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Review Article

In Addition to Mathematical Models, the Behavioural Theories May Explain the Reason Why Voluntary Self-isolation at Home and Voluntary Quarantine during the COVID-19 Pandemic is a Preferable Public Health Intervention

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Abstract

Introduction: As questions raised during COVID-19 pandemic from various groups, if voluntary self-isolation makes any sense as there is no way to trace people who are on self-isolation or voluntary quarantine. The Primary purpose of this article to analyze human behavior during a pandemic to understand why people adopt recommended health behavior voluntarily. In some sections of this article, author discussed various elements of behavior change theories/models to analyze the voluntary self-isolation process or social distancing measures recommended by public health authorities all over the world. This article also shows supportive elements from the mathematical model to prove isolation, and quarantine interventions assist in reducing the number of secondary transmission during a pandemic. The author also briefly addresses ethical issues associated with isolation or quarantine to understand the impediments associated with restrictive measures to control epidemics.

Objective: The objective of this article is to discuss voluntary self- isolation or voluntary quarantine measures in light of popular socio-behavioral models.

Method: 1) Conceptual analysis and 2) A literature review.

Limitation: The author used various elements of popular behavioral models to discuss possible outcomes of voluntary self-isolation and quarantine. The limitation of this article is the lack of statistical data from previous studies using various cognitive and social constructs of behavior change models.

Keywords: *Mathematical Models; Behavioural Theories; Voluntary Quarantine; COVID-19*

Introduction

As of today, COVID-19 pandemic is the most concerning health risk to people all over the world. This pandemic has shaken the modern health care system with it's rapidly evolving and highly infective nature. There are lots of uncertainties that still exist in terms of scientific fact, epidemiology, and the extent and duration of this pandemic. On the other hand, pandemic like COVID-19, where the vaccine is still unavailable and no effective medical treatment yet to prevent severe illnesses, complications and death, the only practical route to prevent the rapid spread of infection is to implement proven public health measures. Public Health advocates and leaders all around the world are

emphasizing on maintaining the respiratory etiquette, recommending voluntary home isolation, applying available legal tools to mandatory quarantine, and advising to maintain the social distancing among people to bring success to minimize the outcomes of this pandemic.

Public health measures those have proven to be useful to control the outbreak

One of the primary steps to prevent the spread of infectious agents is to implement infection prevention and control measures. During COVID-19, an individual must be strict with the essential infection prevention and control (IPAC) measures to prevent being ill or spread the infection to others. Individuals must ensure they maintain proper hand hygiene and maintain proper respiratory etiquette.

Besides, they must adequately clean and disinfect contaminated surfaces and avoid sharing of personal items that come in contact with nasal or oral fluids. Finally, they must receive an influenza vaccine to prevent influenza that may prevent the complication of influenza and co-infection with COVID-19. Ensuring a minimum distance of 2 meters between an infected person and others [1-3].

These are some of the standard measures applicable for any respiratory infectious diseases, including COVID-19. Amid COVID-19 pandemic; it is highly infectious and has a high morbidity and mortality rate, it is essential to implement additional measures to prevent the spread of infection. Some of these public health measures are voluntary self-isolation of the ill person, quarantine of exposed person at home or other facilities who are not yet symptomatic, application of legal tools to enforce quarantine measures, the social distancing measure, and finally, community containment [3,4]. These measures were implemented in the past during an epidemic or pandemic. This article addresses some crucial elements of socio-behavioral theories in the context of COVID-19 pandemic to understand why and how people adopt recommended health measures that restrict autonomy and civil liberty. It is essential to understand the concept of how an individual may respond or behave at a very personal level during a pandemic, and that may influence voluntary acceptance of restrictive public health measures by the majority, not all; as public health authorities are repeatedly advocating for societal responsibilities at an individual level to bring success to mitigation affords of the COVID-19 pandemic, along with tremendous roles and responsibilities played by national and international health organizations and government and non-government agencies worldwide [5].

