



# How did the COVID-19 Pandemic impact the relationship between residential environments and older rural adults' physical activity levels?

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**Abstract:** Background: The COVID-19 pandemic may have influenced the physical activity levels of older adults in rural areas due to the impact of community shutdowns and government regulations. The purpose of this study was to investigate changes in the physical activity of rural older adults during the pandemic as well as the environmental and social barriers and facilitators associated with their participation. Material and methods: The data were collected in two-time frames: pre-pandemic from 2019-2020 (Survey I, n=153) and the pandemic in 2020 (Survey II, n=301). In the survey questionnaire, PASE (Physical Activity Scale for the Elderly) was employed to assess physical activity levels of rural older adults. Also, additional questions relating to perceived residential environment were used. Results: Comparing the two survey groups, there were no significant group differences in PASE scores, perceived residential environments, and demographic characteristics of rural older adults. However, there were significant mean differences of PASE scores by demographic variables of Survey I (age, education, marital status) and Survey II (ethnicity, marital status, income), respectively. When comparing perceived residential environments and social relations through the demographic variables of Survey I and Survey II, respectively, significant mean differences were found in both survey groups in terms of age. Multiple regression analyses reveal rural older adults who rated higher satisfaction rate for a town environment and higher connection with family and friends were likely to have higher physical activity scores. Conclusion: The study's findings can increase understanding of the unique perceived benefits and barriers associated with physical activity during a pandemic for rural older adults.

**Keywords:** physical activity, PASE, residential environment, rural older adults, social relation

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## INTRODUCTION

SARS-CoV-2 is the novel coronavirus that causes the COVID-19 disease. The virus originated in Wuhan, China [1] and rapidly spread worldwide, leading the World Health Organization (WHO) to declare the Coronavirus Disease a pandemic on March 11th, 2020. As of April 2022, the virus has claimed over 80 million lives, with over one million deaths in the United States alone. The Centers for Disease Control [2] recommended guidelines to help prevent the spread of the virus, which included wearing masks/face shields, testing, hand washing, and maintaining six feet of distance from other people. On March 15, 2020, most states in the U.S. began to shut down to prevent the spread of COVID-19. The lockdown included both domestic and international travel restrictions, and stay-at-home or curfew orders, in an effort to stop the transmission of this virus. As a result, businesses, schools/universities, community centers, gyms, and most in-person events shut down. While these regulations were implemented first and foremost to protect public safety, they created other health-related challenges, specifically, challenges to physical activity (PA) in older adults.

The older adult population (> 65 years) is rapidly becoming the largest population in the U.S. A study by Vincent and Velkoff [3] estimates the U.S. older adult population will double between 2010 and 2050, rising from 13% (40.2 million) to 20% (88.5 million) of the population. Regular PA is one of the most important predictors of healthy independent living among older adults. PA reduces the risk of disease and falls, improves bone and muscle strength, and enhances mental and functional health [4]. According to the Office of Disease Prevention and Health Promotion [5], for older adults to achieve substantial health benefits, they recommend one of the following: (1) 150 minutes (2 hours and 30 minutes) each week of moderate-intensity aerobic PA (such as brisk walking or gardening); (2) 75 minutes (1 hour and 15 minutes) each week of vigorous-intensity aerobic PA (such as jogging or swimming laps); (3) an equivalent combination of moderate- and vigorous-intensity aerobic PA. Despite these benefits, only 16% of people aged 65 years and older engage in the recommended levels (2.5 hours) of moderate-intensity activity per week [6]. With the current literature indicating that PA leads to a possible enhancement of immune function [7-9], meeting these guidelines could prove crucial during a pandemic as they may help individuals to improve their immune response to the disease and improve the health outcomes of those who contract the disease. In women, PA has an inverse association with the development of diseases such as pneumonia, an outcome that is commonly associated with COVID-19, and an 18% reduction in upper respiratory tract infections in men [7,9]. Currently, three mechanisms have been associated with the immune enhancement effects of exercise – an increase in immune system cell mobilization, surveillance, and response. Immune cells are preferentially mobilized, increase in circulation after exercise, and are observed at higher concentrations in the lungs, potentially improving surveillance of and defense against respiratory viruses [10-12]. Finally, exercise may increase the response of the immune system to vaccines, which may be analogous to the response that would be seen upon infection from a true pathogen and potentially improve vaccine efficacy [13].

