DETERMINING THE EFFECT OF MEDICAL MASKS ON MAXIMAL AEROBIC ENDURANCE IN TRAINED INDIVIDUALS

A Thesis

presented to

the Faculty of Natural and Applied Sciences

at Notre Dame University-Louaize

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

GEORGE EMMANUEL MAALOUF

NOVEMBER 2020

We hereby approve the thesis of

George-Emmanuel Maalouf

Candidate for the degree of Master of Science in Biology

Dr. Diala El Khoury — Supervisor, Chair

Dr. Re-Mi Hage — Committee Member

Dr. Zaher El Hage — Committee Member

Dr. Pauline Aad — Committee Member

TABLE OF CONTENTS

ACKNOWELDGEMENTS

I would like to thank the individuals who have contributed to the work in this thesis project.

First, I would like to deeply thank my supervisor, Dr. Diala El Khoury, for her support, and patience to work with me in these difficult times. Working with Dr. Diala allowed me to work at my full potential and allowed me to mentally grow in the field of biology. My thesis project has been a great experience and I look forward to working in future research projects. Dr. Diala has been a huge part of my life in science, playing the constant role of a mentor. We co-authored my first peer reviewed published paper, as well as a second paper in review; and for that I am forever grateful. An additional appreciation goes to Dr. Zaher El Hage, who also served as a guiding collaborator and gave me the encouragement, positivity, and tools in order to go forward and complete the project.

I am also grateful for the help and expertise of Dr. Re-Mi Hage in the statistical analysis and critical review of my work.

Finally, my thanks go to the participants, many of which are my classmates and colleagues including Dr. Nadim Nassif, for their help, determination and punctuality in participating in the experiments.

ABSTRACT

Purpose: With the rapid increase in respiratory illnesses and pollution, facemasks such as clothe masks, N95 masks, and surgical masks are becoming increasingly more common in everyday life. The recent SARS-CoV-2 outbreak has led to the exponential worldwide use of these masks in everyday activities. However, little is known about the effects of these masks on maximal oxygen consumption during exhaustive exercise.

Methods: 11 Athletic individuals and 7 recreational individuals were recruited and took part in the 20 m shuttle run test, also known as the "beep test", while wearing surgical masks and N95 masks. Maximal oxygen consumption was quantified by measuring Level, heart rate, and rate of fatigue. These parameters were statistically analyzed to yield VO_2 max, but rate of fatigue did not contribute to the quantification of VO_2 max.

Results: Our results showed a significant slight decrease of 3.2% upon reaching VO_2 max while heart rates and level of fatigue showed no significant difference.

Conclusion: Equipping a surgical mask while performing maximal endurance exercise significantly decreased VO_2 max and affected performance without affecting the other parameters measured.

Keywords: Masks, Maximal oxygen consumption, Athletes, Fatigue, Paired sample t-test, Shapiro-Wilk Test

LIST OF FIGURES

LIST OF TABLES

Abbreviations:

ARDS: Acute respiratory distress syndrome

COVID-19: Corona Virus Disease Of 2019

CDC: Centers for Disease Control

HIIT: High intensity interval training

MERS: Middle east respiratory syndrome

mRNA: Messanger ribonucelic acid

RNA: Ribonucelic acid

SARS-COV-2: Severe acute respiratory syndrome coronavirus 2

SARS: Severe acute respiratory syndrome

VO_2 max: Maximum volume of oxygen consumed/Maximal oxygen consumption

WHO: World Health Organization

I. Introduction

The world is currently facing a crippling pandemic caused by the novel corona virus, SARS-COV-2 that causes Corona Virus Disease Of 2019 (COVID-19) (Hui, Azhar et al. 2020). Despite worldwide efforts, an effective treatment remains elusive and preventive measures remain the only ways to control the spread of the virus. These preventive measures include quarantine, social distancing, and equipping masks in public areas (Anderson, Heesterbeek et al. 2020). With a vaccine not expected until 2021, these measures appear to be present for the long term due to potential risk for more waves of COVID-19 (Rhee, Kim et al. 2020). Adapting daily life to these conditions is crucial in order to halt the spread of the disease. The use of different facemasks in daily life may be easily adaptable, however, in some cases the mask may have negative effects on the user such as in the case of intense exercise (Wong, Ling et al. 2020). The use of facemasks with exercise is poorly understood in the literature with some studies suggesting that the masks impede gaseous exchange, cause discomfort and increase metabolic workload on the body (Tong, Kale et al. 2015, Wong, Ling et al. 2020). Other types of masks that have been used in exercise such as the elevation mask, showed significant improvement in performance (Porcari, Probst et al. 2016). The use of masks will likely become more common in sports areas such as gyms and closed fields. In order to simulate these conditions, this study determines the effects of different medical masks (Surgical and N95) on maximal aerobic capacity during the beep test in order to simulate the use of masks during outdoor intense aerobic training.

II. Literature review

1. Coronaviruses

Coronaviruses are types of RNA viruses that induce disease in mammals and birds. The main target of coronaviruses is the respiratory system. Several types of illnesses are caused by coronaviruses ranging from mild such as the common cold to more severe such as SARS, MERS, and currently COVID-19 (Gorbalenya, Baker et al. 2020). Coronaviruses are well known for their unique morphology(Figure 1) (Fan, Zhao et al. 2019).They have a spherical shape with round protruding projections. This shape is reminiscent to a solar corona from which their name is derived (Figure 1)(Henry 2020).It is suggested that the earliest common ancestor of coronaviruses originated around 8000 BCE while others suggest that the coronaviruses' evolution coexisted with that of avian and bat species 55 million years ago (Wertheim, Chu et al. 2013). The warm blooded nature of both bats and birds allows the coronaviruses to thrive and provides the ideal environment for replication (Woo, Lau et al. 2012).

The earliest discovery for human coronaviruses dates back to the 1960s when a unique virus responsible for the common cold was detected (Kahn and McIntosh 2005). Unlike the rhinovirus, and other common cold viruses however, the new coronavirus was not cultured using normal techniques and required new methods for cultivation using organ cultures (Tyrrell and Bynoe 1965).

1.1. Microbiology

The morphology of a coronavirus is described as a relatively large virus with an average diameter of 120 nm and a genome size of around 26 to 32 kilobases (Masters 2006). Coronaviruses use the characteristic spikes to attach to a specific cellular receptor which leads to the fusion of the virion and the cell. On average a coronavirus has around 74 surface spikes of 20 nm length composed of a trimer of S proteins (Neuman, Kiss et al. 2011). The S1 domain is the most important domain of the spike proteins and it is responsible for harbouring the receptor binding site and responsible for cell specificity, while the S2 domain is the attachment site to the virion (Lalchhandama 2020). The virus enters the cell using the S proteins which are activated after cleavage by host cell proteases. After fusion, the virus genome enters the cell and RNA of the virion is then translated by the host ribosomes to produce the viral structural proteins; spikes, envelope proteins, membrane proteins (Figure 1) (Simmons, Zmora et al. 2013). These particles then bind to the nucleocapsid via protein-protein interactions meditated by membrane proteins in order to form the virus. The newly formed viruses are then secreted by the host cell via exocytosis (Weiss and Navas-Martin 2005, Fehr and Perlman 2015).

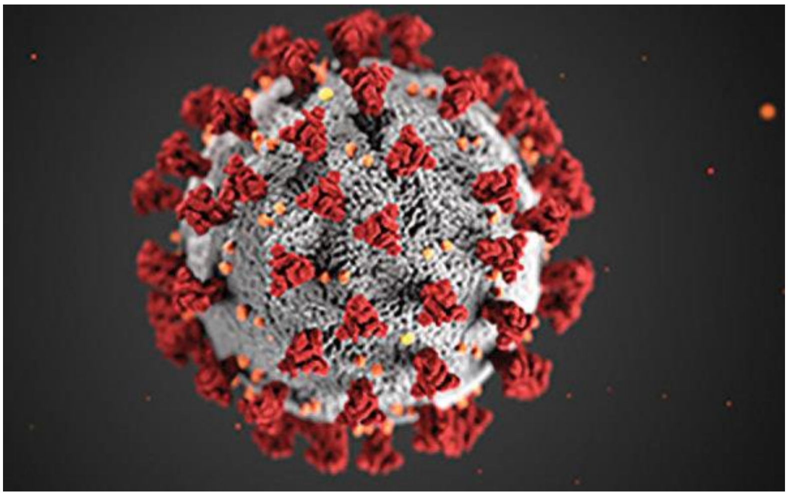


Figure 1: Illustration of the coronavirus structure with protruding spikes (red), envelope proteins(yellow), membrane proteins (orange), and lipid bilayer envelope (grey) (Henry 2020).

1.2. Examples of Coronaviruses

Several types of coronaviruses make up around 15% of common cold infections showing mild symptoms in children and adults especially during colder climates (Charlton, Babady et al. 2018, Mayburd 2020). Another type of coronavirus was responsible for the SARS outbreak that occurred in 2003 in China. The virus infected more than 8000 people and caused the deaths of 774 people (Centre 2004).

Infection in animals is also common especially in domestic and farm animals. One type of coronavirus causes avian infectious bronchitis with a high mortality rate in poultry reducing meat and egg production leading to significant economic loss (Bande, Arshad et al. 2015). Due to the lack of available treatment, destruction of entire herds may be necessary to prevent further infection (Cavanagh 2007) . Feline coronavirus affects domestic cats and can result in feline infectious peritonitis which also has a high mortality rate (James 2017) .

In December of 2019, a series of pneumonia like symptoms appeared across Wuhan, China caused by a new strain of corona virus, SARS-COV-2 with the disease caused by this virus now known as COVID-19 (Zhou, Yang et al. 2020). Analysis has shown that the new strain of coronavirus that causes COVID-19 is in the same subgenus as that of SARS (Zhu, Zhang et al. 2020). RNA sequencing has shown that this virus is closely related to two betacoronaviruses found in bats suggesting that the origin could be primarily bats either directly or indirectly (Zhou, Yang et al. 2020). The new strain of coronavirus has been shown to have 70% genetic similarity to the virus responsible for the SARS outbreak in 2003 (Hui, Azhar et al. 2020).

2. The current COVID-19 pandemic

Globally, the disease has currently infected over 30 million people leading to the death of over 1million people while over 25 million people have recovered (Hui, Azhar et al. 2020). Unfortunately, the reported cases are highly underestimated since only a fraction of the of infections are diagnosed and reported (Stringhini, Wisniak et al. 2020). The main target of this illness is the respiratory system with the primary symptoms manifesting as shortness of breath, fatigue, fever, cough, and loss of smell and taste (Cascella, Rajnik et al. 2020). The SARS-COV-2's main method of infection involves the spiked protrusions which are considered its functional receptor and bind to the angiotensin converting enzyme 2 receptor (ACE2) significantly found in the lungs which is one of the main reasons that symptoms mainly manifest in the respiratory system (Letko, Marzi et al. 2020).

2.1. SARS-COV-2 Lifecycle:

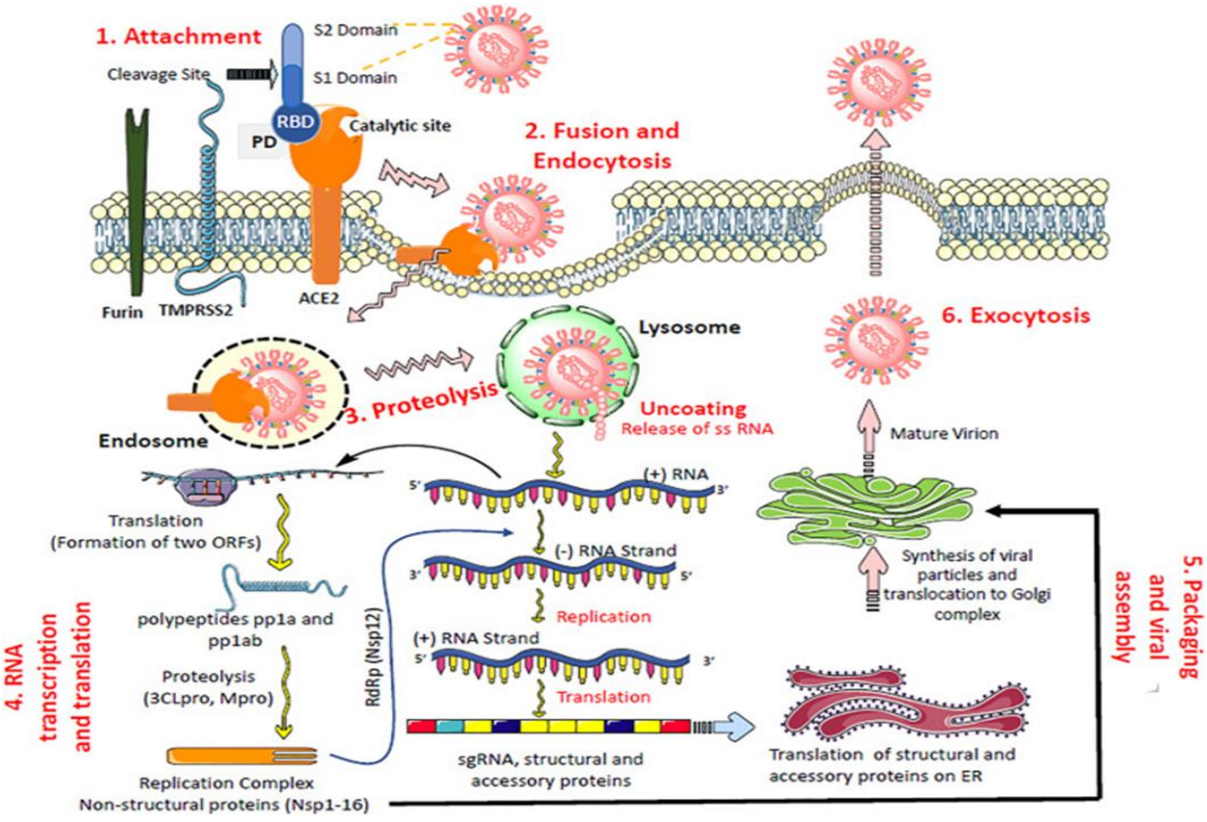


Figure 2 : Illustration of SARS-COV-2 lifecycle after binding, fusion, replication and translation, and excocytosis (Poduri, Joshi et al. 2020)

The S protein attaches to the ACE2 receptor and initiates cleavage on its S2 domain along with fusion of the viral and host cell membranes (Kubo, Yamada et al. 1994, Belouzard, Chu et al. 2009). After entering the host cell, the viral and endosomal membranes fuse releasing the viral genetic material. The RNA released is then translated by the host cell machinery along with the production of viral enzymes. These viral enzymes consist of the pp1a and pp1ab protein complexes(Ziebuhr, Snijder et al. 2000). These protein complexes play a dual role in viral replication. They produce crucial non-structural proteins that are required for the formation of viral replicase machinery Nsp1-16. The Nsps form the replicase-transcriptase complex which is responsible for viral RNA replication and transcription of sub-genomic mRNAs (Sethna, Hofmann et al. 1991). The translation of the sub-genomic mRNAs yield the structural and accessory proteins of the viral particle. After replication of the RNA and translation of the sub-genomic mRNA, the viral proteins and RNA are inserted into the endoplasmic reticulum and move along the secratory pathway into the endoplasmic reticulum Golgi intermediate compartment to be packaged and form the new viral progeny (Figure 2). The viral particles are then carried in vesicles and released by excocytosis(Krijnse-Locker, Ericsson et al. 1994).

