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EXPLORING MULTIMORBIDITY PATTERNS IN PATIENTS WITH OSTEOARTHRITIS USING MACHINE LEARNING

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ABSTRACT

Osteoarthritis (OA) is a degenerative joint disease often accompanied by multimorbidity, particularly cardiometabolic diseases. OA is also associated with comorbidities, thus requiring an analytical approach capable of identifying patterns of relationships between diseases and rational therapies. This study aims to explore patterns of multimorbidity and treatment patterns in hospitalized patients with osteoarthritis using a machine learning (ML) approach. This study employed a retrospective design using medical records of hospitalized OA patients from January 2020 to January 2025 at Sultan Agung Islamic Hospital in Semarang. Analysis was performed using the Frequent Pattern Growth (FP-Growth) algorithm with support, confidence, and lift parameters. The minimum support value was set at 1% to identify a wider variety of patterns. A total of 25 patients were analyzed, with the majority being female (14 patients; 56%) and aged ≥59 years (14 patients;96%), with comorbidities predominantly obesity and hypertension. Association Rule Mining (ARM) results showed cardiometabolic multimorbidity patterns, with the strongest association in the combination OA+HT→DM (lift 1.93). Therapy pattern analysis indicated that disease combinations were associated with the use of therapies such as NSAIDs for OA and metformin for diabetes, as well as the addition of adjuvant therapies. Multimorbidity patterns in hospitalized OA patients are dominated by the cardiometabolic group, with complex therapeutic regimens. ML approaches are effective in identifying patterns of disease and therapy relationships, therapy supporting more rational clinical decision-making.

Keywords: Osteoarthritis, Multimorbidity, Machine Learning, FP-Growth, Therapy, Hospitalization

INTRODUCTION

OA is a joint condition characterized by inflammation and stiffness of the cartilage (Steinmetz et al., 2023). The global prevalence of OA is approximately 595 million people (95% CI: 535–656 million). In Asia, the prevalence is 5,677 per 100,000 people, while in Southeast Asia it reaches 8,632 per 100,000(Steinmetz et al., 2023). OA also causes disability, with a global total of 255.0 Years of

Life Lost Due to Disability (YLD) (Coaccioli et al., 2022).

Multimorbidity is a condition in which an individual has two or more diseases at the same time (NICE, 2016). The prevalence of multimorbidity is approximately 67% in the population aged 65 and older and increases with age (Otgonbaatar et al., 2025). Among patients with OA, the prevalence of multimorbidity is very high approximately 85% with the most common comorbidities including obesity, hypertension, type 2 diabetes mellitus, dyslipidemia, cardiovascular disease, and other musculoskeletal disorders such as low back pain (LBP) and herniated nucleus pulposus (HNP) (Dell'Isola et al., 2024; Halabitska et al., 2024; Hidayah et al., 2022). Therefore, the presence of multimorbidity in patients with OA requires a more rational therapeutic approach, making the identification of multimorbidity patterns crucial in supporting clinical decision-making.

The management of multimorbidity in patients with osteoarthritis tends to focus on a single-disease approach. This approach contributes to increased polypharmacy, the risk of drug side effects, drug interactions, and higher hospitalization rates (Tsang et al., 2024). The management of multimorbidity should be patient-centered, taking into account the interactions between diseases and the selection of rational therapies. Irrational management can lead to a decline in quality of life, increased morbidity, and higher utilization of health care services and treatment costs (Delord et al., 2024; Seakamela et al., 2025).

The use of machine learning can identify complex patterns and relationships between variables that cannot be analyzed using conventional statistical methods. The use of association rule mining (ARM) can reveal patterns of diseases that frequently occur together in a more comprehensive manner, thereby supporting more accurate clinical decision-making (Xie et al., 2024).

Research on multimorbidity among OA patients in Indonesia still has limitations. Previous studies have generally been descriptive in nature and have not yet been able to explore the relationships between diseases (Butarbutar et al., 2024). Therefore, this study aims to identify clinical profiles and patterns of multimorbidity in hospitalized patients with OA using an ML approach to support rational clinical decision-making.

