

# Running Achilles on Your CDM

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## 1 Introduction

In this vignette we cover how to run the Achilles package on your Common Data Model (CDM) database in order to characterize the dataset and run data quality (DQ) checks. The characterizations and DQ results can help you learn more about your dataset’s features and limitations, and can then be consumed graphically using AchillesWeb or Atlas Data Sources.

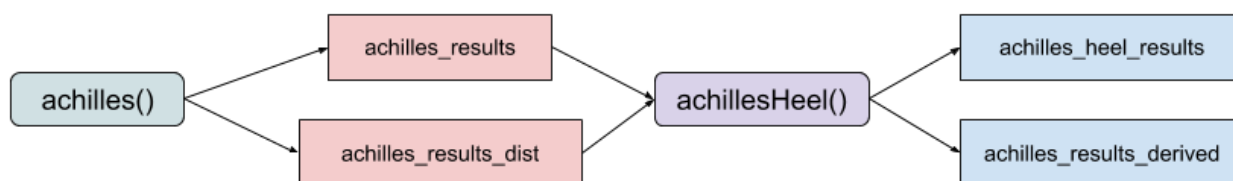
It is a best practice for all OHDSI sites to run Achilles on their CDM datasets to ensure researchers can evaluate study feasibility and contextualize study results.

## 2 General Approach

The Achilles package consists of:

1. The **achilles** function runs a set of SQL scripts to characterize the domains and concepts of the CDM.
2. The **achillesHeel** function uses the results of the **achilles** function to run a set of DQ scripts to evaluate the conformance and feasibility of your dataset.
3. The **createIndices** function creates table indices for the achilles tables, which can help improve query performance.
4. The **getAnalysisDetails** function provides descriptions about the full set of Achilles analyses.
5. The **dropAllScratchTables** function is useful only for multi-threaded mode. It can clear any leftover staging tables.
6. The **exportToJson** function can be used to export all Achilles results to JSON files, which is necessary for using AchillesWeb.
7. The **addDataSource** function can point a data source’s JSON files to the AchillesWeb application.

The Achilles package should be run sequentially. That is, **achilles** should be run first to generate the `achilles_results` and `achilles_results_dist` tables, and then optionally, **achillesHeel** should be run next to generate the `achilles_heel_results` and `achilles_results_derived` tables.



## 2.1 SQL Only Mode

In most Achilles functions, you can specify `sqlOnly = TRUE` in order to produce the SQL without executing it, which can be useful if you'd like to examine the SQL closely or debug something. The SQL files are stored in the `outputFolder`.

## 2.2 Logging

File and console logging is enabled across most Achilles functions. The status of each step is logged into files in the `outputFolder`. You can review the files in a common text editor, or use the Shiny Application from the `ParallelLogger` package to view them more interactively.

```
ParallelLogger::launchLogViewer(logFileName = "output/log_achilles.txt")
```

Log File Viewer - /home/ajit/git/alongdhe/Achilles/output/log\_achilles.txt

Level	Timestamp	Thread	Level	Package	Function	Message
INFO	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Beginning single-threaded execution
Thread	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Beginning single-threaded execution
All	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Beginning single-threaded execution
Package	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Beginning single-threaded execution
All	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Executing multiple queries. This could take a while
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Executing multiple queries. This could take a while
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Executing multiple queries. This could take a while
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Executing multiple queries. This could take a while
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Executing multiple queries. This could take a while
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Analysis 1823 (Number of measurement records, by measurement_concept_id and operator_concept_id) -- START
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Analysis 1823 (Number of measurement records, by measurement_concept_id and operator_concept_id) -- START
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Analysis 1823 (Number of measurement records, by measurement_concept_id and operator_concept_id) -- START
	2018-10-06 22:43:24	[Main thread]	INFO	Achilles	achilles	Analysis 1823 (Number of measurement records, by measurement_concept_id and operator_concept_id) -- START
	2018-10-06 22:43:26	[Main thread]	INFO	Achilles	achilles	Analysis 1823 -- COMPLETE (1.875295 secs)
	2018-10-06 22:43:26	[Main thread]	INFO	Achilles	achilles	Analysis 1823 -- COMPLETE (1.875295 secs)
	2018-10-06 22:43:26	[Main thread]	INFO	Achilles	achilles	Analysis 1823 -- COMPLETE (1.875295 secs)

## 2.3 Verbose Mode

The `verboseMode` parameter can be set to `FALSE` if you'd like less details about the function execution to appear in the console. Either way, all details are written to the log files. By default, this is set to `TRUE`.

