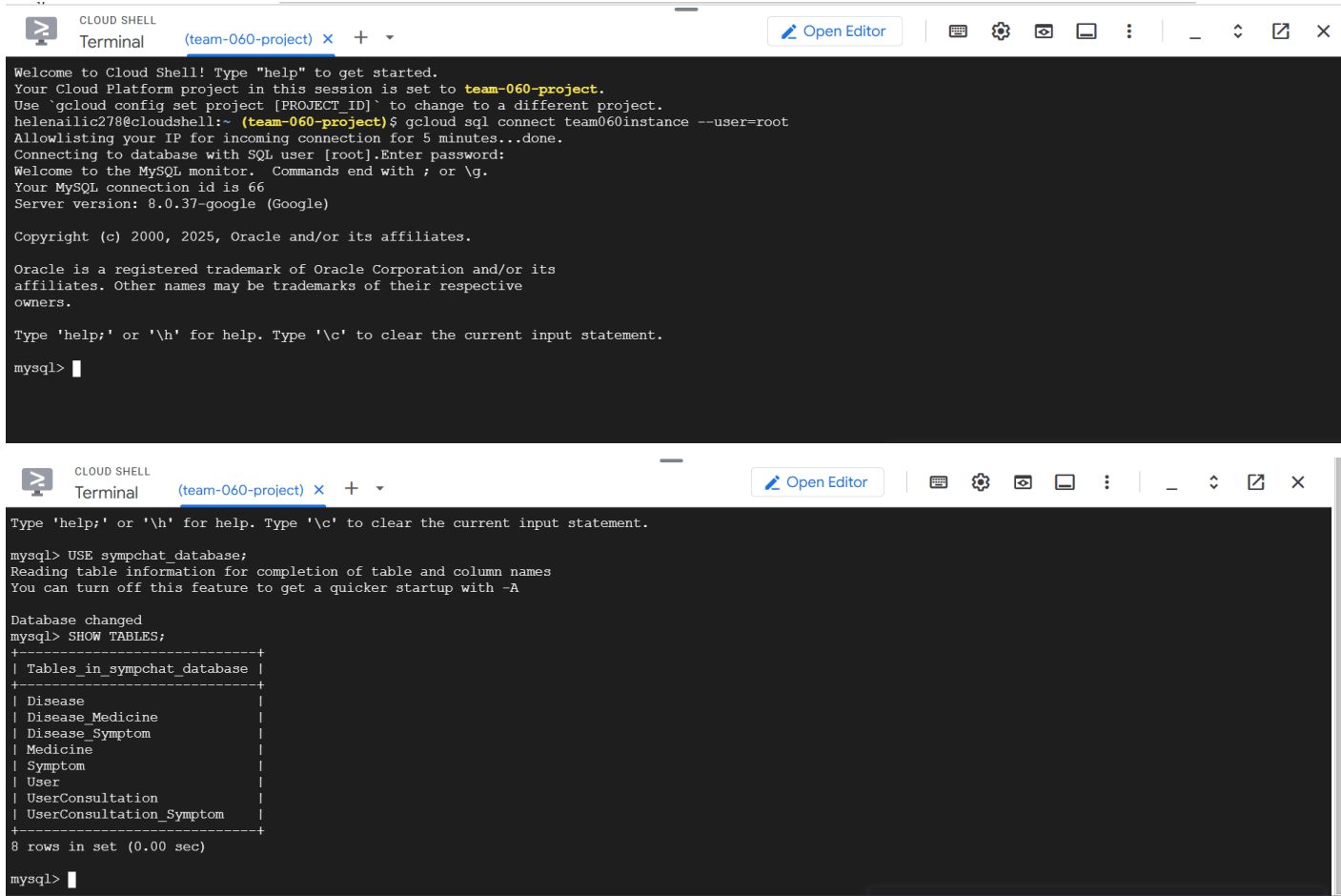


Implementation of the database on GCP connection screenshot:



```
Cloud Shell
Terminal (team-060-project) x +
Welcome to Cloud Shell! Type "help" to get started.
Your Cloud Platform project in this session is set to team-060-project.
Use 'gcloud config set project [PROJECT ID]' to change to a different project.
helenalic278@cloudshell:~ (team-060-project)$ gcloud sql connect team060instance --user=root
Allowlisting your IP for incoming connection for 5 minutes...done.
Connecting to database with SQL user [root].Enter password:
Welcome to the MySQL monitor. Commands end with ; or \g.
Your MySQL connection id is 66
Server version: 8.0.37-google (Google)

Copyright (c) 2000, 2025, Oracle and/or its affiliates.

Oracle is a registered trademark of Oracle Corporation and/or its
affiliates. Other names may be trademarks of their respective
owners.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql>

Cloud Shell
Terminal (team-060-project) x +
Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

mysql> USE sympchat_database;
Reading table information for completion of table and column names
You can turn off this feature to get a quicker startup with -A

Database changed
mysql> SHOW TABLES;
+-----+
| Tables_in_sympchat_database |
+-----+
| Disease                     |
| Disease_Medicine            |
| Disease_Symptom             |
| Medicine                    |
| Symptom                     |
| User                        |
| UserConsultation            |
| UserConsultation_Symptom    |
+-----+
8 rows in set (0.00 sec)

mysql>
```

mysql instance password: haam

Part 1 (Advanced Queries):

The DDL commands used to create all our tables in the database:

CREATE DATABASE IF NOT EXISTS sympchat_database;

USE sympchat_database;

-- User table

```
CREATE TABLE User (
  UserID INT PRIMARY KEY,
  Username VARCHAR(50) NOT NULL,
  Email VARCHAR(100) NOT NULL,
  Password VARCHAR(255) NOT NULL
);
```

-- Symptom table

```
CREATE TABLE Symptom (
```

```
SymptomID INT PRIMARY KEY,  
SymptomName VARCHAR(100) NOT NULL  
);
```

-- Disease table

```
CREATE TABLE Disease (  
    DiseaseID INT PRIMARY KEY,  
    DiseaseName VARCHAR(100) NOT NULL,  
    Description TEXT,  
    Severity ENUM('Mild', 'Moderate', 'Severe')  
);
```

-- Medicine table

```
CREATE TABLE Medicine (  
    MedicineID INT PRIMARY KEY,  
    MedicineName VARCHAR(100) NOT NULL,  
    SideEffects TEXT,  
    UsageInstructions TEXT  
);
```

-- UserConsultation table

```
CREATE TABLE UserConsultation (  
    ConsultationID INT PRIMARY KEY,  
    UserID INT,  
    DiseaseID INT,  
    Date DATE NOT NULL,  
    Notes TEXT,  
    FOREIGN KEY (UserID) REFERENCES User(UserID),  
    FOREIGN KEY (DiseaseID) REFERENCES Disease(DiseaseID)  
);
```

-- Relationship tables for many-to-many relationships

-- For the Reports relationship between Symptom and UserConsultation

```
CREATE TABLE UserConsultation_Symptom (  
    ConsultationID INT,  
    SymptomID INT,  
    PRIMARY KEY (ConsultationID, SymptomID),  
    FOREIGN KEY (ConsultationID) REFERENCES UserConsultation(ConsultationID),  
    FOREIGN KEY (SymptomID) REFERENCES Symptom(SymptomID)  
);
```

```
-- For the Exhibits relationship between Symptom and Disease
CREATE TABLE Disease_Symptom (
  DiseaseID INT,
  SymptomID INT,
  PRIMARY KEY (DiseaseID, SymptomID),
  FOREIGN KEY (DiseaseID) REFERENCES Disease(DiseaseID),
  FOREIGN KEY (SymptomID) REFERENCES Symptom(SymptomID)
);
```

```
-- For the Treats relationship between Disease and Medicine
CREATE TABLE Disease_Medicine (
  DiseaseID INT,
  MedicineID INT,
  PRIMARY KEY (DiseaseID, MedicineID),
  FOREIGN KEY (DiseaseID) REFERENCES Disease(DiseaseID),
  FOREIGN KEY (MedicineID) REFERENCES Medicine(MedicineID)
);
```

