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An Individual-based Rurality Measure and Its Health Application: A Case Study of Latino Immigrants in North Florida, USA

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Abstract

Rurality has been frequently noted by researchers as pathways to understand human health in rural and remote areas. Current measures of rurality are mostly oriented to places, not individuals, and have not accounted for individual mobility, thus inappropriate for studying health and well-being at an individual level. This research proposed a new concept of individual-based rurality by integrating personal activity spaces. A feasible method was developed to quantify individuals' rural experience using household travel surveys and geographic information systems (GIS). For illustration, the proposed method was applied to understand the well-being and social isolation among rural Latino immigrants, who had participated in a community-based participatory research (CBPR) study in North Florida, USA. The resulting individuals' rurality indices were paired with their scores of well-being and social isolation to identify potential associations. The correlation analysis showed that the proposed rurality can be related to the social isolation, mental and physical well-being of individuals in different gender groups, and hence could be a suitable tool to investigate rural health issues.

Keywords

USA; Rural health; Activity space; Health and Well-being; Latino Immigrant; GIS

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Introduction

The worldwide rural population face considerable risks to poor health and well-being, as they are more likely than their urban counterparts to be poor, have lower education, less employment opportunities and unequal access to health care (AIHW, 2015; Alfero et al., 2013; Van Dis, 2002). There are, for example, lower rates of hospital surgical procedures and general practice consultation in remote areas than in major cities (Jordan et al., 2004; Laditka et al., 2009). People from remote areas tend to be more likely than their major city counterparts to smoke and drink alcohol in harmful or hazardous quantities (Coomber et al., 2011; Lutfiyya et al., 2008). Further, living in rural areas may adversely affect the mental health of residents, particularly for minority groups who have limited language proficiency, work in low-paying jobs and are spatially segregated (Warren & Smalley, 2014). Thus, the concept of 'rurality' has been widely acknowledged in regional planning, health policy making, and resource allocation (Judd et al., 2002; Smith et al., 2008).

To date, a variety of methods have been proposed to define 'rurality' qualitatively and quantitatively (Hall et al., 2006), but most definitions are constrained by the fact that they are place-based. That is, rurality is often measured as a property of places, which are identified as administrative units, such as counties, census tracts, or postal-code areas (Hart et al., 2005). There are two limitations for those place-based definitions. First, many health outcomes are measured at the individual level, for instance, blood pressure, smoking behavior, and mental status. Previous studies had to aggregate these individual measures by place to accommodate place-based rurality, and thus potential associations can only be investigated at the place level. Due to the ecological fallacy, results from such ecological analysis should not be used to infer individual experiences (Kwan, 2009; Wong & Shaw, 2011). Second, individuals are mobile and could visit multiple places on a daily, weekly, or monthly basis to carry out a range of activities. The rurality of one place is not adequate to fully portray the rural environment an individual is exposed to, which could in turn mislead the relationships between rurality and human health.

To address these limitations, this research proposed that measurements of rurality need to be individualized and be capable of considering individual mobility. The following literature review shows that limited studies have been undertaken along this line of thinking. This article describes the development of a new individual-based rurality index, and illustrates its application in studying the social isolation and well-being of rural Latino immigrants in North Florida, USA.

Literature Review

Development of rurality measures

Like concepts such as truth, beauty, or justice, everyone knows the term 'rural', but no one can precisely define the term (Weisheit et al., 2005). In the literature, there have been a number of attempts to define and measure rurality, but no consensus has been reached so far (Hewitt, 1989; Weinert & Boik, 1995). The US Census uses a dichotomous taxonomy: an area is either urban or rural. An urban area is composed of contiguous census blocks or block groups that has, in its core, a population density of at least 1,000 persons per square

mile and has a total population of 2,500 or more residents (USCensus, 2010). All areas outside of urban areas are defined as rural. The definition is limited to represent the rural-urban transition or capture the breadth of variation in rural areas.

