Analysis of Common Opioid Dependency Risk Factors in Rural Chronic Pain Patients Using Knowledge Graph-Based Semantic Modeling

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Abstract

Chronic pain is a silent epidemic that ensnares individuals in a vicious cycle of physical agony and mental anguish. The ripple effects of chronic pain extend beyond the physical aspect, as chronic pain patients are markedly more susceptible to anxiety disorders, depression, and a host of other chronic conditions. The burden is heavy, and chronic pain patients face increased medical expenses, psychological distress, and a diminished perception of their general health status. In addition, the serious issue of opioid addiction and mortality exacerbates the situation as opioid seems to be the only approachable solution for patients to seek relief from their suffering. This study aims to analyze common attributes among rural chronic pain patients with high risk of opioid addiction using the knowledge graph framework. Through converting the 2021 National Health Interview Survey data into an ontology model using Neo4j, a graph database management system that stores and queries interconnected data as nodes and relationships, we could identify complex patterns and associations within the dataset. The study revealed that high-risk chronic pain patients demonstrated significantly elevated centrality in musculoskeletal conditions (66.3% higher hip pain, 59.0% higher back pain, 48.1% higher arthritis rates) and psychological factors (33.7% higher anxiety disorders, 32.5% higher depression treatment rates). The demographic profile showed these patients were predominantly economically disadvantaged, married, obese women in their 60s living in southern regions with significant medical bill concerns.

Key Words: Semantic Knowledge Graph, Biopsychosocial Model, Ontology, Pain informatics

Introduction

Among adults in the United States, the deep-rooted presence of high levels of persistent chronic pain (i.e., pain lasting over three months), a multifactorial condition, has profound biological, psychological, and socioeconomic burdens on their lives (Mills, Nicolson, & Smith, 2019). It has emerged as a detrimental public health problem, resulting in substantial costs attributed to lost workdays and medical expenses and severe addiction to opioid-based analgesics. The annual cost of pain is estimated to range from $560 to $635 billion (Gaskin & Richard, 2012). Particularly, chronic pain is more prevalent in rural areas than urban areas, where the opioid addiction crisis has had a consequential impact (Rafferty et al., 2021). While analgesic-based treatments, particularly opioid-based analgesics, are commonly utilized in rural populations for managing high-intensity chronic pain, they are not the definitive solution. Fundamentally, the constant consumption of opioid-based analgesics does not necessarily always lead to improvements in chronic pain conditions, potentially contributing to a higher rate of opioid addiction and mortality (Nadeau, Wu, & Lawhern, 2021).

Due to the fact chronic pain is a highly multifaceted condition that derives from intertwined factors, a more comprehensive approach to chronic pain management that goes beyond relying solely on opioid-based analgesics and understanding chronic pain is necessary. This study sought to integrate a knowledge graph model to identify high-risk groups in rural areas who are at risk of dependence on analgesics and have a high potential risk of escalating to opioid-based analgesics. The objective is to identify common attributes among individuals in these high-risk groups and implement preventive measures to ensure that individuals with these characteristics do not progress to dependence on opioid-based analgesics. This study analyzed the 2021 National Center for Health Statistics, National Health Interview Survey (NHIS) data, considered the best source for tracking pain, to offer a comprehensive insight into the intricately intertwined intersection point among chronic pain patients with high-intensity pain in rural areas to identify high-risk groups in rural areas further later possibly. As knowledge graphs are powerful tools for complex pattern analysis due to their structure, which represents highly interconnected data with complex relationships (Tian, 2023), our study

presents a novel and effective methodology for further analyzing chronic pain.

Related Work

Biopsychosocial Characteristics of Pain

Pain is a heterogeneous condition that arises from the interaction of sensory, emotional, and psychological processes within the brain, not simply based on nociceptor activation alone (Harvey, 1995). However, from the previous work by the Centers for Disease Control and Prevention (CDC) that analyzed how chronic pain is more prevalent among US rural residents compared to urban residents, biological reasons were solely stated as the main determinants of chronic pain. More specifically, the research paper, ”Rural, Suburban, and Urban Differences in Chronic Pain and Coping Among Adults in North Carolina: 2018 Behavioral Risk Factor Surveillance System” (Rafferty et al., 2021), which was based on Behavioral Risk Factor Surveillance System (BRFSS)’s first chronic pain module in 2018, has reported that primary causes of chronic pain were solely due to arthritis, sciatica, slipped disk, spondylosis, accident or injury, muscle pain, neuropathic pain, and hip, knee, or other joint pain.

