# DEVELOPER MANUAL

## ANTHROCLOUD

Software Modernization for Cloud-based Pediatric Anthropometry

December 4, 2019

Version 1

COT 6931
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# Change History

| Version | Date | Author | Changes |
|---|---|---|---|
| 1.0 | December 4, 2019 | Dusty Wright | Initial Document |
| | | | |

# Table of Contents

# 1 Introduction

## 1.1 Purpose

The purpose of this document is to describe the technical implementation of the AnthroCloud software solution. Both stakeholders and developers are the intended audience for this document. This document lays out technical details of activities performed during the AnthroCloud software creation.

## 1.2 Scope

This document serves as a helpful reference and source for the construction of the AnthroCloud software solution. AnthroCloud software solution is a modern cloud-based WHO Child Growth Standard compliant anthropometric calculator designed to provide a more flexible, maintainable, and portable solution to meet the changing needs of users. The scope of this document is limited to client/server setup, data implementation, web service application programming interface design, web application design. These activities are necessary for WHO Child Growth Standard data storage, z-score calculations, percentile calculations, growth curves, and plotted scores.

## 1.3 Definitions, acronyms, abbreviations

| | | |
|---|---|---|
| API | Application Programming Interface | A publicly available web-based application programming interface that accesses functions to returns data. |
| App | Application | An application is referred to as “app” in this context is a type of application software designed to run in the Cloud. |
| HTML | HyperText Markup Language | A markup standard that defines properties and behaviors of web page content. |
| HTTP | HyperText Transfer Protocol | HTTP is a protocol for transferring data over the Web. |
| IDE | Integrated Development Environment | An application that provides software development resources. |
| MVC | Model-View-Controller | A design pattern for decoupling the user-interface, data, and controller. |
| REST | Representational State Transfer | A set of architectural constraints for web services that define standards for communication. |
| SQL | Structured Query Language | A language standard for communicating with databases. |
| UI | User Interface | The screens and visual elements that interface with the software. |
| WHO | World Health Organization | A United Nations agency concerned with international public health. |

## 1.4 References

Link GitHub commits, pull requests, and issues to work items. (2019, July 7). Retrieved November 17, 2019, from https://docs.microsoft.com/en-us/azure/devops/boards/github/link-to-from-github

Getting Started with GitHub using Visual Studio 2019. (2019, April 4). Retrieved November 17, 2019, from https://www.azuredevopslabs.com/labs/devopsserver/github/

# 2 Setup

The resources for this project are made available through the University of West Florida (UWF) Computer Science Department. This project uses software from the Microsoft Imagine program made available to UWF students. Microsoft Azure is the targeted cloud platform.

- The source code can be found at https://github.com/rdw28/AnthroCloud.
- The project application URL is http://anthrocloud.azurewebsites.net/.

## 2.1 Source Control

GitHub is the host for version control. The repository is called AnthroCloud. The repository is owned by student account rdw28. The repository is public. Commits, insights, statistics, activities, and contributions, are visible from this site.

Commits record a timeline of activity from the initial commit in August 28, 2019 through December 4, 2019. Commit comments record a summation of coding activities performed during that specific check-in. Specific files and lines of code impacted during the change are highlighted and visible on the specific commit page. Comments linked to an Azure Boards tasks begin with 'AB'.

Follow the steps below to configure and clone a GitHub repository using Visual Studio 2019:

1. Open Visual studio
2. Click Continue without code
3. From Team Explorer, click Manage Connections
4. Under GitHub, click Connect. Sign into GitHub
5. Click Clone. (GitHub, 2019)

## 2.2 Planning Tool

Azure Boards is integrated with GitHub for this project. When committing changes from Visual Studio 2019 to GitHub, a comment was created to associate the code changes with tasks in Azure Boards. AB#{ID} mentions link GitHub comments to Azure Boards work items (Link, 2019). For example, checking in the comment "AB#70" for this project associated Task 70 Integrate HTML 5 Template with commit global identifier 8cf5250932510ac427289a6075021ea4e032d474. See Figure 1 for an example of Azure Boards integration with GitHub. Also, checking in comments prefix with the word "Fixed" will transition a work item's state to "Done".

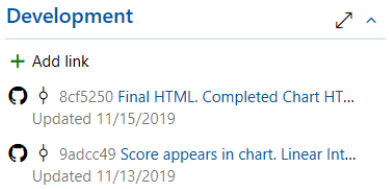



*Figure 1 - Azure Boards to GitHub Commit Link*

## 2.3 Development Environment

The AnthroCloud software solution was created using the Visual Studio Enterprise 2019 Integrated Development Environment (IDE). The tool was primarily used for debugging and testing. The Azure App Services deployment profiles for the Web Application and Web Service are created using this tool. The GitHub source control and Azure Boards planning tool are integrated.

## 2.4 Cloud Resources

All Azure resources are created with an Azure Resource Group. This group is where database and applications reside. The database, web service, and web application are deployed to these resources. All resource groups have a specified location. The closest regional location is East U.S. or Virginia. The

subscription model used is Azure for Students. The AnthroCloudResourceGroup, shown in Figure 2, is comprised of the AnthroCloud SQL Database, AnthroCloud App Service, AnthroCloudAPI App Service.

| NAME | TYPE | RESOURCE GROUP | LOCATION | SUBSCRIPTION |
|---|---|---|---|---|
| anthrocloudsql | SQL server | AnthroCloudResourceGroup | East US | Azure for Students |
| AnthroCloud | SQL database | AnthroCloudResourceGroup | East US | Azure for Students |
| AnthroCloudAPI | App Service plan | AnthroCloudResourceGroup | East US | Azure for Students |
| AnthroCloudPlan | App Service plan | AnthroCloudResourceGroup | East US | Azure for Students |
| AnthroCloud | App Service | AnthroCloudResourceGroup | East US | Azure for Students |
| AnthroCloudAPI | App Service | AnthroCloudResourceGroup | East US | Azure for Students |

*Figure 2 - AnthroCloud Azure Resource Group*

The SQL database is hosted in the Azure cloud. The AnthroCloud SQL Database resides on the AnthroCloudSQL SQL Server. The most economic and basic method of pricing was chosen for this project to lengthen the availability of the $100 allocated to student accounts. Figure 3 shows the $4.99 monthly cost estimate as seen in the Azure Portal during setup.