2.2. Severity and mortality rate

Age appears to be an important factor in COVID-19 prognosis with fewer than 1% of cases being under 10 years old and 4% between the ages of 10-19 years. Individuals under the age of 50 appear to have a significantly low death rate at 0.5% while older individuals have a death rate of up to 8% (Castagnoli, Votto et al. 2020). In severe cases, symptoms manifest as COVID-19 induced pneumonia, acute respiratory distress syndrome (ARDS), multi-organ failure, and sepsis which can eventually lead to death (Cascella, Rajnik et al. 2020). ARDS induced by COVID-19 leads to alveolar damage and fibroblast proliferation with 17% of patients had fibrous stripes in chest CT scans(Figure 3) (Ye, Zhang et al. 2020). Potential long term effects after severe sickness remains under study with some cases showing potential long term damage to the lungs after infection (Figure 4) (Servick 2020).

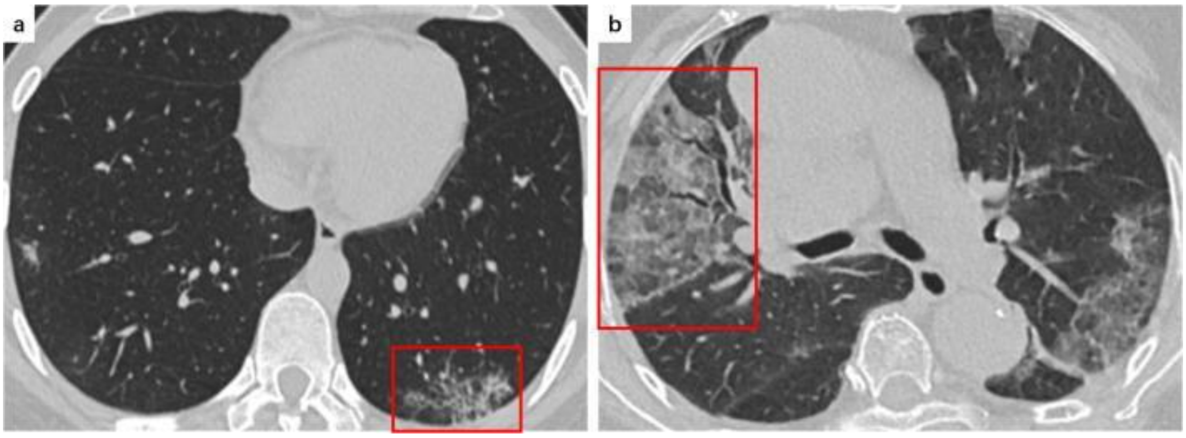


Figure 3: A 34 year old patient with COVID-19 symptoms.a: reticular pattern can be seen in the left lower lobe and subpleural area of the lungs(red frame) using a CT scan, b: An 81-year-old patient with COVID-19 patient. CT scan shows reticular pattern superimposed on the background of GGO, resembling the sign of crazy paving stones in the right middle lobe (red frame) (Ye, Zhang et al. 2020).

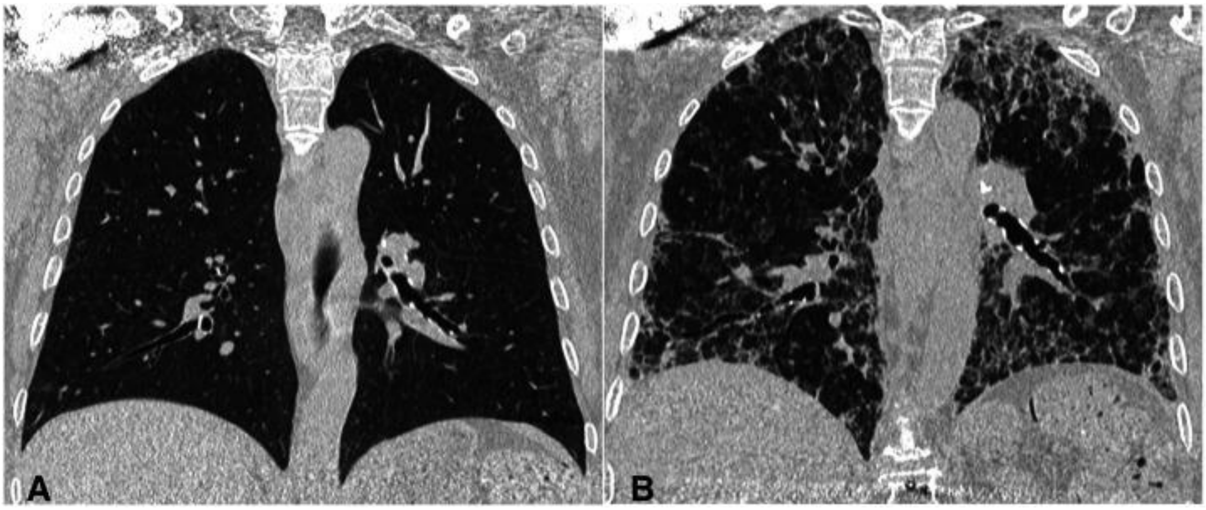


Figure 4: Chest tomography of a 69 year old patient after recovering from severe COVID-19 symptoms. A:Healthy lungs before infection and B: Lungs after COVID-19 infection showing lung architecture distortion ,bronchial wall thickening,and peripheral honeycombing (Orsi, Oliva et al. 2020).

2.3. Mode of transmission

The SARS-COV-2 virus spreads through direct and indirect means. It can spread directly from person to person through close range contact via respiratory droplets through coughing, sneezing, singing or talking (Liu, Ning et al. 2020). It can also spread after contact with contaminated surfaces then touching mucous membranes such as the eyes or mouth (Van

Doremalen, Bushmaker et al. 2020). The current infection rate of SARS-COV-2 ranges from 2.24 to 3.58 where one individual could potentially infect 2 to 4 person verifying the rapid propagation of this virus (Zhao, Lin et al. 2020). Infectiousness has been shown to appear 2 to 3 days before the onset of symptoms with peak infection rate at around 1 day before symptoms appeared accounting for asymptomatic or presymptomatic transmission (He, Lau et al. 2020). Asymptomatic transmission has been shown to occur biologically. The presence of infectious virus was detected in the upper respiratory tract of asymptomatic individuals up to six days prior to infection (Arons, Hatfield et al. 2020). Risk of reinfection is still mildly studied with only a few cases documented. It appears that the risk of reinfection after a short duration (2-3 months) remains low (To, Hung et al. 2020).

3. COVID-19 in Lebanon

With Lebanon currently facing major political economic crises, the COVID-19 pandemic appears to add insult to injury to the Lebanese people (Bizri, Khachfe et al. 2020). Data retrieved from the Lebanese Ministry of Public Health shows a total of more than 100,000 confirmed cases with an increase of more than 1000 reported deaths (MOPH 2020). While these numbers may be low on a global level, Lebanon’s health care system is severely struggling to cope (MOPH 2020). Intensive care units have reached a critical 82% capacity while medical supplies are dwindling due to a collapsing economy. Despite controlling the pandemic in its earlier phases, the severe economic crisis has redirected political priorities and eased preventive measures allowing the virus to spread (The Daily Star 2020). In spite of rising cases, Lebanon maintains a 0.8% COVID-19 mortality rate compared to the global mortality rate of around 3.4% (Center 2020). The Lebanese government has implemented several measures to control the outbreak. On 15 March, Lebanon declared a state of medical emergency and imposed closures of the Beirut Airport, sea port and land entrances (Yassine 2020). On 26 March, the Lebanese government instated mandatory curfews and lockdowns on the population. Public areas and businesses such as restaurants, nightclubs, gyms, and cinemas were temporarily closed (Geldi 2020). On August 4, COVID-19 cases surged after the Beirut explosion that killed over 200 people causing hospitals to be severely crowded with wounded citizens (Eye 2020). On November 2, several villages were placed under lockdown and a curfew was reinstated (News 2020).

4. Covid-19 Preventive Measures

Currently, a COVID-19 vaccine is not expected until 2021 at the earliest (Rhee, Kim et al. 2020). Thus, preventive measures are crucial to halt the spread of the disease. Due to the lack of effective treatments, the best strategy to control the pandemic is reducing infection rates and 'flattening the curve' (Anderson, Heesterbeek et al. 2020). Some of the methods used to decrease infection rates include good respiratory hygiene, washing hands thoroughly, social distancing, avoiding crowds, and wearing masks in public locations (Figure 5) (Adhikari, Meng et al. 2020). The most affected countries include the United States of America with more than 8 million confirmed cases and more than 200,000 deaths, followed by India with more than 6 million cases, then by Brazil and Russia with more than 4 million and 1.5 million confirmed cases respectively. In the USA, there have been fluctuating spikes of corona virus depending on the preventive measures adapted. In the states where mask use is highest, there is a 25% decline in cases, while states with more lenient mask use have seen a 70% increase in cases (Roser, Ritchie et al. 2020).

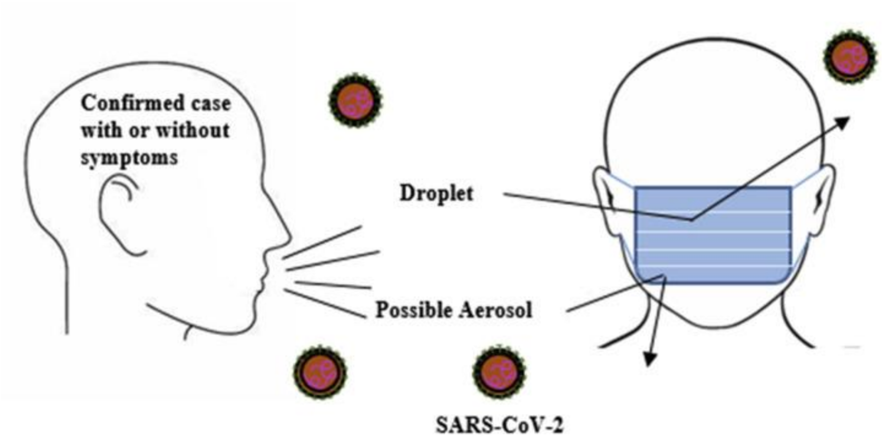


Figure 5: Descriptive figure showing protective effects of wearing masks while in contact with aerosols from an infected individual (Wang, Pan et al. 2020).

The most successful countries at slowing down infection have implemented several strategies. Japan informed the population that highest risk of infection was found in crowded areas, closed spaces with poor ventilation, and close contact settings. Japan then targeted the areas with the highest risk of infection such as gyms and nightclubs (Roser, Ritchie et al. 2020). Further success was seen in Germany by strictly enforcing social distancing and banning groups of more than two people in public areas (Stafford 2020). Germany also reduced the number of infections in the older population which reduced the fatality rate at 4.6% compared to 14.1% and 12% in Italy and Spain respectively (Weiss and Murdoch 2020). Other countries have also employed similar interventions to reduce infections such as stay-at-home orders, school, venue and non-essential business closure, bans on public gathering, travel restrictions with screening, and isolating individuals who have been exposed or infected (Zeng, Wang et al. 2020).

These precautions were similarly implemented during the Spanish Flu pandemic of 1918. The Spanish Flu led to the deaths of approximately 50 million people (Johnson and Mueller 2002). The cities that were able to control the outbreak such as St. Louis implemented school closure, bans on public gathering and quarantine. This resulted in a 30% to 50% decrease in mortality rate in these regions (Bakalar 2007, Bootsma and Ferguson 2007). Managing asymptomatic individuals with potential infection involves following several specific measures. The CDC suggests self-quarantine at home for 14 days after potential exposure maintaining a distance of at least 2 meters from other individuals. Avoiding contact with high risk individuals. Checking body temperature twice daily and watching for any symptoms such as fever, coughing, and dyspnoea (Prevention 2020). Preventive measures in health care settings are also crucial due to potential close contact with infected individuals. In order to identify patients with potential infection, many institutions have implemented the use of nucleic acid testing prior to admission to determine appropriate infection control protocols (Organization 2020). Protective masks should be worn in all healthcare settings by healthcare workers, patients, and visitors. In case of shortages, cloth masks may be a feasible alternative for healthcare workers who are not in direct contact with patients (McIntosh 2020).

