Research papers 2021

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Six sigma in healthcare service: a case study on COVID 19 patients' satisfaction

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Abstract

Purpose – The purpose of this paper is to determine the major influencing factors for the COVID 19 patients' satisfaction with a six sigma framework model and to explore the successful deployment of six sigma in the health-care sector.

AQ: 4

Design/methodology/approach – The study is based on a descriptive research design conducted in Chennai, India between May to July 2020 wherein 1,000 COVID 19 patients were studied. The convenience sampling method is used by the researcher for data collection. In this research paper, define-measure-analysis-improve-control methodology has been applied and factors such as assurance, process standardization, infrastructure, waiting time, cost were analyzed using QFD, regression analysis and Monte Carlo simulation.

AQ: 5

Findings – The applied six sigma model indicated that process standardization contributed the most toward the variation in COVID 19 patients' satisfaction. Assurance by doctors is the second important factor. The interpersonal quality is important, which indicates a higher level of psychological needs in COVID 19 patients. Waiting time is another important factor influencing COVID 19 patients' satisfaction. One of the unexpected findings is that cost is insignificant in influencing COVID 19 patients' satisfaction.

Originality/value – Six Sigma focuses on process variation improvement that encourages data analysis and problem-solving statistical techniques and evaluates the ability of a process to perform defect-free. Six sigma focused toward COVID 19 patients' satisfaction has not been carried out, which this paper has done.

Keywords Six sigma, Regression, DMAIC, QFD, COVID 19

Paper type Research paper

1. Introduction

In recent years, the health-care system has been facing various difficulties, not only in India but also in many developed countries. The most critical issue is that the operating costs keep increasing. US health care spending grew 4.6% in 2019, reaching $3.8tn or $11,582 per

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satisfaction in India. The proposed six sigma conceptual framework model with DMAIC for COVID 19 patients' satisfaction would identify the key role of the variables influencing the performance of the Indian health-care system and also will be instrumental in improving the performance of Indian health-care industries. The major limitation of this study that the respondents were limited to patients from one city in India. Though the concurs with other studies conducted in other cities, future research exercises should consider taking samples from different parts of India that conclusions are universally relevant. AQ: 8

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DOM-CHROMATIC NUMBER OF CERTAIN SPLITTING GRAPHS

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Abstract

Graph Theory is a branch of Mathematics which has found a plenty of applications in this modern era. Domination and coloring are the two major concepts in Graph Theory which have seen a major development in the research field. For a given χ-coloring of a graph G, a dominating set is said to be a dom-coloring set, if it contains at least one vertex from each color class of G. In this paper we have determined the dom-chromatic number of splitting graphs for path and comb graphs.

1. Introduction

Today, Graph theory has seen a major development in various research fields due to its strong connection with Computer Science. It plays an important role in several areas of computer science such as logical design, artificial intelligence, formal languages, information organization and retrieval including the areas of social science, linguistics and communication engineering. In 1958, domination was formalized as a theoretical area in

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graph theory by C. Berge [1]. He referred to the domination number as the introduction co-efficient of external stability [7]. In 1962, Ore was the first to use the term "domination" for undirected graphs and he denoted the domination number by $\delta(G)$ [8]. He also introduced the concepts of minimal and minimum dominating sets of vertices in a graph. In 1977, Cockayne and Hedetniemi introduced the accepted notation $\gamma(G)$ to denote the domination number [4, 5]. Further study on domination, resulted in the introduction of connected domination in graphs which has vast real life applications [12]. Moreover, graph coloring and domination problems are often in relation. Chellali and Volkmann showed some relations between the chromatic number and some domination parameters in the graph [3].

2. Preliminaries

Definition 2.1 [6]. Let G be a finite, simple and undirected graph with n vertices. A non-empty subset S of a graph $G(V, E)$ is said to be dom-coloring set if for every vertex v in $V(G) - S$, there is a vertex u in S such that u is adjacent to v. This set S is said to be a minimum dominating set if it has the least number of vertices. The cardinality of a minimum dominating set is called the domination number of G and is denoted by $\gamma(G)$.

Definition 2.2 [7]. Graph coloring is the assignment of colors to the vertices of a graph G such that no two adjacent vertices receive the same color. The least number of colors needed to color the graph G is called the chromatic number and is denoted by $\chi(G)$.

Definition 2.3 [2]. For a given χ-coloring of a graph G, a dominating set is said to be dom-colouring set if it contains at least one vertex from each color class of G. The cardinality of the minimum dom-coloring set is called the dom-chromatic number and is denoted by $\gamma_{dc}(G)$.

3. Results

In this section, we have determined the dom-chromatic number of the splitting graph of path P_n and comb graphs P_n^+.

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3.1. Dom-chromatic number of splitting graph of path P_n

Definition 3.1 [9]. The splitting graph $S'(G)$ of a graph G is obtained by adding a new vertex v' corresponding to each vertex v of G such that $N(v) = N(v')$, where $N(v)$ and $N(v')$ are the neighborhood sets of v and v' respectively in $S'(G)$. See figure 1

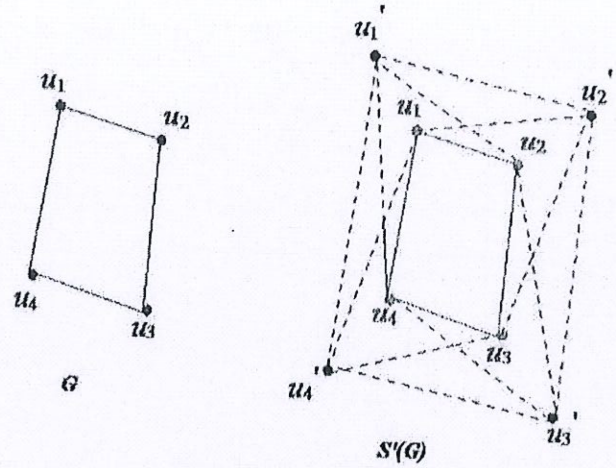

Figure 1. Splitting graph of a 2-Regular graph.