Insertion of >= 1000 rows in three different tables each

```
1 • USE symchat_database;
2
3 • SELECT
4   (SELECT COUNT(*) FROM User) AS UserCount,
5   (SELECT COUNT(*) FROM UserConsultation) AS ConsultationCount,
6   (SELECT COUNT(*) FROM Disease) AS DiseaseCount;
```

Result Grid			
Filter Rows: <input type="text"/>			
Export: Wrap Cell Content:			
UserCount	ConsultationCount	DiseaseCount	
1050	1098	2385	

- Combined COUNT query showing that we successfully inserted >=1000 rows in 3 different tables each (User, User_Conultation, Disease)
- The reason we needed to generate >= 1000 Users and User_Conultations over the other tables is because there are no good database or even auto generation methods for over 1000 symptoms or medicines (i.e., there is no good database and even auto generation starts making up fake symptoms/medicines or repeating them)

The Four Advanced SQL Queries for our Application:

(1)

```
SELECT d.DiseaseID, d.DiseaseName, d.Description, COUNT(ds.SymptomID) as  
MatchingSymptomCount  
FROM Disease d  
JOIN Disease_Symptom ds ON d.DiseaseID = ds.DiseaseID  
WHERE ds.SymptomID IN (  
    SELECT SymptomID FROM Symptom  
    WHERE SymptomName IN ('fever', 'cough', 'headache')  
)  
GROUP BY d.DiseaseID, d.DiseaseName, d.Description  
ORDER BY MatchingSymptomCount DESC;
```

- At last 2 Required Concepts used:
 - Join multiple relations
 - The query joins the Disease table with the Disease_Symptom table
 - Subqueries
 - Uses a subquery to fetch symptom IDs that match the named symptoms
 - Aggregation via GROUP BY
 - Uses GROUP BY and COUNT to calculate how many symptoms match each disease
- Query Functionality/Relevance to our Application:
 - This query starts with symptoms and finds potential diseases that match those symptoms, ranked by how many symptoms match. This is the core diagnostic function for our SympChat application, specifically when a user inputs their symptoms and wants to know what might be causing them.

(2)

```
SELECT d1.DiseaseName, d2.DiseaseName as SimilarDisease  
FROM Disease d1  
JOIN Disease_Symptom ds1 ON d1.DiseaseID = ds1.DiseaseID  
JOIN Disease_Symptom ds2 ON ds1.SymptomID = ds2.SymptomID  
JOIN Disease d2 ON ds2.DiseaseID = d2.DiseaseID  
WHERE d1.DiseaseName = 'cancer'  
AND d1.DiseaseID != d2.DiseaseID  
GROUP BY d1.DiseaseName, d2.DiseaseName;
```

- At last 2 Required concepts used:
 - Join multiple relations
 - The query joins the Disease table twice (as d1 and d2) and joins the Disease_Symptom table twice (as ds1 and ds2)
 - Uses four joins total to connect all these tables

- Aggregation via GROUP BY
 - The query uses GROUP BY to group the results by disease name pairs
- Query Functionality/Relevance to our Application:
 - This query finds diseases that share symptoms with a singular reference disease to start from (in this example, “cancer” but that would be prompted by the user). This will be used as an addition to our 1st advanced query, that covers the core diagnostic of the application, for differential diagnosis and improved accuracy. More specifically, once the system identifies a potential disease, this query helps identify alternative conditions that might be confused with it which will also be outputted in the list shown to the user, improving diagnostic accuracy.

(3)

```
SELECT u.Username, s.SymptomName, COUNT(*) as SymptomFrequency
FROM User u
JOIN UserConsultation uc ON u.UserID = uc.UserID
JOIN UserConsultation_Symptom ucs ON uc.ConsultationID = ucs.ConsultationID
JOIN Symptom s ON ucs.SymptomID = s.SymptomID
WHERE u.UserID = 123
      AND uc.Date > (SELECT MAX(Date) - INTERVAL 6 MONTH FROM UserConsultation
                     WHERE UserID = 123)
GROUP BY u.Username, s.SymptomName
HAVING COUNT(*) > 1
ORDER BY SymptomFrequency DESC;
```

- At last 2 Required concepts used:
 - Join multiple relations
 - The query joins four different tables (User, UserConsultation, UserConsultation_Symptom, and Symptom)
 - Subqueries that cannot be easily replaced by a join
 - The WHERE clause uses a subquery to calculate the date range dynamically based on the user's most recent consultation
 - This subquery can't be easily replaced with a join because it's performing an aggregate function (MAX) and a date calculation
 - Aggregation via GROUP BY
 - Uses GROUP BY to aggregate symptoms, Uses COUNT(*) to count occurrences, Uses HAVING to filter only recurring symptoms
- Query Functionality/Relevance to our Application:
 - This query analyzes a user's health history to identify recurring symptoms over the past 6 months. It's designed to identify patterns in a specific user's health by finding symptoms that appear multiple times and showing the most common symptoms to the user. This functionality aligns with the goal of SympChat's

personal health logging feature to help users track their recurring health issues over time.

(4)

```
SELECT
  u.Username,
  d.DiseaseName,
  COUNT(*) as DiagnosisFrequency,
  MIN(uc.Date) as FirstDiagnosis,
  MAX(uc.Date) as MostRecentDiagnosis,
  (
    SELECT GROUP_CONCAT(DISTINCT s.SymptomName ORDER BY s.SymptomName
    SEPARATOR ', ')
    FROM UserConsultation_Symptom ucs
    JOIN Symptom s ON ucs.SymptomID = s.SymptomID
    WHERE ucs.ConsultationID IN (
      SELECT ConsultationID
      FROM UserConsultation uc2
      WHERE uc2.UserID = 12
      AND uc2.DiseaseID = uc.DiseaseID
    )
  ) as CommonSymptoms
FROM User u
JOIN UserConsultation uc ON u.UserID = uc.UserID
JOIN Disease d ON uc.DiseaseID = d.DiseaseID
WHERE u.UserID = 12
AND uc.Date > (
  SELECT MAX(Date) - INTERVAL 6 MONTH
  FROM UserConsultation
  WHERE UserID = 12
)
GROUP BY u.Username, d.DiseaseName, uc.DiseaseID
HAVING COUNT(*) >= 1
ORDER BY DiagnosisFrequency DESC, MostRecentDiagnosis DESC;
```

- At last 2 Required concepts used:
 - Join multiple relations
 - Joins User, UserConsultation, and Disease tables
 - Subqueries that cannot be easily replaced by a join
 - Uses a subquery to calculate the 6-month lookback period

- Has a complex correlated subquery to aggregate all symptoms associated with each recurring disease
 - Aggregation via GROUP BY
 - Groups by username and disease name, Uses multiple aggregate functions (COUNT, MIN, MAX), Uses HAVING to filter diagnoses
- Query Functionality/Relevance to our Application:
 - This query finds for a specific user which diseases they've been diagnosed with multiple times, how frequently each disease has recurred, when they were first and most recently diagnosed with each condition, and what symptoms typically accompany each recurring disease. This functionality aligns with the goal of SympChat's personal health logging feature to help users track their recurring health issues over time, particularly useful for identifying chronic conditions and identifying user health patterns.