To overcome the dichotomous limitation, there have been efforts to describe the rural-urban transition with discrete coding systems. For example, the US Office of Management and Budget (OMB, 2010) defines metropolitan, micropolitan, and non-core counties, according to the population size and the contiguity between counties. Based on the OMB taxonomy, the United States Department of Agriculture (USDA, 2013c) developed the Urban Influence Codes (UICs) that further divide the three OMB-categories into 12 sub-categories with a set of thresholds concerning the urban populations and adjacency to a metro area. Similarly, the Rural-Urban Continuum Codes (RUCC), previously known as the Beale codes, form a classification scheme that distinguishes the three OMB-categories of counties by 9 sub-categories (USDA, 2013b). The Rural-Urban Commuting Area (RUCA) codes classify U.S. census tracts and ZIP codes into 10 numerical categories using measures of population density, urbanization, and daily commuting.(USDA, 2010). In Australia, the Rural, Remote and Metropolitan Areas (RRMA) classification allocates each statistical local areas (SLA) into 7 categories based on population numbers, population density and the straight-line distance to various population centers (McGrail & Humphreys, 2009). Although these classification schemes describe the rurality as numerical codes, they still remain discrete, spatially coarse, and ultimately limiting since they mask rural variations within a geographic unit that are necessary for fine-grained individual analysis. Further, the subjective thresholds between categories can lead to misclassification of geographic units that are similar.

To solve these issues, a number of continuous measures have been developed. These studies have shifted the focus from the question of ‘Is a place rural or urban?’ to ‘What is the degree of rurality for a place?’ For instance, Waldorf (2006) structured a continuous index of relative rurality through averaging the normalized scores of population size, density, percentage of urban residents, and distance to the closest metropolitan area. The index was calculated for US counties to understand the spatial-temporal variation of rurality. Caschili et al. (2015) have constructed a Composite Indicator of Rurality (CIR) using principal component analysis and weighted linear combination of demographic, socio-economic, and settlement factors. The CIR was applied to municipalities on an Italian island to examine the relationship between accessibility and rurality. The Accessibility/Remoteness Index of Australia (ARIA) is another continuous index estimated on a 1 km grid of Australia, using road distances from over 12,000 populated localities to their nearest service centers in five categories based on the population size (Dunne et al., 2001). Compared to the discrete coding systems, the continuous degree of rurality offers a more detailed description of urban-rural continuum, and allows more sophisticated numerical analysis on rurality and related social issues from education to poverty, unemployment, and health.

The literature shows that rurality is mostly gauged as a property of places, such as counties, census tracts, and cell locations. Few studies have consider rurality as a property of individuals (Kwan, 2009). There are two limitations for these place-based measures in social/health studies. First, the associations between the rurality and health outcomes can only be explored at the aggregate level, for example the county or tract level. The ecological

fallacy can cloud the identification of true relationships at the individual level. Given that many health outcomes are actually obtained at the individual level, a rurality measure of the same level is more appropriate for epidemiologic studies. Second, individuals are mobile and could visit multiple places on a daily, weekly, or monthly basis for a wide range of activities. The rurality of one place (e.g. the home ZIP code) cannot accurately represent the full scale of rural environment an individual is exposed (Farber et al., 2012; Wong & Shaw, 2011). To address the limitations, this research adopted an activity-space approach to define an individual-based rurality.

Activity-space approach

The concept of activity space has a long history in the geography and transportation literature, and has been extensively used to represent spatial behavior of individuals (Axhausen & Gärling, 1992; Farber et al., 2013; Wang & Cheng, 2001). A widely recognized definition states that an activity space is a set of potential places, such as homes, workplaces, schools, and shops, where an individual may perform routine activities (Golledge & Stimson, 1997). Major data sources to construct individual activity spaces are household travel surveys and individual travel dairies. Recent advance of geo-locating technologies, such as the global positioning system and location-aware smart phones, makes possible the study of activity spaces for a large amount of individuals (Raanan & Shoval, 2014; Silm & Ahas, 2014). Geographic maps are the major tool to depict individual activity spaces, with points, lines, polygons representing locations, travel routes, and spatial extent, respectively (Kwan, 2004). In addition, there is a variety of methods to summarize individual activity spaces (Schönfelder & Axhausen, 2003), such as a two dimensional ellipse (that envelopes all places being visited by an individual), kernel densities (of places being visited), and the minimum distance routes between all locations visited (the minimum spanning tree).

