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A Novel Housing-Based Socioeconomic Measure Predicts Hospitalization and Multiple Chronic Conditions in a Community Population

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Abstract

Background—Socioeconomic status (SES) is an important predictor for outcomes of chronic diseases. However, it is often unavailable in clinical data. We sought to determine whether an individual housing-based SES index termed *HOUSESES* can influence the likelihood of multiple chronic conditions (MCC) and hospitalization in a community population.

Methods—Participants were residents of Olmsted County, Minnesota, aged >18 years who were enrolled in Mayo Clinic Biobank on December 31, 2010, with follow-up until December 31, 2011. Primary outcome was all-cause hospitalization over 1 calendar year. Secondary outcome was MCC determined through Minnesota Medical Tiering score. Logistic regression model was used to assess association of *HOUSESES* with Minnesota tiering score. With adjustment for age, sex, and

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Contributing Author Statement

Each author reviewed and made modifications to the manuscript. This included intellectual content to the manuscript. The specific contributions are noted below.

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Competing Interests

Paul Y. Takahashi, MD, serves on a medical advisory board for Axial LLC.

MCC, the association of HOUSES with hospitalization risk was tested using Cox proportional hazards model.

Results—Eligible patients totaled 6,402 persons (median age, 57 years; 25th-75th quartiles, 45-68 years). The lowest quartile of HOUSES was associated with higher Minnesota tiering score after adjustment for age and sex (odds ratio [95% CI], 2.4 [2.0-3.1]) when compared with the highest HOUSES quartile. Patients in the lowest HOUSES quartile had higher risk of all-cause hospitalization (age, sex, MCC-adjusted hazard ratio [95% CI], 1.53 [1.18-1.98]) compared with those in the highest quartile.

Conclusion—Low SES, as assessed by HOUSES, was associated with increased risk of hospitalization and greater MCC health burden. HOUSES may be a clinically useful surrogate for SES to assess risk stratification for patient care and clinical research.

Keywords

health behavior; hospitalization; multiple chronic conditions; quality of life; social determinant

Introduction

Reducing health care costs while improving health outcomes and health care quality is a national priority in the United States and is reflected in the strategic goals of the Centers for Medicare and Medicaid Services. Health systems strive to improve quality of life and health outcomes at a reasonable cost through a health care value equation, the Institute of Healthcare Improvement's Triple Aim (1). Adults with multiple chronic conditions (MCC) are disproportionately at risk for increased morbidity, health care costs, and death (2). Identification of factors predicting all-cause hospitalization and MCC will be useful in achieving the Triple Aim. The underlying causes for all-cause hospitalization and MCC are likely multifactorial, with sociodemographic, socioeconomic, and clinical influencers. The causes also are likely multidimensional at individual, neighborhood, and societal levels (3).

As Oakes and Rossi (4) have discussed, socioeconomic status (SES) reflects differential access to desired resources of materialistic, human, and social capital. These factors may account for underlying health disparities under the model suggested by the Centers for Population Health and Health Disparities, which is sponsored by the National Institutes of Health (5). SES likely operates its impact on health outcomes through multiple pathways (6). SES measures provide an important basis for identifying populations with greater unmet medical or social needs, such as MCC and frequent hospitalizations. In a systematic review of SES factors affecting hospital readmission for patients with heart failure and pneumonia, such social factors as education, income, and employment were associated with hospital readmission. However, some questions are ongoing about the influence of the living situation and social support (7).

SES may be an important predictor of health outcomes and behavior. Yet, it often is unavailable in the medical record or in health system administrative data. To address this concern, investigators commonly have used a neighborhood SES derived from census data as a surrogate marker for a person's SES (8-14). However, neighborhood SES causes

misclassification (22%-31%) of individual SES and can itself be a predictor of health outcomes (3,15-18). Therefore, we developed and validated a distinct housing-based SES measure termed *HOUSES* (19). This SES index was formulated by geocoding address information with individual property data (ie, individual-level SES measure) at the time of a health event of interest. Although *HOUSES* has been shown to be associated with pediatric health outcomes (19) and postmyocardial infarction mortality in adults (20), whether *HOUSES* can predict future all-cause hospitalization and MCC is unknown. We hypothesized that a lower SES, as measured by *HOUSES*, is associated with higher risk of hospitalization and MCC.

