the not the same as in saliva and it is incorrect to assume that every RNA copy detected is a potentially infectious virion [14].

Implicit in the challenge we performed is a general point regarding transmission in real-world situations via surfaces. Whether the surface retains the virus and whether it can act as a vector to other humans are two fundamentally separate questions that likely require different experimental approaches. First, one is asking for the surface simultaneously to be good at retaining the virus but also allowing the virus to be taken off the surface easily by touch. Secondly, to the extent it can be removed by touch, the natural ex-human impacts in sport serve to reduce the probability that such extraction would result in a human infection.

Further experiments need to be performed using different viral concentrations directly applied to sport balls, then submitted to different scenarios expected in sporting such as touch, kicks, brief polish with fabrics, etc in order to establish the possibility of transmission from player to player. Where possible, longer time point and the effects of saliva and/or sweat should also be tested. Clearly, using live virus in a 'real world' setting would be more valuable, but our data represents a proof of concept.

Various mitigation measures have been implemented to fight the coronavirus disease 2019 (COVID-19) pandemic, including widely adopted social distancing and mandated face covering. However, assessing the effectiveness of those intervention practices hinges on the understanding of virus transmission, aspects of which remain uncertain.

## Declaration of competing interest

JS conflicts can be found at: <https://www.nature.com/nc/nc/editors>. None are relevant here. No other authors declare a conflict.

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