5. Effectiveness of different masks against airborne pathogens

Currently the World Health Organization recommends the use of masks and agrees that the masks prevent spread of infectious airborne diseases such as COVID-19, with 75 countries mandating the use of masks in public (Organization 2020). The most widely used types of masks include the cloth facemask, the surgical mask and the N95 mask (Control and Prevention 2020).

Cloth facemasks have been recommended due to short supply of medical masks. One *in vitro* study suggested that cloth masks made of cotton and polyester had similar filtration rate to surgical masks (Rengasamy, Eimer et al. 2010). However cloth masks offer inferior protection against respiratory illnesses due to air leakage and moisture retention (Godoy, Jones et al. 2020). Surgical masks offer better protection by blocking out large droplets, or splatters of saliva that may contain the virus. The surgical mask also prevents the wearer’s saliva from spreading to other individuals thus providing protection to and from the user (Food, Food et al.

2020). However, the surgical mask does allow small particles to pass through the mask due to its loose fit on the surface of the face (Food, Food et al. 2020). In practice, however, the surgical mask has been shown to be as effective as N95 against infections such as influenza (Godoy, Jones et al. 2020, Long, Hu et al. 2020). Furthermore, the N95 mask filters 95% of airborne particles according to the US National Institute for Occupational Safety and Health (Control and Prevention 2016). One study comparing different mask effectiveness after 3 hour use showed no significant difference between mask efficacy before and after 3 hour use , however in pandemics mask use may be extended to days or weeks which may limit mask use(Figure 6) (van der Sande, Teunis et al. 2008).

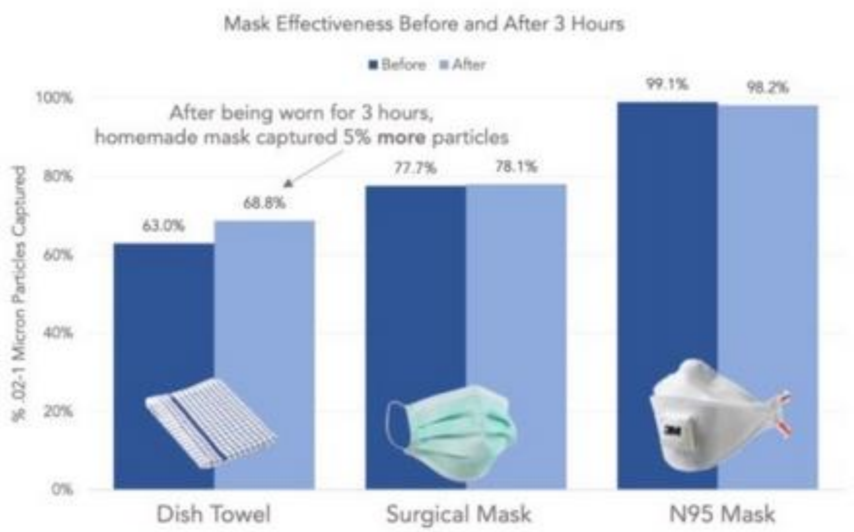


Figure 6: Efficacy comparison between homemade, surigcal, and N95 mask before and after 3 hour use.(van der Sande, Teunis et al. 2008)

6. Comfort, use, and safety of different masks

The main issue with N95 and other similar masks is the correct donning and obtaining the perfect fit. Untrained individuals rarely obtain a perfect fit to provide maximal protection (Patel, Skaria et al. 2016). N95 masks have also been shown to have potential risks on gaseous exchange. This is was seen in pregnant health care workers where breathing led to an increase in metabolic workload on the individuals (Tong, Kale et al. 2015).One study showed that humidity build up in N95 masks after a 4 hour period did not significantly affect breathing resistance (Roberge, Bayer et al. 2010). A study conducted on both N95 masks and surgical masks marked significant increase in temperature of the microclimates of the N95 mask as compared to the surgical mask. The results also showed that surgical masks were more comfortable than both nano-treated and untreated N95 masks (Li, Tokura et al. 2005).

It is predicted that there will be a second wave of COVID-19 potentially caused by easing preventive measures, returning expats and global travel (Ali and Preparedness 2020). The use of masks will likely become part of daily life and routine.

7. Maximum volume of oxygen consumed (VO_2 max)

While most tasks of daily life may be unaffected by mask use, exercise with masks remains a point of discussion especially with the gradual re-opening of gyms (Blocken, van Druenen et al. 2020). Aerobic exercise is a type of either low or high intensity exercise that requires the use of oxygen using aerobic metabolism. Examples of aerobic exercise including jogging, cycling, swimming and walking (McArdle, Katch et al. 2006). Aerobic exercise intensity can be classified based on the percentage of maximal heart rate (Levine 2008). VO_2 is commonly used to measure the direct amount of oxygen consumed at a certain intensity to determine the overall metabolic challenge on the body.VO_2 max is the maximal intensity reached with oxygen consumption. It is regarded as a strong predictor of future health and a determinant of overall aerobic cardiovascular fitness (Levine 2008).

7.1. VO_2 max training and limiting factors

Depending on various sports, different levels of VO_2 are trained at different intensities. These intensities are classified as zones based on the percentage of heart rate reached at each zone. Zone 1 begins at around 60% of maximal heart rate reaching zone 5 at VO_2 max which is around 95% maximal heart rate (Table 1) (Jackson, Sharkey et al. 1968, Sylta, Tønnessen et al. 2014, Neufeld, Wadowski et al. 2019).

Table 1: The five-zone scale used to determine training zones for athletes(Sylta, Tønnessen et al. 2014):

Intensity zone	VO_2 (%max)	Heart Rate (%max)	Lactate (mmol. L^{-1})	Duration within zone
1	45-65	55-75	0.8-1.5	1-6 h
2	66-80	75-85	1.5-2.5	1-3 h
3	81-87	85-90	2.5-4	50-90 min
4	88-93	90-95	4-6	30-60 min
5	94-100	95-100	6-10	15-30 min

Training for VO_2 max involves various methods. The most common method involves high intensity interval training (HIIT) (Astorino, Allen et al. 2012). HIIT consists of short intervals of vigorous near maximal exercise at around 85-95% of maximal heart rate coupled with active rest periods of similar duration (Moholdt, Amundsen et al. 2009). It is also shown to be more applicable to individuals of all ages as compared to other maximal and supramaximal training regimes that exclude elderly and people with life-style related diseases (Figure 7) (Ito 2019).

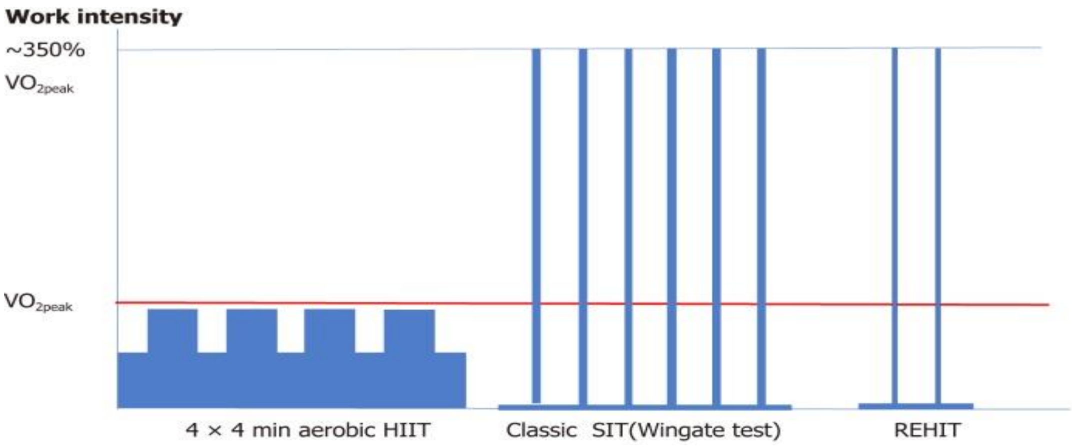


Figure 7: HIIT protocol compared to other supramaximal tests (Wingate and REHIT) showing that HIIT involves a lower training intensity compared to other VO_2 max training protocols (Moholdt, Amundsen et al. 2009).

Other methods of training involve aerobic exercise at moderate to slightly intense levels. These methods have also shown an increase of VO_2 max. One study suggests low intensity (50%) and moderate intensity (75% HR) showed a 14% and 10% increase in VO_2 max respectively. Several factors affect VO_2 max training (Gormley, Swain et al. 2008). These include age, gender, type of training and altitude (Wagner and reviews 2000). Studies have shown that sedentary individuals' VO_2 max tends to decrease by around 12% each decade while athletes with continuous training had a VO_2 max reduction of around 5% every decade (Rogers, Hagberg et al. 1990). Other internal limiting factors include cardiac output, capillary density, and mitochondrial enzymes. These factors work cohesively thus if one factor is limiting the whole system becomes restricted (Wagner and reviews 2000).

7.2. VO_2 max in sports

Achieving a high VO_2 max in professional sports that require endurance is crucial to compete. Elite runners can have a VO_2 max of between 60 and 80 ml/kg/min depending on distance ran (Legaz-Arrese, Munguía-Izquierdo et al. 2007) while elite football players have an average VO_2 max of 62.5 ml/min/kg (Abade, Teixeira et al. 2014). However, the highest VO_2 max belongs to cross country skiers averaging levels higher than 80 ml/min/kg (Holmberg 2009). Average VO_2 max in different sports and between males and females can be seen in Table 2.

Table 2: VO_2 max ($ml.min^{-1}.kg^{-1}$) comparisons between males and females in different sports (Hawley and Burke 1998).

Sport	Male	Female
Cross Country Skiing (Olympics/WC)	83.8	
Cycling (U.S. National Team)	74	
Running (U.S. Elite)	77.8	67.2
Triathlon (Elite, Professional)	75.4	65.6
Rowing (U.S. Olympic Team)	70.9	58.6
Swimming (U.S. Collegiate)	56.2	
Soccer (English First Division)	66	
Field Hockey (U.K. National Team)	62.2	
Cricket (South African Team)	60.5	

7.3. Testing for VO_2 max

Several methods exist for accurate estimation of VO_2 max. The methods used depend on the individuals 'sport. To estimate VO_2 max for a cyclist, exercise is performed on a cycle ergometer with gradual increments of intensity from moderate to maximal intensity until complete exhaustion is reached (Andersen and sports 1995). A runners VO_2 max can similarly be calculated by incrementing intensities on a treadmill until exhaustion is reached (Blair, Kohl et al. 1989).Tests for team sports include the multi-stage 20m fitness test or beep test. The athlete must run from one line to another 20m apart before a timed beep at increasing intervals (Leger, Lambert et al. 1982). The VO_2 max is then calculated based on the level reached and number of shuttles completed using the following formula VO_2 max = 3.46 * (L + SN / (L * 0.4325 + 7.0048)) + 12.2 where SN is the number of shuttles and L is the level completed

(Ramsbottom, Brewer et al. 1988). However, these tests are maximal tests, thus may be dangerous for those suffering from respiratory or cardiovascular diseases. To avoid such risks other submaximal tests have been developed such as the Cooper test which involves running for 12 minutes at the maximal sustainable pace. The VO_2 max is then derived from the distance covered in 12 minutes (Bandyopadhyay 2015).

7.4. Effect of Elevation Masks on aerobic training

Masks in aerobic training have been used to simulate high altitude conditions. Training with elevation masks (Figure 8) has shown several benefits to improve aerobic capacity. A study conducted on elevation masked deduced that high intensity (70%VO_2max) cycling with elevation masks induced modest hypoxaemia without affecting heart rate variability potentially simulating high altitude training (Jung, Lee et al. 2019). Another study suggested that the use of elevation masks significantly increased VO_2max of trained athletes by 16.5% compared to 13.5% increase compared to control group (Porcari, Probst et al. 2016).

Figure 8: Elevation training mask (Porcari, Probst et al. 2016).

8. Objective of the study

With the rapid increase in respiratory illnesses and pollution, facemasks such as clothe masks, N95 masks, and surgical masks are becoming increasingly more common in everyday life. The recent SARS-CoV-2 outbreak has led to the exponential worldwide use of these masks in everyday activities. However, little is known about the effects of these masks on maximal oxygen consumption during exhaustive exercise. Determining the exact effects of surgical masks and N95 masks on VO_2 max may help determine the applicability of these masks in high intensity exercise during the pandemic.

III. Materials and Methods

1. Health Questionnaire

Prior to conducting the first experiment, the individuals were given a health questionnaire to determine the gender, age, weight, and height to calculate the BMI. It also contains questions to detect the existence of factors that could influence the outcome of the results (Paradisis, Zacharogiannis et al. 2014). These questions clarify whether the individuals are smokers or non-smokers, the number of hours of exercise performed per week and any underlying health conditions such as high cholesterol, high blood pressure, diabetes, asthma or any other metabolic or respiratory diseases, and any medication usage. The questionnaire also aims to seek the presence of any orthopedic injuries that could affect running at high speeds. Exclusion criteria involved illness and injuries that affected performance, severe fatigue and muscle soreness, and intense exercise prior to the experiment. All the participants are non-smokers with no underlying health condition.

The individuals were allowed to withdraw from the experiment at any time without incurring any penalty. This work was supported by Notre Dame University – Louaize, Lebanon. The university provided the sport field facility and the masks.

The study protocol was approved by the Ethical Committee of the Faculty of Natural applied Sciences of the Notre Dame University-Louaize, Lebanon.