## 2.4 Preparation for running Achilles

In order to run the package, you will need to determine if you'd like the Achilles tables and staging tables to be stored in schemas that are separate from your CDM's schema (recommended), or within the same schema as the CDM.

### 2.4.1 Multi-Threaded vs Single-Threaded

As the `achilles` and most of the `achillesHeel` functions can run independently, we have added a multi-threaded mode to allow for more than 1 SQL script to execute at a time. This is particularly useful for massively parallel processing (MPP) platforms such as Amazon Redshift and Microsoft PDW. It may not be beneficial for traditional SQL platforms, so only use the multi-threaded mode if confident it can be useful.

Further, while multiple threads can help performance in MPP platforms, there can be diminishing returns as the cluster has a finite number of concurrency slots to handle the queries. A rule of thumb: most likely you should not use more than 10.

In the multi-threaded mode, all scripts produce permanent staging tables, whereas in the single-threaded mode, the scripts produce temporary staging tables. In both, the staging tables are merged to produce the final Achilles tables.

## 3 Achilles Parameters (Both Modes)

The following sub-sections describe the optional parameters in **achilles** that can be configured, regardless of whether you run the function in single- or multi-threaded mode.

### 3.1 Staging Table Prefix

To keep the staging tables organized, the **achilles** function will use a table prefix of “tmpach” by default, but you can choose a different one using the **tempAchillesPrefix** parameter. This is useful for database platforms like Oracle, which limit the length of table names.

### 3.2 Source Name

The **sourceName** parameter is used to assign the name of the dataset to the Achilles results. It is used in the Dashboard page in AchillesWeb and Atlas Data Sources. If you set this to NULL, the **achilles** function will try to obtain the source name from the CDM\_SOURCE table.

### 3.3 Create Table

The **createTable** parameter, when set to TRUE, drops any existing Achilles results tables and builds new ones. If set to FALSE, these tables will persist, and the **achilles** function will just insert new data to them.

### 3.4 Limiting the Analyses

By default, the **achilles** function runs all analyses detailed in the **getAnalysisDetails** function. However, it may be useful to focus on a subset of analyses rather than running the whole set. This can be accomplished by specifying analysis Ids in the **analysisIds** parameter.

### 3.5 Cost Analyses

By default, the **achilles** function does not run analyses on the COST table(s), as they can be very time-consuming, and are not critical to most OHDSI studies. However, you can choose to run these analyses by setting **runCostAnalysis** to TRUE. The cost analyses are conditional on the CDM version. If using CDM v5.0, then the older cost tables are queried. If using any version after 5.0, the unified cost table is queried.

### 3.6 Small Cell Count

To avoid patient identification, you can establish the minimum cell size that should be kept in the Achilles tables. Cells with small counts (less than or equal to the value of the **smallCellCount** parameter) are deleted. By default, this is set to 5. Set to 0 for complete summary without small cell count restrictions.

### 3.7 Drop Scratch Tables

*See the Post-Processing section to read about how to run this step separately*

*This parameter is only necessary if running in multi-threaded mode*

The `dropScratchTables` parameter, if set to `TRUE`, will drop all staging tables created during the execution of **achilles** in multi-threaded mode.

### 3.8 Create Indices

*See the Post-Processing section to read about how to run this step separately*

The `createIndices` parameter, if set to `TRUE`, will result in indices on the Achilles results tables to be created in order to improve query performance.

### 3.9 Return Value

When running **achilles**, the return value, if you assign a variable to the function call, is a list object in which metadata about the execution and all of the SQL scripts executed are attributes. You can also run the function call without assigning a variable to it, so that no values are printed or returned.