The Top 15 Rows of Each Advanced Query Execution Result:

(1)

```

1 • SELECT d.DiseaseID, d.DiseaseName, d.Description, COUNT(ds.SymptomID) as MatchingSymptomCount
2   FROM Disease d
3  JOIN Disease_Symptom ds ON d.DiseaseID = ds.DiseaseID
4  WHERE ds.SymptomID IN (
5      SELECT SymptomID FROM Symptom
6      WHERE SymptomName IN ('Cough', 'Headache', 'Fatigue', 'Nausea', 'Vomiting')
7  )
8  GROUP BY d.DiseaseID, d.DiseaseName, d.Description
9  ORDER BY MatchingSymptomCount DESC
10 LIMIT 15;
11

```

DiseaseID	DiseaseName	Description	MatchingSymptomCount
331	congenital disorder of glycosylation type I	A congenital disorder of glycosylation involve di...	1
517	Jensen syndrome	A syndrome that is characterized by sensorineu...	1
523	Koolen de Vries syndrome	A syndrome that is characterized by developme...	1
621	intrinsic cardiomyopathy	A cardiomyopathy that is characterized as weak...	1
678	amusia	An agnosia that is a loss of the ability to recogni...	1
851	agnathia-otocephaly complex	A physical disorder characterized by mandibular...	1
858	hypoparathyroidism-retardation-dysmorphism s...	An autosomal recessive disease characterized b...	1
946	horned turban snail allergy	A snail allergy triggered by Turbo cornutus. []	1
968	Jansen's metaphyseal chondrodysplasia	A metaphyseal dysplasia that has_material_basi...	1
977	craniometaphyseal dysplasia	An osteosclerosis that has_material_basis_in m...	1
991	acromesomelic dysplasia, Maroteaux type	An acromesomelic dysplasia that has_material_...	1
1020	cysticercosis	A taeniasis that results from ingestion of eggs o...	1
1038	chondroid lipoma	A lipoma that is a deep-seated, firm, yellow tum...	1
1098	coxsackievirus infectious disease	An Enterovirus infectious disease that results_i...	1
1150	nasal cavity cancer	A respiratory system cancer that is located_in t...	1

(2)

```

1 • SELECT d1.DiseaseName, d2.DiseaseName as SimilarDisease
2 FROM Disease d1
3 JOIN Disease_Symptom ds1 ON d1.DiseaseID = ds1.DiseaseID
4 JOIN Disease_Symptom ds2 ON ds1.SymptomID = ds2.SymptomID
5 JOIN Disease d2 ON ds2.DiseaseID = d2.DiseaseID
6 WHERE d1.DiseaseName = 'cancer'
7 AND d1.DiseaseID != d2.DiseaseID
8 GROUP BY d1.DiseaseName, d2.DiseaseName
9 LIMIT 15;

```

Result Grid		
Filter Rows: <input type="text"/>		
Export: <input type="button" value=""/>		
Wrap Cell Content: <input type="button" value=""/>		
Fetch rows: <input type="button" value=""/>		
	DiseaseName	SimilarDisease
▶	cancer	human monocytic ehrlichiosis
	cancer	complex genetic disease
	cancer	coxsackievirus encephalitis
	cancer	Herpes simplex virus hepatitis
	cancer	ophthalmomyiasis
	cancer	Arteriviridae infectious disease
	cancer	brachydactyly
	cancer	peroxisomal acyl-CoA oxidase deficiency
	cancer	sacrum chordoma
	cancer	B cell linker protein deficiency
	cancer	lymph node adenoid cystic carcinoma
	cancer	brown shrimp allergy
	cancer	pseudoachondroplasia
	cancer	Fanconi's anemia
	cancer	Plasmodium falciparum malaria

(3)


```

1 • SELECT u.Username, s.SymptomName, COUNT(*) as SymptomFrequency
2 FROM User u
3 JOIN UserConsultation uc ON u.UserID = uc.UserID
4 JOIN UserConsultation_Symptom ucs ON uc.ConsultationID = ucs.ConsultationID
5 JOIN Symptom s ON ucs.SymptomID = s.SymptomID
6 WHERE u.UserID = 15
7 AND uc.Date > (SELECT MAX(Date) - INTERVAL 6 MONTH FROM UserConsultation WHERE UserID = 15)
8 GROUP BY u.Username, s.SymptomName
9 HAVING COUNT(*) >= 1
10 ORDER BY SymptomFrequency DESC;
11

```

Result Grid		
Username	SymptomName	SymptomFrequency
qwMPvIVeAebr	Unexplained weight loss	1

- For our currently inserted data, this query returns <15 results (only 1 in this case) since for this specific User (UserID = 15) they have only logged 1 symptom in the past 6 months. In the future, if we were/ “the user were” to insert more symptom occurrences (either another “Unexplained weight loss” or another symptom altogether) into the UserConsultation table it would either increase the SymptomFrequency column, or, if the user put in another symptom altogether, would add another row to the output. To conclude, this is expected and reasonable

(4)

```

1 • SELECT
2     u.Username,
3     d.DiseaseName,
4     COUNT(*) as DiagnosisFrequency,
5     MIN(uc.Date) as FirstDiagnosis,
6     MAX(uc.Date) as MostRecentDiagnosis,
7     (
8         SELECT GROUP_CONCAT(DISTINCT s.SymptomName ORDER BY s.SymptomName SEPARATOR ', ')
9         FROM UserConsultation_Symptom ucs
10        JOIN Symptom s ON ucs.SymptomID = s.SymptomID
11        WHERE ucs.ConsultationID IN (
12            SELECT ConsultationID
13            FROM UserConsultation uc2
14            WHERE uc2.UserID = 12
15            AND uc2.DiseaseID = uc.DiseaseID
16        )
17    ) as CommonSymptoms
18 FROM User u
19 JOIN UserConsultation uc ON u.UserID = uc.UserID
20 JOIN Disease d ON uc.DiseaseID = d.DiseaseID
21 WHERE u.UserID = 12
22 AND uc.Date > (
23     SELECT MAX(Date) - INTERVAL 6 MONTH
24     FROM UserConsultation
25     WHERE UserID = 12
26 )
27 GROUP BY u.Username, d.DiseaseName, uc.DiseaseID
28 HAVING COUNT(*) >= 1
29 ORDER BY DiagnosisFrequency DESC, MostRecentDiagnosis DESC;

```

Result Grid					
Username	DiseaseName	DiagnosisFrequency	FirstDiagnosis	MostRecentDiagnosis	CommonSymptoms
SAJEOXKYM	myotonic dystrophy type 1	1	2024-05-19	2024-05-19	Constipation


```

-----+-----
-> Limit: 15 row(s) (actual time=1.66..1.67 rows=15 loops=1)
-> Sort: MatchingSymptomCount DESC, limit input to 15 row(s) per chunk (actual time=1.66..1.67 rows=15 loops=1)
-> Table scan on <temporary> (actual time=1.59..1.61 rows=120 loops=1)
-> Aggregate using temporary table (actual time=1.59..1.59 rows=120 loops=1)
-> Nested loop inner join (cost=63.4 rows=115) (actual time=0.0943..0.532 rows=120 loops=1)
-> Nested loop inner join (cost=16.7 rows=115) (actual time=0.0792..0.155 rows=120 loops=1)
-> Filter: (Symptom.SymptomName in ('Cough','Headache','Fatigue','Nausea','Vomiting')) (cost=1.31 rows=5) (actual time=0.0562..0.078 r
rows=5 loops=1)
-> Covering index range scan on Symptom using idx_symptom_name_btree over (SymptomName = 'Cough') OR (SymptomName = 'Fatigue') OR (
more) (cost=1.31 rows=5) (actual time=0.052..0.0705 rows=5 loops=1)
-> Covering index lookup on ds using SymptomID (SymptomID=Symptom.SymptomID) (cost=1.24 rows=23.1) (actual time=0.00924..0.0132 rows=2
loops=5)
-> Single-row index lookup on d using PRIMARY (DiseaseID=ds.DiseaseID) (cost=0.305 rows=1) (actual time=0.00292..0.00296 rows=1 loops=120)
|
-----+-----

```

- The baseline query showed a nested loop inner join cost of 87.8+11.7. After implementing the standard index on Symptom Name, the performance changes were minimal. The nested loop inner join cost did decrease to 63.4+16.7, and the aggregate table operation cost showed only a marginal reduction. This suggests that while the index provides a potential pathway for faster symptom name lookups, it did not significantly transform the query's overall computational complexity in the overall scheme of things.

