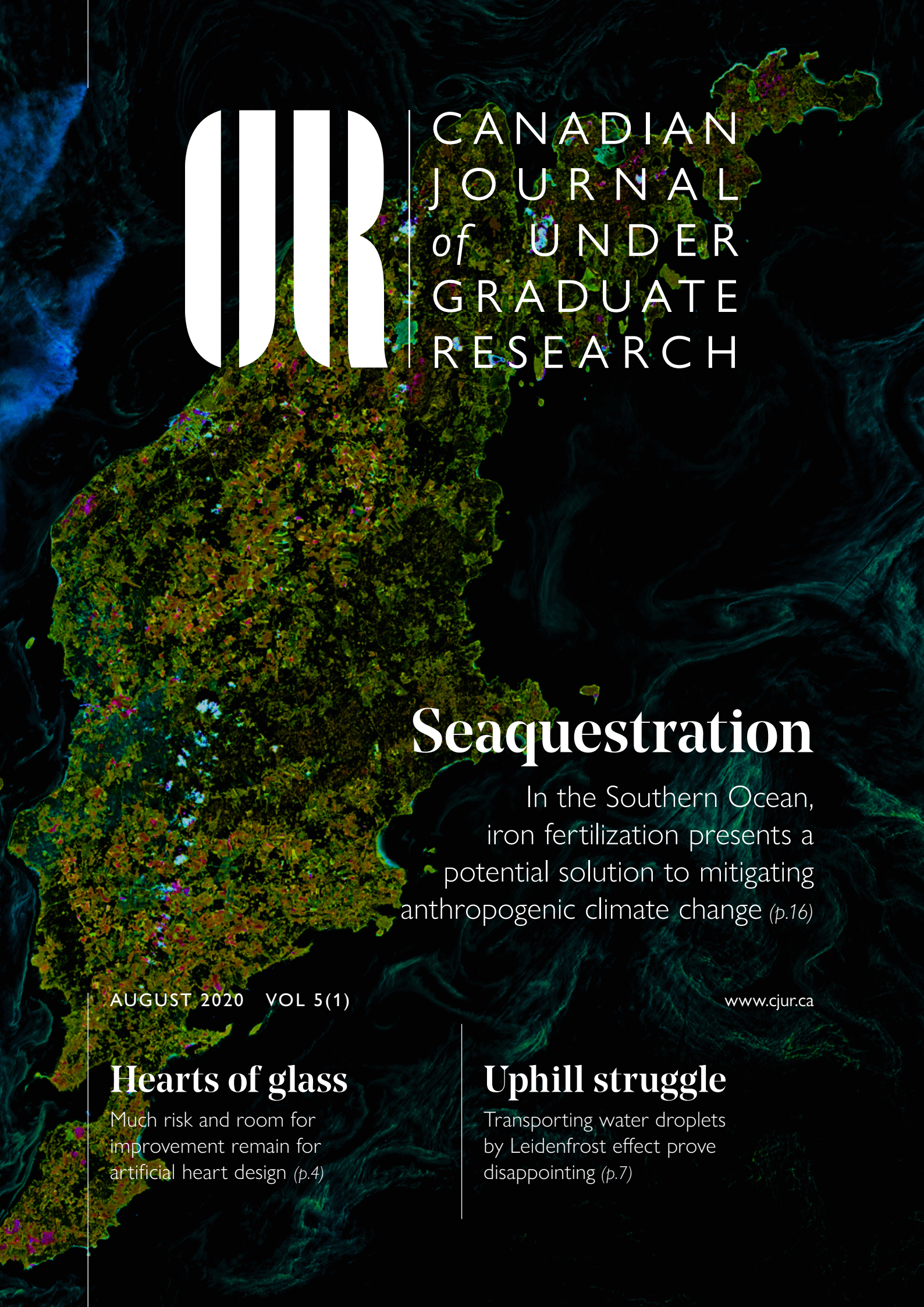

CANADIAN JOURNAL of UNDER GRADUATE RESEARCH

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Hearts of glass

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Uphill struggle

Transporting water droplets by Leidenfrost effect prove disappointing *(p.7)*

CANADIAN JOURNAL *of* UNDERGRADUATE RESEARCH

A student-led publication that aims to highlight research by undergraduate students of all disciplines

First Issue of the Fifth Volume August 2020

Courtesy of the Undergraduate Research Opportunities, University of British Columbia, Vancouver

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Letter from the editor-in-chief

It is my pleasure and great privilege to present to you Volume 5 Issue I of the Canadian Journal of Undergraduate Research (CJUR). Throughout the years, we at CJUR have made it our mission to support undergraduates across Canada by providing them the opportunity to share their research, experience the peer-reviewed publishing process, and engage in multidisciplinary academic dialogue.

Since our founding in 2015, we have received immense positive feedback from numerous students, professors, and organizations in the academic community. We have increased both the number and diversity of submissions, enhanced our peer-review process, and headed new initiatives with the aim of reaching out to more undergraduates from more universities. The journal also features a distinguished editorial board comprised of students who are passionate about research and academic discourse. Over the course of two years, we have led multiple recruitment events and have built a database consisting of strong reviewers that have a vital role in the peer-review process. Through our ongoing efforts, we plan to continue seeing CJUR grow over the years.

This issue contains submissions from the University of British Columbia, McGill University, Western University, Quest University Canada, and Simon Fraser University. Each manuscript has undergone two extensive review stages by graduate students and professors specializing in the respective field of research.

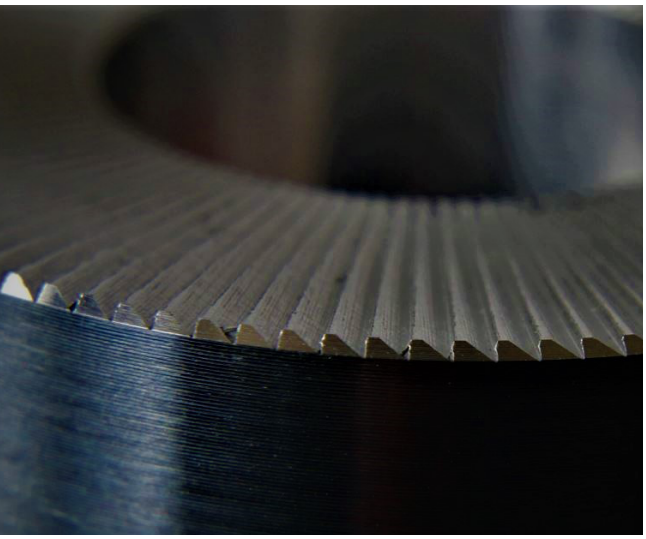
In this issue, we discuss a diverse range of topics, from the advances in the technology of different artificial hearts to the effects of marine iron fertilization. Each manuscript reflects the dedication and efforts that undergraduates put into their research, and I hope you join us in celebrating their work.

Thank you for your continued support and I hope you enjoy Volume 5 Issue I.

Yours sincerely,

Mahta Amanian BSc

Editorial board



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The artificial heart: medical improvements on infections and strokes

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Abstract Artificial hearts are designed to eliminate the need for heart transplants, which are in short supply. However, these devices are prone to creating complications such as infections or strokes. The complications occur from the mechanical aspects of the device. Therefore, the devices' effectiveness is influenced by their design. This paper investigates the advances in technology of different artificial hearts that are being developed. The four devices evaluated in this paper are: the total artificial heart, the left ventricular assist device, the total internal artificial heart, and the HeartWare ventricular assist device. Research shows that the total artificial heart may result in both infections and strokes. The left ventricular assist device lowered the probability of these complications but did not eliminate the risk altogether. While the internal artificial heart was able to eliminate the risk of infections entirely, it introduced new complications. Finally, the HeartWare ventricular assist device decreased the rate of adverse events for the complications occurring over time. Given these results, artificial hearts still require further research to improve the risk of complication before the phasing out of heart transplants can occur.

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INTRODUCTION

Artificial hearts are being engineered as an alternative solution to heart transplants. This issue was addressed by Gray and Selzman (2006). While heart transplantation remains a viable solution, shortages in the donor supply have limited this surgery to less than 2,500 patients per year. Consequently, about 10% to 20% of the patients on a waiting list die annually (Gray and Selzman, 2006). They concluded that "the disparity between the numbers of patients needing transplants and the availability of heart donors has refocused efforts to find other ways to support the severely failing heart" (Gray and Selzman, 2006, p. 4). Therefore, for the past two decades, some biomedical research has been focused on developing a working artificial heart.

Artificial hearts would be an ideal solution to heart transplants; however, there are many complications with them. The two main complications discussed here are infections and strokes (Stewart Garrick, 2012). Infections are caused from bacterial growth due to open incisions on the skin. The incisions, which depend on the specific device, must be made for the tubing to connect the internal components to a battery (DeVries, 1988). In addition, strokes can be caused from clots forming (thrombosis). These clots, called thrombi, are formed due to fragments of blood cells sticking to the mechanical device, and then breaking off (Stewart Garrick, 2012). Brand new designs are being created to improve the situation. There are two different types of artificial hearts that have been developed: the total artificial heart (TAH), and the left ventricular assist device (LVAD) (Zareba, 2002). This paper investigates how the devices, and variations of these devices, deal with the two main complications in order to make an appropriate recommendation.

DISCUSSION

The total artificial heart

Researchers had to start somewhere, and so the main function of the TAH was to ensure complete blood flow coming from the ventricles by allowing the device to adjust the pressure (Griffith et al., 1987). One of the first TAHs created was the Jarvik-7. This TAH had two "air-powered pumps" that mimicked heartbeats. Each chamber had a "disc-like mechanism" that pushes the blood through the device from the inflowing valve to the exiting valve (Khan & Jehangir, 2014, p. 123). By making cuts on the skin, this device was powered from an "external console" by using a tether (Zareba, 2002, p. 73). Due to the large size of the external power console, patients using this device had to remain immobile (Zareba, 2002).

Since this device required open incisions on the skin, it allowed for infections to occur. DeVries (1988) performed case studies of five patients who had the device implanted. He explained the "neurological, haematological, renal, and infectious complications" experienced by the patients, which lead to each of their deaths within 620 days (DeVries, 1988, p. 849). From these case studies, the risk of infection was seen to increase with the duration of the support from the device (Cohn, Timms, & Frazier, 2015).

The next main complication was stated to be strokes, which occurred from blood cells sticking to the wall of the device and thus forming clots. This complication lead to many secondary problems such as "sepsis, convulsions, kidney failure, respiratory problems, and multi-organ system failure" (Zareba, 2002, p. 73). Many engineers were discouraged with these obstacles, which diminished further interest in TAH research.

Due to the tragic results of the Jarvik-7, the United States' Food and Drug Administration (FDA) suspended further trials in 1990 (Zareba, 2002). Thus, engineers decided to backtrack and instead focus on designing an alternative device. They sought for a device that could at least prolong the life of an existing heart. This would later become the left ventricular assist device.

The left ventricular assist device

In order to decrease the risk of complications, the main function of the LVAD was to aid the pumping of the left ventricle to the aorta in order to allow better blood flow. A frequently used LVAD is the HeartMateII (Zareba, 2002). The main components of the LVAD usually had a mechanism to create a pulsatile flow using a pumping chamber and multiple valves. Alternatively, it can use a rotary pump that creates continuous-flow (From, Hasan, Froehler, & Goerbig-Campbell, 2013). The main feature of the LVAD was that it could be worn, thus allowing the patient to be mobile. Therefore, the main problem that concerned the TAH is eliminated on the LVAD by removing the tether to the console. Instead, a driveline is used to attach the valves inside the body to the control system that is outside.

This design improves the issue of infections being caused from the open wound. Drivelines are smaller and more stable than tethers (Rose et al., 1999). However, research still showed that a 28% incidence of infection occurred within 3 months (Zareba, 2002). Unlike with the earlier device, these infections can be treated easily, and patients are often taught how to treat their wounds in order to decrease the risk (Zareba, 2002).

The Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) study was done to view the health risks involved with the LVAD (Rose et al., 1999; Travis et al., 2007; Zareba, 2002). The study initially showed that only minor incidents occurred regarding strokes. However, the LVAD still increased the risk of strokes, due to clot formation, despite it not directly causing them. Patients with newer model of a LVAD will not have a pulse because they have a steady and continuous blood flow (Travis et al., 2007). A heart's pulse creates enough force to prevent most clots from naturally forming, and thus reduces the risks of strokes. Therefore, the LVAD also eliminated the heart's natural defence against blood clots forming. LVADs are currently designed to sustain the heart for only a few months since they still need an external power source (Zareba, 2002). Strokes may arise not only from clot formation on a pump component, but also from ingested blood clots that are propelled through the device (Stewart Garrick, 2012). Moreover, a paramedic without much knowledge on LVADs could improperly treat an unconscious patient due to the lack of pulse experienced with LVADs. While this newer technology represented real progress, the search for a better solution continued. According to Zareba (2002), a fully transplantable replacement heart might be possible using "new transcutaneous energy transmission technology" (p. 75).

The total internal artificial heart

The total internal artificial heart is a unique type of the TAH. The main difference is that this device contains two pumps instead of one, as well as that the main components are internal. These features have thereby been shown to reduce the risk of infection by removing the need for incisions used for tubing (Zareba, 2002). The first total internal artificial heart created was the AbioCor Implantable Replacement Heart. The AbioCor is an "advanced medical system" that resembles the function of the human heart. It consists of an "internal thoracic unit, an internal rechargeable battery, an internal miniaturized electronics package, and an external battery pack" (Zareba, 2002, p. 75).

This device involves advanced technology by allowing for wireless charging, which prevents the issue of infections since no open incisions needed to be made in order to apply power to the device. An internal and an external coil are used to form a transcutaneous air-core transformer, which can transfer energy electromagnetically through the skin and tissue. The primary coil is powered by an external power source that drives an oscillator while the secondary coil is simply implanted inside the patient (Zareba, 2002).

Because of the new technologies involved in this device, the FDA approved it to be implanted in humans in 2001 (Zareba, 2002). It was decided that the device would be used in fourteen patients who had a 70% chance of mortality within 30 days. Most of the patients lived up to 512 days. It was later reported that eleven of the patients suffered from non-device-related infections. However, none of them died as a result of the infection (Samak et al., 2015).

Unlike the previous versions, the AbioCor simulates the rhythm of the heartbeat. The device is equipped with an internal motor, which moves the blood through the entire body. The motor allows for pulsing, which can prevent strokes by eliminating natural clots from forming (Zareba, 2002). While theoretically this simulation should minimize the risk of strokes, nine deaths of the fourteen patients were reported due to strokes (Samak et al., 2015). Additionally, new issues are brought up due to its size. This device cannot be placed in most adults who have a smaller stature, and cannot at all be used by children (Zareba, 2002). It is evident that more research needs to be completed.

The HeartWare ventricular assist device

Researchers wanted to incorporate the advances found in continuous-flow LVADs into the TAH design in order to reduce the risk of complications even further (Cohn et al., 2015). In 2005, the Researchers at the Texas Heart Institute succeeded in developing two continuous-flow LVADs, thereby creating a continuous-flow TAH. A wide variety of LVAD pumps were designed, such as the HeartWare Ventricular Assist Device (HVAD), over the following 8 years (Cohn et al., 2015). However, it was expected that complications would be similar to experiences with both single-ventricle mechanical circulatory support. The most apparent complications are once again infection and thrombosis, which causes strokes (Mulvihill et al., 2017). It was expected that the HVAD would limit the risk of strokes compared to the LVAD, but results showed that stroke events occurred in patients regardless of the type of device used (Maxhera, 2017).

Maltais et al. (2017) conducted the ADVANCE bridge to-transplant (BTT) and continued access protocol (CAP) trial, approved by the FDA. In the ADVANCE BTT CAP trial, 382 patients were assessed for infection and hemorrhagic stroke, among other complications, during predetermined time periods after HVAD implant for 3 years. Immediately post implant, incidence of infections and strokes were highest. These complications occurred in lower rates after 6 months. Furthermore, after 1 year, all complications exhibited stable rates. This changing risk over time has clinically meaningful implications toward improving patient management. For instance, the decreased risk for complications over time suggests the HVAD is effective for patients who require longer duration of mechanical circulatory support (Maltais Simon, 2017).

Researchers reported that implantation of HVAD is safe and offers benefits in regard "to less bleeding and fewer transfusion requirements, shorter operating room times, and also decreased need for mechanical ventilation" (Gregoric Igor, 2017, p. 71). Therefore, the

HVAD provides significant improvements in survival and quality of life. Additionally, unlike the AbioCor, the HVAD permits biventricular support in smaller patients (Cohn et al., 2015). Advances in LVAD design are likely to further reduce device-related complications in the future (Gregoric Igor, 2017).

CONCLUSION

Each of the four aforementioned devices approach the problem of heart transplants their own way. While each of the devices accomplished their goal of providing the functions of a human heart, they still had to deal with the complications of infections and strokes. As previously stated, infections were caused from bacterial growth due to open incisions on the skin. Strokes were caused from clots forming due to fragments of blood cells sticking to the mechanical device, and then breaking off.

The use of TAHs was discontinued due to excessive complications relating to infections and strokes. This was proven in several case studies and showed that the TAH (Jarvik-7 in particular) was a failure. Next, the LVAD allowed patients to be mobile by attaching the battery to a belt. This improved their quality of life as they could still go about their daily routine. The device still showed complications relating to infections and strokes. The LVAD is an improvement from the Jarvik-7; however, patients do not generate a pulse. Moreover, the LVAD still had risk of complications, particularly strokes. As such, the LVAD should only be seen a temporary solution. The AbioCor improved upon some of the design problems of its predecessor. The AbioCor was the first wireless mechanical heart to be created by using coils to electromagnetically transfer energy without the use of wires. By doing so, the AbioCor finally made a big improvement on complications with infections because open incisions were unnecessary. However, strokes are still a reoccurring problem. The device is also too big; therefore, it cannot be used by men of smaller stature, women, or children. While the AbioCor is the most successive artificial heart technology to date, it should be avoided until further improvements are done to this design to make it more accessible. The HVAD still had the same issues as the LVAD; however, the improved design decreased the rate of adverse events occurring over time, thus decreasing the chance of infection or stroke. Therefore, complications and risk of death were greatly decreased after the first year of implantation.