## 4 Running Achilles: Single-Threaded Mode

In single-threaded mode, there is no need to set a `scratchDatabaseSchema`, as temporary tables will be used. Here we will focus only on achilles execution and skip running Heel.

```
connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

achilles(connectionDetails = connectionDetails,
          cdmDatabaseSchema = "cdm",
          resultsDatabaseSchema = "results",
          vocabDatabaseSchema = "vocab",
          sourceName = "Synpuf",
          cdmVersion = 5.3,
          numThreads = 1,
          runHeel = FALSE)
```

## 5 Running Achilles: Multi-Threaded Mode

In multi-threaded mode, you need to specify `scratchDatabaseSchema` and use `> 1` for `numThreads`. Here we will focus only on achilles execution and skip running Heel.

```
connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")
```

```

achilles(connectionDetails = connectionDetails,
          cdmDatabaseSchema = "cdm",
          resultsDatabaseSchema = "results",
          scratchDatabaseSchema = "scratch",
          vocabDatabaseSchema = "vocab",
          sourceName = "Synpuf",
          cdmVersion = 5.3,
          numThreads = 5,
          runHeel = FALSE)

```

## 6 Achilles Heel Parameters (Both Modes)

### 6.1 Staging Table Prefix

To keep the staging tables organized, the **achillesHeel** function will use a table prefix of “tmpheel” by default, but you can choose a different one using the **tempHeelPrefix** parameter. This is useful for database platforms like Oracle, which limit the length of table names.

### 6.2 Drop Scratch Tables

*See the Post-Processing section to read about how to run this step separately*

*This parameter is only necessary if running in multi-threaded mode*

The **dropScratchTables** parameter, if set to TRUE will drop all staging tables created during the execution of **achillesHeel** in multi-threaded mode.

### 6.3 Thresholds

The **ThresholdAgeWarning**, **ThresholdOutpatientVisitPerc**, and **ThresholdMinimalPtMeasDxRx** parameters can be used to configure DQ thresholds in **achillesHeel**.

- **ThresholdAgeWarning** refers to the maximum age to allow in the dataset; by default, this is 125 years of age.
- **ThresholdOutpatientVisitPerc** refers to the maximum percentage of outpatient visits allowed among all visits. This is by default set to 0.43.
- **ThresholdMinimalPtMeasDxRx** refers to the minimum percentage required of patients with at least 1 measurement, 1 condition, and 1 drug exposure. This is by default set to 20.5%.

## 7 Running Achilles Heel: Single-Threaded Mode

In single-threaded mode, there is no need to set a **scratchDatabaseSchema**, as temporary tables will be used.

```

connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

```

```

achillesHeel(connectionDetails = connectionDetails,
             cdmDatabaseSchema = "cdm",
             resultsDatabaseSchema = "results",
             vocabDatabaseSchema = "vocab",
             cdmVersion = 5.3,
             numThreads = 1,
             outputFolder = "output")

```

## 8 Running Achilles Heel: Multi-Threaded Mode

In multi-threaded mode, you need to specify `scratchDatabaseSchema` and use `> 1` for `numThreads`.

```

connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

achillesHeel(connectionDetails = connectionDetails,
             cdmDatabaseSchema = "cdm",
             resultsDatabaseSchema = "results",
             vocabDatabaseSchema = "vocab",
             cdmVersion = 5.3,
             numThreads = 5,
             outputFolder = "output",
             scratchDatabaseSchema = "scratch")

```

## 9 Post-Processing

This section describes the usage of standalone functions for post-processing that can be invoked if you did not use them in the **achilles** function call.

### 9.1 Creating Indices

*Not supported by Amazon Redshift or IBM Netezza; function will skip this step if using those platforms*

To improve query performance of the Achilles results tables, run the **createIndices** function.

```

connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

createIndices(connectionDetails = connectionDetails,
             resultsDatabaseSchema = "results",
             outputFolder = "output")

```

### 9.2 Dropping All Staging Tables (Multi-threaded only)

If the **achilles** or **achillesHeel** execution has errors, or if you did not enable this step in the call to these functions, use the **dropAllScratchTables** function.