Methods

Study Setting and Participants

This study enrolled all eligible adult Mayo Clinic primary care patients who were enrolled voluntarily in the Mayo Clinic Biobank (MCB) (21) and were residents of Olmsted County, Minnesota (22). We limited our study patients to MCB participants living in Olmsted County at the time of MCB enrollment because *HOUSES* is available to the Olmsted County population only. All participants were enrolled in primary care and had an assigned primary care provider. A participant was seen by the medical provider within 3.5 years of the index date. Mayo Clinic primary care involves family medicine, community pediatric medicine, and internal medicine. Both the MCB and the present study were approved by the Mayo Clinic Institutional Review Board (23). The study also was approved by the MCB access committee. It adhered to the principles of the Declaration of Helsinki and maintained participant privacy (21).

Covariate Data

Age and sex data were obtained from the electronic medical record. At enrollment in the MCB, participants completed a questionnaire that included self-reported educational level and race/ethnicity. Race/ethnicity was dichotomized into white and nonwhite. Educational level was categorized into high school or less, some college, bachelor's degree, and graduate school. We also obtained any missing educational level information. The MCB questionnaires are available online (<http://www.mayo.edu/research/documents/biobank-questionnaire/doc-20086430>).

Categorization of Participants by *HOUSES*

HOUSES is a composite index formulated from housing characteristics of property data and address information. Development and initial testing of the *HOUSES* index were completed in Olmsted County and in Jackson County, Missouri. After development, *HOUSES* was applied to a study setting in Sioux Falls, South Dakota (19,20,24-26), which suggested the potential generalizability of *HOUSES* to other study settings. The details of *HOUSES* have been described elsewhere (19). In brief, staff obtained and geocoded patients' addresses at MCB enrollment, using publicly available property data from the Olmsted County Assessor office. Our original work, based on principal components factor analysis, showed 4 housing features: assessor's housing value, square footage, number of bedrooms, and number of bathrooms. These housing features were not adjusted for family size. We formulated a

standardized HOUSES index score by summing each variable after transforming the 4 variables to z-scores. This formulation allowed a comparison across different study settings using a standardized index. A higher HOUSES index score represents a higher SES. HOUSES was categorized into 4 quartiles for comparison.

Hospitalization and Minnesota Medical Tiering

For hospitalization, billing codes were used to identify all hospitalizations in the study population from December 31, 2010, to December 31, 2011. Hospitalization was based on billing codes for the inpatient hospitalization, with exclusions for outpatient surgical procedures. All patients in Mayo Clinic primary care had Minnesota Medical Tiering (MMT) performed on December 31, 2010, which included the subset in the MCB (27). MMT is based on the Johns Hopkins Adjusted Clinical Groups (ACG) system (28). MMT compares well with other instruments that measure MCC, including the Charlson Comorbidity Index and the Hierarchical Condition Categories (27). In brief, the International Classification of Diseases, Ninth Revision, billing codes for each outpatient encounter (4) and for each inpatient admission (25) were obtained and a computer algorithm was used that counted comorbid conditions and scored patients on the basis of the number of conditions and the severity of the chronic condition. The algorithm placed the conditions within expanded diagnosis clusters, which were further categorized into 22 major, expanded diagnosis clusters. All patients had a cluster count and were placed into tiers based on the cluster count: tier 0, low (0 chronic condition); tier 1, basic (1-3 conditions); tier 2, intermediate (4-6 conditions); tier 3, extended (7-9 conditions); and tier 4, complex (10 conditions). MMT is the basis for case mix disease severity for Minnesota medical home patients. We dichotomized tiers into participants in tiers 3 and 4 and those in tier 2 or less. This distinction is a clinical one because patients in our clinical practice are eligible for care management with MMT tier 3 or 4.