Theorem 3.1. *For any path P_n, $n \geq 4$, the dom-chromatic number of the splitting graph of P_n is given by*

$$\gamma_{dc}(S'(P_n)) = \begin{cases} \dfrac{n}{2} & \text{if } n \equiv 0 \pmod 4 \\ \left\lceil \dfrac{n}{2} \right\rceil & \text{if } n \equiv 1, 3 \pmod 4 \\ \dfrac{n}{2} + 1 & \text{if } n \equiv 2 \pmod 4. \end{cases}$$

Proof. Consider the path P_n, $n \geq 4$. Let the vertices of P_n be labeled as u_i, $i = 1, 2, \ldots, n$. Clearly P_n is 2 colorable. Therefore the vertices of P_n can be colored alternatively with colors 1 and 2. Let G be the splitting graph $S'(P_n)$ of the path P_n. Let u_i', $i = 1, 2, \ldots, n$ represent the copies of u_i, $i = 1, 2, \ldots, n$. The splitting graph G thus obtained can also be colored with $\chi(P_n)$ colors, by assigning the same color of P_n to each copy of the

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corresponding vertices u_i', $i = 1, 2, \ldots, n$. We now find the dom-chromatic number of G under the following cases.

Case (i). $n \equiv 0 (\text{mod } 4)$.

The $2n$ vertices of G can be partitioned into set of 8 vertices as in B_k. Figure 2. Let $B_k = \{u_i, u_i' : 4k - 3 \leq i \leq 4k\}$, for all $k = 1, 2, \ldots, \frac{n}{4}$ represent the $\frac{n}{4}$ such components. Each component is dominated by 2 adjacent vertices which is the minimum dominating set of each component. Hence $D = \{u_{4i-2}, u'_{4i-1} : 1 \leq i \leq \frac{n}{4}\}$ is the minimum dominating set which contains at least one vertex from each color class of G.

Dom-chromatic number of each component = domination number of each component = 2. Hence the cardinality of the dc-set $= \gamma_{dc}(G) = |D|$ $= 2 \times \frac{n}{4} = \frac{n}{2}$.

Case (ii). $n \equiv 1 (\text{mod } 4)$.

The $2n$ vertices of G can be partitioned into $\frac{n-1}{4}$ components with 8 vertices in each component and the remaining 2 vertices as shown in the Figure 3. Then $V(G) = B_k \cup \{u_n, u_n'\}$ where $B_k = \{u_n, u_n' : 4k - 3 \leq i \leq 4k\}$, for all $k = 1, 2, \ldots, \frac{n-1}{4}$ represents the $\frac{n-1}{4}$ such components. Each component B_k, $k = 1, 2, \ldots, \left\lfloor \frac{n-2}{4} \right\rfloor$ is dominated by 2 adjacent vertices $\left\{u_{4i-2}, u'_{4i-1} : 1 \leq i \leq \left\lfloor \frac{n-2}{4} \right\rfloor\right\}$ and the component $B_{\frac{n-1}{4}}$ is dominated by 3 adjacent vertices $\{u_{n-3}, u'_{n-2}, u_{n-1}\}$. Hence $D = \left\{u_{4i-2}, u'_{4i-1} : 1 \leq i \leq \left\lfloor \frac{n-2}{4} \right\rfloor\right\}$ $\cup \{u_{n-3}, u'_{n-2}, u_{n-1}\}$ is the minimum dominating set which contains at least one vertex from each color class of G.

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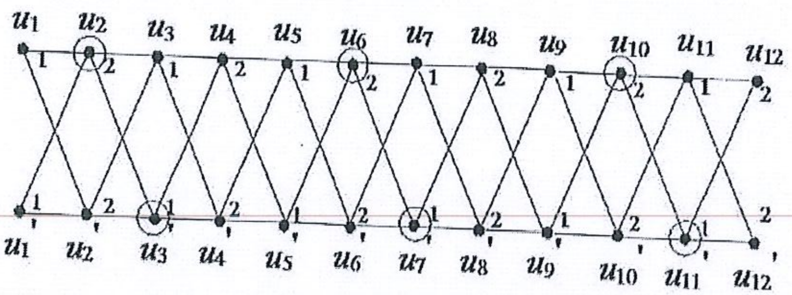

Figure 2. Splitting graph $S'(P_{12})$.

Hence the cardinality of the dc-set $= \gamma_{dc}(G) = |D| = 2 \times \left\lfloor \frac{n-2}{4} \right\rfloor + 3$

$= 2 \times \left(\frac{n-1}{4} - 1 \right) + 3 = \frac{n+1}{2} = \left\lceil \frac{n}{2} \right\rceil.$

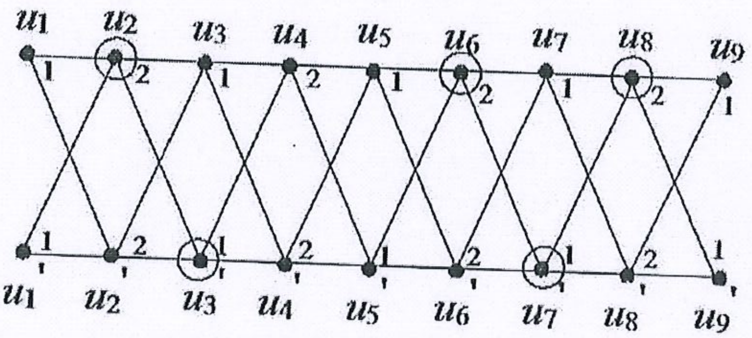

Figure 3. Splitting graph $S'(P_9)$.

Case (iii). $n \equiv 2 (\text{mod } 4)$.

The $2n$ vertices of G can be partitioned into $\frac{n-2}{4}$ components with 8 vertices in each component and the remaining 4 vertices as shown in the Figure 4. Then $V(G) = B_k \cup \{u_{n-1}, u'_{n-1}, u_n, u'_n\}$ where $B_k = \{u_i, u'_i : 4k-3 \le i \le 4k\}$, for all $k = 1, 2, \ldots, \frac{n-2}{4}$ represents the $\frac{n-2}{4}$ such components. Each component B_k, $k = 1, 2, \ldots, \frac{n-2}{4}$ is dominated by 2 adjacent vertices $\{u_{4i-2}, u'_{4i-1} : 1 \le i \le \frac{n-2}{4}\}$ and the

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remaining 4 vertices are dominated by 2 adjacent vertices $\{u_{n-1}, u'_n\}$. Hence $D = \{u_{4i-2}, u'_{4i-1} : 1 \le i \le \frac{n-2}{4}\} \cup \{u_{n-1}, u'_n\}$ is the minimum dominating set which contains at least one vertex from each color class of G.

