Correlating the Cholesterol Levels to Glucose for Men and Women

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Abstract—Objectives: This paper explores the correlation between multiple cholesterol levels of the lipid profiles of patients and their diabetes regulation abilities in men and women.

Methodology: The methodology includes the following techniques: i) Pearson correlation ii) Spearman rank correlation and iii) setting thresholds for certainty of class assumption.

Data: The methods were applied on data from 161 patients of which 110 male and 41 female, analyzing the variables about patients’ age, height, weight, BMI, lipid profile (total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides), glycated hemoglobin levels with respective glucose regulation and diabetes classes, history of heart, diabetes and other chronic illnesses, habitual behaviors (smoking, alcohol consumption, physical activity), and medications intake (calcium channel blockers, beta blockers, anti-arrhythmics, ake/arb inhibitors, diuretics, statins anti-aggregation medication and anticoagulants).

Conclusion: Analyzing the correlations between the lipid profile and glucose regulation in patients led to different results when the analysis was done separately on men and women. Thus, better predictions and insights can be made dependent on gender. The research found no strong stand-alone correlation when analyzing all data, but when the data was segmented in male and female records, a strong negative linear ($r=-0.52$, $p=0.001$) and non-linear ($r=-0.55$, $p=0.001$) correlation was found for the HDL-C and glucose levels in female patients. In men, statistically significant negative correlations with HbA1c were assessed for Chol ($r=-0.27$, $p=0.009$), LDL-C ($r=-0.33$, $p=0.002$) and HDL-C ($r=-0.23$, $p=0.026$).

Index Terms—cholesterol, diabetes, glucose regulation, correlation, lipid profile

I. INTRODUCTION

This research is part of the Glyco project [1] aiming to detect blood glucose level out of an electrocardiogram (ECG) measurement. In addition to the main research goal of this project, we have noticed possible correlations between the lipid profile and glucose regulation ability of the patients. Therefore, in this paper, we present the research and findings analyzing all possible correlations between measured biochemical parameters that describe a complex health condition of a patient, and especially analyzing the gender differences in the correlations.

The dataset within the realized project contains a total of 161 patients (110 male and 41 female) and among all medical records we focused on patients’ age, height, weight, BMI, lipid profile (total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides), history of heart, chronic and diabetes illnesses, habitual behaviors (smoking, alcohol consumption, physical activity), medications intake (calcium channel blockers, beta blockers, anti-arrhythmics, ake/arb inhibitors, diuretics, statins anti-aggregation medication and anticoagulants).

II. RELATED WORK

Researchers typically have been investigating various correlations between patient’s lipid profile and glucose regulation ability. We classify their findings according to the diabetes category (prediabetes, type1 and type 2 diabetes).

A. Prediabetes patients

Calanna et al. [2] concluded that prediabetes patients exhibited lower HDL and higher Triglycerides levels.

B. Type 1 diabetes

Prado et al. [3] found that HbA1c levels are positive correlated to Total Cholesterol, Triglycerides and LDL cholesterol, but found that there is no significant correlation between HDL cholesterol and HbA1c. Kim et al. [4] had a similar conclusion except for the LDL cholesterol, and concluded that for LDL cholesterol there is no a statistically significant correlation.

C. Type 2 diabetes

Triglycerides are positively and HDL cholesterol is negatively correlated with HbA1c in diabetic patients according to [5] and [2].

A significant positive correlation is found for Total Cholesterol, Triglycerides and LDL cholesterol when compared to HbA1c by several studies [6], [7], [8], [9], [10], although no significant correlation of HDL cholesterol is reported for worsened diabetes condition.

Similar conclusion for positive correlation of non-HDL (Total Cholesterol, Triglycerides and LDL) cholesterol is reported by [11], [12], [13], [14], [15], [16] and a significant negative correlation with HDL cholesterol.
III. METHODS

A. Experimental setup

Data of 161 patients was analyzed within this research. Table I shows the distribution of male and female patients. Table II and Table III show the distribution of the numerical and categorical variables which consist of the patients’ age, height, weight, BMI, lipid profile, glycated hemoglobin levels with respective glucose regulation and diabetes classes, history of heart, diabetes and other chronic illnesses, habitual behaviors (smoking, alcohol consumption, physical activity), medications intake (calcium channel blockers, BETA blockers, antiarrhythmics, AKE/ARB inhibitors, diuretics, statins, antiaggregation medication and anticoagulants).

Table IV presents the blood glucose i.e. glycated hemoglobin HbA1c and the lipid profile which is made up of four continuous variables; Total Cholesterol (Chol), LDL Cholesterol (LDL-C), HDL Cholesterol (HDL-C) and Triglycerides (TG). These are the main variables that will be subject to analysis for possible correlations between the lipid profile and glucose regulation.

