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AIMS Public Health

Aims and Scope

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Contents

Oral health status and cardiovascular risk profile in Cameroonian military population

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ABSTRACT

Background: Periodontal diseases (PD) seem to appear today as predictors of some cardiovascular diseases (CVD). There is a lack of data on the oral health among Cameroonian military population, and its relationship with CVD. Purpose: Investigate on the link between oral health of Cameroonian military from the Ngaoundéré garrison and their cardiovascular risk profile. Participants and methods: A cross-sectional study at the Fifth Military Sector Health Center in Ngaoundéré was conducted. General health parameters assessment was done according to the World Health Organization STEPS manual for surveillance of risk factors for non-communicable chronic diseases and the Alcohol Use Disorders Identification Test. The periodontal status was assessed using Dutch Periodontal Screening Index. Results: Two hundred and five participants who were officers and non-commissioned officers (aged 47 ± 08 and 32 ± 08 years respectively), with 86.4% of men were included. Smoking was associated to periodontitis (OR = 4.44 [1.73–11.43], p =0.0031). Quality of oral hygiene was associated to high cardiovascular risk profile, poor/good (OR = 3.96 [1.07–14.57], p = 0.0386) and medium/good (OR = 3.44 [1.11–10.66], p = 0.0322). Conclusion: Lifestyle as tobacco consumption and poor oral hygiene were associated to CVD among military, and this call for change.

Keywords: *oral health; cardiovascular risk; cardiovascular diseases; militaries*

1. Introduction

Noncommunicable diseases (NCDs), also known as chronic diseases, are one of the major challenges for health and sustainable human development. To date, the global NCD response has focused on the four major NCDs: cardiovascular (heart), diabetes, chronic respiratory diseases, cancers [1–3]. The association between oral health status and cardiovascular health has been highlighted by numerous studies [4–9]. Indeed, some oral diseases such as periodontal diseases (PD) seem to appear today as predictors of cardiovascular diseases (CVD) [7]. Blaizot et al. [5] found that patients with PD, the risk of developing CVD is doubled. Similarly, evidence on the role of periodontitis in the genesis of atherosclerosis is reported in several publications [10–12]. Periodontal diseases being inflammatory pathologies, they induce the production of inflammatory mediators such as tumor necrosis factor α

(TNF-α), interleukins (IL-1, IL-6, IL-8) and the C-reactive protein (CRP) that have been shown to be associated with atherogenesis [10–12]. In addition, certain bacteria of the oral flora such as Porphyromonas gingivalis (Pg), Aggregatibacter actinomycetemcomitans (Aa) and Streptococcus sanguis (Ss) have been found in patch of atheroma probably due to transient bacteremia by crossing the dental sulcus [10–12]. Finally, more recent work demonstrates the beneficial effect of periodontal therapeutics on endothelial function [13].

CVD (ischemic heart disease, stroke, peripheral vascular disease) are responsible for a third of global world mortality, i.e. 17.9 million deaths worldwide and 147.6 thousand deaths in sub-Saharan central Africa [14]. The fight against the spread of CVD requires the reduction and control of classical cardiovascular risk factors such as smoking, harmful alcohol consumption, physical inactivity, unbalanced diet, high blood pressure, hypercholesteromia, diabetes, and obesity among others, but also the reduction of poor oral health [15,16]. To achieve this, the level of exposure of the populations should first be identified.

The military population did not seem to be exposed to CVD, yet published studies on this topic showed that military personnel are equally exposed to CVD as civilians and sometimes even more [16,17]. A recent meta-analysis on military population reveals that frequencies of cardiovascular risk factors among soldiers were 26% for hypertension, 9% for hyperglycemia, 14% for obesity, and 35% for overweight [16]. Another study comparing military personnel to civilians found significant associations between being military personnel and smoking; being military personnel and excessive alcohol consumption; and being veteran and CVD [17].

Military personnel are generally required to work for long hours, or deployed for fighting operations, which exposes them to stress, fatigue, excessive consumption of tobacco and/or alcohol,less body and oral hygiene time. All of these factors contribute to increase susceptibility of military personnel for oral diseases including PD [18–22]. A meta-analysis, focusing on soldiers deployed in fighting areas, soldiers in maneuvers, soldiers in submarine missions and soldiers in mission in Antarctica, reveals that among the oral pathologies encountered, the frequencies of PD were 6.4%, 8.6%, 21.6% and 10.0% respectively [23].

Numerous works have been dedicated to the distribution of CVD and cardiovascular risk factors in Cameroon.

However, to our knowledge, there is no data on the oral health of Cameroonian soldiers, even less on the

relationship that could exist between this oral health and the general health of the Cameroonian military population. Thus, the objective of this study was to assess the link between oral health of soldiers from the Ngaoundéré garrison and their cardiovascular risk profile.

2. Methods

2.1. Study design

This was a descriptive and analytical cross-sectional study.

2.2. Study area and population

The study concerned soldiers of the garrison of Ngaoundéré, a city located in the Adamawa region of Cameroon and headquarter of Sector N°5. Were included in the present study, any soldier who attended the Military Medical Center of Sector N°5 for the annual re-engagement medical visit and accepted to be submitted to an oral examination in addition to the general systematic clinical examination. Those with any diagnosed cardiovascular disease was excluded.

2.3. Medical examinations, data collected and definitions of variables

A questionnaire developed from the World Health Organization (WHO) STEPS manual for surveillance of risk factors of NCDs was used to collect socio-demographic information (age, gender, military rank); information on habits related to healthy living, alcohol consumption and smoking (answering by "yes" or "no" to the question) in particular; and information about the medical history of study participants. An additional tool, the Alcohol Use Disorders Identification Test (AUDIT) was used to assess the participant's level of alcohol consumption. Participant's anthropometric data (height and weight) were measured to determine their Body Mass Index (BMI).

Each participant's blood pressure was measured using an electronic blood pressure monitor (BP-103H, IDASS, Unit W2-3, Scarne Business Park, Launceston, Cornwall, United-Kingdom), at a seated position after resting for 15min. Measurements were made on each arm after with ten minutes between two measurements. When participants diastolic and/or systolic pressures ≥90 mmHg and/or 140 mmHg respectively, a second measurement was made on both arms after ten minutes. In all cases, the lowest values were considered for each participant. Blood pressure superior to normal (BPSN) was considered when systolic blood pressure ≥140 mmHg and/or diastolic ≥90 mmHg.

The fasting capillary blood glucose test was carried out using strips and glucometer (One Touch Ultra®2, Lifescan Canada Ltd, 675 Avenue Belvédère, Quebec, QC G1S 3E6, Canada). Fasting blood glucose ≥7 mmol/L was considered diabetic.

Full-mouth examination was carried using the Oral hygiene index (OHI); the Decayed, Missing, and Filled teeth Index (DMFT) for the level of tooth decay; and the Dutch Periodontal Screening Index (DPSI) for periodontal status.

a) Quality of oral hygiene: 3 modalities were defined according to OHI. Poor (OHI >3), medium (1.3≤ OHI <3), good (OHI ≤1.2).
b) Healthy periodontium: DPSI = 0.
c) Gingivitis: DPSI = 1 or 2.
d) Periodontitis: DPSI ≥3.

The cardiovascular risk was evaluated by summing the participant's cardiovascular risk factors, precisely: smoking, excessive alcohol consumption (defined by an AUDIT score ≥8), overweight or obesity, hypertension, and diabetes. The cardiovascular risk was considered high if the participant had a combination of at least 3 risk factors.

2.4. Statistical analysis

All analyzes were performed using Epi info version 7.2 software (CDC, Atlanta, Georgia). The Fisher exact test was used for comparing proportions. The Mann-Whitney test and the analysis of variances (ANOVA) were carried out according to their indications to compare numeric variables. Univariate and multivariate logistic regressions were performed to analyze the relationship between periodontal parameters and high cardiovascular risk. The significance threshold was set at $p < 0.05$.

2.5. Ethical considerations

The study was authorized by the military hierarchy (ref. 016082/AU/DSM/RSM3/SSM5) and the participants all agreed to the use of the information collected for the purposes of this study. The study was conducted in conformity with the recommendations of the Declaration of Helsinki revised in 1989.

3. Results

3.1. General characteristics of the sample

Two hundred and five participants were included, among whom 188 (91.7%) were non commissioned officers (NCOs). The participant's age range was 22 to 58 years. Officers were older than NCOs (47 ± 08 versus 32 ± 08 years; p = 0.00001). Males represented 86.4% of the sample. 182 (88.8%) participants were non-smokers. 142 (69.2%) participants included participants consumed alcohol. The proportion of participants consuming alcohol was higher among officers than among NCOs (94.1% (16) versus 67.0% (126); p = 0.0251).

Concerning weight status, 80 (39.5%) participants were normal weight, 01 (0.5%) was underweight, 100 (48.8%) were overweight and 23 (11.2%) obese.

The number of cardiovascular risk factor per subject was higher among officers than the NCOs (medians [inter quartile range]: 2 [2–3] versus 1 [1–2]; p = 0.0032).

Table 1. General characteristics of the sample.

Characteristics	Total (n = 205)	Officers (n = 17)	NCOs (n = 188)	p*
	Count (%)			
Gender				
Women	28 (13.66)	2 (11.76)	26 (13.83)	1.0000
Men	177 (86.34)	15 (88.24)	162 (86.97)	
Smoking	23 (11.22)	2 (11.76)	21 (11.17)	1.0000
Excessive alcohol consumption	122 (59.51)	13 (76.47)	109 (57.98)	0.1970
Obesity or overweight	123 (60.00)	14 (82.35)	109 (57.98)	0.0688
Hypertension	33 (16.10)	6 (35.29)	27 (14.36)	0.0364
Diabetes	3 (1.46)	1 (5.88)	2 (1.06)	NA
High cardiovascular risk	29 (14.15)	6 (35.29)	23 (12.23)	0.0192
Gingivitis	130 (64.41)	7 (41.18)	123 (65.43)	0.0644
Periodontitis	32 (15.61)	3 (17.65)	29 (15.43)	0.7334
	Median [IQR]			p**
Age (years)	28 [26–39]	48 [43–53]	28 [26–36]	0.0000
SBP (mmHg)	125 [116–135]	134 [124–143]	125 [116–135]	0.0152
DBP (mmHg)	78 [69–85]	82 [78–89]	77 [68–84]	0.0081
BMI (Kg/m^2)	25.8 [23.8–27.8]	27.8 [25.8–29.4]	25.6 [23.7–27.5]	0.0138
Glycemia (mmol/l)	5.19 [4.88–5.69]	5.34 [5.09–5.69]	5.14 [4.69–5.69]	0.4373
AUDIT Score	9 [0–10]	10 [9–12]	9 [0–9]	0.0091
OHI	1.66 [1.00–2.49]	1.00 [0.16–2.16]	1.66 [1.00–2.49]	0.1014
DMFT	2 [1–5]	1 [0–5]	2 [1–5]	0.2245
DPSI	2 [2–2]	2 [2–2]	2 [2–2]	0.2263

Note: NCOs: non-commissioned officers; %: percentage; NA: not applicable; IQR: inter quartile range; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; AUDIT: alcohol use disorders identification test; OHI: oral hygiene index; DMFT: decayed, missing and filled teeth index; DPSI: Dutch periodontal screening index; p*: Fisher exact test; p**: Mann Whitney test.

Concerning oral hygiene, 81 (39.5%) participants had good hygiene, 94 (45.9%) medium level of hygiene, and 30 (14.6%) poor oral hygiene. PD was present in 162 (79.0%) participants. The distribution of PD was not significantly different among officers and NCOs. The general characteristics of the sample are presented in Table 1 and Figure 1.

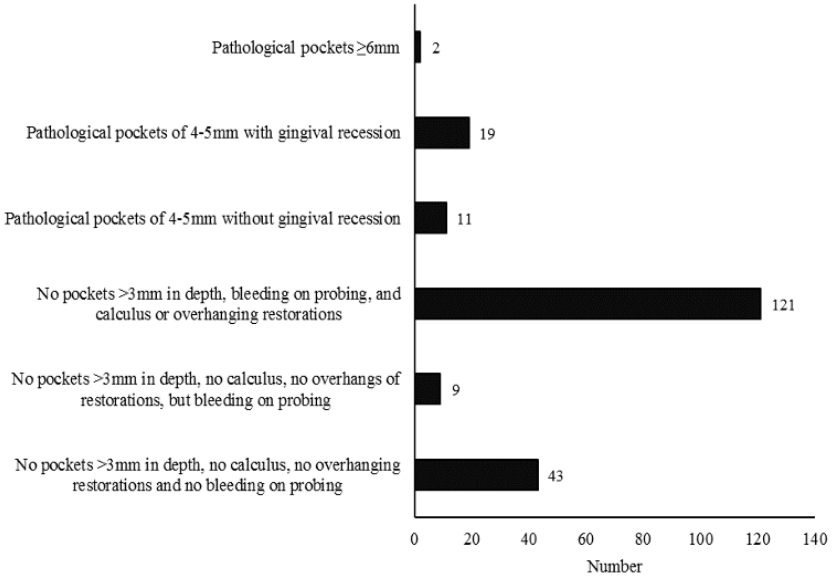

Figure 1. Participants and their clinical periodontal characteristics.