Why isolation, quarantine and social distancing are effective public health measures

In mathematical models, infectivity or rate of infection of an infectious disease is calculated based on various factors. One of the popular models is the SIR model used to measure the outcomes of an epidemic of infectious disease. In this model, the total population (N) consists of three groups [6,7]. These are

- S - Susceptible people (anyone who can develop infection)
- I - Infected people (anyone who already developed infection)
- R- Removed people (anyone who recovered from the infection and anyone who died from infection).

These three groups keep changing over time as pandemic progress.

The total population (N) consists of all three groups mentioned above. Initially, the number of susceptible individuals remains very high as minimal numbers of people get the disease and almost no one is part of the removed group. Over time more susceptible individuals convert to infected individuals, so the number of infected individuals grows. Eventually, infected individuals recover, or some infected individuals die that contributes to the number of removed people. So, the number of susceptible individuals at the beginning is highest and decreases as epidemic progress. The number of infected individuals increases as many susceptible individuals get sick. Gradually, the removed people also increase as many infected people recover; some of them die [7]. The total number of susceptible individuals convert to infected individuals depending on q (contact ratio) q is the measure of contact with an infected individual during the period of infectiv-

ity. R0 is the measure of the infectivity of an organism. It varies among various infectious diseases. Although every contact may not cause disease, it is essential to realize that when the contact between a susceptible group and an infected individual is high or prolonged, the more susceptible people convert to infected people. R0 is the reproductive number, which represents how many new infections transmitted by an infected person during a period of infectivity without intervention. An Epidemic sustains if R0 is > 1 [8]. Some previous studies indicated that for COVID19 the R0 is approximately 2.5 to 3 that means one infected person can infect 2.5 to 3 other individuals as a result of contact or exposure [4,6-8]. One article showed the effect of isolation and quarantine on the R0 by using probability models, and the result showed that R0 reduced from 2.26 to 0.62, which is below the epidemic threshold [8].

Unless public health measures are in place, we may see that most of the susceptible individuals in a geographical area get ill, especially when the infectivity (R0) of an organism like COVID-19 is very high. So, the growth rate appears as exponential due to rapid spread.

Another factor that helps propagate the infection from one person to another is the density or crowded living conditions like settings like cruise ships or institutions without proper infection control and prevention protocols [6]. These public health measures include 1) basic respiratory etiquette, 2) isolation of infected persons as early as possible, 3) isolation of ill or quarantine of exposed individuals, 4) social distancing. All these help to break the chain of transmission of an infectious disease like COVID-19. These public health measures create a distance or barrier between susceptible individuals and infected individuals. So less susceptible people convert to infected people and fewer hospitalizations and deaths result from the infection [11].

Prioritization of vulnerable groups is also crucial as more vulnerable susceptible individuals have more severe forms of infection and death. Individuals who are part of a marginalized group and already in isolation for various reasons (e.g. mobility issue, age, low social support) suffer detrimental effects from restrictive measures unless adequate tailoring of public health interventions [9,10]. Considering these factors such as age, underlying medical conditions, other socioeconomic determinants such as income, living conditions or housing, education, gender, and drug or alcohol abuse [9,10] to implement public health measures are very important to reach success. It is also vital to ensure that public health authorities implement less restrictive measures to achieve goals to prevent unnecessary or unexplainable hardship for target people [12]. The voluntary self-isolation or voluntary quarantine measures must apply before any restrictive means [12]. The "reciprocity" is an essential ethical principle, which means when authorities ask people to maintain isolation or quarantine, they are also responsible for ensuring the well being of these people by ensuring they receive adequate support to maintain such measures [12].