The socio-ecological theory of health behavior is a model that proposes that behavior is influenced by interpersonal, sociocultural, policy, and physical-environmental factors [14]. The purpose of this model is to focus on the environmental causes of behavior and to identify environmental interventions to promote health and well-being [15]. Ecological theory has been widely used to determine correlates of PA. For example, seasons and time spent outside are critically associated with PA [14]. Proximity to PA programs or facilities is another important factor for both young individuals [16] and older adults [17]. Particularly, it is important for older rural adults who heavily rely on cars and spend more time driving [18] than walking or jogging in their daily lives. These residential and environmental barriers may cause older rural adults to have less interest in increasing their levels of PA [19] and these factors influence their inactive health

behaviors. Convenient exercise facilities were strongly associated with PA as confirmed by a study that showed individuals who live near coastal regions reported higher levels of PA [20].

This study is also grounded in social contagion theory, which indicates that individual behaviors are contagious, spreading through networks and through multiple mechanisms including: 1) induction - when one person's behavior induces a change in others because of their influence in the network; 2) proximity effects or shared environmental factors; and 3) homophily - when people associate with others similar to themselves [21]. This study is also supported by the convoy model of social relations, where social networks influence health and behavior through network structure and supportive ties [22,23]. A study involving Australians aged 60 years and older found that having friends who participated regularly in PA, safe footpaths for walking, and access to parks were significantly associated with regular PA [24]. Lian and his colleagues [25] also reported that one of the key barriers to PA for old adults was a lack of exercise partners, which emerged as the greatest influence on leisure time activity.

The COVID-19 pandemic may change the various determinants that influence the PA behaviors of older adults in rural areas because of the impact of community shutdowns and government regulations [26,27]. There might be different thoughts regarding the relationship between the pandemic and the level of PA for rural seniors because the social distancing and lockdown regulations were less lenient than in urban areas in US [28] and a few counties like Sweden even did not enforce a strict lockdown regulation [29]. By comparing PA behaviors before the pandemic to during the pandemic, this study will fill an existing gap in the literature concerning patterns of PA in this social group. In addition, this study will increase understanding of the unique perceived benefits and barriers associated with PA during a pandemic for this demographic. By increasing scientific understanding of PA behaviors in this way, the findings of this study can be used to develop PA interventions that are tailored separately to remove the barriers and promote incentives for this unique group during periods of social isolation. In this study, the authors propose to investigate changes in the PA of older adults in rural areas during the COVID-19 pandemic as well as the environmental and social barriers and facilitators associated with their participation. The overall hypothesis is that PA will significantly decrease during the pandemic compared to the pre-pandemic era due to these unique perceived barriers particularly for older adults living in rural areas. To test this hypothesis, we examine the following two aims:

1. To investigate the changes in leisure time PA levels of rural older adults because of the COVID-19 pandemic lockdown. Levels of physical activity will be compared between the pre-pandemic and the middle of the pandemic.
2. To investigate the relationship among the residential environmental and social relation variables, and leisure PA for rural older adults during the COVID-19 pandemic.

## **MATERIAL AND METHODS**

### *Participants and Recruitment Procedure*

The data presented in this study were collected in two-time frames, pre-pandemic from 2019-2020 (namely, Survey I) and pandemic in 2020 (Survey II) in North Carolina (NC). According to the Senior Center Operations and Program Evaluation by NC Department of Health and Human Services [30], NC senior centers provide their activities and service programs to participants age 55 or older, therefore we used this age range for recruitment. All participants were recruited from the rural NC. Rural is defined as counties with an average population density of 250 people per square mile or less [31]. The Institutional Review Board at North Carolina Agricultural and Technical State University approved this study (#19-0049). It was pilot tested with older adults in rural communities.

Survey I (pre-pandemic from 2019-2020): Between October 1, 2019, and March 6, 2020 (total 24 weeks), we conducted a structured, face-to-face survey with rural older

adults (55 and over) in four rural NC counties. The average driving distance from the researcher's institution (a mid-sized city) to these counties was about 1 to 1.5 hours. We liaised with service providers in rural NC areas as contacts to announce our study purpose to clients or organization members and to arrange a place and time for the survey. Seven site visits to six organizations (four senior centers, one senior housing community, and one community center) were conducted for the survey activity by a group of three researchers. All study participants provided written informed consent. A total of 158 older adults in rural NC areas participated. For data analysis, a usable sample is 153 rural older adults in Survey I.