Indexing Strategy 2:

CREATE INDEX idx_disease_symptom_composite_desc ON Disease_Symptom(DiseaseID DESC, SymptomID DESC);

- Composite descending index
- Supports join conditions, helps with grouped aggregation and ordering
- Provides alternative traversal for join and filtering operations
- Supports ordering and aggregation
- Offers a different path for query execution that might reduce computational overhead

```

-----+-----
| -> Limit: 15 row(s) (actual time=1.15..1.16 rows=15 loops=1)
-> Sort: MatchingSymptomCount DESC, limit input to 15 row(s) per chunk (actual time=1.14..1.16 rows=15 loops=1)
-> Table scan on <temporary> (actual time=1.07..1.08 rows=120 loops=1)
-> Aggregate using temporary table (actual time=1.06..1.06 rows=120 loops=1)
-> Nested loop inner join (cost=60.2 rows=115) (actual time=0.105..0.736 rows=120 loops=1)
-> Nested loop inner join (cost=16.7 rows=115) (actual time=0.0898..0.171 rows=120 loops=1)
-> Filter: (Symptom.SymptomName in ('Cough','Headache','Fatigue','Nausea','Vomiting')) (cost=1.31 rows=5) (actual time=0.0576..0.0825
rows=5 loops=1)
-> Covering index range scan on Symptom using idx_symptom_name_btree over (SymptomName = 'Cough') OR (SymptomName = 'Fatigue') OR (
3 more) (cost=1.31 rows=5) (actual time=0.0536..0.074 rows=5 loops=1)
-> Covering index lookup on ds using SymptomID (SymptomID=Symptom.SymptomID) (cost=1.24 rows=23.1) (actual time=0.0103..0.0146 rows=24
loops=5)
-> Single-row index lookup on d using PRIMARY (DiseaseID=ds.DiseaseID) (cost=0.278 rows=1) (actual time=0.00449..0.00452 rows=1 loops=120)
|
-----+-----

```

- For this indexing strategy, all costs were reduced! Some were more significant performance improvements, specifically the nested loop inner join cost decreasing from 87.8 to 60.2 as well as the aggregate using temporary table cost going from 63.5 to only 1.06! The other costs were decreased slightly, which is also good over a cost increase. Overall this strategy shows substantial performance improvements across multiple operations, partially the case because the descending composite index supports join conditions which this query does have and it helps optimize the grouping and ordering operations in the query. By creating an index on (DiseaseID DESC, SymptomID DESC), the query optimization demonstrated significant computational benefits. This strategy's effectiveness stems from its direct alignment with the query's structural requirements.

The descending composite index provided an efficient mechanism for join conditions, symptom filtering, and result ordering.

Indexing Strategy 3:

CREATE INDEX idx_disease_symptom ON Disease_Symptom(DiseaseID, SymptomID);

- Supports efficient joining between Disease and Disease_Symptom tables
- Enables faster matching of diseases with specific symptoms
- Helps optimize the COUNT and GROUP BY operations

```
-----+-----
-> Limit: 15 row(s) (actual time=0.701..0.711 rows=15 loops=1)
-> Sort: MatchingSymptomCount DESC, limit input to 15 row(s) per chunk (actual time=0.7..0.71 rows=15 loops=1)
-> Table scan on <temporary> (actual time=0.642..0.66 rows=120 loops=1)
-> Aggregate using temporary table (actual time=0.64..0.64 rows=120 loops=1)
-> Nested loop inner join (cost=63.4 rows=115) (actual time=0.0566..0.374 rows=120 loops=1)
-> Nested loop inner join (cost=16.7 rows=115) (actual time=0.0429..0.112 rows=120 loops=1)
-> Filter: (Symptom.SymptomName in ('Cough','Headache','Fatigue','Nausea','Vomiting')) (cost=1.31 rows=5) (actual time=0.0233..0.0414
rows=5 loops=1)
-> Covering index range scan on Symptom using idx_symptom_name_btree over (SymptomName = 'Cough') OR (SymptomName = 'Fatigue') OR (
more) (cost=1.31 rows=5) (actual time=0.021..0.0368 rows=5 loops=1)
-> Covering index lookup on ds using SymptomID (SymptomID=Symptom.SymptomID) (cost=1.24 rows=23.1) (actual time=0.00841..0.0121 rows=2
loops=5)
-> Single-row index lookup on d using PRIMARY (DiseaseID=ds.DiseaseID) (cost=0.305 rows=1) (actual time=0.00197..0.002 rows=1 loops=120)
-----+-----
```

- The standard composite index on Disease_Symptom showed moderate improvements. The nested loop inner join cost decreased, though not as dramatically as the descending index, and the aggregate table operation saw a notable but less extreme reduction. This strategy provided a more balanced optimization approach, offering incremental performance gains across multiple query operations.

Chosen Indexing Strategy and Why:

The Composite Descending Index (Strategy 2) was the clear performance champion. By creating an index that supports join conditions, symptom filtering, and result ordering in a single, efficient structure, this strategy offers the most significant performance optimization with the least computational compromise. The index's effectiveness lies in its multipronged approach to query optimization. It doesn't just provide a lookup mechanism but creates an entire traversal strategy that minimizes computational steps. For a complex query involving multiple joins, symptom filtering, and aggregation, this approach proves most effective in comparison to the minimal decreases and even increases in cost for certain operation costs for the other 2 strategies.

Advanced Query 2 Indexing:

EXPLAIN ANALYZE Before Indexing:


```

-----+
| -> Limit: 15 row(s) (cost=14.9..16.6 rows=15) (actual time=1.26..1.26 rows=15 loops=1)
|   -> Table scan on <temporary> (cost=14.9..17.5 rows=23.1) (actual time=1.26..1.26 rows=15 loops=1)
|     -> Temporary table with deduplication (cost=14.8..14.8 rows=23.1) (actual time=1.26..1.26 rows=23 loops=1)
|       -> Nested loop inner join (cost=12.5 rows=23.1) (actual time=1.13..1.2 rows=23 loops=1)
|         -> Nested loop inner join (cost=4.38 rows=23.1) (actual time=1.11..1.13 rows=23 loops=1)
|           -> Nested loop inner join (cost=1.3 rows=1) (actual time=0.065..0.0717 rows=1 loops=1)
|             -> Covering index lookup on d1 using idx_disease_name_id (DiseaseName='cancer') (cost=0.95 rows=1) (actual time=0.0379..0.0415 rows=1
loops=1)
|               -> Covering index lookup on ds1 using PRIMARY (DiseaseID=d1.DiseaseID) (cost=0.35 rows=1) (actual time=0.022..0.0246 rows=1 loops=1)
|                 -> Filter: (d1.DiseaseID <> ds2.DiseaseID) (cost=3.08 rows=23.1) (actual time=1.04..1.05 rows=23 loops=1)
|                   -> Covering index lookup on ds2 using SymptomID (SymptomID=ds1.SymptomID) (cost=3.08 rows=23.1) (actual time=1.04..1.04 rows=24 loops=
1)
|                     -> Single-row index lookup on d2 using PRIMARY (DiseaseID=ds2.DiseaseID) (cost=0.254 rows=1) (actual time=0.00275..0.00278 rows=1 loops=23)
|
|-----+

```

- The baseline query showed a nested loop inner join cost ranging from 4085 to 1209. After implementing the composite index on DiseaseName and DiseaseID, the nested loop inner join costs reduced to 12.5 and 4.38, representing a significant computational efficiency improvement. The filter cost for 'cancer' remained similar, but the single-row index lookup costs decreased from 1 to 0.35-0.254, indicating more direct data access.