Hence the cardinality of the dc-set $= \gamma_{dc}(G) = |D| = 2 \times \left(\frac{n-2}{4}\right) + 2$ $= \left(\frac{n-2}{2}\right) + 2 = \frac{n+2}{2} = \frac{n}{2} + 1.$

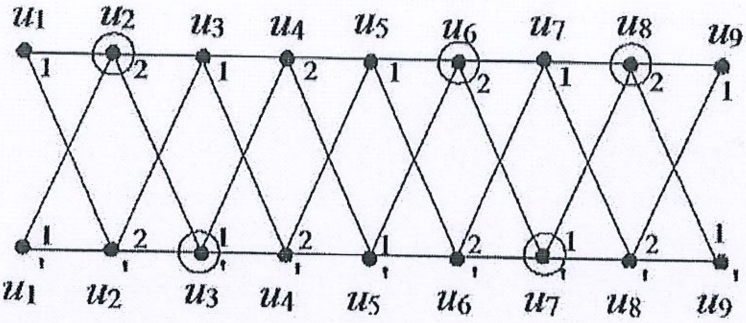

Figure 4. Splitting graph $S'(P_{10})$.

Case (iv). $n \equiv 3 (\text{mod } 4)$.

The $2n$ vertices of G can be partitioned into $\frac{n-3}{4}$ components with 8 vertices in each component and the remaining 6 vertices as shown in the Figure 5. Then $V(G) = B_k \cup \{u_i, u'_i : n-2 \le i \le n\}$ where $B_k = \{u_i, u'_i : 4k-3 \le i \le 4k\}$, for all $k = 1, 2, \ldots, \frac{n-3}{4}$ represents the $\frac{n-3}{4}$ such components. Each component B_k, $k = 1, 2, \ldots, \frac{n-3}{4}$ is dominated by 2 adjacent vertices $\{u_{4i-2}, u'_{4i-1} : 1 \le i \le \frac{n-3}{4}\}$ and the remaining 6 vertices are dominated by 2 adjacent vertices $\{u_{n-1}, u'_n\}$. Hence $D = \{u_{4i-2}, u'_{4i-1} : 1 \le i \le \frac{n-3}{4}\} \cup \{u_{n-1}, u'_n\}$ is the minimum dominating set which contains at least one vertex from each color class of G.

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Hence the cardinality of the *dc*-set $= \gamma_{dc}(G) = |D| = 2 \times \left(\frac{n-3}{4}\right) + 2$ $= \left(\frac{n-3}{2}\right) + 2 = \frac{n+1}{2} = \left\lceil \frac{n}{2} \right\rceil$.

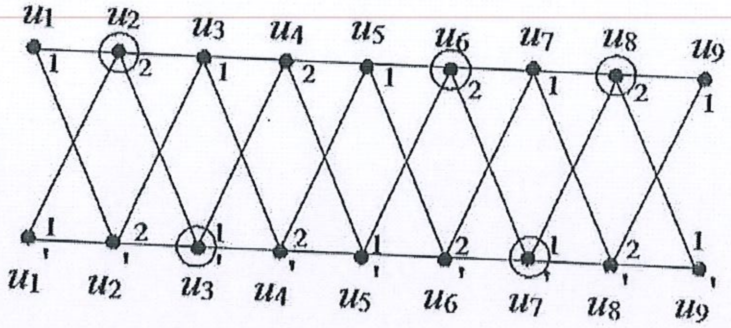

Figure 5. Splitting graph $S'(P_{10})$.

Definition 3.2 [10]. A graph obtained by attaching a single pendant edge to each vertex of a path P_n is called a comb graph and is denoted by P_n^+. It consists of $2n$ vertices and $2n-1$ edges.

Theorem 3.2 [11]. *Let G be a comb graph* P_n^+. *Then* $\gamma_{dc}(G) = n$ *for all n.*

Theorem 3.3. *For any comb graph* $P_n^+, n > 2$ *vertices, the dom-chromatic number of the splitting graph is given by* $\gamma_{dc}(S'(P_n^+))$ $= \gamma_{dc}(P_n^+) = n$.

Proof. Let G be a comb graph P_n^+ with $n > 2$ vertices labeled as $u_i, v_i = 1, 2, \ldots, n$. Clearly G is 2 colorable. Let the vertices $u_i, i = 1, 2, \ldots, n$ of the graph G be colored alternately with colors 1 and 2. The pendant vertices $v_i, i = 1, 2, \ldots, n$ are colored alternately with colors 2 and 1. Let $S'(G)$ be the splitting graph of G, with vertices $u_i', v_i', i = 1, 2, \ldots, n$ which are copies of vertices $u_i, v_i, i = 1, 2, \ldots, n$. The splitting graph $S'(G)$ thus obtained can also be colored with 2 colors, by assigning the same colors of G to each copy of the corresponding vertices $u_i', v_i', i = 1, 2, \ldots, n$. Let $D = \{u_i, i = 1, 2, \ldots, n\}$ be the minimum dom-

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coloring set of G. In the splitting graph $S'(G)$, the same set of vertices minimum dom-coloring set D of G dominates all the vertices of $S'(G)$ which yields the minimum dom-coloring set. D is the minimum dominating set which contains at least one vertex from each color class of G. Hence D is a dom-coloring set of $S'(G)$.

Therefore the cardinality of the dc-set $= \gamma_{dc}(S'(G)) = n$.

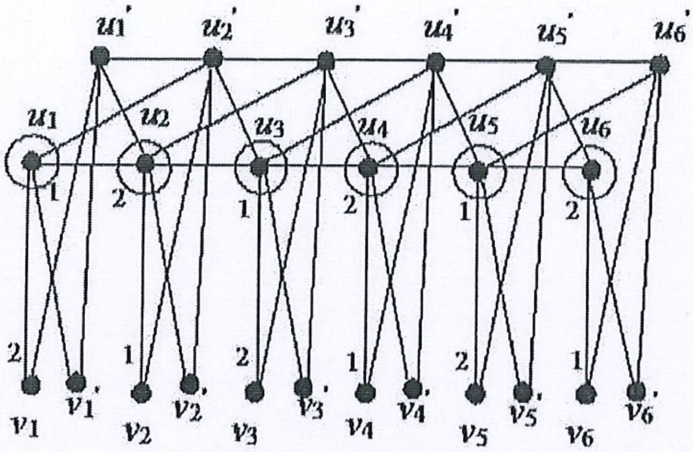

Figure 6. Splitting graph $S'(P_6^+)$.