Survey II (pandemic in 2020): Between September 2 and 7, 2020 (total 6 days), a sample of 318 older adults 55 and older in rural NC was purchased from a U.S. experienced management company that mainly assists in online survey activities. The participants were selected from the Tier 1 counties categorized as rural and distressed areas [32]. The company assisted in data collection by distributing the website link for the survey questionnaire via email to their consumer panels who were aged 55 or over. Soft launch (n = 26) was conducted to identify any potential discrepancies or issues, and subsequently a full launch was initiated. A usable sample of 301 rural older adults was considered for Survey II.

### *Data Collection and Tools*

**Demographics.** The survey measured demographic information including age, gender, ethnicity, marital status, education, and income, which were self-reported. Each question and its response choices were adapted from the American Housing Survey of the U.S. Department of Housing and Urban Development and the U.S. Bureau of Census [33].

**Perceived residential environment and social relations.** Questions assessed perceived residential environment regarding their perceptions of neighborhood and town, by asking the following questions: "how satisfied are you with your neighborhood" (scale: 1 = not at all satisfied, 5 = extremely satisfied) and "how would you rate your town as a good place to age?" (scale: 1 = poor, 5 = excellent)." In addition, the importance of social relations was measured with two questions: (1) how satisfied are you with your town in terms of connections to family and (2) how satisfied are you with your town in terms of connection to friends, with a Likert scale from "not at all satisfied (1)" to "extremely satisfied (5)." The term "town" in these questionnaires refers to the rural areas where they reside. The United States Department of Agriculture (USDA) defines "rural" as non-metro areas or small-towns [33]. Existing and validated survey instruments were used to develop these survey questions including (1) the Aging-in-Place Instrument from the aging-in-place project funded by the U.S. Department of Agriculture's National Institute of Food and Agriculture [34]; and (2) the Age-Friendly Community Survey, which the American Association of Retired Persons (AARP) has used to define livable communities in the U.S. [35].

**Physical activity level.** Physical Activity for the Elderly (PASE) scale was used to measure individual physical activity levels [36]. PASE is a well-known and reliable instrument designed specifically to assess physical activity in older persons over a one-week time frame ( $r = 0.75$ ). Participation in leisure physical activities, including walking outside the home and light, moderate, and strenuous sport, recreation activities, and muscle strengthening were recorded as never, seldom (1–2 days/week), sometimes (3–4 days/week), and often (5–7 days/week). Duration of the activities was categorized as less than 1 hour, between 1 and 2 hours, 2–4 hours, or more than 4 hours. Paid or unpaid work, other than work that involves mostly sitting, was recorded in total hours per week. Housework (light and heavy), lawn work/yard care, home repair, outdoor gardening, and caring for others were recorded as yes/no [37].

### Statistical Analysis

This study mainly focuses on correlates of PA and residential environmental variables in rural older adults. Variable means and proportions were used to describe the demographic profiles, residential environment, social relations, and physical activity levels of the sample, stratified by background demographics. One-way analysis of variance (ANOVA) was used to examine mean differences in PA between pre-pandemic (Survey I) and the pandemic (Survey II) for different characteristics; and the significance level among the continuous variables by categorical demographic variables for Survey I and Survey II, respectively. Pearson's bivariate correlations were calculated to examine the relationship between the PA level and other continuous variables (i.e., residential environment and social relation variables). Lastly, multivariate linear regression was conducted to determine the constructs most associated with PASE in rural older adults. Data were analyzed using the SPSS 28. Significance was set at  $p < 0.05$ .

## RESULTS

### Participants' Demographics

Table 1 presents the demographic characteristics of rural older adults who participated in our two-phase surveys. A total of 154 rural older adults completed the first survey before the 2020 pandemic (namely, Survey I) and, subsequently, 301 rural older adults responded to the second survey administered in the year 2022 which was in the middle of the pandemic (Survey II). In both surveys, a majority of respondents were female (74.7% vs. 59.8%), Caucasian (56.5% vs. 92.7%), and had at least a high school education or above (82.5% vs. 98.7%). Some different demographic characteristics were found in the two surveys. For Survey I, those in their 70s was the largest age group (43.5%), while for Survey II it was those in their 60s (40.5%). Compared Survey II, most rural older adults in Survey I were not currently married. They were widowed, divorced/separated, or never married (67.6% vs. 36.5%), and earned less than \$25,000 annually (51.9% vs. 20.3%).

