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Differences in the Community Built Environment Influence Poor Perceived Health among Persons with Spinal Cord Injury

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Abstract

Objectives—To assess the association between characteristics of the built environment and differences in perceived health among persons with spinal cord injury (SCI) using objective measures of the local community derived from Geographic Information Systems (GIS) data.

Design—Secondary analysis of cross-sectional survey data.

Setting—Community.

Participants—503 persons with chronic SCI enrolled in the Spinal Cord Injury Model Systems (SCIMS) database. All cases were residents of New Jersey, completed an interview during the years 2000–2012, had a complete residential address, and were community living at the time of follow-up.

Intervention—Not applicable.

Main Outcome Measure—Perceived health.

Results—Bivariate tests indicated that persons with SCI residing in communities with more (versus less) mixed land use and small (versus large) amounts of open space were more likely to report poor perceived health. No associations were found between perceived health and differences in the residential or destination density of the community. Adjusting for variation in demographic, impairment, quality of life, and community socioeconomic characteristics accounted for the gap in the odds of reporting poor health between persons living in areas with large versus small amounts of open space (OR 0.54; 95% CI 0.28–1.02). However, even after accounting for

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Conflicts of interest:
None.

individual background differences, persons living in communities characterized by more heterogeneous land use were twice as likely to report poor health compared to persons living in less mixed areas (OR 2.14; 95% CI 1.12–4.08).

Conclusions—Differences in the built characteristics of communities may be important to the long-term health and well-being of persons with SCI who may have greater exposure to the features of their local area due to limited mobility. The results of this study suggest living in a community with more heterogeneous land use was not beneficial to the perceived health of persons with chronic SCI living in New Jersey. Further investigation is needed to assess if the relationships observed in this analysis are influenced by differences in infrastructure and resources across communities. Further research is also needed to investigate the role built environment plays in the long-term health and well-being of persons with SCI in other geographic locales.

Keywords

Perceived health; Built environment; Spinal cord injury

Return to the community following rehabilitation is not met with equal success by all survivors of traumatic spinal cord injury (SCI). In addition to impairment-related complications to adjustment, research finds that long-term differences in health and well-being after SCI are also influenced by social factors. Specifically, persons who are disadvantaged due to gender, low socioeconomic status (SES), ethnic minority background, and older ages are more likely to report poorer health outcomes, diminished quality of life (QOL), and limitations to functioning, mobility, and social participation.^{1–4} Some people are also geographically disadvantaged in that the conditions of the communities and neighborhoods where they live are detrimental to health and well-being.^{5, 6} Several recent studies of the SCI population demonstrate that living in socially and economically disadvantaged communities has negative implications for physical activity, participation, and quality of life,^{7–10} suggesting that community characteristics may influence differences in long-term outcomes after injury. To date, few studies have investigated the influence that differences in the physical infrastructure of communities, often referred to as the built environment, may have on outcomes following SCI.¹¹

A number of studies in the general population suggest that certain aspects of the built environment are positively associated with morbidity and mortality. Evidence demonstrates that greater land use mix—that is, community development that mixes multiple residential, commercial, and recreational uses in the same area—residential density, and proximity of recreational destinations are associated with more physical activity and lower rates of health problems, such as obesity and cardiovascular disease.^{12–19} The natural features of communities—often referred to as open or greenspace—may also benefit health and well-being. Analyses of population-based data suggest that higher proportions of greenspace in the residential area are associated with lower rates of mortality,²⁰ common morbidities,²¹ and perceived poor health.²² Researchers attribute these associations to natural areas supporting healthy behaviors such as physical activity and social interaction.^{23–25} Additionally, proximity to “viewable” open space may be psychologically beneficial based on evidence that open space attenuates the relationship between stress and poor health for vulnerable populations.^{20, 26, 27} This suggested mechanism may have particular relevance to

the well-being of persons with SCI because the high rates of mobility limitations, participation restrictions, and unemployment^{28, 29, 30, 31} that are common following injury may result in more exposure to the conditions of local communities.