METHODS

1. Research Design and Population

This study was conducted retrospectively using medical records of patients diagnosed with OA from January 2020 to January 2025 at Sultan Agung Islamic Hospital, Semarang, Central Java. The inclusion criteria were age ≥25 years, a confirmed diagnosis of OA based on ICD-10, and inpatient status. The study population comprised 25 inpatients with a history of ≥2 comorbidities.

2. Research Variables

The variables in this study include sociodemographic factors (gender, age, type of OA, comorbidities, address, and education). Comorbidities include hypertension, diabetes mellitus, dyslipidemia, cervical spondylosis, low back pain, peptic ulcer, and obesity.

3. Data Processing

The collected data underwent preprocessing, which included data cleaning, transformation of categorical variables, and encoding of comorbidity variables into a binary format (0 = absent, 1 = present). Data exploration was then conducted to understand the distribution and characteristics of the variables.

4. Data Analysis

Data analysis was performed statistically using Python via Google Colaboratory. The algorithm used was Frequent Pattern Growth (FP-Growth) with the parameters support, confidence, and lift. A threshold value (minimum support) of 1% was used to generate more diverse patterns capable of capturing rare combinations of multimorbidity that may have clinical significance, thereby providing a more comprehensive picture of patterns in patients with OA.

5. Research Ethics

This study has received ethical approval from the Health Research Ethics Committee of RSI Sultan Agung, with approval number No. 188/KEPK-RSISA/VIII/2025, and was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS AND DISCUSSION

The results of this study show that inpatients with OA were predominantly female (14 patients, 56%) (Table 1). These results are consistent with Dhaifullah et al., (2023) At Sanglah General Hospital in Denpasar, the prevalence of osteoarthritis was found to be predominantly among women (76.9%). Steinmetz et al. (2023) reports that the prevalence of OA is higher in women, particularly postmenopausal women, due to hormonal changes that affect cartilage metabolism and increase susceptibility to joint

degeneration. In addition, there is an increase in lysosomal activity as a person ages (Nugraha et al., 2023). However, Ching et al. (2023) and Unverzagt et al. (2024) report that the prevalence of osteoarthritis among men and women may vary depending on exposure to environmental factors, particularly strenuous physical activity. Jobs involving high physical demands—such as heavy lifting, kneeling, and repetitive tasks—have been shown to increase the risk of osteoarthritis in both sexes; thus, in certain populations.

Table 1. Characteristic sosiodemographic in patient OA

Characteristic		Frekuensi	Persentase
Sex	Female	14	56
	Male	11	44
Age (year)	45-59	11	44
	≥59	14	56
Education Level	Junior High School	0	0
	Senior High School	15	60
	Diploma	5	20
	Bachelor	5	20
Type of OA	Knee	24	96
	Hand	1	4
	Hip	0	0
Comorbidities	Hypertension	7	28
	Diabetes Mellitus	1	4
	Hyperlipidemia	1	4
	Hernia Nucleus Pulposus	0	0
	Low Back Pain	0	0
	Peptic Ulcer Disease	0	0
	Obesity	16	64
Distric	Outside Semarang City	22	88
	In Semarang City	3	12
Grade OA	0	0	0
	1	5	20
	2	7	28
	3	8	32
	4	5	20

In the age group of 59 years and older, the incidence of OA was higher (14 patients, 56%). These results are consistent with Mustaqim et al., (2025) that OA patients are in the 50–69 age group (46.2%). Based on the pathophysiology of aging, changes occur in the cells and extracellular matrix of joint tissue, leading to the accumulation of AGEs (Advanced Glycation End-Products). This causes the joint surface area to become thinner compared to younger adults (aged 18–44 years). These changes alter the mechanical properties of cartilage, making it weaker and more susceptible to degeneration (Adani et al., 2021).

The predominant type of OA in this study was knee OA (24 patients, 96%). This finding is consistent with Alshahrani et al. (2025) and Shi & Schlenk. (2022) The knee joint is the most common site affected by OA, as the knee serves as a weight-bearing joint and is subjected to high mechanical stress. Regarding comorbidities, this study found that the most common conditions were obesity (64%) and hypertension (14%). Obesity is a comorbidity in OA that contributes to the condition through increased mechanical stress on the joints and chronic inflammation caused by the production of pro-inflammatory adipokines, thereby accelerating cartilage damage (De Luca et al., 2025; Wei et al., 2023). In addition, hypertension plays a role through impaired subchondral perfusion and endothelial dysfunction (Shi & Schlenk, 2022; Yang et al., 2024; Yeater et al., 2023).