### PASE, Residential Environments, and Social Relations

Table 2 provides a wide range in the level of physical activity, as measured by PASE, and mean scores of variables measuring perceived residential environments (neighborhood and town satisfaction) and social relations (connection to family and connection to friends) for both Survey I and II.

When comparing the pre-pandemic (Survey I) to the pandemic (Survey II), no significant mean differences were found in terms of PASE scores. However, when comparing PASE scores by the demographic variables of Surveys I and II, respectively, significant mean differences were found.

For Survey I, in terms of age groups, PASE mean scores of rural older adults were higher in the 50s ( $163.8 \pm 95.4$  score) compared with 60s ( $119.1 \pm 92.1$  score), 70s ( $114.3 \pm 81.3$  score), and 80s above ( $124.3 \pm 93.4$  score), which showed significant mean differences ( $F = 2.64, p < 0.05$ ). Regarding education levels in Survey I, the PASE scores of those with some college, an associate degree ( $157.2 \pm 100.0$  score), a Bachelor's degree, or more ( $143.5 \pm 125.0$  score) were significantly than those having less than a high school education ( $99.8 \pm 58.1$  score) or a high school graduate ( $109.7 \pm 78.7$  score), indicating significant mean differences ( $F = 3.039, p < 0.05$ ). Also, PASE scores differed significantly by marital status ( $F = 2.693, p < 0.05$ ) in that married ( $144.2 \pm 88.7$  score) and divorced ( $146.8 \pm 134.3$  score) groups showed significantly higher PASE scores than separated ( $67.6 \pm 34.5$  score) and widowed ( $100.4 \pm 61.7$  score) groups in Survey I. Lastly, there was no statistically significant difference between male and female in this survey.

Table 1. Profile of Rural Older Adults in Survey I and Survey II

Group	Indicator	Survey I			Survey II		
		Female 115 (75.2%)	Male 38 (24.8%)	Total 153 (100%)	Female 180 (59.8%)	Male 121 (40.2%)	Total 301 (100%)
Age [years]	Female	3 (2.6%)	2 (5.3%)	5 (3.2%)	22 (12.2%)	18 (14.9%)	40 (13.3%)
	Male	36 (31.3%)	7 (18.4%)	43 (28.6%)	72 (40.0%)	51 (42.1%)	123 (40.9%)
	55 – 59	47 (40.9%)	20 (52.6%)	67 (43.5%)	75 (41.7%)	47 (38.8%)	122 (40.5%)
	60s	29 (25.2%)	9 (23.7%)	38 (24.7%)	11 (6.1%)	5 (4.1%)	16 (5.3%)
Ethnicity	70s	57 (50.0%)	30 (78.9%)	87 (56.5%)	166 (92.2%)	113 (93.4%)	279 (92.7%)
	80s and above	52 (45.6%)	8 (21.1%)	60 (39.6%)	11 (6.1%)	1 (0.8%)	12 (4.0%)
	Caucasian	1 (0.9%)	0 (0%)	1 (0.6%)	1 (0.6%)	0 (0%)	1 (0.3%)
	African American	4 (3.5%)	0 (0%)	4 (2.6%)	2 (1.1%)	7 (5.8%)	9 (3.0%)
Marital status	Asian	35 (30.4%)	13 (35.1%)	48 (31.8%)	104 (54.5%)	87 (45.5%)	191 (63.5%)
	Others	28 (24.3%)	6 (16.2%)	34 (22.1%)	28 (63.3%)	17 (36.7%)	45 (15.0%)
	Married	5 (4.3%)	3 (8.1%)	8 (5.2%)	3 (1.6%)	1 (0.8%)	4 (1.3%)
	Divorced	37 (32.2%)	8 (21.6%)	45 (29.3%)	36 (87.8%)	5 (12.2%)	41 (13.6%)
	Separated	10 (8.7%)	7 (18.8%)	17 (11.0%)	9 (45.0%)	11 (55.0%)	20 (6.6%)
Education	Widowed	18 (16.2%)	4 (10.5%)	22 (14.3%)	4 (2.2%)	0 (0.0%)	4 (1.3%)
	Never Married	48 (43.2%)	19 (50.0%)	67 (43.5%)	48 (26.7%)	13 (10.7%)	61 (20.3%)
	≤ high school	30 (27.0%)	10 (26.3%)	40 (26.0%)	84 (46.7%)	40 (33.1%)	124 (41.2%)
	High school	15 (13.5%)	5 (13.2%)	20 (13.0%)	44 (24.4%)	68 (56.2%)	112 (37.2%)
Income (\$)	College	60 (60.0%)	20 (62.5%)	80 (51.9%)	44 (24.4%)	17 (14.0%)	61 (20.3%)
	≥Bachelors	17 (17.0%)	4 (12.5%)	21 (13.6%)	28 (15.6%)	9 (7.4%)	37 (12.4%)
	< \$25K	16 (16.0%)	4 (12.5%)	20 (13.0%)	34 (18.9%)	18 (14.9%)	52 (17.3%)
	25K -35K	5 (5.0%)	3 (9.4%)	8 (5.2%)	38 (21.1%)	28 (23.1%)	66 (21.9%)
	35K -50K	2 (2.0%)	1 (3.1%)	3 (1.9%)	36 (20.0%)	49 (40.5%)	85 (28.2%)