Each time a new device emerged, the quality of life for the patients improved. Although the technology has improved as well, patients continue to experience these serious complications. With the changes in adverse events being documented over time, researchers should focus on developing patient management strategies to minimize the occurrence of specific complications when the patients are most at risk.

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Engine efficiency of a Leidenfrost droplet transport system

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Abstract We calculate the engine efficiency of a Leidenfrost droplet transport system to assess application for various industrial processes. The engine relies on the Leidenfrost effect to transport water droplets in a straight line across a superheated aluminium surface with ratchet-like topography. The engine efficiency of such a system has not been calculated in the literature thus far. Acceleration-time data was collected using Logger Pro 3® motion-tracking software and mechanical work was calculated using a midpoint Riemann sum. A power meter measured total power input at a constant rate. Average trial times were used to determine the power input for each trial, and engine efficiencies were subsequently calculated. Droplet volume and ratchet angle were varied as parameters in attempt to optimize engine efficiency. Our results give an extremely low average percent efficiency (2.86E-07%), which agrees with previously reported results for an analogous turbine system, to an order of magnitude. Varying the ratchet angle does not affect engine efficiency to any statistically meaningful extent. Increasing droplet volume in the 15-35 µL range tends to marginally improve engine efficiency for steep ratchet angles.

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INTRODUCTION

All compounds have characteristic phase-change temperatures. Past the boiling point of a compound, an interesting phenomenon can be observed which allows the compound to maintain liquid or even solid form while in contact with a superheated surface (Bernardin et al., 1999; Biance et al., 2003; Cole et al., 2015; Hashmi et al., 2012; Lagubeau et al., 2011; Linke et al., 2006; Ok et al., 2011; Quéré, 2013; Walker, 1994; Wells et al., 2015). Most famously, when a liquid water droplet is placed onto a superheated aluminium surface (hotter than its boiling temperature) a vapour layer instantaneously forms underneath the droplet, insulating the liquid water and thereby preventing its rapid evaporation. Water vapour conducts thermal energy approximately one order of magnitude lower than liquid water (Walker, 1994). The temperature at which the droplet exists for the longest time is called the Leidenfrost temperature. Near the Leidenfrost temperature, liquid water droplets can be maintained for several minutes (Biance et al., 2003; Lagubeau, et al., 2011; for a review see Quéré, 2013).

As first demonstrated by Linke et al. (2006), liquid water droplets on a superheated metal slab with ratchet-like topography travel in a well-defined direction with a well-defined velocity. This locomotive force is thought to be caused by the exiting of vapour under the droplet directed by the asymmetric topography of the metal surface (Lagubeau et al., 2011, Linke et al., 2006). Following the successful proof-of-concept study (Linke et al., 2006), many practical applications have been envisioned for the Leidenfrost system. The low friction environment and lack of moving parts alludes to an efficient and potentially advantageous mechanism for transporting liquid, dissolved solutes, or supported objects. Hashmi et al. (2012) showed that multiple Leidenfrost drops traveling together could be harnessed to transport 'carts' weighing up to 50 g.

Cole et al. (2015) showed that it is possible to engineer the trajectory of a Leidenfrost droplet to be sensitive to surface temperature. This discovery opened up a wide possibility for feedback cooling mechanisms that do not rely on electrical or moving components. Ok et al. (2011) observed that ratchet-like structures can help injected droplets adhere to the hot metal surface. This allows for a controlled and continuous transfer of heat, a necessary requirement for fuel-injection and combustion systems, steam generators, cooling systems for nuclear reactors, and spray quenching systems (Ok et al., 2011).

The incentive to develop technologies that exploit the Leidenfrost effect motivates our present work. The engine efficiency of a system that relies on the Leidenfrost effect to produce mechanical work in a straight line has not been previously calculated in the literature. However, Wells et al. (2015) constructed a Leidenfrost turbine which applies a torque to a solid carbon-dioxide disk, producing rotational motion. Their system relied on a similar ratchet like-topography to turn a dry-ice disk which sublimated on contact with a superheated aluminium surface (Wells et al., 2015). The engine efficiency of the turbine system was reported to be on the order of 1E-06%. In our experiment, two parameters thought to affect the dynamics of the water droplet were examined: ratchet angle and droplet volume. These parameters were varied within reasonable values based on the available literature.

METHODS

Aluminium slabs were machined to have an asymmetric ratchet-like surface topography (Fig. 1). Table 1 provides the dimensions of the machined aluminium slabs with 15° and 30° ratchet angles. These dimensions closely resemble those studied by Linke et al (2006). The slabs were positioned on a hot-plate perpendicular to a Canon T3i® DSLR camera and a thermocouple was used to monitor the surface temperature of the slabs. One end of the thermocouple was placed in a beaker of ice-water (0° Celsius) and the other was coiled tightly around an accessory aluminium slab,

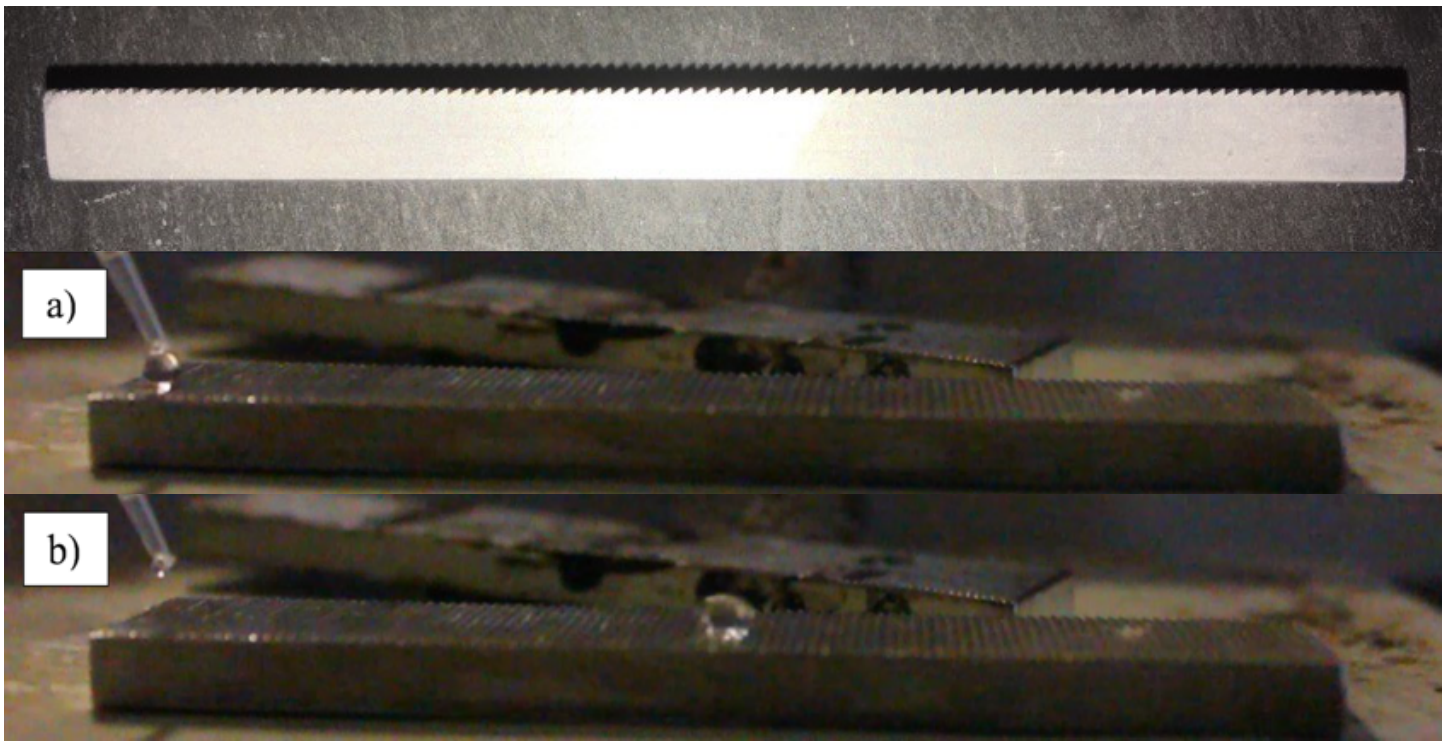


Fig. 1 (top) Close-up of aluminum slab with ratchet-like topography. Ratchet angle is defined for an individual ratchet as the angle of the hypotenuse relative to the horizontal, which is constant for the entire slab.

Fig. 2a (middle) Sample still from recorded video data - a water droplet initially stationary on the slab.

Fig. 2b (bottom) Sample still from recorded video data - the same droplet a short while later.

used as a weight, to measure hotplate surface temperature. The camera was mounted level to the experimental setup to record position-time data. A magnetic-assist pipette was used to control the droplet volume which was varied between 15-35 μL in 5 μL increments. Droplets of this size reliably accelerated in the expected direction, did not spontaneously divide, and could be manually deposited onto the superheated surface with relative ease. A water droplet accelerating due to the Leidenfrost effect after pipetting is shown in Fig. 2.

The hotplate was heated to a temperature well above boiling (335° Celsius), slightly hotter than the recorded Leidenfrost temperature for water on aluminium (Bernardin et al., 1999). The aluminium surface temperature remained relatively constant throughout (± 7°C) and was monitored closely during experimentation using a thermocouple. The entire experimental setup is shown in Fig. 3.

Initial tests suffered from an unreliable and inconsistent way of depositing stationary droplets on the heated aluminium surface. An established protocol (Table 2) was implemented and determined which replicates would contribute to the average engine efficiency. The protocol ensured the water droplets were initially stationary and were only accelerating due to the Leidenfrost effect. Recorded videos of the accepted replicates were analysed using Logger Pro 3® motion-tracking software. The known length of the ramp was used as a calibration scale.

Efficiency calculation

Energy efficiency was calculated by measuring the mechanical work done on the Leidenfrost droplet and the energy input from the hotplate, as summarized by the following equation:

$$Efficiency = (\frac{Work}{Energy\ \ input}) \times 100 \quad (1)$$

Work refers to mechanical work done in the direction perpendicular to the aluminium ratchets, across the full length of the slab. The work for a given replicate was calculated by numerically integrating the force function with respect to position, similar to the method used by Linke et al. (2006):

$$Work = \int^{x} \vec{F}(x') \cdot dx' \quad (2)$$

Position, velocity, and acceleration was determined using Logger Pro 3® software and a Canon T3i shooting at 60fps. Acceleration in the direction across the full length of the aluminium slab was considered work; all other acceleration was considered a system inefficiency. Using Newton's second law and the known mass of the water droplet, force was calculated as a function of position. The mass for each water droplet was calculated using the known droplet volume and the density of water at room temperature (1g/mL). The droplet density was assumed to be that at room temperature as the droplet was well-insulated by the vapour layer.

Instantaneous acceleration was calculated by taking the second-order time derivative of the position-time data using finite difference in Logger Pro 3®. The change in position between each time step was calculated using position-time data, converting acceleration as a function of time to acceleration as a function of position (relative to the initial starting position of the droplet). After obtaining force as a function of position, a midpoint rule Riemann sum with a 16.683 ms time-step was used to numerically approximate Eq. (2). The standard deviation for work was calculated between replicates of the same trial (same droplet volume and ratchet angle).

Energy input was measured using a power meter. The power input was monitored over a three-hour period and a constant power input of 266.67 J/s was observed. The energy input for a given replicate was calculated by multiplying the total time the water droplet spent in contact with the aluminium slab, by the constant power input. Uncertainty in the power measurement was defined as the

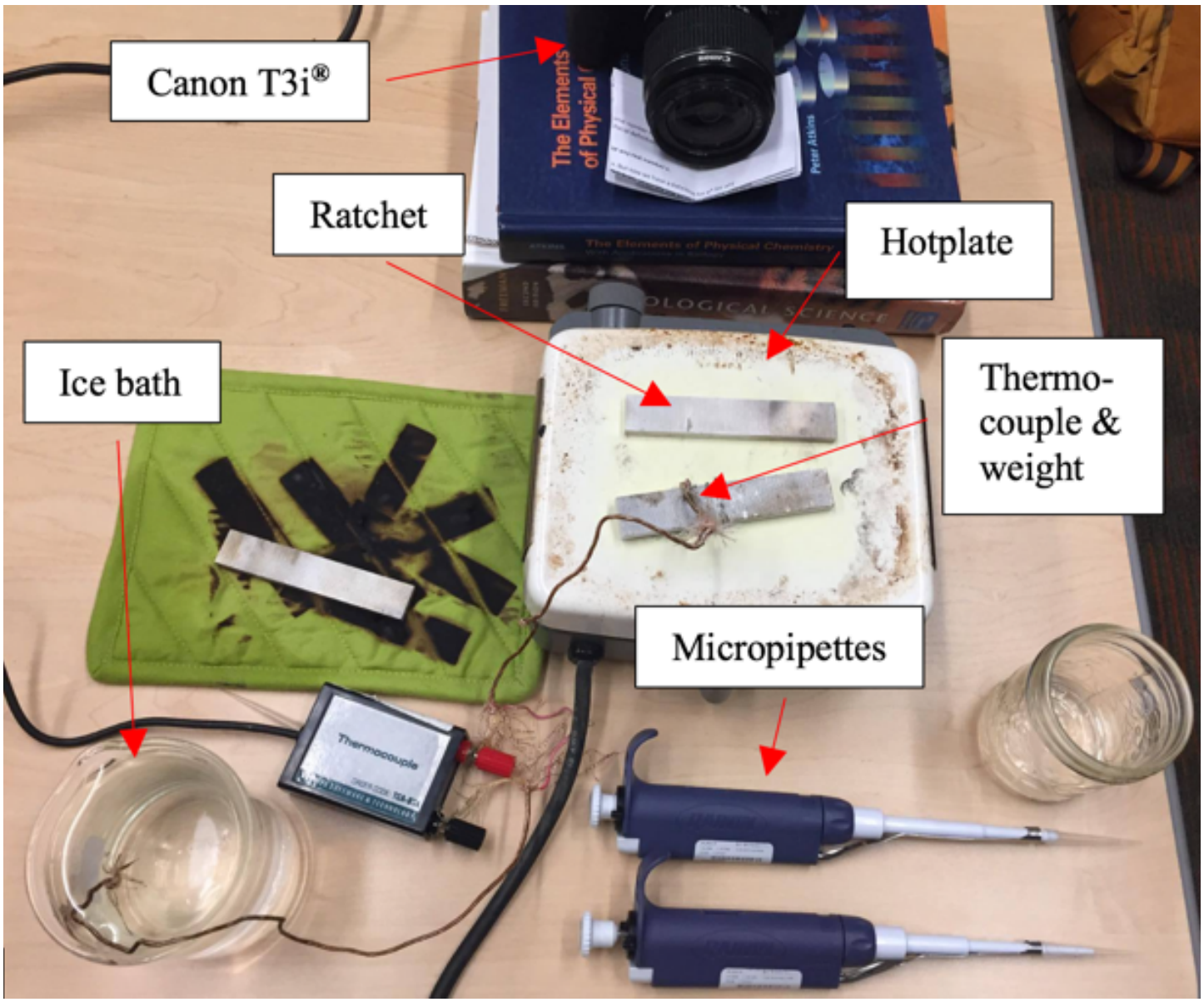


Fig. 3 Top-down view of experimental setup.

digital uncertainty in the power meter:

$$Energy\ \ input = Replicate\ \ time \times 266.67 J/s \tag{3}$$

RESULTS

To determine if we had reproduced the experimental conditions of Linke et al. (2006), we measured the average acceleration as a function of droplet volume. Comparing with their Fig. 5, our average droplet acceleration for 15° ratchet angle and 30 µL droplet volume, was 0.245 m/s2, which agrees with the value obtained by Linke et al. for 30 µL to one significant figure.

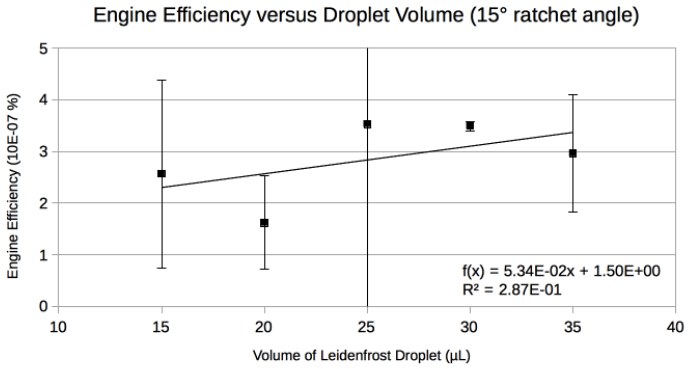
Figures 4 & 5 show the engine efficiency versus droplet volume for Slabs 1 & 2 respectively (see Table 1). Fig. 4 shows a relatively large standard deviation for the 30 µL trial which motivated us to double the sample size. After taking more measurements, the relatively large standard deviation persisted. The sample size was similarly doubled for 30 µL in Fig. 5 to allow for a comparison between ratchet angles. A least-squares fit was performed to determine the linearity of the relationship. For the steeper 30° ratchet angle, increasing droplet volume in the 15-35 µL range tends to marginally improve engine efficiency. The low R_2 value in Fig. 5 does not support a similar trend for the shallower 15° ratchet angle.

Our Leidenfrost droplet transport system had an extremely low average percent efficiency: 2.86E-07%. This is because the average work done on a Leidenfrost droplet was extremely low relative to the energy input. The extremely low engine efficiency is not dissimilar to that obtained by Wells et al. (2015) which was reported to be on the order of 1E-06%.

Table 3 compares the mean engine efficiencies between the aluminium slabs with 30° and 15° ratchet angles. A two-sample T-test for equal means was used to infer a change in mean efficiency between slabs:

$$T = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(\sigma_1)^2}{N_1} + \frac{(\sigma_2)^2}{N_2}}} \tag{4}$$

μ_1 and μ_2 are the sample means for Slab 1 and Slab 2 respectively, σ_1 and σ_2 are the sample standard deviations, and N_1 and N_2 are the sample sizes. A p-value (two-tailed), was generated from the two sample T-test. A p-value greater than 0.05 does not allow one to conclude that varying ratchet angle from 30° to 15° has a statistically meaningful effect on engine efficiency.