Statistical Analysis

Participant characteristics were compared across groups with Kruskal-Wallis test for continuous variables and Pearson χ^2 test for categorical variables. A *P* value of .05 or less was considered significant. Cox proportional hazards model was used to estimate the impact of HOUSES (unadjusted, adjusted for age and sex, and adjusted for age, sex, and MMT) on the hazard of hospitalization. The relation between MMT scores (MCC) and HOUSES was assessed by calculating γ coefficient for the degree of association. Logistic regression models (unadjusted and adjusted for age and sex) were used to test the association between HOUSES and high MMT score (tier 3 or 4 with high comorbid health burden compared with 2 illnesses or less). The highest quartile of HOUSES with the highest SES was used as the reference. Degree of concordance between HOUSES and level of education was estimated using γ coefficient. The spline method was used to incorporate nonlinear-age function. Level of education also was considered in the model, with and without HOUSES. Receiver operating characteristic curves for each model (HOUSES only, education only, and both HOUSES and education) and their area under the curve (AUC) were also calculated to estimate the predictability of each model for higher MMT score. Education level was considered with and without MMT. C statistic also was reported.

Results

Participants

As of December 31, 2010, a total of 16,578 participants were enrolled in the MCB, with 8,927 (54%) receiving primary care at Mayo Clinic's campus in Rochester, Minnesota. Among this percentage, 6,402 participants resided in Olmsted County and had HOUSES indexing at enrollment. MCB participants outside Olmsted County who received primary care but were not included in the study had similar median age and sex distribution compared with the study participants (data not included). In the overall group, median age was 57 years, 95% were white, and 50% had at least a bachelor's degree (Table 1). In Olmsted County in 2010, 86% self-identified as white and 40% with a bachelor degree in people older than 25 years (29). The distribution is illustrated in Supplemental Figure 1. Higher HOUSES index score was associated with lower proportion of adults older than 75 years, as well as higher level of education (Supplemental Figure 2). The γ coefficient for degree of association equaled 0.31 ($P < .001$) (Supplemental Figure 2). There were differences in missing educational data, with 10.8% (95% CI, 9.3%-12.5%) missing for participants in the lowest-quartile HOUSES compared with 7.6% (95% CI, 6.4%-9.0%) in the highest quartile (Supplemental Table 1).

HOUSES and Minnesota Medical Tiering

Table 2 outlines the counts and percentages of MMT by the HOUSES quartiles. Patients with a higher HOUSES score had a lower MMT score (Figure 1), with the γ coefficient for degree of association at -0.17 ($P < .001$). We found that only 1% of patients in the highest HOUSES quartile were tier 4 vs 3.5% of patients in the lowest quartile. When we dichotomized MMT into the highest (tier 3 or 4) and lowest (tier 0, 1, or 2) risks, we found that 14.3% of patients in the highest HOUSES quartile were in tier 3 or 4 vs 34.4% in the lowest quartile. The odds of a higher-risk MMT decreases as the quartile of HOUSES increases (tier 3 or 4) (odds ratio [95% CI], 2.7 [2.2-3.4] for lowest HOUSES quartile vs highest quartile). Patients in the lowest HOUSES quartile had an odds ratio of 2.4 (95% CI, 2.0-3.1) for being in the tier 3 or 4 compared with the highest HOUSES quartile (Supplemental Table 2). Predictability of all 3 models was similar (AUC was 0.66 for model with HOUSES, 0.64 for model with education, and 0.66 for model with HOUSES and education). All 3 models were adjusted for age and sex.

HOUSES and Hospitalization

We found 200 hospitalizations (12.5%) over 1 year in participants in the lowest quartile compared with 93 hospitalizations (5.8%) in the highest quartile (Figure 2). This finding shows that, after adjustment for age and sex, the lower the HOUSES index, the higher the risk of hospitalization. When we compared the first, second, and third quartiles to the fourth quartile, we found the following data: hazard ratio (95% CI), 1.78 (1.74-2.84); 1.45 (1.12-1.88); and 1.30 (1.0-1.69), respectively. After adjustment for age, sex, and MMT, the effect was attenuated but stayed significant (hazard ratio [95% CI], 1.53 [1.18-1.98]) for the first quartile compared with the fourth quartile and for the third quartile compared with the fourth quartile (Table 3).