Totals may not sum to 153 for Survey I and 301 for Survey II due to missing responses. ≤ high school = Less than high school; High school = High school graduate; College = Some college or associate degree; ≥Bachelors = Bachelors degree or more; < \$25K = Less than \$25K; ≥ 75K = 75K and over

Table 2. Mean Scores (SDs) of PASE; Mean Scores of Perceived Residential Environment and Social Relation Variables of Rural Older Adults

Group	Indicator	Survey I (n = 153)					Survey II (n = 301)				
		PASE (SD)	Perceived Residential Environment		Social relation		PASE (SD)	Perceived Residential Environment		Social relation	
			Nbd <sup>a</sup>	Town <sup>b</sup>	Family <sup>a</sup>	Friends <sup>a</sup>		Nbd <sup>a</sup>	Town <sup>b</sup>	Family <sup>a</sup>	Friends <sup>a</sup>
Gender	Female	119.4 (89.4)	3.75	3.58	3.80	3.77	117.0 (65.9)	3.70	3.61	3.37	3.58
	Male	140.35 (105.4)	3.79	3.70	3.61	3.63	123.4 (72.6)	3.61	3.58	2.97	3.27
Age	55 - 59	163.8 (95.4)	4.0	4.0	4.0	3.80	124.6 (73.5)	3.73	3.53	3.18	3.58
	60s	119.1 (92.1)	3.93	3.50	3.74	3.67	117.4 (67.2)	3.77	3.61	3.35	3.54
	70s	114.3 (81.3)	3.70	3.68	3.69	3.71	121.2 (69.1)	3.56	3.57	3.07	3.39
	80s and above	124.3 (93.4)	3.63	3.58	3.79	3.78	111.0 (69.2)	3.50	3.81	3.25	3.06
Ethnicity	Caucasian	119.9 (95.1)	3.84	3.71	3.67	3.76	122.9 (66.8)	3.70	3.64	3.18	3.46
	African American	125.1 (83.4)	3.67	3.48	3.85	3.60	57.8 (40.1)	3.08	2.83	3.50	3.33
	Asian	329.9 (0.00)	4.0	4.0	3.0	4.0	78.6 (0.00)	4.00	3.00	4.00	4.00
	Others	174.3 (166.1)	3.25	3.25	3.50	4.25	105.6 (113)	3.33	3.22	3.56	3.67
Marital Status	Married	144.2 (88.7)	3.84	3.78	3.83	3.79	129.8 (66.8)	3.71	3.70	3.15	3.47
	Divorced	146.8 (134.3)	3.68	3.38	3.28	3.39	101.3 (76.2)	3.69	3.44	3.47	3.56
	Separated	67.6 (34.5)	3.63	3.50	3.75	3.75	117.7 (87.0)	3.00	3.25	3.00	3.00
	Widowed	100.4 (61.7)	3.59	3.80	3.93	3.73	99.4 (57.1)	3.78	3.61	3.34	3.63
	Never Married	112.2 (77.7)	3.59	3.41	3.82	4.13	104.6 (72.7)	3.10	3.00	3.00	2.85
Education	≤ high school	99.8 (58.1)	3.73	3.86	3.68	3.73	79.7 (42.7)	3.50	3.50	4.00	4.25
	High school	109.7 (78.7)	3.70	3.64	3.77	3.73	112.7 (68.5)	3.72	3.70	3.49	3.49
	College	157.2 (100.0)	3.85	3.50	3.74	3.70	116.6 (64.3)	3.55	3.56	3.27	3.44
	≥Bachelors	143.5 (125.0)	3.85	3.50	3.74	3.80	128.1 (73.5)	3.77	3.57	2.96	3.44
Income	< \$25K	112.9 (100.1)	3.74	3.74	3.74	3.74	94.1 (69.4)	3.70	3.44	3.36	3.43
	25K -35K	128.5 (79.2)	3.48	3.48	3.48	3.48	117.1 (56.1)	3.51	3.46	3.32	3.57
	35K -50K	145.1 (70.3)	4.05	4.05	4.05	4.05	108.4 (64.4)	3.58	3.52	3.23	3.54
	50K -75K	174.9 (90.4)	3.88	3.88	3.88	3.88	127.3 (71.4)	3.59	3.73	3.20	3.47
	≥ 75K	238.5 (89.0)	4.33	4.33	4.33	4.33	139.7 (67.5)	3.81	3.71	3.05	3.38