Although biological factors may be one of the primary factors influencing chronic pain in rural populations, chronic pain is a complex, multifaceted condition (Thomas, 2004). However, the literature on determinants that influence the higher prevalence of chronic pain in rural areas compared to urban areas, beyond biological factors from biopsychosocial models, is limited. Thus, this study sought to expand further the research conducted by the CDC by particularly focusing on biopsychosocial determinants linked with chronic pain patients who reported high-intensity chronic pain and reaffirming identified biological factors by the CDC.

Knowledge Graph for Analysis of Multifactorial Chronic Pain Condition

Knowledge graphs provide a powerful framework for modeling complex, interconnected relationships within heterogeneous datasets, making them particularly well-suited for chronic pain research where multiple biopsychosocial factors interact dynamically (Tian, 2023). This semantic modeling approach enables comprehensive pattern recognition and cluster analysis across diverse data types, including clinical records, demographic

information, prescription histories, and psychosocial assessments. In the context of rural chronic pain populations, knowledge graphs can effectively capture the multifaceted risk factors contributing to opioid dependency by representing relationships between geographic isolation, healthcare access barriers, socioeconomic determinants, and clinical variables (Reddan, 2021).

Methods

National Health Interview Survey Dataset

This study used data from the 2021 National Center for Health Statistics, National Health Interview Survey (NHIS) data coordinated by the Centers for Disease Control and Prevention. The NHIS is a comprehensive study that gathers health-related information from a representative sample of 29,482 adults through 622 survey questions covering various socioeconomic and demographic aspects. In 2021, 62.8% of adult interviews in the sample were conducted partially through telephone, with a response rate of 50.9%. The 2022 and 2023 NHIS did not include a specific question on respondents' chronic pain status, so this study used the 2021 data for our chronic pain analysis. Due to the fact that the 2021 NHIS highlighted disparities among different population groups, it serves as a reputable dataset.

High-Risk Group Assumption

This study examined the mutual biological, psychological, and demographic factors that a group of chronic pain patients who are prescribed medication but continue to experience high-intensity chronic pain, frequent difficulties in working, and high-frequency pain episodes experience. Due to the daily impact of intense and frequent pain on work and life, there is a high likelihood that these individuals may require stronger medications, such as opioid-based analgesics, in the future. Additionally, rural areas, compared to urban areas, have lower accessibility to medical services and non-pharmacological treatment options, which also contributes to the reliance on medication for pain management (Rafferty et al., 2021).

The high-risk group is defined as individuals who have the affordability, accessibility, and experience of medication yet continue to experience intense and persistent pain that significantly impacts their work and daily life. Specifically, individuals in rural areas with limited access to

non-pharmacological treatments still do not experience improvement in chronic pain despite having good access to prescription medication.

Based on the NHIS survey data, respondents are classified into the high-risk group if they exhibit the following six factors: (a) Reside in rural areas, (b) Experience strong pain, (c) Report always or often experiencing chronic pain, (d) Feel that pain always influences their work and daily life (e) Have access to affordable medication (f) Have had experience with prescription medication within the past year.

Knowledge Graph Modeling

Neo4j, a Graph Database management system, was used to turn NHIS 2021 survey data into an ontology model for data analysis (Tian, 2023). The NHIS 2021 dataset was initially processed to extract relevant data for this study. Each respondent, identified by a unique HHX (label given by NHIS dataset) identifier, was represented as an individual node within the Neo4j database. Irrelevant questions (e.g., Which people living in this household are X's foster parents?) were excluded from the analysis, focusing on those directly or possibly related to chronic pain. The selected questions were categorized into three main areas: (1) Biological, (2) Psychological, and (3) Demographical. Each question's responses were divided into distinct nodes based on the response (e.g., Anxiety Yes and Anxiety No) and connected to the corresponding HHX respondent nodes through the relationship. The questions are very detailedly divided into responses for detailed analysis of common factors (e.g., Nervousness All Of The Time, Hopeless Most Of The Time, Moderate Depression, StrongAnxiety). The study employed degree centrality within the graph to identify commonalities among a predefined risk group for chronic pain, integrating additional biological, psychological, and demographic features.