Evidence supports the salience of built environment to vulnerable groups, such as older adults and persons with mobility impairments.^{32–35} Specifically, features related to poor infrastructure such as broken sidewalks, unsafe parks, and lack of public transportation are associated with the increased likelihood of reported mobility^{36, 37} and participation limitations,³⁸ whereas better connected neighborhoods have been associated with less reported disability among older adults.³⁹ Clarke et al³⁴ identified that living in neighborhoods characterized by mixed land use predicted greater functional independence among persons over 65 years old. To our knowledge, few studies have investigated the effect of open space on disability-related outcomes or among disabled groups. An exception is a recent analysis by Botticello and colleagues¹¹ demonstrating that adults with chronic SCI living in communities with large portions of open space were more likely to report full physical, occupational, and social participation.

Although research attention for the built environment has increased, investigations of the relevance of community characteristics to the health and well being of chronically impaired populations, such as SCI, are few. Awareness of the influence that places have on outcomes is critical to understanding the potential complications to successful adjustment following injury and the prevention of further disability. The objective of this study was to explore the relationship between the built environment and perceived health in SCI in order to assess the relevance of community differences for a relatively unexplored segment of disabled population. This analysis investigated several aspects the built environment, including residential density, land use mix, destination density, and open space, reported to influence health-related outcomes. Perceived health is an important global indicator of morbidity and mortality^{40, 41, 42} and studies of community effects on perceived health have widely demonstrated that exposure to disadvantaged economic, social, and physical community conditions increase reports of poor perceived health.^{43, 44} The relationship between the built environment and perceived health was analyzed by linking survey data from the national Spinal Cord Injury Model Systems (SCIMS) database⁴⁵ with Geographic Information Systems (GIS) data on the built environment.

METHODS

Participants

This analysis involved a sample of 577 SCIMS database participants from New Jersey. SCIMS database participants are persons who complete inpatient rehabilitation for traumatic SCI at a collaborating SCIMS center and consent to participate in follow-up interviews 1-year post-discharge and at subsequent 5-year intervals. Cases were included if the participant was age 18 or older at the time of injury, completed a follow-up interview between 2000 and 2012, and had a valid residential address. SCIMS data collection is longitudinal. In cases where participants contributed multiple interviews over time, the last completed interview was selected for cross-sectional analysis. Of the 540 cases identified that met these criteria, 97% of the addresses were successfully geocoded (i.e., matched to

spatial coordinates) enabling linkages of survey and geographic data. Unmatched cases due to incomplete address information and cases with systematically missing values on the outcome variable were excluded from the analysis, yielding a final analytic sample of N=503. The protocol for this study was approved by the primary author's local institutional review board.

Communities

Communities were defined by analytically constructing five-mile buffer zones around residential addresses. Information on built environment characteristics was obtained from GIS data published by the New Jersey Department of Environmental Protection (NJDEP) and spatial data published by ESRI.^{46–48} The buffer areas for a 8.4% portion of the sample extended over state lines, requiring supplementation with GIS data published by the United States Geological Survey (USGS).^{49, 50} Both data sources classify land use and land cover (LU/LC) using the same detailed taxonomy, the modified Anderson Classification System.⁵¹ Two raster (i.e., grid formatted data) files were created using 2001/2002 and 2006/2007 LU/LC values to account for changes in community development over the 2000–2012 data collection timeframe. Persons with a SCIMS interview completed prior to or during 2005 were assigned 2001/2002 LU/LC data and interviews obtained after 2005 were assigned 2006/2007 data. Census-tract level data on economic indicators was obtained from the 5-year (2007–2011) American Community Survey data.⁵²

Measures

Perceived health—*Perceived health* was assessed by the survey question “In general, would you say that your health is: (1) excellent, (2) very good, (3) good (4) fair or (5) poor.”⁵³ Responses were combined into a binary vccexcellent, very good, and good categorized as good health (0) and ratings of poor or fair indicated poor perceived health (1) similar to population-based approaches using this variable as a global indicator of health.⁵⁴