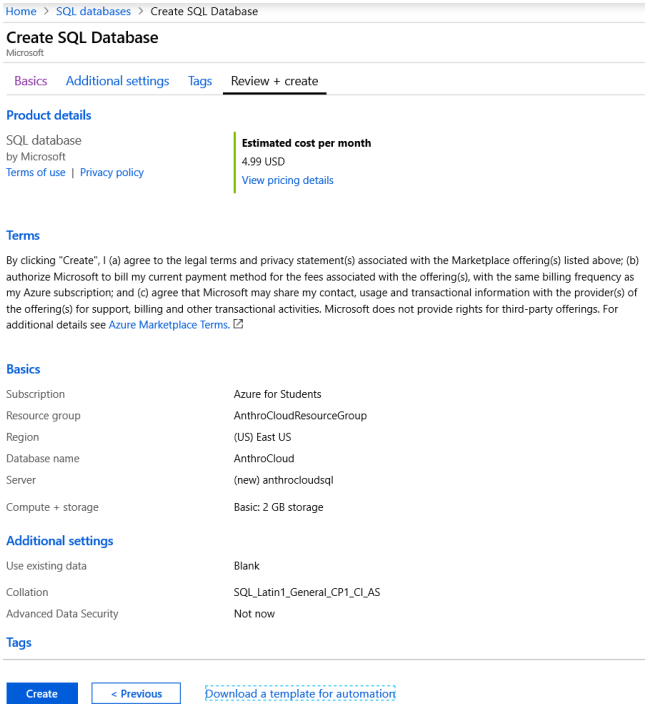



*Figure 3 - SQL Server Cost Estimation*

The AnthroCloud Web Application is hosted by AnthroCloud App Service shown in Figure 4.

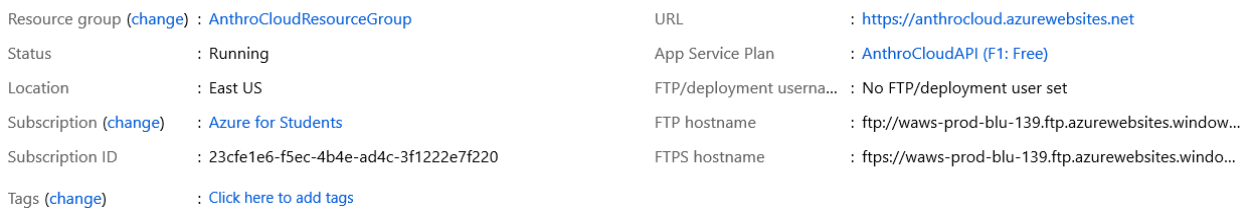



*Figure 4 – Web Application*

The AnthroCloud Web API Service is hosted by AnthroCloud App Service shown in Figure 5.

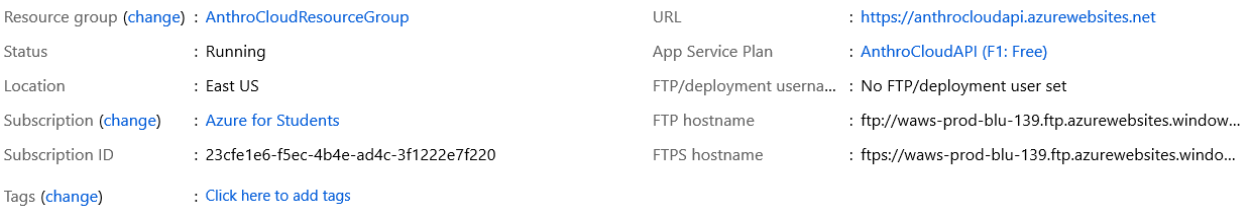



*Figure 5 – Web API*

Both the Web Application and Web Service are assigned to the AnthroCloudAPI App Service Plan shown in Figure 6.

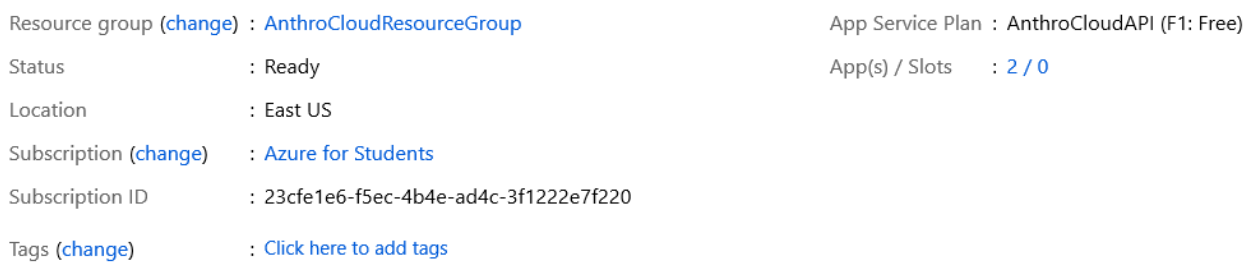



*Figure 6 - App Service Plan*

The AnthroCloud SQL Database is shown in Figure 7.

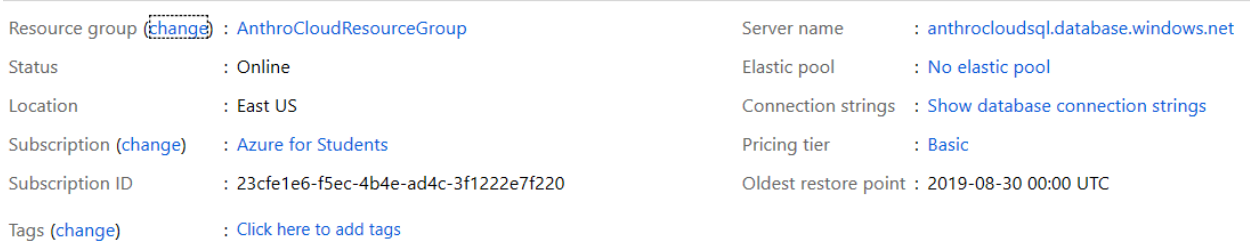



*Figure 7 - SQL Database*

The AnthroCloud SQL Server is shown in Figure 8.

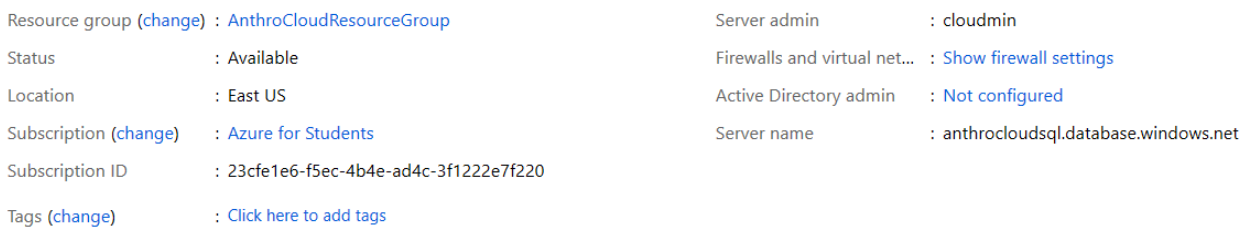



*Figure 8 - SQL Server*

## 2.5 Solution Architecture

The AnthroCloud solution architecture uses layered architecture to partition logic into layers. Components are architected in a hierarchical fashion. The solution uses a dependency diagram to validate architecture. The projects and layers are described below.

Presentation (UI) contains all presentation components and logic and serves as the presentation layer. All presentation actions between the user interface and service occur here. See AnthroCloud.UI.Web in Appendix B – Architectural Model.

Service contains all service components and logic and serves as the service layer. All service-related Web API (REST) implementation resides here. See AnthroCloud.API in Appendix B – Architectural Model.