Discussion

In our cohort study, we found an association between lower SES as measured by HOUSES and an increased risk of future all-cause hospitalization. The increased risk of being hospitalized in 1 year was greater than 50%, after adjustment for age, sex, and MMT, for patients in the lowest HOUSES quartile compared with the highest quartile. In a previous study of the HOUSES index for 637 patients with myocardial infarction, a lower HOUSES score predicted death; however, it was nonsignificant after adjustment for age and comorbidity (20). In a systematic review of 27 risk prediction models for hospitalization, 8 models included a measure of SES as a predictor of hospitalization, with most accounting for living alone or the presence of a caregiver (30). The probability of repeated admission is commonly used hospital predictor and uses informal caregiver status as a predictor for hospitalization (31); however, the team did not find a relation with hospitalization and low income or race (31). Our findings suggest an association between SES as determined by housing characteristics of the patient and increased hospitalization independent of age, sex, and ongoing MCC health burden.

The findings that a lower HOUSES index is associated with higher hospitalization use have clinical and public health face validity. We found that lower HOUSES quartile was associated with higher MMT score, which may account for some of the increased risk of hospitalization. We previously reported higher risks of hospitalizations and emergency department visits for patients with MMT of 3 or 4 compared with lower tier scores (27). ACG, on which MMT is based, has also shown a relation between a higher ACG score and hospitalization (32). After accounting for high MMT scores, we still saw an increased risk of hospitalization among the patients in the lowest HOUSES quartile.

The living situation may account for health status beyond a comorbid health diagnosis. In the Health and Retirement Study, the 16,191 participants living in public housing were more than twice as likely to self-rate their health as poor or fair compared with participants living within the community (33).

HOUSES had a moderate correlation with education levels, suggestive that HOUSES potentially captures a different construct underlying SES (eg, wealth) from education level. Because the AUC for models with HOUSES and the AUC for models with HOUSES plus education levels were the same, education level did not seem to improve predictability of MCC beyond the HOUSES predictability. Thus, HOUSES likely represents the constructs of SES that predict adverse health outcomes. In a systematic review of education and hospitalization in heart failure patients, educational levels did not predict future hospitalization (34).

We are not sure why housing characteristics are associated with hospitalization. Housing may reflect the physical environment of the house or the neighborhood. For example, in the Health in Common study of 812 participants living in Boston, Massachusetts, those participants in low-income housing had greater exposure to pests, combustion byproducts, mold, and ventilation problems (35). In people living in the lower HOUSES quartile, smoking may be more acceptable in their neighborhood, which can be seen with persons

living with lower SES (36). They also reported a low self-rated health level. The potential adverse health events from poor housing include mental health concerns, asthma, lead exposure, and injuries (37). Patients living in low-SES housing may lack access to the “built environment attributes” such as sidewalks or bike lanes or to nutritious food (38). In Rochester, the largest city in Olmsted County, many older adults living in the community lack access to various services within a walkable distance (39).

The HOUSES index has potential advantages over other measures of SES. Its primary advantage is potentially that it overcomes the absence of SES measures in commonly used clinical or administrative datasets. We found that participants in the lowest quartile of the HOUSES index were more likely to omit self-reported education than the highest quartile, which suggests a potential systematic reporting bias. Another advantage is the dynamic ability to reflect changes in housing status. Education level is a common SES measure, with a relation to other health outcomes or behaviors in older adults (40). The measure is generally static after young adulthood. While education is generally static, changing homes is relatively common—thus, the dynamic nature of HOUSES. In 2012 to 2013, 11.7% of US households moved (41), although we do not have this information in our cohort. Some of these moves reflect changes going up or down in SES that may be captured in home characteristics; however, further work will be required to quantify this detail within our population. The moves may represent a change in functional status or disability. Using an index that reflects these changes may be beneficial.

Another important advantage of using the HOUSES index includes the ability to account for changes in functional status, as well as economic status. We speculate that participants may move to smaller living environments as they get older and have functional disability with less ability to care for a bigger home. We found that 15% of participants in the lowest HOUSES quartile were older than 75 years compared with 4% in the highest quartile, indicating higher concentration of older adults. However, the US Census suggests that poverty rates decrease after age 65 years (42); thus, the housing changes may reflect factors other than financial considerations.