3.2. Relationship between oral health and cardiovascular risk profile

Table 2. Relationship between cardiovascular risk factors and periodontal diseases.

Cardiovascular risk factors	Gingivitis			Periodontitis		
	OR	95%CI	P	OR	95%CI	p
Smoking	0.88	[0.36–2.15]	0.8204	4.44	[1.73–11.43]	0.0031
Excessive alcohol consumption	1.06	[0.59–1.88]	0.8832	1.91	[0.83–4.36]	0.1693
Obesity or overweight	0.91	[0.51–1.64]	0.8824	1.13	[0.52–2.46]	0.8454
Hypertension	1.99	[0,85–4.68]	0.1188	0.49	[0.14–1.72]	0.4305
Diabetes	1.16	[0.10–12.97]	1.0000	2.76	[0.24–31.35]	0.4006

Note: OR: odd ratio; 95%CI: 95% confidence interval.

Table 3. Relationship between age, gender, periodontal parameters and high cardiovascular risk.

Variables	Univariate analyze			Multivariate analyze*		
	OR	95%CI	p	OR	95%CI	p
Age	1.11	[1.06–1.15]	0.0000	1.11	[1.06–1.16]	0.0000
Gender (M/W)	1.43	[0.40–5.09]	0.5771	-	-	-
DPSI	1.33	[0.95–1.87]	0.0992	-	-	-
Quality of oral hygiene						
Poor/Good	6.51	[1.97–21.52]	0.0021	3.96	[1.07–14.57]	0.0386
Medium/Good	2.88	[1.00–8.33]	0.0501	3.44	[1.11–10.66]	0.0322

Note: *: variables in the logistic regression model: age and quality of oral hygiene; OR: odd ratio; 95%CI: 95% confidence interval; M: men; W: women.

Regarding the relationship between oral health and cardiovascular risk factors smoking was associated with periodontitis (Odd Ratio: 4.44 [1.73–11.43], p = 0.0031).

The quality of hygiene was found to be associated with the cardiovascular risk profile regardless the age. Thus, participants with poor and medium oral hygiene quality had a high cardiovascular risk profile (Odd Ratio [95%: 3.96 [1.07–14.57], p = 0.0386 and 3.44 [1.1110.66], p = 0.0322, respectively).

The results on the relationship between periodontal health and cardiovascular risk profile are presented in Tables 2 and 3.

4. Discussion

The objective of the current study was to assess the link between oral health of military from the Ngaoundéré garrison and their cardiovascular risk profile. Tobacco consumption was notably associated with periodontitis.

These results reinforce the idea that PD and CVD have common risk factors. Tobacco is a classic risk factor known for both PD and CVD. Likewise, several studies have highlighted the fact that poororal hygiene which is the main risk factor for PD increases the risk of CVD.

In addition of assessing the link between periodontal health and the cardiovascular risk profile of soldiers from the Ngaoundéré garrison, this study provides the first data on oral health of Cameroonian soldiers. Thus, regarding the distribution of PD in among the 205 participants included, the frequency of gingivitis was 64.4% and that of periodontitis, 15.6%. These results showed that the frequency of gingivitis and periodontitis was similar to the general population (62% and 15% respectively) in the Cameroon as reported by Essama et al. [8] in a multicenter study.

Tooth decay, can be considered as low since the median DFMT was equal to 2. This low level of tooth decay could be explained by the fact that only 14% of the participants had poor oral hygiene.

Regarding cardiovascular risk factors, we found that the distribution of behavioral risk factors seems to be higher than in the general Cameroonian population, smokers in the current study reprensented11.2% compared to 8.3% in the general population of Ngaoundéré [24]. On the other hand, participants were less affected by diabetes and hypertension; 1.4% diabetic against 5.8% [25]; and 16.10% hypertension, against 32.1% in the Cameroonian general population [26]. This lower affection by diabetes and

hypertension; 1.4% diabetic against 5.8% [25]; and 16.10% hypertension, against 32.1% in the Cameroonian general population [26]. This lower affection by diabetes and hypertension could be explained by the fact that Cameroonian soldiers carry out regular physical activity compared to the general population. All military units in Cameroon have at least two compulsory days of collective sports per week.

A couple of limitations of the current study, could be the epidemiological tools used to determine the periodontal status of participants and their cardiovascular risk profile. In fact, regarding the cardiovascular risk profile, we opted for the summation of risk factors as a method of determining this risk profile because more economic and easier to implement. Indeed, the most widespread methods of determining cardiovascular risk use scores, but these scores were defined from studies carried out on non-African populations and their use on African people remains controversial. Also, the use of the cardiovascular risk prediction tables of the WHO and the International Society of Hypertension, but these are dedicated to subjects over 40 years. We therefore retained the summation of the risk factors already described in the literature [27]. The periodontal status assessment tool did not pose any problem because the DPSI is a validated index already widely used [28].

5. Conclusions

Association between some oral health status parameters and cardiovascular risk profile of military of the Ngaoundéré garrison has been highlighted. This call, military to correct certain lifestyle habits such as tobacco consumption and poor oral hygiene, which are harmful both to periodontal and cardiovascular health.

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Conflict of interests

The authors declare that they have no competing interest.

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Integrated care by community health workers in Malawi: Rehabilitation and blood pressure monitoring

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ABSTRACT

Background: Community health workers (CHWs) are essential providers of integrated care for people in low-resourced settings with a high burden from noncommunicable diseases (NCDs). Aims: The purpose of this study was to evaluate a CHW training program in rural Malawi integrating blood pressure (BP) monitoring into rehabilitation care. Methods: This was a retrospective crosssectional study. The participants were a convenience sample of home-based palliative care CHWs at the local hospital (n = 59). Data collected included: a written pre- and post-knowledge test, skills competency checklist and a post-training program survey. Descriptive frequencies and paired t-tests ($\alpha = 0.05$) *were used for quantitative analyses. Themes in narrative responses in the post-training survey were analyzed qualitatively. Results: Participant knowledge regarding BP monitoring procedures improved significantly on the post-test (M = 8.24, SD = 1.654) compared to the pre-test (M = 6.59, SD = 1.683), Z (49) = −5.569, p < 0.001. The pre-and post-tests were scored 0–10 points. All participants demonstrated competency in 100% of the skills. Participants reported the lack of transportation, teamwork and resources as barriers to their work. They reported trainings and opportunities to collaborate as facilitators to their work. Discussion: This study demonstrated the effectiveness of a training program for CHWs which integrated BP monitoring with rehabilitation care for people with NCDs. This retention of knowledge and application to clinical practice serve as strong indicators of the feasibility and sustainability of the CHW training and care delivery program in resource-limited settings. Conclusion: Our findings help demonstrate that training CHWs can be an effective way to help bridge the gap in health care access for people with disabilities in resource limited countries.*

Keywords: *community health workers; integrated care; palliative care; noncommunicable disease*

1. Introduction

The health burden of noncommunicable diseases and injuries (NCDIs) is growing even as healthcare in low-income countries remains focused on communicable, maternal, neonatal, and nutritional conditions. In fact, NCDIs contributed to 79.8% of overall global mortality in 2015, with over half of those deaths occurring in low- and middle-income countries [1]. To reduce inequities in care, health systems need to intentionally prioritize the needs of people with noncommunicable diseases [2,3]. Health workers who provide care for those with NCDIs are in short supply [4]. However, community health workers (CHWs) play an integral role in filling this gap. CHWs are health care generalists who serve the communities in which they live [5]. They are an effective and low-cost subsystem of health workers in sub-Saharan Africa [6]. Malawi, a low-income country in southeast Africa, has a population

of 21.2 million with 75% of the country's population living below the poverty line [7,8]. Four percent of the population live with a physical disability and 22% of these persons have difficulty walking [6]. Malawi has a heavy burden of disease. In 2015, estimates suggest that Malawi lost 58,000 disability adjusted life years (DALYs) per 100,000 population when accounting for all diseases [1]. NCDIs account for approximately one third of all deaths and disabilities in Malawi [1].

Therefore, consideration of NCDI risk factors, interventions, and prevention policies is critical [1,9]. Located in Namitete, Malawi, a rural hospital serves over 250,000 people within a 60km radius [10]. This is one of the few hospitals in the country that offers a home-based palliative care (HBPC) program. This program serves patients in the village with a variety of life-limiting or life-threatening conditions and includes a HBPC coordinator and 60 volunteer CHWs with specialized training in palliative care. Trainings were held annually since 2013 with a focus on rehabilitation skills so that the CHW could better serve patients who were bed-ridden or had physical disabilities. In recent years, the hospital staff noted an increase in patients with stroke or second stroke and wanted to initiate strategies to mitigate this trend. High blood pressure (BP) was identified as an indicator of risk of stroke or second stroke. The stakeholders at the hospital (medical director and HBPC coordinator) wanted the CHW trainings to include BP monitoring because many of the patients in the HBPC program have NCDs with related BP issues. In addition, the CHWs in the HBPC program reach the doorsteps of these patients providing access to care in the large catchment area. They saw the opportunity for the CHWs to increase appropriate referrals to the hospital and monitor BP issues in conjunction with their rehabilitative care in the village.

For the training evaluated in this study, the training content was unique to this program. It was developed in collaboration with the hospital staff, HBPC coordinator, a licensed physical therapist, student physical therapists and CHWs. All written training materials and assessments were translated into Chichewa by native Chichewa speakers. The training was delivered with Chichewa interpreters as needed. The purpose of this study was to evaluate a CHW training program that integrated BP monitoring into their rehabilitation care in the home-based setting.

2. Methods

2.1. Study Design

This is a retrospective, cross-sectional study of a training program in December 2019.

2.2. Subjects

The participants were a convenience sample of all active home-based palliative care community health workers at a local hospital in Namitete, Malawi (n = 61). Table 1 is a summary of their known demographic characteristics.

Table 1. Participant demographic characteristics.

	Group 1 n/N (%)	Group 2 n/N (%)	All n/N (%)
Gender			
Female	19/28 (68%)	16/31 (52%)	25/59 (42%)
Male	9/28 (32%)	15/31 (48%)	34/59 (58%)
Mean Age (SD)	47.89 (7.661)	54.94 (9.842)	51.59 (9.487)
Region			
TA Kalolo	18/28 (64%)	21/31 (68%)	39/59 (66%)
TA Mavwere	10/28 (36%)	10/31 (32%)	20/59 (34%)

Note: TA = Traditional Authority.

2.3. Training planning

The training content was developed in collaboration with the medical director, HBPC coordinator and 5 CHWs in December 2018. To evaluate the feasibility of CHW BP monitoring, 5 BP machines were distributed to 5 CHWs in 5 different geographic areas. The CHWs were assessed for correct BP monitoring (30 observations). Of 30 observations, all CHWs measured BP correctly without physical assistance (one received verbal directions), all CHWs except one accurately entered the BP information in the patient's health book (one observation with no response). This training planning established the feasibility of training CHWs in BP monitoring and informed the planning for the full training in December 2019. Based on the input from the CHWs involved in the planning, instructions were clarified, documentation processes developed, and assessment measures determined.

2.4. Training program details

The training program included 2 days of instruction on NCDs, BP monitoring, criteria for referral to the hospital, documentation of BP monitoring, as well as stroke prevention education and rehabilitation skill review. The type of content included knowledge, psychomotor skill, application to work processes and cases. The teaching methods included lecture, discussion, demonstration, practice, small and large group discussions and application of material to case and workflow examples. The assessment methods were congruent with the content and teaching methods including knowledge tests, psychomotor skill competency, application of the workflow process and application of concepts to case examples in the

village context. Figure 1 outlines the CHW workflow process of the integration of BP monitoring with rehabilitation care. The training program was two days. Lecture, demonstration, practice and discussion were part of both days. On the second day, the focus was on workflow processes and clinical reasoning with application to case scenarios in the village context. Group 1 attended the training on the first two days, and Group 2 on the second two days of the training week. Two groups were trained separately due to limitations in the size of the training space and the need for small group discussions. Group 1 and Group 2 training was delivered by the same training team. Table 2 summarizes the training program details, teaching methods and assessment methods.

Table 2. Training program details.