2. Experimental Design

The participants underwent the 20 m shuttle run test or the “beep test” until exhaustion. The test involves continuous running between 2 lines measured at a distance of 20 meters apart. The individual begins running at the first beep and turns when signaled by the next beep. After a specific amount of time the beep interval shortens requiring the individual to run at a faster pace. The beep intervals progressively shorten. The individual must reach the line before the beep, if not, they are given a warning. If the line is not reached after the warning, the subject is eliminated (Leger, Lambert et al. 1982). The beep test is then repeated while equipping the surgical mask, and then the N95 mask. The beep test was used to estimate VO_2 max, and it was calculated, according to the level (L) and shuttles (SN) completed with the following formula (Ramsbottom, Brewer et al. 1988):

$$VO2_{max} = 3.46\left(L + \frac{SN}{0.4325L + 7.0048}\right) + 12.2 \qquad (1)$$

Where

- SN is the number of shuttles
- L is the level completed

Heart rate was measured using an Apple Watch series 4 to ensure that the maximal effort was achieved while post-exercise fatigue was measured using a rate of fatigue scale adapted from Micklewright (Micklewright, St Clair Gibson et al. 2017).

The tests were completed between the months of June and July from 5 PM to 7 PM. The control and experimental testing were completed on days with the same climate temperature with range between 27 °C and 31 °C in order to maintain identical experimental setting. Participants of both groups engaged in a 5-minute warm-up prior to beginning the test. The first day involved the regular beep test; the number of shuttles and levels completed by each individual were recorded. After a 3-day interval, the participants returned to complete the test once again while wearing a 3-ply surgical mask (Anhui Yikang Medical Technology Co., Ltd.) (Figure 8). After another 3-day interval, the participants repeated the beep test while equipping the N95 mask

(Americo Inc. Item 951125). The beep test was performed on an open sports field at the campus of Notre Dame University-Louaize (NDU), Lebanon. Participants were asked to terminate the test in case significant dizziness and/or dyspnea was sensed. A first-aid trained paramedic was present for emergencies.

3. Selection Criteria for Athletes and Recreational Group Recruitment

A group of 11 healthy individuals with a training schedule exceeding 10 hours of exercise per week and participated in competitive sports was recruited and classified as athletes. The recreational group of 7 individuals was recruited with a training schedule of 4-8 hours of exercise per week. The athletes participated in competitive sports activities such as rally driving, tennis, mountain biking, marathon running, football, futsal, and basketball. The recreational group participated in weight training, jogging, and other leisure exercise.

4. Statistical Analysis

The main variables in the study were level, VO_2 max, heart rate and rate of fatigue. Data were entered, edited, and analyzed using IBM SPSS Data editor and R studio. Descriptive statistics was used to describe and present the variables in the study. The box-plot was used to identify the presence of outliers. The observations were then assessed for normality using the Shapiro-Wilk Test. Finally, Paired sample t-test was used to test if there were a significant difference between related paired sample (without mask(control)/with surgical mask/with N95 mask) for the variables under study in this case-control study: Level, VO_2 max ($ml.kg^{-1}.min^{-1}$), Heart Rate (BPM), and Rate of Fatigue (0-10).

IV. Results

1. Results of Athletes with Surgical Masks

Age, height and weight values were collected from each of the participants and their BMI calculated by dividing the weight over the height squared (Prime). The mean physical values of the athletes are listed in Table 3. All individuals had a BMI within the normal range (Organization, eHealth et al. 2006).

Table 3: Physical characteristics of the athletes

Characteristics	Mean	SD	Range
Age (Years)	24.5	8.2	18-43
Height (m)	1.75	.068	1.62-1.83
Weight (kg)	70.73	7.125	61-82
BMI ($kg \cdot m^{-2}$)	23.20	1.849	21.62-27.08

Figure 9: Athletic individuals performing the beep test with surgical masks on NDU campus.

The main variables in the study were level, VO_2 max, heart rate and rate of fatigue, which were measured as described in the below section with and without a surgical mask. The mean and standard deviation of the latter variables are presented in Table 4.

Table 4: Mean and standard deviation of Level, VO_2 max, heart rate and rate of fatigue after completing the beep test with and without equipping a surgical mask, p-value of the Shapiro-Wilk test for normality, and Results of paired sample T-test.

				Shapiro-Wilk Test	**Paired Samples Test the difference between without and with surgical mask**			
		Mean	Std. Deviation	*p*-value	Mean Difference	Std. Deviation	95% Confidence Interval of the Difference	*P*-value
Level	without Surgical Mask	10.68	1.60	0.271	0.436	0.48	0.11; 0.76	0.013*
	with Surgical Mask	10.25	1.44	0.554				
VO_2max (ml.kg-1.min-1)	without Surgical Mask	49.06	5.55	0.255	1.555	1.67	0.43; 2.67	0.012*
	with Surgical Mask	47.5	5.01	0.641				
Heart Rate (BPM)	without Surgical Mask	182.73	15.47	0.344	0.222	13.61	-10.24; 10.68	0.962
	with Surgical Mask	182.55	11.39	0.565				
Rate of Fatigue (0-10)	without Surgical Mask	8.27	0.91	0.522	-0.1	0.57	-0.51; 0.31	0.591
	with Surgical Mask	8.36	1.03	0.366				

The values for VO_2 max ($ml.kg^{-1}.min^{-1}$) for each individual with and without a surgical can be seen in Figure 10. From Table 4 we can conclude that only level and VO_2 max ($ml.kg^{-1}.min^{-1}$)

showed significance differences between their mean values while comparing their values with or without surgical masks where $p<0.05$.

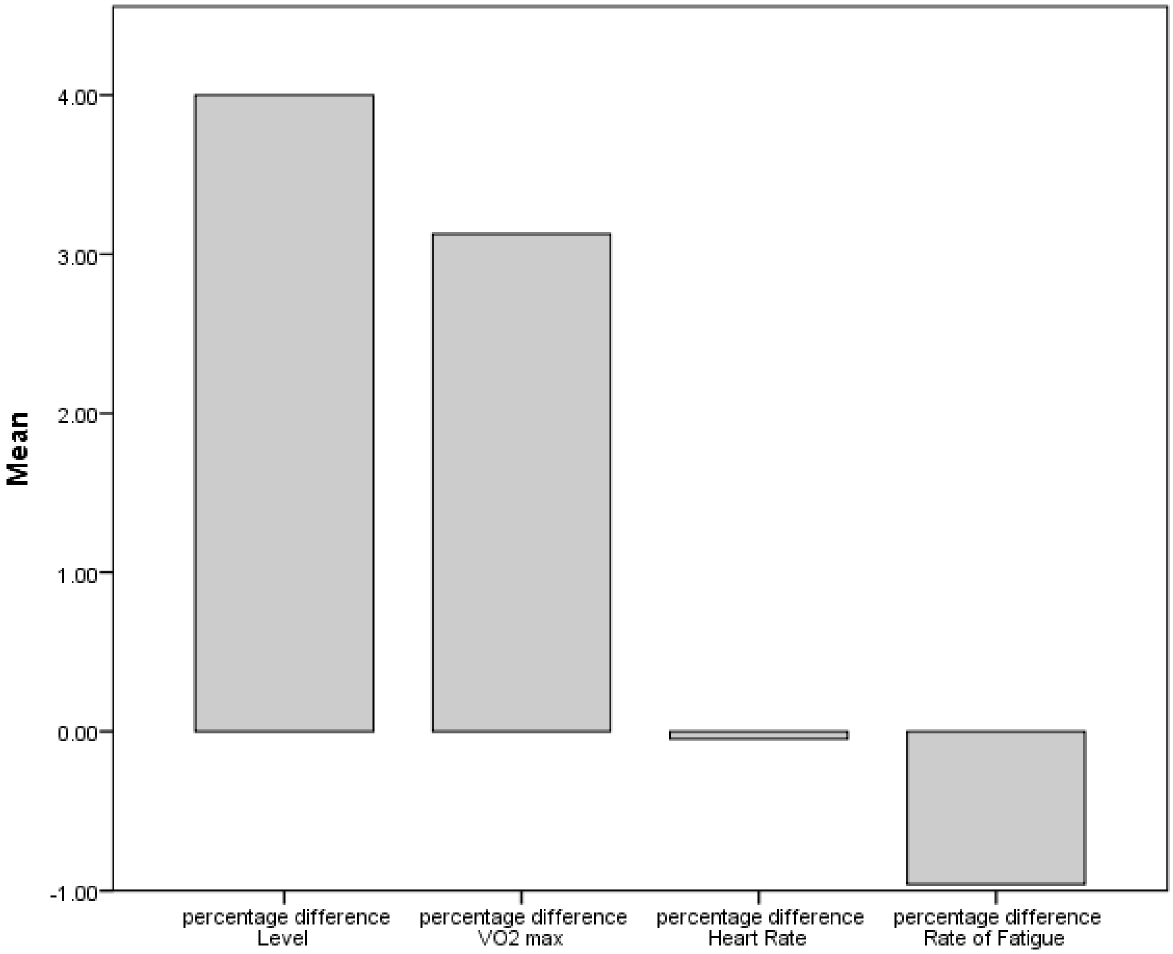


Figure 11: Mean percent difference for Level, VO_2 max, heart rate, and rate of fatigue

The VO_2 max of individuals equipped with a surgical mask are significantly less than individuals without. There was a mean decrease of 1.56 ($ml.kg^{-1}.min^{-1}$) with 3.2 percentage difference (Figure 11) using the following formula compared to the control individuals $p<0.05$.

$$\left(\frac{\text{Control} - \text{Surgical Mask}}{average(\text{Control} + \text{Surgical Mask})}\right) \times 100$$

Participants' main complaints were about difficulty inhaling large breaths due to the flexible nature of the mask interfering with breathing, as well as agitation from increased facial temperatures and humidity similar to the results seen in a previous study (Li, Tokura et al. 2005).

The rates of fatigue had no significant difference between the mask group and the control group, showing a potential mechanical disadvantage where the same fatigue is achieved with decreased energy output. The reduction in VO_2 max shows potential consequences on reaching maximal performance. This can be seen by the mean reduction in level during the beep test, equaling to 0.43, which is equivalent to 86m in the 20m beep test. Participants all obtained similar heart rates after completing the beep test with and without the surgical masks, showing that maximal effort was achieved in both cases.

2. Results of Recreational Group with Surgical Mask and N95

Table 5: Physical Characteristics of Recreational Group

	Mean	**Std. Deviation**
Age (years)	**22**	**2.191**
Height (m)	**1.78**	**0.07348**
Weight (kg)	**73.25**	**6.571**
BMI (kg·m−2)	**23.08792**	**0.935267**

Table 6**:** Mean and standard deviation of Level, VO_2 max, heart rate and rate of fatigue after completing the beep test without a mask, with surgical mask and with N95 mask.

	Means	**Stdev**
Level	9.167	0.8937
Level with surgical mask	8.917	0.8085
Level with N95 mask	8.8	0.9716

VO_2 max (ml.kg-1.min-1)	43.233	3.3756
VO_2 max(ml.kg-1.min-1) with surgical mask	43.033	2.7674
VO_2 max(ml.kg-1.min-1) with N95 mask	42.583	3.2939
Heart Rate (BPM)	178.67	10.501
Heart Rate (BPM) with surgical mask	180.83	8.01
Heart Rate (BPM) with N95 mask	176	5.55
Rate of Fatigue 0-10	8.33	0.816
Rate of Fatigue 0-10 with surgical mask	8.17	0.753
Rate of Fatigue 0-10 with N95 mask	7.67	1.033

Table 7: P-value comparisons between Level, VO_2 max, heart rate and rate of fatigue after completing the beep test without a mask, with surgical mask and with N95 mask.