In addition, moderate-to-severe OA (grade 2 = 7 patients; 28% and grade 3 = 8 patients; 32%) indicates that the hospitalized population consists of cases with a higher severity level. This differs from Evers. (2021) In addition, moderate-to-severe OA (grade 2 = 7 patients; 28% and grade 3 = 8 patients; 32%) indicates that the hospitalized population consists of cases with a higher severity level. This differs from Du et al. 2021) that limited access to health care in remote areas contributes to delays in the diagnosis and treatment of chronic diseases.

From a social perspective, the majority of patients have a low to moderate level of education, which affects their health literacy and adherence to treatment. Low health literacy is associated with suboptimal management of chronic diseases and an increased risk of complications (Jannah & Rahman, 2023). The results of the ARM analysis in hospitalized OA patients revealed a pattern of cardiometabolic multimorbidity (Table 2).

Table 2. Result ARM pattern multimorbidity in patient OA

Antecedent	Consequent	Support	Confidence	Lift
OA+HT	DM	0.221	0.610	1.93
OA+HT	HPD	0.113	0.639	1.92
OA+HPD	HT	0.113	0.678	1.87
OA+DM	HT	0.194	0.810	1.27

The dominant pattern in the OA+HT→DM rule (support 0.221; confidence 0.610; lift 1.93) is followed by OA+HT→DM (support 0.113; confidence 0.639; lift 1.92). Comorbidities such as hypertension, diabetes mellitus, dyslipidemia, and obesity contribute to the progression of OA through chronic inflammation. Hypertension also plays a role through mechanisms involving impaired subchondral perfusion. Increased blood pressure can cause changes in the subchondral bone microcirculation, thereby reducing the supply of nutrients to the cartilage, which ultimately accelerates joint degeneration (Yeater et al., 2023).

In diabetes mellitus, there is an increase in proinflammatory cytokines such as IL-6 and TNF-α, which can stimulate cartilage degradation and inhibit joint tissue repair. Chronic hyperglycemia can lead to the formation of AGEs in joint tissues and increase cartilage stiffness and susceptibility to damage. In addition, insulin resistance also contributes to metabolic dysfunction, which exacerbates the inflammatory process (Fujita et al., 2023; Halabitska et al., 2024). In addition, in dyslipidemia, the accumulation of lipids and the oxidation of lipoproteins can trigger oxidative stress, which accelerates the damage to chondrocytes and the joint's extracellular matrix (Dai et al., 2022). Obesity not only increases the mechanical load on the joints but also acts as an endocrine organ that produces pro-inflammatory adipokines, which accelerate the progression of osteoarthritis (King et al., 2020).

The rule with the highest confidence score was found in the OA+DM → HT pattern (0.810), indicating that the majority of OA patients with diabetes also have hypertension. This can be explained by interrelated pathophysiological mechanisms, in which insulin resistance and endothelial dysfunction contribute to elevated blood pressure (Astiani et al., 2025).

In addition, lift values greater than 1 across all rules indicate a positive association

between conditions, meaning that the presence of one condition increases the likelihood of the other condition occurring. The highest lift value in the OA+HT → DM rule (1.93) indicates the strongest association among the identified patterns. This confirms that multimorbidity in OA patients does not occur randomly but forms specific patterns that can be identified through a machine learning approach. (Anthonimuthu et al., 2025).

The results of the ARM analysis indicate that comorbidities in OA patients are associated with the treatment regimens prescribed (Table 3). For patients with OA and hypertension who also have diabetes mellitus, NSAIDs plus metformin (OA+HT → DM+oral NSAIDs+metformin) were prescribed as first-line therapy for OA pain, and metformin was prescribed as first-line therapy for type 2 diabetes mellitus (Courties et al., 2024; Faruetti et al., 2022).