The activity space approach has been used as an individual-level spatial construct in a wide variety of social science studies. For example, Schönfelder and Axhausen (2003) investigated the activity spaces of individuals who may be at risk of social exclusion (female, lower income, elderly) in two German cities, in terms of the ellipses, kernel densities, and minimum spanning trees. Wong and Shaw (2011) devised an individual-based social segregation measure as a function of an individual's exposure to other groups within his/her activity space. The new measure was used to evaluate the social segregation of different ethnic groups in tricounty areas in southeast Florida, USA. Farber et al. (2012) integrated individual activity spaces into the Getis and Ord's *G* statistics, and proposed a measure of residential clustering and exposure patterns. Their approach enables statistical tests for hotspots of social segregation in Montreal, Canada. Recently, Raanan and Shoval (2014) utilized GPS tracking technology to construct individual activity space, and to understand the relationship between perceived territorial boundaries and actual spatial activities of women in Jerusalem, Israel. Despite the wide use of activity-space approach in social sciences, most studies have been focused on measuring social problems in urbanized areas. Few studies have integrated activity space into the rurality measures and have demonstrated how the individual rural experiences may relate to health outcomes.

Methodologies

This research defines a new individual-based rurality as the weighted sum of rurality degrees within the activity space of an individual. Specifically, the rurality score of individual i , R_i , can be expressed as Equation 1:

$$R_i = \frac{\sum_{L=1}^n Prob_{L,i} \times RuralDegree_L}{\sum_{L=1}^n Prob_{L,i}} \quad (\text{Eq. 1})$$

where n is the total number of places within individual i 's activity space, and L ($=1, 2, \dots, n$) represents any one of these places. $Prob_{L,i}$ is the probability of visiting place L by individual i , and $RuralDegree_L$ is the degree of rurality at place L . The denominator is the sum of all probabilities to standardize the individual-based rurality to a common scale. A person would have a great rurality score if he/she visits highly rural places very often, e.g., every day.

The proposed definition accounts for an individual's experiences of rural environment at various places, as a result of their spatial activities. Each place is weighted by the frequency of visiting so that the time dimension of activities can be included. Eq. 1 can be further modified to contrast an individual's home rurality and non-home rurality. The home rurality of an individual can be calculated by confining the L only to the home location. This is equivalent to the traditional place-based rurality. The non-home rurality can be computed by considering L as all places in the activity space except for the home. The comparison of the non-home rurality to the home rurality could highlight the effects of out-of-home rural experiences on individual health.

From an implementation perspective, the probability of visiting a place $Prob_{L,i}$ can be estimated from the frequency of visits reported in travel surveys, travel dairies, or GPS tracking records. The degree of rurality for place L , $RuralDegree_L$ can be computed as either a discrete (e.g., the RUCC) or continuous variable (a composite index) with the methods reviewed in the preceding section. The resulting individual-based rurality can then be paired with social/health measures of individuals for subsequent epidemiological studies. To demonstrate the use of individual-based rurality in health studies, the following section articulates a case study among Latino immigrants in the US.

Case study of Latino immigrants in North Florida

From 2000 to 2010, the rural Latino population in the US had grown by 44.6%, faster than any other racial or ethnic minority group, and accounted for 56% of all nonmetropolitan population growth (USDA, 2013a). These Latino immigrants may experience discrimination due to their different culture, language and physical image, and as a result, be excluded from rural environmental and social spaces. This exclusion may further lead to the feelings of cultural, geographic, linguistic and social isolation (Lichter, 2012; Mora et al., 2013; Ornelas et al., 2009), which can adversely affect their long-term well-being by acting as chronic stressors (Ko & Perreira, 2010). This case study aims to evaluate how individual rural experiences interact with the well-being and social isolation of Latino immigrants in North Florida, USA.