Analysis of the voluntary self- isolation measures/social distancing measures in the perspective of Socio-behavioural theory

During COVID-19 pandemic, people who are a COVID-19 case or contact of COVID-19 case or return travelers from high COVID-19 impacted countries are investigated and advised by local public health departments to self isolate themself at home. The question arises of how these measures work in real life as the voluntarily self-isolated person is not under surveillance camera for 24 hours and no one can monitor them throughout their period of quarantine or self-isolation. In this paragraph, various elements of behavior change theories/models discuss to analyze the self-isolation process or social distancing measures recommended by public health authorities all over the world. It is explainable why individuals change their behavior to adapt and maintain health recommendations such as voluntary social isolation to prevent the spread of illness during the COVID-19 pandemic by applying various constructs or elements described in popular behavior change models [13-18]. Why people do certain things or adopt some very new health recommendations within a short period can be influenced by their observation of the surrounding environment, information received through various sources, previous or recent experiences, and the associated change in the thought process. During the COVID-19 pandemic, a majority of people perceive the risk of acquiring the disease, and the majority believe that COVID-19 causes serious illness, including hospitalization and death. Some of the reasons for such perception of risk are the information or health news they are having through various media; what they are observing in their neighborhood, COVID-19 related news, and communication they are receiving through various media acts as a "cues". People with

the knowledge of health literacy can be influenced by statistical data, which is rapidly expanding daily acts as cues to shape their thought and increase the "perception of disease susceptibility", "perception of risk", as described in the health belief model [16-18]. News that contain information on the uncertainty of treatment success or unavailability of equipment or medication to treat an infected person with COVID-19 (for example due to shortage of respirator/ventilator, shortage of PPE, no vaccine) are some cues to increase the level of threat of becoming ill and uncertainty of getting help after infection. These "perceptions of risk" increase somehow the "perception of benefits" of taking certain measures such as staying home, maintaining social distancing, and remaining self-isolated at home. Public education by health authorities acts as an additional cue to take action or follow preventive steps such as voluntary self-isolation after exposure or after becoming ill with COVID-19. When an individual's "perception of barriers" is higher than the "perception of benefits," they often become unsuccessful followers of the recommended behavior. Public health authorities, again and again, advising people to stay home at this time of COVID-19 pandemic to contain this pandemic. Many employers cannot offer work from home options to their employees because of the nature of the work they do. So, the rate of unemployment is high. Rigorous lockdown of cities may put many vulnerable groups at danger as they lose the usual amenities from various sources, such as from various organizations and non-profit agencies. Voluntary self-isolation may not work for some people, especially when it is harmful to them and their dependents. So, programs must consider the socio-demographic aspects and support those individuals who are in desperate need of help. "Self-efficacy" is an important construct added to the health belief models and other models [16-18]. It is the willpower, confidence, or self-motivation of accepting the change and also embracing the health behavior to protect health and prevent disease [16-18]. When a person strongly believes that they are capable of adapting the behavior, they usually become successful in maintaining that behavior, possibly overcoming some challenges. When a person is well aware of their capability, such as belief in an existing support system, availability of resources, and are knowledgeable of the health outcomes of adopting or not adopting certain measures are more confident to comply with the behavior. Another two important concepts under the theory of planned behavior are the "social norm" and "subjective norms" [15,17]. For example, during COVID-19 pandemic wearing masks to avoid transmission of the disease has become a social norm in some communities or countries. It influences some groups more strongly than others. For example, many people living in various parts of the world started wearing masks at the beginning of the epidemic, when the outbreak only affected Wuhan province in China. Many of them adopt this behavior as they see it as part of the culture or influenced by the situation in their back home. Staying home voluntarily, working from home are well-accepted activities among many people because people's behavior depends on how much they believe that the particular behavior is effective to prevent the spread of infection. Social distancing works as the majority in the society accept this behavior (either voluntarily or by enforcement of laws to ensure people maintain the behavior) during a pandemic, gradually it becomes a social norm and expectable by the majority. Acceptance of some new health recommendations by the majority supported by the "diffusion of innovation theory. " In this theory, it is described how a new idea or innovation spread through society or community. In this theory, some people are quicker than others to adopt a new idea, behavior, or product than others. "In the end, the majority adopts the innovation [17]". "Researchers found five groups such as 1) Innovators 2) early adaptors 3) Early majority 4) Late majority 5) Laggards [17]". For example, hypothetically, During the COVID-19 pandemic, innovators were health authorities who recommended new measures such as self-isolation at home for 14 days. People returned from impacted countries are early adopters to self-isolation; either they return from a high impacted area, or they are told by the authority to do so. The majority of people, businesses followed the social distancing measures either for fear of contracting disease or fear of facing penalties by law enforcement. Some youth may be part of the late majority and laggards as they have peer pressure or misconception of who becomes ill severely and who doesn't [14]. But once the idea gets popular, it becomes generalized. For example, covering cough and sneezing is a popular recommendation and social norm.