Experimental Design for Risk Factor Identification

The dataset comprised responses from a total of 29,482 participants (n = 29, 482) from the 2021 NHIS survey. These participants were divided into two distinct groups using a 7:3 ratio. The model learning group comprised 70% of the total respondents, equating to 20,637 individuals (n = 20, 637). This group was primarily utilized to identify and model common factors among high-risk chronic pain patients. The remaining 30% of the sample, which included 8,845 respondents (n = 8, 845), was allocated to the testing group. The objective was to apply the patterns identified within the model learning group to this testing cohort, thereby validating the model by

assessing whether individuals with identified risk factors corresponded to the high-risk group.

Experiment 1: Centrality Comparison with Chronic Pain Patients

This experiment compared factor centrality between the high-risk opioid dependency group and a baseline chronic pain control group. The control group consisted of patients with frequent chronic pain episodes (always/often experiencing pain) but without documented opioid dependency risk indicators. This comparison identified risk factors beyond those inherent to chronic pain conditions generally.

Experiment 2: Centrality Comparison with Rural Residents

The second experiment contrasted the high-risk group against rural residents without chronic pain diagnoses. This rural-only control group enabled isolation of geographic and socioeconomic factors specific to opioid dependency risk, separate from general rural population characteristics such as healthcare access limitations or demographic patterns.

Experiment 3: Centrality Comparison with Rural Chronic Pain Patients

The final experiment compared high-risk patients against rural chronic pain patients without opioid dependency indicators. This control group combined both rural residency and chronic pain factors, allowing identification of additional risk factors that distinguish opioid-dependent patients from the broader rural chronic pain population.

Centrality Analysis Methodology

For each experiment, we calculated the difference in centrality scores between the high-risk group and respective control groups. Factors were ranked by magnitude of centrality difference, with the largest disparities indicating the strongest discriminating power. Factors consistently showing high centrality across all comparisons were identified as primary risk indicators unique to rural chronic pain patients with opioid dependency.

Pattern Validation

This study hypothesizes that common risk attributes exist among high-risk chronic pain patients in rural areas. The primary objective is to identify patterns within a learning set, constituting 70% of the NHIS data, and

subsequently validate these findings within the remaining 30% of the data set. Validation does not employ the initial seven factors (rural, strong pain, frequency of pain, impact on work and life, affordability of medicine, and prescription medication experience within a year) used to distinguish the risk group. Instead, it assesses whether individuals experiencing chronic pain (categorized as always, often, or sometimes) exhibit a higher exposure to other identified factor patterns compared to a control group. These patterns include strong chronic pain, frequent pain, significant impact on work and life, affordability of medicine, and prescription medication experience within a year.

The study employs a factor analysis approach to identify patterns within the risk group, focusing on factors with high centrality—indicative of a greater number of relations within the risk group compared to a control group. The analysis involves extracting top factor nodes with significant centrality differences and conducting three comparative experiments to quantify the centrality variance between the risk and control groups for each factor.

For instance, the ’Female’ factor demonstrated a 12.5% higher centrality in the risk group compared to the control group, suggesting a higher possibility of women being part of the risk group due to greater exposure to the six identified risk factors. Further comparative analysis, excluding the rural factor, showed an 11.4% higher centrality for the ‘Female’ factor in the risk group against a general chronic pain patient group, indicating a higher rate for women to belong to the risk group. The study concludes that factors with higher centrality values, consistent across all three comparative experiments, are more relevant in characterizing the risk group. This methodology provides a framework for identifying and validating risk factors among chronic pain patients in rural areas, contributing to targeted interventions and improved healthcare outcomes.

Results

High-Risk Group Characteristics and Centrality Analysis

Respondents exposed to six factors according to the definition of a high-risk group demonstrated higher centrality in musculoskeletal pain, arthritis, and mental stress factors such as anxiety and depression when compared to a control group without any conditions. These factors with elevated centrality are largely consistent with the findings of existing

literature on rural chronic pain patients conducted by CDC (Rafferty et al., 2021).