This study is an arm of a larger mixed-methods design that uses community-based participatory research (CBPR) with rural Latinos in North Florida to promote mental health (J.-M. R. Stacciarini et al., 2011). The study sites were the Levy, Lafayette and Suwannee Counties, which are rural areas of North Florida with vast farmland and scattered residences. Participants were rural Latino immigrant parents at least 25 years old, who have been living in the US for up to 20 years, resided in one of three rural counties and spoke Spanish. Community engagement principles were used to identify and recruit this hard-to-reach population: 1) study team members talked to potential participants during community events especially in churches and schools, 2) the principal investigator received referrals from the community advisory board leaders, 3) community workers followed up on recruitment attempts, and 4) followed referrals from other study participants. The final sample in the study was $N=60$ participants (30 couples). The subsequent analysis was completed in three stages (Figure 1).

Stage 1: Measuring rurality degree of places

Based on three previous quantitative work (Caschili et al., 2015; Mountrakis et al., 2005; Waldorf, 2006), the rurality degree of places was conceptualized as a composite indicator of three macro-components, namely, demography (D), socio-economy (SE), and accessibility (AC). Each macro-component consists of a number of factors (Table 1). Mathematically, the rurality degree of a place is formulated as a weighted linear combination of multiple factors (Eq. 2):

$$Rurality_L = \alpha \cdot D_L + \beta \cdot SE_L + \gamma \cdot AC_L = \alpha \cdot (w_1 \cdot PD_L) + \beta \cdot (w_2 \cdot ED_L + w_3 \cdot LU_L + w_4 \cdot I_L) + \gamma \cdot (w_5 \cdot T_L + w_6 \cdot HD_L + w_7 \cdot SD_L) \quad (\text{Eq. 2})$$

where L represents a place, and $Factor_L$ is the quantitative measure (score) of this factor at the place L . α , β , γ , are the weights of macro-components, and w_k ($k=1, 2, \dots, 7$) are weights of factors, indicating their importance to the rurality.

The study area was divided into a grid of cells with a resolution of $600\text{m} \times 600\text{m}$, which is the average size of Florida census blocks. Each cell location was considered as a place and its degree of rurality was calculated using Eq. 2. According to the approach from Caschili et al. (2015), the three macro-components were assumed to be equally important, i.e., $\alpha=\beta=\gamma=1/3$. The values of factors at each cell location was derived from the data sources (Table 1) using ArcGIS 10.1. The derived values were further standardized into scores between 0 and 100 based on the maximum and minimum values (Eq. 3). A greater $Score_{k,L}$ indicates more contribution of factor k to the rurality of place L .

$$Score_{k,L} = \left(1 - \frac{V_{k,L} - V_{k,min}}{V_{k,max} - V_{k,min}}\right) \times 100, k=1, 2, \dots, 7 \quad (\text{Eq. 3})$$

With regard to the factor weights w_k , the w_1 was simply set to 1, because the ‘Demography’ macro-component only had one factor (PD). The principal component analysis (PCA) was employed to determine other weights, following the established approach by Caschili et al. (2015). For factors in the ‘Socio-economy’ and ‘Accessibility’ macro-components, correlation analysis showed that the correlation coefficients between each pair of factors are

below 50%, and hence these factors were not significantly correlated. The PCA (Table 2) shows that both macro-components can be adequately represented by their first principal components, which have the largest eigenvalues.

Subsequently, the extraction of each factor was computed to indicate its contribution to the first component (Table 3). A weight proportional to the extraction was assigned to each factor, and all weights were standardized so that they were summed up to a unity. Finally, the weights and factor scores were plugged into Eq. 2 to produce the rurality degree of every cell location.