Business contains all business components and logic and serves as the business layer. All business decision between the data and user interface occur here. See AnthroCloud.Business in Appendix B – Architectural Model.

Data contains all data components and logic and serves as the data access layer. All data interactions between the database and application occur here. See AnthroCloud.Data in Appendix B – Architectural Model.

Shared projects such as Entities and Framework serve as an architectural sidecar to be shared across layers. All data models reside in entities. All cross-cutting components in Framework. See AnthroCloud.Entities and AnthroCloud.Framework in Appendix B – Architectural Model.

Tests contain all the test logic and serves as the container for multiple test types. See AnthroCloud.Tests in Appendix B – Architectural Model.

# 3 Database

There are two types of WHO Child Growth Standards data. One, growth chart data can be easily identified with most tables using a month column as an age identifier and fewer rows. This is ideal for chart display. Viewing the x-axis for any “for-age” charts mirror the 0 – 60 months data. This project uses month-based identifier data for chart display. Two, the calculation data or “extended tables” can be easily identified with most tables using “AgeInDays” as a column identifier. This is ideal for precise Z-score and Percentile calculation. Both SQL scripts have been provided to load data.

## 3.1 Data Files

The data loaded as part of the AnthroCloudDB_Tables SQL script for this project uses the files listed in Table 1. Download standard data from https://www.who.int/childgrowth/standards/en. This data is used to draw charts. In order to mirror WHO Anthro desktop functionality, not all columns are used or are necessary to depict standard deviation and percentile curves.

| Measure | File |
|---|---|
| Length/height-for-age | lhfa_boys_0_2_zscores.txt |
| Length/height-for-age | lhfa_boys_2_5_zscores.txt |
| Length/height-for-age | lhfa_girls_0_2_zscores.txt |
| Length/height-for-age | lhfa_girls_2_5_zscores.txt |
| Length/height-for-age | tab_lhfa_boys_p_0_2.txt |
| Length/height-for-age | tab_lhfa_boys_p_2_5.txt |
| Length/height-for-age | tab_lhfa_girls_p_0_2.txt |
| Length/height-for-age | tab_lhfa_girls_p_2_5.txt |
| Weight-for-age | tab_wfa_boys_p_0_5.txt |
| Weight-for-age | tab_wfa_girls_p_0_5.txt |
| Weight-for-age | wfa_boys_0_5_zscores.txt |
| Weight-for-age | wfa_girls_0_5_zscores.txt |
| Weight-for-length/height | tab_wfl_boys_p_0_2.txt |
| Weight-for-length/height | tab_wfl_girls_p_0_2.txt |
| Weight-for-length/height | wfl_boys_0_2_zscores.txt |
| Weight-for-length/height | wfl_girls_0_2_zscores.txt |
| Weight-for-length/height | tab_wfh_boys_p_2_5.txt |
| Weight-for-length/height | tab_wfh_girls_p_2_5.txt |
| Weight-for-length/height | wfh_boys_2_5_zscores.txt |
| Weight-for-length/height | wfh_girls_2_5_zscores.txt |
| Body mass index-for-age (BMI-for-age) | bmi_boys_0_2_zcores.txt |
| Body mass index-for-age (BMI-for-age) | bmi_boys_2_5_zscores.txt |
| Body mass index-for-age (BMI-for-age) | bmi_girls_0_2_zscores.txt |
| Body mass index-for-age (BMI-for-age) | bmi_girls_2_5_zscores.txt |
| Head circumference-for-age | tab_hcfa_boys_p_0_5.txt |
| Head circumference-for-age | tab_hcfa_boys_z_0_5.txt |
| Head circumference-for-age | tab_hcfa_girls_p_0_5.txt |
| Head circumference-for-age | tab_hcfa_girls_z_0_5.txt |
| Arm circumference-for-age | tab_acfa_boys_p_3_5.txt |
| Arm circumference-for-age | tab_acfa_boys_z_3_5.txt |
| Arm circumference-for-age | tab_acfa_girls_p_3_5.txt |
| Arm circumference-for-age | tab_acfa_girls_z_3_5.txt |
| Subscapular skinfold-for-age | tab_ssfa_boys_p_3_5.txt |
| Subscapular skinfold-for-age | tab_ssfa_boys_z_3_5.txt |
| Subscapular skinfold-for-age | tab_ssfa_girls_p_3_5.txt |
| Subscapular skinfold-for-age | tab_ssfa_girls_z_3_5.txt |
| Triceps skinfold-for-age | tab_tsfa_boys_p_3_5.txt |
| Triceps skinfold-for-age | tab_tsfa_boys_z_3_5.txt |
| Triceps skinfold-for-age | tab_tsfa_girls_p_3_5.txt |
| Triceps skinfold-for-age | tab_tsfa_girls_z_3_5.txt |

*Table 1 - WHO Child Growth Standard Files*

## 3.2 Data Dictionary

The data dictionary describes the contents, format, and structure of the AnthroCloud database. The selected columns from WHO Child Growth Standard data files are described in Table 2 – 11. Appendix A captures the Physical Data Model in a single design.

**LengthHeightForAge** – This table is used to chart the length or height for age of an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | tinyint | - | Box-Cox transformation where 1 is no transformation | 1 |
| M | decimal(6,4) | - | median | 49.8842 |
| S | decimal(6,5) | - | coefficient of variation | 0.03795 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 44.205 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 46.098 |
| SD0 | decimal(6,3) | - | The z-score median. | 49.884 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 53.670 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 55.564 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 46.324 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 47.922 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 49.884 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 51.846 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 53.445 |
| Primary Key(s): Age + Sex | | | | |

*Table 2 - Length/height-for-age*

**WeightForLength** – This table is used for Birth to 2 years. Weight-for-length and weight-for-height charts are separate. Weight-for-length ranges from 45 cm to 110 cm.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| LengthInCM | decimal(3,1) | Primary Key | 45 cm to 110 cm | 45.0 |
| L | decimal(5,4) | - | Box-Cox transformation | -0.3521 |
| M | decimal(6,4) | - | median | 2.441 |
| S | decimal(6,5) | - | coefficient of variation | 0.09182 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 1.877 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 2.043 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 2.230 |
| SD0 | decimal(6,3) | - | The z-score median. | 2.441 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 2.680 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 2.951 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 3.261 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 2.064 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 2.223 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 2.441 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 2.689 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 2.917 |

| Primary Key(s): Sex + LengthInCM |
|---|

*Table 3 - Weight-for-length*

**WeightForHeight** – This table is used for 2 to 5 years. Weight-for-length and weight-for-height charts are separate. Weight-for-height ranges from 65 cm to 120 cm

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| HeightInCM | decimal(3,1) | Primary Key | 65 cm to 120 cm | 65.1 |
| L | decimal(5,4) | - | Box-Cox transformation | -0.3521 |
| M | decimal(6,4) | - | median | 7.4327 |
| S | decimal(6,5) | - | coefficient of variation | 0.08217 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 1.877 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 2.043 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 2.230 |
| SD0 | decimal(6,3) | - | The z-score median. | 2.441 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 2.680 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 2.951 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 3.261 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 6.394 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 6.834 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 7.433 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 8.104 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 8.713 |
| Primary Key(s): Sex + HeightInCM | | | | |

