Health Informatics Platform to Understand the Impact of Insulin to Control Diabetes Using an Object-Oriented Approach

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Abstract

Insulin Dependent Diabetes Mellitus (IDDM), commonly known as Type 1 Diabetes, is a chronic and critical condition that occurs when the pancreas produces little to no insulin, resulting in elevated blood sugar levels (hyperglycemia), which can in turn cause blindness, kidney failure, heart disease, and even death. Consequently, the treatment of IDDM is mainly concerned with administering insulin to lower the blood sugar level to as close as possible to normal. The goal of this research is to identify the level of impact that the administration of different types of insulin and the dosage units has on blood sugar levels and how it can help manage diabetes. This research extracts real-world Multivariate, Time-Series Diabetes patients' dataset from the publicly available UC Irvine Machine Learning Repository. We implemented our data model and algorithm using Java programming language in an object-oriented approach and grouped the blood sugar levels into different impact groups such as low, normal, and high, assuming typical meal ingestion and exercise levels. The preliminary experiments conducted using our tool are helpful to understand the impact of insulin types and dosage units to control diabetes.

Introduction

IDDM is a chronic condition that occurs when one's own immune system attacks the body, specifically the beta cells in the pancreas that produce insulin. Insulin is essential as it allows the body to use glucose (sugar) for energy, and without adequate insulin, glucose accumulates in the bloodstream, resulting in high blood sugar levels. Due to the uncontrolled blood sugar levels, individuals may experience symptoms such as excessive thirst, frequent urination, and fatigue. In the long term, poorly managed IDDM can lead to serious complications including cardiovascular disease, nerve damage, kidney failure, and vision loss, significantly impacting overall health and quality of life and potentially ending in death. Therefore, effective treatment of IDDM is imperative, with successful management largely contingent upon insulin therapy to maintain optimal blood sugar balance. Owing to this, there is a growing need to understand the impact of different insulin types and dosages on blood sugar levels, namely regular, NPH (Neutral Protamine Hagedorn), and UltraLente insulin.

- Regular insulin is short-acting; it takes about 0.5-1 hours to fully work and lasts 6-8 hours.
- NPH insulin is categorized as an intermediate-acting insulin; it takes 1-2 hours to fully work and lasts for about 12-16 hours.
- UltraLente insulin is a long-acting insulin; it lasts for 20-36 hours.

In this research, we utilize the data sets from the UC Irvine Machine Learning Repository and the Java programming language to construct a comprehensive data model and algorithm following an object-oriented approach. Assuming typical meal consumption and exercise patterns, our methodology involves categorizing blood sugar levels into groups using the normal range of blood sugar levels as a frame of reference. By employing this framework, we aim to discern patterns and trends within the dataset, facilitating a deeper understanding of glucose regulation.

Methodology

The Health Informatics Platform (HIP) algorithm is designed to analyze a diabetes dataset, D, containing blood sugar measurements and insulin type and dosage records. Firstly, the algorithm extracts the data items from the dataset, D, and identifies intervals between blood sugar measurements (BSM). Within each interval, the algorithm locates the start blood sugar level, P1, and end blood sugar level, P2, and retrieves the most recent insulin administered, P3 – containing insulin type and dose, between P1 and P2. The algorithm then calculates the difference, Diff, between P1 and P2, capturing the rise or drop of blood sugar levels. Based on the dosage information, P3.dosage, the algorithm assigns these differences into predefined ranges, R1 to R5, each associated with a specific insulin type. For instance, if the dosage falls within range R2, the calculated difference is assigned to that range with its insulin type. Following this process for each dataset, the algorithm generates insulin measurements, IM, consisting of insulin type and dose, within a range, with the corresponding difference.