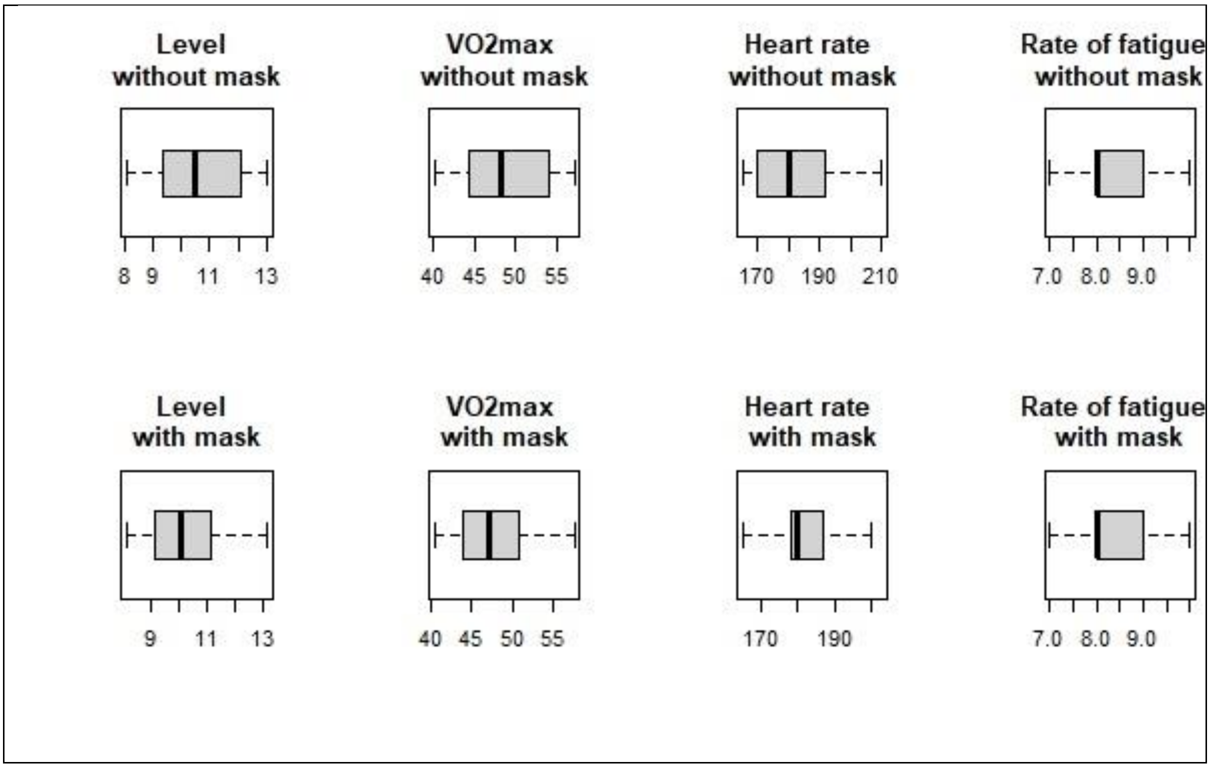
Pair 1	Level - Level with Surgical Mask	0.053
Pair 2	Level - Level with N95 Mask	0.043*
Pair 3	Level with Surgical Mask - Level with N95 Mask	0.302
Pair 4	VO_2 max (ml.kg-1.min-1) - VO2max (ml.kg-1.min-1) with Surgical Mask	0.811
Pair 5	VO_2 max (ml.kg-1.min-1) - VO2max (ml.kg-1.min-1) with N95 Mask	0.487
Pair 6	VO_2 max (ml.kg-1.min-1) with Surgical Mask - VO2max (ml.kg-1.min-1) with N95 Mask	0.236
Pair 7	Estimated Heart Rate (BPM) - Estimated Heart Rate (BPM) with Surgical Mask	0.326
Pair 8	Estimated Heart Rate (BPM) - Estimated Heart Rate (BPM) with N95 Mask	0.357
Pair 9	Estimated Heart Rate (BPM) with Surgical Mask - Estimated Heart Rate (BPM) with N95 Mask	0.057
Pair 10	Rate of Fatigue 0-10 - Rate of Fatigue 0-10 with Surgical Mask	0.611
Pair 11	Rate of Fatigue 0-10 - Rate of Fatigue 0-10 with N95 Mask	0.235
Pair 12	Rate of Fatigue 0-10 with Surgical Mask - Rate of Fatigue 0-10 with N95 Mask	0.456

After removing one outlier, the results are shown in Table 6. The P-values of each pair showed that only Level-Level with N95 surgical masks showed significant differences with $p<0.05$ while the other parameters compared showed no significant difference(Table 7). These preliminary results show a potential disadvantage while training with N95 masks in recreational athletes while surgical masks did not affect performance. This suggests potential reduction in maximal aerobic endurance while equipping the N95 masks while surgical masks had no significant effect in recreational athletes.

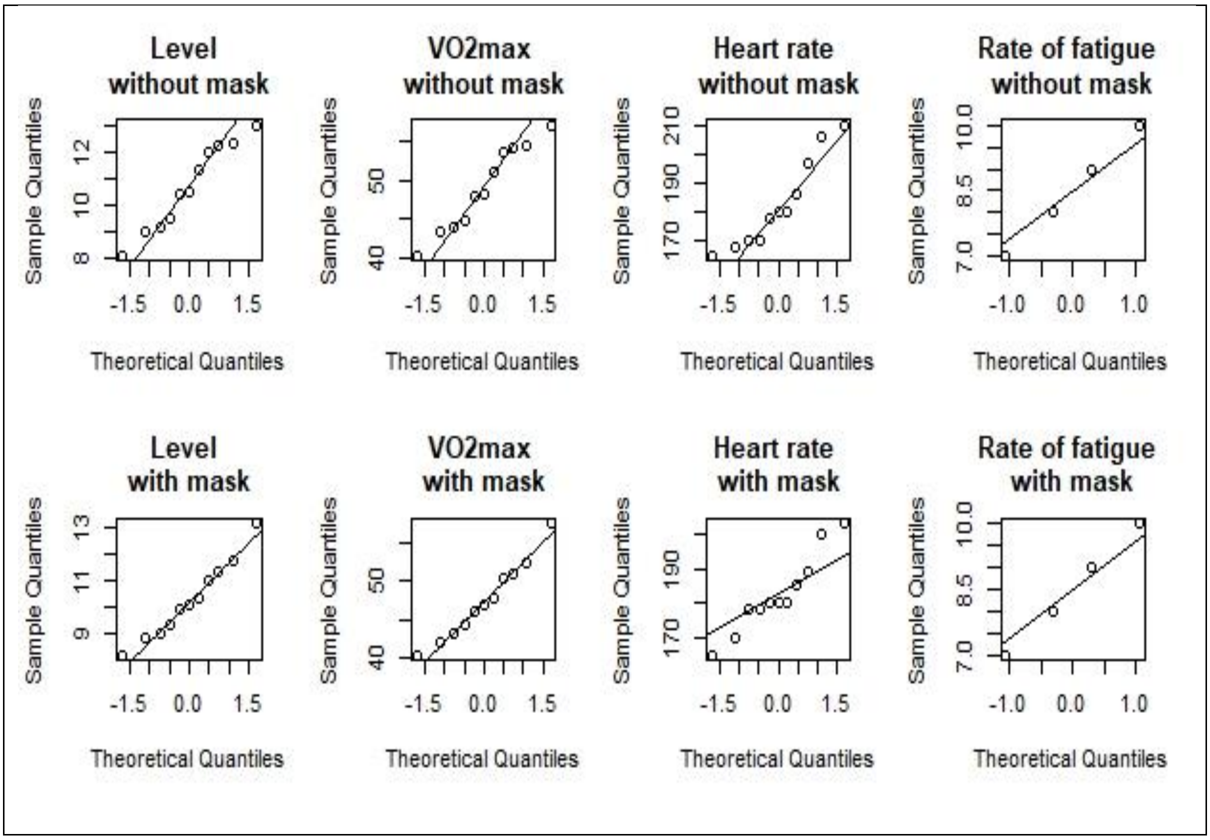
Discussion:

3. Testing for Outliers

Athletic group:

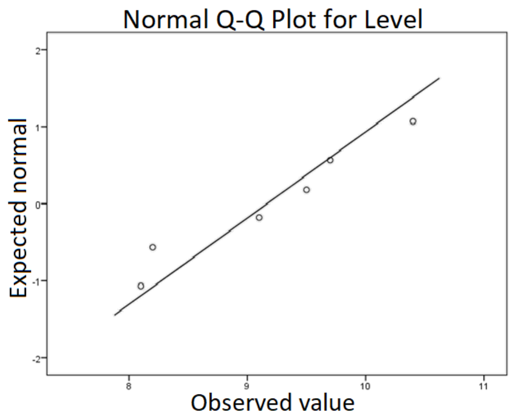


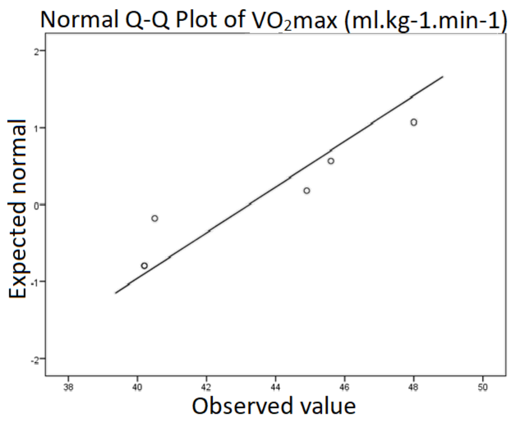
A

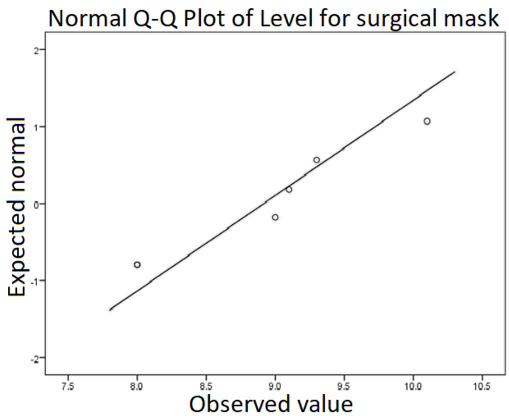


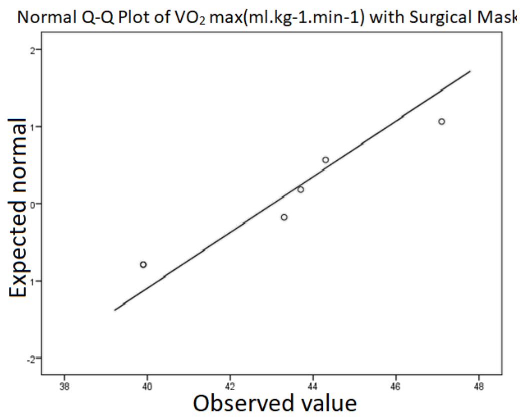
B

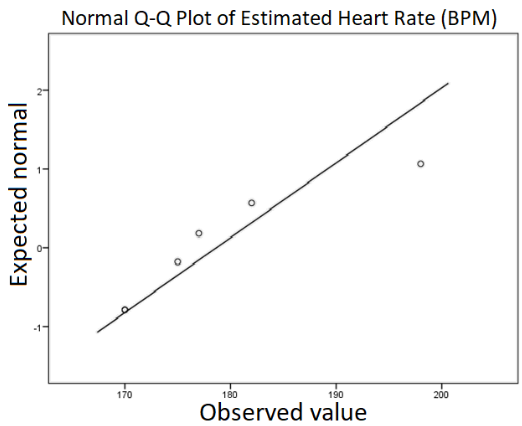
Figure 12: A-Box plot for the variables under study. B- Q-Q plot graphs for the variables under study for the Athletic group.

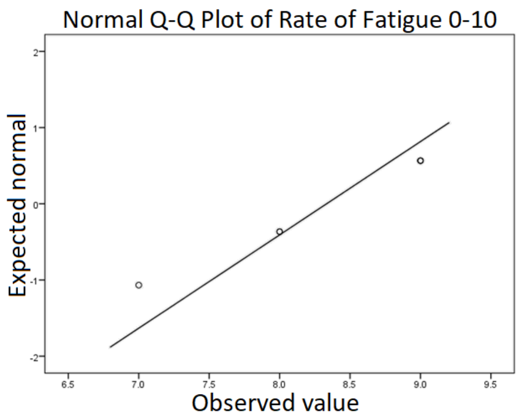

Normal Q-Q Plot for Level
Expected normal
Observed value

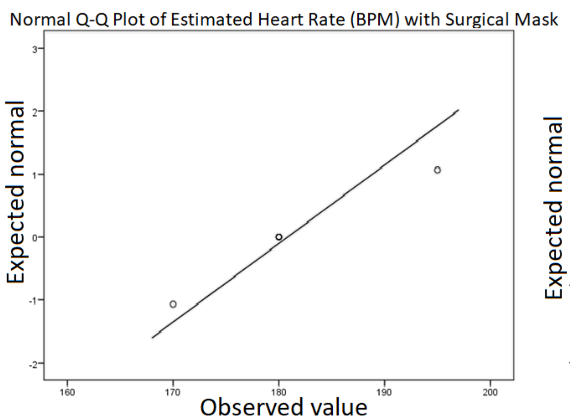

Normal Q-Q Plot of VO2max (ml.kg-1.min-1)
Expected normal
Observed value

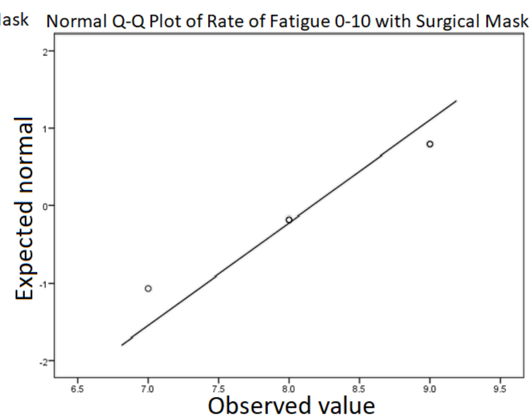

Normal Q-Q Plot of Level for surgical mask
Expected normal
Observed value


Normal Q-Q Plot of VO2 max(ml.kg-1.min-1) with Surgical Mask
Expected normal
Observed value


Normal Q-Q Plot of Estimated Heart Rate (BPM)
Expected normal
Observed value


Normal Q-Q Plot of Rate of Fatigue 0-10
Expected normal
Observed value


Normal Q-Q Plot of Estimated Heart Rate (BPM) with Surgical Mask
Expected normal
Observed value


Normal Q-Q Plot of Rate of Fatigue 0-10 with Surgical Mask
Expected normal
Observed value