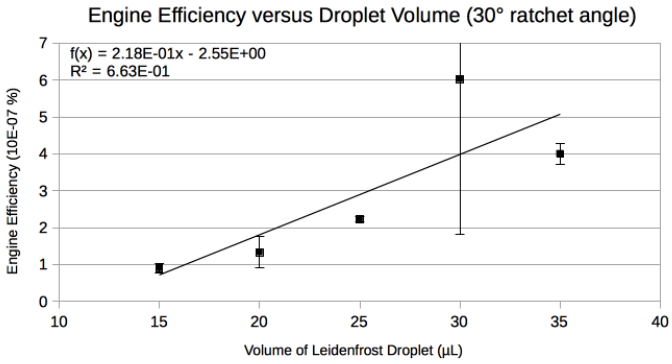


Fig. 4 (left) and 5 (right) Engine efficiency versus droplet volume for Slabs 1 and 2, respectively (see Table 1). Error bars represent standard deviation. Sample size is $n = 3$ for 15 µL, 20 µL, 25 µL, and 35 µL and $n = 6$ for 30 µL. A least-squares fit was performed to determine the linearity of the relationship.

DISCUSSION

The discrepancy between our calculated engine efficiency and the engine efficiency calculated by Wells et al. (2015) may be explained by the difference in exposed hotplate area. Hotplate area that is not in direct contact with the aluminium slab heats the surrounding air which does not contribute to the total work. The exposed hotplate area in our experimental setup seems to be larger than the exposed hotplate area in Wells et al.'s (2015) experiment. The discrepancy may also be explained by the difference in transport load. The maximum load for an insulated carbon-dioxide disk is much larger than the maximum load for a stable water droplet. A larger load would increase the work done and therefore increase engine efficiency.

In order to reach the Leidenfrost temperature of water, a large amount of input energy was required. Liquids with lower Leidenfrost temperatures would decrease the required energy input and therefore increase engine efficiency. Moreover, Leidenfrost 'carts' could increase engine efficiency. In a recent development by Hashmi et al., loads as massive as 50 g were supported by multiple Leidenfrost droplets travelling together. A higher load capacity could dramatically increase the engine efficiency of a Leidenfrost droplet transport system and a similar calculation to our present work should be performed for the 'cart' system.

Varying the droplet volume and ratchet angle within the experimental values did not have a major effect on engine efficiency. Efficiency optimization must be achieved by varying other parameters such as ratchet size (Ok et al., 2011), or by making significant design changes to the system.

CONCLUSION

The engine efficiency of a Leidenfrost droplet transport system, which transports droplets in a straight line, was calculated. Our results give an extremely low average percent efficiency (2.86E-07%), which agrees with the result from Wells et al. (2015) for an analogous turbine system, to an order of magnitude. Differences in exposed hotplate area and maximum load between the two experiments may explain the difference in calculated engine efficiency. Droplet volume and ratchet angle were varied in an attempt to optimize engine efficiency. Varying the ratchet angle does not affect efficiency to any statistically meaningful extent. Increasing droplet volume in the 15-35 µL range tends to marginally improve engine efficiency for steep ratchet angles. Further optimization must therefore be achieved by varying other parameters such as ratchet size or by making significant design changes to the system. Leidenfrost 'carts', which rely on multiple Leidenfrost droplets travelling together to support more massive loads, may provide a mechanism to dramatically increase the engine efficiency of a Leidenfrost droplet transport system.

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TABLES

Table 1 Dimensions of the machined aluminium slabs with varying ratchet angles.

Dimension	Slab 1	Slab 2
Ratchet angle (°)	30	15
Length (mm)	100	100
Height (mm)	5.0	5.0
Depth (mm)	19	19
Height of ratchet (mm)	0.58	0.30
Length of ratchet (mm)	1.00	1.12

Table 2 Data recording protocol outlining accept/reject conditions for a replicate to be analysed using Logger Pro 3®.

Record data if	Do not record data if
A droplet is formed	Spray occurs
Droplet is initially stationary	Water is leftover in the pipette tip
Droplet travels full length of the ramp	Droplet has an initial velocity caused by pipetting
	Droplet does not travel full length of the ramp

Table 3 Two-sample t-Test for equal means between slabs for a given droplet volume. Slab 1 has a 30° ratchet angle and Slab 2 has a 15° ratchet angle. A p-value greater than 0.05 means that one cannot say that μ_1 and μ_2 are different, considering the measured systematic uncertainties.

Droplet volume (μL)	Engine efficiency test statistic (slabs 1 and 2)	p-value
15	0.850	0.443
20	0.248	0.316
25	0.366	0.733
30	0.527	0.610
35	0.435	0.686

Bangladesh's unlikely attainment of the 4th Millennium Development Goal

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Abstract The 2015 Millennium Development Goals (MDGs) were an historic United Nations (UN) initiative aimed at bridging many of the world's inequalities. Since its conclusion, the success of the project has been hotly debated, as progress at the international level was markedly uneven. In order to ensure the success of future initiatives, it is necessary to determine why these goals failed so decisively in some contexts but succeeded in others. Given the innumerable nations involved in the project, the scope of the essay was narrowed to focus on a single country and MDG goal. This study centres on the improbable attainment of the fourth development goal (pertaining to neonatal and newborn health) in Bangladesh, one of the world's poorest countries. Using official UN documents, seminal literature, and consultation with crucial UN actor Uzma Syed herself, this study demonstrates that Bangladesh's success was a result of efficient programming, data acquisition, and transnational, individual, and domestic cooperation. This allowed a small nation like Bangladesh to significantly reduce its under-five and infant mortality rates, illustrating that it is, in fact, possible to enact meaningful change in difficult circumstances. Following the conclusion of the initiative, the country has decided to maintain child survival as a government health priority, as inequalities between populations persist. According to former Secretary-General Ban Ki-moon, a continued, strategic focus on under-fives is imperative, with a particular emphasis on the structural and social determinants of health. Looking, now, toward the Sustainable Development Goals (SDGs), Bangladesh's triumph can be used to build a framework for continued progress in the realms of child and neonatal health.

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INTRODUCTION

One of the most significant proposals aimed at bridging the Global North/South divide was the 2015 UN Millennium Project, more commonly known as the Millennium Development Goals (MDGs). Initiated by then-Secretary-General Kofi Annan in September 2000, the project proposed eight ambitious developmental priorities to be achieved, worldwide, by 2015: (1) the eradication of extreme poverty and hunger; (2) the establishment of universal primary education; (3) the promotion of gender equality and the empowerment of women; (4) the reduction of child mortality; (5) the improvement of maternal health; (6) the control and suppression of HIV/AIDS, malaria, and other diseases; (7) a commitment to environmental sustainability; and (8) the development of a worldwide partnership for aid and development. These time-bound targets held global significance, as they were agreed upon by many of the world's countries and developmental organizations (Ojcius and Wallander, 2010). But were they 'adequate' in bridging the North-South divide? The simple answer is yes, and no. The UN Millennium Development Project has gone down in history as the most successful anti-poverty movement ever created. The progress made was astounding but uneven; inequalities persist.

Years after the conclusion of the initiative, the success of the project continues to be debated in academic and humanitarian circles alike. Initially a sceptic, Microsoft Corporation founder and philanthropist Bill Gates expressed that the targets were "picked arbitrarily", but later acknowledged that "without them, the world would not have made such progress in reducing ... child and infant mortality" (Gulland, 2013). MDG 4 was created to address this need, and stressed that mortality rates of children under five be reduced by two-thirds by 2015. In the years leading up to the deadline, this goal was one of the furthest from being realized (Motluk 2010) with just six countries on track to achieve it—Laos, Cambodia, Nepal, Egypt, China, and Bangladesh (Gulland, 2013). It is necessary to determine why this particular goal was attained in some countries but failed in others. Given the numerous nations involved, the scope of this study will be narrowed to focus solely on the improbable attainment of MDG 4 by Bangladesh. Given that it is the poorest of the nations listed above, Bangladesh's success is that much more extraordinary. Bangladeshi techniques and approaches aimed at improving neonatal health were particularly impressive given the initial lack of resources. Bangladesh's achievement of MDG 4 in spite of extreme poverty levels will be analysed, highlighting the importance of the accountability and strategic cooperation of domestic governments, non-governmental organization (NGOs), and individual actors. Firstly, the methods of this study will be outlined, followed by an overview of existing literature, a presentation of the results, a brief discussion and contextualization of the findings, and lastly, conclusions and implications.

METHODS

In order to ensure the success of the Sustainable Development Goals (SDGs)—direct successor to the MDGs—it is crucial that the triumphs of the MDGs be thoroughly investigated; it would be impractical to forge ahead into the next initiative without adequate exploration of the successes of its predecessor. A focus on a

single case study will allow for an in-depth analysis of the Bangladeshi context. Similarly, only MDG 4 will be explored, as opposed to all of the goals, because it was the goal Bangladesh was able to achieve thoroughly and completely, and in fairly short order. While it is beyond the purview of this work to compare Bangladesh's progress to that of all other high-performing, low-income countries and their respective circumstances, the aim is not to focus solely on Bangladesh, as the MDGs are geared toward a collective rather than individual good. Bangladesh will therefore act as a case study and will be positioned within the broader framework of the Millennium and Sustainable Development Projects as it pertains to child and neonatal health. In the paragraphs that follow, Bangladeshi techniques and approaches will be investigated so that they may be applied to future initiatives, most notably the SDGs.

EXISTING LITERATURE

The importance of neonatal health cannot be overstated. The first 28 days of life, the 'neonatal' period, is the most vulnerable time in a child's life ("The neonatal period", 2016). A nation's under-five survival rate is generally a good indicator of the strength of that nation's health care system and standard of living overall, as it demonstrates the attention paid to the most vulnerable members of the society—young mothers and their children. The existing literature on the attainment of MDG 4 in Bangladesh is generally quantitative and macro-level in nature, such as Halder and Kabir (2008), which discusses reforms that could be made in order to bridge health inequality gaps, such as standardizing the quality of health coverage. A ten-year overview of health developments in Bangladesh echoes this, stating that future initiatives need to focus on the quality and consistency of care (Rubayet, 2012). Such analyses are useful in understanding trends at the national level, but say little about action that can be taken at the community level. Similarly, Minnery et al. (2015) provides a quantitative, high-level analysis, comparing national and sub-national rates of neonatal mortality in order to compute relative and absolute inequalities between groups. In spite of inequalities and limited resources, the concluding United Nations Millennium Development Report (2015) posits that low income does not need to be an impediment to progress, as evidenced by the strong reductions in under-five mortality rates in a number of low-income countries, Bangladesh included. Bangladeshi success can be partially attributed to "intermestic development circles" (Stiles, 2002), which bring together international donor agencies, the domestic community, and private organizations.

While Bangladesh was successful in reducing under-five mortality rates, the progress across all the Least Developed Countries (LDCs) was mediocre (Akanda, 2015). Martín et al. provide an overview of the performance of MDGs 4 and 5 in the least developed nations in Asia, highlighting the programs that contributed to Bangladesh's performance, as well as the role of political stability in affecting change. Even in Bangladesh, however, there is still progress to be made in terms of bridging inequalities between communities, reducing 'growth stunting' among under-fives, and universal access to reproductive health ("Bangladesh Progress Report 2015", 2015; Chowdhury, S. et al., 2011).

Seminal articles with MDG 4 as a focus tend to take a quantitative, macro-level approach, giving little attention to the individual actors and bodies which made possible Bangladesh's attainment of MDG 4. Qualitative metrics are an equally important measure of success, as they provide a more holistic view of health across populations. Assessments of neonatal and under-five health cannot only rely on numbers; there needs to be a human face applied to the data. This study will work to address these gaps in the literature. While quantitative analyses are useful, a qualitative, micro-level approach will be taken instead, focusing on individual actors and initiatives that allowed Bangladesh, in particular, to surpass the other LDCs in its attainment of MDG 4.

RESULTS

To begin, this study will discuss Bangladesh's economic position within the international arena. In today's world, around 60 per cent of the world's one billion extremely poor people live in just five countries: India, Nigeria, China, the Democratic Republic of the Congo, and Bangladesh ("The Millennium Development Goals Report 2015", 2015). As the most populous of Asian LDCs, Bangladesh is home to many of the world's poorest people (Martín et al., 2016). A critical link has been drawn between a country's GDP and its child mortality rates, which serves to explain, at least partially, Bangladesh's high initial neonatal mortality rate of 151 per 1000 live births, of which two-thirds of all deaths were children younger than one year. Prior to the MDGs, little emphasis was placed on essential newborn care in Bangladesh, as it was only one of eight elements of reproductive health and was not among the indicators used to measure health sector performance (Shiffman and Sultana, 2013).

Agenda setting

The creation of the MDGs was the first step toward placing neonatal care on health agendas worldwide, as it pressured nation-states to act and provided them with specific targets toward which to strive. Upon their introduction, the MDGs were immediately integrated into Bangladesh's long- and mid-term development plans and were placed at the forefront of government health policy. While it was customary for lower-income countries to designate child health a low priority, Bangladesh quickly became "an exception to this inattention" (Shiffman and Sultana, 2013, p. 623). By 2011, four years shy of the deadline, the country had made progress far ahead of that of the other LDCs and had already achieved the MDG 4 goal of a two-thirds neonatal mortality rate reduction (Martín et al., 2016). While "low income need not be an impediment to saving children's lives", as stated in their culminating 2015 MDG report, Bangladesh's success was not achieved without the focused commitment of multiple actors (UN, 2015).

The range of organizations present in Bangladesh—from domestic, to international, to non-governmental, to governmental—played a vital role in the reduction of neonatal and child mortality rates. The United States Agency for International Development (USAID), The United Nations International Children's Emergency Fund (UNICEF), and the Gates foundation were just a few of the organizations that provided financial support, as well as program establishment and maintenance (Shiffman and Sultana, 2013). For example, the domestic NGO Bangladesh Rural Advancement Committee (BRAC) spearheaded a maternal, neonatal, and child health project that positively impacted eight million residents of urban slums, supported by $25 million in funding from the Gates Foundation. The United Kingdom, Australia, and the European Commission provided $71.5 million to fund three governmental programs pertaining to maternal, newborn, and child survival in fifteen of Bangladesh's sixty-four districts (Shiffman and Sul-

tana, 2013). Saving Newborn Lives (SNL)—a program of Save the Children USA—had by far the most meaningful impact on Bangladesh's transformation. Soon after its creation, SNL sought to create a global alliance of organizations aimed at the promotion of newborn survival, and selected Bangladesh as one of its six focal countries. Company officials moved quickly to establish a presence in Bangladesh, providing the impetus for the first large-scale child health movement in the country.

The power of the individual

Transnational involvement alone was not enough to create change. On the individual level, a number of domestic "political entrepreneurs" captured the attention of the Bangladeshi state, including the leaders of several domestic medical associations and Dr Uzma Syed, a Bangladeshi physician on the faculty of the University of Dhaka (Shiffman and Sultana, 2013). She took the lead on newborn survival and played a central role in launching and generating awareness around the issue. She conducted situational analysis to emphasize the lack of attention that had been given to child health, which she presented at a meeting in February 2001 attended by many health sector officials. She later joined Save the Children (an SNL program) in April 2001, and would go on to become the director of the program in Bangladesh (Syed, 2017). At the same meeting, Indian physician Abhay Bang's findings related to the biomedical causes of neonatal mortality and the simplicity with which it could be controlled were highlighted ("World Prematurity Day", 2014), generating widespread media coverage. The highest-level political authority championing the MDG cause was Bangladesh's visionary Prime Minister Shiekh Hasina, renowned for her unwavering dedication not only to child health, but to women's education, the alleviation of poverty, and sustainable environmental reform (Alam, 2015). She received the South-South Award, 'Digital Health for Digital Development,' for her use of communication and information technology to advance the health of women and children ("Bangladesh Progress Report 2015", 2015). Individual actors like Syed, Bang, and Shiekh laid the foundation for progress in Bangladesh.

As director of SNL (Syed, 2017) Dr. Syed proceeded to "cultivate ownership for the issue among multiple organizations and individuals—especially those in the government (Shiffman and Sultana, 2013). The existence of SNL and Syed's persistence allowed for the creation of a 'policy community,' a network of organizations and individuals collaborating and sharing a keen interest in the issue. Elsewhere referred to as 'development circles,' these networks involve collaboration between foreign donors—private and public, bilateral and multilateral—and local non-state actors. The groups often experience a "disassociation from traditional loyalties" and a "new sense of identity as a member of the development circle first and foremost" (Stiles, 2002). The MDG 4 policy community linked the Bangladeshi government, SNL, UN agencies, a Bangladeshi research institution, and several medical associations with a commitment to neonatal health. Working together, they were able to identify several core causes of the slow rate of neonatal mortality reduction, including a lack of skills among community health workers, lack of nurse midwives, and low postnatal care coverage (Stiles, 2012). They also organized attention-generating 'focusing events' that served the dual purpose of making the issue visible to government officials and influencing policy. The importance of generating such interest and awareness around a pertinent issue like child mortality cannot be understated, especially in a country like Bangladesh, where it was historically considered a low health priority.

The policy community in Bangladesh continually assessed relevant data in order to track progress and therefore ensure accountability (Shiffman and Sultana, 2013). The necessity of such 'checks and balances' has been highlighted by Joy Phumaphi, co-chair of a UN group tasked with analysing the connection between accountability and the MDGs. She points out that the "few countries that that were due to meet targets on both infant and maternal mortality had all introduced strong oversight and accountability mechanisms" (Gulland, 2013). Bangladesh's continued publication of credible data allowed policymakers to reach evidence-based consensuses on the interventions and policy alternatives needed to make progress. From this, it becomes clear that information, national oversight, and accountability are all critical components in achieving large-scale policy goals and ultimately accomplishing change.

Effective programming

Programs pertaining to immunization, the control of diarrheal diseases, and the supplementation of Vitamin A have aided not only in the decline of child deaths in Bangladesh but have also contributed to economic and social growth. In the post-MDG era, the country has emerged as global leader in the development of low-cost interventions such as oral rehydration solution, the use of zinc to counteract childhood diarrhoea, and tetanus vaccinations for pregnant women. These interventions have been introduced locally and then scaled-up ("Bangladesh Progress Report 2015", 2015). This combined with larger-scale initiatives like family-planning, and more targeted reforms such as increased human resources in underserved areas, have contributed considerably to overall progress (Minnery et al., 2015). As cost-effective and targeted initiatives, these programs were well-suited to the Bangladeshi context, and are indicative of the benefits of smart, effective programming.