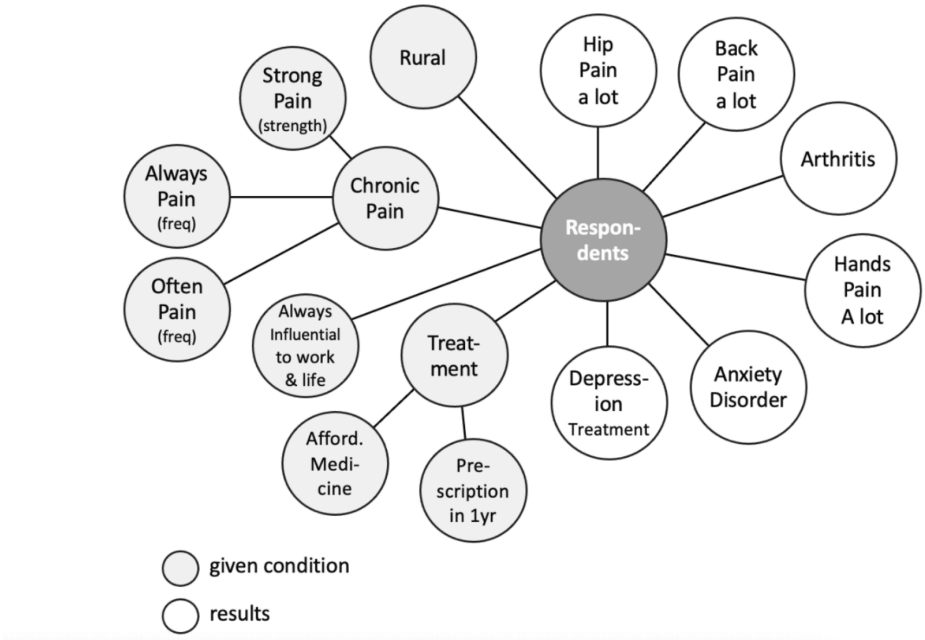

FIGURE 1. The ontological representation of the Risk Group having factors of rural, strong pain, always or often pain influential to work and life, affordable medicine, prescription medication experience in 12 months against no conditional control group.

The comparative analysis between chronic pain patients and a control group without chronic pain revealed major differences. Patients suffering from chronic pain exhibited a 66.3% higher possibility of experiencing severe hip chronic pain compared to the control group not experiencing chronic pain, and a 59.0% greater probability of severe back chronic pain compared to the control group not experiencing chronic pain. Additionally, these patients were 48.1% more susceptible to arthritis compared to the control group not experiencing chronic pain, and similarly, 48.1% reported severe chronic hand pain compared to the control group not experiencing chronic pain.

The study also found that chronic pain patients were 33.7% more likely to have an anxiety disorder compared to the control group not experiencing chronic pain, and 32.5% more likely to be undergoing treatment for depression compared to the control group not experiencing chronic pain. Furthermore, there was a 31.1% increase in the number of

chronic pain patients receiving hypertension medication compared to the control group not experiencing chronic pain, and a 30.9% increase in those receiving anxiety treatment compared to the control group not experiencing chronic pain.

Rural respondents having chronic Pain	**Against Control group**
HipChronicPainALot	+66.3%
BackChronicPainALot	+59.0%
Arthritis	+48.1%
HandsChronicPainALot	+43.5%
AnxietyDisorder	+33.7%
DepressionTreatment	+32.5%
HypertensionMedicineTreatment	+31.1%
AnxietyTreatment	+30.9%
GeneralHealthStatusPoor	+26.7%
ExperiencedSeriousPsychologicalDistress	+23.4%
VeryWorriedInPayingMedicalBill	+23.3%
CholesterolMedicineTreatment	+23.1%
DiabetesMedicineTreatment	+22.3%
COPD	+22.2%
South	+21.1%

TABLE 1. The table represents a comparison of rural respondents with chronic pain against a control group, displaying the top 15 results based on centrality.