Demographic and injury characteristics—The demographic covariates assessed for this analysis included *age* (measured in years), *gender*, and *race* (Non-Hispanic White, African American, Hispanic, and Asian/Other). *Current education level* (less than high school, high school diploma, and some college or more), *marital status* (single, married, and divorced/separated/widowed) were measured based on information provided at the participants' last interview. Neurologic level of injury was classified using the American Spinal Cord Injury Association Impairment Scale (AIS)⁵⁵ recorded at discharge from inpatient rehabilitation. Participants were categorized as tetraplegic (C1–C8) or paraplegic (T1 and below) and complete or incomplete. *Length of injury* was measured in the number of years elapsed between the date of the injury and the last interview and dichotomized as recent (injured less than 2 years) versus chronic (injured 2 years or more) injuries. A binary variable was used to categorize *assistive technology (AT) use* as wheelchair versus another AT device. The 13-item motor subscale of the Functional Independence Measure (FIM) assessed at last interview⁵⁶ was used to indicate *functional independence*. Items were summed and divided by the item total, creating a continuous variable ranging from 1 to 7 where higher scores indicate greater functional independence.

Quality of life—Two aspects of quality of life—*satisfaction with life (SWL)* and *depressive symptoms*—were assessed as potential confounding influences. SWL was assessed using the 5-item Diener scale. SWL total scores were summed and divided by the number of questions, yielding scores that ranged from 1 to 7 where higher scores corresponded with greater satisfaction. Depressive symptoms were assessed using the Brief Patient Health Questionnaire (PHQ-2), which uses two core items (*i.e., in the past two weeks, how often have you been bothered by: little interest or pleasure in doing things; feeling down, depressed, or hopeless*) scored on a scale of 0 to 3. A score of 3 or more and this cutoff was used to create a binary measure of depression as non-symptomatic (0) or symptomatic (1).

Community characteristics—Four measures of the built environment were created from GIS data for the 5-mile “community” buffer for each participant. Residential density was measured as a sum of the proportions residential land use. (Land Use Mix = $\{(-1) \sum_k [(p_i)(\ln p_i)]\} / (\ln k)$ where p_i is the area proportion of a developed land use type and k is the total of developed land uses.)

Land use mix was based on prior approaches using a weighted index of the proportions of the following developed uses: single-family residential, multi-family residential, commercial, industrial, recreational, and mixed urban use.^{60, 61} Scores ranged from 0 to 1, with higher scores representing more land use heterogeneity. Due to a skewed distribution, the land use mix index was divided into tertile scores categorizing each community as low, moderate, or high heterogeneity. Destination density was measured by tertile scores (low, moderate, and high destination density) of the aggregate count of religious, entertainment, landmark, and retail locations in each community. The proportion of open space was measured as the sum of the proportions of all natural undeveloped (e.g., forest, wetland) and developed (e.g., farmland, beach) land cover types. Measures of the proportion of open space were dichotomized at the 75th percentile. Scores above this cutpoint categorized the community as having a large proportion of open space in line with prior research.^{11, 20, 26} Community SES was measured using the median home value of the participant’s Census tract.

Statistical Analyses—The associations between the built environment characteristics and perceived health were initially assessed using t-test or chi-square tests for continuous and categorical predictors, respectively. Built environment predictors of poor health that were statistically significant at the 0.05 level warranted further analysis. Logistic regression models were used to estimate the likelihood of reporting poor health, first controlling for demographic and injury-related characteristics and then for the confounding effects of QOL and community SES differences. Covariates that were significant at the 0.05 level were retained for the full models for the sake of parsimony. Subsequently the models were adjusted for the built environment predictors. Diagnostics for all of the independent variables included in the adjusted logistic regression models indicated that multicollinearity was not a concern (*i.e.*, variance inflation factor (VIF) ranging 1.05 – 2.14; Tolerance ranging from 0.47 – 0.96). The relationship between the predictors and poor health was reported in the estimated odds ratios (ORs) and 95% confidence intervals. Model fit was assessed using the Hosmer-Lemeshow test and comparisons between models were assessed

based on changes to the Bayesian information criterion (BIC). All analyses were conducted using Stata 13.1.

RESULTS

The sample summary statistics are reported in Table 1. More than 25% of the sample rated their health as poor or fair. These individuals were mostly young, with a mean age of 44.5 ± 16.5 years, male, Non-Hispanic White, and high school educated. The reports on current employment status and married relationship status were low (33.5%, and 21% respectively). The types of injuries represented were evenly split between paraplegia and tetraplegia and complete injuries were slightly overrepresented (57.8%). Approximately one-third of the sample was recently injured (i.e., less than 2 years) and the majority reported a wheelchair as their primary assistive device. The mean FIM score (5.4 ± 1.5) indicated that most people reported moderate functional independence. One in five persons were symptomatic for depression and on average this sample reported experiencing slight dissatisfaction with life. The average median home value for the Census tract is $\$384,700 \pm 144,200$.