4. Conclusion

The concepts on domination number and dom-chromatic number have been discussed in this paper. The results have been extended to the splitting graphs of path and comb graphs. Study on determining the dom-chromatic number of tree related networks are in progress.

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CERTIFICATE OF PRESENTATION

This is to certify that **Ms. Beulah Angeline E F, Assistant Professor** of Nazareth College of Arts and Science presented a paper titled "Dom-Chromatic number of splitting graphs" in the International Conference on Resea Trends in Mathematics (ICRTM-2020) organized by the Division of Mathematics, School of Advanced Scien Vellore Institute of Technology, Chennai, India held during August 25-26, 2020 through online platform.

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ON RADIUS PROBLEMS FOR SOME SUBCLASSES OF ANALYTIC UNIVALENT FUNCTIONS

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Abstract: In this article we compute the radii of the largest disks for which the functions in the class S of normalized, analytic and univalent functions belong to certain subclasses of it.

Keywords and Phrases: Analytic function, univalent function, radius problem, polynomial equations.

2020 Mathematics Subject Classification: 30C45.

1. Introduction

Let $\mathcal{A}$ be the class of normalised analytic functions f defined on the open unit disk $\Delta = \{z \in \mathbb{C} : |z| < 1\}$ with Taylor's series expansion of the form

$$f(z) = z + \sum_{n=2}^{\infty} a_n z^n \tag{1}$$

and S denote the subclass of it containing univalent functions [3].

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The radius problem for subclasses of $\mathcal{A}$ or $\mathcal{S}$ is defined as follows: if $\mathcal{M}$ is a class of functions and $\mathcal{P}$ is a property which the functions in $\mathcal{M}$ may or may not possess in the disk $|z| < r$, the radius for the property $\mathcal{P}$ in the set $\mathcal{M}$ is the largest R such that every function in the set $\mathcal{M}$ has the property $\mathcal{P}$ in each disk $\{z \in \mathbb{C} : |z| < r\}$ for every $r < R$. In other words, if $\mathcal{F}$ and $\mathcal{G}$ are two given subsets of $\mathcal{A}$ then the $\mathcal{G}$ radius of f in $\mathcal{F}$ is the largest R such that for each $f \in \mathcal{F}, r^{-1}f(rz) \in \mathcal{G}$ for each $r \leq R$ [4].

Several authors had considered this problem for various pairs of subclasses of $\mathcal{S}$. Gavrilov [5] in 1970 showed that the radius of univalence of functions in the class $\mathcal{A}$ satisfying the inequality $|a_n| \leq n$ is the real root of the equation $2(1-r)^3-(1+r)=0$ and the same for those functions satisfying $|a_n| \leq M$ is $1-\sqrt{M/(1+M)}$. In 1982, Yamashitha [13] showed that the radius of univalence obtained by Gavrilov is also the radii of starlikeness for the corresponding functions.The radius of starlikeness and convexity of functions in the class $\mathcal{S}$ were found to be $tanh(\pi/4)$ and $2-\sqrt{3}$ respectively [4]. The radius of univalence of certain combination of two analytic functions was obtained by [2, 7, 8].

In this paper we obtain few radii results for functions in the class $\mathcal{S}$ of analytic, normalized univalent functions to be in certain standard subclasses of it defined and studied by various authors.

2. Preliminaries

We recall certain standard subclasses of $\mathcal{S}$ and the respective sufficient conditions for a function $f \in \mathcal{S}$ to be in these subclasses.

Definition 2.1. [12] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{D}$ if*

$$\Re(f'(z)) > |zf''(z)|, \; for\ all\ z \in \Delta.$$

Theorem 2.1. [12] *A function $f \in \mathcal{D}$ if it satisfies the condition*

$$\Sigma_{n=2}^{\infty} n^2 |a_n| \leq 1.$$

Definition 2.2. [10] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{UCD}$ if*

$$\Re(f'(z)) > 2|zf''(z)|, \; for\ all\ z \in \Delta.$$

Theorem 2.2. [10] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty} n(2n-1)|a_n| \leq 1$$

then $f \in \mathcal{UCD}$.

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Theorem 2.7. [1] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty} n|a_n| \leq \frac{1-\alpha}{1+\beta}$$

then $f \in \mathcal{SD}(\alpha, \beta)$.

3. Main Results

We now obtain the radii results for functions in the class $\mathcal{S}$ to be in the above subclasses.

Theorem 3.1. *The $\mathcal{D}-$ radius of $f \in \mathcal{S}$ is the real root of the equation $r^4 + 8r^3 - 11r^2 + 12r - 1 = 0$ lying in $(0, 1)$.*

Proof. Let $f \in \mathcal{S}$ be given by (1). For $0 < r_0 < 1$,

$$\frac{1}{r_0} f(r_0 z) = z + \sum_{n=2}^{\infty} a_n r_0^{n-1} z^n.$$

Since $|a_n| \leq n, \ n \geq 2$,

$$\sum_{n=2}^{\infty} n^2 |a_n| r_0^{n-1} \leq \sum_{n=2}^{\infty} n^3 r_0^{n-1} = \frac{1 + 4r_0 + r_0^2}{(1-r_0)^4} - 1.$$

If $\frac{1}{r_0} f(r_0 z) \in \mathcal{D}$ then we must have

$$\frac{1 + 4r_0 + r_0^2}{(1-r_0)^4} - 1 = 1$$

$$\implies 2r_0^4 + 8r_0^3 - 11r_0^2 + 12r_0 - 1 = 0.$$

Thus r_0 is the root of the equation $2r^4 + 8r^3 - 11r^2 + 12r - 1 = 0$ lying in $(0, 1)$.