Sample Dataset			
Date	Time	Code	Value
04-25-1991	17:24	62	206
04-25-1991	17:24	33	022
04-25-1991	21:54	48	288
04-25-1991	21:54	33	002
04-26-1991	5:52	58	077
04-26-1991	5:52	33	009
04-26-1991	5:52	34	014
04-26-1991	13:06	35	012
04-26-1991	17:26	62	228
04-26-1991	17:26	33	007
04-27-1991	10:03	58	259
04-27-1991	10:03	33	010
04-27-1991	10:03	34	004
04-27-1991	17:20	62	256
04-27-1991	17:20	34	006
04-28-1991	8:42	58	109
04-28-1991	8:42	33	010
04-28-1991	8:42	35	014
04-28-1991	17:06	62	097

HIP Algorithm

```
Input: Diabetes Dataset, D
Output: Insulin Measurements, IM
P ← Extract items between start and end BSM in D
R ← [R1, R2, R3, R4, R5]
for each interval p in P
    P1 ← Find the start blood sugar level in interval p
    P2 ← Find the end blood sugar level in interval p
    P3 ← Extract the most recent insulin-type and dosage in interval p
    Diff ← P2 – P1
    if (P3.dosage <= 10)
        IM ← Assign Diff to range P3.insulin-type, R1
    else if (P3.dosage > 10 and <= 20)
        IM ← Assign Diff to range P3.insulin-type, R2
    else if (P3.dosage > 20 and <= 30)
        IM ← Assign Diff to range P3.insulin-type, R3
    else if (P3.dosage > 30 and <= 40)
        IM ← Assign Diff to range P3.insulin-type, R4
    else
        IM ← Assign Diff to range P3.insulin-type, R5
end for
return IM
```

Codes
33 – Regular insulin
34 – NPH insulin
35 – UltraLente insulin
48, 57, 58, 59, 60, 61, 62, 63, 64 – BSM

Values
Measurements for BSM and insulin dosage
(Dataset does not specify unit of measurement)

Intermediate Dataset		
Insulin Type	Dose	Difference
33	22	82
33	2	-211
35	12	151
33	7	31
34	4	-3
34	6	-147
35	14	-12

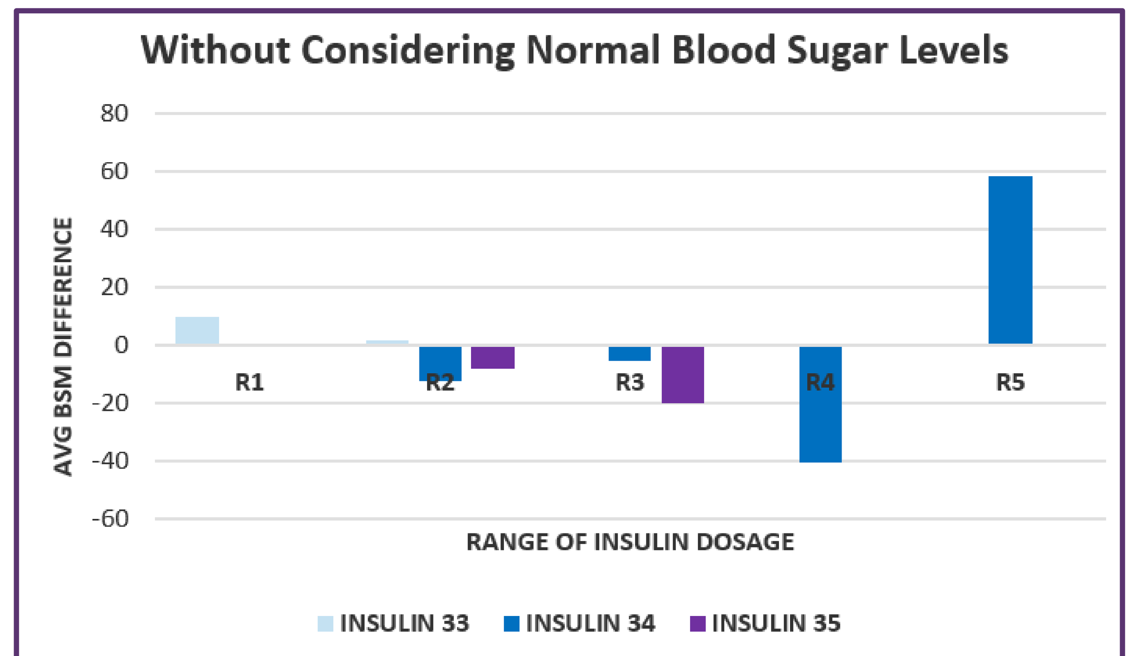
Final Dataset		
Insulin Type	Range	Average Difference
33	0-10	-90
	21-30	82
34	0-10	-75
35	11-20	69.5