*Table 4 - Weight-for-height*

**WeightForAge** – This table is used to chart the weight for age of an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | decimal(5,4) | - | Box-Cox transformation where 1 is no transformation | 0.3487 |
| M | decimal(6,4) | - | median | 3.3464 |
| S | decimal(6,5) | - | coefficient of variation | 0.14602 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 2.080 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 2.459 |
| SD0 | decimal(6,3) | - | The z-score median. | 3.346 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 4.419 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 5.031 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 2.507 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 2.865 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 3.346 |

| | | | | |
|---|---|---|---|---|
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 3.878 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 4.35 |
| Primary Key(s): Age + Sex | | | | |

*Table 5 - Weight-for-age*

**BMIForAge** – This table is used to chart the body mass index for age of an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | decimal(5,4) | - | Box-Cox transformation | -0.3053 |
| M | decimal(6,4) | - | median | 13.4069 |
| S | decimal(6,5) | - | coefficient of variation | 0.0956 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 10.184 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 11.133 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 12.201 |
| SD0 | decimal(6,3) | - | The z-score median. | 13.407 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 14.773 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 16.326 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 18.100 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 11.254 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 12.16 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 13.407 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 14.826 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 16.13 |
| Primary Key(s): Age + Sex | | | | |

*Table 6 - Body mass index-for-age (BMI-for-age)*

**HCForAge** – This table is used to chart the head circumference for age of an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | tinyint | - | Box-Cox transformation where 1 is no transformation | 1 |
| M | decimal(6,4) | - | median | 34.4618 |
| S | decimal(6,5) | - | coefficient of variation | 0.03686 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 30.651 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 31.921 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 33.192 |
| SD0 | decimal(6,3) | - | The z-score median. | 34.462 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 35.732 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 37.002 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 38.273 |

| | | | | |
|---|---|---|---|---|
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 32.073 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 33.145 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 34.462 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 35.778 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 36.851 |
| Primary Key(s): Age + Sex | | | | |

*Table 7 - Head circumference-for-age*

**MUACForAge** – This table is used to chart the arm circumference for age of an infant or child against a population for 3 months to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | decimal(5,4) | - | Box-Cox transformation where 1 is no transformation | 0.3933 |
| M | decimal(6,4) | - | median | 13.4779 |
| S | decimal(6,5) | - | coefficient of variation | 0.07474 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 10.658 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 11.554 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 12.493 |
| SD0 | decimal(6,3) | - | The z-score median. | 13.478 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 14.508 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 15.585 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 16.709 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 11.663 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 12.458 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 13.478 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 14.547 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 15.454 |
| Primary Key(s): Age + Sex | | | | |

*Table 8 - Arm circumference-for-age*

**SSFForAge** – This table is used chart the head circumference for age an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | decimal(5,4) | - | Box-Cox transformation where 1 is no transformation | -0.303 |
| M | decimal(6,4) | - | median | 7.692 |
| S | decimal(6,5) | - | coefficient of variation | 0.17019 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 4.785 |

| | | | | |
|---|---|---|---|---|
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 5.564 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 6.516 |
| SD0 | decimal(6,3) | - | The z-score median. | 7.692 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 9.161 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 11.017 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 13.395 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 5.667 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 6.478 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 7.692 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 9.221 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 10.771 |
| Primary Key(s): Age + Sex | | | | |

*Table 9 - Subscapular skinfold-for-age*

**TSFForAge** – This table is used chart the head circumference for age an infant or child against a population for Birth to 5 years.

| Column Name | Data Type | Constraints | Description | Examples |
|---|---|---|---|---|
| Month | smallint | Primary Key | The child or infant age in total months. | 60 |
| Sex | tinyint | Primary Key | ISO/IEC 5218 standard<br>1 = male<br>2 = female | 1, 2 |
| L | decimal(5,4) | - | Box-Cox transformation where 1 is no transformation | 0.003 |
| M | decimal(6,4) | - | median | 9.7658 |
| S | decimal(6,5) | - | coefficient of variation | 0.16611 |
| SD3neg | decimal(6,3) | - | Three standard deviations of the mean. | 5.931 |
| SD2neg | decimal(6,3) | - | Two standard deviations of the mean. | 7.004 |
| SD1neg | decimal(6,3) | - | One standard deviation of the mean. | 8.271 |
| SD0 | decimal(6,3) | - | The z-score median. | 9.766 |
| SD1 | decimal(6,3) | - | One standard deviation of the mean. | 11.530 |
| SD2 | decimal(6,3) | - | Two standard deviations of the mean. | 13.612 |
| SD3 | decimal(6,3) | - | Three standard deviations of the mean. | 16.068 |
| P3 | decimal(6,3) | - | The 3rd percentile is below 97% of values with 3% of values below the score. | 7.144 |
| P15 | decimal(6,3) | - | The 15th percentile is below 85% of values with 15% of values below the score. | 8.221 |
| P50 | decimal(6,3) | - | The 50th percentile is at the median. | 9.766 |
| P85 | decimal(6,3) | - | The 85th percentile is above 85% of values with 15% of values above the score. | 11.6 |
| P97 | decimal(6,3) | - | The 97th percentile is above 97% of values with 3% of values above the score. | 13.345 |
| Primary Key(s): Age + Sex | | | | |

*Table 10 - Triceps skinfold-for-age*

## 3.3 Database Connection

SQL Server Management Studio v18.2 was used for this project. Connecting to a SQL Azure database is no different than connecting to a local database. The server name for this project is shown in Figure 9, anthroclloudsql.database.windows.net. The subscription is Azure for Students. The pricing tier is basic. The connection string for programmatic connection to the server and instance can be obtained from "Connection strings" under SQL databases in the Azure Portal.

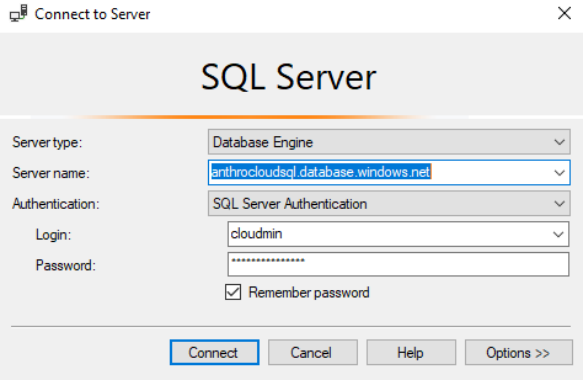



*Figure 9 - Database Login*

## 3.4 Seed Data (Script)

Two scripts were created to populate the database with WHO Child Growth Standard data. The scripts can be found in the AnthroCloud GitHub repository and are listed below:

- AnthroCloudDB_Tables.sql
- AnthroCloudDB_Tables_Expanded.sql

## 3.5 Data Access

The AnthroCloud software solutions uses Entity Framework (EF) Core. The EF Core reverse engineering process scaffolded entity classes and a database context mapping class based on the existing AnthroCloud database schema. Code 1 block shows the executable command. The component contains data access commands that call the database context and model results with entity classes.

```
1. Scaffold-DbContext 'Data Source=(localdb)\SQLEXPRESS;Initial Catalog=AnthroCloudDB; ' Microsoft.EntityFrameworkCore.SqlServer
```

*Code 1 – Reverse Engineering*

The following commands, listed in Code 2 block, are required to scaffold entity classes. The SQL Server package is necessary for communication to the database. The Tools package is necessary for Entity Framework to create model classes from the database. The Design Package is required for the Entity Framework Core Tools to work.

```
1. Install-Package Microsoft.EntityFrameworkCore.SqlServer
2. Install-Package Microsoft.EntityFrameworkCore.Tools
3. Install-Package Microsoft.EntityFrameworkCore.Design
```

*Code 2 – Package Console Manager*

# 4 Web Service

The AnthroCloudAPI is a RESTful HTTP service created using the ASP.NET Core Web Application project configured via the API project template.

## 4.1 Design

The AnthroCloud RESTful API is designed to support retrieval operations. The REST guidelines in Table 11 suggest HTTP calls to make to the server. The calls are safe as they do not change the state of data.

| **AnthroCloud Rest API** |
|---|

| Resource Type | HTTP Verb | Resource API | Description |
|---|---|---|---|
| **Anthro** | GET | /ANTHRO/AGE/{birth}/{visit} | Returns a human readable string in either Months or Year-Month (TotalMonths) format. |
| **Anthro** | GET | /ANTHRO/AGE/DAYS/{birth}/{visit} | Returns string of age in total days. |
| **Anthro** | GET | /ANTHRO/AGE/MONTHS/{birth}/{visit} | Returns string of age in total months. |
| **Anthro** | GET | /ANTHRO/AGE/YEARS/{birth}/{visit} | Returns string of age in total years. |
| **Anthro** | GET | /ANTHRO/BMI/{weight}/{height} | Returns BMI rounded to tenths. |
| **Chart** | GET | BFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of body mass index by age used to create a WHO chart. |
| **Chart** | GET | HCFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Head circumference-for-age used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | LHFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Length/height-for-age used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | MUAC/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Arm circumference-for-age used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | SSFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Subscapular skinfold-for-age used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | TSFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Triceps skinfold-for-age used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | WFA/{id}/{x}/{y} | Returns a list of age-based indicator table data for measurement of Weight-for-length/height used to create a WHO chart. Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | WFH/{id}/{x}/{y} | Returns a list of height-based indicator table data for measurement of Weight-for-length/height used to create a WHO chart (2 to 5 years). Data point (x,y) is insert if new; otherwise updated. |
| **Chart** | GET | WFL/{id}/{x}/{y} | Returns a list of height-based indicator table data for measurement of Weight-for-length/height used to create a WHO chart (Birth to 2 years). Data point (x,y) is insert if new; otherwise updated. |
| **Statistics** | GET | STATS/{indicator}/{measurement}/{ageInDays}/{id} | Returns a tuple of both calculated Zscore and Percentile values. |

*Table 11 - AnthroCloud Rest API*

## 4.2 Business

The AnthroCloud.Business project serves as the business component. This establishes a boundary as a business logic layer. Classes in this project will coordinate between the data access layer and Web API and ultimately the user interface. The Data Access Layer is charged when retrieving the data and that's it. In the Code 3 block below, the Chart business class is responsible for deciding when to populate attributes necessary to draw a vertical line. This logic would otherwise be placed in the user interface or data component. This logic is specific to decisions made outside of data storage.

```
1.  public List<BmiforAge> ListBmiforAge(Sexes sex, byte newX, decimal newY)
2.      {
3.          var chartDAC = new ChartDAC();
4.          List<BmiforAge> bmiCurves = chartDAC.ListBmiforAge(sex);
5.
```

```
6.          // Update adjacent length-for-age and height-for-age with a vertical
7.          // line at 2 years of age to mark the change from length to height;
8.          // from 0 - 60 completed months
9.          var markElement = bmiCurves.FindIndex(0, x => x.Month == 24);
10.         bmiCurves[markElement].Mark = "Length | Height";
11.         bmiCurves[markElement].Marktext = "Length | Height";
```

*Code 3 – Business Logic*

## 4.3 Data

The AnthroCloud.Data project serves as the data component. This establishes a boundary as a data access layer. Classes in this project will retrieve data. In the Code 4 block below, a strongly typed list of objects is retrieved based on specified criteria.

```
1.  /// <summary>
2.  /// Gets a strongly typed typed list of BFA objects.
3.  /// </summary>
4.  /// <param name="sex">Filters by ISO/IEC 5218 standard (1 = male, 2 = female)</param>
5.  /// <returns>Returns a strongly typed list of BFA objects.</returns>
6.  public List<BmiforAge> ListBmiforAge(Sexes sex)
7.  {
8.      using var db = new AnthroCloudContext();
9.
10.     IQueryable<BmiforAge> query = db.Set<BmiforAge>();
11.
12.     query = query.Where(c => c.Sex == (byte)sex);
13.
14.     return query.ToList();
15. }
```

*Code 4 – Data Logic*

## 4.4 Framework

The AnthroCloud.Framework project serves as a shared component. This establishes a shared solution library like an enterprise library. The common and shared function for this project is the Drawing class. The standard set of chart data is available for retrieval. A new data point that does not already appearing as an x and y in the data will have to be drawn. In order to draw a new data point, the new data point must be interpolated. The Code 5 block below illustrates interpolation for a known value of x to find y:

```
1.  /// <summary>
2.  /// Calculates Y for a known value of x.  Y occurs between Y0 and Y1.
3.  /// </summary>
4.  /// <returns>Return Y for a known value of x.  Y occurs between Y0 and Y1.</returns>
5.  public decimal CalculateY()
6.  {
7.      if ((X1 - X0) == 0)
8.      {
9.          return (Y0 + Y1) / 2;
10.     }
11.     return Y0 + (X - X0) * (Y1 - Y0) / (X1 - X0);
12. }
```

*Code 5 – Framework Logic*

## 4.5 Deployment

The Visual Studio publish profile is a set of configurable attributes used by MSBuild to deploy the AnthroCloud.API project to Azure. The Publish Profile can be obtained through the Azure Portal by

clicking ‘Get publish profile’ from the AnthroCloudAPI App Service. Once configured, you right click the project and select Publish to deploy from Visual Studio.