Stage 2: Representing individual activity space

To account for human mobility, the 60 participants were asked questions about routine activities as follows: *Which ZIP code do you live in? Where have you traveled (e.g. places or ZIP codes)? What are the names of places you had visited in the last month? How long did it take you to get each place? How often have you been there in the last month?* According to the reported trips, the activity space of each participant was constructed by following two steps:

1) Travel rings from home location—To protect individual privacy, the home location of each participant was registered to the population mean center of the reported ZIP code, i.e., the geographic mean center weighted by the populations of census blocks within the ZIP code area. A set of travel rings was generated to represent reachable areas from homes by driving less than 10, 11–20, 21–30, and 31–40 minutes, respectively, on a real road network (Figure 2). The road network data of Florida and the ArcGIS network analyst were utilized to create these travel rings.

2) Geo-referencing reported places—Based on the reported travel time of a trip, one travel ring was selected and superimposed onto the Google Earth to identify the potential destinations (Figure 2). Those places that fall within this travel ring and match the reported destination were recorded as potential places for this trip. For example, if ‘15 minutes to a church’ was reported for a trip, the travel ring of 11–20 minutes would be chosen. All churches shown on the Google Earth and within the selected travel ring were regarded as potential places for this trip. Their latitude and longitude were extracted from the Google Earth for mapping. The reason that ‘all potential’ places were considered, rather than “exactly one” place, was due to the vagueness of many reported place names, as well as the protection of individual privacy. When potential places were identified for all reported trips, the activity space of a participant was mapped onto the place-based rurality map (from Stage 1), and the degree of rurality for all places ($RuralDegree_L$ in Eq. 1) were extracted with ArcGIS.

Each potential place of activity was also associated with the probability of a visit per day. It was computed according to the reported frequency of visits by the participant during the last month. Specifically, the probability was set as 1 if ‘every day’ was mentioned, as 1/7 if ‘once a week’, or as 1/30 if ‘once a month’. If there are multiple potential places for an activity, the probability was further prorated to each place by dividing the number of potential places. With the visiting probability of a place ($Freq_{L,i}$ in Eq. 1) and the degree of

rurality for this place ($RuralDegree_L$ in Eq. 1), this study calculated the home rurality and non-home rurality for each participant.

Stage 3: Statistical analysis on individual-based rurality and health outcomes

Besides the rurality for 60 participants, their mental health, physical health, and social isolation were also assessed by the SF-12v2™ Health Survey (Well-being) and the short version of the PROMIS Health Organization Social Isolation (8 items). The mental component score of the SF-12v2™ was used to assess mental well-being, which measures vitality, social functioning, effects of emotional problems on daily activities, and mental health. The physical component of the SF-12v2™ was used to assess physical well-being, which measures physical functioning, effects of physical problems on daily activities, bodily pain, and general health. Proprietary scoring procedures were used to generate a norm based mental component score (MCS-12) and physical component score (PCS-12) that range from 0 to 100, and have a mean scores of 50 (Std. Dev.=10). Higher scores reflected better perception of well-being. The PROMIS social isolation scale measures perceptions of being avoided, excluded, detached, disconnected from, or unknown by, others. A score of 50 (Std. Dev.=10) is the average for the US general population, and higher scores indicate a greater degree of social isolation. The mental health, physical health, and social isolation scores were paired respectively with individual rurality scores for women and men, and the Spearman correlation coefficients were used to test associations.

Results

Participant demographics

Of the 60 participants, most were 26–45 years old with 3–4 children, primarily from Mexico, and have been living in the US for more than ten years (Table 4). All participants selected Spanish as a preferred language for the interview. On average, the education years were longer for women than men, while the employment rate was higher for men. Women had visited more places during the last month than men had.