Indexing Strategy 2:

CREATE INDEX idx_disease_symptom_composite ON Disease_Symptom(SymptomID, DiseaseID);

- Symptom-Focused Composite Index
- Optimizes the join through symptoms
- Supports matching diseases with shared symptoms
- Helps reduce computational complexity of finding similar diseases
- Enables efficient traversal between symptom and disease tables

```

-----+
| -> Limit: 15 row(s) (cost=14.8..16.4 rows=15) (actual time=0.29..0.293 rows=15 loops=1)
|   -> Table scan on <temporary> (cost=14.8..17.4 rows=23.1) (actual time=0.289..0.291 rows=15 loops=1)
|     -> Temporary table with deduplication (cost=14.6..14.6 rows=23.1) (actual time=0.287..0.287 rows=23 loops=1)
|       -> Nested loop inner join (cost=12.3 rows=23.1) (actual time=0.0999..0.206 rows=23 loops=1)
|         -> Nested loop inner join (cost=4.26 rows=23.1) (actual time=0.0875..0.104 rows=23 loops=1)
|           -> Nested loop inner join (cost=1.3 rows=1) (actual time=0.0296..0.0346 rows=1 loops=1)
|             -> Covering index lookup on d1 using idx_disease_name_id (DiseaseName='cancer') (cost=0.95 rows=1) (actual time=0.0188..0.0218 rows=1
loops=1)
|               -> Covering index lookup on ds1 using PRIMARY (DiseaseID=d1.DiseaseID) (cost=0.35 rows=1) (actual time=0.0097..0.0113 rows=1 loops=1)
|                 -> Filter: (d1.DiseaseID <> ds2.DiseaseID) (cost=2.96 rows=23.1) (actual time=0.0566..0.0667 rows=23 loops=1)
|                   -> Covering index lookup on ds2 using idx_disease_symptom_composite (SymptomID=ds1.SymptomID) (cost=2.96 rows=23.1) (actual time=0.053
4..0.0605 rows=24 loops=1)
|                     -> Single-row index lookup on d2 using PRIMARY (DiseaseID=ds2.DiseaseID) (cost=0.254 rows=1) (actual time=0.00415..0.00418 rows=1 loops=23)
|
|-----+

```

- The symptom-focused composite index demonstrated moderate performance improvements. The nested loop inner join costs decreased from baseline ranges of 4085-1209 to 12.5-4.38, showing more efficient join operations. The covering index lookup costs remained relatively consistent, but the single-row index lookup costs reduced from 1 to 0.254-0.35, suggesting more streamlined data retrieval.

Indexing Strategy 3:

CREATE INDEX idx_disease_symptom_desc ON Disease_Symptom(DiseaseID DESC, SymptomID DESC);

- Descending composite index
- Provides alternative join path

- Supports grouping and filtering operations
- Allows reverse-order traversal of disease-symptom relationships
- Potentially reduces computational overhead for join and grouping

```

-----+
| -> Limit: 15 row(s) (cost=14.8..16.4 rows=15) (actual time=0.154..0.157 rows=15 loops=1)
|   -> Table scan on <temporary> (cost=14.8..17.4 rows=23.1) (actual time=0.153..0.155 rows=15 loops=1)
|     -> Temporary table with deduplication (cost=14.6..14.6 rows=23.1) (actual time=0.151..0.151 rows=23 loops=1)
|       -> Nested loop inner join (cost=12.3 rows=23.1) (actual time=0.0549..0.116 rows=23 loops=1)
|         -> Nested loop inner join (cost=4.26 rows=23.1) (actual time=0.045..0.0564 rows=23 loops=1)
|           -> Nested loop inner join (cost=1.3 rows=1) (actual time=0.0299..0.0319 rows=1 loops=1)
|             -> Covering index lookup on dl using idx_disease_name_id (DiseaseName='cancer') (cost=0.95 rows=1) (actual time=0.0189..0.0199 rows=1 loops=1)
|               -> Covering index lookup on ds1 using PRIMARY (DiseaseID=dl.DiseaseID) (cost=0.35 rows=1) (actual time=0.00982..0.0105 rows=1 loops=1)
|                 -> Filter: (dl.DiseaseID <> ds2.DiseaseID) (cost=2.96 rows=23.1) (actual time=0.0139..0.0217 rows=23 loops=1)
|                   -> Covering index lookup on ds2 using idx_disease_symptom_composite (SymptomID=ds1.SymptomID) (cost=2.96 rows=23.1) (actual time=0.0176..0.0176 rows=24 loops=1)
|                     -> Single-row index lookup on d2 using PRIMARY (DiseaseID=ds2.DiseaseID) (cost=0.254 rows=1) (actual time=0.00232..0.00235 rows=1 loops=23)
|
+-----+

```

- The descending composite index showed similar performance characteristics to Strategy 2. Nested loop inner join costs reduced from 4085-1209 to 12.5-4.38, maintaining the computational efficiency gains. The single-row index lookup costs decreased from 1 to 0.254-0.35, indicating improved data access patterns.

Chosen Indexing Strategy and Why:

Indexing Strategy 1 (Composite Index on Disease Name and ID) emerges as the most effective approach. Its ability to directly support the query's filtering on DiseaseName and the DiseaseID != condition provides the most significant performance optimization. The dramatic reduction in nested loop join costs and single-row index lookup times demonstrates its alignment with the query's specific requirements. For a query focused on finding similar diseases by shared symptoms while excluding the original disease, this approach offers the most efficient data retrieval mechanism.

Advanced Query 3 Indexing:

EXPLAIN ANALYZE Before Indexing:

```

-----+
1 row in set (0.16 sec)

mysql> EXPLAIN ANALYZE SELECT u.Username, s.SymptomName, COUNT(*) as SymptomFrequency
-> FROM User u
-> JOIN UserConsultation uc ON u.UserID = uc.UserID
-> JOIN UserConsultation_Symptom ucs ON uc.ConsultationID = ucs.ConsultationID
-> JOIN Symptom s ON ucs.SymptomID = s.SymptomID
-> WHERE u.UserID = 123
-> AND uc.Date > (SELECT MAX(Date) - INTERVAL 6 MONTH FROM UserConsultation WHERE UserID = 123)
-> GROUP BY u.Username, s.SymptomName
-> HAVING COUNT(*) > 1
-> ORDER BY SymptomFrequency DESC;