Training Day	Teaching Content	Teaching Method	Assessment Method
Day 1	Knowledge: Blood pressure (BP) basics, rehabilitation skills rationale, CHW roles and responsibilities	Lecture, small group discussion	Written, paper-and-pencil Pre-Test
	Psychomotor Skills: BP, rehabilitation skills	Demonstration and practice, large and small group discussion	Skill Competency Observation
Day 2	Knowledge, continued: Blood pressure (BP) basics, rehabilitation skills rationale, CHW roles and responsibilities	Lecture, small group discussion	Written, paper-and-pencil Post-Test
	Psychomotor Skills, continued: BP, rehabilitation skills	Demonstration and practice, large and small group discussion	Skill Competency Observation
	Applied Understanding: Case and Workflow	Application to cases and workflow, large and small group discussion	Case examples, Workflow examples

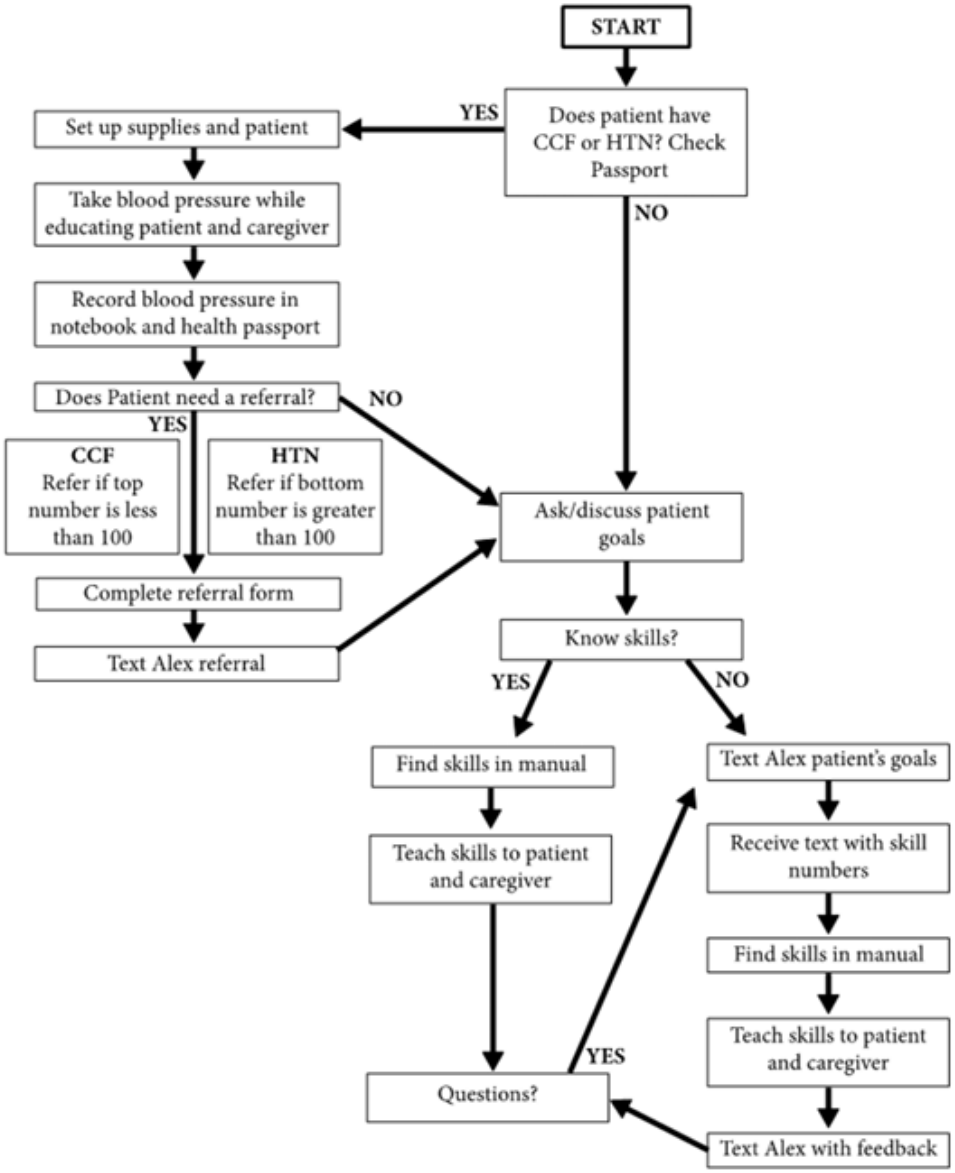

Figure 1. Integrated Care Workflow. Note: CCF = Chronic Cardiac Failure, HTN = Hypertension, Alex = Home-Based Palliative Care coordinator.

2.5. Data collection

Data collected included assessment of the CHW's cognitive, psychomotor and clinical reasoning skills. Knowledge was assessed with a paper-and-pencil written multiple choice pre- and post-test on BP monitoring procedures and the integrated care workflow. The pre-test was administered after introductions on the first day and the post-test was administered after the final training activities on the second (final) day. The knowledge test was scored using an answer key by the instructors. Assessment of competent skills and reasoning included: proper use of the BP monitor, identification of important numbers on the BP monitor (systolic and diastolic BP), identification of referral criteria for known

hypertension, identification of referral criteria for chronic cardiac failure, accurate recording in the Health Passport, accurate recording in the CHW Registry, accurate completion of the Referral Form, demonstration of rehabilitation skills using a reference manual (teaching patient and caregiver), demonstration of teaching stroke prevention, and application of the workflow to actual patient cases. Assessors were trained by the HBPC coordinator and physical therapist project lead to evaluate the expected skill competencies. Each skill was directly observed by an instructor and evaluated for competency. Participants were asked about potential facilitators and barriers to their work as part of the post training survey. Appendix 1 contains the training materials including the pre-post-test, skill competency list and post-training survey.

2.6. IRB Approval

The study was submitted to the Office of Research and Sponsored Program Institutional Review Board. Upon review of our protocol, it was approved as exempt from a need for full review under 45CFR 46.101(b). The data were coded in such a manner that the participants cannot be identified, directly or through linked identifiers. The investigators are the only persons with access to the data. All data were coded, and individual identifiers excluded from the dataset. A codebook was kept in a locked location. The individuals were not identifiable in any reporting of the findings of this study.

2.7. Data analyses

All results were de-identified. Descriptive frequencies (percentages) were used to describe skill competency and quantitative responses from the post-training programme survey. Given that the data were not normally distributed, the Wilcoxon Signed Rank Test ($\alpha = 0.05$) was used to compare the means and determine if there was a significant difference in the paired outcome (pre-and post-knowledge test scores). Data analyses were undertaken using SPSS software, Version 25 [11]. This study sample size of n = 59 exceeds the sample size of 34 to achieve a power 80% at a level of significance of 5% for detecting an effect size of 0.5 [12]. Narrative responses in the post-training programme survey were analysed qualitatively using a thematic analysis. Thematic analysis included coding each participant's response, comparing responses across participants and identifying core categories (themes) [13].

3. Results

3.1. Attendance

Sixty-one CHWs were invited to attend the training and 96.7% completed both days of training (n = 59). Two participants attended only one day of training (child illness and a village funeral were the reasons

for missing the second day). There was no significant difference in age or gender distribution between Groups 1 and 2. Group 2 had more participants from Traditional Authority (TA) Kalolo than Group 1 (overall there were more participants from TA Kalolo than TA Malware).

3.2. Knowledge pre-and post-test

The average score on the knowledge pre-test was 6.59 out of 10 (range of 2–9) and the average score on the knowledge post-test was 8.24 out of 10 (range of 3–10). There was a statistically significant improvement from the pre-posttest for Group 1, Group 2 and for both Groups combined (Table 3).

Table 3. Pre- and post-training knowledge for 2019 training.

Training Year	Group	N	Pre-test Mean[a] (Standard Error, SD)	Pre-test Range	Post-test Mean[a] (Standard Error, SD)	Post-Test Range	Z-statistic (p value)
2019	1	28	7.36 (0.225, 1.193)	5–9	8.61 (0.220, 1.166)	7–10	−3.736 (p < 0.001)*
2019	2	31	5.90 (0.319, 1.777)	2–9	7.90 (0.351, 1.955)	3–10	−4.181 (p < 0.001)*
2019	1 and 2	59	6.59 (0.219, 1.683)	2–9	8.24 (0.215, 1.654)	3–10	−5.569 (p < 0.001)*

Note: *significant at $p < 0.05$; [a] Possible score ranged from 0 to 10 with 10 being a perfect score.

3.3. Skills competency

One hundred percent of the participants who attended both days of training (n = 59) demonstrated all of the 10 skills at the expected level of competency (Appendix 1).

3.4. Application

On the final day of the training, the participants applied the workflow to patient scenarios based on real patients in the village and presented their cases. Table 4 is a summary of the cases presented.

Table 4. Application of training: case examples.

Patient Case	BP/Referral Decision	Rehabilitation Skills Recommended
Age: 75; Married; Chronic Cardiac Failure; 6 children. He is failing to walk because of swollen legs and difficulties in breathing.	85/55, Referred	Hand-held and cane assistance for walking
Age: 43; Hypertension. He has weakness on the left side (2 years ago). Leg and arm are weak but also, he feels pain in his head and back.	123/108, Referred	Elbow, hip and knee range of motion
Male; Age: 55; Hypertension; 3 children; Farmer; Left arm and leg are weak.	183/105, not referred. This was an incorrect decision and was corrected during the training.	Shoulder, elbow, hand and hip range of motion
Female; Age: 50; Hypertension; 5 children; Farmer; Stroke: Left arm and leg. Wants to walk alone.	99/60, not referred	Walking assistance with a cane, standing exercises
Age: 55; Chronic Cardiac Failure; Married; Farmer; Weakness of the leg and arm.	80/70, referred	Shoulder, elbow, hand, hip, knee and ankle range of motion
Age: 77; Hypertension; Married; Had a stroke 26/6/19 and his left arm and leg were weak, but he cannot talk. He has swelling and painful legs.	114/69, not referred	Shoulder, hand, hip, knee and ankle range of motion
Age: 68; Chronic Cardiac Failure; Married; 4 children; Farmer.	90/60, referred	Position changes to prevent pressure injury, feeding positioning to prevent aspiration, arm and leg range of motion
Age: 63; Hypertension; Married; 5 children; Farmer. Left leg and arm are weak. He can walk around outside with help. He gets short of breath and rests. Patient wants to walk and use his arm.	127/91, not referred	Shoulder, elbow, hand, hip, knee and ankle range of motion. Sit to stand exercise
Age: 45; Hypertension; Married; 3 children. Has left arm and leg weakness.	82/50, not referred	Shoulder range of motion, sit to stand exercise, standing exercises
Female; Hypertension; Age: 73; 4 children; Farmer, Church member. Stroke in 2017. Right arm and left are weak, can sit in chair but cannot walk around outside.	166/91, not referred	Arm and leg range of motion, sit to stand exercise, standing exercises
Age: 65; Hypertension; 3 Children; Our patient had a stroke three months ago. The left arm and leg are weak. Fingers, elbow and ankle are stiff.	180/170, referred	Shoulder, elbow, hand and hip range of motion

3.5. Post training survey

The post training survey included questions about the helpfulness of the training related to skill review, BP monitoring, referral criteria and documentation procedures. The survey also captured open-ended question responses about facilitators and barriers to their work. Overall, the participants reported that the training provided a helpful skill review, as well as instruction in BP monitoring, referral and documentation. Table 5 is a summary of the Likert scale responses as well as the themes in their narrative responses.

Table 5. Post-training survey summary.

Quantitative Results (n = 59)				
Question	A lot (%)	Some (%)	A little (%)	None (%)
Did this training help you review your skills?	68	29	2	0
Did this training help you know how to read blood pressure?	66	30	2	0
Did this training help you know when to refer?	57	36	3	0
Did this training help you know when to write in the notebook, health passport and referral form?	70	29	2	0

Qualitative Results

Question	Themes	Exemplary Quote
What did you learn in this training? List 3 most important things you learned.	BP monitoring protocol: procedures, referral and documentation Rehabilitation Skills Communication with patients and the hospital	"*We have learned to know which patients are supposed to be referred*" *"We have also learned how to help our patients move/walk"* *"We have learned to ask out patients what they want us to do for them"*
What more would you like to learn about in the next training for physio?	More about BP including medications and management More about rehabilitation skills More about patient difficulties: oral motor, nonverbal, visually impaired, deaf More about other conditions: sickle cell, malaria, cancer, swelling	"*We should have more BP trainings on how we can do better in measuring*" *"I want to learn more skills"*
What did you learn from the follow up home visits?	Building guardian and patient relationships Seeking guidance from HPBC [Home Based Palliative Care] coordinator Learned how to use rehabilitation skills Collaborating with other volunteers	"*We learned to show our love to our patients and making good relationships with people from the villages*" *"Writing a referral to the hospital and sending text to Alex"* *"We have learned other skills from our fellow volunteers, and they call us community doctors"* *"We should move together, not alone when seeing patients"*
Describe one example of one patient's progress	Able to walk longer distances/use assistive device Able to sit up Able to move alone Able to do simple things alone Compliant to medication	*"Patient is now doing fine, is uses a cane to walk"*
Describe one example of one patient's continued difficulty	Not improving due to: Lack of medicine compliance Continues to smoke, drink Not compliant to rehabilitation program Not cooperative Lack of guardian involvement Other medical co-morbidities	*"The guardians are not taking part of the care team"*
Describe one thing that makes your work easier	Mutual respect, open communication between volunteers Training and education Encouraged by patient improvement Trainings Materials (phone, BP machine, manual/book, supplies) Teamwork and encouragement from the hospital Good relationships with chiefs and village headmen	*"I am dedicated by observing time to see my patients. I spare my own time to see these patients"* *"We should have more frequent trainings"*
Describe one thing that makes your work difficult	Transportation (long distances, lack of bicycle)—noted in 76% of responses Lack of teamwork Lack of supplies (raincoat, BP machines, phone)	*"I travel long distances to see patients, which makes work difficult"* *"Not having teamwork spirit"*

4. Discussion

This study demonstrated the effectiveness of a training program for CHWs which integrated BP monitoring with rehabilitation care for people with NCDs. Cognitive, psychomotor and clinical reasoning aspects of their learning were evaluated. The participants acquired knowledge (an average improvement of 1.2 points on a 10-point test), demonstrated competency with skills (100% of participants demonstrated all skills) and applied what they learned to patient cases and workflow processes (100% of participants demonstrated application of training material to cases and workflow). Given the importance of addressing NCDs in Malawi, the present study is an example of how CHWs can effectively perform rehabilitation skills, teach these skills to patients and caregivers, deliver stroke prevention education and monitor BP [1,9]. By evaluating training effectiveness, leaders of global health initiatives can be accountable for the feasibility and sustainability of CHW education [14]. Through their presentations of clinical cases, the CHWs demonstrated direct applications of what they learned in the trainings to patient care in their villages. Their retention of knowledge and application to clinical practice serve as strong indicators of the feasibility and sustainability of the CHW training program. All of the CHWs in this study showed potential to increase access to integrated care in this low-resource setting. Our findings provide evidence for Perry et al.'s (2012) description of CHWs as "the world's most promising health workforce resource for enabling health systems in resource-constrained settings to reduce the burden of disease" [15].