Table 3. Result ARM patern multimorbidity+therapeutic in patient OA

Atencedent	Consequent	Support	Confidence	Lift
OA+HT	DM+NSAID Oral+Metformin	0.194	0.769	1.24
OA+HT	HPD+NSAID	0.167	0.943	1.03
OA+HPD	HT+NSAID Oral	0.294	0.845	1.24
OA+DM	HT+NSAID+Adjuvan	0.488	0.788	1.24

In addition, in more complex combinations such as OA+DM → HT+NSAID+adjuvant, the treatment regimen tends to be more varied with the addition of adjuvant medications. This suggests that patients with OA and metabolic disorders require a combination therapy approach, particularly in the management of chronic pain (Courties et al., 2024).

The ARM visualization results (Figure 1) also reinforce the finding that cardiometabolic disease is at the center of the multimorbidity network in hospitalized OA patients. This pattern indicates that hypertension is the condition most frequently associated with other comorbidities. These findings are consistent with Xu et al. (2025) hypertension is one of the most common comorbidities in patients with multimorbidity and plays a significant role in determining clinical outcomes.

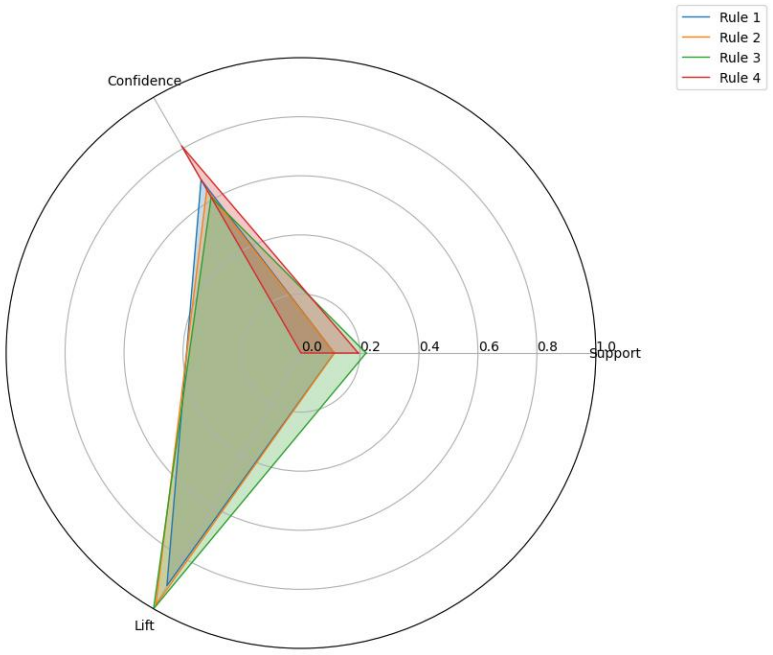

Figure 1. Radar chart pattern multimorbidity in Patient OA. Notes= Rule 1 (OA+HPD→HT); Rule 2 (OA+HT→HPD); Rule 3 (OA+HT→DM); Rule 4 (OA+DM→HT)

The radar chart visualization indicates that the area of each rule is directly proportional to the rules formed within the ARM. Rules with larger areas represent an optimal combination of support, confidence, and lift values, making them more dominant in describing patterns of multimorbidity and treatment in patients with osteoarthritis (Rule 3). Methodologically, the use of ARM in this study proved capable of identifying multimorbidity patterns more comprehensively than conventional statistical methods. This approach allows for the exploration of non-linear relationships and complex interactions between diseases that are difficult to identify through conventional analysis, making it effective in discovering rare patterns (Chen et al., 2025).

However, this study has limitations, including the use of retrospective data that relies on the completeness of medical records and cannot establish causal relationships between variables. Furthermore, the patterns identified are associative in nature and therefore require further validation to confirm their clinical relevance. Nevertheless, the findings of this study provide important insights into patterns of multimorbidity and treatment options for hospitalized OA patients and may serve as a foundation for future research.

CONCLUSION

This study shows that inpatients with OA are predominantly elderly women with patterns of cardiometabolic multimorbidity, particularly obesity, hypertension, and diabetes mellitus. The patterns identified through ARM indicate a strong association among comorbidities and suggest that disease complexity determines the treatment regimens prescribed. The use of NSAIDs as the primary therapy for OA is often combined with specific therapies for cardiometabolic comorbidities, such as metformin and adjuvant medications. ML approaches have proven capable of identifying patterns of disease and therapy relationships more comprehensively than conventional methods, thereby potentially supporting more rational clinical decision-making. Further research is recommended using prospective methods, the addition of variables, and a combination of algorithms such as Apriori/ECLAT to explore patterns of multimorbidity and therapy to support clinical decision-making.