<sup>a</sup> Scale: 1=not at all satisfied, 5 = extremely satisfied. <sup>b</sup> Scale: 1= poor, 5 = excellent. Nbd = Neighborhood; ≤ high school = Less than high school; High school = High school graduate; College = Some college or associate degree; ≥Bachelors = Bachelors degree or more; < \$25K = Less than \$25K; ≥ 75K = 75K and over

For Survey II, significant mean differences in PASE were found by ethnicity ( $F = 3.80, p < 0.05$ ), marital status ( $F = 3.062, p < 0.05$ ), and income ( $F = 4.717, p < 0.05$ ). Caucasians ( $122.9 \pm 66.8$  score) showed significantly high PASE score than African Americans ( $57.8 \pm 40.1$  score). Similar to Survey I, married groups ( $129.8 \pm 66.8$  score) reported the highest PASE compared to divorced and widowed groups ( $101.3 \pm 76.2$  and  $99.4 \pm 57.1$  score, respectively). Lastly, incomes of \$75K and over ( $139.7 \pm 67.5$  score) and \$50K to \$74K ( $127.3 \pm 71.4$  score) showed significant higher PASE score than low income groups ( $94.1 \pm 69.4$  score for less than \$25K and  $117.2 \pm 56.1$  score for \$25K to \$34K). As similarly as Survey I, there was no statistically significant difference between male and female in Survey II.

Like the PASE comparison, the perceived residential environments (measured by neighborhood and town satisfaction) and social relations (measured by family and friend connection) of rural older adults did not show significant mean differences between pre-pandemic (Survey I) and pandemic (Survey II). However, when comparing perceived residential environments and social relations by the demographic variables of Survey I and Survey II, respectively, significant mean differences in town satisfaction (i.e., residential environments) were found in terms of age. That is, age groups in the 70s, 80s, and above showed higher satisfaction rates than the 50s and 60s groups, which showed significant differences,  $F = 3.89, p < 0.05$  for Survey I and  $F = 2.73, p < 0.05$  for Survey II.

For Survey II, town satisfaction showed significant mean differences by ethnicity ( $F = 3.35, p < 0.05$ ) and marital status ( $F = 2.89, p < 0.05$ ). Additionally, neighborhood satisfaction scores in Survey II differed significantly among marital status groups ( $F = 2.54, p < 0.05$ ). In terms of social relations assessed by two variables, (1) connection to family and (2) connection to friends, only family connection showed significant mean differences by educational level in Survey II ( $F = 2.94, p < 0.05$ ).

#### *Regression Analysis of Physical Activity with Residential Environment and Social Relation Factors*

Tables 3 showed a Pearson correlation coefficient matrix of all the correlates of physical activity (PASE) measured in this study for Survey I and Survey II, respectively. As shown in Table 3, none of the residential environment (satisfaction with neighborhood and town) and social relation (connection to family and friends) factors were significantly associated with physical activity (PASE) for rural older adults for Survey I. PASE is significantly correlated with town environment ( $r = 0.164$ ) and connection with friends ( $r = 0.213$ ) for Survey II. All the components of the theoretical factors were correlated for both Surveys I and II.

Table 3. Correlation for PASE and Perceived Residential Environment and Social Relation Factors.