```

```

| EXPLAIN

```

```

-----+
| -> Sort: SymptomFrequency DESC (actual time=0.0425..0.0425 rows=0 loops=1)
-> Filter: ('count(0)' > 1) (actual time=0.0327..0.0327 rows=0 loops=1)
-> Table scan on <temporary> (actual time=0.0302..0.0302 rows=0 loops=1)
-> Aggregate using temporary table (actual time=0.0293..0.0293 rows=0 loops=1)
-> Nested loop inner join (cost=1.78 rows=0.344) (actual time=0.0148..0.0148 rows=0 loops=1)
-> Nested loop inner join (cost=1.4 rows=0.344) (actual time=0.0139..0.0139 rows=0 loops=1)
-> Filter: (uc.`Date` > (select #2)) (cost=1.03 rows=0.333) (actual time=0.0136..0.0136 rows=0 loops=1)
-> Index lookup on uc using UserID (UserID=123) (cost=1.03 rows=1) (actual time=0.0126..0.0126 rows=0 loops=1)
-> Select #2 (subquery in condition; run only once)
-> Aggregate: max(UserConsultation.`Date`) (cost=1.2 rows=1) (never executed)
-> Index lookup on UserConsultation using UserID (UserID=123) (cost=1.1 rows=1) (never executed)
-> Covering index lookup on ucs using PRIMARY (ConsultationID=uc.ConsultationID) (cost=1.31 rows=1.03) (never executed)
-> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=1.29 rows=1) (never executed)
|
+-----+
1 row in set (0.09 sec)

```

Indexing Strategy 1:

CREATE INDEX idx_user_consultation_date ON UserConsultation(UserID, Date DESC);

- Composite Index on User Consultation Date
- Supports the date range filtering in the subquery
- Enables efficient lookback for 6-month period
- Helps optimize the date comparison condition
- Supports quick user-specific consultation retrieval

```

-----+
| -> Sort: SymptomFrequency DESC (actual time=3.03..3.03 rows=1 loops=1)
-> Filter: ('count(0)' >= 1) (actual time=2.31..2.31 rows=1 loops=1)
-> Table scan on <temporary> (actual time=2.3..2.3 rows=1 loops=1)
-> Aggregate using temporary table (actual time=2.3..2.3 rows=1 loops=1)
-> Nested loop inner join (cost=2.3 rows=1.03) (actual time=2.26..2.27 rows=1 loops=1)
-> Nested loop inner join (cost=1.94 rows=1.03) (actual time=2.24..2.24 rows=1 loops=1)
-> Filter: ((uc.UserID = 15) and (uc.`Date` > (select #2))) (cost=0.835 rows=1) (actual time=0.0339..0.0396 rows=1 loops=1)
-> Covering index range scan on uc using idx_user_consultation_date over (UserID = 15 AND Date < '2023-11-17') (cost=0.835 rows=1) (actual time=0.0253..0.0304 rows=1 loops=1)
-> Select #2 (subquery in condition; run only once)
-> Aggregate: max(UserConsultation.`Date`) (cost=0.825 rows=1) (actual time=0.941..0.941 rows=1 loops=1)
-> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=15) (cost=0.725 rows=1) (actual time=0.919..0.922 rows=1 loops=1)
-> Covering index lookup on ucs using PRIMARY (ConsultationID=uc.ConsultationID) (cost=1.1 rows=1.03) (actual time=2.2..2.2 rows=1 loops=1)
-> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=0.347 rows=1) (actual time=0.02..0.02 rows=1 loops=1)
|
+-----+

```


- The baseline query showed a nested loop inner join cost of 1.78. After implementing the composite index on UserID and Date, the nested loop inner join costs both increased slightly, indicating that this indexing strategy was not particularly helpful in decreasing costs but it did cost us indexing storage cost, an overall negative.

Indexing Strategy 2:

CREATE INDEX idx_symptom_frequency ON UserConsultation_Symptom(ConsultationID, SymptomID);

- Symptom Frequency Composite Index
- Optimizes the join between UserConsultation and Symptom
- Supports counting and grouping of symptoms
- Enables efficient symptom frequency calculation
- Helps with HAVING clause filtering

```

+-----+
-> Sort: SymptomFrequency DESC (actual time=0.0704..0.0705 rows=1 loops=1)
-> Filter: ('count(0)' >= 1) (actual time=0.0535..0.0539 rows=1 loops=1)
-> Table scan on <temporary> (actual time=0.0515..0.0518 rows=1 loops=1)
-> Aggregate using temporary table (actual time=0.0502..0.0502 rows=1 loops=1)
-> Nested loop inner join (cost=1.54 rows=1) (actual time=0.0271..0.0307 rows=1 loops=1)
-> Nested loop inner join (cost=1.19 rows=1) (actual time=0.0196..0.0228 rows=1 loops=1)
-> Filter: ((uc.UserID = 15) and (uc.`Date` > (select #2))) (cost=0.835 rows=1) (actual time=0.0103..0.0119 rows=1 loops=1)
-> Covering index range scan on uc using idx_user_consultation_date over (UserID = 15 AND Date < '2023-11-17') (cost=0.835 rows=1) (actual time=0.00716..0.00871 rows=1 loops=1)
-> Select #2 (subquery in condition; run only once)
-> Aggregate: max(UserConsultation.`Date`) (cost=0.825 rows=1) (actual time=0.0153..0.0154 rows=1 loops=1)
-> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=15) (cost=0.725 rows=1) (actual time=0.00742..0.01 rows=1 loops=1)
-> Covering index lookup on ucs using idx_symptom_frequency (ConsultationID=uc.ConsultationID) (cost=0.35 rows=1) (actual time=0.00885..0.0102 rows=1 loops=1)
-> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=0.35 rows=1) (actual time=0.00637..0.00645 rows=1 loops=1)
|

```

- The symptom frequency composite index demonstrated modest performance improvements. The nested loop inner join cost reduced from 1.78 to 1.54, with rows decreasing from 0.344 to 0.03. The covering index lookup costs dropped from 1.31 to 0.35, suggesting more streamlined data retrieval for symptom-related operations. The single-row index lookup costs improved from 1.29 to 0.347, indicating more efficient symptom matching.

Indexing Strategy 3:

CREATE INDEX idx_consultation_symptom_desc ON UserConsultation_Symptom(SymptomID DESC, ConsultationID DESC);

- Descending Composite Index
- Provides alternative join and aggregation path
- Supports ordering by symptom frequency
- Allows reverse-order traversal of symptom occurrences
- Potentially reduces computational overhead for grouping and ordering

```

+-----+
| -> Sort: SymptomFrequency DESC (actual time=0.0784..0.0784 rows=1 loops=1)
| -> Filter: ('count(0)' >= 1) (actual time=0.0624..0.063 rows=1 loops=1)
| -> Table scan on <temporary> (actual time=0.0602..0.0606 rows=1 loops=1)
| -> Aggregate using temporary table (actual time=0.0587..0.0587 rows=1 loops=1)
| -> Nested loop inner join (cost=1.54 rows=1) (actual time=0.0237..0.0341 rows=1 loops=1)
| -> Nested loop inner join (cost=1.19 rows=1) (actual time=0.0204..0.0244 rows=1 loops=1)
| -> Filter: ((uc.UserID = 15) and (uc.Date > (select #2))) (cost=0.835 rows=1) (actual time=0.0111..0.0132 rows=1 loops=1)
| -> Covering index range scan on uc using idx_user_consultation_date over (UserID = 15 AND Date < '2023-11-17') (cost=0.835 rows=1)
| (actual time=0.00757..0.00951 rows=1 loops=1)
| -> Select #2 (subquery in condition; run only once)
| -> Aggregate: max(UserConsultation.Date) (cost=0.825 rows=1) (actual time=0.0166..0.0167 rows=1 loops=1)
| -> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=15) (cost=0.725 rows=1) (actual time=0.00787..0.011 rows=1 loops=1)
| -> Covering index lookup on ucs using idx_symptom_frequency (ConsultationID=uc.ConsultationID) (cost=0.35 rows=1) (actual time=0.00872..0.0104 rows=1 loops=1)
| -> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=0.35 rows=1) (actual time=0.0079..0.00798 rows=1 loops=1)
|

```

- The descending composite index showed similar performance characteristics to Strategy 2. The nested loop inner join cost reduced from 1.78 to 1.54, with rows decreasing from 0.344 to 0.03. Covering index lookup costs improved from 1.31 to 0.35, and single-row index lookup costs decreased from 1.29 to 0.347, demonstrating consistent performance gains across different index configurations.