The `tableTypes` parameter can be used to specify which batch of staging tables to drop (“achilles”, “heel”). The default value is to drop them all.

```
connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

dropAllScratchTables(connectionDetails = connectionDetails,
                     scratchDatabaseSchema = "scratch", numThreads = 5)
```

## 10 Examining the Heel Results

To view the Heel results, you can use the `fetchAchillesHeelResults()` function or the `launchHeelResultsViewer()` function. The former produces an R data frame that you can then export to various formats. The latter launches a Shiny application that renders the results in an easy to consume HTML file that can be viewed in your internet browser.

Heel Results are warnings split into 3 categories:

- **ERROR:** Something is probably not right with the way you transformed your native dataset into the CDM dataset. Review the error message and the associated Achilles analysis Id and Heel rule Id to investigate further. Use the `getAnalysisDetails` function to identify the Achilles analysis, and use the `fetchAchillesAnalysisResults` function to view the exact results of that analysis. Additionally, the `launchHeelResultsViewer` function launches a Shiny Application that can directly provide you with the associated SQL scripts.
- **WARNING:** Something *may* be an issue with the domain or concept associated with the Achilles analysis Id or Heel rule Id. However, not all datasets are the same; Achilles Heel tries to compare yours to a gold-standard dataset, so it is very likely you will encounter some WARNINGS. Feel free to ignore these WARNINGS if they are acceptable deviations from the gold-standard, but it is good practice to document these deviations for other researchers’ knowledge.
- **NOTIFICATION:** These messages simply tell you how your dataset’s content compares to practical thresholds on things like age, concept counts, death events, and visit types. These thresholds are not necessarily gold-standard, just values that are thought to be reasonable expected minimums or maximums. Feel free to ignore these NOTIFICATIONS if the expected values do not make sense with your particular dataset.

### 10.1 Fetch a data frame with the Heel Results

Once **achillesHeel** is run, you can fetch the results into a data frame for further consumption into whichever format you like using the `fetchAchillesHeelResults` function.

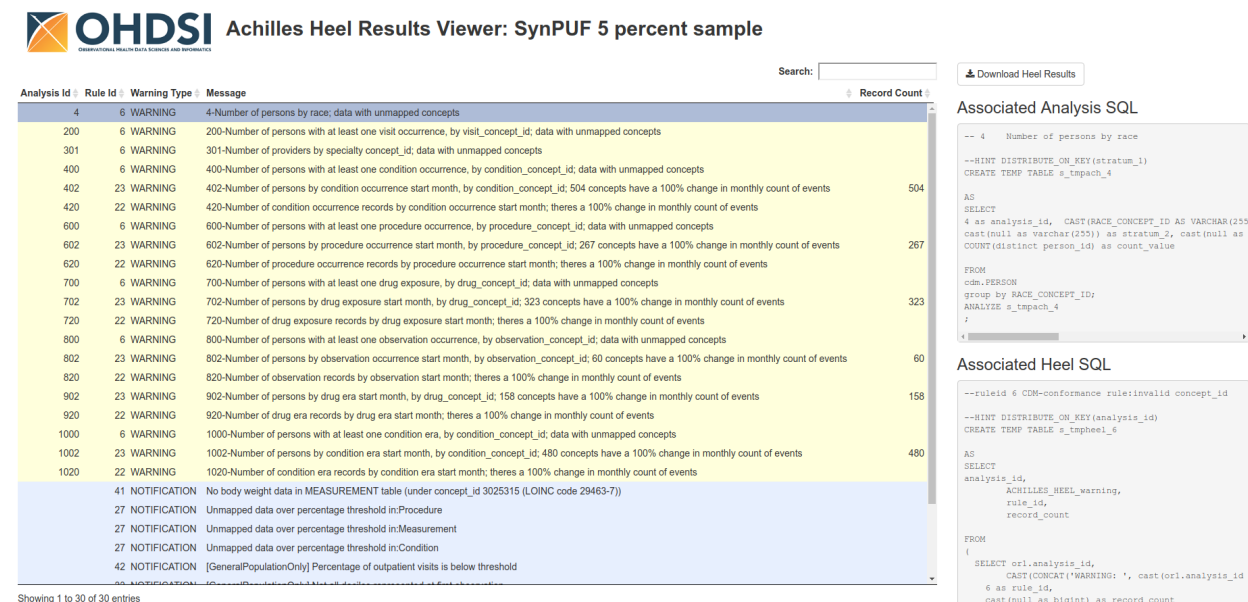
```
connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

fetchAchillesHeelResults(connectionDetails = connectionDetails,
                          resultsDatabaseSchema = "results")
```