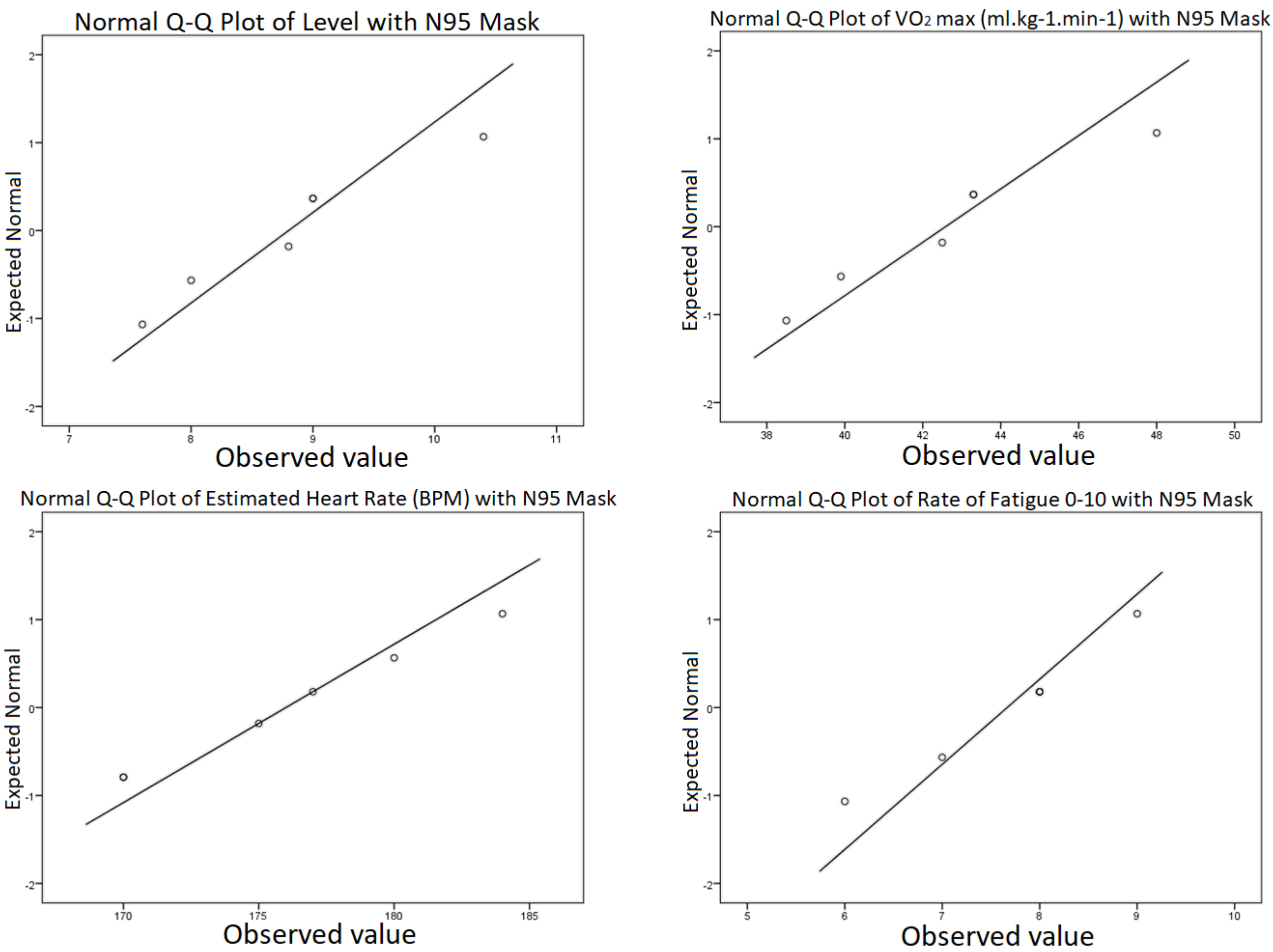
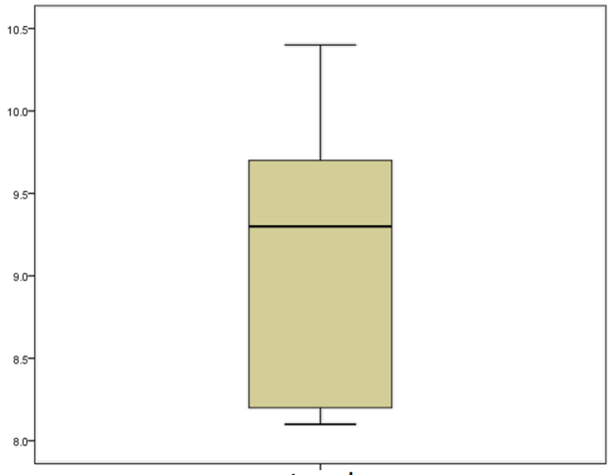
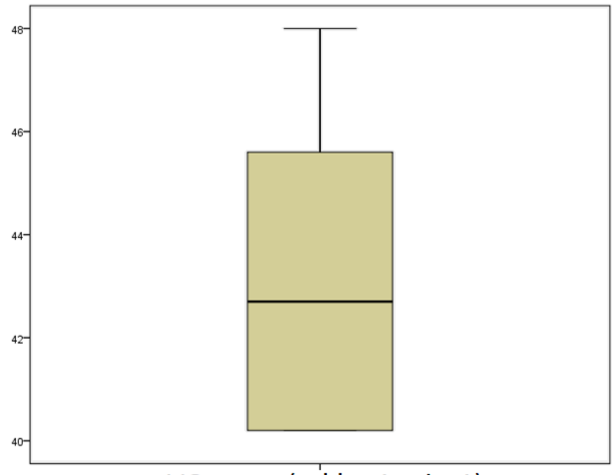


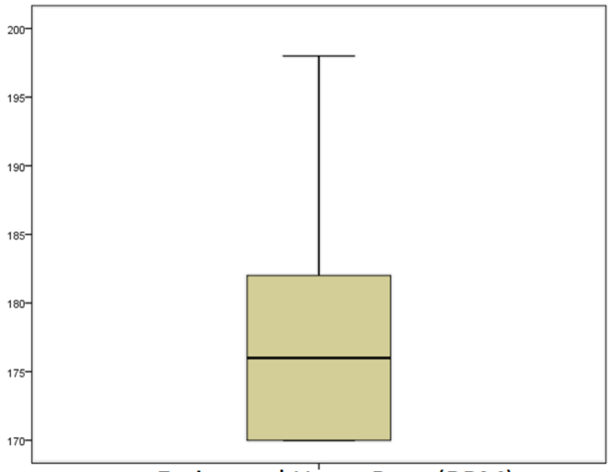
Figure 13: Q-Q plot graphs for the variables under study for the recreational group:



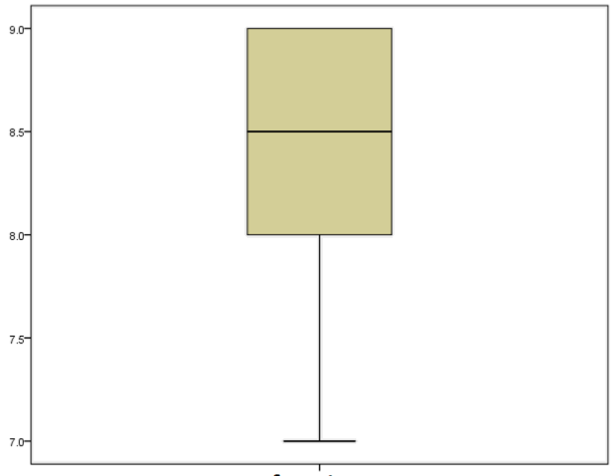
Level



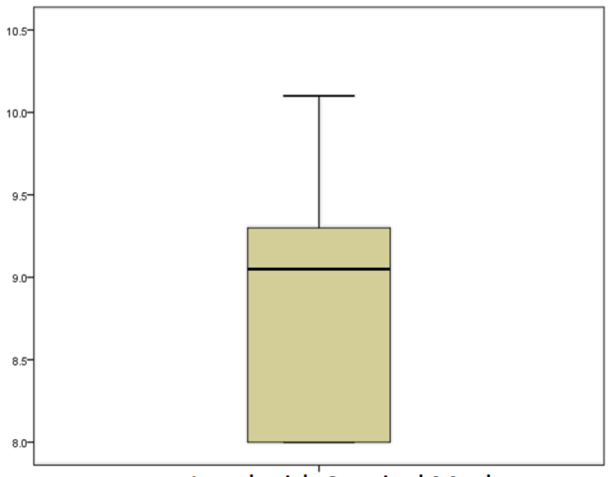
VO_2 max (ml.kg-1.min-1)



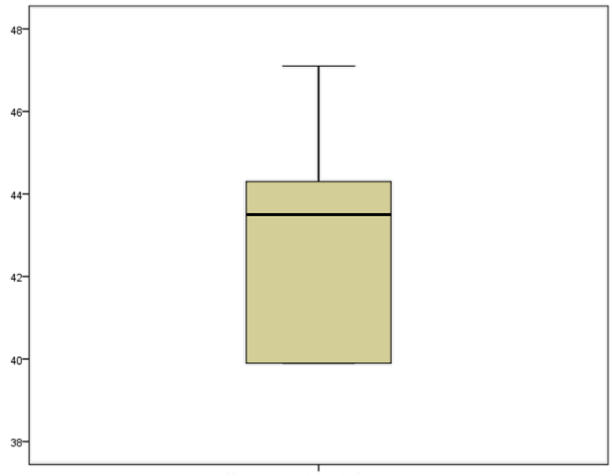
Estimated Heart Rate (BPM)



Rate of Fatigue 0-10



Level with Surgical Mask



VO_2max (ml.kg-1.min-1) with Surgical Mask

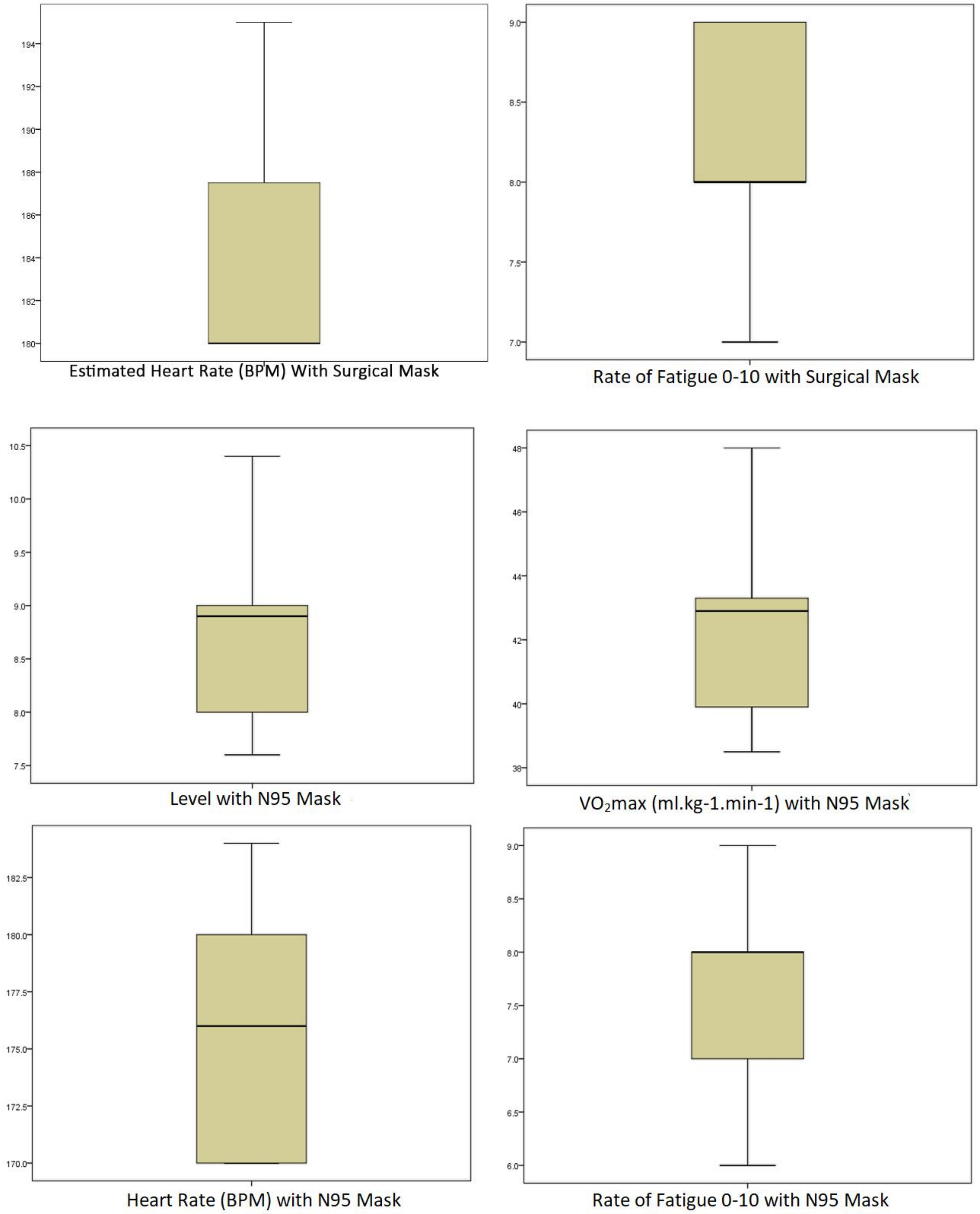


Figure 14: Box plot for variables under study for the recreational group:

Table 8: Shapiro-Wilk test for normality P-values

Shapiro-Wilk test	P- value
Level	0.938
VO2max (ml.kg-1.min-1)	0.84
Estimated Heart Rate (BPM)	0.842
Rate of Fatigue 0-10	0.822
Level with Surgical Mask	0.909
VO2max (ml.kg-1.min-1) with Surgical Mask	0.909
Estimated Heart Rate (BPM) with Surgical Mask	0.805
Rate of Fatigue 0-10 with Surgical Mask	0.866
Level with N95 Mask	0.933
VO2max (ml.kg-1.min-1) with N95 Mask	0.938
Estimated Heart Rate (BPM) with N95 Mask	0.933
Rate of Fatigue 0-10 with N95 Mask	0.915

The sample size in this paper is less than 50. Therefore, the fourth assumption was checked using the Shapiro-Wilk test. All *p*-values described in Table 4 and Table 8 are greater than .05; thus, all the variables are normally distributed. The normal Q-Q plot for all the variables are represented in Figure 12b, and Figure 13. All data points are close to the diagonal line; therefore, the observations are assumed to be normally distributed.