The present study has some limitations. The primary outcome of MMT classification score is dependent on accurate coding of the medical diagnosis. Possibly, misclassification or missed diagnosis occurred if the patient sought care outside of the Mayo Clinic Health System. HOUSES may not completely represent SES because SES is a multifactorial classification. Our cohort was derived from the MCB and may not reflect a population-based sample and may reflect some selection bias (43). In addition, Olmsted County tends to have a greater white population and higher education levels than counties nationwide. It represents the Upper Midwest of the United States and may not represent other populations (44). The use of geocoded data that form the basis of HOUSES may not be widely available, which may hinder the applicability to certain locations. Despite these limitations, the findings confirm other widely published results on SES and hospitalization. Another important strength of our study is that both SES measure and health outcomes are based on objective measures instead of self-report.

Conclusion

We found that participants within the lowest HOUSES quartile had an increased risk of hospitalization and MCC compared with the highest quartile. These findings provide evidence that HOUSES is a useful tool for clinical research concerning health disparities, as a surrogate measure for SES. These findings also provide further evidence of the connection between SES measured by the HOUSES index and health outcomes. The clinical utility involves further emphasis on the broader understanding of health in the social context.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

ACG	Johns Hopkins Adjusted Clinical Groups
AUC	area under the curve
MCB	Mayo Clinic Biobank
MMT	Minnesota Medical Tiering
SES	socioeconomic status

References

1. Berwick DM, Hackbarth AD. Eliminating waste in US health care. *JAMA*. Apr 11; 2012 307(14): 1513–6. Epub 2012 Mar 14. [PubMed: 22419800]
2. Naessens JM, Stroebe RJ, Finnie DM, Shah ND, Wagie AE, Litchy WJ, et al. Effect of multiple chronic conditions among working-age adults. *Am J Manag Care*. Feb; 2011 17(2):118–22. [PubMed: 21473661]
3. Pardo-Crespo MR, Narla NP, Williams AR, Beebe TJ, Sloan J, Yawn BP, et al. Comparison of individual-level versus area-level socioeconomic measures in assessing health outcomes of children in Olmsted County, Minnesota. *J Epidemiol Community Health*. Apr; 2013 67(4):305–10. Epub 2013 Jan 15. [PubMed: 23322850]
4. Oakes JM, Rossi PH. The measurement of SES in health research: current practice and steps toward a new approach. *Soc Sci Med*. Feb; 2003 56(4):769–84. [PubMed: 12560010]
5. Warnecke RB, Oh A, Breen N, Gehlert S, Paskett E, Tucker KL, et al. Approaching health disparities from a population perspective: the National Institutes of Health Centers for Population Health and Health Disparities. *Am J Public Health*. Sep; 2008 98(9):1608–15. Epub 2008 Jul 16. [PubMed: 18633099]
6. Diez Roux AV. Conceptual approaches to the study of health disparities. *Annu Rev Public Health*. Apr.2012 33:41–58. Epub 2012 Jan 3. [PubMed: 22224879]