Survey		PASE	Satisfaction with neighborhood	Satisfaction with town	Connection to family
I	Satisfaction with neighborhood	0.119	-		
	Satisfaction with town	-0.037	0.384**	-	
	Connection to family	-0.026	0.281**	0.324**	-
	Connection to friends	-0.061	0.275**	0.276**	0.749**
II	Satisfaction with neighborhood	0.097	-		
	Satisfaction with town	0.164**	0.528**	-	
	Connection to family	0.048	0.311**	0.273**	-
	Connection to friends	0.213**	0.480**	0.414**	0.636**

\* $p < 0.05$ ; \*\*  $p < 0.01$ .



Table 4. Linear Regression Analysis of Predictive Validity for Physical Activity (PA) Measurement

Models	<i>r</i>	<i>R</i> <sup>2</sup>	<i>F</i>	<i>p</i>
PA's association with residential environment and social connection predictors <sup>a</sup> (Survey I)	0.076	0.006	0.411	0.664
PA's association with residential environment (Survey II)	0.165	0.027	4.144	0.017
PA's association with residential environment and social connection predictors <sup>a</sup> (Survey II)	0.260	0.067	5.347	<0.001

PA = Physical activity which was measured by PASE. <sup>a</sup> Predictors included satisfaction with neighborhood, town, and connection to family and friends.

A multiple regression analysis was conducted to evaluate how well the residential environment and social relation factors predicted rural older adults' physical activity (PA) levels. As shown in Table 4, the linear combination of the residential environment and social relation measures was not significantly related to physical activity level for Survey I. However, the results of Survey II predictors indicated that both residential environmental and social relation factors accounted for a significant amount of physical activity variability ( $R^2 = 0.067$ ,  $F(4,296) = 5.347$ ,  $p < 0.05$ ), indicating that rural older adults who rated higher satisfaction rate of a town environment, and higher connection with family and friends, tended to have higher physical activity scores. The sample multiple correlation coefficient was 0.26, indicating that approximately 6.7% of the variance of the physical activity in the sample can be accounted for by the linear combination of the residential environment and social relation factors.

## DISCUSSION

The present study examined the effects of the Covid-19 pandemic and lockdown regulations on older adults' PA, particularly those who reside in rural areas. In addition, it assesses how their PA was accounted for from their residential environments and social relations.

The first aim of this study was to assess the changes in the leisure time PA levels of rural older adults because of the COVID-19 pandemic lockdown. Interestingly, there was no significant difference regarding the level of PA compared to the pre-pandemic era. This means individuals were maintaining their PA levels even though pandemic-related restrictions were enforced. A study conducted in Scotland observed similar trends, noting a significant difference in PA minutes per week before and during the initial lockdowns, though this study used general population information in which age was not limited [38].

In this study, PA using the PASE scale was assessed by demographic variables for each survey, Survey I (pre-pandemic period from 2019-2020) and Survey II (pandemic period in 2020). While age, education, and marital status in Survey I were significantly associated with the behavior of PA in a rural setting, Survey II showed somewhat different variables that were significantly related to PA levels including ethnicity, marital status, and income level. A reason for this disparate finding can be traced to the fact both samples were not equally distributed by demographic variables. For example, most participants from Survey II were Caucasian (92.7%), some college experience or more (78.4%), and income of \$25K or more (79.8%) compared with their counterparts' characteristics (Survey I) including Caucasian (56.5%), some college experience above (39.0%), and \$25k income plus (33.7%). Another reason may come from the relatively low PASE scores. In the present study, the average PASE scores for both participants in this study were 124.3 ( $SD = 93.4$ ) in Survey I and 119.6 ( $SD = 68.6$ ) in Survey II, which are relatively lower than the scores of previous studies [39,40] conducted in the U.S. This output could be caused by the same reason as stated above. Additionally, this present study targets rural older adults

who are commonly known not to have access to sidewalks in their neighborhoods. Therefore, they may have limitations in taking advantage of regular walking or jogging. In terms of age, previous studies reported that younger participants had significantly higher mean PASE scores [17,40-42] and Survey I showed similar findings. Survey II showed insignificant mean differences in PASE by age groups which can be traced to reasons addressed above in terms of the nature of the sample. Lastly, groups with higher education backgrounds (Survey I only) and income levels (Survey I and II) are associated with being more active in their PA. This outcome is consistent with previous studies indicating that individuals with higher incomes and more education were more likely to participate in PA than those with lower incomes and less education [43-45].