As a result of efficient programming, data acquisition, and transnational, individual, and domestic cooperation, Bangladesh was able to bring its under-five mortality rate from 151 to just 41 deaths per 1000 live births, and the infant mortality rate from 94 to 32 deaths per 1000 live births ("Bangladesh Progress Report 2015", 2015). Bangladesh received international acclaim for its progress and was given a UN award for its attainment of MDG 4. Tellingly, in their terminal MDG report, Bangladeshi officials stated that their success could be attributed to a combination of factors, including: "political will and commitment, sound strategies, adequate resources, effective and affordable treatments, and improved service delivery" ("Bangladesh Progress Report 2015", 2015). However, challenges still remain. Bangladesh has pledged to keep child survival on the global development agenda, as major inequalities between populations still exist, and childhood injuries, particularly drowning, have become responsible for a quarter of the deaths among children one to four years of age ("Bangladesh Progress Report 2015", 2015). The neonatal mortality rate is still high when compared to the global average of 19 deaths per 1000 live births, and low levels of skilled birth attendants persist ("Neonatal Mortality", 2018). A continued push may be needed to maintain and continue the reduction of under-five and neonatal mortality ("Bangladesh Progress Report 2015", 2015) and further research may need to be conducted to assess the sustainability of these progresses (Akanda 2015). But despite this, as the report states quite simply: "the achievement of Goal 4 by a significant

number of [...] very poor countries, shows that it can be done" ("Bangladesh Progress Report 2015", 2015).

DISCUSSION

The Bangladeshi attainment of MDG 4 will now be positioned within the broader context of the UN Millennium Development Project and future developmental goals. In the culminating MDG report, UN Secretary General Ban Ki-Moon stated that while progress had been uneven and inequalities persisted, the UN Millennium Development Project was by far the most successful anti-poverty movement in history, according to the final MDG report. With regard to MDG 4, the international child mortality rate was cut in half, declining from 90 to 43 deaths per 1000 live births, while the number of deaths of children under five had declined from 12.7 million to almost six million globally. Given that MDG 4 was not achieved on the global scale, Ki-Moon emphasized that continued, strategic focus on newborn and child health was imperative, and that structural and social determinants such as poverty, illiteracy, and female disempowerment should not be overlooked ("The Millennium Report 2015", 2015). The direct successor of MDG 4 is now Sustainable Development Goal 3, which aims to "end preventable deaths of newborns and children under 5 years of age ... reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births" ("Sustainable Development Goal 3", 2017).

Looking now to the SDGs, Bangladesh's success should be used to create a framework to ensure future progress in the realms of neonatal and child health. Given that the socio-economic contexts of the LDCs vary widely, the inequalities within them being nearly as significant as the inequalities between them, adjustments will need to be made (Halder and Kabir, 2008). Bangladesh itself was a very specific case, given its complex health system with innumerable actors. But while specific plans must be developed for each country, there are some commonalities to success. In a comparative report co-authored by individuals from a number of non-profit organizations, including Dr Syed, researchers found that overarching drivers of progress include elements such as "local ownership and involvement, [a] broad representation of all stakeholders in formulating national-level technical oversight of research and associated politics [...] community involvement, locally-generated data, and site visits by policy makers in-country in order to effectively implement and maintain policy and program innovations (Rubayet et al., 2012). From this, it becomes clear that Bangladesh's success is not solely to its own benefit; there is much to be gained by the international community as well.

CONCLUSIONS AND IMPLICATIONS

As one of the world's poorest countries, with "widespread poverty, low levels of female literacy" and "more than two-thirds of births occurring without ... skilled assistance", Bangladesh has demonstrated that it is possible to enact change in even the unlikeliest of circumstances (Rubayet et al., 2012). Progress required a combined effort and targeted attempts to bring the issue to the forefront of the national imagination. As demonstrated by the Bangladeshi context, an effective framework might feature the participation of determined political entrepreneurs, the persistence of an organized and accountable policy community, the ongoing publication of credible data, evidence-based consensuses on policy decisions, as well as the availability of funding from international and domestic donors. Most importantly, substantial progress requires global agreements such as the UN Millennium Development Project, which encourage accountability and push states to act.

Bearing in mind that MDG 4 was not globally attained, this analysis of Bangladesh's success is aimed at encouraging a dialogue and further research. Future analysis may address: (1) the societal transitions—economic, political, and social—that occurred in Bangladesh throughout the 1990s and early 2000s, which may have assisted or inhibited their developmental progress; and (2) Bangladeshi advancements not only in child health, but in decreasing poverty, supporting gender equality in primary and secondary education, combatting HIV and tuberculosis, among others. Bangladeshi strategies should be put toward the creation of a developmental framework applicable to other LDCs, which would ensure continued advances not only in the Sustainable Development Goals, but in future global health initiatives.

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Marine iron fertilization: effects on phytoplankton carbon uptake in the Southern Ocean

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Abstract The scarcity of iron in marine environments, particularly in the Southern Ocean, provides ideal experimental grounds for large-scale iron fertilization. The Iron Hypothesis, proposed in the 1980s, sparked a series of in-situ fertilization experiments in the HNLC waters of the Southern Ocean aiming to prove that the addition of Fe(II) to iron-deficient phytoplankton populations would enhance photosynthetic processes to the point where they could serve as a viable method of mitigating anthropogenic carbon emissions through the acceleration of oceanic carbon sequestration. By examining the mechanisms behind iron fertilization, as well as contributions to the field and the gaps in knowledge pertaining to three major iron fertilization experiments – SOIREE, SOFeX, and LOHAFEX – this review will provide a comprehensive overview of the past, present, and future of iron fertilization.

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INTRODUCTION

Iron is an essential nutrient in key biological processes such as amino acid synthesis, oxygen transport, respiration, nitrogen fixation, the citric acid cycle, and photosynthesis. Obtaining iron, however, presents a challenge particularly for microorganisms living in iron-limited environments (Butler & Sandy, 2009). While iron is the fourth-most abundant transition metal on the planet, the insolubility of Fe(III) (ferric iron – Ksp of $Fe(OH)_3$ = 6.0×10^{-38}) and Fe(II) (ferrous iron – Ksp of $Fe(OH)_2$ = 2.0×10^{-15}) at physiological pH in aerobic environments severely limits the biological availability of this essential nutrient (Sillén et al., 1964). Marine organisms face a greater challenge than terrestrial organisms, as seawater contains 0.001-0.003 ppm of available iron in comparison to 0.5-1 ppm in river water and 100 ppm in groundwater (Lenntech, n.d.). Despite low oceanic iron concentrations, phytoplankton are the world's most influential primary photosynthetic producers, producing an estimated 50-85% of the planet's oxygen (Lin et al., 2003). It follows that phytoplankton are capable of intaking large volumes (30-50%) of the world's carbon dioxide (CO2) to carry out photosynthetic processes, thereby transforming the ocean into the largest carbon sink on the planet (Block, 2018; The Earth Institute, 2009).

It had been determined by 1980 that phytoplankton photosynthesis is limited by iron bio-availability, as opposed to other essential nutrients. Iron is a natural fertilizer and an essential nutrient for the synthesis of chlorophyll and electron transport proteins in plants, including phytoplankton. Without it, they are unable to reduce carbon dioxide and create the organic compounds needed for their survival (Paytan & Street, 2005). John Martin of the Moss Landing Marine Laboratories hypothesized that by increasing the amount of bio-available iron in oceans, overall photosynthetic processes would increase, and the ability for the ocean to sequester carbon from the atmosphere would increase accordingly; this was coined the Iron Hypothesis (Weier, 2001). This hypothesis has been tested on more than 10 different occasions and in all cases, massive phytoplankton blooms have resulted. However, the results are not consistent. Blooms persisted for variable periods of time under various, uncontrolled, open ocean conditions, and the effectiveness of phytoplankton blooms in sequestering carbon has yet to be confirmed (Paytan & Street, 2005). This minireview will explore the question pervading the minds of oceanographers, marine biologists/chemists, environmental scientists and geoengineers alike: can iron fertilization in the Southern Ocean, through increasing the primary productivity of phytoplankton, accelerate carbon sequestration in the deep ocean, therefore decreasing atmospheric CO_2 concentrations? This review will examine papers on three iron fertilization experiments in the Southern Ocean and their findings. Themes between papers on each experiment will be examined, focusing first on the contributions of each paper to the progression of the field and then on weaknesses that could be addressed through further experimentation.

One of the original guiding principles upon which understanding of marine biogeochemistry was based was the correlation between macronutrient availability and phytoplankton production. Yet, observations and experiments conducted in the 1920s suggested high marine nutrient levels but low phytoplankton biomass (High Nutrient Low Chlorophyll or HNLC) occurring uniquely in the Southern Ocean. This dilemma came to be known as the Antarctic paradox (Broecker & Peng, 1991). It was the attempt to reconcile the Antarctic paradox that spurred research on nutrient levels in the Southern Ocean. It was not until the late 1980s that improvements in analytical techniques confirmed low dissolved iron levels and thus the potential to accelerate phytoplankton processes in the open Southern Ocean via iron fertilization (Ducklow, Hanson, Field, 2000). With the emergence of the Iron Hypothesis came the increased importance of iron's role in the Southern Ocean, as the threat of dangerous atmospheric carbon levels loomed with no solution in sight. The study of the response of biogeochemical cycling in the surface mixed layer to iron enrichment was unfortu-

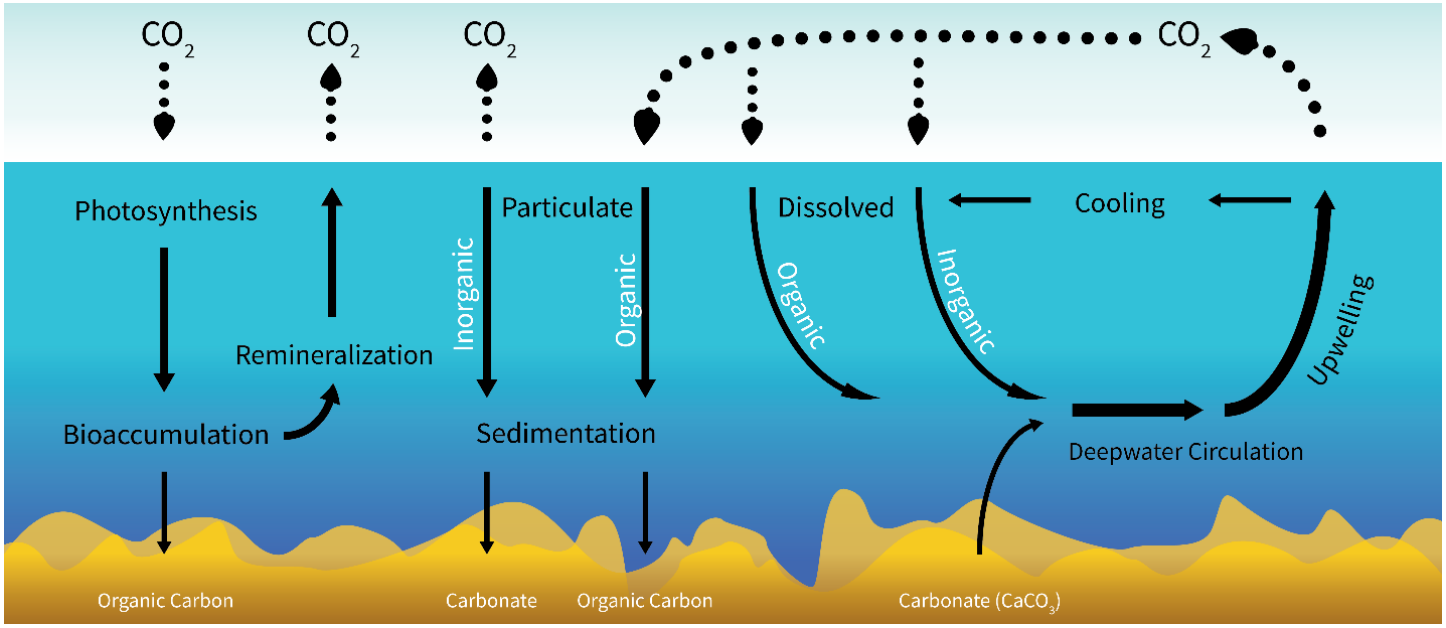

Fig. 1 Simplified diagram depicting the movement of carbon throughout the lithosphere (rock), hydrosphere (water), and atmosphere (air) as understood during SOIREE. Oceanic carbon inputs include particle deposition, biotic debris, atmospheric CO2 and photosynthesis/respiration of phytoplankton, which then die and become organic carbon sediment to be incorporated into the lithosphere. Carbon that enters the lithosphere exits as inorganic calcium carbonate, which reacts with the low-pH ocean to produce CO2 to be released into the atmosphere, however, the majority remains sequestered on the ocean floor. It is hypothesized that the addition of iron, as it is a limiting nutrient, will accelerate the growth of photosynthetic phytoplankton, increasing the amount of sediment sequestering carbon into the ocean floor (Iron Hypothesis).

nately limited at the time. Modelling simulations of the influence of iron enrichment in the Southern Ocean on atmospheric CO_2 levels had yet to be verified and validated (Broecker & Peng, 1991). In the absence of data, such models assumed that iron enrichment resulted in complete utilization of upper ocean macronutrients. Yet these predictions did not align with results from lab experiments (Boyd et al., 2007) nor observations on natural blooms in the open Southern Ocean (Keith & Moore, 1999). These issues could only be addressed by conducting an in-situ iron fertilization experiment in open Southern Ocean waters to assess what controls the magnitude of phytoplankton stocks.

There are two steps to sequestering atmospheric carbon. First, removal from the atmosphere; second, conversion to a form that is unable to re-enter the atmosphere. Currently, the most effective carbon removal on the planet is performed by photosynthesizers, a role filled in ocean ecosystems by phytoplankton. Phytoplankton in the upper ocean fix carbon dioxide using solar energy. This fixation results in particulate organic carbon (POC), which is grazed upon by herbivorous zooplankton or consumed directly or indirectly by heterotrophic microbes feeding on solubilized remains of phytoplankton. Between 1 and 40% of the primary production is exported out of the upper ocean, and it exponentially attenuates towards the base of the mesopelagic zone at around 1,000m deep (Broecker & Peng, 1991). Remineralization of organic matter in the oceanic water column converts the organic carbon back to carbon dioxide. Hence, only about 1% of the surface production reaches the sea floor (Fig. 1). Carbon that reaches the sea floor to enter the lithosphere exits as inorganic calcium carbonate, which reacts with the low-pH ocean to produce CO_2 to be released into the atmosphere, however, the majority remains sequestered. This cycle is called the biological pump, and it is one of several ways carbon can be sequestered in the ocean. Other oceanic carbon inputs include particle deposition, biotic debris, and atmospheric CO_2 diffusion, and are sequestered by processes not specified in this paper (Fig. 2).

LITERATURE REVIEW

SOIREE (Southern Ocean Iron Experiment): 1999

SOIREE was the first *in situ* iron fertilization experiment undertaken in the polar waters of the Southern Ocean. Approximately 165 mol/km² of $FeSO_4 \cdot 7H2O$ was added to a 65 m deep surface mixed layer over an area of 50 km². Croot et al. (2001) sought to distinguish SOIREE as an experiment that pointed to the previously unheralded importance of Fe(II) and organic complexation in the Southern Ocean. This mindset was shared amongst many of the marine biogeochemists studying SOIREE. Boyd et al. (2000) were convinced the findings of SOIREE not only provided context and significance for iron's role in surface phytoplankton ecosystems, but allegedly confirmed the Iron Hypothesis in its findings on "the relative roles of iron supply, uptake, algal growth and community structure, and grazing" (p. 699). From further study on iron fertilization it is evident the researchers had not confirmed the Iron Hypothesis in its entirety, as both the mechanisms and rate or length of enhanced photosynthesis had yet to be determined. Additionally, the mechanism by which carbon dioxide was sequestered remained a mystery.