7. Calvillo-King L, Arnold D, Eubank KJ, Lo M, Yunyongying P, Stieglitz H, et al. Impact of social factors on risk of readmission or mortality in pneumonia and heart failure: systematic review. *J Gen Intern Med*. Feb; 2013 28(2):269–82. Epub 2012 Oct 6. [PubMed: 23054925]
8. Kattan M, Mitchell H, Eggleston P, Gergen P, Crain E, Redline S, et al. Characteristics of inner-city children with asthma: the National Cooperative Inner-City Asthma Study. *Pediatr Pulmonol*. Oct; 1997 24(4):253–62. [PubMed: 9368259]
9. Lang DM, Polansky M, Sherman MS. Hospitalizations for asthma in an urban population: 1995-1999. *Ann Allergy Asthma Immunol*. Aug; 2009 103(2):128–33. [PubMed: 19739425]
10. Simon AE, Lukacs SL, Mendola P. Emergency department laboratory evaluations of fever without source in children aged 3 to 36 months. *Pediatrics*. Dec; 2011 128(6):e1368–75. Epub 2011 Nov 21. [PubMed: 22106081]
11. Hausauer AK, Swetter SM, Cockburn MG, Clarke CA. Increases in melanoma among adolescent girls and young women in California: trends by socioeconomic status and UV radiation exposure. *Arch Dermatol*. Jul; 2011 147(7):783–9. Epub 2011 Mar 21. [PubMed: 21422322]
12. Diez-Roux AV, Kiefe CI, Jacobs DR Jr, Haan M, Jackson SA, Nieto FJ, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. *Ann Epidemiol*. Aug; 2001 11(6):395–405. [PubMed: 11454499] Erratum in: *Ann Epidemiol*. 2001 Aug;30(4):924.
13. Krieger N. Overcoming the absence of socioeconomic data in medical records: validation and application of a census-based methodology. *Am J Public Health*. May; 1992 82(5):703–10. [PubMed: 1566949]
14. Majorana A, Cagetti MG, Bardellini E, Amadori F, Conti G, Strohmenger L, et al. Feeding and smoking habits as cumulative risk factors for early childhood caries in toddlers, after adjustment for several behavioral determinants: a retrospective study. *BMC Pediatr*. Feb 15. 2014 14:45. [PubMed: 24528500]
15. Brown AF, Ang A, Pebley AR. The relationship between neighborhood characteristics and self-rated health for adults with chronic conditions. *Am J Public Health*. May; 2007 97(5):926–32. Epub 2007 Mar 29. [PubMed: 17395847]
16. Meyer OL, Castro-Schilo L, Aguilar-Gaxiola S. Determinants of mental health and self-rated health: a model of socioeconomic status, neighborhood safety, and physical activity. *Am J Public Health*. Sep; 2014 104(9):1734–41. Epub 2014 Jul 17. [PubMed: 25033151]
17. Juhn YJ, Sauver JS, Katusic S, Vargas D, Weaver A, Yunginger J. The influence of neighborhood environment on the incidence of childhood asthma: a multilevel approach. *Soc Sci Med*. Jun; 2005 60(11):2453–64. Epub 2005 Jan 11. [PubMed: 15814171]
18. Juhn YJ, Qin R, Urm S, Katusic S, Vargas-Chanes D. The influence of neighborhood environment on the incidence of childhood asthma: a propensity score approach. *J Allergy Clin Immunol*. Apr; 2010 125(4):838–43. e2. Epub 2010 Mar 17. [PubMed: 20236695]
19. Juhn YJ, Beebe TJ, Finnie DM, Sloan J, Wheeler PH, Yawn B, et al. Development and initial testing of a new socioeconomic status measure based on housing data. *J Urban Health*. Oct; 2011 88(5):933–44. [PubMed: 21499815]
20. Bang DW, Manemann SM, Gerber Y, Roger VL, Lohse CM, Rand-Weaver J, et al. A novel socioeconomic measure using individual housing data in cardiovascular outcome research. *Int J Environ Res Public Health*. Nov 12; 2014 11(11):11597–615. [PubMed: 25396769]
21. Olson JE, Ryu E, Johnson KJ, Koenig BA, Maschke KJ, Morrisette JA, et al. The Mayo Clinic Biobank: a building block for individualized medicine. *Mayo Clin Proc*. Sep; 2013 88(9):952–62. [PubMed: 24001487] Erratum in: *Mayo Clin Proc*. 2014 Feb;89(2):276.
22. Takahashi PY, Ryu E, Olson JE, Anderson KS, Hathcock MA, Haas LR, et al. Hospitalizations and emergency department use in Mayo Clinic Biobank participants within the employee and community health medical home. *Mayo Clin Proc*. Sep; 2013 88(9):963–9. [PubMed: 24001488]
23. Mayo Clinic. [2015 Mar 16] Institutional Review Board [Internet]. Available from: <http://www.mayo.edu/research/institutional-review-board/resources>