According to social cognitive theory, the social environment has a significant influence on how an individual learns behavior and maintains a behavior [17]. This theory addressed that individuals' experience helps them to shape their behavior [17]. Most of the public health measures recommended for COVID-19 are proven to be effective in previous epidemics, such as the SARS outbreak. It is a fact that these recommendations are selected based on scientific evidence that gathered from the previous epidemic and also healthcare work-

ers are quick adaptors of these recommendations as they are the 1st responders, they are knowledgeable and may have learned from previous experiences. It is essential to bring statistics and scientific facts on how COVID-19 spread can be prevented by home isolation to gain more public acceptance. According to social cognitive theory, humans learn by dynamic and reciprocal interaction of a person, environment, and behavior [17]. For example, individuals learn from various media regarding social distancing and notice each and everyone is maintaining that social distancing and face criticism of not maintaining or face law enforcement as a result of the violation of bylaws during COVID-19 pandemic. So, it is clear that a person behaves in a certain way because of the previous experiences or learning through a source and then matches these experiences with a social environment where they are performing the behavior. Economic and environmental factors also influence behavioral capability, such as when a person has advised to self-isolate at home, they able to do so if social structure supports that. For example, if they have sufficient money in your credit cards to order food online, know how to order food online, have a credit card or computer to perform the task. The individual needs to have a home to isolate himself and social support to meet his daily needs to survive. He needs his employer to provide him enough support to stay home or work from home. According to this theory, people follow others' behavior, also mentioned as observational learning. Once someone noticed others to follow voluntary self-isolation rules, another person also learned from observation [17] and once he needed to be self-isolated, he would follow the same rules.

Discussion in terms of the benefit of self-quarantine

Self-efficacy is one of the crucial elements of behavior change models [16-18]. It is the core belief or mental status of an individual regarding a change. If the person believes that they can manage the 2 weeks of quarantine situation at home [16-18]. then the individual agrees and be successful in maintaining the quarantine stage. People with adequate support systems such as the adequate supply of food, prescribed medicine, entertainment such as television, internet at home, telephone to connect with others help them to maintain the quarantine situation without much disruption. If this person is socioeconomically capable of running a family without earning/paid sick leave; they are more capable of maintaining the quarantine measures. On the other hand, individuals with a lack of social support may suffer irreparable difficulty maintaining family and dependence without income. On the other hand, knowledge of the outcome associated with behavior change enhances self-efficacy. A person's understanding of how 14 days of quarantine measures decrease the spread of disease may play an important role. Public health professionals can counsel clients to increase their knowledge on this issue to ensure enhanced knowledge acts as a precondition for compliance.