## 10.2 View Heel Results in Interactive Shiny Application

The Heel Results Shiny Application can be useful in interacting with the Heel Results. The Heel warnings are color-coded based on severity (“ERROR”, “WARNING”, “NOTIFICATION”), and are searchable. You can also click on a row to see the associated Analysis and Heel SQL scripts to try to debug the root cause. Results can be downloaded to CSV using the “Download Heel Results” button.



**OHDSI Achilles Heel Results Viewer: SynPUF 5 percent sample**

Search:  Download Heel Results

Analysis Id	Rule Id	Warning Type	Message	Record Count
4	6	WARNING	4-Number of persons by race; data with unmapped concepts	
200	6	WARNING	200-Number of persons with at least one visit occurrence, by visit_concept_id; data with unmapped concepts	
301	6	WARNING	301-Number of providers by specialty concept_id; data with unmapped concepts	
400	6	WARNING	400-Number of persons with at least one condition occurrence, by condition_concept_id; data with unmapped concepts	
402	23	WARNING	402-Number of persons by condition occurrence start month, by condition_concept_id; 504 concepts have a 100% change in monthly count of events	504
420	22	WARNING	420-Number of condition occurrence records by condition occurrence start month; there's a 100% change in monthly count of events	
600	6	WARNING	600-Number of persons with at least one procedure occurrence, by procedure_concept_id; data with unmapped concepts	
602	23	WARNING	602-Number of persons by procedure occurrence start month, by procedure_concept_id; 267 concepts have a 100% change in monthly count of events	267
620	22	WARNING	620-Number of procedure occurrence records by procedure occurrence start month; there's a 100% change in monthly count of events	
700	6	WARNING	700-Number of persons with at least one drug exposure, by drug_concept_id; data with unmapped concepts	
702	23	WARNING	702-Number of persons by drug exposure start month, by drug_concept_id; 323 concepts have a 100% change in monthly count of events	323
720	22	WARNING	720-Number of drug exposure records by drug exposure start month; there's a 100% change in monthly count of events	
800	6	WARNING	800-Number of persons with at least one observation occurrence, by observation_concept_id; data with unmapped concepts	
802	23	WARNING	802-Number of persons by observation occurrence start month, by observation_concept_id; 60 concepts have a 100% change in monthly count of events	60
820	22	WARNING	820-Number of observation records by observation start month; there's a 100% change in monthly count of events	
902	23	WARNING	902-Number of persons by drug era start month, by drug_concept_id; 158 concepts have a 100% change in monthly count of events	158
920	22	WARNING	920-Number of drug era records by drug era start month; there's a 100% change in monthly count of events	
1000	6	WARNING	1000-Number of persons with at least one condition era, by condition_concept_id; data with unmapped concepts	
1002	23	WARNING	1002-Number of persons by condition era start month, by condition_concept_id; 480 concepts have a 100% change in monthly count of events	480
1020	22	WARNING	1020-Number of condition era records by condition era start month; there's a 100% change in monthly count of events	
41	NOTIFICATION		No body weight data in MEASUREMENT table (under concept_id 3025315 (LOINC code 29463-7))	
27	NOTIFICATION		Unmapped data over percentage threshold in Procedure	
27	NOTIFICATION		Unmapped data over percentage threshold in Measurement	
27	NOTIFICATION		Unmapped data over percentage threshold in Condition	
42	NOTIFICATION		[GeneralPopulationOnly] Percentage of outpatient visits is below threshold	