The distributions of the built environment characteristics are presented on Table 2. The values of the original measures that correspond with the created categories, with the exception of total residential land use, are presented. Communities categorized with low, moderate, and high land use heterogeneity corresponded with average index score of 0.43, 0.67, and 0.80 out of a range of 0 to 1. Areas categorized with low, moderate, and high destination density in the community had an average of 36, 168, and 346.5 destinations, respectively. Communities with a large amount of open space had on average 66% of natural area in the 5-mile buffer area. The bivariate associations between the likelihood of reporting poor health after SCI and community differences in each of these characteristics was tested and found to be significant for land use mix and open space (results not tabled). The proportions of people reporting poor health were 20.2, 28.5, and 34.1 among persons living in communities with low, moderate, and high land use heterogeneity, respectively ($X^2 = 8.1949$, $df=2$, $p = 0.017$), suggesting that perceived poor health was disproportionately reported by persons with SCI living in communities with more heterogeneous land use. Bivariate tests also indicated that persons with SCI living in areas with less open space were also more likely to report poor health compared to persons living in communities with more natural area (30.5 versus 18.2; $X^2 = 6.5214$, $df=1$, $p = 0.011$). Due to the theoretical relationship between the built environment and differences in material advantage in the community, the differences between community SES, land use, and open space were also tested. There was a strong inverse association between land use mix and median home values ($F = 32.27$, $df=2$, $p=0.000$) with average median home values of $\$427 \pm \14.9 , $\$409 \pm \15.5 , and $\$316 \pm 15.5$, for areas with low, moderate, and high land use heterogeneity, respectively. In comparison, the difference in median home values by open space was not significant.

Adjusted logistic regression models were used to assess if the observed associations between differences in land use mix, open space, and perceived poor health were attributable to differences in demographic background, impairment, and QOL among persons with SCI (Table 3). In Model 1, poor health was more likely to be perceived with increasing age,

among minorities (compared to persons who were Non-Hispanic White), among females, and significantly less likely among persons who were primarily wheelchair users. Greater satisfaction with life decreased the odds of reporting poor health by approximately 40% whereas persons who were symptomatic for depression were over four times as likely to report poor health. Model 2 tested the addition of land use mix in the final adjusted model. Persons living in highly mixed areas were significantly more likely to report poor health compared to persons living in communities with low land use heterogeneity (OR 2.14; 95% CI 1.12 to 4.08) controlling for individual differences in key background, impairment, and QOL indicators. This inverse association between land use heterogeneity and poor health is presented in Figure 1, which illustrates that individuals living in areas with highly heterogeneous land usage having approximately twice the probability of reporting poor health compared to persons living in areas with low land use heterogeneity. In contrast, the association between differences in open space in the local community and perceived health (Model 3) was accounted for by individual differences in demographic, impairment, and quality of life after SCI (OR 0.54; 95% CI 0.28–1.02).

DISCUSSION

This exploratory analysis found an association between perceived health and characteristics of the built environment in a community-based sample of persons with SCI. In particular, living in a community with greater land use heterogeneity did not benefit adults with chronic mobility limitations in terms of their perceived health. In contrast, persons living in a community with more open space were less likely to report poor health although this relationship was mitigated by differences in individual background, impairment severity, and SES. The overall pattern that emerges from this analysis is consistent with the findings of previous studies suggesting that living in greener, less developed areas may positively influence the well being of persons from vulnerable groups.^{22, 26} The results of the current study are in contrast to findings from the general population suggesting that greater residential density and land use heterogeneity are indicative of a more connected, walkable community and has positive implications for health.^{16, 62, 63} However, these studies have largely focused on physical activity and related health outcomes in healthy, middle-aged adults, which may not be generalizable to persons with disabilities. The difference between this investigation and the results of prior population-based analyses may also be attributable to the assessment of the built environment using measures of land uses and density rather than other aspects of the physical community such as the age and quality of the physical infrastructure of a community that may be encountered by persons with SCI. The condition of community infrastructure and accessibility features has been linked to activity limitations among other samples of adults with mobility impairments^{64, 65} and more work is needed to identify which qualities of the developed areas of the communities may prohibit or enhance better outcomes among persons with limited mobility.