Knowledge is essential for the person to understand the outcomes of a specific behavior in terms of physical, social, and self-evaluative [16]. During the period of quarantine, the individual is under daily monitoring by public health professionals and also advised to self monitor their symptoms. Although there is uncertainty regarding the physical outcomes of a sick individual (a case) or a contact (been exposed to risk), the person doesn't feel isolated and lonely or helpless when the designated health professionals monitor them as require. They receive advice to seek immediate medical attention if the disease progresses to severity. Although they are told to avoid unnecessary health care visits but advised to receive help in time of need. Similarly, the person who is a returning traveler from an impacted area or who is a contact/exposed to the case receives continuous health assessment and support from a public health investigator. The investigator arranges diagnostic tests if they get sick during the quarantine. Modern technology, such as communication tools, make this quarantine process much more convenient both for the client and health care providers. The social outcome of the self-quarantine process is enormous and satisfactory to the person under quarantine. Individual's actions during an epidemic are often influenced by what society approved and what kind of activities society disapproved of, especially by the social connections [15,17]. The individual feels positive peer pressure to be compliant with public health measures to prevent the spread of infection. The individual is relieved from self-blame or guilt of spreading the disease as soon as he/she knows he/she can spread the disease to family members and community. Self-quarantine helps individuals to protect loved ones from becoming ill; as a result, they can get support from family who are not ill. They were relieved from the fear of spreading the disease to vulnerable community members, coworkers, and loved ones [13,16]. Self-isolation relieves individuals from the stigma of spreading diseases to others, as others appreciate that the individual is following the direction from health authorities

appropriately. The self-isolation process built a trustworthy relationship between patient and caregiver as they maintain the continuity of care until release from self-isolation [13,16].

Another important outcome is self evaluatory [13]. At the end of the quarantine period, the client feels worth undergoing this process; both client and investigator feel satisfaction after completing the process as per best practice guideline [3,18]. The client feels more comfortable when they are asked to self-isolate at home because people are usually more comfortable at home than being displaced to a camp, hotel, or hospital. Their privacy well maintained when they are isolating at home. Public health authorities exclude them from work, which is a reliable source to validate the reason for absence without divulging information details [3,18]. As self-isolation at home helps individuals to give lots of autonomy and dignity; they do not lose their self-worth through the process. They feel more responsible as they are treated fairly and with dignity.

The immediate goal of such public health measures is to reduce the spread of the disease to others and reduce the number of cases. Long Term outcome is to control the unfortunate outcome of a pandemic or shorten the duration of a pandemic by flattening the epidemic curve. It also enhances the capacity for urgent care by reducing mortality and morbidity related to pandemic. Therefore, it also reduces hospital stay and cost of healthcare care. At an individual level, the outbreak measures are short term goals, and for the health authorities, actions taken by each client contribute to fulfilling the long term goal.

Implementation of public health measures

Some people in a geographic area prepared more than other people to handle a pandemic crisis based on many factors [16]. The individual level of preparation to fight a health challenge or pandemic results from lifelong learning of a healthy habit and proper application of that in time of need [16]. For example, individuals who learned respiratory etiquette since childhood will maintain throughout their life to prevent respiratory illness. This skill will contribute to the prevention of disease transmission during the COVID-19 pandemic. In a society, more people are health literate; the community will get more benefits as a result. At the structural level, the health system of a country offers various health promotion and disease prevention related programs at multiple levels of organizations. This approach, over time, built a community of more people who are ready to fight a health challenge.

Structural preparation also includes preparation inside the government agencies' and the health care system [16]. Coordination of various levels of the government is key to success during a pandemic. Coordination, integration of acute care and public health systems is a must to fight a health challenge. Integration among national and international authorities is vital to manage large scale outbreaks [16]. The social cognitive theory addresses step-wise implementation models to meet the needs of various subgroups of people [12,13,16]. The public health authority may consider this step-wise implementation process. This approach sounds effective as the population is a group of heterogeneous mixed in terms of the level of preparation to accept various public health recommendations. For example, one group of the community is highly motivated because of acquired knowledge and experiences. They can overcome barriers to behavior change to see positive outcomes. For them, minimum guidance is enough. 2nd group of people has self-doubt about their efficacy [16] and perception of benefit is low either they don't trust authority or poor knowledge or inadequate evaluation of particular behavior. These people need additional support to enhance their understanding and reduce their doubts. Self-efficacy can be positively influenced by support individuals receive through the public health system. Most Individuals usually feel a social responsibility during a time of pandemic and try to avoid the stigma of being not responsible. Public health education, counselling, and messaging through various sources such as mass media has tremendous influence. Risk communication by multiple levels of health organization to dispel miscommunication will have an immense effect at the societal level as well as individual level. Individuals are often influenced by societal approval or influenced by their social collection or social cohesion.