A 26.7% higher proportion of chronic pain patients rated their general health status as poor compared to the control group not experiencing chronic pain, and 23.4% more reported experiencing serious psychological distress compared to the control group not experiencing chronic pain. Concerns over medical bill payments were 23.3% more prevalent among chronic pain patients compared to the control group not experiencing chronic pain. Additionally, there was a 23.1% increase in the use of cholesterol medication compared to the control group not experiencing chronic pain, and a 22.3% increase in diabetes medication treatment within this group compared to the control group not experiencing chronic pain. Chronic Obstructive Pulmonary Disease (COPD) was 22.2% more common compared to the control group not experiencing chronic pain, and there was a 21.1% higher tendency for these patients to reside in the South compared to the control group not experiencing chronic pain.

Comparative Centrality Analysis Results

factors	Comparisons		
	comparison 1 against chronic all	comparison 2 against rural only	comparison 3 against rural chronic all
HipChronicPainALot	58.7%	0.0%	0.0%
BackChronicPain	46.3%	0.0%	0.0%
HandsChronicPain	40.6%	0.0%	0.0%
Arthritis	38.1%	0.0%	0.0%
South	21.3%	15.8%	0.0%
Female	11.4%	11.7%	10.4%
AnxietyDisorder	29.6%	0.0%	0.0%
DepressionTreatment	28.8%	0.0%	0.0%
AnxietyTreatment	27.4%	0.0%	0.0%
GeneralHealthStatusPoor	25.3%	0.0%	0.0%
Obese	11.9%	8.5%	4.5%
HypertensionMedicineTreatment	24.9%	0.0%	0.0%
HypertensionYes	24.8%	0.0%	0.0%
AnxietyDaily	22.4%	0.0%	0.0%
ExperiencedSeriousPsychologicalDistress	22.1%	0.0%	0.0%
VeryWorriedInPayingMedicalBill	21.9%	0.0%	0.0%
COPD	20.1%	0.0%	0.0%
Age60	7.1%	7.6%	5.5%
PoorFoodSecurity	19.3%	0.0%	0.0%
StrongDepression	19.0%	0.0%	0.0%
CholesterolMedicineTreatment	17.9%	0.0%	0.0%
CholesterolYes	17.9%	0.0%	0.0%
DiabetesMedicineTreatment	17.9%	0.0%	0.0%
Married	4.7%	6.7%	6.1%
DiabetesInsulinShot	17.3%	0.0%	0.0%
DepressionDaily	17.2%	0.0%	0.0%
EverHasDiabetesYes	17.1%	0.0%	0.0%
MigrainerChronicPainALot	16.3%	0.0%	0.0%
AbdominalChronicPain	16.0%	0.0%	0.0%
MigrainerChronicPain	16.0%	0.0%	0.0%
Dissatisfied	15.8%	0.0%	0.0%
RestlessMostOfTheTime	13.6%	0.0%	0.0%

TABLE 2. The table illustrates three comparisons: against all chronic pain, against rural respondents only, and against rural chronic pain all within the risk group.

The investigation into identifying relevant factors for the risk group was conducted through three comparative experiments. In the analysis, instances of double negatives, such as responses indicating never experiencing sadness (e.g., Sadness None Of The Time), were excluded due to their potential for ambiguous interpretation, especially given the presence of directly related factors like Sadness Daily and Sadness Treatment. Additionally, factors with opposing meanings that both exhibited significant centrality values, such as Mental Health Care Medicine and No Mental Health Care Medicine, were omitted from consideration as they presented challenges in clearly identifying them as relevant factors for the risk group. The experimental results revealed that factors associated with musculoskeletal disorders, including Hip, Back, Hands, and Arthritis, displayed high centrality within the risk group, aligning with findings from existing research (Rafferty et al., 2021). Following these, factors related to mental stress and disorders, such as

Anxiety and Depression, were also prominently featured. Notably, from a demographic perspective, the risk group predominantly consisted of economically disadvantaged, married, obese women in their 60s living in the southern regions, who expressed significant concern over medical bills. Furthermore, a higher prevalence of chronic conditions such as Hypertension, Cholesterol, and Diabetes was observed within this group, alongside lower levels of life satisfaction.

In this study, we sought to identify patterns of factors associated with increased risk within chronic pain patients by focusing on combinations of representative factors from three categories: Biological, Psychological, and Demographic. The aim was to determine the extent to which certain factor patterns could predict membership in a high-risk group defined by (1) strong pain, (2) always chronic pain/often chronic pain, (3) always influential to work and life, (4) affordable medicine, and (5) prescription medication experience in the past year.