In the post-training survey, CHWs reported that they will be able to apply their new skills and knowledge to improve the health of the villages they serve. Similar to CHWs in other settings, participants reported the lack of transportation, teamwork, and resources as barriers to their success [16–18]. Participants also noted facilitators of their success, including trainings and opportunities to collaborate— also reported by Greenspan et al. (2013) [19].

The WHO initiative for UHC emphasizes integrated, person-centered care with a focus on optimal processes of care delivery and patient experience [4]. Studies have shown that CHWs are cost-effective and integral to the success of health systems in Sub-Saharan Africa [6,20]. Prior to this training, the CHWs showed they were successful in reaching people with disabilities with rehabilitation care. [21,22]. With BP monitoring, their scope of care was expanded. They now have a workflow process for monitoring BP, providing preventative education to patients and families and connecting them to the local hospital. In this setting, CHWs improve the patient experience by combining preventative and rehabilitation services into home-visits and by facilitating connections between the community and local access points of health care such as the hospital. The quality of the patient experience is potentially

improved because of the integrated, person-centered approach.

A recent systematic review which included 127 studies from low- and middle-income countries highlighted that people with disabilities have higher healthcare needs yet encounter more barriers to accessing services [23]. This lack of health coverage and access not only violates the rights of people with disabilities under international law but also results in poorer health outcomes [23]. The WHO recommends integrating CHWs into health systems, as they can improve health equity by improving access to people who may not have the means for transport to a hospital [24]. Because they are embedded into the communities in which they serve, CHWs can identify needs in their communities and provide a healthcare access point. A study undertaken in India demonstrated that CHW training in management of disabilities led to earlier identification of people with disabilities in rural settings [25]. In Malawi, accessing health care is difficult and health inequities are widespread, but the presence of CHWs may alleviate some of these burdens. The HBPC program at a rural hospital in Malawi demonstrated that training CHWs in basic rehabilitation and monitoring skills is effective over a seven-year period. The CHWs applied their knowledge to ongoing care in the villages and they reported positive changes in health outcomes. Our findings help demonstrate that training CHWs can be an effective way to help bridge the gap in health care access for people with disabilities in resource-limited countries.

5. Conclusion

This is the first study to demonstrate the effectiveness of incorporating preventative care in a community-based rehabilitation program. Integrated care improves the quality of the patient experience and access to medical services in underserved areas. Global health initiatives in these low-resource settings must focus on creating sustainability by cultivating relationships with local health providers [26]. CHWs play a vital role in these healthcare systems by extending the access point for care and delivering care with a person-centered focus. Future studies will be undertaken to identify the barriers in the present CHW model that prevent patients from receiving appropriate medical care. The national NCD report in Malawi highlights the importance of understanding structural determinants of health in relation to NCD management [1]. We will continue to investigate how these factors affect the management of NCDs in this setting but see potential for this ongoing care model to have an impact on health access for people with chronic conditions.

Limitations

One possible limitation of this study is the lack of generalizability due to administration of the training in

one group of CHWs in Malawi. Although all trainings, tests, and surveys were administered in the participants' native language, they were unfamiliar with the written testing format due to their cultural and educational background. Because the authors of the study were present while administering all aspects of training and testing, participants' responses to the post-test survey may have been biased.

Conflict of interests

The authors declare that they have no competing interest.

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Regional forecasting of COVID-19 caseload by non-parametric regression: a VAR epidemiological model

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ABSTRACT

Objectives: The COVID-19 pandemic (caused by SARS-CoV-2) has introduced significant challenges for accurate prediction of population morbidity and mortality by traditional variable-based methods of estimation. Challenges to modelling include inadequate viral physiology comprehension and fluctuating definitions of positivity between national-to-international data. This paper proposes that accurate forecasting of COVID-19 caseload may be best preformed non-parametrically, by vector autoregression (VAR) of verifiable data regionally. Methods: A non-linear VAR model across 7 major demographically representative New York City (NYC) metropolitan region counties was constructed using verifiable daily COVID-19 caseload data March 12–July 23, 2020. Through association of observed case trends with a series of (county-specific) data-driven dynamic interdependencies (lagged values), a systematically non-assumptive approximation of VAR representation for COVID-19 patterns to-date and prospective upcoming trends was produced. Results: Modified VAR regression of NYC area COVID-19 caseload trends proves highly significant modelling capacity of observed patterns in longitudinal disease incidence (county R2 range: 0.9221–0.9751, all $p < 0.001$). Predictively, VAR regression of daily caseload results at a county-wide level demonstrates considerable short-term forecasting fidelity ($p < 0.001$ at one-step ahead) with concurrent capacity for longer-term (tested 11week period) inferences of consistent, reasonable upcoming patterns from latest (model data update) disease epidemiology. Conclusions: In contrast to macroscopic variable-assumption projections, regionally-founded VAR modelling may substantially improve projection of short-term community disease burden, reduce potential for biostatistical error, as well as better model epidemiological effects resultant from intervention. Predictive VAR extrapolation of existing public health data at an interdependent regional scale may improve accuracy of current pandemic burden prognoses.

Keywords: *novel coronavirus; COVID-19; vector autoregression; VAR; model; prediction; SIR; SARS-CoV-2*

1. Introduction

The ongoing global outbreak of novel coronavirus disease 19 (COVID-19, caused by the coronavirus strain SARS-CoV-2) represents a leading public health emergency. To date, it has affected at least 217 countries and territories, leading to more than 100 million positive cases and 2.2 million deaths as of January 2021 [1]. In this time, COVID-19 has demonstrated extensive unique properties including an extended incubation period, likelihood for high levels of asymptomatic transmission, and a very nonspecific symptomology leading to difficulty in accurately identifying positive cases. In addition, COVID-19 exhibits a high basic reproduction ratio (R0) combined with a high prevalence of cases having mild clinical presentation. Current literature shows that up to 80% of infected people may exhibit

negligible respiratory impact [2]. Subclinically afflicted individuals are more likely to engage with communities during active infection periods and less likely to seek out health care services, given inconspicuous course of illness as well as minimal impact on quality of life. Collectively, these factors inherent to COVID-19 have impeded epidemiologic characterization and contributed marked difficulty towards efforts at accurate prognostication of future disease behaviors.

Many contemporary infectious disease models rely on the S-I-R (susceptibility, infection, removed or resistant) population transmission-based framework. However, this approach, which utilizes a multitude of assumed variables and draws data from highly divergent sources, has received prominent criticism over predictive inaccuracies skewing both positive and negative in trend [3,4]. In combination with computational challenges associable to estimating the atypical real-time development of COVID-19, significant concerns have been raised regarding data integrity when collected at a macroscopic level, both in terms of accuracy for reported figures [5] between contrasting sources (i.e. separate agencies) as well as differing national-to-international classifications for what constitutes a positive COVID-19 identification [6]. More involved attempts to model the projected influence of changing population dynamics as well as quarantine measures, as operationalized through SUQC (susceptible, unquarantined infected, quarantined infected, confirmed infected) models, have likewise noted significant variation in data veracity, which has reduced predictive value even within a weekly timeframe [7,8]. Therefore, it is the position of this paper that accurate prediction modelling of COVID-19 disease progression at a community level in an upcoming weeks-to-month timeframe is best achieved at a local rather than macroscopic level, be built upon reliable data sources of observed COVID-19 patterns, and be adaptable to fluctuating inputs that change with management, contextualizing that pandemic processes will likely occur non-linearly and with imperfect (and difficult to express via singular-entity variables) causal relationships.

2. Methods

Herein a modified vector autoregression (VAR) model based upon daily U.S. county-level public health agency test-positivity rate and mortality data in COVID-19 for the NYC metropolitan area (operationalized through selected diverse, representative counties) is developed with prediction of upcoming regional disease patterns given late July 2020 disease control status as well comprehensive data encompassing past local caseload patterns (March 8 to July 23, 2020). VAR modelling attempts to quantify interrelationships wherein two or more time-dependent series are collectively impactful upon observable trends, wherein all referenced variables are treated as being endogenous (y, dependent), rather than necessitating fundamental independent (x) assumptions, as might be appreciated in S-I-R

projections. Reliable county level COVID-19 morbidity data was derived from governmental sources in the New York metropolitan area comprising of seven designated major counties within New York State (NYS) of noted COVID-19 burden (New York, Bronx, Rockland, Nassau, Queens, Westchester, Kings respectively; specific county data inputs available as supplemental material) and exported to classification on a daily continuum. Per protocol vector autoregression (VAR) of the filtered dataset was then conducted, sequentially in seven repetitions utilizing each individual county progression as the dependent (y) variable. Subsequently, one through three day lagged values were used as the independent variable matrix inside the encompassing VAR framework.

VAR modelling for each county was identified using a backward stepwise regression approach, applied to identify the final regression equation using a validated Akaike Information Criteria (AIC) methodology. AIC represents an estimator of out-of-sample prediction error that quantifies the amount of information lost by using the model to approximate an underlying series (the true daily COVID-19 new caseload). That is, it signifies juxtaposition of the error created by using a specific model against the actual data. The lesser the degree of information loss therefore, the better a trialed model is valued. AIC was used in this manner to sort through and quality-control the entirety of possible county-specific VAR models, relative to each of all alternative models under logical consideration. This process was done in the R project software, using the "olsrr: Tools for Building OLS Regression Models" package for procedures. As per the cited backward regression methodology, model analysis started with the full matrix of all lagged variables and then an AIC value was calculated for each variable. Variables that did not meet AIC criteria were iteratively dropped, until a final set of perceived best-representative regression variables, that all met AIC criterion, for county-wide COVID-19 caseload projections resulted. As reference, the initial equation for New York County is shown below.

The equation in general form (variables interchangeable by individual county):

$$NY_t = \alpha + \sum_{j=1}^{3} \beta 1_j B_{t-j} + \sum_{l=1}^{3} \beta 2_l K_{t-l} + \sum_{m=1}^{3} \beta 3_m N_{t-m} + \sum_{n=1}^{3} \beta 4_n NY_{t-n} + \sum_{p=1}^{3} \beta 5_p Q_{t-p} + \sum_{s=1}^{3} \beta 6_s R_{t-s} + \sum_{u=1}^{3} \beta 7_s W_{t-s} + \varepsilon_t \quad (1)$$

wherein:

α = Intercept
$\beta 1, \beta 2, \beta 3, \beta 4, \beta 5, \beta 6, \beta 7$ = Regression coefficients
B = Bronx County COVID cases
K = Kings County COVID cases
N = Nassau County COVID cases

NY = New York County COVID cases
Q = Queens County COVID cases
R = Rockland County COVID cases
W = Westchester County COVID cases
$\mathcal{E}_t$ = Regression error term
t = Time subscript
j, l, m, n, p, s, u = individual counting subscripts for lags

A representative implementation of output model selection for New York County follows:

$$< NY_t > = 1.14716 + < 0.15238B_{t-1} > - < 0.26944K_{t-2} > + < 0.19612N_{t-1} > + < 0.53047NY_{t-1} > + < 0.17727NY_{t-3} > - < 0.14725Q_{t-2} > + < 0.15276R_{t-1} > - < 0.10518R_{t-2} > + < 0.24493W_{t-2} > - < 0.10089W_{t-3} >$$

wherein variables are as defined previously, and < xt > represents the expected value operator for new COVID cases in the county of reference (here New York county) at time t.

The described AIC analysis sequence was stopped when the backward process indicated that an optimal solution (model) had been reached, in that the latest attained AIC value (minimization of regression variance) exists less than all other possible candidate values. Translationally, the determined endpoint therefore indicates statistically that remaining independent variables correspond to the best predictors of disease progression for the input county data per the criterion. Modelling was performed by log of cases rather than raw caseloads, followed by translation into raw daily future caseload projections. This decision derives from the fact that in tracking available COVID-19 data historically, the distribution of new cases generally followed a lognormal distribution more closely than it did a normal distribution. All resultant equations were utilized to forecast predicted disease progression in the 7 counties (AIC-selected county regression models, available as supplemental data). County oneday and multi-day ahead forecasts of daily caseloads were generated from best-fit VAR models.