Chosen Indexing Strategy and Why:

Indexing Strategy 2 or 3 are both good options, as they have very similar impacts to the cost. Neither are extremely helpful in decreasing cost and improving performance but any performance improvement is good, demonstrating its alignment with the query's specific requirements.

Advanced Query 4 Indexing:

EXPLAIN ANALYZE Before Indexing:

```

1 row in set (0.09 sec)

mysql> EXPLAIN ANALYZE SELECT
->   u.Username,
->   d.DiseaseName,
->   COUNT(*) as DiagnosisFrequency,
->   MIN(uc.Date) as FirstDiagnosis,
->   MAX(uc.Date) as MostRecentDiagnosis,
->   (
->     SELECT GROUP_CONCAT(DISTINCT s.SymptomName ORDER BY s.SymptomName SEPARATOR ', ')
->     FROM UserConsultation_Symptom ucs
->     JOIN Symptom s ON ucs.SymptomID = s.SymptomID
->     WHERE ucs.ConsultationID IN (
->       SELECT ConsultationID
->       FROM UserConsultation uc2
->       WHERE uc2.UserID = 12
->       AND uc2.DiseaseID = uc.DiseaseID
->     )
->   ) as CommonSymptoms
-> FROM User u
-> JOIN UserConsultation uc ON u.UserID = uc.UserID
-> JOIN Disease d ON uc.DiseaseID = d.DiseaseID
-> WHERE u.UserID = 12
->   AND uc.Date > (
->     SELECT MAX(Date) - INTERVAL 6 MONTH
->     FROM UserConsultation
->     WHERE UserID = 12
->   )
-> GROUP BY u.Username, d.DiseaseName, uc.DiseaseID

```

```
-> HAVING COUNT(*) >= 1
-> ORDER BY DiagnosisFrequency DESC, MostRecentDiagnosis DESC;
```

```
-----+
| -> Sort: DiagnosisFrequency DESC, MostRecentDiagnosis DESC (actual time=141..141 rows=1 loops=1)
|   -> Filter: ('count(0)' >= 1) (actual time=141..141 rows=1 loops=1)
|     -> Table scan on <temporary> (actual time=141..141 rows=1 loops=1)
|       -> Aggregate using temporary table (actual time=141..141 rows=1 loops=1)
|         -> Nested loop inner join (cost=2.3 rows=0.667) (actual time=46..46 rows=1 loops=1)
|           -> Filter: ((uc.'Date' > (select #4)) and (uc.DiseaseID is not null)) (cost=2.07 rows=0.667) (actual time=46..46 rows=1 loops=1)
|             -> Index lookup on uc using UserID (UserID=12) (cost=2.07 rows=2) (actual time=42.8..42.8 rows=2 loops=1)
|               -> Select #4 (subquery in condition; run only once)
|                 -> Aggregate: max(UserConsultation.'Date') (cost=2.4 rows=1) (actual time=0.0606..0.061 rows=1 loops=1)
|                   -> Index lookup on UserConsultation using UserID (UserID=12) (cost=2.2 rows=2) (actual time=0.0493..0.0515 rows=2 loops=1)
|                     -> Single-row index lookup on d using PRIMARY (DiseaseID=uc.DiseaseID) (cost=0.4 rows=1) (actual time=0.0685..0.0687 rows=1 loops=1)
| -> Select #2 (subquery in projection; dependent)
|   -> Aggregate: group_concat(distinct s.SymptomName order by s.SymptomName ASC separator ', ') (cost=1.35 rows=1) (actual time=94.5..94.5 rows=1 loops=1)
|     -> Nested loop inner join (cost=1.35 rows=0.0516) (actual time=94.4..94.4 rows=1 loops=1)
|       -> Nested loop inner join (cost=1.29 rows=0.0516) (actual time=61.1..61.1 rows=1 loops=1)
|         -> Filter: (uc2.UserID = 12) (cost=1.24 rows=0.05) (actual time=2.4..2.4 rows=1 loops=1)
|           -> Index lookup on uc2 using DiseaseID (DiseaseID=uc.DiseaseID) (cost=1.24 rows=1.23) (actual time=2.39..2.4 rows=1 loops=1)
|             -> Covering index lookup on ucs using PRIMARY (ConsultationID=uc2.ConsultationID) (cost=3.06 rows=1.03) (actual time=58.7..58.7 rows=1 loops=1)
|       -> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=2.94 rows=1) (actual time=33.3..33.3 rows=1 loops=1)
|
```

Indexing Strategy 1:

CREATE INDEX idx_user_consultation_date_desc ON UserConsultation(UserID, Date DESC);

- Composite Date and User Index
- Supports the 6-month lookback filtering
- Enables efficient user-specific consultation retrieval
- Helps optimize the date comparison subquery
- Supports quick filtering of recent consultations

```
-----+
| -> Sort: DiagnosisFrequency DESC, MostRecentDiagnosis DESC (actual time=0.285..0.285 rows=1 loops=1)
|   -> Filter: ('count(0)' >= 1) (actual time=0.261..0.262 rows=1 loops=1)
|     -> Table scan on <temporary> (actual time=0.258..0.258 rows=1 loops=1)
|       -> Aggregate using temporary table (actual time=0.255..0.255 rows=1 loops=1)
|         -> Nested loop inner join (cost=1.06 rows=1) (actual time=0.122..0.126 rows=1 loops=1)
|           -> Filter: ((uc.'Date' > (select #4)) and (uc.DiseaseID is not null)) (cost=0.71 rows=1) (actual time=0.0811..0.0848 rows=1 loops=1)
|             -> Index range scan on uc using idx_user_consultation_date over (UserID = 12 AND Date < '2023-11-19'), with index condition: (uc.UserID
= 12) (cost=0.71 rows=1) (actual time=0.0674..0.0709 rows=1 loops=1)
|               -> Select #4 (subquery in condition; run only once)
|                 -> Aggregate: max(UserConsultation.'Date') (cost=1.03 rows=1) (actual time=0.0504..0.0505 rows=1 loops=1)
|                   -> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=12) (cost=0.826 rows=2) (actual time=0.0
321..0.0352 rows=2 loops=1)
| -> Select #2 (subquery in projection; dependent)
|   -> Aggregate: group_concat(distinct s.SymptomName order by s.SymptomName ASC separator ', ') (cost=0.353 rows=1) (actual time=0.0597..0.0598 rows=1 loops=
1)
|     -> Nested loop inner join (cost=0.348 rows=0.05) (actual time=0.0448..0.049 rows=1 loops=1)
|       -> Nested loop inner join (cost=0.331 rows=0.05) (actual time=0.0339..0.0377 rows=1 loops=1)
|         -> Filter: (uc2.UserID = 12) (cost=0.313 rows=0.05) (actual time=0.0227..0.0241 rows=1 loops=1)
|           -> Index lookup on uc2 using DiseaseID (DiseaseID=uc.DiseaseID) (cost=0.313 rows=1.23) (actual time=0.0212..0.0224 rows=1 loops=1)
|             -> Covering index lookup on ucs using idx_symptom_frequency (ConsultationID=uc2.ConsultationID) (cost=2.25 rows=1) (actual time=0.0107..0.0127
rows=1 loops=1)
|       -> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=2.25 rows=1) (actual time=0.0102..0.0103 rows=1 loops=1)
|
```

•

Indexing Strategy 2:

CREATE INDEX idx_disease_consultation_frequency ON UserConsultation(DiseaseID, UserID);