Theorem 3.2. *The $\mathcal{UCD}-$ radius of $f \in \mathcal{S}$ is the real root of equation $r^4 - 5r^3 + 3r^2 - 15r + 1 = 0$ lying in $(0, 1)$.*

Proof. Since $f \in \mathcal{S}$, we have $|a_n| \leq n, \ n \geq 2$ and hence

$$\sum_{n=2}^{\infty} n(2n-1)|a_n| r_0^{n-1}$$

$$\leq \sum_{n=2}^{\infty} n(2n-1) n r_0^{n-1}$$

$$= 2\sum_{n=2}^{\infty} n^3 r_0^{n-1} - \sum_{n=2}^{\infty} n^2 r_0^{n-1}$$

$$= 2\left[\frac{1 + 4r_0 + r_0^2}{(1-r_0)^4} - 1\right] - \left[\frac{1 + r_0}{(1-r_0)^3} - 1\right]$$

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$$=\frac{2(1+4r_0+r_0^2)-(1-r_0^2)-(1-r_0)^3}{(1-r_0)^4}.$$

For $\frac{1}{r_0}f(r_0z)$ to be in the subclass $\mathcal{UCD}$, we must have

$$\frac{2(1+4r_0+r_0^2)-(1-r_0^2)-(1-r_0)^3}{(1-r_0)^4}=1$$
$$\implies 2(1+4r_0+r_0^2)-(1-r_0^2)-(1-r_0)^3=(1-r_0)^4$$
$$\implies r_0^4-r_0^3+3r_0^2-15r_0+1=0.$$

Thus r_0 is the root of the equation $r^4-5r^3+3r^2-15r+1=0$ lying in $(0,1)$.

Theorem 3.3. *The $\mathcal{SD}-$ radius of $f\in\mathcal{S}$ is the real root of equation $2r^3-6r^2+7r-1=0$ lying in $(0,1)$.*

Proof. Let $f\in\mathcal{S}$. Then $|a_n|\leq n,\ n\geq 2$.

$$\sum_{n=2}^{\infty}n|a_n|r_0^{n-1}\leq\sum_{n=2}^{\infty}n^2r_0^{n-1}=\frac{1+r_0}{(1-r_0)^3}-1.$$

Now, $\frac{1}{r_0}f(r_0z)\in\mathcal{SD}$ if

$$\frac{1+r_0}{(1-r_0)^3}-1=1$$
$$\implies 2r_0^3-6r_0^2+7r_0-1=0.$$

Hence the $\mathcal{SD}-$ radius of f is the root of the equation $2r^3-6r^2+7r-1=0$ lying in $(0,1)$.

Theorem 3.4. *Let $\alpha>0$. The $\mathcal{UCD}(\alpha)$-radius of $f\in\mathcal{S}$ is the real root of equation $2r^4-8r^3+11r^2-6(1+\alpha)r+1=0$ lying in $(0,1)$.*

Proof. Since $f\in\mathcal{S}$, we have $|a_n|\leq n, n\geq 2$ and hence

$$\sum_{n=2}^{\infty}n[n\alpha+(1-\alpha)]|a_n|r_0^{n-1}$$
$$\leq\sum_{n=2}^{\infty}n[n\alpha+(1-\alpha)]|a_n|r_0^{n-1}$$
$$=\alpha\left[\frac{1+4r_0+r_0^2}{(1-r_0)^4}-1\right]+(1-\alpha)\left[\frac{1}{(1-r_0)^2}-1\right]$$
$$=\alpha\frac{1+4r_0+r_0^2}{(1-r_0)^4}+\frac{1-\alpha}{(1-r_0)^2}-1.$$

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If $\frac{1}{r_0}f(r_0z) \in \mathcal{UCD}(\alpha)$ then we must have

$$\alpha(1+4r_0+r_0^2)+(1-\alpha)(1-r_0)^2 = 2(1-r_0)^4$$
$$\Longrightarrow 2r_0^4 - 8r_0^3 + 11r_0^2 - 6(1-\alpha)r_0 + 1 = 0.$$

Let $f(r) = 2r^4 - 8r^3 + 11r^2 - 6(1-\alpha)r + 1$ we have $f(0) = 1$ and $f(1) = -6\alpha < 0$. Then $f(0)f(1) < 0$ if $\alpha > 0$. The $\mathcal{UCD}(\alpha)$- radius of $f \in \mathcal{S}$ is the root of the equation $2r^4 - 8r^3 + 11r^2 - 6(1-\alpha)r + 1 = 0$ in the interval $(0,1)$ whenever $\alpha > 0$.

Theorem 3.5. *If $\alpha > 0$, then $\mathcal{SD}(\alpha)-$ radius of $f \in \mathcal{S}$ is the real root of equation $2r^3 - 6r^2 + (5+2\alpha)r - 1 = 0$.*

Proof. Since $|a_n| \le n$ for $f \in \mathcal{S}$,

$$\begin{aligned}
&\sum_{n=2}^{\infty}[1+\alpha(n-1)]|a_n|r_0^{n-1}\\
\le&\sum_{n=2}^{\infty}[1+\alpha(n-1)]nr_0^{n-1}\\
=&(1-\alpha)\sum_{n=2}^{\infty}nr_0^{n-1} + \alpha\sum_{n=2}^{\infty}n^2r_0^{n-1}\\
=&\frac{1-\alpha}{(1-r_0)^2} + \frac{\alpha(1+r_0)}{(1-r_0)^3} - 1.
\end{aligned}$$

If $\frac{1}{r_0}f(r_0z) \in \mathcal{SD}(\alpha)$ then we must have

$$\frac{1-\alpha}{(1-r_0)^2} + \frac{\alpha(1+r_0)}{(1-r_0)^3} - 1 = 1$$

calculation gives, $2r_0^3 - 6r_0^2 + (5+2\alpha)r_0 - 1 = 0$.
Let $f(r) = 2r^3 - 6r^2 + (5+2\alpha)r - 1 = 0$. Then $f(0) = -1$, $f(1) = 2\alpha$. Also, $f(0)f(1) < 0$ implies $\alpha > 0$. This implies the $\mathcal{SD}(\alpha)-$ radius of f is r_4 where r_4 is the root of the equation $2r^3 - 6r^2 + (5+2\alpha)r - 1 = 0$ provided $\alpha > 0$.