The advantage of in-situ experiments is the incorporation of natural large-scale ocean phenomena that potentially affect the rate, length, and efficiency of photosynthetic carbon sequestration absent from underdeveloped simulations or lab experiments. These phenomena could provide insight on the length of time carbon is sequestered away in the ocean before returning to the atmosphere as carbon dioxide (Fig. 2). Law & Boyd (2001) recognized this gap in the research in their conclusions, stating that the fate of accumulated carbon, once used in photosynthesis, could only be speculated. Whether it was remineralized into inorganic CO_2 and returned to the atmosphere or subducted along with the carbon-rich remains of phytoplankton – or both – was undetermined. Thus, the longer-term sequestration of carbon in the Southern Ocean could not be extrapolated and the magnitude of the iron enrich-

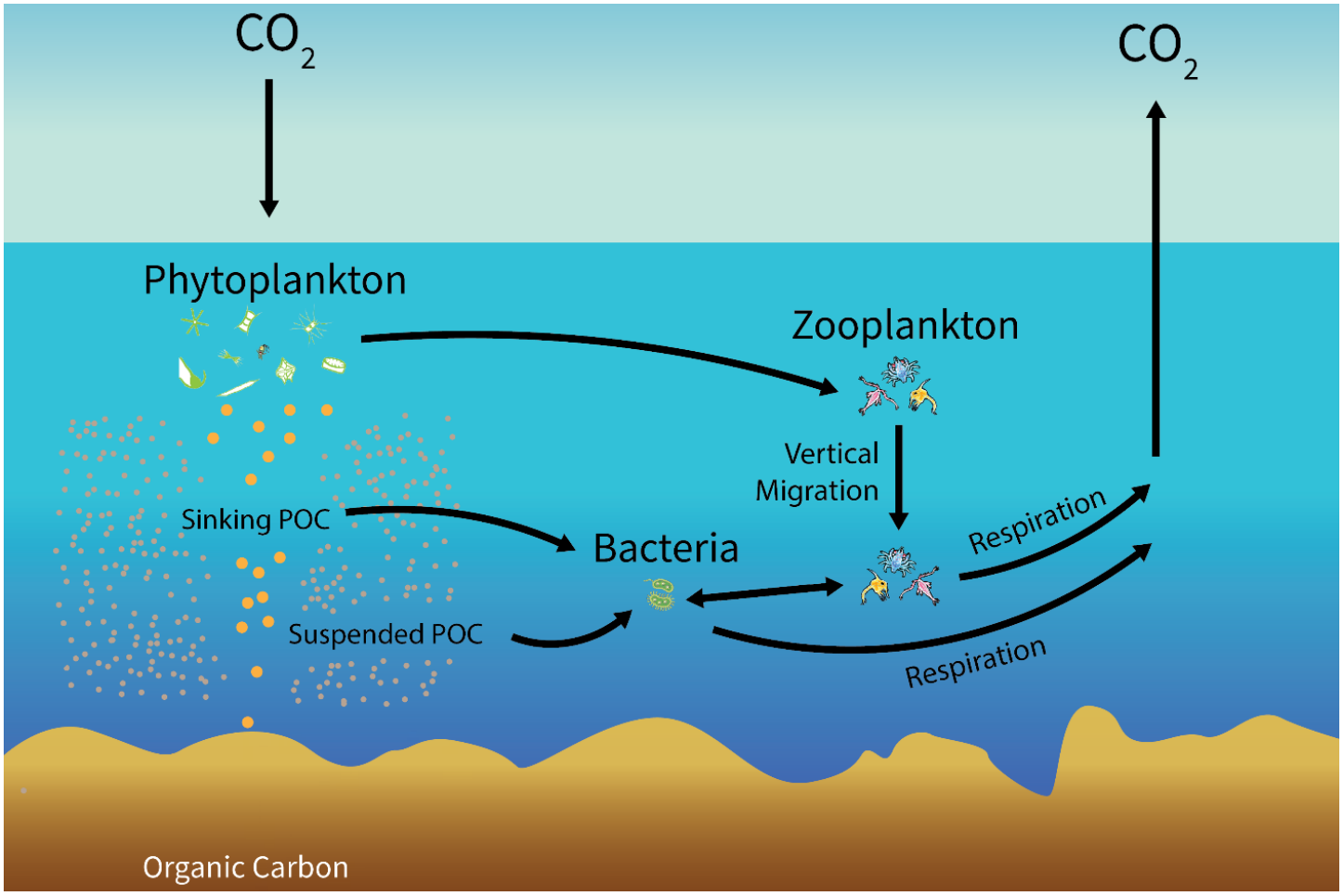

Fig. 2 The biological pump. Phytoplankton in the upper ocean fix carbon dioxide using solar energy. The particulate organic carbon (POC) produced is grazed on by herbivorous zooplankton or consumed directly or indirectly by heterotrophic microbes feeding on solubilized remains of phytoplankton. Between 1 and 40% of the primary production is exported out of the upper ocean, and it exponentially attenuates towards the base of the mesopelagic zone at around 1,000 m depth. Remineralization of organic matter in the oceanic water column converts the organic carbon back to carbon dioxide. Only about 1% of the surface production reaches the sea floor.

ment effect on marine production and atmospheric CO_2 remained uncertain (Buesseler, 2004).

SOFeX (Southern Ocean Iron Experiment): 2002

Between SOIREE and SOFeX the German EisenEx (2000) iron fertilization experiment took place in the Southern Ocean but will not be discussed in this review due to its proximity to SOIREE (occurring less than a year after the first experiment). Consequently, the advancement in the field of marine biogeochemistry and insight on the Iron Hypothesis were minimal. One notable finding is the influence of mechanical stirring of the ocean surface on phytoplankton bloom success. EisenEx saw a bloom four times more efficient in drawing CO2 from the atmosphere than the SOIREE bloom due to stormier oceans in the northern section of the Southern Ocean, north of the Antarctic Polar Front (Bakker et al., 2005). Despite this finding, the researchers of EisenEx had made no progress on examining the biological or carbon systems that drive phytoplankton carbon sequestration.

SOFeX was the first iron fertilization experiment designed to examine the biological and carbon system response to the effects of purposeful addition of iron to high-nutrient low-chlorophyll (HNLC) waters in the Southern Ocean, specifically the polar front zone (PFZ). Multiple enrichments were performed on areas of 225 km^2 to total approximately 88 mol/km^2 of $FeSO_4$ north and south of the PFZ (Bishop, 2004). In previous iron fertilization experiments in the Southern Ocean, the demonstration of an obvious carbon flux response in the atmosphere or the phytoplankton ecosystem was absent, although in every case enhanced primary production and a biomass increase was reported (Buesseler, 2004). SOFeX sought to eliminate the uncertainty surrounding the effectiveness of iron fertilization in sequestering CO_2 by taking a multifaceted approach to measuring carbon flux in the ocean and atmosphere.

In marine environments, sequestration often proceeds via the biological pump, which incorporates phytoplankton photosynthesis, bioaccumulation, and particulate organic carbon (POC) sedimentation (Fig. 1) (Herndl & Reinthaler, 2013). This process is more specific than the cycling SOIREE researchers explored (Fig. 2) and directly addresses the mechanisms that constitute the relationship between phytoplankton and carbon sequestration. Researchers of the SOFeX experiment measured the extent of the biological pump in iron fertilized areas. Their approach would account for the gap Law & Boyd recognized in their research in 2001: the unknown fate of accumulated carbon once utilized in phytoplankton photosynthesis. The amount of carbon that sank to the ocean floor because of fertilization could finally be determined by updated technology not available during SOIREE. Bishop et al. (2004) deployed autonomous submarine sensors to investigate the systematics of POC export with an optically derived carbon flux index at depths of up to 1000 m. Buesseler et al. (2004) engaged an autonomous float to measure carbon flux at the ocean's surface. By interpreting the data obtained from these instruments, SOFeX researchers concluded that iron addition indeed had a measurable impact on carbon sequestration rates. Carbon flux increases were

not limited to the top, iron-fertilized layer of the ocean, but also below in the "shadow" of the SOFeX patch (Buesseler, 2004).

Researchers, however, admitted to difficulties in predicting the impact of iron fertilization on atmospheric carbon composition because the timespan of carbon remineralization and the large-scale impacts of iron enrichment on processes below the surface layer had yet to be understood. In other words, SOFeX demonstrated technological progress in terms of carbon inputs to a biological system but lacked the acknowledgement of carbon outputs. Despite prolonged observation of the bloom, the absence of data on the magnitude of remineralization left the potential for gaps when considering net sequestration over a long period of time. They "[did] not know whether the bloom eventually led to substantially higher C export after [they] left, or whether organic matter was remineralized within the surface ocean, resulting in no additional impact on C sequestration." (Buesseler, 2004, p. 417). This had the potential to pose an issue for geoengineers exploring iron fertilization as an option for carbon capture.

Even excluding remineralization, many researchers who studied SOFeX are worried that the amount of carbon dioxide sequestered in experiments is not nearly enough to address rising atmospheric CO2 concentrations. Carbon flux measurements were taken for the first time during SOFeX, and their results were not promising. Coale et al. (2004) found the flux of carbon, although significant, was similar in magnitude to that of natural blooms in the Southern Ocean and thus small relative to global carbon budgets and proposed geoengineering plans to sequester atmospheric carbon dioxide in the deep sea. Buesseler et al. (2004) failed to see how iron fertilization with such a low C(sequestered): Fe(added) export efficiency could scale up to solve larger global C imbalance problems without consuming tons of iron salts. Only further exploration of carbon transport within and below phytoplankton blooms as well as further insight on the mechanisms of carbon uptake would provide geoengineers with the information needed to continue or abandon iron fertilization as an option for lowering atmospheric CO_2 levels.

LOHAFEX (Iron Fertilization Experiment): 2007

LOHAFEX is the most recent iron fertilization performed in the Southern Ocean. ~101 mol/km^2 of $FeSO_4 \cdot 7H_2O$ was added to an area of 150 km^2. While all previous experiments showed an enhancement of primary production and biomass in response to iron increases in phytoplankton blooms, the relatively short duration of these studies did not allow researchers to determine the fate of exported POC from said blooms. Many studies on LOHAFEX aimed to understand the impact of an artificial iron-induced bloom in terms of mesopelagic remineralization processes (Martin et al., 2013). It is important to note that the shallow export flux of POC, often measured at 100 m, generally does not sequester carbon from the atmosphere for climatically relevant time scales. Long-term sequestration requires POC to sink below the permanent thermocline, and it is this deeper flux that would need enhancing for geoengineering to work (Buesseler, 2008). POC flux can decrease sharply between these two depths, and the magnitude of this decrease depends on the biological make-up in the surface and mesopelagic (Boyd & Buessler, 2009; Jacquet et al., 2008; Buesseler, 2007; Bishop & Lam, 2007). Thus, enhancing POC export does not necessarily enhance carbon sequestration. Therefore, examining both the remineralization processes and the depth to which particles sink, as demonstrated by LOHAFEX, is of the utmost importance when determining the sequestration potential of iron fertilization.

Advances in sediment collection and analysis allowed researchers to differentiate between types of POC export, revealing the majority of POC undergoing downward flux is faecal matter from zooplankton feeding on phytoplankton in excess. The decrease of faecal pellets with depth, and the increase in unrecognisable detritus particles observed points to intense reprocessing (consumption & excretion) of faecal pellets by heterotrophic bacteria and plankton at greater depths (Ebersbach et al., 2014). Ebersbach et al. believe this means two things, both of which result in an increase of carbon output from the system: i) the smaller, reprocessed faecal pellets sink more slowly, providing a greater chance for remineralization before descending past the thermocline, ii) heterotrophic bacteria in the process of consuming faecal pellets release CO2 as they respire and defecate. Despite this, mesopelagic remineralization levels during iron fertilization remain far below natural mesopelagic remineralization levels (Ebersbach et al., 2014). Jacquet et al. (2008) found that export from large, artificial phytoplankton blooms is less prone to remineralization than natural blooms. Their explanation for their observations is incompatible with Ebersbach's analysis, for Jacquet assumes a faster transfer of matter through the water column leaving less time for mesopelagic remineralization to occur, even including heterotrophic reprocessing. Jacquet claims heterotrophic reprocessing is slowed because of low water temperatures. This conflict around the speed of POC sinking has yet to be resolved.

In addition to remineralization research, many studies on particle flux characterisation and sedimentation patterns within and below the phytoplankton bloom reveal particle flux decreases strongly between 100 and 200–450m (Martin et al., 2013). This indicates that little POC is attaining depths below the thermocline, indicating that long-term sequestration is unlikely to be enhanced. On top of this, Martin et al. (2013) claim iron fertilization enhances neither shallow export nor deep POC flux based on their observations, supporting Ebersbach's analysis. These findings contradict the idea that iron fertilization stimulates POC export and sequestration in Southern Ocean HNLC conditions. However, such conclusions ignore the higher transfer efficiencies of flux to depths that have been reported upon collapse of these artificial blooms. With the deaths of so many organisms and their carbon carcasses falling to the ocean floor, large quantities of carbon sink past the thermocline due to sheer numbers. LOHAFEX was designed to be a long-term experiment for this very reason, allowing the iron-fertilized phytoplankton bloom to be monitored "until its senescence and decay, thereby closing a gap in our understanding of carbon transport" (Thiele et al., 2012). Unfortunately, the long-term monitoring of the LOHAFEX bloom never came to fruition due to its early conclusion in response to protests from environmental campaigns about the potentially harmful effects of iron fertilization.

CONCLUSIONS

The probability that iron fertilization will be implemented on a large scale to reduce atmospheric carbon dioxide is slim. The optimism arising from the initial conception of the Iron Hypothesis has faded, and which is supported by scientific evidence. As technology improves and datasets grow, our understanding of oceanic carbon sequestration has increased greatly, alongside the realization that oceanic carbon fixation processes are much more compli-

cated than originally believed. These experiments are costly and difficult to run, and the environmental side effects of interfering with an ecosystem to such a great extent are unknown. It is for this reason that iron fertilization experiments in the Southern Ocean have not taken place in over a decade, and computers are taking over in the hopes that climate models will provide the solution to excessive atmospheric CO_2 levels that the world is waiting for.

The real barrier to answering the outlined research question stems not from large gaps in knowledge or unclear results from research. It comes from the distrust of geoengineering. Scientists and the public alike fear repercussions from the deliberate imbalance of biological systems and nutrient cycles. This is not an unjustified fear, for it is the anthropogenic imbalance of global systems which generated dangerous climate change in the first place. Luckily, in-situ experiments are no longer the only method of accumulating accurate data, for models have improved drastically since 1999. Key findings from iron fertilization experiments offer new insights for modellers, although a limited number of these findings can be extrapolated directly to regional and seasonal scales for iron enrichment (Table 1). Such limited extrapolation speaks to limitations in experimental design and to uncertainties in the understanding of iron biogeochemistry (Boyd et al., 2007).

Modelling studies can improve our understanding of iron biogeochemistry by allowing for different conditions to be altered in a short time span and without risk of environmental repercussions. For example, as opposed to adding iron in one large dose, breaking the addition up into smaller, more frequent doses could result in more sustained blooms. Altering other nutrient concentrations such as silicon, barium, or nitrogen may be effective (Boyd et al., 2007). The technologies available today (and the countless more that will be available in the future) will allow research into iron fertilization as a method of accelerated carbon sequestration to be explored deeper than ever before. Perhaps one day iron will be more than an essential nutrient - it will be the key to maintaining life on Earth.

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Economic factors contributing to universal health coverage in the BRIC countries

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Abstract The objective of this study was to determine the economic factors and characteristics of universal healthcare development among Brazil, Russia, India and China (BRIC). A policy review was used to achieve this objective. This review established a comparative criterion of the key factors and characteristics of universal healthcare coverage development. Further, a comparison of three countries with established universal healthcare coverage, comprising of tax-based and social insurance models, was undertaken against BRIC healthcare systems. The decided upon factors and characteristics of developing and BRIC countries were used to inform and understand the development of process of universal healthcare coverage. The analysis found that continual economic growth and investment into the healthcare coverage are essential to successful universal healthcare coverage implementation and expansion. Understanding the models of healthcare systems along with the key economic factors and characteristics provides important context and understanding into the processes and mechanisms that drive successful universal healthcare coverage in developing countries. The factors and characteristics presented in this study provide a preliminary framework for understanding the conditions that contribute to universal healthcare coverage. This framework can be used as a template for a critical comparison and analysis that can be applied to all high, middle- and low-income countries in their effort to establish universal healthcare coverage.

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INTRODUCTION

A current movement in global policy has been the push towards establishing universal healthcare coverage (Tediosi, Finch, Procacci, Marten & Missoni, 2016). This agenda was emphasized during the development of the United Nations Sustainable Development Goals in goal 3.8 "Achieving Universal Healthcare Coverage" (Tediosi et al., 2016). In 2001, British economist Jim O'Neill coined the term 'BRIC' (Brazil, India, Russia and China) claiming these countries as the next economic superpowers. In 1990, these countries represented 5.8% of the world economy. In 2015, that increased to 25.6%, and was projected to be between 25.6% and 40% of the world economy over the subsequent two decades (Siddiqui, 2016). These countries represent 21.6% of the world's population, roughly 3 billion people (Tediosi et al., 2016). Recent economic growth has provided the opportunity for these countries to provide universal healthcare coverage (Wang, 2015).

Universal healthcare coverage has two main objectives: to provide everyone with the healthcare they need and protect people from catastrophic healthcare expenditure. Countries with universal healthcare coverage consistently have better population health, with the highest effects seen amongst the most impoverished populations (Moreno-Serra & Smith, 2012). However, there are many ways to design, finance and implement universal healthcare coverage.

Various economic factors are essential in the development and sustainability of universal healthcare systems (Borgonovi & Compagni, 2013). This study aims to identify economic factors and characteristics that contribute to universal healthcare development among emerging economies, especially understanding how these factors influence the two goals of universal healthcare coverage: access to necessary healthcare and financial protection from catastrophic healthcare spending.

All four BRIC countries have made political commitments towards universal healthcare coverage (Marten et al., 2014). However, the results of universal healthcare coverage expansion in BRIC countries varies. An analysis of the economic factors and characteristics is required to better identify and understand factors that enable and hinder universal healthcare development in BRIC countries. In addition, three countries were selected to be mapped against the BRIC countries; Canada, Germany, and the United Kingdom. These countries provide a baseline and standard of measurement for analysing and comparing the healthcare systems of BRIC countries. These four countries are examples of how the national and social insurance models can be used to finance universal healthcare coverage. The purpose of the analysis is to understand how the economic factors and characteristics of BRIC countries contribute to the goals of universal healthcare coverage.

METHODS

This paper consists of reviewing both literature and policy papers. The purpose of the first component of the literature review was to understand universal healthcare coverage and healthcare systems. This consisted of reviewing literature on healthcare system financing designs. The purpose of the second component was to identify the common themes and gaps surrounding the economic factors and characteristics. This included a broad search aimed at finding important economic characteristics and factors commonly arose as important measures used to determine the overall performance and successful healthcare system development. A policy and literature review were then undertaken to summarize and compare the

healthcare systems of individual countries. This included reviewing the current healthcare system policies of all BRIC countries and identifying both success and gaps across each county. These reviews were used to inform the analysis. No framework was used but rather a collection of indicators was used to identify the key economic factors and characteristics in the development of universal healthcare coverage in BRIC countries.

REVIEW

Universal healthcare coverage

The World Health Organization (WHO) defines universal healthcare as the meaning "that all people and communities can use the promotive, preventive, curative, rehabilitative and palliative health services they need, of sufficient quality to be effective, while also ensuring that the use of these services does not expose the user to financial hardship" (World Health Organization, 2010). The motivation behind universal healthcare coverage is to provide everyone with access to necessary healthcare services and offer protection from catastrophic financial healthcare expenditure. Effective universal healthcare coverage contributes to the development process by reducing disease burdens and offering financial protection from health-related events (Frenk & de Ferranti, 2012). Typically, assessment and measurement of universal healthcare systems are primarily concerned with the economic costs (Borgonovi & Compagni, 2013). Economic factors inform the processes involved in creating sustainable, effective universal healthcare coverage (Borgonovi & Compagni, 2013).