DAFTAR PUSTAKA

Adani, A. F., Hadipoetro, F., & Triturawati, E. (2021). Gambaran Faktor Risiko Pasien Osteoartritis Genu di Pelayanan Rehabilitasi Medik RSIJ Pondok Kopi Januari Desember 2019. *Seminar Nasional Penelitian LPPM UMJ*.

Alshahrani, A. S., Aljaffar, A. B., Albin Ahmed, B. J., Altabash, M. W., Dajani, Z. A., Alamer, A. H., Alzawad, A. J., Alanii, F., & Alzahrani, M. M. (2025). Correlation between Kellgren-Lawrence classification of osteoarthritis and Knee Injury and Osteoarthritis Outcome Score. *World Journal of Orthopedics*, *16*(11). https://doi.org/10.5312/wjo.v16.i11.111953

Anthonimuthu, D. J., Hejlesen, O., Zwisler, A.-D. O., & Witt, F. (2025). Application of Machine Learning in Multimorbidity Research: Protocol for a Scoping Review. *JMIR RESEARCH PROTOCOLS*.

Astiani, R., Anggraeni, R., Luthfiana, F., Sari, D. P., Laila, D., Khan, K., & Ananta, I. W. (2025). Terapi Obat Pada Pasien Osteoarthritis Hip Dextra Grade 4 Dengan Komorbid Hipertensi Dan Diabetes Melitus Tipe 2. *Social Clinical Pharmacy Indonesia Journal*.

Butarbutar, J. Cp., Basuki, P., Sungono, V., Riantho, A., & Fidiasrianto, K. (2024). Burden of osteoarthritis in Indonesia: A Global Burden of Disease (GBD) study 2019. *Narra J*, *4*(2), e884. https://doi.org/10.52225/narra.v4i2.884

Chen, S., Chen, M., Chen, C., Xie, C., Yu, Y., Shao, Z., & Xiao, G. (2025). Epidemiological Trends And Characteristics Of Osteoarthritis in China during 1990–2021. *Journal of Orthopaedic Translation*, *51*, 218–226. https://doi.org/10.1016/j.jot.2025.02.006

Ching, A., Prior, Y., Parker, J., & Hammond, A. (2023). Biopsychosocial, work-related, and environmental factors affecting work participation in people with Osteoarthritis: A systematic review. *BMC Musculoskeletal Disorders*, *24*(1), 485. https://doi.org/10.1186/s12891-023-06612-6

Coaccioli, S., Sarzi-Puttini, P., Zis, P., Rinonapoli, G., & Varrassi, G. (2022). Osteoarthritis: New Insight on Its Pathophysiology. *Journal of Clinical Medicine*, *11*(20), 6013. https://doi.org/10.3390/jcm11206013

Courties, A., Kouki, I., Soliman, N., Mathieu, S., & Sellam, J. (2024). Osteoarthritis year in review 2024: Epidemiology and therapy. *Osteoarthritis and Cartilage*, *32*(11), 1397–1404. https://doi.org/10.1016/j.joca.2024.07.014

Dai, D., Sharma, A., Alvarez, P. J., & Woods, S. D. (2022). Multiple Comorbid Conditions And Healthcare Resource Utilization Among Adult Patients With Hyperkalemia: A Retrospective Observational Cohort Study Using Association Rule Mining. *Journal of Multimorbidity and Comorbidity*, *12*, 26335565221098832. https://doi.org/10.1177/26335565221098832

De Luca, V., Virgolesi, M., Vetrani, C., Aprano, S., Cantelli, F., Di Martino, A., Mercurio, L., Iaccarino, G., Isgrò, F., Arpaia, P., Colao, A., & Illario, M. (2025). Digital interventions for weight control to prevent obesity in adolescents: A systematic review. *Frontiers in Public Health*, *13*, 1584595. https://doi.org/10.3389/fpubh.2025.1584595