Theorem 3.6. *The $\mathcal{SD}(\alpha,\beta)$-radius of $f \in \mathcal{S}$ is r_5 where r_5 is the root of equation $(2-\beta)r^4 - 4(2-\beta)r^3 + (11-6\beta-\alpha)r^2 - (4\beta+6\alpha+10)r + 1 - \beta = 0$ lying in $(0,1)$ provided $7\alpha + 8\beta + 4 > 0$.*

Proof. Let $f \in \mathcal{S}$. Then $|a_n| \le n$ for $f \in \mathcal{S}$.

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Definition 2.3. [6, 9] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{UCD}(\alpha)$ if*

$$\Re(f'(z)) > \alpha|zf''(z)|, \ for\ all\ z \in \Delta, \alpha \geq 0.$$

Theorem 2.3. [10, 11] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty} n[n\alpha + (1-\alpha)]|a_n| \leq 1$$

then $f \in \mathcal{UCD}(\alpha)$.

Definition 2.4. [10] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{SD}$ if*

$$\Re\left(\frac{f(z)}{z}\right) > \left|f'(z) - \frac{f(z)}{z}\right|, \ for\ all\ z \in \Delta.$$

Theorem 2.4. [10] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty} n|a_n| \leq 1$$

then $f \in \mathcal{SD}$.

Definition 2.5. [10] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{SD}(\alpha)$ if*

$$\Re\left(\frac{f(z)}{z}\right) > \alpha\left|f'(z) - \frac{f(z)}{z}\right|, \ for\ all\ z \in \Delta, \alpha \geq 0.$$

Theorem 2.5. [10] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty}[1 + \alpha(n-1)|a_n| \leq 1$$

then $f \in \mathcal{SD}(\alpha)$.

Definition 2.6. [10] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{SD}(\alpha, \beta)$ if*

$$\Re\left(\frac{f(z)}{z}\right) > \beta\left|f'(z) - \frac{f(z)}{z}\right| + \alpha, \ for\ all\ z \in \Delta,\ 0 \leq \alpha < 1,\ 0 \leq \beta \leq 1.$$

Theorem 2.6. [10] *Let $f \in \mathcal{S}$. If f satisfies*

$$\Sigma_{n=2}^{\infty}[\beta n + (1-\beta)]|a_n| \leq 1 - \alpha$$

then $f \in \mathcal{SD}(\alpha, \beta)$.

Definition 2.7. [1] *A function $f \in \mathcal{S}$ is said to be in the class $\mathcal{SR}(\alpha, \beta)$ if*

$$\Re(f'(z)) > \beta|f'(z) - 1| + \alpha, \ for\ all\ z \in \Delta,\ 0 \leq \alpha < 1,\ 0 \leq \beta \leq 1.$$

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Therefore

$$\sum_{n=2}^{\infty}[\alpha n+(1-\alpha)]|a_n|r_0^{n-1}$$
$$\leq\sum_{n=2}^{\infty}[\alpha n+(1-\alpha)]nr_0^{n-1}$$
$$=\frac{\alpha(1+4r_0+r_0^2)}{(1-r_0)^4}+\frac{1-\alpha}{(1-r_0)^2}.$$

Thus $\frac{1}{r_0}f(r_0z)\in\mathcal{SD}(\alpha,\beta)$ if

$$\alpha(1+4r_0+r_0^2)+(1-\alpha)(1-r_0)^2=(2-\beta)(1-r_0)^4$$
$$\Longrightarrow(2-\beta)r_0^4-4(2-\beta)r_0^3+(11-\alpha-6\beta)r_0^2-(4\beta+6\alpha+10)r_0+(1-\beta)=0.$$

Let $f(r)=(2-\beta)r^4-4(2-\beta)r^3+(11-\alpha-6\beta)r^2-(4\beta+6\alpha+10)r+(1-\beta)$, then $f(0)=1-\beta$, $f(1)=-4-8\beta-7\alpha$ and hence $f(0)f(1)<0$ implies $7\alpha+8\beta+4>0$. Hence the $\mathcal{SD}(\alpha,\beta)$ radius of $f\in\mathcal{S}$ is the root of equation $(2-\beta)r^4-4(2-\beta)r^3+(11-6\beta-\alpha)r^2-(4\beta+6\alpha+10)r+1-\beta=0$ in $(0,1)$ provided $7\alpha+8\beta+4>0$.

4. Conclusion

We conclude that the radii of the largest disk inside the unit disk for which the functions in the class of normalized, analytic and univalent functions S belong to certain standard subclasses of it are the unique roots in $(0,1)$ of certain polynomial equations.

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RELATIONSHIP BETWEEN COVID-19 LOCKDOWN LONELINESS AND DAILY SPIRITUAL EXPERIENCE AMONG THE GENERAL POPULATION

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Abstract
Background: COVID-19 has become a huge public health crisis worldwide and the measures taken to contain the spread like lockdown, social distancing, quarantine etc., has led to a rise in loneliness. Many strategies are laid down in the literature to combat lockdown loneliness. The role of spiritual experiences in coping with loneliness has yielded mixed results.
Methods: This study determined the relationship between daily spiritual experience and COVID-19 lockdown loneliness using cross-sectional online survey design among the general population (N=100).
Results: The mean average COVID-19 lockdown loneliness score was 11.63 (total score 60) indicating greater loneliness; mean overall closeness with God score was 3.08 (total score 4); and mean daily spiritual experience score was 11.79 (total score 54) indicating greater spiritual experience. Loneliness significantly correlated negatively with overall closeness with God at r = -0.306, p = 0.01.
Conclusion: Findings suggest that to prevent or reduce loneliness during COVID-19, interventions should be targeted to strengthen spiritual connectedness.

Keywords : Isolation, lockdown, spirituality, loneliness and social distance.

"All of humanity's problem stem from man's inability to sit quietly in a room alone"
- Blaise Pascal

Introduction

Humans are not meant to be in isolation. We have always been social beings. One may argue that those who have access to a smart phone and internet, staying connected should not be a problem. However, these ways of socializing merely supplement our need for connection; they don't' fulfill it. They cannot replace a hug, a reassuring hand on your shoulder, intimacy, or the myriad of ways humans communicate non-verbally. Loneliness is proposed to break this essential construct and disrupt social integration leading to increase in isolation. Loneliness is also one of the prime indicators of social-wellbeing (Cacioppo & Patrick, 2008).