Statistical determination of strength of prediction and association between VAR model projected values to observed quantities was the primary outcome of analysis in the present study. A one-step ahead projection was first examined to quantify goodness-of-fit for the VAR model to represent existing COVID trends. To establish longer-term prediction power for this model, an approximately 11-week (from latest date of model adjustment on July 23 forecasting to October 9, 2020) simulation was performed following for all 7 incorporated study counties (sample New York and Nassau County projections demonstrated in Figures 1–2, counterpart projections for other counties and comprehensive raw projection outputs available as supplemental Figures 3–6). Following evaluation of derivative findings, critical examination of model implications alongside relevant strengths and limitations was

offered (see Discussion).

3. Results

Correlation between predicted and observed COVID-19 new case values proved consistently significant at one-day-ahead predictions given latest daily caseload data ($p < 0.001$ all counties between March 8, 2020 to July 23, 2020), indicative of a high degree of model accountability for the multifactorial influences which have moderated COVID-19 caseload changes from the onset of pandemic spread (and data availability) to present. By assessment therefore of both past caseload and present disease status representation, the AIC-driven modified VAR model described presently was deemed appropriately representative of disease evolutions to-date and by extension thusly appropriate for extrapolation of future COVID-19 potentiality.

Having established model fidelity (based upon daily COVID-19 new case reports thru July 23, 2020 across the included jurisdiction of interest), wider prediction of caseloads beyond one-step ahead assessment was performed, likewise independently for each county dataset. Herein estimates on daily new COVID+ case incidence was generalized to 11 weeks into the future (to October 9, 2020), again utilizing the latest modified VAR regression per-county based on July 23, 2020 input figures. Examination of this model's expectations for disease progression across a 10 to 11 week (from July 23, 2020 onwards) for the greater NYC region revealed relatively consistent, gradual increases in COVID-19 prevalence across all seven counties of interest. Average percentage of predicted daily case growth from July 23 to October 9, 2020 ranged from approximately 75% to 135% between counties, a significant although less distinct acceleration as compared to numerous locales nationally or periods of rapid disease transmission in the same NYC metro region during preceding months of 2020. Demonstration of county-specific projected versus observed COVID caseloads for Nassau County and New York county (Manhattan) are demonstrated in Figures 1 and 2 respectively, wherein the modified VAR projection was able to relatively consistently demonstrate expected new daily case quantities at one-step-ahead based on existing data influence on the county-specific models throughout the duration of the 11-week ahead period of prediction; all other county projections are included in supplemental Figures 3–6.

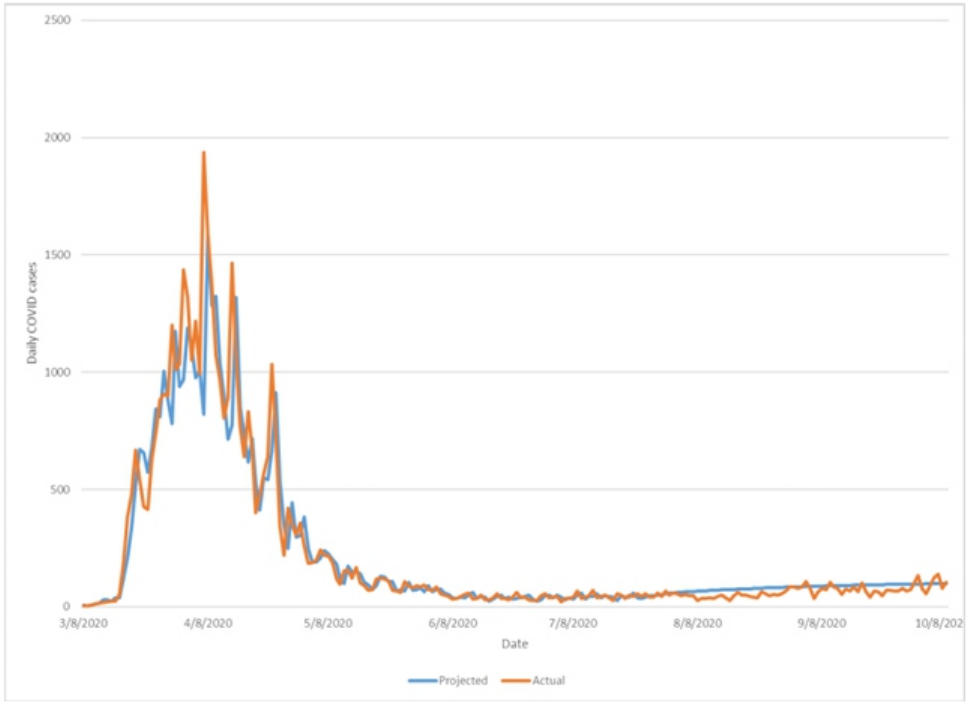

Figure 1. Multi-step (11 weeks) ahead comparison of projected upcoming daily COVID-19 caseloads against observed new daily cases of Nassau county-wide COVID+.

As depicted in Figure 1 (Nassau sample), based on COVID-19 containment status and case progression in Nassau County (and similarly across all seven examined counties in this study) from the onset of COVID community spread in early March through late July, the VAR projected rate of future caseload anticipated relatively stable, small-amplitude increases across the upcoming 11-week predictive timeframe. By illustration, in contrast to the lowest daily new cases of 26 persons noted June 28, 2020 (smallest quantity recorded since March 12, 2020, during the earliest stages of community COVID-19 outbreak in the NYC region), a proposed VAR model for Nassau County suggested that by October 9, 2020 daily caseload would likely rebound to approximately 105 or more positive cases per day. Upon retrospective comparison of the actual recorded COVID+ daily values to those projected, strength of predictive correlation remained high, with error rate of new daily test positives in Nassau county minimized at an average of roughly 22 patients for the entirety of the 11week prediction period from July 23 to October 9, 2020 (Table 1). This measured uncertainty also did not increase throughout the timeframe of projection (as dates of estimation became further in future from time of modelling).

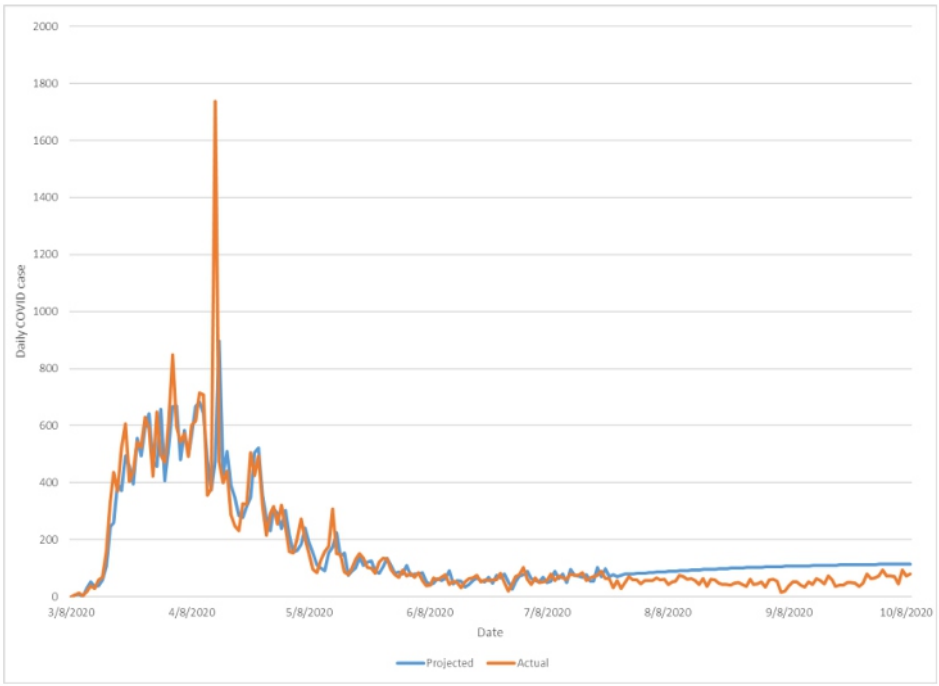

Figure 2. Multi-step (11 weeks) ahead comparison of projected upcoming daily COVID-19 caseloads against observed new daily cases of New York county-wide COVID+.

Similar projective extrapolation as modelled by the VAR function upon 7/23/2020 caseload data for New York county is demonstrated in Figure 2, and all other county models are shown in supplemental materials as aforementioned. New York County VAR-estimated to actual daily caseloads exhibited a comparable average error of approximately 46 patients per day countywide, comparable to both the Nassau findings described previously as well as all other county samples (error range of 20 to 90 patients per county per day; see Table 1). For all analyzed counties in this study furthermore, the out-of-sample (11-weeks prediction) error from subsequently observed was similar if slightly smaller than in-sample (VAR representation of past and current data used for projection, 3/8–7/23/2020) which intuitively suggests that at an 11-week frame of projection the current VAR model for the 7 presently selected NYC metropolitan counties was able to accurately correlate future forecasts with existing community data.

Table 1. Multi-step predictive VAR model mean absolute error (MAE) of daily COVID-19 cases across select NYC metro counties.

MAE	Bronx	Kings	Nassau	New York	Queens	Rockland	Westchester
In Sample	72.04	96.10	65.78	48.03	109.27	31.86	62.03
Out of Sample	67.72	71.17	21.81	46.36	88.79	23.54	34.36
Total	70.48	87.10	49.90	47.43	101.87	28.86	52.04

Table 1 Mean absolute error of daily predicted COVID-19 positive caseloads per county by modified VAR regression. Note error levels are separated by in-sample (VAR representation of past and current case trends through 7/23/2020) and out-of-sample (future projections from 7/2310/09/2020). MAE units of measurement as demonstrated is individual patients (persons).

Of note, wherein the sampled NYC region data over the period of VAR analysis has relatively reliably progressed within relatively small magnitudes of caseload variation, the capacity for this VAR model's "shock"-predicting capacity (commonly utilized in econometrics to predict market response to individual events) relative to exponential real-time case increases as in Florida or Texas, could not be efficaciously evaluated. A new case data outlier recorded on April 14, 2020 (1737 cases) resulting from inclusion of previously uncounted presumed COVID positives (owing to changes to data classification guidelines by the CDC and NY State Department of Health) provides only a very limited amount of insight towards this consideration given the limited sample size (including one-day duration) and extenuating data spike circumstances (case allocation reclassification). With wider available data and empirical course of COVID-19 community transmission however, the strong expectation persists that adapted VAR impulse-response evolution estimates may well concurrently provide a moderately accurate accommodation of periods of either rapid growth or decay in regional COVID-19 new identifications incidence. Empirical quantification of VAR model adjustment from extreme trends of epidemiological data alteration therefore requires further investigation and follow-up.

4. Discussion

This paper proposes that COVID-19 community containment and modeling may be best represented at a local or regional level, given persistent uncertainties regarding data quality and reliability at national and global scale. Furthermore, the study develops a modified VAR-based predictive representation based on New York City metropolitan area (7 NYS counties) disease data from July-through-October at the county level, in order to demonstrate prospective near- and mediumterm epidemiological trends for COVID-19 cases. Note that the presently proposed model has been built with a minimum of distributional assumptions (inferences on either variable interrelationships or resultant caseload outcomes), allowing any results to closely mirror observable empiric trends [9]. Moreover, a VAR foundation is useful in examining the dynamic effects of each variable on all others simultaneously [10]. Across incorporated datasets across major NYC regions subjected to VAR analysis, the modified VAR model suggested that under late July 2020 containment status and continued maintenance of local management measures (data available to the VAR system at the time of predictive modelling) COVID-19 cases would expect to rebound in daily incidence, although at a less marked (or unsustainable) pattern as seen in numerous other regions of the United States. Through comparison of actually recorded subsequent caseload figures over the NYC metropolitan region over a following 11-week period (until October 9, 2020), the accuracy of VAR projections at caseloads at such a projective timeframe proved generally accurate (Figures 1–2) with average error in expected versus actual daily COVID cases falling approximately between 20 to 90 patients per county per day (Table 1, out-of-sample error). Considering

that U.S. management strategy of COVID-19 has centered around reduction of peak disease burden to a systemically manageable level rather than systematic viral eradication [11], evidence proposed presently would suggest that the greater NYC region remains amongst few counterparts currently close to meeting such expectations of temporally-dispersed and manageable COVID case burdens upon local healthcare infrastructure. However, as has been observed across both the U.S. as well as numerous countries globally, changing community containment stringency as well as seasonal population patterns may considerably exacerbate case progression beyond what has been projected by this model herein.

A modified VAR model carries marked regression capacity of representing observed caseload patterns alongside generally significant predictive value for estimation of new COVID-19 cases as shown by an analysis of NYC metropolitan county data from the period of July 23 (latest date of data entry and by association model adjustment) to October 9, 2020. This functionality and efficacy denotes a significant improvement upon both prospective and retrospective accuracy reached by numerous mainstream state- and national-level models founded upon variations of S-I-R epidemiologic interactions [12,13], and as such may be utilized to better prepare regional public health and medical resources for expected immediate-term changes to new case patterns. In context of this model's mean daily COVID caseload error of between 50 to 100 individuals per county, this variability in the authors' opinion represents a practically manageable level of uncertainty at the county scale (unlikely to cause sudden, unexpected medical resource strain).