Models of healthcare systems

A 'healthcare system' is comprised of service delivery, financing and economic policy. The combination of these mechanisms and policies lead to healthcare access and can be built upon to achieve universal healthcare coverage (Kulesher & Forrestal, 2014). Historically, two broad models of healthcare systems financing are typically used to provide publicly universal healthcare coverage: the national health model and the social insurance model (Kulesher & Forrestal, 2014).

The national health insurance model provides healthcare coverage for all citizens through the central government (Kulesher & Forrestal, 2014) . Typically, central governments create policies and regulations and care is delivered through local and regional governments (Hejduková & Kureková, 2016). National insurance models are primarily financed through tax revenue that is collected and pooled, then allocated to local and regional governments.

The second type of healthcare system is the social insurance model (Bloom, Khoury, & Subbaraman, 2018). The social insurance model covers citizens under mandatory or compulsory health insurance. These insurance plans are financed through an employee and employer tax or contribution. Individuals may have a mandated insurance plan based on their occupation, or the option to select an insurance plan based on their preferences (Kulesher & Forrestal, 2014). Unlike the national health insurance model, insurance funds are managed independently (Hejduková & Kureková, 2016).

The third type of healthcare system financing is private healthcare spending. This can be in the form of private healthcare insurance offered by a company or paying for healthcare directly out-of-pocket (OOP). Typically, this is reserved for services outside of the scope of public healthcare and is rarely used as a primary driver of universal healthcare coverage. However, supplementary and complimentary private insurance are commonly found among publicly funded healthcare systems.

Universal healthcare coverage can be achieved using these models individually or in combination. National health insurance typically covers citizens by entitling citizens with the right to healthcare coverage while the social insurance model requires citizens to select a compulsory insurance plan delivered through non-governmental actors. Universal coverage is achieved by governments ensuring that all people are entitled to healthcare insurance.

Canada, Germany, and The United Kingdom are examples of how these models can be used to achieve universal healthcare coverage. Canada primarily uses the national insurance model, Germany primarily uses the social insurance model, while the United Kingdom uses a combination of both. All three countries have some level of private and out-of-pocket expenditure.

Economic considerations

Sufficient economic growth and resources are prerequisites to universal healthcare coverage (Russo, Bloom, & McCoy, 2017; Wang, 2015). Sufficient economic growth must be accompanied by a rise in healthcare expenditure (Hall & Jones, 2007). This means that a country should increase healthcare expenditure as its economic growth increases. A standard measure of economic growth is the Gross Domestic Product (GDP). A particular measure of healthcare expenditure is the proportion of GDP spent on healthcare. The proportion of GDP spent on healthcare measures the strength of the country's economy and how much a country spends on healthcare relative to other goods and services (OECD, 2017). There is no exact measure for how much GDP a country should spend on healthcare. However, the WHO noted: "It is difficult to get close to universal coverage at less than 5% of GDP". In 2017, the OECD average of healthcare expenditure as a proportion of GDP was 9.0% (OECD, 2017). These two measures provide a baseline for assessment when comparing BRIC countries.

A key economic characteristic that measures financial protection is the percentage of healthcare coverage that is financed publicly. Public expenditure on healthcare demonstrates a government's level of commitment to providing universal healthcare coverage, as well as the progress that each country has made in achieving financial protection by increasing share of public health expenditure over out-of-pocket (World Health Organization, 2017). This is measured by the percentage of public healthcare expenditure. Another economic measure used to assess universal healthcare coverage is health expenditure per capita. Healthcare expenditure per capita provides insight into the resources a country has devoted to healthcare and how spending has changed in context to social and economic factors. It also provides insight into the financing mechanism and the organizational structure of a healthcare system (OECD, 2017).

While there are no exact measures for per capita spending, the WHO found that improvements in healthcare service coverage occurred when countries spent $40 to $80 per capita on healthcare. However, to achieve both health and financial protection, public expenditure needed to be greater than $200 per capita (World Health Organization, 2010). Among OECD countries, the average health expenditure per capita was $4003.00 in 2016 (OECD, 2017). The WHO's $200.00 per capita will be used to determine if countries

are spending enough to provide adequate health and financial protection. While the OECD average of $4000 per capita will be used to compare BRIC countries against developed countries with high achieving universal healthcare coverage.

Lastly, two measures of out-of-pocket expenditure are used to determine catastrophic health expenditure; out-of-pocket spending exceeding 10% and 25% of household income. Spending 15-20% or more of an individual or family's annual income on healthcare has been shown to significantly increase the chances of impoverishment from healthcare costs (World Health Organization, 2017). These measures are important to understanding if universal healthcare coverage is achieving its goal of protecting people from catastrophic healthcare expenditure.

BRIC healthcare systems: Brazil

Brazil's healthcare system is both funded and delivered publicly and privately (Kulesher & Forrestal, 2014). In 1998 Brazil develop the Unified Health System (UHS), offering free care at the point of delivery. The UHS covers 75% of the population (Jakovljevic, 2014).

The UHS is financed and delivered on the national, provincial and municipal levels, most closely resembling the National Health Insurance Model. Funding is designated from a value-added tax and social security contributions (Reich et al., 2016). From 2000 to 2014, Brazil increased healthcare spending from 7.0% to 8.3% of GDP, along with an increase in per capita spending on healthcare from $263 to $947 (Massuda, Hone, Leles, Castro, & Atun, 2018). The distribution of Brazil's healthcare spending is split between the public and private sector. Free, government funded healthcare is offered to the population, but this only accounts for 46.0% of all healthcare spending. While the private sector, which primarily consists of people paying out-of-pocket for healthcare services, comprises 54% of all healthcare spending (Massuda et al., 2018). Out-of-pocket spending is still high in Brazil, with 25.6% of the population still spending 10% of their income and 3.46% spending more than 25% of their income on healthcare (World Health Organization, 2017).

BRIC healthcare systems: Russia

The Russian healthcare system does not use a National or Social Insurance model. Instead, the healthcare system is delivered through the Semashko model of healthcare. The model is an entirely universal system, entitling all citizens to free healthcare. The main characteristics of this model are publicly funded medical facilities, salaried healthcare workers, and high amounts of government administration (Sheiman, Shishkin, & Shevsky, 2018).

Currently, Russia contributes 3.5% of its GDP to healthcare, spending $1,474 per capita on healthcare. Further, 61% of healthcare expenditure was public (OECD, 2017). Russia does the best job of financial protection among BRIC countries, with 4.9% of the population spending 10%, and 0.60% of the population spending 25% or more of their income on out-of-pocket health expenditure (World Health Organization, 2017).

BRIC healthcare systems: India

In 1983, India mandated "health for all" through the establishment of the National Health Policy (NHP) (Agarwal & Tofighi, 2016). India's healthcare system covers people through three streams; Rashtriya Swasthya Bima Yojana for people who fall below the poverty line, the Employee State Insurance for factory workers, and Scheme and the Central Government Health Scheme for civil servants (Mossialos, 2017). Through these three schemes, healthcare coverage extended to approximately 20% of the population. India's healthcare system is predominately financed through taxes on the national, state and provincial level (Mossialos, 2017).

In 2015, the World Bank reported that India spent 3.9% of its GDP on healthcare, a decrease from 4.0% spent in 2000 (World Bank, 2018). In 2015, India spent $238 per capita on healthcare.17.3% of people spend 10% of their income, and 3.9% of people spend 25% or more on health expenditure (World Health Organization, 2017).

BRIC healthcare systems: China

In 2005 less than 50% of the Chinese population was covered by some form of health insurance. By 2011, 95% of Chinese citizens had access to public healthcare, marking the largest expansion of health insurance coverage in human history (Yu, 2015). The central government is responsible for health legislation, policy, and administration. Every citizen is entitled to receive a basic, pre-set package of healthcare services (Mossialos, 2017).

China's healthcare system is comprised of three public insurance schemes; New Rural Co-Operative Medical Scheme, Urban Resident Basic Medical Scheme, and Urban Employee Basic Medical Insurance (Yu, 2015). All citizens are required to put forth $30 to $50 annually to subsidize public health insurance (Yip et al., 2012).

WHO reports that China has increased healthcare spending from 2000 to 2016 form 4.49% to 5.32% of GDP (World Bank, 2019) and spends $761 per person on healthcare (World 2019). In 2014, 38% of China's healthcare system was financed publicly (Mossialos, 2017). Out-of-pocket spending is still high in China, with 17.3% of people spending 10% of their income, and 4.8% of their population spend 25% or more on healthcare services (World Health Organization, 2017).

Analysis

Recent economic development has poised BRIC countries to develop and expand universal healthcare coverage (Rao, Petrosyan, Araujo, & McIntyre, 2014). All four countries exceed the WHO's $40 to $80 per capita to achieve adequate health protection and the $200 per capita mark set for health and financial protection. However, BRIC nations lag per capita healthcare expenditure when compared to the listed developed countries and the OECD average, as all BRIC fall far below the OECD average of $4003.00 per capita. Russia, China, and Brazil spend around 20% of the OECD average, while India spent less than 10% (OECD, 2017). When comparing this measure against the lowest of the listed developed countries; the United Kingdom ($4245.50), BRIC countries are still far behind. The proportion of GDP spent on healthcare is a way to measure of a countries commitment to providing public healthcare services. Brazil stands out, spending 8.3% of their GDP on healthcare, relatively close to the 9.0% of OECD average, but still far behind Canada, Germany which spend close to or more than 10% of their GDP on healthcare.

To examine financial protection, it is important to examine the proportion of healthcare expenditure coming from of out-of-pocket. With the exception of Russia; BRIC Countries have a considerably higher proportions their populations who spend 10% of their income on healthcare services when compared against countries who predominately provide universal healthcare coverage through the

National and Social Health Insurance models such as Canada, Germany, and the United Kingdom. Further, Canada, Germany, and the United Kingdom all have less than 1% of their population paying more than 25% of their income on healthcare. In Brazil, China, and India range from 3.5 to 4.8% of their population paying more than 25% of their income on healthcare.

These numbers are highly suggestive of the progress that needs to be made in Brazil, China, and India to protect people from catastrophic healthcare expenditure. These numbers can be more informative when analysed in the context of the proportion of healthcare spending that is publicly financed. In Brazil, Russia, India, and China, less than 50% of the healthcare GDP expenditure is publicly financed. In Canada, Germany and the United Kingdom, the public GDP expenditure ranges from 69.8% to 78%. This suggests the possibility of a strong relationship between public financing and a reduction in catastrophic healthcare expenditure. This relationship is further supported by research suggesting that financial protection does not increase directly with a rise in the proportion of GDP spent on healthcare. Rather, financial protection is more strongly associated through the pathways of healthcare spending (Wagstaff et al., 2018). This finding along with the low proportion of catastrophic healthcare expenditure in Canada, Germany and the United Kingdom strengthens the case for building universal healthcare coverage around the publicly funded national and social insurance models (Bloom et al., 2018).

Each BRIC country faces a unique set of challenges in their efforts towards achieving universal healthcare coverage. The findings in this review suggest that BRIC countries should prioritize modelling their healthcare systems after publicly funded national and social insurance healthcare financing models. The success these models in Canada, Germany and the United Kingdom, along with the relative success achieved in China and Brazil, demonstrates that these models could be effectively used towards achieving universal healthcare coverage.

The sustainability of universal healthcare systems has come into question in the developed world due to rising costs. It is essential that BRIC countries prioritize their budgets and focus on risk pooling to increase the efficiency of revenue collection. Pooling revenue is a highly effective method towards achieving and sustaining universal healthcare coverage. Also, pooling funds are an essential part of all national and social insurance models (Reich et al., 2016). Pooling funds allow finances and risk to be spread and shared across an entire population. This prevents catastrophic health expenditure by This leads to more affordable and equitable services and prevents catastrophic healthcare expenditure which ultimately results in improved population health (Lagomarsino, Garabrant, Adyas, Muga, & Otoo, 2012; Moreno-Serra & Smith, 2012). Pooling funds builds system capacity by creating a more unified healthcare system that enables a responsive healthcare system which can invest in the specific needs of populations. In addition to pooling funds, BRIC countries should focus on innovative ways to finance their healthcare systems to continue investing in their healthcare systems. For example, countries have added taxes to items such as sugar-sweetened beverages and tobacco (Mossialos, 2017) that are earmarked to raise revenue specifically for their healthcare systems. These mechanisms have been found to increase revenue for the healthcare systems but also encourage health promoting behaviours. Investment into healthcare systems needs to be continuous and persistent in order to each universal healthcare coverage. Healthcare systems that are not reliant on one source of funding are more likely to be sustainable and resilient through times economic, political and social change.

CONCLUSIONS

BRIC countries are all at different levels of universal healthcare coverage. All four countries have taken different approaches during implementation and coverage expansion. However, progress in all BRIC countries is required before universal coverage can truly be achieved. Ideally, BRIC countries should prioritize modelling their public healthcare systems after the national and social insurance models through the development of pooling financial resources and finding innovative ways to finance their healthcare systems.

Further research and analysis to support the preliminary analysis of this review would beneficial. In particular, establishing statistical correlations between the selected indicators and healthcare coverage expansion would add legitimacy to the arguments in this paper. Also, an examination of the selected factors over more extended periods (longitudinal) analysed would increase the depth of this study. Lastly, this approach could be applied to further developing economies, such as Mexico, Indonesia, Nigeria and Turkey (MINT), which have been identified as growing economies undergoing reform towards expanding healthcare coverage.

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TABLES

Table 1 mapping of economic factors of BRIC and developed countries

Country	Health expenditure as % of GDP	Public financing as % of health expenditure	Health expenditure per capita (US$)	% of population spending 10%+ of income OOP	% of population spending 25%+ of income OOP
Canada	11.30	69.8	4,826.30	2.64	0.51
Germany	11.14	74.0	5,728.50	1.14	0.07
UK	9.60	78.8	4,245.50	1.64	0.48
Brazil	8.30	46.0	947.00	25.56	3.46
Russia	3.50	61.0	1474.00	4.87	0.60
India	3.89	21.0	238.00	17.33	3.90
China	5.32	38.0	762.00	17.33	4.77

Judges' views on offences against under-aged sex workers: a Canadian perspective

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Abstract The objective of this research is to investigate Canadian criminal judges' views on offences related to procuring, seeking, or controlling under-aged sex workers, and factors influencing sentence severity. A qualitative analysis was conducted on sentencing court reports in Canada obtained through the Canadian Legal Information Institute (CanLII) database. Twelve sentencing court reports that fit the criteria of inclusion were selected as samples. Data analysis and coding procedures were guided by theories put forth by Amirault and Beauregard (2014), and Kingsnorth, MacIntosh, and Wentworth (1999), in combination with a grounded theory approach. Results revealed that mitigating and aggravating factors, and existing provisions in the Criminal Code of Canada were the main factors influencing judges' decisions on sentence severity. Furthermore, judges viewed these offences as inherently wrong, and attributed culpability entirely on the offender by referring to under-aged sex workers as vulnerable victims, and chastising offenders by referring to their behaviours as selfish and disgusting. Implications in relation to current societal views on sex-workers were discussed, and strategies for future research were suggested.

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INTRODUCTION

The act of selling sex is not illegal in Canada, although communication and other activities related to obtaining sexual services from prostitutes have been prohibited by the Criminal Code of Canada (Criminal Code) (Shaver, 2011). The ground-breaking judgement in *Canada (Attorney General) v Bedford* SCC 72 (2013) where the Supreme Court of Canada struck down several laws regulating activities related to prostitution (e.g. bans on street soliciting and brothels) illustrates our society's changing views on sex workers. Prior to the Bedford case, feminist movements in the 1970's challenged the constitutionality of Canada's prostitution laws, arguing that sex workers should be viewed as victims and not criminals (Davies, 2015). Under this view, individuals who procure or exploit sex workers should be the ones criminalized (Rotenberg, 2016). Moreover, public perceptions towards sex offenders who target victims under 18 years old are overtly negative, and the public highly stigmatized them (Corabian & Hogan, 2015) due to the fact that children are often viewed as a vulnerable population (Bill C-2, 2005, "Summary", (b)(c)). A heinous act victimizing under-aged sex workers would therefore create a 'double-jeopardy' in terms of severity of the crime.

Recent research has shown that the community's attitude towards sex offenders are generally negative, propelled by beliefs that sex offenders are compulsive, incapable of changing their irrational behaviours, and socially withdrawn (Wevodau, Cramer, Gemberling, & Clark III, 2016). Additionally, Bumby and Maddox (1999) found that the public often demanded swift and extreme punishments for sex offenders, increased mandatory minimum sentences, and sex offender registries (the Sex Offender Information Registration Act (SOIRA) in Canada). As representatives of the public, judges are expected to accommodate the public's concerns and attitudes towards sex offenders, and to uphold social justice through sentencing. Some studies have found that the public's opinion on the ideal length of sentences is similar to what has been given by judges (Devilly & Le Grand, 2015). Additionally, other research has shown that judges have predisposed biases when it comes to sex offenders which align their opinions with public perceptions and would result in more punitive sentences when compared to non-sexual offenders (Rydberg, Cassidy, & Socia, 2017).

In Canada, §718.2 of the Criminal Code outlines sentencing principles, which considers mitigating and aggravating factors that judges would have to take into account when imposing sentences. Some studies have found that the main aggravating factor in influencing the length of prison sentence is prior criminality (Roberts, 2008). However, other studies have shown that judges consider offence-based characteristics (e.g. violent offences like rape or murder) as being more important than the characteristics of the victim or offender (Patrick & Marsh, 2011). In other words, judges find the act of the sex offence so heinous that it is considered an aggravating factor of its own. Further, Kingsnorth, MacIntosh, and Wentworth (1999) found that victims' 'negative' characteristics (e.g. acts of prostitution) contributed to lower sentence severity for sex offenders. This finding suggests that, although the public may assign victimized roles to sex workers, the fact that sex workers 'choose' such a line of work could still present a mitigating factor when it comes to sentencing sex purchasers.