Dell'Isola, A., Recenti, F., Englund, M., & Kiadaliri, A. (2024). Twenty-year trajectories of morbidity in individuals with and without osteoarthritis. *RMD Open*, *10*(2), e004164. https://doi.org/10.1136/rmdopen-2024-004164

Delord, M., Sun, X., Learoyd, A., Curcin, V., Wolfe, C., Ashworth, M., & Douiri, A. (2024). Patient-oriented unsupervised learning to uncover the patterns of multimorbidity associated with stroke using primary care electronic health records. *BMC Primary Care*, *25*(1), 419. https://doi.org/10.1186/s12875-024-02636-6

Dhaifullah, M. R., Meregawa, P. F., Aryana, I. G. N. W., & Subawa, I. W. (2023). Hubungan Usia, Jenis Kelamin, Dan Pekerjaan Terhadap Derajat Keparahan Penderita Osteoartritis Lutut Berdasarkan Kellgren-Lawrence Di Rsup Sanglah Denpasar. *E-Jurnal Medika Udayana*, *12*(1), 107. https://doi.org/10.24843/MU.2023.V12.i01.P18

Du, S., Liu, J., & Fu, Z. (2021). The Impact of Village Rules and Formal Environmental Regulations on Farmers' Cleaner Production Behavior: New Evidence from China. *International Journal of Environmental Research and Public Health*, *18*(14), 7311. https://doi.org/10.3390/ijerph18147311

Evers, S. (2021). Non-Invasive Neurostimulation Methods for Acute and Preventive Migraine Treatment—A Narrative Review. *Journal of Clinical Medicine*, *10*(15), 3302. https://doi.org/10.3390/jcm10153302

Faruetti, M. L., De la Torre, A. M., Burkard, T., Obozinski, G., & M.Burden, A. (2022, December 12). *Identification of polypharmacy patterns in new-users of metformin using the Apriori algorithm: A novel framework for investigating concomitant drug utilization through association rule mining*. International Conference for Pharmacoepidemiology.

Fujita, R., Ota, S., Yamamoto, Y., Kataoka, A., Warashina, H., Inoue, T., Ozeki, S., & Sugiura, H. (2023). Effect of diabetes mellitus on physical activity in patients with knee osteoarthritis: A cross-sectional study. *Journal of Orthopaedic Surgery*, *31*(2), 10225536231197726. https://doi.org/10.1177/10225536231197726

Halabitska, I., Oksenych, V., & Kamyshnyi, O. (2024). Exploring the Efficacy of Alpha-Lipoic Acid in Comorbid Osteoarthritis and Type 2 Diabetes Mellitus. *Nutrients*, *16*(19), 3349. https://doi.org/10.3390/nu16193349

Hidayah, L., Darmawan, E., & Yuliani, S. (2022). The increased risk of random blood glucose, body mass index and

abdominal circumference in the schizophrenic patients using clozapine and quetiapine. *Pharmacology, medical reports, orthopedic, and illness details (comorbid)*, *1*(1), 83–92. https://doi.org/10.55047/comorbid.v1i1.67

Jannah, N. I., & Rahman, F. (2023). Beda Profil Status Well-Being pada Kondisi Osteoarthritis, Diabetes Mellitus Tipe II dan Hipertensi Berdasarkan Tingkat Pendidikan. *Jurnal Kesehatan*, 280–290. https://doi.org/10.23917/jk.v16i3.2544

King, L. K., March, L., & Anandacoomarasamy, A. (2020). Obesity & osteoarthritis. *Indian J Med Res*, *138*.

Mustaqim, M. R. R., Lufiana, F., & Rangkuti, D. M. (2025). Hubungan Antara Tingkat Aktivitas Fisik Dengan Derajat Keparahan Osteoartritis. *Jambura Health and Sport Journal*, *7*(2).

NICE. (2016). Multimorbidity: Clinical assessment and management. *National Institute for Health and Care Excellence*.