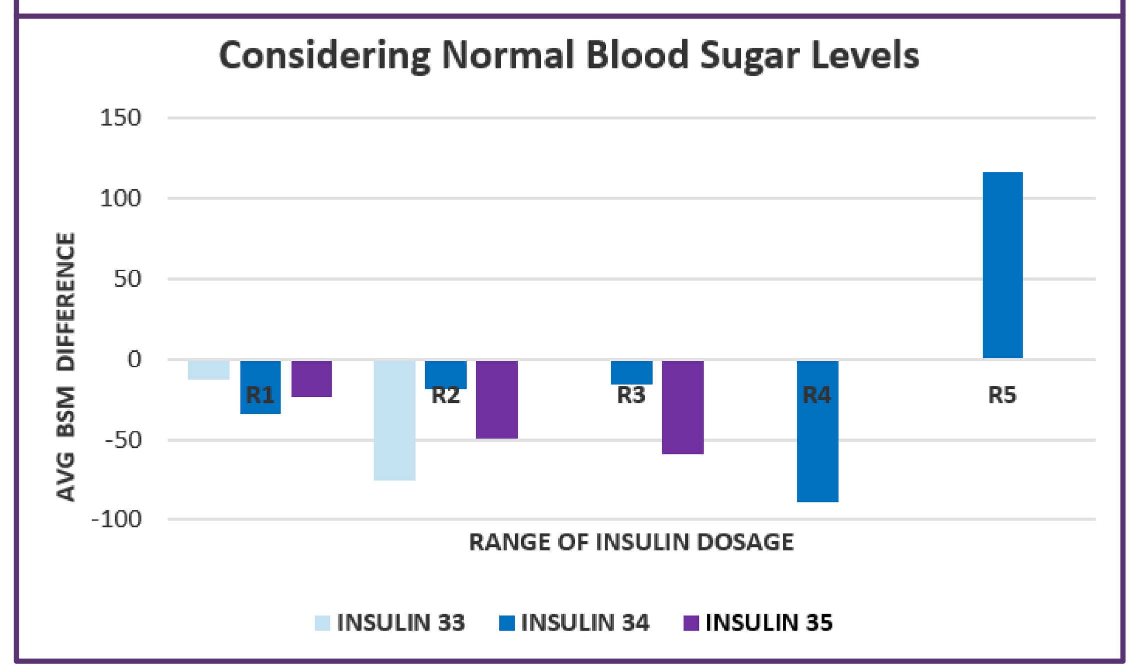
Experiments

These charts visualize the relationship between insulin dose ranges and their average impact on blood sugar levels for each insulin type.

Range		
Name	Low	High
R1	0	10
R2	11	20
R3	21	30
R4	31	40
R5	41+	-

BSM – Blood Sugar Measurement





On an average, NPH insulin administered within the dosage range R4 has lowered the blood sugar levels of patients by 40.5 units when normal blood sugar levels are not taken into account and by 89.1 units when normal blood sugar levels are considered.

Within dosage ranges R1 – R3, there is a significant change observed in the average BSM difference across all insulin types, and hence their impact on blood sugar, regardless of normal blood sugar levels.

Additionally, we observed that dosage range R5 for all insulin types has the least number of data points. Whether or not we consider normal blood sugar levels, it appears to have a high average BSM difference.

Conclusion

The NPH insulin within the dosage range R4 demonstrates the highest efficacy in managing diabetes, i.e., maintaining a patient's blood sugar levels within the normal range. Based on the the limited data we have, the dosage range R5, for all three insulin types, appears to be the least effective in managing diabetes. In fact, it increases blood sugar levels in diabetes patients.