Individual-based rurality and well-being measures

Figure 3a shows the urban-rural continuum across the study area (North Florida), measured by the rurality degree from Eq. 1. Rural areas (high degree values) are concentrated in the central part of the study area, while urbanized areas (low degree values) are clustered along the eastern and western sides. Figure 3b–d summarizes three typical patterns of activity spaces among participants. The first pattern represents a small-size activity space, in which all routine activities were localized around the home location (Figure 3b). The second pattern (Figure 3c) reflects a medium-size activity space, in which the individual traveled approximately half hour to a small town once a week or a month to carry out activities, such as grocery shopping and eating out. The third pattern (Figure 3d) exemplifies a large-size activity space, in which the individual not only traveled short distances to a small town, but also took long trips (more than one hour driving) to large cities once a month.

The statistical summary in Table 5 indicates that the average home rurality (=89.6) was roughly 10% greater than that of the non-home rurality (=78.8), suggesting that rural Latino

immigrants tend to visit places less rural than where they live to perform routine activities. Between genders, there is no difference between the home rurality of women and men couples (due to living together), but the non-home rurality of women is slightly higher than that of men. On the other hand, women had a significant higher mean of social isolation score (women = 41.67 and men = 37.37; $p=.00$), poorer mental (women = 52.39 and men = 56.40; $p=.00$) and lower physical well-being scores (women = 53.34 and men = 55.19 $p=.00$). When compared to the US average, 30% of women had higher scores (>50) of social isolation and 31% lower scores (worst) of mental well-being. Amongst males, 5% had higher scores of social isolation and 10% lower scores (worst) of mental well-being.

Correlation analysis

The analysis showed interesting correlations among the rurality, well-being, and social isolation, within and between gender groups (Table 6). A favorable statistical trend of negative correlation between home rurality and social isolation ($r_s = -.31$, $p=.09$) was found in women (lower scores of social isolation if living in more rural areas), but the same was not observed for men. Another negative correlation between the home rurality and physical well-being ($r_s = -.45$, $p=.016$) was found in men (a lower score of physical well-being if living in more rural areas), but the same was not for women. Women's non-home rurality was negatively associated to men's mental well-being ($r_s = -.52$, $p = .005$). That is, women visiting places of low rurality for routine activities are associated to their male partners' better mental well-being. Furthermore, the men's non-home rurality was found to positively related to the women's physical well-being ($r_s = .435$, $p = .021$). In other words, men visiting places of low rurality are associated to their female partners' better physical well-being.

Discussion

Being part of a minority group may add to the inequalities residents of rural areas experience (Parr et al., 2004; Probst et al., 2004). In fact, the literature have described that individuals of diverse excluded groups have difficulty navigating rural public spaces without feeling stigmatized, which over time can impact their well-being. However it is not easy to untangle what factors most influence their well-being (Rigby et al., 2011). The correlation analysis shows that home rurality tended to mitigate the perception of social isolation in women, while that was not observed in their male partners. Living in more rural areas could be seen as a way of covering up, their undocumented status as immigrant, their sentiment of being "outsiders" and the constant fear of deportation, which they live with (Stacciarini et al., 2015). In the studied areas, more rural implies less people, less social interactions and consequently less discriminatory experiences and perceptions of being "left out". However, rurality cannot be seen as an independent variable; in fact women and minorities have been considered a vulnerable population in rural areas across the world due to several other social implications beyond those taken into account for this study when calculating the rurality index (demography, accessibility and socio-economics). For example, women have greater likelihood of constrained job opportunities, acceptable invisibility, and greater risk for intimate partner violence; these factors may increase the risks for overall isolation and poor health; particularly mental health (Archambeau et al., 2010; Kermode et al., 2007; Simmons

et al., 2008; Stacciarini et al., 2014). In addition, undocumented status and being non-English speaking can be significant social health determinants within rural areas, where our study population may be more visible. A qualitative study performed by our research team, found that rural Latino women, due to their undocumented status, tend to socially isolate themselves in order to protect themselves and their family members (Stacciarini et al., 2014).