However, under-aged sex workers may be viewed differently. Literature has shown that child-sex offenders were sentenced more severely compared to other violent offences (Champion, 1988). In researching mitigating and aggravating factors on sentence severity among Canadian sex offenders, Amirault and Beauregard (2014) found that the victim's age and physical violence towards the victim were strong aggravating factors for increased sentences. This finding is in accordance with Devilly and Le Grand's (2015) research showing that the public believed imprisonment was more appropriate for sexual assault against children when compared to other types of offences. Although much research has been conducted in examining factors that contribute to the sentencing of sex offend-

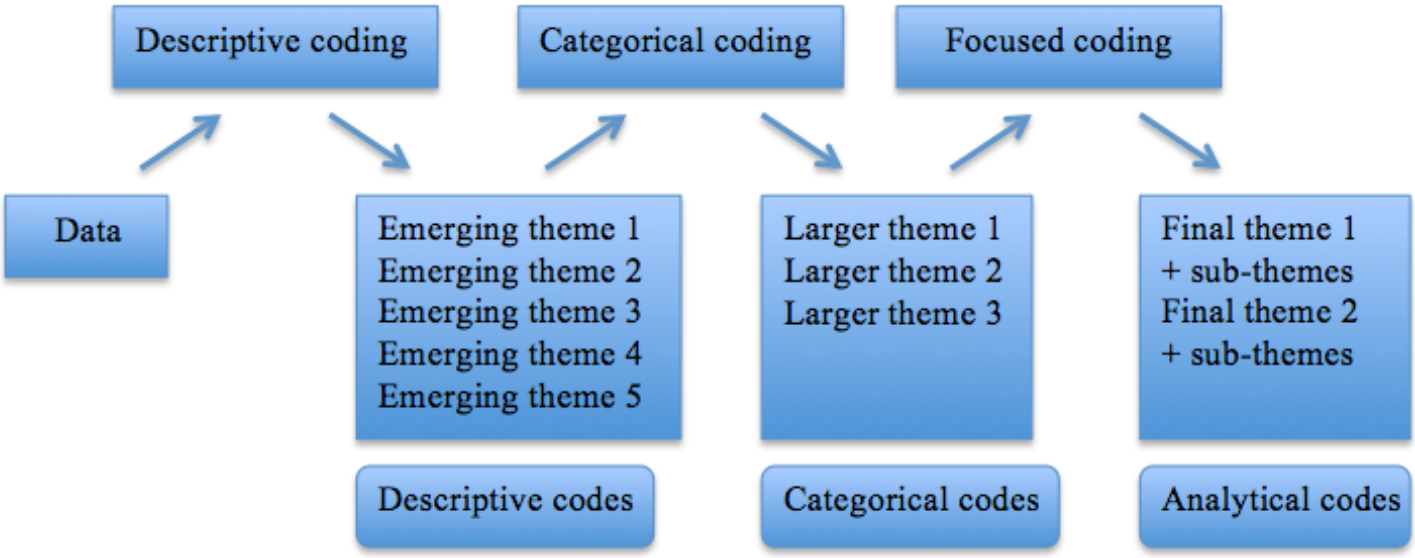

Fig. 1 Coding process conducted for the study's data.

ers through quantitative analysis, there seems to be a gap in qualitative literature, which this study aims to fill. Thus, the research questions for this study are: 1) how do Canadian criminal court judges view offences related to procuring, seeking, or controlling under-aged sex workers?; and 2) how do they justify sentencing the offenders who were found guilty of the crime(s)?. Correspondingly, this exploratory study is guided by two theories outlined above: that 1) a victim's age influences sentence severity (Amirault & Beauregard, 2014), and that 2) a victim's negative characteristics act as a mitigating factor in sentencing (Kingsnorth et al., 1999; Horowitz, Kerr, Park, & Gockel, 2006).

METHODS

This paper consists of reviewing both literature and policy papers. The purpose of the first component of the literature review was to understand universal healthcare coverage and healthcare systems. This consisted of reviewing literature on healthcare system financing designs. The purpose of the second component was to identify the common themes and gaps surrounding the economic factors and characteristics. This included a broad search aimed at finding important economic characteristics and factors commonly arose as important measures used to determine the overall performance and successful healthcare system development. A policy and literature review were then undertaken to summarize and compare the healthcare systems of individual countries. This included reviewing the current healthcare system policies of all BRIC countries and identifying both success and gaps across each county. These reviews were used to inform the analysis. No framework was used but rather a collection of indicators was used to identify the key economic factors and characteristics in the development of universal healthcare coverage in BRIC countries.

METHODS

Materials

Data was extracted from published Canadian court sentencing reports at the provincial level. These court reports represent the unobtrusive and non-live unit of analysis. Specifically, court reports were retrieved from the legal database provided by the Canadian Legal Information Institute (CanLII). Twelve reports represented the final sample for this study.

Sampling procedure

Based on the research question of this study, the following criteria of inclusion were applied: 1) criminal court reports of offences involving the procuring, seeking, or controlling of sex workers, 2) cases with victims under the age of 18, 3) court reports from provincial courts, 4) cases of convicted and sentenced individuals, 5) sentence length of at least 12 months, and 6) court reports of reasons for sentences. For criteria five, the Criminal Code specifies that less serious offences (summary offences) will result in a sentence of 2 years less-a-day, whereas more serious offences (indictable offences) will result in sentences of at least 2 years. Thus, in order to include a wider spectrum of crime severity, the decision was made to include cases that were on the higher end of summary sentences spectrum (i.e. 1 year to 2 years less-a-day). Further, to ensure that this sample is representative of Canada, a stratified purposive sampling (i.e. samples within samples) was employed – cases were chosen from different provinces including six from Ontario, two from Nova Scotia, and one each from Manitoba, British Columbia, Saskatchewan, and Quebec. There were no cases from other provinces found in the CanLII database which satisfied the criteria of inclusion above. These cases were chosen to represent the sample as this will better reflect modern society's views on the sexual exploitation of under-aged sex workers. The date range for this study's data dated between 1993 and 2017.

Data analysis and coding

This study adopts both deductive and inductive methods in its analysis. In terms of deductive method, two theories from the literature guided the research question: that 1) a victim's age influences sentence severity (Amirault & Beauregard, 2014), and that 2) a victim's negative characteristics act as a mitigating factor in sentencing (Kingsnorth et al., 1999; Horowitz, Kerr, Park, & Gockel, 2006). This is coupled with an inductive approach using grounded theory analysis. Grounded theory is a method of analysis in which the development of theory follows analysis of the data itself (Glaser & Strauss, 1967). Once the sample has been gathered, a first read-through of all the court reports were conducted. Each court report was tagged numerically (e.g. Case 1, Case 2). In this first read-through, broad emerging themes were highlighted for descriptive coding. Next, an Excel spreadsheet was created to record emerging themes and subthemes. In the second read-through, categorical coding was conducted, where descriptive codes found earlier were

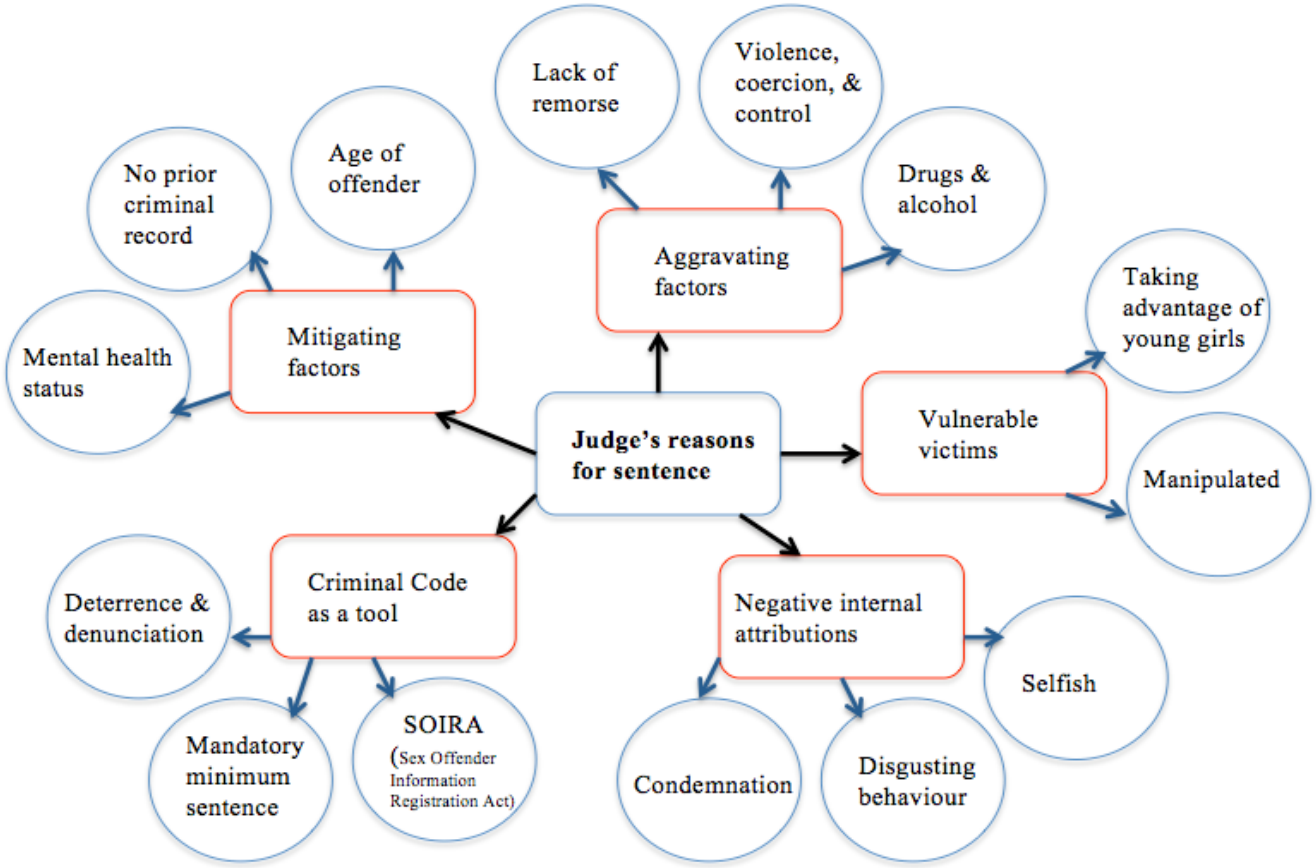

Fig. 2 Judge's reasons for sentencing; grounded theory analysis revealed five main themes and their associated subthemes.

grouped together into larger themes. For the third read-through, focussed coding was conducted, where descriptive and categorical codes were compared against each other, which were then developed into analytical categories. These analytical categories were refined to include a broader interpretation of the data, where entire sentences or paragraphs were included in part of the analysis. Through a grounded theory approach, five main emerging themes were identified, along with corresponding subthemes (Figure 1). A fourth and final read-through was conducted on the sample to ensure that no new themes emerged, and reflexivity was performed throughout the analysis process to ensure that the data was appropriately categorized.

RESULTS

The present study identified five main themes related to judges' reasons and views towards sentencing individuals who were convicted of offences related to procuring, seeking, or controlling under-aged sex workers: 1) mitigating factors, 2) aggravating factors, 3) vulnerable victims, 4) negative internal attributes towards the offender, and 5) the Criminal Code as a tool to guide sentencing. Each main theme further consisted of subthemes, as outlined in Figure 2.

Mitigating factors

In every court sentencing report, judges weighed mitigating factors surrounding the accused in determining the sentence severity; these factors were usually presented by the defence in hopes of a lighter sentence. Within mitigating factors, three subthemes emerged: 1) *mental health*, 2) *lack of a prior criminal record*, and 3) the *offender's age.*

Mental health was a common mitigating factor that judges looked for in sentencing decisions as it decides the accused's moral culpability. For example, in Case 12, the judge reiterated the defence's arguments:

> [...] defence counsel also urged the court to find that Mr. Finestone's diagnoses of Autism Spectrum Disorder further serves to mitigate his circumstances as it played a contributing role in the offence before the court. (Case 12, ¶ 51)

In the above case, the judge considered the accused's mental illness but ruled that it appeared to be mild (according to expert testimony), and "...that it was not the only factor causing Mr. Finestone to commit this offence..." (Case 12, ¶ 58). Moreover, judges also look to any prior criminal record and the offender's age:

> I note Mr. Ackman's age, that he has no past criminal record and that he has support in the community as significant mitigating factors. (Case 2, ¶ 29)

> [...] but he's a young man and he enjoys the support of his family. There's ample room for rehabilitation and that remains an important goal of sentence. (Case 7, ¶ 11)

It is important to note that, although the lack of a prior criminal record and an offender's being a young adult may serve as mitigating factors, judges seemed to put more weight on the seriousness of the offence itself, in which constitutes an aggravating factor.

Aggravating factors

Along with mitigating factors, judges also considered aggravating factors which surrounds the crime. This is usually put forth by the Crown in hopes of achieving the maximum penalty. In terms of aggravating factors, three subthemes were identified: 1) *violence, control, and coercion*, 2) *drugs and alcohol*, and 3) *lack of remorse*:

> Mr. Moazami used violence and the threat of violence, intimidation and coercion in relation to M.N. during their association between 2009 and 2011. When M.N. first began working as a prostitute for Mr. Moazami, he used a threat of slapping her as a means of coercing her into accepting a client that she had initially refused to service. (Case 1, ¶ 47)

The above example echoes Amirault and Beauregard's (2014) finding that offenders who used violence to control the victim during the crime were given longer and harsher sentences, compared to offenders who did not use violence. Furthermore, offenders were judged more harshly if they introduced or provided illicit substances to under-aged sex workers during the commission of the crime. Illicit substances and alcohol abuse have been proven throughout the decades to have contributed to impaired attention, memory, and executive attention in adults (Luciana, M., Collins, P., Muetzel, R., & Lim, K., 2013), and the effects are much more detrimental to adolescents (O' Shea, Singh, Mcgregor, & Mallet, 2004; Schubart et al., 2011). As exemplified by the judge in Case 1:

> [...] he plied her with drugs and alcohol to ensure that she was physically and emotionally dependent upon him. (Case 1, ¶ 70)

Previous research has shown that an offender's signs of remorse (or lack thereof) can greatly influence the judge's sentencing decisions. Offenders who did not provide statements of oral or written communications in recognition of wrongdoing were often seen as unremorseful, and were given harsher sentences (Zhong et al., 2014). In this current study, an offender's choice to remain silent when given the opportunity to make a statement during sentence hearing, or claim that he did not know the sex workers were under-aged, were considered as aggravating factors:

> [...] he has not shown any remorse or insight to his criminal behaviour. And, he has not accepted any meaningful responsibility for hurting or exploiting or exposing to danger any of the girls or young women. (Case 2, ¶ 29).

This finding is contradictory to Amirault and Beauregard's (2014) research results, where the authors found that an offender's degree of remorse had no effect on sentence severity. One possible explanation is that victims in the present study's sample were marginalized women. Failure on the offender's part to recognize how his actions had caused physical and psychological damage to these victims speaks to his moral character, thus leading to an increase in sentence severity.

Vulnerable victims

Another emergent theme that surfaced from judges' reasonings during sentencing was the view that under-aged sex workers were vulnerable victims. Particularly, judges view the offender as 1) *taking advantage* of young girls, and 2) *manipulating* them into the sex-work environment.

All of the offenders in this sample were adult males, and some were significantly older than their victims (highest range was 30 years). Judges took this into regard during sentencing, often viewing the offenders as "exploit[ing] underage women" (Case 4, ¶ 14). As one judge in Case 12 noted:

> I draw from this that the coercion involved related to manipulation of a vulnerable young person as opposed to explicit or even implied threats or violence. (Case 12, ¶ 37)

The above excerpt showed that the under-aged sex worker was viewed as a victim, despite her role as a sex worker. This is contrary to Kingsnorth et al.'s (1999) finding where a victim's negative characteristics led to lower sentence severity. One possibility is that the victims in this study were minors and were thus viewed as vulnerable; any person who takes advantage of their vulnerability and innocence should be highly condemned, regardless of the victim's background.

Negative internal attribution

The fourth theme that emerged from this study was the way judges attributed the offenders' behaviours internally through 1) being *selfish*, 2) being *disgusting*, and that 3) they *warranted condemnation*.

Judges attributed the offences as acts of greed and self-centredness, "[...] a horrible display of vanity and self-aggrandizement" (Case 2, ¶ 37). Although certain mitigating factors may serve to lessen the severity of their sentences (e.g., no prior criminal record), judges did not hold back from verbalizing their perceptions of the offenders:

> At the end of the day, Mr. Ackman is a middle-aged man with no past criminal record, who for no obvious reason except money and vanity happily wallowed in the grimy underbelly of the sex-trade business with its oft built-in exploitation and sexual abuse. (Case 2, ¶ 45)

> Mr. Moazami's treatment of H.W. was abusive, callous, and borders on psychopathic. She was his property to sell and to misuse. (Case 1, ¶ 112)

> Well informed members of our community would be shocked and disgusted by Mr. Moazami's conduct. (Case 1, ¶ 71)

This finding is reminiscent of Rydberg et al.'s (2017) study where they found judges tend to hold negative stereotypes for sex offenders mirroring the public's attitude. Offenders who took advantage of under-aged sex workers, whether to procure them, seek their services, or control them were labelled "parasites of our society" (Case 12, ¶ 76) in judges' eyes. This negative inclination against offenders will no doubt have an immense effect on the severity of their sentence.

Criminal Code as a tool

The final theme that emerged from this study was the judges' referring to existing legislations and regulations (the Criminal Code) that were used as tools to establish sentencing decisions. Particularly, judges pointed to 1) *mandatory minimum sentences*, 2) *deterrence and denunciation*, and 3) *SOIRA*.

In all of the reports sampled, judges made references to the mandatory minimum sentence outlined in §212 (2.1) of the Criminal Code, which specifies that the offence of "living off the avails of child prostitution" mandates a minimum 5 years' imprisonment sentence. Although judges referred to precedent cases to help them determine the sentence for the case at hand, existing provisions like mandatory minimum sentences played a larger role in the judge's decision in order to deter and denounce such acts:

It is clearly a sentence that reflects Parliament's intention that certain designated offences be subject to a minimum sentence due to their serious nature. Further, I find that the sentencing provisions

of the Criminal Code reflect the community's belief that offenders should be required to serve at least the minimum sentence for each offence they commit against young persons. (Case 1, para 141)

This reflects, without a doubt, the position of Courts across the country stating that deterrence and denunciation were paramount when determining the appropriate sentence in such cases. (Case 4, ¶ 8)

More than half of the reports sampled resulted in the judge ordering a SOIRA order against the offender, ranging from 10 years to a lifetime. Research has found that the public were generally supportive of swift and harsh punishments for sex offenders (Bumby & Maddox, 1999; Levenson, Brannon, Fortney, & Baker, 2007), which include mandatory minimum sentences and SOIRA. Further, according to Devilly and Legrand (2015), the lengths of sentences imposed by judges on sex offenders were found to be similar to what the public would like to have imposed as well. This relationship is evident in the current study, where judges agreed with the attitudes and beliefs of the public as found in previous literature (Levenson et al., 2007) with regards to offenders who exploit under-aged sex workers.