24. Butterfield MC, Williams AR, Beebe T, Finnie D, Liu H, Liesinger J, et al. A two-county comparison of the HOUSES index on predicting self-rated health. *J Epidemiol Community Health*. Mar; 2011 65(3):254–9. Epub 2010 May 3. [PubMed: 20439350]
25. Harris MN, Lundien MC, Finnie DM, Williams AR, Beebe TJ, Sloan JA, et al. Application of a novel socioeconomic measure using individual housing data in asthma research: an exploratory study. *NPJ Prim Care Respir Med*. Jun 26.2014 24:14018. [PubMed: 24965967]
26. Johnson MD, Urm SH, Jung JA, Yun HD, Munitz GE, Tsigrelis C, et al. Housing data-based socioeconomic index and risk of invasive pneumococcal disease: an exploratory study. *Epidemiol Infect*. Apr; 2013 141(4):880–7. Epub 2012 Jul 3. [PubMed: 22874665]
27. Haas LR, Takahashi PY, Shah ND, Stroebel RJ, Bernard ME, Finnie DM, et al. Risk-stratification methods for identifying patients for care coordination. *Am J Manag Care*. Sep; 2013 19(9):725–32. [PubMed: 24304255]
28. Weiner JP, Starfield BH, Steinwachs DM, Mumford LM. Development and application of a population-oriented measure of ambulatory care case-mix. *Med Care*. May; 1991 29(5):452–72. [PubMed: 1902278]
29. United States Census Bureau. [2015 Jul 13] State and county quickfacts: Olmsted County, Minnesota [Internet]. 2010. Available from: <http://quickfacts.census.gov/qfd/states/27/27109.html>
30. Wallace E, Stuart E, Vaughan N, Bennett K, Fahey T, Smith SM. Risk prediction models to predict emergency hospital admission in community-dwelling adults: a systematic review. *Med Care*. Aug; 2014 52(8):751–65. [PubMed: 25023919]
31. Boulton C, Dowd B, McCaffrey D, Boulton L, Hernandez R, Krulewicz H. Screening elders for risk of hospital admission. *J Am Geriatr Soc*. Aug; 1993 41(8):811–7. [PubMed: 8340558]
32. Lemke KW, Weiner JP, Clark JM. Development and validation of a model for predicting inpatient hospitalization. *Med Care*. Feb; 2012 50(2):131–9. [PubMed: 22002640]
33. Parsons PL, Mezuk B, Ratliff S, Lapane KL. Subsidized housing not subsidized health: health status and fatigue among elders in public housing and other community settings. *Ethn Dis*. 2011; 21(1):85–90. Winter. [PubMed: 21462736]
34. Damiani G, Salvatori E, Silvestrini G, Ivanova I, Bojovic L, Iodice L, et al. Influence of socioeconomic factors on hospital readmissions for heart failure and acute myocardial infarction in patients 65 years and older: evidence from a systematic review. *Clin Interv Aging*. Jan 12.2015 10:237–45. [PubMed: 25653510]
35. Adamkiewicz G, Spengler JD, Harley AE, Stoddard A, Yang M, Alvarez-Reeves M, et al. Environmental conditions in low-income urban housing: clustering and associations with self-reported health. *Am J Public Health*. Sep; 2014 104(9):1650–6. Epub 2013 Sep 12. [PubMed: 24028244]
36. Paul CL, Ross S, Bryant J, Hill W, Bonevski B, Keevy N. The social context of smoking: a qualitative study comparing smokers of high versus low socioeconomic position. *BMC Public Health*. Apr 27.2010 10:211. [PubMed: 20420707]
37. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health*. May; 2002 92(5):758–68. [PubMed: 11988443]
38. Hood E. Dwelling disparities: how poor housing leads to poor health. *Environ Health Perspect*. May; 2005 113(5):A310–7. [PubMed: 15866753]
39. Takahashi PY, Baker MA, Cha S, Targonski PV. A cross-sectional survey of the relationship between walking, biking, and the built environment for adults aged over 70 years. *Risk Manag Healthc Policy*. 2012; 5:35–41. Epub 2012 Apr 24. [PubMed: 22570581]
40. Haider SI, Johnell K, Weitoft GR, Thorslund M, Fastbom J. The influence of educational level on polypharmacy and inappropriate drug use: a register-based study of more than 600,000 older people. *J Am Geriatr Soc*. Jan; 2009 57(1):62–9. Epub 2008 Nov 14. [PubMed: 19054196]
41. Ihrke, D. Reason for Moving: 2012 to 2013 [Internet]. US Census Bureau; Washington (DC): Available from: <http://www.census.gov/prod/2014pubs/p20-574.pdf> [2015 Mar 16]
42. Bishaw, A.; Stern, S. Evaluation of poverty estimates: a comparison of the American Community Survey and the Current Population Survey [Internet]. US Census Bureau; Washington (DC): Jun 15. 2006 Available from: https://www.census.gov/hhes/www/poverty/about/datasources/acs_cpspovcompreport.pdf [2015 Mar 16]