Interesting patterns of how the non-home rurality measures relate to the conjugal wellbeing were observed. Women's non-home rurality was negatively associated to their male partners' mental well-being, and men's non-home rurality was positively associated with women's physical well-being. These cross-gender associations imply that spatial activities in less rural areas could be a pathway to shape social-cultural interactions and well-being of Latino couples. These associations have not been revealed before by traditional place-based rurality indices, indicating the usefulness of integrating activity space into rurality measure. However, the small sample size of this study, does not allow furthering explore if rurality could be a moderator of partners' well-being. A previous study have reported that more rural environment is negatively associated to the familial well-being; the relationship of distress levels in mothers and fathers residing within the same household has been shown to intensify with increasing remoteness (Novello et al., 2011).

From the results, this research suggests community-based participatory interventions to improve the well-being of women in the studied population. Community health workers, after training, can meet on a regular basis with community members to identify health needs and intervention priorities for the populations (Michael et al., 2008). Diverse types of interventions can be applied to Latino women with health priorities to increase the intensity and space of their activities, for example, a soccer team, tour group, and shopping group, thus helping them develop wider social networks, foster community involvement and social/geographic inclusion *with* and *for* rural Latino immigrants (Stacciarini, 2014).

Three limitations need to be mentioned when interpreting the results. First, several factors that may affect individuals' rural experience have not been considered, for instance their occupation and social networks. The primary reason is the lack of detailed data at fine geographic scales, such as the individual and census block levels. After all, it is argued that geographic classifications of rurality cannot capture all aspects within a single measure, and can only be appropriate for a specific purpose (McGrail & Humphreys, 2009). Second, certain amount of spatial uncertainty was introduced into the analysis because the exact home locations were unknown and some places were reported in vague names. Although individual privacy was protected, these inevitable uncertainties may cloud the identification of more interesting relationships. Third, the associations found in this research may be limited in the rural Latino immigrants of North Florida. The sample size is relatively small in the statistical analysis (30 for either gender) and not random, given the difficulty of reaching this population. Particularly, only a small proportion of male participants score as socially isolated and with poor mental well-being, which may account for non-significant associations between their rurality indices and well-being measures. All these limitations warrant a more sophisticated design but they do not override the significance of the present

case study, which potentially links rurality to social isolation, and well-being in an understudied population-U.S. rural Latino immigrants.

Conclusions

This research brought two contributions to the current literature of rural health. First, this research proposed a new concept of individual-based rurality defined on activity space, and a reliable GIS method to compute this rurality using detailed travel surveys. As compared to the traditional place-based rurality that assumes identical rural experience for all individuals living at the same place, the new definition offers a closer representation of individuals' real rural experience by integrating their activity spaces. This individualized index also makes possible the fine-grained analysis of rural experiences and human well-being at the individual level, thus avoiding the ecological fallacy issue associated with previous place-based rurality measures. Second, in the past two decades, GIS technologies and detailed geographic data have been gradually involved into a variety of human health studies, such as infectious diseases and environment exposure (Croner et al., 1996). However, these technologies have seldom been used in studying rural health of Latinos, an underserved and understudied population. This research is one of the first attempts to introduce GIS analyses and models into this field, and thus opens many new opportunities for understanding human activities and health.

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Research Highlights

1. A new definition of individual-based rurality that accounts for human mobility;
2. A GIS method to estimate individual-based rurality using activity space;
3. A community-based participatory research for wellbeing of rural Latinos;
4. Associations between individual rurality and wellbeing of Latino immigrants;

Figure 1.
Data flow and stages of analysis in the case study.

Figure 2. Travel rings of 10, 20, 30, and 40 minutes (from the inner to the outer) around the population mean center (the home symbol) of an example Zip code area based on a real road network and superimposed on the Google Earth.

Figure 3.

(a) The geographic extent of the study area and the estimated rurality degree by cell location; (b–d) Examples of three individuals' activity spaces being overlaid onto the rurality map. Colored symbols represent all possible locations to carry out routine activities, and the color ramp shows the range of probability of visiting per day. The place with the darkest color indicates the participant's home location.