B. Correlation methods

The research is based on the following correlation methods compliant to the research goal:

- **Pearson correlation**
  Pearson’s correlation captures only linear correlations between two continuous variables.

- **Spearman rank correlation**
  In order to capture non-linear correlations as well, Spearman rank correlation was included. Spearman’s coefficient captures all relationships, linear and non-linear.

IV. RESULTS

As HbA1c is the marker for glucose regulation diagnosis, we can further indirectly reevaluate the correlation between the cholesterol attributes and the glucose regulation by assessing the Pearson and Spearman coefficients. The results of conducting the Pearson and Spearman rank correlation methods are presented in Table VI.

This solidifies our findings about the lack of strong correlation between diabetes and cholesterol without splitting the data set. After the division, one coefficient and it’s p-value stand out the most and that is the HDL-C and HbA1c correlation for the female patients.

Table VII contains thresholds for the cholesterol variables for specific scenarios where we can decide if the patient has or does not have diabetes and the corresponding certainty of...
TABLE IV
DISTRIBUTION OF CONTINUOUS CHOLESTEROL AND GLUCOSE VARIABLES OF THE PROPRIETARY DATASET (INNOVATION DOOEL)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Feature</th>
<th>Unit of measurement</th>
<th>All</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chol</td>
<td>Total Cholesterol</td>
<td>mmol/L</td>
<td>5.21 ± 1.23</td>
<td>5.16 ± 1.30</td>
<td>5.34 ± 1.07</td>
</tr>
<tr>
<td>TG</td>
<td>Triglycerides</td>
<td>mmol/L</td>
<td>1.96 ± 1.23</td>
<td>1.98 ± 1.25</td>
<td>1.91 ± 1.02</td>
</tr>
<tr>
<td>LDL-C</td>
<td>Low-Density Lipoprotein</td>
<td>mmol/L</td>
<td>3.06 ± 1.11</td>
<td>3.03 ± 1.16</td>
<td>3.12 ± 1.02</td>
</tr>
<tr>
<td>HDL-C</td>
<td>High-Density Lipoprotein</td>
<td>mmol/L</td>
<td>1.20 ± 0.35</td>
<td>1.15 ± 0.34</td>
<td>1.33 ± 0.36</td>
</tr>
<tr>
<td>HbA1c</td>
<td>Glycated Hemoglobin</td>
<td>%</td>
<td>6.85 ± 1.59</td>
<td>6.82 ± 1.74</td>
<td>6.93 ± 1.18</td>
</tr>
</tbody>
</table>

TABLE V
DISTRIBUTION OF GLUCOSE REGULATION CLASSES OF THE PROPRIETARY DATASET (INNOVATION DOOEL)

<table>
<thead>
<tr>
<th>Distribution(%)</th>
<th>ID</th>
<th>class</th>
<th>HbA1c(%)</th>
<th>All</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>W Well regulation</td>
<td>≤ 6.4</td>
<td>52.8</td>
<td>56.4</td>
<td>45.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Bad regulation</td>
<td>&gt; 6.4</td>
<td>47.2</td>
<td>43.6</td>
<td>54.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE VI
PEARSON AND SPEARMAN CORRELATION COEFFICIENTS BETWEEN THE LIPID PROFILE AND HbA1C

<table>
<thead>
<tr>
<th>feature1</th>
<th>feature2</th>
<th>Pearson c.</th>
<th>p-value</th>
<th>Spearman c.</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Chol</td>
<td>-0.264</td>
<td>0.002</td>
<td>-0.225</td>
<td>0.009</td>
</tr>
<tr>
<td>LDL-C</td>
<td>HbA1c</td>
<td>-0.297</td>
<td>&lt;0.001</td>
<td>-0.271</td>
<td>0.002</td>
</tr>
<tr>
<td>HDL-C</td>
<td>HbA1c</td>
<td>-0.280</td>
<td>0.001</td>
<td>-0.225</td>
<td>0.009</td>
</tr>
<tr>
<td>TG</td>
<td>HbA1c</td>
<td>0.178</td>
<td>0.03</td>
<td>0.116</td>
<td>0.18</td>
</tr>
<tr>
<td>Men</td>
<td>Chol</td>
<td>-0.27</td>
<td>0.009</td>
<td>-0.23</td>
<td>0.027</td>
</tr>
<tr>
<td>LDL-C</td>
<td>HbA1c</td>
<td>-0.33</td>
<td>0.002</td>
<td>-0.31</td>
<td>0.003</td>
</tr>
<tr>
<td>HDL-C</td>
<td>HbA1c</td>
<td>-0.23</td>
<td>0.024</td>
<td>-0.16</td>
<td>0.112</td>
</tr>
<tr>
<td>TG</td>
<td>HbA1c</td>
<td>0.19</td>
<td>0.07</td>
<td>0.08</td>
<td>0.458</td>
</tr>
<tr>
<td>Women</td>
<td>Chol</td>
<td>-0.24</td>
<td>0.14</td>
<td>-0.21</td>
<td>0.206</td>
</tr>
<tr>
<td>LDL-C</td>
<td>HbA1c</td>
<td>-0.17</td>
<td>0.31</td>
<td>-0.07</td>
<td>0.704</td>
</tr>
<tr>
<td>HDL-C</td>
<td>HbA1c</td>
<td>-0.52</td>
<td>0.001</td>
<td>-0.55</td>
<td>0.001</td>
</tr>
<tr>
<td>TG</td>
<td>HbA1c</td>
<td>0.16</td>
<td>0.328</td>
<td>0.2</td>
<td>0.226</td>
</tr>
</tbody>
</table>