43. Takahashi PY, Ryu E, Olson JE, Anderson KS, Hathcock MA, Haas LR, et al. Hospitalizations and emergency department use in Mayo Clinic Biobank participants within the employee and community health medical home. *Mayo Clin Proc.* Sep; 2013 88(9):963–9. [PubMed: 24001488]
44. St Sauver JL, Grossardt BR, Leibson CL, Yawn BP, Melton LJ 3rd, Rocca WA. Generalizability of epidemiological findings and public health decisions: an illustration from the Rochester Epidemiology Project. *Mayo Clin Proc.* Feb; 2012 87(2):151–60. [PubMed: 22305027]

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Overview Take-Home Points

What is already known on this subject?

Socioeconomic status impacts health outcomes and the burden of chronic illness; however, information on education or other measures may be missing or inaccurate in the medical record. The HOUSES index is an individualized, housing-based socioeconomic status measure that potentially overcomes the unavailability of socioeconomic status in commonly used data sources for research and patient care.

What does this study add?

The HOUSES index predicts future hospital utilization and multiple chronic conditions and may help better predict which patients have greater medical and social needs.

Figure1.
Relation Between Multimorbidity as Determined by Minnesota Medical Tiering and
HOUSES Index Quartiles for 6,402 Patients.

Figure 2.
Kaplan-Meier Curves Comparing Hospitalization Risk With HOUSES Index Quartiles.

Table 1
Demographic Characteristics and HOUSES Index Overall and by Quartiles in Study Participants

Variable	Overall (N=6,402)	Quartile				P Value ^a
		First (n=1,600)	Second (n=1,587)	Third (n=1,622)	Fourth (n=1,593)	
Age, median (25th, 75th), y	57 (45, 68)	57 (38, 71)	61 (47, 72)	58 (48, 71)	54 (45, 63)	<.001
Age >75 y, No. (%)	743 (11.6)	244 (15.3)	225 (14.2)	211 (13.0)	63 (4.0)	<.001
Male sex, No. (%)	2,153 (37.5)	444 (30.2)	533 (35.1)	622 (40.5)	554 (36.9)	<.001
White race/ethnicity, %	94.6	91.8	96.5	95.8	94.3	<.001
Education level, %						<.001
High school or less	16.2	25.3	19.9	14.4	5.4	
Some college	33.9	39.2	37.7	34.7	24.0	
Bachelor's degree	27.6	21.2	25.6	29.2	34.2	
Graduate school	22.3	14.2	16.9	21.8	36.3	

^aThe comparisons are of each of the 4 quartiles with the demographic variable.

Table 2

Medical Comorbidity Determined Through MMT and HOUSES Index Quartiles for 6,402 Patients

HOUSES Quartile	MMT Tier, No. (%)				
	0 (n=407)	1 (n=2,855)	2 (n=2,235)	3 (n=681)	4 (n=224)
First (n=1,600)	83 (5.2)	621 (38.8)	585 (36.6)	219 (13.7)	92 (5.8)
Second (n=1,587)	89 (5.6)	674 (42.5)	582 (36.7)	187 (11.8)	55 (3.5)
Third (n=1,622)	96 (5.9)	725 (44.7)	578 (35.6)	170 (10.5)	53 (3.3)
Fourth (n=1,593)	139 (8.7)	835 (52.4)	490 (30.8)	105 (6.6)	24 (1.5)

Abbreviation: MMT, Minnesota Medical Tiering.

Table 3

Association of HOUSES Index With Risk of Hospitalization After Adjustments for Age, Sex, and MMT Tiers

HOUSES Quartile	Patients Hospitalized in 2011, No. (%)	Adjusted for Age and Sex, HR (95% CI)	Adjusted for Age, Sex, and MMT, HR (95% CI)
First (n=1,600)	200 (12.5)	1.78 (1.38-2.29)	1.53 (1.18-1.98)
Second (n=1,587)	161 (10.1)	1.45 (1.12-1.88)	1.33 (1.02-1.73)
Third (n=1,622)	144 (8.9)	1.30 (1.0-1.69)	1.25 (0.96-1.64)
Fourth (n=1,593)	93 (5.8)	Reference	Reference

Abbreviations: HR, hazard ratio; MMT, Minnesota Medical Tiering.