Table 1

Macro-components and factors to define the rurality degree of places

Macro-Component	Factor (Code)	Definition	Data source	Literature
Demography	Population density (<i>PD</i>)	Residential population per unit of area	US census block 2010	(Waldorf, 2006)
Socio-economy	Ethnic diversity (<i>ED</i>)	Number of different ethnic groups	US census block 2010	(Campbell et al., 2009)
	Land use (<i>LU</i>)	Degree of land development	Florida Geographic Data Library	(Waldorf, 2006)
	Income (<i>I</i>)	Mean household income	US census block group 2010	(Higgs & White, 2000)
Accessibility	Transportation network (<i>T</i>)	Density of roads	Census TIGER/LINE	(Caschili et al., 2015)
	Access to healthcare (<i>HD</i>)	Density of health facilities	Florida Geographic Data Library	(Caschili et al., 2015; Mountrakis et al., 2005)
	Access to social service (<i>SD</i>)	Density of social service facilities	Florida Department of Revenue	(Mountrakis et al., 2005)

Table 2

Principal component analysis over factors in macro-components

Socio-economy macro-component			
Component	Eigenvalues	Percent of Variance	Cumulative Percentage
1	299.01	58.30	58.30
2	192.92	37.62	95.92
3	20.91	4.08	100
Accessibility macro-component			
Component	Eigenvalues	Percent of Variance	Cumulative Percentage
1	52.31	65.18	65.18
2	16.99	21.17	86.35
3	10.96	13.65	100

Table 3

Communality matrix and weights for factors

Socio-economy macro-component		
Factor code	Extraction	<i>w</i>
<i>I</i>	0.14	0.083
<i>LU</i>	0.83	0.498
<i>ED</i>	0.70	0.419
Accessibility macro-component		
Factor code	Extraction	<i>w</i>
<i>SD</i>	0.555	0.244
<i>T</i>	0.900	0.396
<i>HD</i>	0.818	0.360

Table 4

Statistical summary of participants

	Women (n=30)	Men (n=30)
Country of Origin		
El Salvador	6.7%	6.7%
Mexico	90.0%	93.3%
Guatemala	3.3%	0%
Language (Spanish)	100%	100%
Years in US		
10 or less	13.3%	16.6%
More than 10	86.7%	83.4%
Age		
26–35	33.3%	33.3%
36–45	53.4%	50%
46–65	13.3%	16.7%
Number of children *		
1–2	24.1%	26.7%
3–4	65.5%	66.7%
5–6	10.4%	6.6%
Employed		
No	33.3%	3.3%
Yes	66.7%	96.7%
Years of education		
0	0%	6.7%
1–4	20%	13.4%
5–8	36.7%	46.6%
9–14	43.3%	33.3%
Family/friends nearby		
No	13.3%	6.7%
Yes	86.7%	93.3%
Mean number of places visited in last month ***	6.4	5.2
Mean number of cities visited in last month *	2.9	2.5

Note:

* 1 missing, valid percentages used,

** 2 missing, valid percentages used

*** >2 missing

Table 5

Statistical mean and standard deviation of rurality and well-being scores

	Home Rurality	Non-Home Rurality	PROMIS Social Isolation	SF12 Mental Component	SF12 Physical Component
Women	89.60 (5.10)	79.63(3.08)	41.97 (8.91)	52.39 (8.62)	53.35(6.12)
Men	89.60 (5.10)	78.82 (3.75)	37.37(5.52)	56.40(6.16)	55.19(3.13)

Table 6

Relationships between individual rurality and well-being scores

	Women			Men		
	PROMIS score	SF12 Mental	SF12 Physical	PROMIS score	SF12 Mental	SF12 Physical
Home rurality	-.307*	.152	.030	-.131	.123	-.450*
Non-Home Rurality Women	.161	.044	-.124	.165	-.520**	-.054
Non-Home Rurality Men	.016	-.058	.435*	.144	.071	-.124

* Correlation significant at p<0.1 level.

** Correlation significant at p<0.05 level. Correlations that were central to the hypothesis of this study are highlighted.