World is currently facing a huge public health crisis as corona virus diseases- 2019 (COVID-19) has emerged as a pandemic. Besides the increase in the number of cases and fatalities, this pandemic has also caused significant socio-economic, political, and psychosocial impact. The COVID-19 pandemic has swept across the globe, resulting in about 69.6 million confirmed cases and about 1.58 million deaths worldwide as of December 12, 2020 [GitHub - CSSEGISandData/COVID-19: Novel Coronavirus (COVID-19) Cases, provided by JHU CSSE]. The pandemic has compelled governments and authorities in affected countries to enforce preventive measures including enforced lockdowns, social distancing, self-isolation, and quarantine to slow down the spread of COVID-19 [Farooq, Laato, Islam, 2020]. These preventative measures have contributed to social isolation and loneliness among people with specific characteristics [https://www. ons.gov.uk]. Staying at home can be quite nice for some time but also can be boring and restricting. Social isolation can lead to chronic loneliness and if prolonged this can have detrimental effect on physical and mental health.

Loneliness is often described as the state of being without any company or in isolation from the community or society. As physical distancing rules have resulted in a decline of in-person social contact, it is suggested that rates of loneliness will rise, which may increase prevalence of mood disorders, self-harm, and suicide, and exacerbate pre-existing mental health conditions [Holmes, O'Connor, Perry, Tracey, Weseley, Arseneaaultet al., 2020]. Loneliness is associated with worse physical and mental health [Mullen, Tong, Sabo, Liaw, Marshal, & Nease, 2019] and increases mortality risk [Holt-Lunstand, Smith, Baker, Harris, Stephenson et al., 2015]. While situational loneliness is associated with mortality risk, it is more pronounced in individuals experiencing chronic loneliness [Shiovitz-Ezra & Ayalon, 2010]. This suggests that, without intervention, prolonged loneliness can have a profound negative impact on health and wellbeing. It is considered to be a dark and miserable feeling, a risk factor for many mental disorders like depression, anxiety, adjustment disorder, chronic stress, insomnia, or even late life dementia (Wilson et al., 2007).

Different strategies have been suggested to manage, cope, and thrive in isolation during the COVID-19 pandemic like accept the reality of the situation, embrace your feelings, don't think about feelings as positive or negative, be mindful of how loneliness can manifest in physiological sensations like elevated heartbeat, use isolation as an opportunity to better get to know and understand yourself, focus on the opportunities isolation provides, rather than the things you have lost, find ways to stay relaxed and connect to your social networks, and practice self-care. Spirituality and spiritual experience have always helped people in all walks of life to cope with various stresses of life.

A growing body of literature suggests that people often turn to religion when coping with stressful events. However, studies on the efficacy of religious coping for people dealing with stressful situations have yielded mixed results. A study was conducted with the purpose to synthesize the research on situation-specific religious coping methods and quantitatively determine their efficacy for people dealing with stressful situations. A meta-analysis of 49 relevant studies with a total of 105 effect sizes was conducted in order to quantitatively examine the relationship between religious coping and psychological adjustment to stress. Four types of relationships were investigated: positive religious coping with positive psychological adjustment, positive religious coping with negative psychological adjustment, negative religious coping with positive psychological adjustment, and negative religious coping with negative psychological adjustment. The results of the study generally supported the hypotheses that positive and negative forms of religious coping are related to positive and negative psychological adjustment to stress, respectively [Ano, Vasconcelles, & Erin, 2005].

So, the current study was undertaken to investigate the relationship between daily spiritual experience and COVID-19 lockdown loneliness among the general public across Tamilnadu.

Methodology

A cross-sectional online survey design has been adopted for the current study. Any individual above the age of 18 years residing in Tamilnadu and willing to participate in the study were considered as samples. The survey was conducted via internet using google forms among 100 individuals. Samples were selected using snowball sampling technique. The tools used for the study had three sections: questionnaire on socio-demographic variables, UCLA loneliness scale, and Daily Spiritual Experience Scale.

Loneliness was measured using UCLA loneliness scale, a 20-item scale designed to measure one's subjective feelings of loneliness as well as feeling of social isolation. Each item was scored from 0 to 3. The total score was 60. Lower the score greater the loneliness and higher the score lesser the loneliness.

Daily Spiritual Experience Scale (DSES) is a 10-item self-report measure of spiritual experience. It specifically aims to measure ordinary, or daily, spiritual experiences – not mystical experiences (e.g., hearing voices) – and how they are an everyday part of the individual's life. The first 9 items of the questionnaire are measured on a 6-point Likert-type scale: many times, a day, every day, most days, some days, once in a while, and never or almost never. Item 10 is measured on a 4-point scale: Not Close at All, Somewhat Close, Very Close, As Close as Possible. The first 9 items are usually scored together as a full-scale score and the score is kept continuous. The total score for the first 9 items is 54. Higher the score reflects lesser spiritual experience and lesser the score greater the spiritual experience. Item 10 is scored separately on a four-point likert scale: Not Close at All, Somewhat Close, Very Close, As Close as Possible.

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Data was collected via google form during the second and third week of May 2020 during the second phase of COVID-19 lockdown. The samples were provided explanations about the study and the return of the filled forms was considered as consent. Assurance was given to the samples on maintenance of confidentiality and anonymity.

RESULTS OF THE STUDY

Table – 1: Distribution of the samples based on their demographic variables

N = 100

S.No.	Demographic Variables	Frequency	Percentage
1.	Age in Years		
	18 – 30 years	35	35%
	31 – 60 years	65	65%
2.	Sex		
	Male	21	21%
	Female	79	79%
3.	Educational Status		
	Student	11	11%
	Undergraduate	23	23%
	Postgraduate	46	46%
	MPhil	10	10%
	PhD	10	10%
4.	Marital Status		
	Married	74	74%
	Unmarried	26	26%
5.	Employment Status		
	Employed	77	77%
	Unemployed	02	02%
	Retired	01	01%
	Housewife	09	09%
	Student	11	11%

Table 1 portrays that nearly two-thirds of the samples (65%) belonged to the age group of 31 to 60 years and majority (79%) were females. A little less than half of them were postgraduates and three-fourth of the samples were married. Majority of them (77%) were employed.