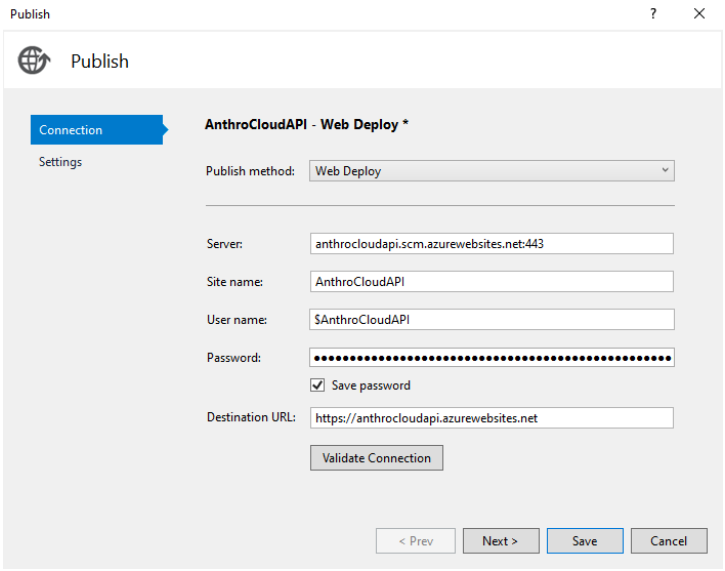



*Figure 10 – Web Service Deployment*

# 5 Web Application

The AnthroCloud application is a ASP.NET Core Web Application project configured using a Web Application (Model-View-Controller) project template.

## 5.1 Design

The AnthroCloud software solution user interface mockup depicts a responsive web design. See Appendix C – User Interface Mockup for the final mockup design. The intent is to provide a design that is adaptive to the user’s behavior and environment, more specifically screen size. The design in Figure 11 collapses for a smaller form factor.

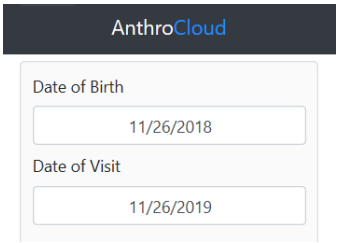



*Figure 11 – AnthroCloud iPhone*

## 5.2 Pattern

The Model-View-Controller pattern separates the AnthroCloud Web application into three main components.

### 5.2.1 Model

The Model represents application data. The Code 6 block is an excerpt from the class model for the AnthroCloud home page. The properties in the class represent the displayed data Birth Date and Visit Date.

```
1.  public class FormViewModel
2.  {
3.      public FormViewModel()
4.      {
5.          DateTime today = DateTime.Today;
6.          DateOfBirth = today.AddYears(-1);
7.          DateOfVisit = DateTime.Today;
8.          .
9.          .
10.         .
11.     }
12.
13.     [DisplayName("Birth Date")]
14.     public DateTime DateOfBirth { get; set; }
15.
16.     [DisplayName("Visit Date")]
17.     public DateTime DateOfVisit { get; set; }
```

*Code 6 – FormViewModel.cs*

### 5.2.2 View

The View represents the application user interface. The Code 7 block is an excerpt from the HTML view for the AnthroCloud home page. The 'asp-for' Razor markup syntax is known as a Tag Helper. This feature allows the HTML markup to recognize properties inside the model by name.

```
1.  <div class="form-row">
2.      <div class="col-md-6 mb-2">
3.          <label asp-for="DateOfBirth">Date of Birth</label>
4.          <input asp-for="DateOfBirth" type="date" class="form-control text-
    center" required>@*placeholder="Enter patient's Date of Birth."*@
5.      </div>
6.      <div class="col-md-6 mb-2">
7.          <label>Date of Visit</label>
8.          <input asp-for="DateOfVisit" type="date" class="form-control text-
    center" required />@*placeholder="Enter patient's Date of Visit."*@
9.      </div>
10. </div>
```

*Code 7 – Index.cshtml*

### 5.2.3 Controller

The controller handles requests by retrieving the data model and returning a response to the View. Once the Submit button is clicked in the View a corresponding event in the Controller called an Action is executed. Code 3 is an excerpt from the AnthroCloud Home controller. The method shows how Birth Date and Visit Date are used to retrieve an age calculation from the Web API service.

```
1.  [HttpPost]
2.  public IActionResult Index(FormViewModel model)
3.  {
4.      HttpClient client = new HttpClient();
5.
6.      client.BaseAddress = new Uri("https://anthrocloudapi.azurewebsites.net/api/");
7.
8.      string BirthDateString = string.Format("{0:yyyy-MM-dd}", model.DateOfBirth);
```

```
9.      string VisitDateString = string.Format("{0:yyyy-MM-dd}", model.DateOfVisit);
10.
11.     string path = "anthro/age/" + BirthDateString + "/" + VisitDateString;
12.
13.     //HTTP GET
14.     var response = client.GetAsync(path).Result;
15.     string res = "";
16.     using (HttpContent content = response.Content)
17.     {
18.       // ... Read the string.
19.       Task<string> result = content.ReadAsStringAsync();
20.       res = result.Result;
21.     }
22.     model.Age = res;
```

*Code 8 – HomeController.cs*

## 5.3 Deployment

The Visual Studio publish profile is a set of configurable attributes used by MSBuild to deploy the AnthroCloud project to Azure. The Publish Profile can be obtained through the Azure Portal by clicking 'Get publish profile' from the AnthroCloud App Service. Once configured, you right click the project and select Publish to deploy from Visual Studio.

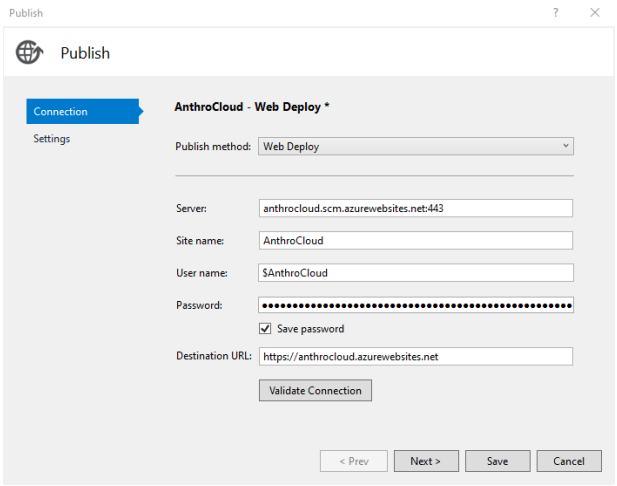



*Figure 12 – Web Application Deployment*

# 6 Test Suite

The AnthroCloud.Tests project was created using the xUnit Test Project (.NET Core) C# project template.

## 6.1 Unit Tests

The automated unit tests created for this project access classes directly to test the smallest piece of verifiable software in the application. All unit tests are organized under the AnthroCloud.Unit.Tests namespace. There are 53 Unit Tests that can be executed from the Test Explorer as shown in Figure 13 – 53 Unit Tests.