The 3rd group is the people with very low self-efficacy because they don't have control over their behavior [16] and they have poor social support. So, they need a very well organized program and detail-oriented implementation plan. Once an individual faces barriers

to maintain health action, their self-efficacy or core belief or motivation decrease, in that case, they need support from their connections and health authorities [9,10].

Lesson learned:

1. Voluntary self-isolation is a preferable option before the forceful or mandatory quarantine.
2. How people behave or how people adapt to recommended health behavior depends on their socioeconomic conditions, knowledge and previous experiences.
3. Humans are heterogeneous in terms of readiness. People with low self determinants will require additional support from tailored public health programs during the time of pandemic as society undergoes restrictive public health measures such as isolation, quarantine, or social distancing.
4. Although mathematical models are commonly used to predict or estimate various outcomes of the pandemic, the socio-behavioral theories or models are essential aspects to understand human behavior or response towards various restrictive measures implemented during a public health emergency. More studies should include behavioral models to measure multiple outcomes.
5. Behavioral models address multiple ways of learning or adapt to new health behavior. Such as 'cues', 'observational learning', 'social norms', or 'social acceptability', 'personal evaluation', 'will power to overcome challenges'. These learning processes also applied to why people adopt and maintain some restrictive measures such as isolation or quarantine.
6. Public health authorities must identify the shortcomings of these restrictive measures and compensate by various support programs to help vulnerable people overcome economic, physical, and mental challenges during restrictive measures.

Conclusion

The main Behavioural change models described different constructs to explain why people behave in specific ways or motivate or inhibit particular behavior [13-18]. If we analyze the novel corona virus disease prevention and health protection and promotion strategies as per the main health behavior models, it will prove why these measures (e.g. voluntary self isolation, voluntary quarantine) work better than not. In the majority of cases, a voluntary approach is a more acceptable idea than a legal procedure. Especially in some society or geographical region, t is more effective in a population where the community is better prepared and has built trustworthy relationships with health care agencies and government over time than other societies where government plays an insignificant role to ensure health and safety of an individual by health protection and promotion activities during a nonepidemic period.

In conclusion, It is important to realize that although there are many benefits of voluntary self-isolation, it is not 100% guaranteed as the population is a heterogeneous mix in terms of preparation to adapt health behavior during a pandemic due to various level of socioeconomic conditions, disabilities, poor health education, poor social cohesion or support system [7,9,10]. In this paper, the author concludes that public health measures, such as voluntary self-isolation measures are a well-balanced approach in comparison to enforcement. The voluntary self- isolation process preserves people's rights and avoids any coercion, as well as this process, maintain people's dignity and respect. This voluntary isolation process helps to reduce the burden on the health care system, therefore increases capacity building in the healthcare sectors (for example, utilization of hospital for an appropriate reason) as people stay in their homes during the isolation process. Self-isolation is a societal responsibility. It frees up community resources for vulnerable people. For example, a library, school, community center use as a quarantine facility for homeless people rather than using it as a quarantine facility for everyone. From behavior change models, we can conclude that at a very personal level, individuals with higher self-efficacy expect successful outcomes of

their health behavior, and they try to overcome barriers to reach success. But it is not right for people with low self-efficacy due to various reasons as discussed. Both the rigorous restriction or quarantine measures, as well as voluntary, self-restriction, are disadvantageous for people who don't have adequate support systems unless the government takes appropriate steps to reduce socioeconomic barriers to facilitate the process smoothly.

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