The second aim of this study was to determine whether there was a change in the level of PA among rural older adults in relation to their perceived residential environments (satisfaction with neighborhood and town) and social relations (connections to family and friends) during the Covid-19 pandemic. Interestingly, residential environments are not an important factor in determining the PA participation levels of rural older adults in the pre-pandemic period (Survey I). However, they were significantly associated with the residential environment (town) and social relation (connection to friends) factors among the participants who responded to the survey during the pandemic (Survey II). Based on the linear regression results (Model 2), where the residential environment alone was significantly associated with PA participation in Survey II, this association was relatively weak ( $R^2 = 0.027$ ). While additional social relation predictors (connection to family and friends) were added to this model (Model 3), the association increased with statistical significance ( $R^2 = 0.067$ ). These findings can be explained in the context that having easier access to PA resources in towns such as parks and recreation facilities, community/senior centers, and gyms is directly related to an increase in PA levels for rural older adults. In fact, most of the indoor PA facilities were shut down during the initial pandemic period, and assessment limitation for these resources directly impacted their participation. In previous studies, convenience and proximity to PA resources were important factors as well as increased intensity of exercise levels for older adults (24,46,47).

Considerable research suggests that social support is an important predictor of PA in rural populations [24,41,42,48]. In this study, social relations for PA were assessed under two categories, including a connection to family and a connection to friends. Higher-rated social support through friends was significantly associated with more participation in PA during the pandemic (Table 3). Evidence suggests that using peer-led exercise programs may positively influence PA behaviors in older adults [49]. Due to lockdown or curfew orders by many states, most older adults had limited interaction with their friends, particularly rural older adults who were geographically isolated compared with their urban counterparts. Surprisingly, social relations via family connection were not significantly associated with PA behavior. We guess this outcome was caused by a relatively high percentage of Survey II participants who were married (63.5%), which was higher than Survey I participants (31.8%).

A main strength of this study is to fill an existing gap in the literature concerning the impact of COVID-19 lockdowns on the PA behaviors of older adults who live in rural areas. Most publications on this topic have mainly focused on the effects of COVID-19 and its regulations on PA levels for the general population. This study extends the research examining the acute effects of the COVID-19 pandemic by exploring behaviors about six months after initial restrictions and regulations were enforced by federal and local governments in the U.S., thus providing in-depth insight on PA behavior patterns through comparison with pre-pandemic behaviors. This allows for a deeper understanding of the changes observed in PA levels and their associations.

Although this study was the first known to assess the change in PA levels impacted by the Covid-19 pandemic for rural older adults, there were some study limitations due to the nature of cross-sectional study designs, including, for example, sample

representativeness, potential selection, social desirability bias, and recall bias [50]. First, this study has a generalization limitation due to the nature of convenience sampling, not random sampling. This means that the study's findings cannot be applied broadly to a wider population because the participants were selected through convenience sampling rather than through a random selection process, which could lead to a sample that does not accurately represent the entire group in this study. For example, these rural older adults were recruited based on their residential zip code. However, it might be possible that some seniors commute to work in the city and rely upon city amenities. Second, a potential selection limitation can be found in this study. Specifically, for Survey I, a face-to-face, paper-and-pencil survey was used for the rural older adults who had enrolled in some income-qualified aging/housing services. This implies the sample can be considered low-income. However, the sample in Survey II was not selected based on their income. Rather we included any 55+ rural older adults who could complete an online survey. Because of the unequal sample sizes between Survey I and Survey II, it could potentially impact the statistical power of comparison as a smaller sample size may be less representative and have a higher margin of error, potentially limiting the generalizability of findings [51]. This limitation may affect the disparate association between PASE and demographic variables. Additionally, time spent on leisure PA was self-reported. This may cause bias as typically individuals over-report their PA time [52]. Recall bias may have an impact on the study as participants were asked to report their PA a week prior to each survey. Finally, we focused on PASE. Thus, our findings do not apply to all forms of PA, including intensity and strength.

## CONCLUSION

The present study examined the effects of the COVID-19 pandemic and lockdown regulations on the PA behaviors of older adults in rural communities. Results indicated insignificant differences in older adults' PA levels before and during the pandemic. For both Survey I and II, there was no statistically significant difference between male and female. However, the impact of COVID-19 has provided unique insight that residential environment and social relation factors are significant in increasing PA levels during the recent pandemic. These findings may help construct effective interventions to increase the physical activity levels of rural older adults by targeting specific barriers and promoting facilitators. This study may also help to inform interventions for future possible pandemics to implement tailored programs quickly to prevent the negative consequences on health for this population.

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