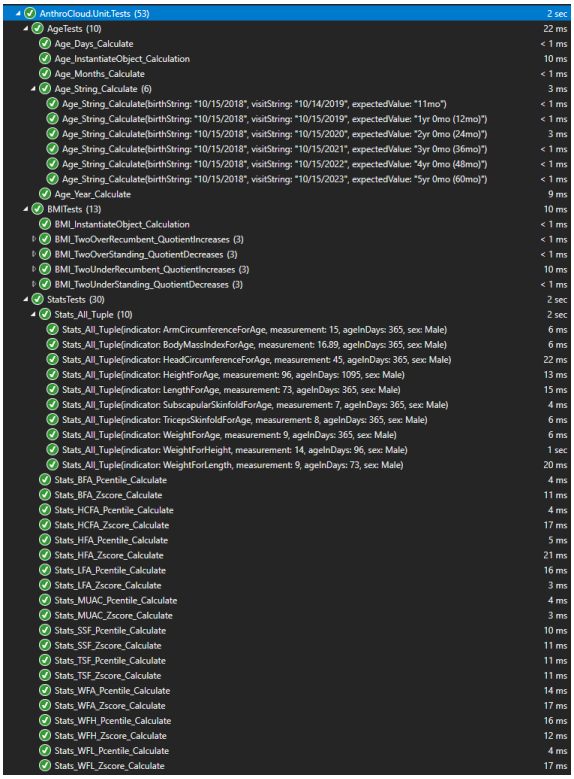



*Figure 13 – 53 Unit Tests*

Automated unit tests can be executed from the development environment. The AnthroCloud test project uses xUnit as the test library. Test attributes [Fact] and [Theory] are available. The [Fact] attribute indicates a test to be executed by the test runner in the development environment. The [Theory] attribute indicates a test that can have different input arguments. The [InLineData] attribute specifies values for input. The xUnit library was specifically chosen for its ability to load data scenarios into a test method.

```
1.  /// <summary>
2.  /// Tests equality comparison an age object's string output.
3.  /// </summary>
4.  /// <param name="birthString">The date of birth</param>
5.  /// <param name="visitString">The date of visit</param>
6.  /// <param name="expectedValue">The </param>
7.  [Theory]
8.  [InlineData("10/15/2018", "10/14/2019", "11mo")]
9.  [InlineData("10/15/2018", "10/15/2019", "1yr 0mo (12mo)")]
10. [InlineData("10/15/2018", "10/15/2020", "2yr 0mo (24mo)")]
11. [InlineData("10/15/2018", "10/15/2021", "3yr 0mo (36mo)")]
12. [InlineData("10/15/2018", "10/15/2022", "4yr 0mo (48mo)")]
13. [InlineData("10/15/2018", "10/15/2023", "5yr 0mo (60mo)")]
14. public void Age_String_Calculate(String birthString, String visitString, String expectedValue)
15. {
16.     DateTime birth = Convert.ToDateTime(birthString);
17.     DateTime visit = Convert.ToDateTime(visitString);
18.
19.     Age age = new Age(birth, visit);
20.     Assert.Equal(expectedValue, age.ToReadableString());
21. }
```

*Code 9 – xUnit Theory*

## 6.2 Integration Tests

Integration testing combines software modules to test Web API controllers that access data. The data retrieval and calculations for the software are conducted here. The purpose is to simulate web client interactions to validate the system and components. All integration tests are organized under the AnthroCloud.Integration.Tests namespace. There are 47 Unit Tests that can be executed from the Test Explorer as shown in Figure 14 – 47 Unit Tests.

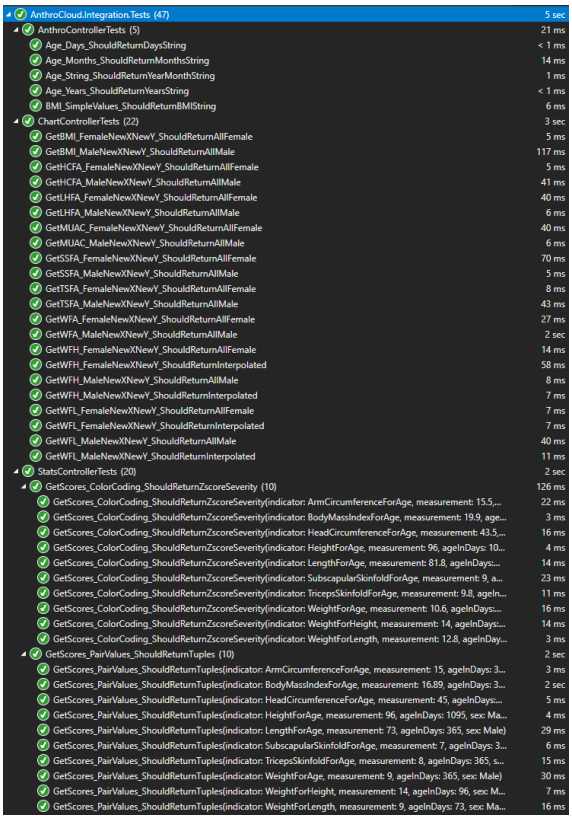



*Figure 14 – 47 Integration Tests*

Automated integration tests can be executed from the development environment. The AnthroCloud test project uses xUnit as the test library. Test attributes [Fact] and [Theory] are available. The [Fact] attribute indicates a test to be executed by the test runner in the development environment. The [Theory] attribute indicates a test that can have different input arguments. The [InLineData] attribute specifies values for input. The xUnit library was specifically chosen for its ability to load data scenarios into a test method.