Table – 2: Mean and standard deviation score of daily spiritual experience, overall closeness with God and COVID-19 lockdown loneliness

N = 100

S.No.	Variable	Total Score	Minimum Score	Maximum Score	Mean Score	Standard Deviation
1.	Daily Spiritual Experience	54	6	24	11.63	3.86
2.	Overall closeness with God	4	2	4	3.08	0.76
3.	COVID-19 Lockdown Loneliness	60	0	39	11.79	9.03

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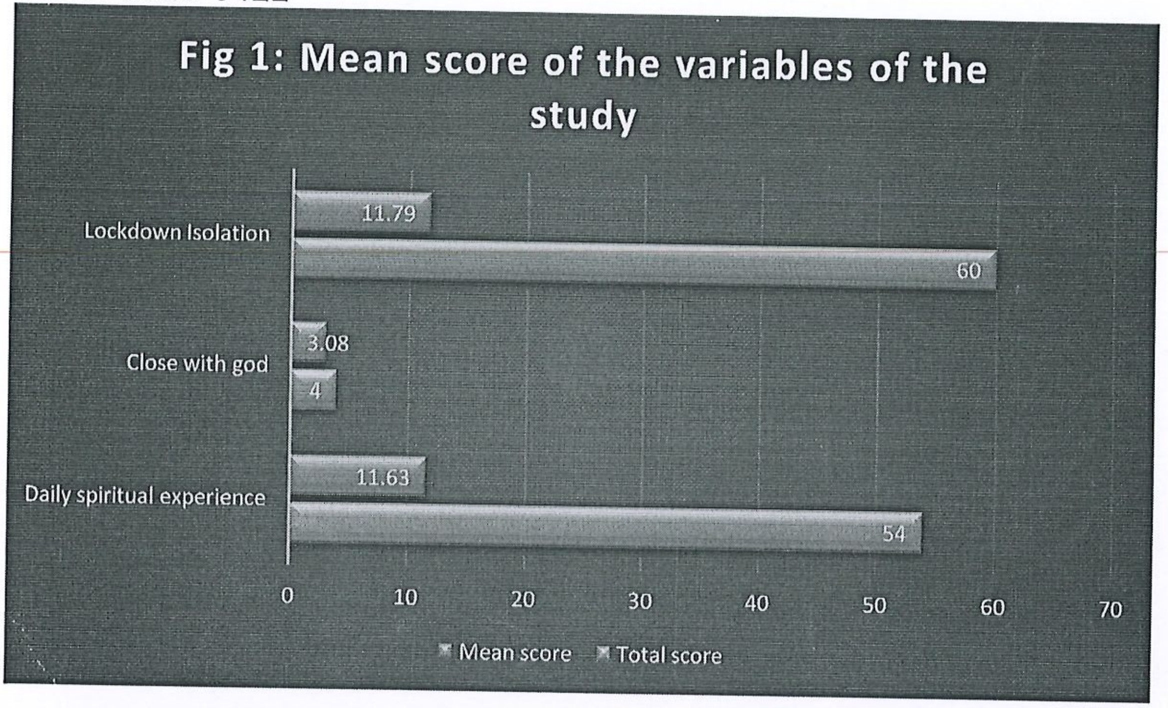

Fig 1: Mean score of the variables of the study

It can be inferred from table 2 and figure 1 that the mean lockdown loneliness score was 11.73, the mean overall closeness with God score was 3.08, and the mean daily spiritual experience score was 11.63.

Table – 3: Bivariate correlation matrix between corona lockdown loneliness, overall closeness with god and daily spiritual experience

Variable		COVID-19 lockdown loneliness	Overall closeness with God	Daily spiritual experience
COVID-19 lockdown loneliness	Pearson Correlation	1	-.306**	-.002
	Sig. (2-tailed)		.002	.987
	N	100	100	100
Overall closeness with God	Pearson Correlation	-.306**	1	.014
	Sig. (2-tailed)	.002		.894
	N	100	100	100
Daily spiritual experience	Pearson Correlation	-.002	.014	1
	Sig. (2-tailed)	.987	.894	
	N	100	100	100
**** - Correlation is significant at the 0.01 level (2-tailed).**				

It can be inferred from table 3 that there was a statistically significant negative relationship between covid-19 lockdown loneliness and overall closeness with God ($r = -0.306$, $p = 0.002$). There was a very weak negative relationship found between covid-19 lockdown loneliness and daily spiritual experience which was not statistically significant ($r = -0.002$, $p = 0.987$).

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DISCUSSION

In the current online survey conducted among 100 samples to determine the relationship between corona lockdown loneliness and daily spiritual experience, the mean corona lockdown loneliness score was 11.70 out of 60. The score revealed that the samples were experiencing significant loneliness since lower the score greater the loneliness. The increase in loneliness during the COVID-19 pandemic has been attributed to increased social isolation because of lockdowns, social distancing, self-isolation, and quarantine measures aimed at reducing the spread of coronavirus [https://www.redcross.org.uk]. The COVID-19 pandemic is therefore being labelled as the pandemic of loneliness [Shaw & Farow, 2020].

There are umpteen number of ways suggested in the literature to beatdown lockdown loneliness but the current study determined the influence of daily spiritual experience on lockdown loneliness. In the current study, there was a very weak negative relationship between lockdown loneliness and daily spiritual experience which was statistically insignificant. The overall closeness with God was evaluated using a single questions and interestingly overall closeness with God had a statistically significant negative correlation with lockdown loneliness. This points to the fact that the samples who shared a close relationship with God felt less lonely and vice versa. The current findings suggest that closeness with God is considered as positive coping strategy to beat lockdown loneliness.

The strength of the study is that it is timely and contributes to a small body of emerging knowledge regarding lockdown loneliness. This study also identified closeness with God as a positive coping strategy to beat lockdown loneliness and the results could be further validated using large small sample size.

The major limitations of the study were that the sample size was small and that the samples were not chosen randomly. Due to the survey being conducted online there was a reliance on self-reported measures of the variables. The measures selected have well established psychometric properties.

Conclusion

Loneliness caused by corona lockdown is widespread worldwide. Social connectedness is important during this crisis and as revealed by the current study spiritual connectedness is more important and measures can be taken to strengthen this. People who have strong spiritual connectedness are in peace with oneself and thus this loneliness can be transformed into solitude blessed with peace and harmony.

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