Showing 1 to 30 of 30 entries

**Associated Analysis SQL**

```
-- 4 Number of persons by race
--HINT DISTRIBUTE_ON_KEY(stratum_1)
CREATE TEMP TABLE s_tmpach_4

AS
SELECT
  4 as analysis_id, CAST(RACE_CONCEPT_ID AS VARCHAR(255))
  cast(null as varchar(255)) as stratum_2, cast(null as
COUNT(distinct person_id) as count_value

FROM
  cdm.PERSON
group by RACE_CONCEPT_ID;
ANALYZE s_tmpach_4
;
```

**Associated Heel SQL**

```
--ruleid 6 CDM-conformance rule:invalid concept_id
--HINT DISTRIBUTE_ON_KEY(analysis_id)
CREATE TEMP TABLE s_tmphheel_6

AS
SELECT
  analysis_id,
  Achilles_heel_warning,
  rule_id,
  record_count

FROM
(
  SELECT ori.analysis_id,
    CAST(CONCAT('WARNING: ', cast(ori.analysis_id
  6 as rule_id,
    cast(null as bigint) as record_count
```

When calling `launchHeelResultsViewer`, use the same parameters you used to execute `achilles` and `achillesHeel`. The Shiny app will use the parameters to render and translate the associated SQL scripts so that you can copy and run them separately to debug issues.

```
connectionDetails <- DatabaseConnector::createConnectionDetails(dbms = "postgresql",
                                                                server = "localhost/synpuf",
                                                                user = "cdm_user",
                                                                password = "cdm_password")

launchHeelResultsViewer(connectionDetails = connectionDetails,
                        cdmDatabaseSchema = "cdm",
                        resultsDatabaseSchema = "results",
                        scratchDatabaseSchema = "scratch",
                        outputFolder = "output",
                        numThreads = 5)
```

## 10.3 Using AchillesWeb

AchillesWeb is a lightweight web application that can be used to consume the Achilles and Heel results graphically. It is no longer actively updated, as development priorities have shifted towards Atlas Data Sources, but AchillesWeb can still be utilized. To connect Achilles results to AchillesWeb, the Achilles results need to be exported to JSON files and the AchillesWeb JSON file needs to point to those JSON files.

Please refer to AchillesWeb for more information.

### 10.3.1 Exporting to JSON

The `exportToJson` function can export all of the Achilles results to JSON files that AchillesWeb can consume.

- The `compressIntoOnFile` parameter, if set to `TRUE`, will compress all of the files into one zip file for easier portability.
- The `reports` parameter can be used to export specific reports rather than all. Use the `showReportTypes` function to see all possible reports.

```
connectionDetails <- createConnectionDetails(dbms = "postgresql",
                                             server = "localhost/synpuf",
                                             user = "cdm_user",
                                             password = "cdm_password")

exportToJson(connectionDetails = connectionDetails,
             cdmDatabaseSchema = "cdm",
             resultsDatabaseSchema = "results",
             outputPath = "output",
             vocabDatabaseSchema = "vocab")
```

### 10.3.2 Adding Data Sources to AchillesWeb

AchillesWeb relies upon a JSON file to point to CDM Achilles result JSON files.

```
addDataSource(jsonFolderPath = "output",
              dataSourcePath = "achillesWeb")
```

## 11 Acknowledgments

Considerable work has been dedicated to provide the Achilles package.

```
citation("Achilles")
```

```
#>
#> To cite package 'Achilles' in publications use:
#>
#> Patrick Ryan, Martijn Schuemie, Vojtech Huser, Chris Knoll, Ajit Londhe and Taha Abdul-Basser (2019)
#> Achilles: Creates Descriptive Statistics Summary for an Entire OMOP CDM Instance. R package version
#> 1.6.7.
#>
#> A BibTeX entry for LaTeX users is
#>
#> @Manual{,
#>   title = {Achilles: Creates Descriptive Statistics Summary for an Entire OMOP CDM Instance},
#>   author = {Patrick Ryan and Martijn Schuemie and Vojtech Huser and Chris Knoll and Ajit Londhe and},
#>   year = {2019},
#>   note = {R package version 1.6.7},
#> }
```