Our analysis revealed that Patterns 1, 2, and 3 all demonstrated significantly higher exposure to the risk group factors compared to the benchmark group of all chronic pain patients ($p < 0.05$). Pattern 3, in particular, showed the highest exposure to the risk group factors. However, due to the stringent combination of factors, the prevalence of respondents classified as high-risk was only 0.1%. This indicates that while stricter factor conditions lead to a higher likelihood of identifying high-risk individuals, they also significantly reduce the number of respondents classified as such.

A noteworthy finding was the comparison between Pattern 1 and Pattern 2, which suggested that psychological stressors such as Anxiety and Depression have a more pronounced effect on the intensity of pain rather than the frequency. When the Anxiety or Depression treatment factor was added, the exposure to Strong Chronic Pain increased from 39.2% to 59.8%, and the Always Influential to Work and Life factor exposure increased from 23.6% to 37.0%. This implies that the presence of strong pain may exacerbate the impact of chronic pain on daily activities.

Another observation was that the addition of the Very Worried In Paying Medical Bill factor in the comparison between Patterns 2 and 3 led to a 26.4% increase in Always Chronic Pain factor exposure. This suggests that financial difficulties may exacerbate the severity of chronic pain conditions. The Prescription Medication Experience in 12 months factor and the Affordable Medicine factor showed nearly 100% exposure across the benchmark and all patterns, indicating that these factors may

not be useful in distinguishing the high-risk group within the chronic pain patient population.

The study's findings underscore the importance of considering a multifaceted approach when identifying high-risk chronic pain patients. The interplay between biological, psychological, and demographic factors can significantly influence the risk profile of chronic pain patients (Reddan, 2021). Future research should continue to explore these complex relationships to better target interventions and support for those most at risk. In terms of focus, the Psychological category emerged as particularly influential in determining the intensity of pain and its impact on life and work, suggesting that future studies should prioritize this category for further investigation.

Additional experiments, Patterns 4, 5, and 6, were conducted to assess which category had the most decisive impact on inclusion in the high-risk group. The results indicate that factors within each category alone significantly increase the exposure to the high-risk group factors compared to the benchmark. Notably, musculoskeletal disorders such as chronic pain in the hips, back, or hands and arthritis demonstrated the strongest explanatory power even with fewer factors. However, it is interesting to note that simple demographic factors, such as being an elderly obese woman living in a rural area, also show a considerably high exposure to the high-risk group. Furthermore, the presence of only two psychological factors, anxiety or depression treatment, indicates a higher risk group exposure than demographic factors alone.

Despite rural chronic pain patients generally having high medication affordability and sufficient prescription experience, the persistence of strong and constant chronic pain suggests a dangerous and highly stressful situation. Based on our epidemiological findings, it can be hypothesized that chronic pain patients with exposure to psychological factors are more likely to belong to the high-risk group. Our data may imply that chronic pain inherently includes a psychological aspect, or it could suggest that what begins as musculoskeletal pain may evolve into neurological or psychological disorders over time; however, there is no biological basis or evidence to suggest this causal relationship. These hypotheses are based solely on the epidemiological associations observed in our dataset. Therefore, a deep relationship between mental health issues and chronic pain could be inferred from our statistical analysis, though the directionality and mechanistic basis of this relationship cannot be determined from the current study design.