Nugraha, R. W., Kurniati, M., Detty, A. U., & Marlina, D. (2023). Hubungan antara usia, pekerjaan dan jenis kelamin dengan kejadian osteoarthritis di RSUD dr. H. Abdul moeloek provinsi lampung. *Jurnal Ilmu Kedokteran dan Kesehatan*, *10*(10), 3073–3082. https://doi.org/10.33024/jikk.v10i10.12728

Otgonbaatar, U., Zhang, X., Zhang, M., & Zhang, C. (2025). Prevalence of multimorbidity among urban–rural older adults in Mongolia: A cross-sectional study. *BMC Public Health*, *25*(1), 1993. https://doi.org/10.1186/s12889-025-22804-2

Seakamela, K. P., Mashaba, R. G., Ntimana, C. B., Kabudula, C. W., & Sodi, T. (2025). Multimorbidity Management: A Scoping Review of Interventions and Health Outcomes. *International Journal of Environmental Research and Public Health*, *22*(5), 770. https://doi.org/10.3390/ijerph22050770

Shi, X., & Schlenk, E. A. (2022). Association of Hypertension with Knee Pain Severity Among People with Knee Osteoarthritis. *Pain Management Nursing*, *23*(2), 135–141. https://doi.org/10.1016/j.pmn.2021.08.002

Steinmetz, J. D., Culbreth, G. T., Haile, L. M., Rafferty, Q., Lo, J., Fukutaki, K. G., Cruz, J. A., Smith, A. E., Vollset, S. E., Brooks,

P. M., Cross, M., Woolf, A. D., Hagins, H., Abbasi-Kangevari, M., Abedi, A., Ackerman, I. N., Amu, H., Antony, B., Arabloo, J., … Kopec, J. A. (2023). Global, regional, and national burden of osteoarthritis, 1990–2020 and projections to 2050: A systematic analysis for the Global Burden of Disease Study 2021. *The Lancet Rheumatology*, *5*(9), e508–e522. https://doi.org/10.1016/S2665-9913(23)00163-7

Tsang, J. Y., Sperrin, M., Blakeman, T., Payne, R. A., & Ashcroft, D. (2024). Defining, identifying and addressing problematic polypharmacy within multimorbidity in primary care: A scoping review. *BMJ Open*, *14*(5), e081698. https://doi.org/10.1136/bmjopen-2023-081698

Unverzagt, S., Bergmann, A., Denny, K., Frese, T., Hirpa, S., & Weyer, J. (2024). Physically Demanding Occupations Among Females And Sex-Related Differences To Develop Osteoarthritis Of The Hip: A Systematic Review And Meta-Analysis. *Journal of Occupational Medicine and Toxicology*, *19*(1), 14. https://doi.org/10.1186/s12995-024-00415-8

Wei, G., Lu, K., Umar, M., Zhu, Z., Lu, W. W., Speakman, J. R., Chen, Y., Tong, L., & Chen, D. (2023). Risk of metabolic abnormalities in osteoarthritis: A new perspective to understand its pathological mechanisms. *Bone Research*, *11*(1), 63. https://doi.org/10.1038/s41413-023-00301-9

Xie, H., Jia, Y., & Liu, S. (2024). Integration of artificial intelligence in clinical laboratory medicine: Advancements and challenges. *Interdisciplinary Medicine*, *2*(3), e20230056. https://doi.org/10.1002/INMD.20230056

Xu, G., Song, Q., Jia, M., Yu, Y., Su, S., & Mao, J. (2025). Network Dynamics Of Metabolic Disease Continuum In Older Adults: A 7-Year Longitudinal Cohort Study In China. *BMC Geriatrics*, *26*(1), 94. https://doi.org/10.1186/s12877-025-06882-w

Yang, Z.-J., Liu, Y., Liu, Y.-L., Qi, B., Yuan, X., Shi, W.-X., & Miao, L. (2024). Osteoarthritis and hypertension: Observational and Mendelian randomization analyses. *Arthritis Research & Therapy*, *26*(1), 88. https://doi.org/10.1186/s13075-024-03321-w

Yeater, T. D., Griffith, J. L., Cruz, C. J., Patterson, F. M., Aldrich, J. L., & Allen, K. D. (2023). Hypertension contributes to exacerbated osteoarthritis pathophysiology in rats in a sex-dependent manner. *Arthritis Research & Therapy*, *25*(1), 7. https://doi.org/10.1186/s13075-022-02966-9