Furthermore, given literature which has noted that a major challenge to accurate prediction of pandemic modeling at a macroscopic level derives at least partially from inherent differences between diverse populations [14,15], a past-data driven model such as that currently described may prove more applicable to individualized regional disease patterns in terms of predicting upcoming development since it amalgamates rather than reduces influential epidemiological influences impactful upon overall observed disease patterns. Concurrently, wherein across S-I-R models multiple assumptions—essentially independent predictions—have to be made before dependent caseload projections can be obtained, relative to VAR only observed relevant data patterns have the capacity to influence the resultant model's expectations and implications. Moreover, wherein S-I-R type models require at a minimum distinct representations of three separate patient population subclasses, more complex models (i.e. SUQC) predicate even more indirectly upon further assumptions of quarantined patients, mortality, or any number of further uncertain disease properties. By contrast, the present VAR modality requires only empirical caseload data as input, and directly translates this single independent dataset towards forecasting of upcoming new cases; additional error from multiple necessary assumptions or prospective confounding variables is minimized in this VAR implementation. The

authors therefore propose that singular estimation of COVID-19 cases represents an appropriate application for the described model, given dynamism in disease severity and prevalence across socio-demographic boundaries [16,17] difficult to linearly represent through susceptibility variable valuation.

4.1. Public health applications and outlook of VAR-based modelling

S-I-R models are fundamentally parametric and so implicitly assume an S-shaped curve for the life of an outbreak. As shown by previous data from representative NYC metropolitan counties however, observed daily infection counts did not in fact follow a logarithmic or logistic sigmoid regression. Instead, new infections started slowly and grew exponentially (as would be expected with a traditional S-I-R model) but consequent infection quantities declined significantly less precipitously and in a more linear fashion than would be projected by many transmission-variable derived models [18]. Prominently propagated examples of S-I-R constraints in active pandemic modelling can be viewed through the Imperial College London (U.K.) and University of Washington (U.S.) morbidity and mortality projections, each of which demonstrated major inflexibility to changing containment conditions and increased data availability for COVID transmission rates and necessitated frequent (bi-weekly respective to the U.S. model) major corrections to upcoming caseload predictions [19]. At both extremes of S-I-R projection from the Washington U.S. model, total COVID morbidity in the U.S. by late October 2020 was variously estimated in May and July as 4 million and 20 million with significant variability in between. To correct for theorized S-I-R methodologic limitations, this paper utilizes a modified multiple regression analysis to forecast county-by-county (Bronx, Kings, Nassau, New York, Queens, Rockland, and Westchester counties) outbreaks in NYC through autoregressive lagged values as well as lagged values from the counterpart neighboring counties. VAR adaptation in this manner allows the produced model to account for the fact that regional viral dissemination encompasses a function of past cases within individual counties as well as established shifts with neighboring locales, given inevitable dynamism of population movement and disease spread across a macroscopically interconnected geography.

The largely non-parametric COVID projection model discussed in this study is founded upon practices inherent to traditional vector autoregression (VAR) modelling within the field of econometrics. VAR models have been well validated in economic studies wherein intertemporal relationships between variables are hypothesized, a characteristic which implies considerable utility in medicine. In the setting of novel infectious diseases, adaptation of VAR allows for the simultaneous evolution of multiple interconnected yet singularly unquantifiable disease-modifying variables such as disease basic reproduction number (R0), test availability, asymptomatic transmission and population susceptibility

status or degree of social contact over time. It is the position of this paper therefore, that a VAR-based modelling of regional disease patterns carries highly translatable advantages in COVID19 modelling derived from this described allowance for multiple evolving variables. Unlike S-I-R or univariate mechanisms, VAR is not critically driven by assumptions or awareness of the underlying forces that impact variable behavior or patterns. VAR as mentioned represents a nonparametric model, indicating that there is no pre-existing shape assumption made about the disease-progression curve; instead, any visualized curve shape is generated solely based on trends in pre-existing data. This contrasts with the parametric S-I-R model that assumes an S-shaped curve. All predictions are based only specific to the ongoing development of COVID-19 community disease spreads, this quality is critical given that all derivative predictions by VAR are extrapolated from existing variable trends (derived from daily case rate) rather than theorized structural statistical relationships.

4.2. Model limitations

Major constraints in predictive value by this model persist mainly from quality of input data. Considering ongoing uncertainties as to the protective value of COVID-19 antibodies in terms of both efficacy as well as duration of immunity [20,21], unaccounted for variability is introduced through the possibility of a changing susceptible baseline population longitudinally. Furthermore, it remains very difficult to regularly predict upcoming disease patterns based on past data for timeframes greater than a few weeks-to-months in advance given highly volatile quarantine and social distancing measures across most surveyed locations. Whereas the improved reliability for predicting caseload (dependent) outcome shifts given a mature data cycle of COVID-19 outbreak as well as management in the NYC region should improve forecast accuracy as opposed to manual estimation of R0 or further variables, it remains largely impossible to quantify with any confidence what impact longitudinal dynamisms such as virus mutation or previous exposure may introduce. When considering COVID-19 represents arguably the most extensive and bio-statistically confounding global pandemic since the 1918 influenza outbreak, there persists high likelihood that the most productive analysis and shaping of future disease modeling practices will occur at the conclusion of generalized COVID-19 spread, wherein detailed examination of disease predictions via contemporary modelling methodologies may be objectively contrasted against quantifiable longitudinal outcomes.

Viewed from a practical perspective moreover, an inherent limitation to VAR-derived epidemiological modelling lies in the lagging of observed-to-predictive patterns, particularly relevant compromise in the setting of large, sudden data modifications. Specific to COVID-19 and disease dynamics, this is important as salient epidemiologic events such as mass holiday travel or fluctuation viral mutants of

differing infectivity variably exert major impacts upon observable downstream caseloads. By illustration, the need for the model to better adjust future projection expectations at a lagging interval to new system shocks (significant deviations) can be preliminarily observed through the model for Rockland County (Supplemental Figure 6), wherein a period of anticipated gradual COVID-case rise (consistent with trends in the encompassing wider region) has been superseded by a rapid early-October week-long spike in cases. In this instance, the predictive VAR model based on 07/23/2020 expectedly becomes more conservative than reality, and a more accurate VAR revision of projections based upon all caseloads through 10/09/2020 would require trend-establishing data of at least several days in order to modify predicted COVID progression with any degree of validity. One potential solution to this inherent VAR lag limitation could be to independently simulate (by VAR) the past influence of such systemic shocks upon subsequently necessary model adjustments, such that newly introduced large data transformations might be able to be accurately accounted for across future instances with only a minimal period of requisite data input (leading to a more adaptable, dynamic model). As discussed previously however, in the setting of the ongoing COVID-19 crisis and associated uncertainty of disease behaviors (see Results), for the present scenario it appears reasonable that only retrospective analysis of extensive datasets in latter stages of the pandemic would enable such a concurrent VAR error-accounting incorporation.

Prognostic modelling involving mortality projections, a similar measure of interest across pandemic progressions, prove more difficult to quantitatively predict given an even greater quantity of uncertainties than is seen in caseload forecasts. Numerous mainstream S-I-R based models have come under heavy criticism for significant temporal adjustments to expected COVID-19 death toll from over the course of the pandemic progression [22,23], yet meaningful improvement of accuracy in this regard necessitate fundamental shifts in the method and means of epidemiologic disease tracking rather than simple refinement of modelling methodology. A comparable past-trend driven estimate for upcoming mortality rates from the present morbidity model remains unfeasible given wide-ranging uncertainties in vital influencing factors such as incomplete hospital censuses, severity symptomology within hospitalized patients, and a host of incompletely understood genetic-demographic factors which appear to critically moderate COVID-19 prognosis. Perhaps even more articulated in mortality VAR estimates would remain input data integrity, given wildly varying debates in society at present regarding what qualifies as a COVID-19 death as well as noted inconsistencies in timely recording of critical mortality figures. Relative to cumulative COVID-19 deaths and longitudinal incidence then, at present an assumptive variable-driver S-I-R (and derivatives) model would appear the most manageable means for estimation. However, whereas the high variability of input assumptive variables central to this approach was previously discussed in context of caseload projections, herein further uncertainty for more

more complex SUQC model population subclasses concurrently arises.

4.3. Future directions for VAR-based epidemiology

Future directions of development from the currently constructed model may center about using VAR to examine possible delivery mechanism between geographic areas at a wider (i.e. national level), possibly allowing for a more concise predictability regarding warning indicators or at-risk medicosocietal practices influencing disease distribution. By example, we might feasibly gain insight towards a potential returned period of caseload maximization in New York City through VAR analysis of laggedindicators between hypothesized influential demographics (i.e. community socio-ethnic status) or bridging of the urban-rural divide (leading time from urban case development to corresponding rural disease increases) in ongoing hotspots (i.e. metropolitan areas within Florida or Texas as of July 2020). A vigilant, regionally-based monitoring program could therefore quickly identify and potential concerns for community COVID-19 exacerbation or recurrence. Further study of VAR translational value for COVID-19 disease modelling thusly persists in need of model predictive power evaluation between the regional geographic scale illustrated herein, and more macroscopic VAR projections in example at the national level. The upcoming question of public health utility should center on if given robust historical case data, whether VAR-type epidemiologic models will be able to accurately predict population disease progression patterns across larger and more diverse patient or dataset characterizations.

Mathematically, one-to-three days lags of the model variables (relatively short) were chosen with intent to most accurately represent regional disease propagation patterns on a short-term basis, due to a continued state of incomplete understanding regarding COVID-19 and its epidemiologic behaviors. Considering the strong capacity of VAR-founded modelling to account for NYC metro region COVID19 caseload trends, an appropriate next step may involve trialing of longer lag times (i.e. 1–2 weeks) in order to more efficaciously evaluate extended-period (multiple months) predictive power of this VAR model. In contrast to S-I-R projections wherein predictive uncertainty rises exponentially with increasingly long-term projection, a validated VAR forecast might reasonably be expected to minimize degree of probable variability given that constituent long-term outlooks are based on similarly extended lag-values (extensive past COVID-19 case patterns) rather than parametric extrapolation of static variables made at a singular timepoint.

5. Conclusions

According to extensively updated reviews, a significant proportion of previous and ongoing modeling

efforts related to COVID-19 are significantly constrained by poor input data quality and inflexible guiding parameters. The current study develops a county-based VAR model derivative from infection data reported in the greater NYC metropolitan area, which demonstrates significantly improved correlation between projected and observed new cases, with promising predictive value at the short (days-to-weeks) to intermediate-term (months) regional level. Furthermore, as described previously the data-driven VAR approach as adapted in this framework remains of greater statistical reliability than assumed dynamics in S-I-R projections, given that all derived inferences built upon the significant quantity of COVID-19 progression data at a local level to-date; this functionality allows for greater tailoring to alternative projections in counterpart geographies or disease settings whilst minimizing quantity of necessary assumptions as long as there exists a robust source of input raw COVID-19 caseload measurements. In example, wherein major increases for New York and comparable U.S. metropolitan areas were separated by significant temporal distribution (March and April versus current June and July respectively), significant similarities in affected population [24] and epidemiologic patterns [25] have been noted between the regions. It would therefore stand to reason that the present modified VAR regression of the initial NYC outbreak of COVID-19 may be not only prove highly applicable to any consequent recurrence in the same geography, but also adaptable to many alternative regions of interest since the currently implemented basis of projection and AIC selection is wholly founded upon disease data available via public records.

It has been well reported in literature that models founded upon estimations of population status relative to disease require significant extrapolation of disease behaviors and epidemiological statistics which may not be appropriate for poorly understood emergent pandemics. Via construction of an adapted VAR extrapolative model which accounts for past patterns of COVID-19 disease trends instead of theoretical representations of pandemic spreading, this paper proposes that existing data-driven estimations of viral dissemination carry significant utility for the real-time projection of regional disease futures. Relative to the ongoing escalation of COVID-19 caseload in many U.S. states, this model was able to predict the gradual increase in COVID cases in the NYC metropolitan region with relative accuracy for a projective period of up to 11-weeks, a highly practical utility especially for information of healthcare infrastructure readiness as well as local public policy related to continued disease containment goals.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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COVID-19 restrictions: experiences of immigrant parents in Toronto

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ABSTRACT

Parenting is a demanding undertaking, requiring continuous vigilance to ensure children's emotional, physical, and spiritual well-being. It has become even more challenging in the context of COVID-19 restrictions that have led to drastic changes in family life. Based on the results of a qualitative interpretive descriptive study that aimed to understand the experiences of immigrants living in apartment buildings in the Greater Toronto Area, Ontario, Canada, this paper reports the experiences of 50 immigrant parents. During the summer and fall of 2020, semi-structured interviews were conducted by phone or virtually, audio-recorded, then translated and transcribed. The transcripts were analyzed using thematic analysis. Results revealed that parenting experiences during the pandemic entailed dealing with changing relationships, coping with added burdens and pressures, living in persistent fear and anxiety, and rethinking lifestyles and habits. Amid these changes and challenges, some parents managed to create opportunities for their children to improve their diet, take a break from their rushed lives, get in touch with their cultural and linguistic backgrounds, and spend more quality time with their family. While immigrant parents exhibit remarkable resilience in dealing with the pandemic-related meso and macro-levels restrictions, funding and programs are urgently needed to support them in addressing the impact of these at the micro level.