DISCUSSION

This study's aim was to uncover and investigate Canadian criminal court judges' views on offences related to procuring, seeking, or controlling under-aged sex workers, and what factors influenced judges' decisions on sentence severity. Through a combination of deductive and inductive analysis, five main themes were uncovered. In terms of judges' views on offenders, it was found that judges made negative internal attributions – the offender was selfish, his behaviour was disgusting, and warranted high condemnation. This negative view on the offender's personality is congruent with Rydberg et al.'s (2017) findings that sex offenders were usually more negatively stereotyped than non-sex offenders. Furthermore, the culpability for these crimes against under-aged sex workers was placed entirely on the offenders. There were no indications that the victims' negative characteristics mitigated the seriousness of the offence, contrary to Kingsnorth et al.'s (1999) findings. In fact, judges viewed under-aged victims as vulnerable victims who were manipulated or taken advantage of by offenders. This could possibly be due to society's changing views on sex-workers (Weitzer, 2015), under which they are viewed as victims, placing the blame on sex purchasers.

In terms of factors that influenced judges' decisions on sentence severity, results showed that judges weighed both mitigating and aggravating factors. In line with previous studies, the victim's age and presence of violence were significant factors that led to an increase in sentence severity (Amirault & Beauregard, 2014; Patrick & Marsh, 2011). Contrarily, judges in the current study also weighed mitigating factors like the offender's mental health and lack of previous criminal convictions when handing out sentences (Crawford, 2000; Frase, 2010). In addition, judges were also found to rely heavily on available sentencing provisions outlined in the Criminal Code by referring to mandatory minimum sentences, and SOIRA while emphasizing the need to impose punitive sentences to achieve deterrence and denunciation of such crimes.

Findings from this study provides a qualitative insight into how Canadian judges view offenders who exploit under-aged sex workers, and to peek into the inner workings of judges' rationality in determining the severity of the sentences. It is interesting that, although judges are seen as trying to remain impartial during sentencing, heuristics and biases against offenders do play a hand in justifications for sentences. This is exemplified by judges referring to offenders' negative internal attributions, and how under-aged sex workers were victims in the hands of these "parasites" (Case 12, para. 76). Thus, the offence of exploiting under-aged sex workers is seen as mala in se (wrong or evil in itself). This study is not without its limitations: the coding and analysis process involved four read-throughs of the sample – however it was only conducted by the primary researcher. Limited resources and time prevented the possibility of a second coder, which could have increased its validity through inter-rater reliability checking. Furthermore, although 12 sentencing court reports were carefully selected to represent the sample, data saturation could not be achieved as the database (CanLII) did not contain sentencing reports from other Canadian provinces besides the six that were surveyed for this study. Future studies could include court reports where sentences were served in the community or were less than 12 months in length.

Future research could examine as to how much effect personal biases and heuristics towards victims have in the role of sentencing. An example could include a survey administered to judges using the Community Attitudes Toward Sex Offenders (CATSO) scale, in which an 18-item self-report questionnaire measures the respondents' attitudes towards sex offenders (Harper, & Hogue, 2015; Wevodau et al., 2016). Items like risk perceptions, stereotype endorsement, and punitiveness within CATSO can help shed some light into the general attitude of the judges and compare the results to their responses concerning non-sex offenders. Future research could also look into whether the existing legislative tools are enough to justify appropriate penalties for offences against vulnerable victims. These questions can add to the sparse qualitative literature on sex offences.

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'Post-truth' politics: a threat to American democracy?

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Abstract Since the 2016 United States presidential election, the spread of misinformation, 'fake news', and 'alternative facts' dominating the public narrative seems to have become so prolific that many scholars, news agencies, and world leaders claim that we are living in a 'post-truth' political world, where facts and evidence have become unimportant compared to an individual's feeling on any particular subject. However, in this article I suggest that modern democracies like the United States are constantly being shaped and challenged by technological advances, shifting ideologies, and global events. By analysing these factors one can better understand how Western society, particularly in the United States, has arrived at this post-truth era, what influence this is having on the democratic process, as well as the relationship between the public and social media in order for our democratic system to evolve.

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'Post truth' politics: the new threat to democracy

On Tuesday, 8 November 2016, the people of the United States elected Donald Trump as their 45th President amidst accusations by both the Republican and Democratic parties of frequent and outright lies communicated to the public through campaign speeches, social media, and news agencies (Hahl et al., 2018). Four years later, the lack of trust in political messaging has increased across the globe to the point where it seems misinformation, 'fake news', and 'alternative facts' dominating the public narrative have now become the norm (OII, 2019; Vosoughi et al., 2018). Many scholars, news agencies, and world leaders claim that we are living in a 'post-truth' political world (Alcorn, 2014; Fish, 2016; Macron, 2018: Parmer, 2012; Peters, 2018; Suiter, 2016).

What is 'post-truth' politics?

Post-truth politics can be defined in several ways. Suiter (2016) describes post-truth politics to be one "where appeals to emotion are dominant and factual rebuttals or fact checks are ignored on the basis that they are mere assertions" (p. 25). Whereas Fish (2016) defines it from the politician's point of view as "a form of politics where there is a willingness to issue warnings regardless of whether there is any real sense of the events being likely to come about, or make promises that there is no real commitment to keeping, or make claims that there is no real reason to believe are true, all for the purpose of gaining an electoral advantage" (p. 211). In like manner, Lockie (2017) adds that:

> It is associated with an increasing disregard for factual evidence in political discourse. What matters is not whether the claims of politicians can be proven true. What matters is whether those listening to those claims would like them to be true – truth being judged not by evidence but by consistency with listeners' existing beliefs and values. (p. 1)

The main consensus is that facts and evidence have become unimportant compared to an individual's feelings and beliefs on a political issue.

Several scholars (Fish, 2016; Parmer, 2012; Suiter, 2016) suggest that post-truth politics are detrimental to democratic practices. However, Farkas & Schou (2020) argue that the term 'post-truth' implies there was previously a "truth era" of politics and democracy, and that democracy has never been solely about an all-encompassing universal Truth, "there have historically been different truths (small t) that have been the product of social and political struggles" (p. 9) and, over time, given shape to our modern liberal democratic system. By building on the ideas of Farkas & Schou, I dispute the notion that 'fake news' and post-truth politics are destroying democracy, and instead argue that modern democracies like the United States are constantly being shaped and challenged by technological advances, shifting ideologies, and global events. To support this, I first discuss the effects a crisis of democracy (Alboim, 2011; Davis, 2010; Taras, 2012) can have on voters. Secondly, I compare two contradicting ideas discussed by Fish (2016) and Fakas & Schou (2020) about the state of democracy in the Western world. I then examine the impact of political marketing (Giasson et al., 2012) and identity politics (Heyes, 2002) during election cycles, and finally I look at the semiotic aspect of political communication through the influences of symbols, indexes, and icons (Maddalena, 2016) and comment on how social media is being used to manipulate voting populations. We need to better understand how Western society, particularly in the United States, has arrived at this post-truth era, what influence this is having on the democratic process, as well as the relationship between the public and social media in order for our democratic system to evolve.

Democracy in crisis?

If Western populations are more educated and have more immediate access to information via the internet than ever before, how is it that post-truth politics have become so prevalent? Are low voter turnouts a cause? Is North America, and other countries in the Western world, in the midst of a crisis of democracy? Alboim (2011) argues that most people are disconnected from political affairs except at election time, so they may not feel that political affairs have any relevance to them. Davis (2010) suggests that

many people may believe that neither candidate represents their needs, and many voters may have the impression that their votes won't matter unless they live in key political constituencies (Suiter, 2016). In addition, "political 'spin', 'lies', and media management" (Davis, 2010, p.152) have had a disenchanting effect on the voting public, which could cause many to make a conscious decision not to vote. Davis also proposes that United States politics is so embedded in international political, financial, and industrial systems that national sovereignty is eroding; the public may feel that their vote will have little impact on global issues. For example, by advocating stricter border controls, anti-globalization, and American nationalism, Trump's election victory may have been a public response to a disenchantment with globalization and a hope for personal economic betterment (Suiter, 2016).

The conflict of truth, consent and democracy

Since at least the 19th century, politicians in the United States have been accused of stretching the truth for their own political gain (Dallek, 2010). However, if politicians themselves are idolized while they are speaking lies, and if the media repeats these lies, will an average citizen be able to make a free and consensual choice on the voting ballot? According to Fish (2016), they cannot. A democratic vote – as outlined in the U.S. Declaration of Independence, para. 2 (1776) – indicates that a majority of citizens have given their consent to be governed by an elected leader. Consent is critical to legitimate democratic governments as "the powers of a government are justly exercised because they derive from the free exercise of their citizens' autonomy" (Fish, 2016, p.212). However, citizens cannot exercise their right to choose if they are provided with false or misleading information (Fish, 2016). Traditional news media play a role in this issue as they try to retain their audience by covering political stories involving conflict and scandal rather than platforms and policy, and they may not be providing the electorate with enough suitable information to make an informed political decision (Taras, 2012; Small et al., 2014). This is the danger of post-truth politics and the core aspect of 'illusory democracy', "in which what appear to be consensual free choices – the marking of particular options on ballot papers, for example - do not count as free choices after all" (Fish, 2016, p.212). Fish argues that, for these reasons, without legal and ethical frameworks in place to make sure the core requirements of consent are met, Western democratic systems are moving more and more towards being illusory democracies.

Farkas & Schou (2020), on the other hand, argue that the debate over what truth and lies are "is an entirely one-sided framing of the problem" (p. 10). They contend that democracy has never been about truth and has never been stable, yet much of the discourse on the idea of a 'post-truth' era "equates the idea of democracy with the ideas of reason, rationality, and truth in an a priori fashion" (p. 5). For as long as people have voted, minority groups have struggled even in democratic systems to gain recognition and legitimacy of their needs and issues regardless of whether facts and truth have been presented by political leaders (Farkas & Schou, 2020). This assumption that democracy is synonymous with truth disregards the fact that the word 'democracy', originating from the Greek *demokratía*, "means a form of government in which, in contradistinction to monarchies and aristocracies, the people rule" (p. 5). To Farkas & Schou (2020), democracy is a product of the will of the people through popular sovereignty, rather than what is and isn't the truth.

Political marketing and identity politics

The use of political marketing in campaigning is when "a political organization uses business techniques to inform and shape its strategic behaviours that are designed to satisfy citizens' needs and wants" (Giasson et al., 2012, p.4) and this can have a significant impact on who people vote for in an election. Theoretically, political marketing can be thought of as a way for political actors to help citizens make informed voting choices. However, in recent years (and especially during the 2016 U.S. election) political marketing has swayed voter opinion without necessarily providing accurate, factual information (Small, 2012). Donald Trump used market-oriented techniques of political marketing in his campaign by addressing consumer needs, then designing provocative messages around them (Giasson et al., 2012). In this way, he recognized voter anger, then tapped into it to present himself as the candidate for 'the people' (Stein, 2016), positioning himself as being diametrically opposite to his competitor, Hillary Clinton (Dufresne & Marland, 2012). Similarly, in the United Kingdom, the Vote Leave campaign of the Brexit referendum used social media messaging to disseminate emotionally charged and frequently non-factual information to the British public, which influenced many to vote based on their emotions rather than fact (Marshall & Drieschova, 2018). The Trump and Vote Leave campaigns focussed strongly on using attack discourse to denigrate all opposing candidates and groups rather than outlining a detailed political platform, appealing mainly to emotions over rationality (Small, 2012; Keaveney, 2016; Ramiro Troitiño et al., 2018).

'Identity politics', the political activity of a demographic that has been neglected or suppressed in a specific regional area (Heyes, 2002), is a major factor in determining the actions of certain demographics during an election. As Suiter (2016) argues, the accelerated pace of globalization and the impact of deregulation in the form of multinational corporate tax arrangements and government bailouts of deregulated banks has had a major impact on certain overlooked demographics of Western society, specifically the rural White working class and under-educated who, as a result of rapid globalization, have seen (1) frequent cuts to their government pensions; (2) decreased wages relative to the cost of living; and (3) an influx of so-called "job-stealing" immigrants in their countries. In the United States, this, along with a loss of over 3.2 million jobs between 2001 and 2013 due to the growing trade deficit between the U.S. and China, has led to an all-encompassing fear of losing control of one's country (Kimball & Scott, 2014).

These notions have given rise to feelings of economic unfairness, fear, and class inequality that reached a breaking point in 2016 (Suiter, 2016). What was evident was that Trump and Vote Leave's tactics harnessed the disgruntled energy from this mainly White working-class demographic in a strong emotional manner and shaped it into a group identity (Suiter, 2016). In this way, instead of feeling overlooked and dissociated from political action, this group could band together behind leaders who appeared to champion their needs for social and economic reform (Smith, 2014). It could be said that these politicians tapped into the populist ideas of social and economic justice so that their speeches would "resonate with sentiments and views already held in some form by a significant part of the population" (Zaller, 1992 in Spruyt et al., 2016, p. 335).

Communicating through symbols, indexes & icons

The method through which political messaging is delivered can heavily influence voting populations. Maddalena (2016) describes political communication as a series of "symbols, indexes, and icons" (p. 246). Before television became a popular medium, complex political discourse was trimmed down to a symbolic political slogan. For example, a slogan from post-war Italy – "In the electoral booth God sees you and Stalin does not" – communicates elements of Christianity, pro-U.S. democracy, anti-surveillance, and anti-communism (Maddalena, 2016, p. 246). The rising popularity of television meant that the main feature of political communication then shifted from symbolic discourse to a visible image of the politician, known as index signs (Maddalena, 2016). As a way of communicating, index signs are simply a visual (sensory) connection between the politician and the viewer (Atkin, 2006). It gives the viewer the ability to base voting preferences on the visual image of the candidate. The television acts as a one-directional medium where the viewer receives an image of a politician on their television set (the sensory feature), which can influence their voting choice (Maddalena, 2016).

Today, the rise of participatory mass media has shifted the focus of political communication into the realm of icons, which hold a physical resemblance to what they represent, but whose meaning can have many interpretations depending on who the receiver is (Maddalena, 2016). For example, a male politician can share images of themselves playing sport with their children through social media. A family-oriented man could then feel that the politician respects the same interests and family values as they do and may be more likely to vote for them. This was particularly evident during Barack Obama's 2008 U.S. presidential candidature and subsequent terms of office where his online and social media presence set him apart from his competitors to certain voting demographics (Hannan, 2018). He used social media to share his taste in everything from television to popular music, and his many public celebrity friendships gained him credibility with young voters: "Voting for Obama was like voting for class president, a candidate whose sheer coolness and hipness certified his political ethos. Indeed, Obama's coolness was his credibility. It mattered more than the actual substance of his political platform" (Hannan, 2018, p. 218). In a like manner, Donald Trump has become a media icon with his "make America great again" slogan to appeal to many in the working-class sectors of America who have been hardest-hit by globalization and the huge flight of manufacturing jobs to China (Kimball & Scott, 2014; Suiter, 2016).

This is not to say that one type of sign - symbolic, indexical, or iconic - is the only type for a particular time period, but one type will dominate depending on the social, economic, and technological atmosphere of a given time and place (Maddalena, 2016). Our current reliance on icons and iconic politics, enhanced by instantaneous news coverage and social media, can be dangerous because the messages conveyed through these icons can be vague and therefore open to personal interpretation that may not truthfully reflect the situation (Maddalena, 2016).

Manipulation through social media

Another worrying development that has arisen from iconic politics is the rise of organized social media manipulation, which "has more than doubled since 2017, with 70 countries using computational propaganda to manipulate public opinion" (OII, 2019, para. 3). When voters base their voting decisions on their emotional connection to a specific political candidate rather than on an informed evaluation of political policies and platforms, they are opening themselves up to potential manipulation by third parties with their own motives (OII, 2019).

The almost ubiquitous trend of social media has played a huge role in the spread of misinformation. In a 2019 survey of 6,127 U.S. adults conducted by the Pew Research Center, around 60% of participants who received their news through social media admitted they had shared fake news at least once (Pew Research Center, 2019). These misleading articles are normally either spread by fake social media profiles run by artificial intelligence (AI) bots or are posted as comments on real social media users' profiles (Panke, 2019). They amplify information in order to sway public opinion on certain issues (Shao et al., 2018). One of the most famous culprits is the Russian Internet Research Agency, who used their digital propaganda to influence not only U.K. and U.S. politics, but also major political movements in other parts of Europe (Tsipursky et al., 2018). In 2016, the media played an instrumental role in the U.S. election by frequently repeating untruthful statements as headlines rather than challenging them (Azari, 2016). However, in recent years, social media powerhouses like Twitter and Facebook, along with traditional news agencies like the Washington Post, are developing algorithms and policies in place to fact-check, identify, and remove false or misleading information from their platforms (Kessler, 2017; Shu & Shieber, 2020). Corporate actions like these are creating the basis for new models of accountability that could help restore faith in the democratic system.

Conclusion: a question of responsibility

If the media and political actors do not perform due diligence in providing truthful statements about policy to the electorate of a country, can they make informed voting decisions? Alboim (2011) believes that each side - the media, political actors, and citizens - has a democratic responsibility to balance one another: the politician to speak the truth, the citizen to be well-informed, and the media to proportionately balance wild statements with factual evidence. This is especially relevant in times of crisis when people are directly affected, as we've seen in the recent CoVID-19 pandemic. Companies like Twitter, Google, and Facebook, pressured by "academics, activists, lawmakers, employees, [and] journalists" (Newton, 2020, para 6) have put new policies in place to decrease the amount of misinformation being spread through their platforms. For a democratic system to evolve, new models of accountability and media intervention will be required. It is up to the people, whom democracy serves, to demand these changes.

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