Table VII
THRESHOLDS FOR SIGNIFICANT CORRELATIONS BETWEEN LIPID PROFILE AND GLUCOSE REGULATION IN DIFFERENT SCENARIOS

<table>
<thead>
<tr>
<th>Feature</th>
<th>Class</th>
<th>Condition</th>
<th>Outcome</th>
<th>Certainty(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>All</td>
<td>LDL-C ≥ 4.1</td>
<td>No Diabetes</td>
<td>89</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>No</td>
<td>LDL-C ≥ 4</td>
<td>No Diabetes</td>
<td>99</td>
</tr>
<tr>
<td>BETA Blockers</td>
<td>Yes</td>
<td>LDL-C ≥ 3.8</td>
<td>No Diabetes</td>
<td>99</td>
</tr>
<tr>
<td>BETA Blockers</td>
<td>Yes</td>
<td>Chol ≥ 5.5</td>
<td>No Diabetes</td>
<td>85</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>No</td>
<td>Chol ≥ 5.5</td>
<td>No Diabetes</td>
<td>90</td>
</tr>
<tr>
<td>Men</td>
<td>All</td>
<td>HDL-C ≥ 1.6</td>
<td>No Diabetes</td>
<td>88</td>
</tr>
<tr>
<td>AKE /ARB inhibitors</td>
<td>Yes</td>
<td>HDL-C ≥ 1.5</td>
<td>No Diabetes</td>
<td>90</td>
</tr>
<tr>
<td>Diabetes in family</td>
<td>No</td>
<td>LDL-C ≥ 3.3</td>
<td>No Diabetes</td>
<td>82</td>
</tr>
<tr>
<td>Diabetes in family</td>
<td>No</td>
<td>Chol ≥ 5.5</td>
<td>No Diabetes</td>
<td>76</td>
</tr>
</tbody>
</table>

V. DISCUSSION

A. Pearson and Spearman rank coefficient

The Pearson and Spearman rank coefficients separated the HDL cholesterol in women as a strong stand-alone correlation with high statistical significance.

B. Thresholds for inferring

Since many factors could influence the glucose regulation classes alongside the lipid profile, we analyzed the correlations and possibilities for inference of positive or negative outcome for the glucose regulation classes (Well or Bad).
Table VII presents the outcomes of setting this threshold. The results (thresholds) were calculated from the percentage of the Well regulation and Bad regulation classes correspondingly and the scatter plots of HbA1c and the cholesterol variables were used to initially place the threshold and then move it around to find the best one.

Figure 1 and Figure 2 present the plots and express the differences in correlation between the male and female patients pointing the different gender behavior of lipid profile and glucose regulation.

C. Comparison to other research

Our findings overlapped in the correlation results regarding the Triglycerides which were positively correlated and HDL-C levels which were negatively correlated with glucose regulation and worse cases of diabetes.

There was a clash in the results when correlating Total Cholesterol and LDL-C levels, which we found to get lower with worse diabetes and glucose regulation classes, instead of elevated as the other papers revealed. This could be the result of some confounding factors in the data that we worked with.

VI. CONCLUSION

We have conducted a clinical research study on 161 patients in order to analyze if the glucose regulation is correlated to the lipid profile of the patient, knowing that the same autonomous nervous system is responsible for them.

Analyzing the correlations between the lipid profile and glucose regulation in patients led to different results when the analysis was done separately on men and women. Thus, better predictions and insights can be made dependent on gender.

The research results show that there are no strong stand-alone correlation when analyzing all data, but when the data was segmented in male and female records.

However, a strong negative linear ($r=-0.52, p=0.001$) and non-linear ($r=-0.55, p=0.001$) correlation was found for the HDL-C and glucose levels in female patients, while in men, statistically significant negative correlations with HbA1c were assessed for Chol ($r=-0.27, p=0.009$) and LDL-C ($r=-0.33, p=0.002$). These findings motivate us to continue the research towards a deeper explanation about different correlations between lipid profile and glucose regulation level for men and women.

REFERENCES