As a parametric procedure, the paired sample t-test makes the following assumptions.

- The dependent variable must be continuous (interval/ratio).
- The observations are independent of one another.
- The dependent variable should not contain any outliers.
- The dependent variable should be approximately normally distributed.

The first two assumptions are met in this paper. For the third assumption, when reviewing a box-plot, an outlier is defined as a data point that is located outside the whiskers of the box plot. After removing one outlier in the recreational group Figure 12a, and Figure 14 have zero observations that lie outside the fences of the box plot. Therefore, the data set in this paper does not contain any outliers for both groups.

4. Discussion

SARS-CoV-2 is regarded as a highly contagious virus currently affecting most countries around the world (Zhao, Lin et al. 2020). The virus is considered airborne and is spread via droplets and, to a lesser extent, contaminated surfaces (Jayaweera, Perera et al. 2020). Preventive measures have been implemented in several countries including quarantine, facemasks, social distancing, and closing of facilities prone to crowds such as gyms and sports areas (Anderson, Heesterbeek et al. 2020). However, decreases in COVID-19 cases will result in gradual re-opening of gyms and sports facilities. This may increase the risk of infection of the virus due to its mode of transmission (Jayaweera, Perera et al. 2020). This is especially the case during excessive physical exertion, which leads to increases in aerosol and droplet release (Blocken, Malizia et al. 2020). The use of surgical masks during training may be beneficial in order to decrease the risk of transmission and infection with SARS-CoV-2 (Adhikari, Meng et al. 2020). Our experiment showed that surgical masks may provide limitations while training for VO_2 max, where some individuals might not reach the necessary aerobic capacity to train effectively (Bacon, Carter et al. 2013). Our study suggested that surgical masks had a slight but statistically significant decrease on VO_2 max in athletic individuals. However, other parameters measured, such as fatigue and heart rate, were not affected. This shows that the same maximal effort was achieved with reduced oxygen consumption and efficiency. Athletic individuals necessitate reaching maximum aerobic capacity and heart rate in order to train and improve their VO_2 max for competitions (Bacon, Carter et al. 2013). The use of a surgical mask may compromise this training by limiting athletes to a lower VO_2 max. However, the slight decrease in VO_2 max fails to prove if submaximal training is affected by surgical mask (Carey 2009, Stöggl and Sperlich 2015). The use of masks may be more feasible in recreational individuals as the results showed that surgical masks had no effect on VO_2 max $p>0.05$(Table 7) while the N95 mask had a minor decrease in Level suggesting potential usability of surgical masks during maximal aerobic effort in recreational individuals.

5. Limitations:

The sample that remained in this study after removing 0 outliers from the athletic group and 1 outlier from the recreational group, the athletic group consisted of 11 individuals the recreational group consisted of 6 individuals .This presents a relatively small sample size where repetition with a larger sample size may further verify the results and reduce error. The beep test is considered as an estimation of VO_2 max rather than a direct measurement, compared with an indirect calorimeter or spirometer. CO_2 released was also not measured due to potential interference of another mask over the surgical mask. The beep test is also considered as a maximal test and thus cannot be used for all individuals such as sedentary individuals, the elderly, or individuals suffering from lifestyle-related metabolic diseases. Future studies may require the use of submaximal tests to determine the effect of masks on lower-intensity aerobic exercise or on anaerobic exercise. It is also difficult to recruit a large number of highly trained athletes over a long duration due to their exhaustive training schedules and expose them to high intensity exercise potentially exacerbating fatigue.

V. Conclusion

Due to the ongoing pandemic, masks must be adapted in all parts of daily life and may start to be used during exercise after the re-opening of gyms and sports fields. Our study, conducted on 11 athletes and 7 recreational individuals, concluded that the use of surgical masks does appear to decrease performance and VO_2 max in athletic individuals by around 3.2%. There is also a slight decrease in Level in recreational individuals while wearing a N95 mask but no change while wearing the surgical mask. These results could be potentially due to the flexible nature of the mask, which interferes with respiration and their interference in VO_2 inhalation and VCO_2 exhalation hindering ideal maximal respiration. Further research is also required to determine the effects of medical masks in trained individuals at lower intensities such as in "fat-burning zones" and in anaerobic conditions such as weight lifting.

VI. Bibliography

Abade, E., N. Teixeira, P. Mourão, S. Paulo and A. Carvalho (2014). Maximal oxygen uptake in professional football players: comparison between levels and playing positions. International congress of exercise and sports performance.

Adhikari, S. P., S. Meng, Y.-J. Wu, Y.-P. Mao, R.-X. Ye, Q.-Z. Wang, C. Sun, S. Sylvia, S. Rozelle and H. J. I. d. o. p. Raat (2020). "Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak period: a scoping review." **9**(1): 1-12.

Ali, I. J. D. M. and P. H. Preparedness (2020). "COVID-19: Are we ready for the second wave?": 1-3.

Andersen, L. B. J. S. j. o. m. and s. i. sports (1995). "A maximal cycle exercise protocol to predict maximal oxygen uptake." **5**(3): 143-146.

Anderson, R. M., H. Heesterbeek, D. Klinkenberg and T. D. J. T. L. Hollingsworth (2020). "How will country-based mitigation measures influence the course of the COVID-19 epidemic?" **395**(10228): 931-934.

Arons, M. M., K. M. Hatfield, S. C. Reddy, A. Kimball, A. James, J. R. Jacobs, J. Taylor, K. Spicer, A. C. Bardossy and L. P. J. N. E. j. o. m. Oakley (2020). "Presymptomatic SARS-CoV-2 infections and transmission in a skilled nursing facility."

Astorino, T. A., R. P. Allen, D. W. Roberson, M. J. T. J. o. S. Jurancich and C. Research (2012). "Effect of high-intensity interval training on cardiovascular function, VO2max, and muscular force." **26**(1): 138-145.

Bacon, A. P., R. E. Carter, E. A. Ogle and M. J. Joyner (2013). "VO2max trainability and high intensity interval training in humans: a meta-analysis." PloS one **8**(9): e73182-e73182.

Bakalar, N. J. N. Y. T. A. (2007). "How (and how not) to battle flu: a tale of 23 cities." **15**: F5.

Bande, F., S. S. Arshad, M. Hair Bejo, H. Moeini and A. R. J. J. o. i. r. Omar (2015). "Progress and challenges toward the development of vaccines against avian infectious bronchitis." **2015**.

Bandyopadhyay, A. (2015). "Validity of Cooper's 12-minute run test for estimation of maximum oxygen uptake in male university students." Biology of sport **32**(1): 59-63.

Belouzard, S., V. C. Chu and G. R. J. P. o. t. N. A. o. S. Whittaker (2009). "Activation of the SARS coronavirus spike protein via sequential proteolytic cleavage at two distinct sites." **106**(14): 5871-5876.

Bizri, A. R., H. H. Khachfe, M. Y. Fares and U. Musharrafieh (2020). "COVID-19 Pandemic: An Insult Over Injury for Lebanon." Journal of community health: 1-7.

Blair, S. N., H. W. Kohl, R. S. Paffenbarger, D. G. Clark, K. H. Cooper and L. W. J. J. Gibbons (1989). "Physical fitness and all-cause mortality: a prospective study of healthy men and women." **262**(17): 2395-2401.

Blocken, B., F. Malizia, T. van Druenen, T. J. Q. Marchal, E. U. o. T. Answers. Website Bert Blocken and K. L. D. s. h. w. u. n. C. html (2020). "Towards aerodynamically equivalent COVID19 1.5 m social distancing for walking and running."

Blocken, B., T. van Druenen, T. van Hooff, P. A. Verstappen, T. Marchal and L. C. Marr (2020). "Can indoor sports centers be allowed to re-open during the COVID-19 pandemic based on a certificate of equivalence?" Building and environment **180**: 107022-107022.

Bootsma, M. C. and N. M. J. P. o. t. N. A. o. S. Ferguson (2007). "The effect of public health measures on the 1918 influenza pandemic in US cities." **104**(18): 7588-7593.

Carey, D. G. (2009). "Quantifying differences in the "fat burning" zone and the aerobic zone: implications for training." J Strength Cond Res **23**(7): 2090-2095.

Cascella, M., M. Rajnik, A. Cuomo, S. C. Dulebohn and R. Di Napoli (2020). Features, evaluation and treatment coronavirus (COVID-19). Statpearls [internet], StatPearls Publishing.

Castagnoli, R., M. Votto, A. Licari, I. Brambilla, R. Bruno, S. Perlini, F. Rovida, F. Baldanti and G. L. J. J. p. Marseglia (2020). "Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in children and adolescents: a systematic review."

Cavanagh, D. J. V. r. (2007). "Coronavirus avian infectious bronchitis virus." **38**(2): 281-297.

Center, L. I. (2020). " "Lebanon Coronavirus (COVID-19) Emergency"."
Centre, W. H. O. J. W. M. (2004). "China's latest SARS outbreak has been contained, but biosafety concerns remain—update 7."
Charlton, C. L., E. Babady, C. C. Ginocchio, T. F. Hatchette, R. C. Jerris, Y. Li, M. Loeffelholz, Y. S. McCarter, M. B. Miller and S. J. C. m. r. Novak-Weekley (2018). "Practical guidance for clinical microbiology laboratories: viruses causing acute respiratory tract infections." **32**(1).
Control, C. f. D. and Prevention (2016). NIOSH-Approved R95 Particulate Filtering Facepiece Respirators.
Control, C. f. D. and Prevention (2020). Coronavirus Disease 2019 (COVID-19). Centers for Disease Control and Prevention.
Eye, M. E. (2020). "Coronavirus: Lebanon reports record 1,006 cases in 24 hours."
Fan, Y., K. Zhao, Z.-L. Shi and P. J. V. Zhou (2019). "Bat coronaviruses in China." **11**(3): 210.
Fehr, A. R. and S. Perlman (2015). Coronaviruses: an overview of their replication and pathogenesis. Coronaviruses, Springer**:** 1-23.
Food, D. A. J. Food and D. Administration (2020). "N95 respirators and surgical masks (face masks)."
Geldi, M. (2020). "Lebanon to impose partial curfew over coronavirus." Anadolu Agency.
Godoy, L. R. G., A. E. Jones, T. N. Anderson, C. L. Fisher, K. M. Seeley, E. A. Beeson, H. K. Zane, J. W. Peterson and P. D. J. B. g. h. Sullivan (2020). "Facial protection for healthcare workers during pandemics: a scoping review." **5**(5): e002553.
Gorbalenya, A. E., S. C. Baker, R. Baric, R. J. d. Groot, C. Drosten, A. A. Gulyaeva, B. L. Haagmans, C. Lauber, A. M. Leontovich and B. W. Neuman (2020). "Severe acute respiratory syndrome-related coronavirus: The species and its viruses–a statement of the Coronavirus Study Group."
Gormley, S. E., D. P. Swain, R. High, R. J. Spina, E. A. Dowling, U. S. Kotipalli and R. Gandrakota (2008). "Effect of intensity of aerobic training on VO2max." Med Sci Sports Exerc **40**(7): 1336-1343.
Hawley, J. and L. Burke (1998). Peak performance: training and nutritional strategies for sport, Allen & Unwin.
He, X., E. H. Lau, P. Wu, X. Deng, J. Wang, X. Hao, Y. C. Lau, J. Y. Wong, Y. Guan and X. J. N. m. Tan (2020). "Temporal dynamics in viral shedding and transmissibility of COVID-19." **26**(5): 672-675.
Henry, R. (2020). "Etymologia: Coronavirus." Emerging Infectious Diseases **26**(5): 1027-1027.
Holmberg, H.-C. (2009). The competitive Cross-Country Skier - an impressive human engine**:** 101-109.
Hui, D. S., E. I. Azhar, T. A. Madani, F. Ntoumi, R. Kock, O. Dar, G. Ippolito, T. D. Mchugh, Z. A. Memish and C. J. I. J. o. I. D. Drosten (2020). "The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China." **91**: 264-266.
Ito, S. (2019). "High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol." World journal of cardiology **11**(7): 171-188.
Jackson, J. H., B. J. Sharkey, L. P. J. R. Q. A. A. f. H. Johnston, Physical Education and Recreation (1968). "Cardiorespiratory adaptations to training at specified frequencies." **39**(2): 295-300.
James, N. (2017). FENNER'S VETERINARY VIROLOGY, Elsevier Academic Press.
Jayaweera, M., H. Perera, B. Gunawardana and J. Manatunge (2020). "Transmission of COVID-19 virus by droplets and aerosols: A critical review on the unresolved dichotomy." Environmental research **188**: 109819-109819.
Johnson, N. P. and J. J. B. o. t. H. o. M. Mueller (2002). "Updating the accounts: global mortality of the 1918-1920" Spanish" influenza pandemic." 105-115.
Jung, H. C., N. H. Lee, S. D. John and S. Lee (2019). "The elevation training mask induces modest hypoxaemia but does not affect heart rate variability during cycling in healthy adults." Biology of sport **36**(2): 105-112.
Kahn, J. S. and K. J. T. P. i. d. j. McIntosh (2005). "History and recent advances in coronavirus discovery." **24**(11): S223-S227.