Other studies have suggested that the psychological benefit of viewing nature is a possible mechanism for the positive association between open space in local communities and well-being, particularly for vulnerable populations^{20, 23, 26} and this explanation may have relevance for the findings obtained from this sample of persons with SCI. Density and development—particularly if the local infrastructure is in disrepair and inaccessible—may

exacerbate the deleterious effects of stress, particularly for persons with disabilities who are likely to have more exposure to their local communities. Neighborhood selection due to individual resources and preferences is also likely involved in the relationship between the built environment and perceived health. The use of cross-sectional data in this investigation limits the ability to disentangle the extent to which individual characteristics—such as SES, race, and age—as well as health status and disability status, drive the selection (or segregation) of people into different communities. Several demographic factors were included in this analysis in order to statistically control for these sources of confounding. However, longitudinal data and information on residential preferences are needed to satisfactorily address issues of selection and migration on the observed association between the built environment and health.

Study Limitations

There are several additional limitations to this investigation, not the least of which is the lack of generalizeability due to the focus on a single, albeit large, geographic area. The older physical infrastructure of New Jersey compared to other regions of the US, relative affluence of this area, and proximity to densely populated and disadvantaged urban areas may render the pattern of results in this investigation particular to this locale. Also, New Jersey is geographically situated between two major metropolitan areas (Philadelphia and New York), so that even the least developed areas of the state are in short driving distance from more developed, metropolitan places with opportunities for employment, healthcare, and recreation. The focus on a single geographic place for this study is consistent other work using GIS data, which often focuses on a single county, metropolitan area, or selected contiguous Census tracts. GIS data is also specific to a geographic area and the detail and availability of GIS information varies widely across states and municipalities. In other ways, a focus on New Jersey was well suited for the purpose of this exploratory investigation as this state is both densely populated and geographically diverse. All major LU/LC types are represented which is not the case in other areas of the country. Although this analysis statistically controlled for a number of demographic and impairment characteristics related to communities and health, there are other key variables such as household income and length of time in the residence that were not included because the data was unavailable. Similarly, future inquires seeking to further explain the relationship between community characteristics and disability-related outcomes may need to explore variation in the availability and accessibility of resources such as healthcare and support services in the local community as potential moderators of this association.

CONCLUSIONS

This study is one of a growing number of investigations using administrative data to develop objective measures of communities in order to better understand the relationship between the environment and disability and one of only a few in SCI. Prior research studies of the relationship between the built environment, health, and well-being are largely based on samples of middle-aged, able bodied adults or in the case of disability-related outcomes, older adults. As research in this area continues to evolve, there is a need to attend to the diversity of experiences and needs in the disabled population. Healthcare practitioners and

disability advocates also need to be aware of the social conditions that will complicate the long-term adjustment following rehabilitation. The inclusion of community risk factors in future investigations may be important in identifying at-risk subgroups for poor long-term outcomes following SCI and identifying amenable risk factors with the potential to improve the health and well-being wide range of people with chronic disability.

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Abbreviations

SCI	spinal cord injury
SCIMS	Spinal Cord Injury Model Systems
GIS	Geographic Information Systems
OR	odds ratio
CI	confidence interval
VIF	variance inflation factor
BIC	Bayesian information criterion
QOL	quality of life
SES	socioeconomic status
NJDEP	New Jersey Department of Environmental Protection
ESRI	Environmental Systems Research Institute
USGS	United States Geological Survey
LU/LC	land use/land cover
AIS	American Spinal Cord Injury Association Impairment Scale
AT	assistive technology
FIM	Functional Independence Measure
SWL	satisfaction with life
PHQ	Patient Health Questionnaire

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Figure 1.
Predicted probability of perceived poor health by land use mix tertiles

Legend

- Unadjusted
- Adjusted

Table 1

Descriptive Statistics (N = 503)