Keywords: *Canada; coronavirus; COVID-19; immigrant; parenting; physical distancing*

1. Introduction

Being a parent is a rewarding yet stressful experience involving multiple demands. In 2020, parents around the world encountered one of the most difficult challenges to date, the COVID-19 pandemic caused by the rapid transmission of SARS-CoV-2, a new strain of coronavirus. Early in the pandemic in February to March 2020, the Canadian federal government announced physical distancing measures that corresponded to those outlined by the World Health Organization. These measures required families to refrain from having contact with those who did not reside in the same household, and to maintain a physical distance of at least two metres from one another indoors and outdoors. Many jobs were lost, homes became workplaces, brick and mortar schools turned into virtual schools, childcare facilities were closed, and families were confined to their homes. School closures forced children to stay at home 24 hours a day, 7 days a week, and to study at home under the supervision of parents while being physically isolated from their peers, friends, extended family members, and neighbours. Parents who lost their jobs

were unable to access paid educational and support services. News and social media have featured many of these parental struggles but thus far, there has not been any published research on the parenting experience among immigrants in Canada that documents these challenges and the responses to them. This paper explores the COVID-19 related changes and challenges experienced by immigrant parents in the Greater Toronto Area of Ontario Canada.

Past research has identified numerous factors associated with parental stress and burnout including parental unemployment, financial insecurity, low levels of social support, and a lack of leisure time [1,2]. Responses to the pandemic including lockdowns, cancelled services, and other public health measures have magnified many of these stressors. Emerging research has identified the emotional and practical demands of working at home (and at times longer than usual hours), childrearing for 24 hours a day, 7 days a week, restriction of access to public spaces, and balancing the demands of paid employment with the increased responsibilities from having children at home [3]. Studies from countries such as Singapore show that the extreme financial and health insecurity, along with physical and social isolation because of COVID-19, can increase tensions in the home environment [4]. Many parents are finding it extremely difficult to secure time for themselves and to achieve balance between their personal, professional, and parental roles and responsibilities [1].

Recent evidence also reveals the gendered effects of challenges and stressors associated with the pandemic, which are disproportionately experienced by mothers [5,6]. During the first month of the lockdown, for example, women in the United Kingdom spent on average two-thirds more time childcare responsibilities than men; in addition, mothers were interrupted much more often than fathers, greatly affecting their ability to work from home during the pandemic [3]. The requirement to stay at home affected mothers' independence, skill acquisition, and feeling of purpose often associated with paid employment outside the home, resulting in isolation, suffocation, boredom, and feelings of oppression and imprisonment [3].

Emerging research also indicates that the pandemic has exacerbated not only gendered inequalities but also existing social, financial, cultural, and racial inequalities [3,7]. Racialized (i.e., visible minorities or people of color) and under-resourced immigrant families are most likely to face the heaviest burden from COVID-19 [8,7]. They are most likely to experience financial insecurity and least likely to live in homes with access to backyards for their children or to be afforded the flexibility to work from home or the option to travel to work by car or via public transportation at less-crowded times. Racialized immigrants, in particular, are over-represented among the groups of essential workers in jobs that require direct contact with people or involve precarious conditions [7]. These challenges add stress to immigrant

parents and their families. Additionally, regulations related to COVID-19 have meant that vital sources of informal and formal support that many immigrant families rely on, such as translation support and services, have been restricted or taken away entirely, thus increasing their risk of stress and burnout [8].

1.1. Study purpose

This paper focuses on the COVID-19 related changes and challenges experienced by immigrant parents living in apartment buildings in the Greater Toronto Area of Ontario Canada. It is based on a larger study that aimed to capture, from the points of view of immigrants living in apartment buildings, the physical-distancing challenges they faced and the successful strategies they used to maintain social connectedness during the COVID-19 pandemic.

2. Materials and methods

2.1. Theoretical approach

Our study was informed by an ecosystemic framework [9], which can help clarify how individuals are influenced by micro- (family), meso- (community), and macro- (society) level factors. Understanding the individual experiences and responses of immigrant parents to the pandemic must consider the multilayered systems that create inequity and inequality in basic need areas such as housing, employment, healthcare, and transportation that affect them [10]. For example, during the first six months (summer and fall of 2020) of the COVID-19 pandemic in Canada, meso- and macrolevel factors and policymakers were primarily responsible for shaping decision-making surrounding COVID-19 restrictions such as school and workplace closures, which were then expected to be implemented by individuals and families. The ecosystemic framework helped reveal how some individuals and families have been disproportionately affected [10] by the COVID-19 restrictions related challenges of parenting during the pandemic.

2.2. Study design

This paper is based on a larger study that sought to capture how apartment-dwelling immigrants are affected by the pandemic, and the meso-level factors such as neighbourhood and city contexts and macrolevels factors such as provincial and federal guidelines related to the pandemic. The study used a qualitative interpretive descriptive method [11], which is widely applied to find practical solutions to real-life problems. This method also allows for flexible inquiry into the experiences of individuals

[11–13]. Consistent with the principles of community-based research, the overall study design, including guidance for culturally, linguistically, and contextually appropriate approaches for pursuing participant recruitment, specification of the interview questions, seeking of informed consent, provision of honoraria, and conduct of interviews, was done in collaboration with our community partners, who have a deep understanding of the interests, concerns, and needs of immigrant communities.

After obtaining approval from the Ryerson Research Ethics Board (REB#2020-179), a purposeful sample of immigrants aged 18 years or older and living in apartment buildings in the Greater Toronto Area was recruited via word of mouth, email, social media, and through our connections in the city and with community partners who work with immigrants. Potential participants contacted (or were contacted by) the research assistants (RAs) to learn more about the study. Those interested in participating were provided a copy of the consent form prior to the interview. They were given the option to complete and return it to the RA prior to the interview or provide verbal consent at the time of the interview. Individual interviews were conducted between May and September 2020 on the phone or using a virtual platform (e.g., Zoom, Skype). Participants who did not have access to such technology were excluded.

Participants were interviewed using semi-structured interview questions that explored their experiences of the changes and challenges in their life related to the physical distancing measures, how they are coping with these changes and challenges, and the successful strategies used to maintain social connectedness. The interview questions were developed in consultations with our community partners. Interviews lasted about 30–45 minutes, on average. An honorarium ($30) was given to each person in consideration of their time in participating in the study.

Interviews were conducted in each participant's language of preference (e.g., Urdu, Spanish, Korean, and Arabic), by bilingual RAs. All interviews were audio-recorded with consent. Interviews conducted in a language other than English were translated into English and transcribed by the RA who conducted the interview. The interviews conducted in English were transcribed by an RA on the research team. Transcripts were read paragraph by paragraph, and coded by three members of the team to establish a coding system. After interviews were fully coded another iteration of analysis ensued with the help of several other team members to compare and contrast codes and to develop similar ideas into subthemes and themes, using thematic analysis [14].

Trustworthiness of the study was ensured through several strategies including interviewer triangulation (interviews were conducted by several interviewers); interviews conducted in different languages (to

gain a broader and more comprehensive understanding of the topic by capturing opinions of participants of diverse ethnocultural and linguistic backgrounds); member-checking (with each participant during her/his interview, and with other study participants during subsequent interviews); and seeking community partners' feedback and reactions to the results and the interpretations of the results.

2.3. Study participants

In total, 72 immigrants participated in the larger study. Of these 50 participants were parents who are the focus of this paper. Of the 50 immigrant parents, the majority (n = 44; 88%) were mothers. Their ages ranged from 26 to 77 years, and most (n = 36; 78%) had two or more children. They described living in difficult conditions marked by confined and overcrowded apartments in high-rise buildings (n = 45) or subsidized housing (n = 5). About 40% of the participants had been in Canada for less than 10 years. Most reported experiencing financial insecurity due to unemployment—from before COVID-19 or as a result of the pandemic—or having only one partner trying to support the entire family by working in a low-income job. Table 1 provides additional demographic information.

Table 1. Socio-demographic characteristics of participants (n = 50).

	N	%
Gender		
Men	6	12
Women	44	88
Age		
26–35	9	18
36–45	12	24
46–55	12	24
>55	11	22.
no response	6	12
Number of children		
1	13	26
2	22	44
3–5	15	30
Number of people residing in household		
1–3	27	54
4–6	19	38
7+	4	8
People living in the same house		
Children only	13	26
Spouse only	6	12
Children and spouse	28	56
Spouse, son, and daughter-in-law	2	4
Other	1	2
Year of arrival to Canada		

Before 1985	2	4
1985–1994	6	12
1995–2004	15	30
2005–2014	11	22
After 2014	16	32
Country of origin		
China	8	16
Pakistan	8	16
Bangladesh	6	12
Afghanistan	5	10
South Korea	4	8
Syria	4	8
India	3	6
Sri Lanka	3	6
Czech Republic	2	4
Philippines	2	4
Iraq	1	2
Nigeria	1	2
Russia	1	2
Slovakia	1	2
Somalia	1	2
	N	%
Current status in Canada		
Canadian citizen	35	70
Permanent resident	15	30
Work status		
Did not work before COVID-19	27	54
Stopped working because of COVID-19	11	22
Currently working from home	6	12
Currently working as essential worker	4	8
Retired	1	2
Maternity leave	1	2

3. Results

Parenting has changed during COVID-19 in terms of parenting roles, responsibilities, and expectations. The following sections explore how immigrant parents experienced changes related to: dealing with changing relationships, coping with added burdens and pressures, living in persistent fear and anxiety, and rethinking lifestyles and habits.

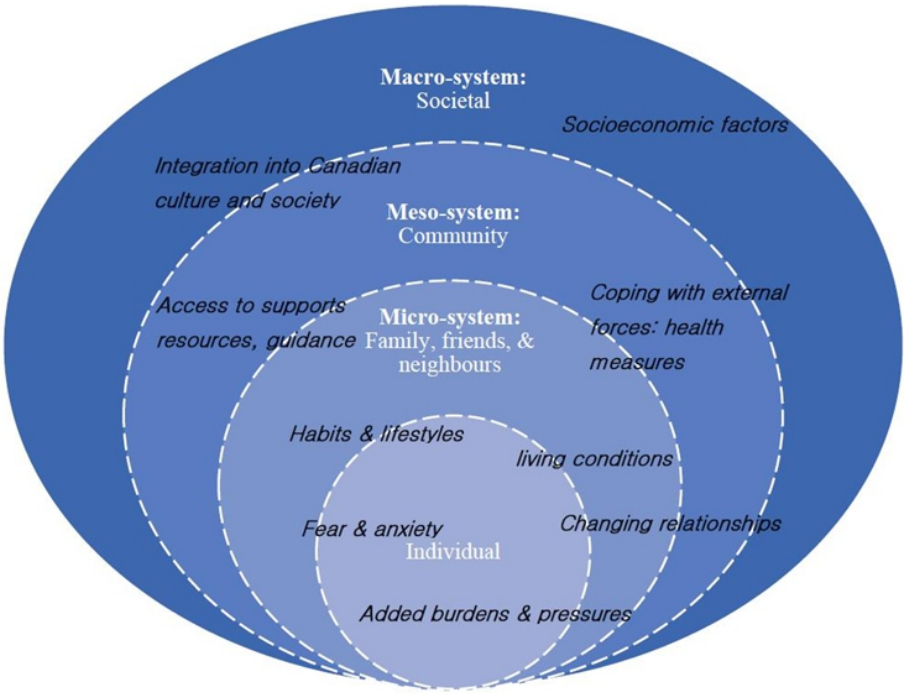

Figure 1. Parenting experience depicted using the ecosystemic framework.

3.1. Dealing with changing relationships

Participants reported that COVID-19 regulations of maintaining physical distancing changed family cohesion. Some reported a diminished sense of closeness within the family. For example, a father explained, "Physical distancing is a good thing to follow but it has separated us from our loved ones". In contrast, some parents viewed having their children at home all the time as an opportunity to become closer and spend quality time with them:

"I spend time with them, and I relate to their experiences more now."
"As a single mother, I have always been close to my daughter. During the pandemic, we do more activities like tea parties, so we feel even more connected. Before [the pandemic] it was go, go, go all the time."
Some participants said that their children appreciated the extra time spent with their parents. For some parents, this provided a chance to connect their children to their cultural and linguistic roots: "My children loved having me home all the time, and we watched Korean dramas on Netflix together so that I could teach my children about the Korean history and culture."

Although they were worried about the pandemic, most parents demonstrated resilience and optimism. Some referred to growth in terms of parent-child relationships:
"During heated arguments while living and spending so much time together in a confined space, we

learned to resolve arguments more diplomatically as we are stuck together instead of walking away or remaining bitter and resentful."

"Being able to stay home with my family and give my child and husband time was a positive experience for me."

However, some explained that spousal relationships, now lacking social and cultural supports combined with the inability to freely go outdoors, were negatively affected. Some participants noted that they had a designated spouse who went to work, and did grocery shopping and other "outside" activities such as going to the post office or taking garbage to the bins outside the apartment building, all of which potentially put them in closer proximity to others. Because of safety concerns for the rest of the family, this spouse was relegated to a different room in the apartment for periods as long as 4 to 6 months, a situation that created tensions between spouses, which, in turn, were noted as affecting their parenting styles.