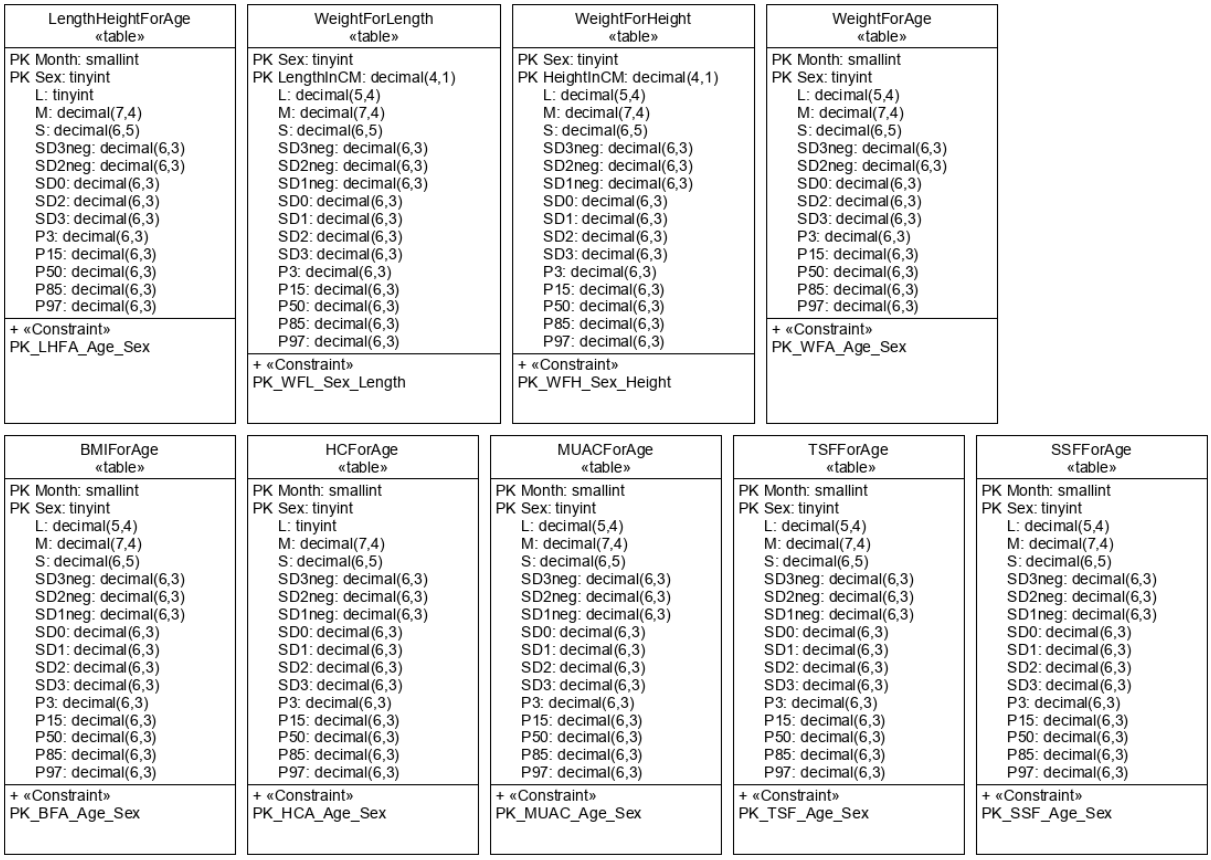
```
1.  /// <summary>
2.  /// Tests InRange comparison theory where percentile and z-score numeric ranges are expected.
3.  /// </summary>
4.  /// <param name="indicator">The growth indicator</param>
5.  /// <param name="measurement">The specified measured value</param>
6.  /// <param name="ageInDays">The age in total days</param>
7.  /// <param name="sex">Human sex designation per ISO/IEC 5218 code</param>
8.  [Theory]
9.  [InlineData(Indicator.ArmCircumferenceForAge, 15.00, 365, Sex.Male)]
10. [InlineData(Indicator.BodyMassIndexForAge, 16.89, 365, Sex.Male)]
11. [InlineData(Indicator.HeadCircumferenceForAge, 45.00, 365, Sex.Male)]
```

```
12. [InlineData(Indicator.HeightForAge, 96.00, 1095, Sex.Male)]
13. [InlineData(Indicator.LengthForAge, 73.00, 365, Sex.Male)]
14. [InlineData(Indicator.SubscapularSkinfoldForAge, 7.00, 365, Sex.Male)]
15. [InlineData(Indicator.TricepsSkinfoldForAge, 8.00, 365, Sex.Male)]
16. [InlineData(Indicator.WeightForAge, 9.00, 365, Sex.Male)]
17. [InlineData(Indicator.WeightForHeight, 14.00, 96.00, Sex.Male)]
18. [InlineData(Indicator.WeightForLength, 9.00, 73.00, Sex.Male)]
19. public void GetScores_PairValues_ShouldReturnTuples(Indicator indicator, double measurement, double ageInDays, Sex sex)
20. {
21.     var controller = new StatsController();
22.     Tuple<double, double> GetScores = controller.GetScore(indicator, measurement, ageInDays, sex);
23.
24.     Assert.InRange(GetScores.Item1, -4, 4);
25.     Assert.InRange(GetScores.Item2, 0, 100);
26. }
```

*Code 10 – xUnit Theory*

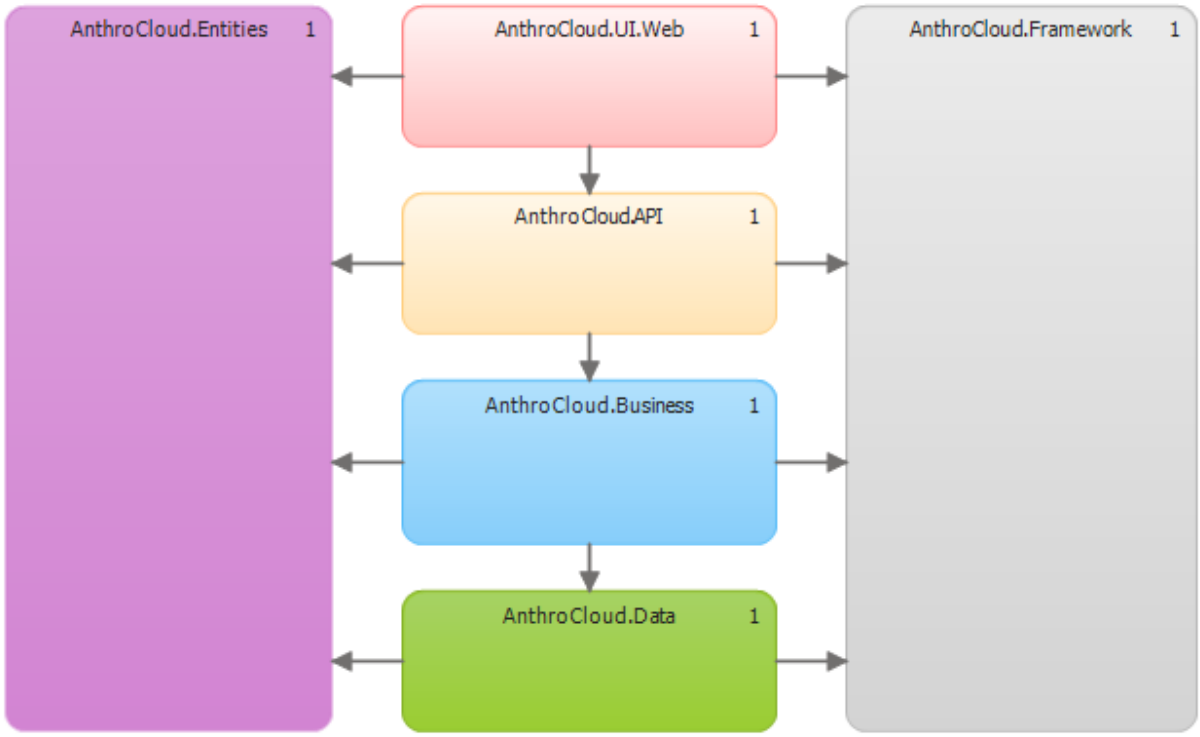
# Appendix A – Physical Data Model

The physical data model captures the data design to be implemented for the AnthroCloud database. The model describes additional attributes expected in tables such as specific data types and primary key constraints.



# Appendix B – Architectural Model

The AnthroCloud software solution conforms to the architectural design below. Dependencies were validated during system development using the dependency validation layer diagram below. The solution will not compile if a dependency violation exists. Arrows between components are read as a "Uses" statement. No single upstream component can perform an End-Run and circumvent the architecture without breaking the build. For example, presentation layer cannot access the data layer directly. This ensures the software is consistent with the intended design and meets requirements.



## Appendix C – User Interface Mockup

The AnthroCloud software solution user interface mockup depicts a responsive web design. The intent is to provide a design that is adaptive to the user's behavior and environment, more specifically screen size. The design collapses for a smaller form factor.