		Benchmark	Pattern 1	Pattern 2	Pattern 3
Learning group (20,637)		Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain
			Rural	Rural	Rural
			Female	Female	Female
			Obese	Obese	Obese
			Age60	Age60	Age60
			Hip/Back/Hands Chronic Pain	Hip/Back/Hands Chronic Pain	Hip/Back/Hands Chronic Pain
			Arthritis	Arthritis	Arthritis
				Anxiety or Depression treat.	Anxiety or Depression treat.
					Very Worried In Paying Medical Bill
Number of Respondents corresponding to Each Pattern		12,766 (61.9%)	126 (0.6%)	92 (0.4%)	29 (0.1%)
Number of Respondents Having Exposure on the Risk Group Factors	**Strong Chronic Pain**	16.9%	39.2%(+22.3%)	59.8%(+42.9%)	62.1%(+45.2%)
	Always Chronic Pain	22.8%	57.3%(+34.5%)	59.8%(+37.0%)	86.2%(+63.4%)
	Often Chronic Pain	13.2%	22.8%(+9.6%)	28.3%(+15.1%)	13.8%(+0.6%)
	Always Influential to Work and Life	7.8%	23.6%(+15.8%)	37.0%(+29.2%)	41.4%(+33.6%)
	Affordable Medicine	77.3%	97.5%(+20.2%)	100.0%(+22.7%)	100.0%(+22.7%)
	Prescription Medication Experience in 1yr	100.0%	100.0%(+0.0%)	100.0%(+0.0%)	100.0%(+0.0%)

FIGURE 2. The table illustrates three patterns discovered from the learning group with the conditions of Always/Often/Sometimes Chronic pain.

		Benchmark	Pattern 4	Pattern 5	Pattern 6
Learning group (20,637)		Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain
			Rural	Rural	Rural
			Female		
			Obese		
			Age60		
				Hip/Back/Hands Chronic Pain	
				Arthritis	
					Anxiety or Depression treat.
Number of Respondents corresponding to Each Pattern		12,766 (61.9%)	110 (0.5%)	1,348 (6.5%)	790 (3.8%)
Number of Respondents Having Exposure on the Risk Group Factors	**Strong Chronic Pain**	16.9%	26.4%(+9.5%)	38.4%(+21.5%)	32.2%(+15.2%)
	Always Chronic Pain	22.8%	37.3%(+14.5%)	63.1%(+40.3%)	45.3%(+22.5%)
	Often Chronic Pain	13.2%	14.5%(+1.4%)	17.7%(+4.5%)	15.6%(+2.4%)
	Always Influential to Work and Life	7.8%	11.8%(+4.0%)	26.0%(+18.2%)	22.2%(+14.6%)
	Affordable Medicine	77.3%	94.5%(+17.3%)	93.9%(+16.6%)	99.2%(+22.0%)
	Prescription Medication Experience in 1yr	100.0%	100.0%(+0.0%)	100.0%(+0.0%)	100.0%(+0.0%)

FIGURE 3. The table illustrates additional three patterns discovered from the learning group.

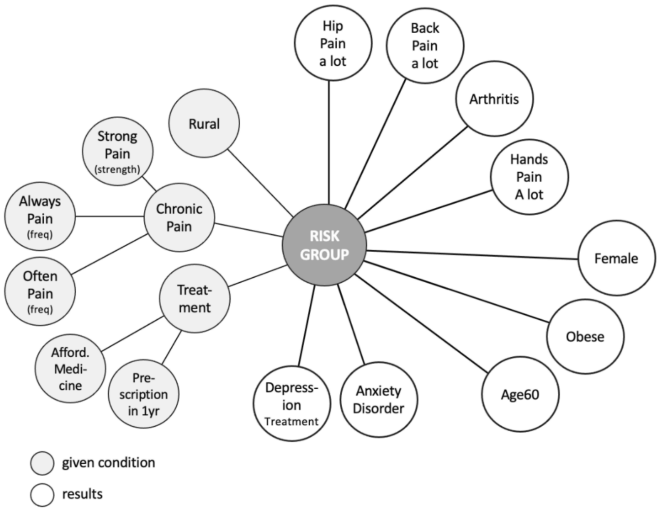

FIGURE 4. The ontological representation of the Risk Group having commonalities.

Pattern Validation

The primary objective of this validation was to ascertain a predictive model developed from 70% of the data (training set) by testing on the remaining 30% (testing set) to identify individuals at high risk for intense and frequent pain. The validation process revealed that respondents who reported suffering from hip, back, and hand pain, chronic pain, or arthritis were more likely to experience higher pain intensity and frequency. Additionally, individuals undergoing treatment for anxiety or depression were also found to have increased pain intensity and frequency. The impact of these conditions on work and life was detrimental across all groups. Notably, the majority of respondents indicated that medication was affordable and that they had used prescription medication within the past year. The results from the validation were consistent with the initial findings derived from the 70% training dataset, reinforcing the predictive model's reliability in identifying high-risk individuals.