Krijnse-Locker, J., M. Ericsson, P. Rottier and G. J. T. J. o. c. b. Griffiths (1994). "Characterization of the budding compartment of mouse hepatitis virus: evidence that transport from the RER to the Golgi complex requires only one vesicular transport step." **124**(1): 55-70.
Kubo, H., Y. K. Yamada and F. J. J. o. V. Taguchi (1994). "Localization of neutralizing epitopes and the receptor-binding site within the amino-terminal 330 amino acids of the murine coronavirus spike protein." **68**(9): 5403-5410.
Lalchhandama, K. (2020). "The chronicles of coronaviruses: the electron microscope, the doughnut, and the spike."
Legaz-Arrese, A., D. Munguía-Izquierdo, A. N. Nuviala, O. Serveto-Galindo, D. M. Urdiales, J. R. J. S. Masía and sports (2007). "Average VO2max as a function of running performances on different distances." **22**(1): 43-49.
Leger, L. A., J. J. E. j. o. a. p. Lambert and o. physiology (1982). "A maximal multistage 20-m shuttle run test to predict $$\dot V $$ O2 max." **49**(1): 1-12.
Letko, M., A. Marzi and V. Munster (2020). "Functional assessment of cell entry and receptor usage for SARS-CoV-2 and other lineage B betacoronaviruses." Nature microbiology **5**(4): 562-569.
Levine, B. D. J. T. J. o. p. (2008). ": what do we know, and what do we still need to know?" **586**(1): 25-34.
Li, Y., H. Tokura, Y. P. Guo, A. S. W. Wong, T. Wong, J. Chung and E. Newton (2005). "Effects of wearing N95 and surgical facemasks on heart rate, thermal stress and subjective sensations." International archives of occupational and environmental health **78**(6): 501-509.
Liu, Y., Z. Ning, Y. Chen, M. Guo, Y. Liu, N. K. Gali, L. Sun, Y. Duan, J. Cai and D. J. B. Westerdahl (2020). "Aerodynamic characteristics and RNA concentration of SARS-CoV-2 aerosol in Wuhan hospitals during COVID-19 outbreak."
Long, Y., T. Hu, L. Liu, R. Chen, Q. Guo, L. Yang, Y. Cheng, J. Huang and L. J. J. o. E. B. M. Du (2020). "Effectiveness of N95 respirators versus surgical masks against influenza: a systematic review and meta-analysis." **13**(2): 93-101.
Masters, P. S. J. A. i. v. r. (2006). "The molecular biology of coronaviruses." **66**: 193-292.
Mayburd, A. J. E. O. o. D. D. (2020). "A public-private partnership for the express development of antiviral leads: a perspective view." 1-16.
McArdle, W. D., F. I. Katch and V. L. Katch (2006). Essentials of exercise physiology, Lippincott Williams & Wilkins.
McIntosh, K. (2020). MD Coronavirus Disease 2019 (COVID-19): Epidemiology, Virology, and Prevention.
Micklewright, D., A. St Clair Gibson, V. Gladwell and A. Al Salman (2017). "Development and Validity of the Rating-of-Fatigue Scale." Sports Med **47**(11): 2375-2393.
Moholdt, T. T., B. H. Amundsen, L. A. Rustad, A. Wahba, K. T. Løvø, L. R. Gullikstad, A. Bye, E. Skogvoll, U. Wisløff and S. A. J. A. h. j. Slørdahl (2009). "Aerobic interval training versus continuous moderate exercise after coronary artery bypass surgery: a randomized study of cardiovascular effects and quality of life." **158**(6): 1031-1037.
MOPH (2020). "Epidemiological surveillance program of COVID-19."
Neufeld, E. V., J. Wadowski, D. M. Boland, B. A. Dolezal and C. B. Cooper (2019). "Heart Rate Acquisition and Threshold-Based Training Increases Oxygen Uptake at Metabolic Threshold in Triathletes: A Pilot Study." International journal of exercise science **12**(2): 144-154.
Neuman, B. W., G. Kiss, A. H. Kunding, D. Bhella, M. F. Baksh, S. Connelly, B. Droese, J. P. Klaus, S. Makino and S. G. J. J. o. s. b. Sawicki (2011). "A structural analysis of M protein in coronavirus assembly and morphology." **174**(1): 11-22.
News, A. (2020). "Lebanon locks down 115 areas, imposes new curfew hours as coronavirus cases continue rise."
Organization, W. H. (2020). Advice on the use of masks in the context of COVID-19: interim guidance, 5 June 2020, World Health Organization.

Organization, W. H. (2020). "Infection prevention and control during health care when novel coronavirus (nCoV(infection is suspected: interim guidance, 25 January 2020."
Organization, W. H., W. H. O. G. O. f. eHealth and W. G. O. f. eHealth (2006). Building foundations for eHealth: progress of Member States: report of the WHO Global Observatory for eHealth, World Health Organization.
Orsi, M. A., G. Oliva and M. Cellina (2020). "The Lungs Before and After COVID-19 Pneumonia." The American journal of tropical medicine and hygiene **103**(1): 6-6.
Paradisis, G. P., E. Zacharogiannis, D. Mandila, A. Smirtiotou, P. Argeitaki and C. B. Cooke (2014). "Multi-Stage 20-m Shuttle Run Fitness Test, Maximal Oxygen Uptake and Velocity at Maximal Oxygen Uptake." J Hum Kinet **41**: 81-87.
Patel, R. B., S. D. Skaria, M. M. Mansour, G. C. J. J. o. o. Smaldone and e. hygiene (2016). "Respiratory source control using a surgical mask: an in vitro study." **13**(7): 569-576.
Poduri, R., G. Joshi and G. Jagadeesh (2020). "Drugs targeting various stages of the SARS-CoV-2 life cycle: Exploring promising drugs for the treatment of Covid-19." Cell Signal **74**: 109721.
Porcari, J. P., L. Probst, K. Forrester, S. Doberstein, C. Foster, M. L. Cress and K. Schmidt (2016). "Effect of Wearing the Elevation Training Mask on Aerobic Capacity, Lung Function, and Hematological Variables." Journal of sports science & medicine **15**(2): 379-386.
Prevention, C. f. D. C. a. (2020). "Implementing Safety Practices for Critical Infrastructure Workers Who May Have Had Exposure to a Person with Suspected or Confirmed COVID-19."
Prime, B. "Body mass index."
Ramsbottom, R., J. Brewer and C. Williams (1988). "A progressive shuttle run test to estimate maximal oxygen uptake." British journal of sports medicine **22**(4): 141-144.
Rengasamy, S., B. Eimer and R. E. J. A. o. o. h. Shaffer (2010). "Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles." **54**(7): 789-798.
Rhee, E.-J., J. H. Kim, S. J. Moon and W.-Y. Lee (2020). "Encountering COVID-19 as Endocrinologists." Endocrinol Metab **35**(2): 197-205.
Roberge, R. J., E. Bayer, J. B. Powell, A. Coca, M. R. Roberge and S. M. Benson (2010). "Effect of Exhaled Moisture on Breathing Resistance of N95 Filtering Facepiece Respirators." The Annals of Occupational Hygiene **54**(6): 671-677.
Rogers, M. A., J. M. Hagberg, W. H. Martin, 3rd, A. A. Ehsani and J. O. Holloszy (1990). "Decline in VO2max with aging in master athletes and sedentary men." J Appl Physiol (1985) **68**(5): 2195-2199.
Roser, M., H. Ritchie, E. Ortiz-Ospina and J. J. O. W. i. D. Hasell (2020). "Coronavirus pandemic (COVID-19)."
Servick, K. J. S. (2020). "For survivors of severe COVID-19, beating the virus is just the beginning."
Sethna, P. B., M. A. Hofmann and D. A. J. J. o. v. Brian (1991). "Minus-strand copies of replicating coronavirus mRNAs contain antileaders." **65**(1): 320-325.
Simmons, G., P. Zmora, S. Gierer, A. Heurich and S. J. A. r. Pöhlmann (2013). "Proteolytic activation of the SARS-coronavirus spike protein: cutting enzymes at the cutting edge of antiviral research." **100**(3): 605-614.
Stafford, N. J. B. (2020). "Covid-19: Why Germany's case fatality rate seems so low." **369**.
Stöggl, T. L. and B. Sperlich (2015). "The training intensity distribution among well-trained and elite endurance athletes." Frontiers in physiology **6**: 295-295.
Stringhini, S., A. Wisniak, G. Piumatti, A. S. Azman, S. A. Lauer, H. Baysson, D. De Ridder, D. Petrovic, S. Schrempft and K. J. T. L. Marcus (2020). "Seroprevalence of anti-SARS-CoV-2 IgG antibodies in Geneva, Switzerland (SEROCoV-POP): a population-based study."
Sylta, Ø., E. Tønnessen, S. J. I. j. o. s. p. Seiler and performance (2014). "From heart-rate data to training quantification: a comparison of 3 methods of training-intensity analysis." **9**(1): 100-107.
The Daily Star, L. (2020). "'A matter of survival': Lebanon's hospitals on the brink as COVID cases surge." The Daily Star.

To, K. K.-W., I. F.-N. Hung, J. D. Ip, A. W.-H. Chu, W.-M. Chan, A. R. Tam, C. H.-Y. Fong, S. Yuan, H.-W. Tsoi and A. C.-K. J. C. I. D. Ng (2020). "COVID-19 re-infection by a phylogenetically distinct SARS-coronavirus-2 strain confirmed by whole genome sequencing."
Tong, P. S. Y., A. S. Kale, K. Ng, A. P. Loke, M. A. Choolani, C. L. Lim, Y. H. Chan, Y. S. Chong, P. A. Tambyah and E.-L. Yong (2015). "Respiratory consequences of N95-type Mask usage in pregnant healthcare workers-a controlled clinical study." Antimicrobial resistance and infection control **4**: 48-48.
Tyrrell, D. and M. J. B. m. j. Bynoe (1965). "Cultivation of a novel type of common-cold virus in organ cultures." **1**(5448): 1467.
van der Sande, M., P. Teunis and R. Sabel (2008). "Professional and home-made face masks reduce exposure to respiratory infections among the general population." PloS one **3**(7): e2618-e2618.
Van Doremalen, N., T. Bushmaker, D. H. Morris, M. G. Holbrook, A. Gamble, B. N. Williamson, A. Tamin, J. L. Harcourt, N. J. Thornburg and S. I. J. N. E. J. o. M. Gerber (2020). "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1." **382**(16): 1564-1567.
Wagner, P. D. J. E. and s. s. reviews (2000). "New Ideas on Limitations to JOURNAL/essrv/04.02/00003677-200028010-00004/ENTITY_OV0312/v/2017-07-29T043426Z/r/image-pngo2max." **28**(1): 10-14.
Wang, J., L. Pan, S. Tang, J. S. Ji and X. Shi (2020). "Mask use during COVID-19: A risk adjusted strategy." Environmental pollution (Barking, Essex : 1987) **266**(Pt 1): 115099-115099.
Weiss, P. and D. R. J. T. L. Murdoch (2020). "Clinical course and mortality risk of severe COVID-19." **395**(10229): 1014-1015.
Weiss, S. R. and S. Navas-Martin (2005). "Coronavirus pathogenesis and the emerging pathogen severe acute respiratory syndrome coronavirus." Microbiology and molecular biology reviews : MMBR **69**(4): 635-664.
Wertheim, J. O., D. K. Chu, J. S. Peiris, S. L. K. Pond and L. L. J. J. o. V. Poon (2013). "A case for the ancient origin of coronaviruses." **87**(12): 7039-7045.
Wong, A. Y.-Y., S. K.-K. Ling, L. H.-T. Louie, G. Y.-K. Law, R. C.-H. So, D. C.-W. Lee, F. C.-F. Yau and P. S.-H. Yung (2020). "Impact of the COVID-19 pandemic on sports and exercise." Asia-Pacific journal of sports medicine, arthroscopy, rehabilitation and technology **22**: 39-44.
Woo, P. C., S. K. Lau, C. S. Lam, C. C. Lau, A. K. Tsang, J. H. Lau, R. Bai, J. L. Teng, C. C. Tsang and M. J. J. o. v. Wang (2012). "Discovery of seven novel Mammalian and avian coronaviruses in the genus deltacoronavirus supports bat coronaviruses as the gene source of alphacoronavirus and betacoronavirus and avian coronaviruses as the gene source of gammacoronavirus and deltacoronavirus." **86**(7): 3995-4008.
Yassine, H. (2020). "Breaking: Lebanon Will Officially Shut Beirut Airport." The961.
Ye, Z., Y. Zhang, Y. Wang, Z. Huang and B. Song (2020). "Chest CT manifestations of new coronavirus disease 2019 (COVID-19): a pictorial review." European radiology **30**(8): 4381-4389.
Zeng, W., X. Wang, J. Li, Y. Yang, X. Qiu, P. Song, J. Xu and Y. J. J. o. Wei (2020). "Association of Daily Wear of Eyeglasses With Susceptibility to Coronavirus Disease 2019 Infection."
Zhao, S., Q. Lin, J. Ran, S. S. Musa, G. Yang, W. Wang, Y. Lou, D. Gao, L. Yang and D. J. I. j. o. i. d. He (2020). "Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: A data-driven analysis in the early phase of the outbreak." **92**: 214-217.
Zhou, P., X.-L. Yang, X.-G. Wang, B. Hu, L. Zhang, W. Zhang, H.-R. Si, Y. Zhu, B. Li and C.-L. J. n. Huang (2020). "A pneumonia outbreak associated with a new coronavirus of probable bat origin." **579**(7798): 270-273.
Zhu, N., D. Zhang, W. Wang, X. Li, B. Yang, J. Song, X. Zhao, B. Huang, W. Shi and R. J. N. E. J. o. M. Lu (2020). "A novel coronavirus from patients with pneumonia in China, 2019."
Ziebuhr, J., E. J. Snijder and A. E. J. J. o. G. V. Gorbalenya (2000). "Virus-encoded proteinases and proteolytic processing in the Nidovirales." **81**(4): 853-879.