3.2. Coping with added burdens and pressures

The closure of schools and childcare facilities placed sudden and enormous pressure on parents, especially mothers, to be fulltime parents, spouses, caregivers, and in some cases, full or part-time employees. The majority of mothers had no respite from any of these roles, responsibilities, and expectations:

"When kids were in school I had time for myself but not anymore and I have to deal with pressure from children all the time."

"There are many changes in our lifestyle, all my family works from home, so I am busy a lot now, catering to them all the time and no time for myself."

Some participants noted that the burden of being a mother and wife was magnified as they tried to maintain a "normal" home environment for children (and others) who are also constrained at home with each other often in small apartments for months. The participants noted that they had to be available to "entertain" or spend time with their children most of the time. Some participants remarked that they spent "every waking moment" thinking about and planning activities for their children that could take place within their small apartments to keep them busy. Participants who continued to work during the pandemic found this to be an impossible task.

A major burden identified by respondents that placed enormous pressure on them was related to the quality of their children's education during the pandemic. Due to physical distancing regulations implemented by the Canadian authorities, schools rapidly shifted to an online virtual format. Living in crowded apartments and sharing one computer was common and problematic for families with multiple school-aged children. In total, 75% of the participants had two or more children; 30% had three or more children. Some families did not have enough bandwidth to have multiple Zoom (Zoom Video Communications, a commonly used internet platform) classes and meetings at the same time. In addition, some parents did not speak English at all or sufficiently well enough to help their children learn. Others lacked computer or academic literacy to assist their children with virtual learning. Overall, most parents expressed difficulties in managing the various virtual learning expectations of the school boards, and the challenges were exacerbated for those with multiple children.

The perception that quality of education was compromised contributed to the cumulative stress of parenting. Many felt that online schooling was inadequate and that schools were inadequatelyprepared. As a result, participants felt obligated to fulfill the double burden of serving as a teacher and parent—without appropriate support or preparation. One mother said:

"My children's schooling became a priority over everything else. This took up most of my time and energy."

Not only did most participants believe that in-person schooling is more effective for student learning, but managing their children's disappointment of missing being in school and seeing their friends added to the challenging day-to-day tasks of parenting. Additionally, some participants had come to Canada in hopes of providing their children with better education. They saw the move to virtual learning as limiting their children's opportunities, for example, for developing English proficiency and becoming familiar with Canadian customs by interacting with peers. One mother reported that she had relied on a childcare facility to improve her son's English language skills: "My son does not speak much English. He is two years old, but all daycares are closed." Overall, our study participants found the changes to their children's education to be extremely stressful and a hindrance to promoting their integration into Canadian mainstream culture.

3.3. Living with persistent fear and anxiety

Some participants said that living through the pandemic meant living with persistent fear, especially regarding their children's fate. One mother said, "I am scared for my children, for my children's future. We don't know what's going to happen. It's draining me mentally." Overall, parents felt it necessary to continuously remind children about physical distancing, and expressed constant anxiety because their children could not remember or abide by the specific safety expectations and strategies. As one father said "Taking care of a toddler is more difficult because they do not understand the situation." Mothers, in particular, felt that they had to be constantly vigilant, which they found mentally and physically exhausting. Some were frustrated that their children did not always adhere to public health measures to protect themselves from COVID-19, but they were also aware of the absurd expectations being placed on young children. Some commented about these "no-win" circumstances. For example, one mother told us:

ometimes I don't even know what to do. I can't scold them or yell at them. Look at the situation. You see so many people getting infected everyday. When you go out, you're scared of getting the germs. When you don't go out, you're scared they're going to go crazy from being trapped or become unhealthy."

Children's health, and particularly their mental health, was a relentless concern for parents who were worried that their children's mental health would "deteriorate" and that lockdown could have "negative impacts in their future." As one mother told us:

"My child can't go outside and often feels depressed staying inside as she loves being around people. I worry that this maybe affecting her developmentally, as my child is very young and this age needs socialization and exploring the outside environment."

While acknowledging the importance of technology in keeping their children occupied, connected, and learning, all participants referred to being "very worried" about children's "constant" use of technology during the lockdown, and the potential negative consequences that this could have on their physical health as well. Having to use Zoom or Skype or other platforms for virtual schooling added to this worry. The following quote from a mother captured the reality expressed by all parents: "Kids are home and using electronic devices all the time, it's very hard to make them do physical activities and keep them occupied."

Many questioned the impact that 8 to 10 or more hours of long-term exposure to electronic devices on their children's eyesight, hearing, and brain. These fears are heightened for some because of the immigration context of their lives in Canada. One mother explained:

"I often feel scared that my child will become sick and if so as a first-generation immigrant to Canada I don't think I have enough support to take care of her."

Overall, parents were anxious and afraid about the uncertainty surrounding the pandemic and related restrictions, and their short- and long-term physical, mental, and emotional health consequences on their children.

3.4. Rethinking lifestyles and habits

Parents noted that their lifestyles and daily habits had changed due to the pandemic. Some of these changes are captured in the excerpts below:

"Sleeping habits are a big challenge. My daughter used to go to sleep around 7 or 8 pm. And then she wakes up at 6 or 7. But that has changed for her (…) so I sleep at 1 or 2 am. She still wakes up early. So her sleep is affected and my sleep is affected."

A single mother noted that she had to leave her kids at home alone at times because when she did take them with her on errands (e.g., grocery shopping) she received negative "looks or comments from other people in the store." Due to COVID-19 restrictions, she could not seek help from her other family members, neighbours, or friends who provided such help prior to the pandemic.

Some participants commented on the impact of the COVID-19 restrictions on their daily activities and habits that kept their food and other expenses at a manageable level. As one participant explained:

"I cannot shop around for bargains anymore because I don't want to stay in long lineups or take the bus or the subway because I am worried about spending too much time around other people and…and getting the virus. Some people are not wearing masks and don't do social distancing." These changes have financial consequences on their lives. Other changes to their habits included the extra precautions that they took when interacting with their children:

"When my husband goes outside even for a little while and comes home, I make him take a shower before bringing our child near him."

"Although me and my daughter would still eat together, we each use different plates and other tableware."

More drastic changes to their lives included decisions parents made about their own work and education. One participant noted being afraid of going back to work: "I worry about infecting my daughter if I were

to go back to work." While another noted that her husband had "dropped out of college to take care of our kids."

Despite the added stressors that many of these changes added, not all changes were perceived negatively. Some parents referred to positive changes such as improved family dynamics: "Our life has changed totally, before the pandemic life was very busy everything seemed [to be] going very fast and there was a lot to do, but now the whole family has to stay home, and things have slowed down considerably."

"I made healthy meals for my family and home schooled two of my three children. I created a daily routine for them to follow, which included regular walks in the park nearby." Some of these participants even wondered whether these changes could be maintained if and when life returns to "normal".

4. Discussion and implications

Our findings provide insights into the parenting experiences of immigrants during COVID-19. At the beginning of the pandemic (March 2020), public health guidelines rapidly and frequently changed as new knowledge emerged, leading to changes in federal, provincial, and municipal level health, education, and economic policies that understandably exacerbated public uncertainty and anxiety. Most of these policies ignored the realities of families living in apartment buildings where physical distancing is a challenge. For many Toronto immigrant families living in such spaces, the physical distancing required by policies—and especially separate spaces for children and older persons—was extremely difficult as they tried to navigate crowded apartment buildings, shared elevators, and laundry rooms. Moreover, many take public transport, live in multi-generational and/or multi-family households, and work in essential services.

Most participants did not speak English fluently and were not very comfortable with technology and the virtual world beyond basic use. Many were not very familiar with the Canadian education system and feared the disruptions caused by the pandemic would affect their children's education and futures.

Many immigrant parents came to Canada to provide their children with a better education, which is often seen as a source of upward mobility. During COVID-19, children have been expected to learn from home in an online format, but the rapid shift to virtual delivery of education in Ontario has been underpinned by normative assumptions of families' social locations and privileges, assuming familial access to technology and internet services. The experiences shared by parents in this study reflect other research findings about the digital divide and equity in access to resources [15–17]. Our participants noted that the burden to facilitate virtual delivery of education fell primarily on parents, not all of whom have the skills,

knowledge, or time to provide this support. They found online learning unsatisfactory: many viewed it as hindering their children's learning and worried that it would affect their socialization, English language acquisition, psycho-social development, and overall acculturation to Canada.

Beyond the impact on education, COVID-19 restrictions and government-mandated public health measures such as closure of schools, childcare, and other non-essential services curtailed access to formal and informal support networks. Due to limited English language proficiency and social networking, newcomer immigrant parents already lack social support apart from informal support from their ethno-cultural communities. The loss of informal social connections can amplify factors contributing to parental stress through increased social isolation, inability to access supportive and educational services, and economic difficulties [18]. Given the intimate nature of parent-child relationships, parental experience, particularly parental stress, may influence a child's experiences with the pandemic and overall wellbeing [1].

For mothers who were engaged in paid employment outside the home prior to the pandemic, work provided a sense of freedom and time away from home and family responsibilities. Even those who were not employed in paid work prior to the pandemic noted that having to cater to their children, husbands, and other family members who were always at home meant that they were not able to find any time for themselves. Just over 25% of the study sample did not live with their spouse, and managing these responsibilities were near impossible for them while facing financial constraints and with almost no outside help. The disproportionate impact of the pandemic on families with lower socioeconomic status reflects a lack of understanding about how macro-level factors such as policies play out for immigrants at the meso (community) and micro (family) levels. For living in small apartments had trouble finding and setting up activities for their children given their confined space; they also struggled with sharing limited technology devices and limited or unreliable internet services, highlighting the need to address digital inequity in supporting students from low socioeconomic backgrounds.

Participants were worried about the impact of school closures on their children's health and wellbeing. In addition to the loss of social and emotional space for development and social and cultural integration, they noted that children were less physically active, had longer than usual screen time, and had irregular sleep patterns; some noted that children had less healthy diets, resulting in weight gain and a loss of cardiorespiratory fitness. The psychological impact of stressors such as prolonged duration at home, fears of infection, frustration and boredom, inadequate information, lack of in-person contact with classmates, friends, and teachers, lack of personal space at home, and family and financial loss, all appeared to contribute to tensions in relationships between parents and children.

Overall, participants referred to changes in sleeping patterns, anxiety, fear, frustration, and worry. Mental health resources that are sensitive and responsive to the unique needs and contexts of immigrant families are needed. Supportive strategies could include community-oriented approaches, for example, online community group discussions and parenting groups [7]. This kind of strategy should include interpreters and translators, and may require creativity in order to respond to the varying abilities to access the internet, communication devices, and levels of digital literacy. It will be important to build on the resilience of immigrant families and communities to help them adjust and adapt as the pandemic progresses; it may be beneficial to create a safe space outside the family, especially for mothers. For example, community networking is known to facilitate positive parenting and positive outcomes for children [8]. Immigrant parents obtain most support from their ethnic communities, but broadened networks would allow parents from various backgrounds to share their experiences of living through the pandemic. Additionally, provincial, federal, and local governments should provide targeted information in addition to instrumental, financial, and health-related resources and support to immigrant communities.

The pandemic and the unintended consequences of macro- and meso-level policies have compounded the already considerable health inequities immigrant families experience due to poor housing, unsafe neighbourhoods, lack of access to services, limited income due to underpaid and precarious work, discrimination, and racism [10,19–21]. The lack of availability of resources to support immigrant parents requires immediate attention [1] because it can affect the mental and physical health of parents, parenting, and parent-child relationships.

5. Conclusions

COVID-19 has not only increased pre-existing parental responsibilities but has created many new demands on parents. Contributing to the negative experiences reported by parents in our study is the exacerbation of pre-existing inequalities among immigrants that have been heightened by the pandemic. The situation of many families in this study has become worse due to reduced informal social support, lack of familiarity with the educational system, and lack of ready access to internet, computer, as well as indoor/outdoor space to keep their children socially-connected or occupied while physically distancing. These numerous challenges related to the pandemic have created new stresses, anxieties, fears, and frustrations for them that can affect their own well-being and that of their children. Further, the gendered impact of the pandemic has been enormous on mothers who have been forced to take on most of the family burden related to COVID-19. Yet, they have shown significant resilience in ensuring their children's physical, emotional, and mental health and wellbeing. Building on their resilience, immediate

action must be taken to help vulnerable parents, mothers in particular, in order to prevent the long-lasting negative effects on them and their children.

Limitations

The data collection was conducted virtually, which may not have been convenient for all participants. Immigrant parents who did not have ready access to phone, computer, the internet or the time to participate because of the non-stop paid and unpaid work were prevented from participation. Their experiences may considerably differ from what is presented here. The study sample also consists of primarily mothers. A study sample that consists of primarily fathers may yield different results. Our sample was delimited to immigrant parents who live in apartment buildings in the Greater Toronto Area, who have relatively limited access to open and outdoor spaces. Immigrant families living in single-family homes with backyards, have more ready access to nearby outdoor parks, or have more options to reorganize their lives because of their higher socioeconomic status, may have different experiences.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250-Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

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Acknowledgements

The name and the number of the project or programmed within which the article was realized is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programmed.

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Note