		Validation Group 1	**Validation Group 2**	**Validation Group 3**	**Validation Group 4**
Validation group (8,845)		Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain	Always/ Often/ Sometimes Chronic Pain
		Rural	Rural	Rural	Rural
		Female			Female
		Obese			Obese
		Age60			Age60
			Hip/Back/Hands Chronic Pain		Hip/Back/Hands Chronic Pain
			Arthritis		Arthritis
				Anxiety or Depression treat.	Anxiety or Depression treat.
Number of Respondents corresponding to Each Pattern		110 (1.2%)	1,348 (15.2%)	790 (8.9%)	92 (1.0%)
Number of Respondents Having Exposure on the Risk Group Factors	**Strong Chronic Pain**	26.4%	38.4%	32.2%	59.8%
	Always Chronic Pain	37.3%	63.1%	45.3%	59.8%
	Often Chronic Pain	14.5%	17.7%	15.6%	28.3%
	Always Influential to Work and Life	11.8%	26.0%	22.2%	37.0%
	Affordable Medicine	94.5%	93.9%	99.2%	100.0%
	Prescription Medication Experience in 1yr	100.0%	100.0%	100.0%	100.0%

FIGURE 5. The table that validates the results obtained from the training set.

Discussion and Limitations

The relationship between chronic pain and opioid dependency is particularly concerning, as individuals with chronic pain are at a higher risk of becoming dependent on opioid medications when these are the primary or sole treatment modality (Nadeau et al., 2021). This dependency can lead to a vicious cycle where the management of chronic pain becomes increasingly challenging, and the risk of opioid-related adverse outcomes, including mortality, escalates. The management of chronic pain in rural populations with a high risk of opioid dependency requires a multidimensional approach that goes beyond pharmacological interventions (Reddan, 2021). It is essential to consider the socio-demographic and psychological factors that contribute to the experience of pain and the risk of substance dependency.

One of the primary limitations in the research of chronic pain and its comorbidities, such as arthritis, is the difficulty in establishing causality. Chronic pain and conditions like arthritis can have a bidirectional relationship, where each condition may exacerbate the other (Thomas, 2004). This bidirectional influence poses a significant challenge in determining whether chronic pain leads to conditions like arthritis or vice versa. The complexity is further compounded by the presence of multiple confounding factors, including socio-demographic variables and other comorbidities, which can obscure the true nature of these relationships. Additionally, the research often relies on cross-sectional data, which can identify associations but not causal pathways. Longitudinal studies are needed to better understand the temporal sequence of chronic pain and its associated conditions.

Conclusion

This study successfully employed a knowledge graph for analysis using Neo4j to identify common risk factors among rural chronic pain patients at high risk of opioid dependency (Tian, 2023). The biopsychosocial model proved effective in understanding the multifaceted nature of chronic pain, revealing that high-risk individuals are characterized by a combination of musculoskeletal disorders, psychological distress, and specific demographic factors (Mills et al., 2019).

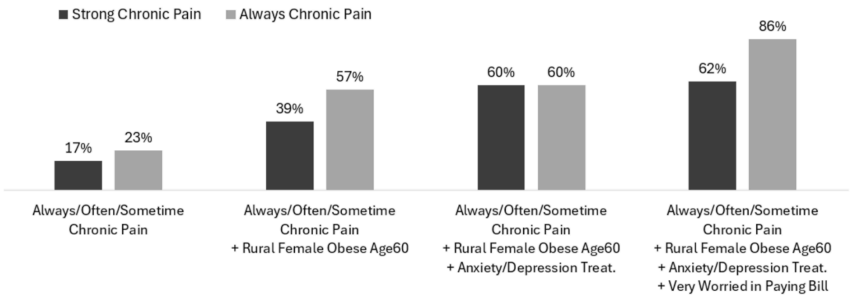

FIGURE 6. Comparison between patients with strong chronic pain and patients with constant chronic pain depicted in a bar chart.

The findings emphasize the importance of comprehensive, multidisciplinary approaches to chronic pain management in rural populations, moving beyond solely pharmacological interventions to address the complex interplay of biological, psychological, and social determinants that contribute to opioid dependency risk (Reddan, 2021).

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