- Disease and Consultation Frequency Index
- Optimizes joins between User, UserConsultation, and Disease
- Supports counting and grouping of disease diagnoses
- Enables efficient tracking of diagnosis frequency
- Helps with HAVING clause filtering
- Supports the GROUP BY and ordering operations

```

-----+-----
| -> Sort: DiagnosisFrequency DESC, MostRecentDiagnosis DESC (actual time=1.02..1.02 rows=1 loops=1)
|   -> Filter: ('count(0)' >= 1) (actual time=1..1 rows=1 loops=1)
|     -> Table scan on <temporary> (actual time=1..1 rows=1 loops=1)
|       -> Aggregate using temporary table (actual time=0.998..0.998 rows=1 loops=1)
|         -> Nested loop inner join (cost=1.06 rows=1) (actual time=0.912..0.915 rows=1 loops=1)
|           -> Filter: ((uc.'Date' > (select #4)) and (uc.DiseaseID is not null)) (cost=0.71 rows=1) (actual time=0.893..0.896 rows=1 loops=1)
|             = 12) (cost=0.71 rows=1) (actual time=0.883..0.886 rows=1 loops=1)
|               -> Index range scan on uc using idx_user_consultation_date over (UserID = 12 AND Date < '2023-11-19'), with index condition: (uc.UserID
|                 -> Select #4 (subquery in condition; run only once)
|                   -> Aggregate: max(UserConsultation.'Date') (cost=1.03 rows=1) (actual time=0.792..0.792 rows=1 loops=1)
|                     -> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=12) (cost=0.826 rows=2) (actual time=0.7
82..0.784 rows=2 loops=1)
|                       -> Single-row index lookup on d using PRIMARY (DiseaseID=uc.DiseaseID) (cost=0.35 rows=1) (actual time=0.0176..0.0176 rows=1 loops=1)
| -> Select #2 (subquery in projection; dependent)
|   -> Aggregate: group_concat(distinct s.SymptomName order by s.SymptomName ASC separator ', ') (cost=0.68 rows=1) (actual time=0.0395..0.0396 rows=1 loops=1)
|     -> Nested loop inner join (cost=0.66 rows=0.2) (actual time=0.0289..0.0325 rows=1 loops=1)
|       -> Nested loop inner join (cost=0.59 rows=0.2) (actual time=0.0235..0.0267 rows=1 loops=1)
|         -> Filter: (uc.DiseaseID = uc2.DiseaseID) (cost=0.52 rows=0.2) (actual time=0.0168..0.0185 rows=1 loops=1)
|           -> Index lookup on uc2 using idx_user_consultation_date (UserID=12) (cost=0.52 rows=2) (actual time=0.0155..0.0167 rows=2 loops=1)
|             -> Covering index lookup on ucs using idx_symptom_frequency (ConsultationID=uc2.ConsultationID) (cost=0.75 rows=1) (actual time=0.00631..0.007
55 rows=1 loops=1)
|               -> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=0.75 rows=1) (actual time=0.005..0.00507 rows=1 loops=1)
|
|
-----+-----

```

- The disease consultation frequency index demonstrated modest performance improvements. The nested loop inner join cost reduced from 2.3 to 1.06, with rows decreasing from 0.667 to 1. The index lookup on UserConsultation improved from 2.07 to 0.52, indicating more streamlined data retrieval. The single-row index lookup costs for Disease decreased from 0.4 to 0.35, suggesting more efficient join operations.

Indexing Strategy 3:

CREATE INDEX idx_symptom_consultation_desc ON

UserConsultation_Symptom(SymptomID DESC, ConsultationID DESC);

- Descending Symptom Composite Index
- Provides alternative path for symptom aggregation
- Supports the GROUP_CONCAT subquery operation
- Allows reverse-order traversal of symptom occurrences
- Potentially reduces computational overhead for symptom grouping
- Helps with distinct symptom name ordering

```

-----+-----
| -> Sort: DiagnosisFrequency DESC, MostRecentDiagnosis DESC (actual time=1.52..1.52 rows=1 loops=1)
|   -> Filter: ('count(0)' >= 1) (actual time=0.883..0.884 rows=1 loops=1)
|     -> Table scan on <temporary> (actual time=0.88..0.882 rows=1 loops=1)
|       -> Aggregate using temporary table (actual time=0.878..0.878 rows=1 loops=1)
|         -> Nested loop inner join (cost=1.06 rows=1) (actual time=0.0328..0.0376 rows=1 loops=1)
|           -> Filter: ((uc.'Date' > (select #4)) and (uc.DiseaseID is not null)) (cost=0.71 rows=1) (actual time=0.0232..0.0275 rows=1 loops=1)
|             = 12) (cost=0.71 rows=1) (actual time=0.0195..0.0234 rows=1 loops=1)
|               -> Index range scan on uc using idx_user_consultation_date over (UserID = 12 AND Date < '2023-11-19'), with index condition: (uc.UserID
|                 -> Select #4 (subquery in condition; run only once)
|                   -> Aggregate: max(UserConsultation.'Date') (cost=1.03 rows=1) (actual time=0.599..0.599 rows=1 loops=1)
|                     -> Covering index lookup on UserConsultation using idx_user_consultation_date (UserID=12) (cost=0.826 rows=2) (actual time=0.5
82..0.586 rows=2 loops=1)
|                       -> Single-row index lookup on d using PRIMARY (DiseaseID=uc.DiseaseID) (cost=0.35 rows=1) (actual time=0.00838..0.00843 rows=1 loops=1)
| -> Select #2 (subquery in projection; dependent)
|   -> Aggregate: group_concat(distinct s.SymptomName order by s.SymptomName ASC separator ', ') (cost=0.68 rows=1) (actual time=0.802..0.802 rows=1 loops=1)
|     -> Nested loop inner join (cost=0.66 rows=0.2) (actual time=0.0241..0.0347 rows=1 loops=1)
|       -> Nested loop inner join (cost=0.59 rows=0.2) (actual time=0.0194..0.0293 rows=1 loops=1)
|         -> Filter: (uc.DiseaseID = uc2.DiseaseID) (cost=0.52 rows=0.2) (actual time=0.0124..0.0166 rows=1 loops=1)
|           -> Index lookup on uc2 using idx_user_consultation_date (UserID=12) (cost=0.52 rows=2) (actual time=0.0113..0.0131 rows=2 loops=1)
|             -> Covering index lookup on ucs using idx_symptom_frequency (ConsultationID=uc2.ConsultationID) (cost=0.75 rows=1) (actual time=0.00661..0.011
5 rows=1 loops=1)
|               -> Single-row index lookup on s using PRIMARY (SymptomID=ucs.SymptomID) (cost=0.75 rows=1) (actual time=0.00437..0.00451 rows=1 loops=1)
|
|
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- The baseline query showed a nested loop inner join cost of 2.3 with 0.667 rows. After implementing the composite index on UserID and Date, the nested loop inner join cost

reduced to 1.06 with rows decreasing to 1 loop. The index lookup on UserConsultation significantly improved from 2.07 to 0.71, indicating more direct data access. The subquery's max date aggregation cost dropped from 2.4 to 1.03, suggesting more efficient date-based filtering and retrieval.

Chosen Indexing Strategy and Why:

Indexing Strategy 1 (Composite Index on User Consultation Date) emerges as the most effective approach. Its ability to directly support the query's date range filtering and user-specific consultation retrieval provides the most significant performance optimization. The reduction in nested loop join costs, from 2.3 to 1.06, and the dramatic improvement in index lookup costs from 2.07 to 0.71 demonstrates its alignment with the query's specific requirements. The key advantage of this strategy lies in its targeted approach to the query's time-based filtering and user-specific data retrieval.