	Mean or %	Std. Dev.	Range
<i>Outcome</i>			
Poor health (v. good health)	27.6		
<i>Demographic characteristics</i>			
Age (years)	44.5	16.5	18 – 89
Male (v. female)	80.5		
Race/Ethnicity			
Non-Hispanic White	58.0		
African American	29.6		
Hispanic	8.4		
Asian Pacific Islander/Other	4.0		
Education			
Less than high school	13.1		
High school diploma	53.5		
Some college or more	33.4		
Married			
Single	48.9		
Married	33.5		
Divorced/Separated/Widowed	17.6		
Currently employed (v. unemployed)	21.3		
<i>Impairment-related characteristics</i>			
Paraplegia (v. tetraplegia)	48.7		
Complete (v. incomplete)	57.8		
Injured <2 years (v. ≥ 2 years)	37.2		
Primarily uses wheelchair (v. other assistive device)	65.2		
Functional independence (FIM)	5.4	1.5	1 – 7
<i>Health-related quality of life</i>			
Depression (v. asymptomatic)	19.0		
Satisfaction with life	3.4	1.6	1 – 6
<i>Community socioeconomic status</i>			
Census tract median home value (thousands)	384.7	144.2	9.5 – 1,000

Table 2

Community Built Environment Characteristics

	Mean	SD	Range
Proportion of total residential use	0.38	0.13	0.06 – 0.62
Land use mix tertiles			
Low heterogeneity	0.43	0.10	0.18 – 0.56
Moderate heterogeneity	0.67	0.06	0.56 – 0.77
High heterogeneity	0.80	0.02	0.77 – 0.85
Destination count tertiles			
Low	36.1	20.2	1 – 76
Moderate	167.7	64.7	77 – 272
High	346.5	55.5	275 – 591
Proportion open space			
Small	0.24	0.13	0.09 – 0.50
Large (75 th percentile)	0.66	0.11	0.50 – 0.91

Table 3

Odds ratios (SE) from logistic regression of poor health and land use mix adjusted for demographic, impairment, and community socioeconomic differences (N = 503)

	Model 1			Model 2			Model 3		
	Odds Ratio (95% CI)	P		Odds Ratio (95% CI)	P		Odds Ratio (95% CI)	P	
Age	1.019 (1.004–1.035)	0.013		1.021 (1.005–1.036)	0.008		1.019 (1.004–1.034)	0.013	
Male (v. female)	0.579 (0.331–1.013)	0.056		0.562 (0.319–0.988)	0.045		0.592 (0.338–1.040)	0.068	
Race/ethnicity ^a									
African American	2.257 (1.248–4.081)	0.007		1.799 (0.959–3.377)	0.067		1.824 (0.971–3.246)	0.062	
Hispanic	2.918 (1.299–6.550)	0.009		2.509 (1.090–5.777)	0.031		2.397 (1.043–5.503)	0.039	
Asian Pacific	3.832 (1.279–11.483)	0.016		3.808 (1.239–11.701)	0.020		3.605 (1.178–11.032)	0.025	
Islander/Other									
Recent injury (v. long-term injury)	1.553 (0.968–2.489)	0.068		1.578 (0.979–2.542)	0.061		1.547 (0.962–2.489)	0.072	
Wheelchair (v. other assistive device)	0.437 (0.267–0.715)	0.001		0.457 (0.278–0.751)	0.002		0.440 (0.269–0.722)	0.001	
Satisfaction with life	0.630 (0.536–0.739)	0.000		0.627 (0.533–0.737)	0.000		0.630 (0.536–0.741)	0.000	
Depressed (v. not depressed)	4.401 (2.564–7.552)	0.000		4.548 (2.637–7.841)	0.000		4.617 (2.672–7.976)	0.000	
Median home value (Census tract)	0.999 (0.999–1.000)	0.438		0.999 (0.999–1.000)	0.751		0.999 (0.999–1.000)	0.316	
Land use mix ^b									
Moderately heterogeneous				1.379 (0.743–2.560)	0.308		—		
Heterogeneous				2.138 (1.120–4.081)	0.021		—		
Large proportion open space (v. small)				—			0.538 (0.284–1.020)	0.058	
Statistic for model fit									
Chi ²	491.20			491.33			499.46		
P	0.5017			0.4746			0.3861		
Statistics for model comparison									
BIC	–2568.539			–2555.390			–2559.872		
BIC Difference				13.149			8.667		