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Correlation of Human Fasting Blood Sugar with Grip Muscle Strength and Reflex Response Time

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Authors' contributions

This work was carried out in collaboration between all authors. Author OMO carried out the bench work. Author JCI designed the study. Author AON wrote the protocol and wrote the first draft of the manuscript. Authors EKN and EMA managed the literature searches and statistical analyses of the study.

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ABSTRACT

In humans, one of the major complications of chronic *Diabetes Mellitus (DM)* is Peripheral Neuropathy. Apparently linked to ischemic Nerve damage, a ravaging puzzle on its pathophysiology, onset prediction, and prognosis is yet to be fully uncovered. Today, what seems to be a major "breakthrough" is the discovery that chronic DM damages signal transduction across Nerve and Muscle tissues, leading to a bad and/or poorly coordinated reflex. The goal of this study was to find in humans, the relationship that binds fasting blood sugar (FBS) with grip muscle strengths and reflex response time. To achieve this, 387 humans were ethically sourced from Ethiope East Local government area of Delta State, Nigeria. Based on their glucometer readings, subjects were then gender-sorted and classified into 3 groups; A (hypoglycaemic), B (normoglycaemic or control), and C (hyperglycaemic). Using the hand-grip dynamometer (HGD)

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and Meter rule, subjects' Grip Muscle strengths (GMS) and Reflex Response times (RRT) were respectively obtained and mapped against their corresponding glucometer reading (FBS). Using the Pearson Product moment correlation coefficient, Statistical measure of association (correlation) was conducted on obtained variables, and ANOVA was used to analyse the differences between means of each groups. Though no actual difference(s) was/were found between GMS and RRT, apparently, there was a weak Auditory-FBS relationship in hypoglycaemic females, and a weak GMS-FBS, plus Tactile-FBS correlations in hypoglycaemic males and females respectively.

Keywords: Reflex; reaction time; reflex response time; grip muscle strength; fasting blood sugar; auditory response; visual response; tactile response.

1. INTRODUCTION

In humans, the model for information flow is represented as:

Stimulus -> Sensory Neurone ->Integrators -> Motor Neurone -> Effector -> Response

In his famous book, Sir Charles Sherrington (1857-1952) defined this as "the unit reactions in nervous integration" or "Reflex". The time taken for this to occur is the "Reflex Response time (RRT)" or "Reaction time (RT)". It is the interval between stimulus application and response detection, usually acting as a negative feedback loop that returns the body to its normal functional state or homeostatic level. One good example of reflex is seen when light is suddenly flashed on the eyes (Pupillary light reflex) in the dark. Suddenly, eyelids close and pupils constrict to protect the retina.

Overtime, researchers have identified several factors that may affect reflex responses in humans, most important of which are, but not limited to gender, age, illnesses, exercise, drugs and dietary [1,2]. Glucose for instance is the monomeric unit from which carbohydrate foods are built. Available findings posit that high levels of blood glucose from carbohydrate supplementations can improve RRT, and is essential for proper functioning of different tissues of the body [3,4]. Skeletal muscles for example depend chiefly on glucose for the synthesis of myo-inositol, a major compound required for signal transduction across the myocytes (muscle cells). In chronic diabetics however, higher level of blood glucose is converted to fructose through a sorbitol intermediate (Polyol Pathway). Failure to further metabolise fructose for ATP generation leads to sorbitol accumulation. Being a toxic compound, excess sorbitol inhibits myo-inositol availability, thus damaging nerve-muscle tissues (Ischemia) with resultant peripheral neuropathies (foot ulcer), sluggish reaction time, and wakened muscular strength [5].

Functionally, the human blood sugar level dramatically fluctuates depending on state. During fasting, starvation, stress and athletics, the demand for glucose rises than expected, warranting a need for its mobilization from the liver by glycogenolysis. This causes a rise in blood sugar levels, increasing ATP generation through glucose catabolism; which is needed for excite-contraction processes in nerve and muscle tissues [6].

Several findings opine that skeletal muscles, particularly postural muscles of the lower limbs undergo atrophy, structural, and metabolic alterations during space flight. However, the effects that varying blood sugar levels pose on "gross muscular efficiency" is still unclear. Dumke and his co-researchers in their 2007 publication on "effect of duration and exogenous carbohydrates on gross muscular efficiency during cycling" found using 15 adult cyclists, that; power output and oxygen levels decreased over time with no difference between trials in 2.5 hours of cycling exercise. They also observed that Relative gross efficiency for those given carbohydrates. This they found greater than those administered a placebo beverage between 40 and 150 minutes. The blood sugar concentration (or blood glucose level) is the amount of glucose (sugar) in milligram (mg) present in one decilitre (dl) of the human blood it is measured in mg/dl of blood, and referred to as the "fasting blood sugar" under fasting conditions. As part of its homeostatic functions, the body tightly regulates this sugar levels, using hormonal agents as insulin or glucagon from the pancreas [7].

1.1 Aim of Study

This study aimed at finding in humans, the relationship that binds fasting blood sugar with

grip muscle strengths and reflex response times. Specifically, study was designed to find a non-invasive means for which human fasting blood sugar can be measured if Reflex Response Time and/or Grip Muscle Strengths is/are known. Study also attempted to obtain a possible sugar range for which any further delay in reflex response time may be indicative of a possible nerve-muscle damage (as seen in diabetics, following sorbitol accumulation). Thus, predicting in chronic hyperglycemics (diabetics), the likelihood of becoming victim of foot ulcer and/or limb amputation.

2. METHODOLOGY

2.1 Resources and Sources

2.1.1 Humans

Three hundred and Eighty seven (**387**) humans were drawn from Ethiope East Local Government Area of Delta State. In Nigerian state of Delta, Ethiope East is a 536 km² local government area with population of about 202,712 (National Population Commission, 2006). Delta State is a $16{,}842/km^2$ area of land that approximately lies between Longitude $5^0 00$ and $6^0 . 45'$ East and Latitude $5^0 00$ and $6^0 . 30'$ North (National gazette, 2007).

The decision to sample 387 humans was informed by the statistical relation:

$$SS = \frac{Z^2 P \times (1 - P)}{C^2}$$

Where →

SS = Sample Size
Z = Confidence level as z-score (95% = 1.96 from z-table)
P = Population proportion variance. (Maximal at 0.5 from binomial distribution table)
C = Confidence interval or margin of error (0.05).

The above relation returned a minimum of 384 samples for a population size as 202,712, the town under study.

2.1.2 Glucometer

A Blood glucose monitoring device (Glucometer) with an Accu-Check trademark was purchased from Roche Diagnostics, Sandhofer Strasse 116, 68305 Mannheim, Germany (www.accu-check.com).

2.1.3 Dynamometer

A hand grip dynamometer (HGD) of Strength interval between 0kg and 135 kg was obtained from the Department of physiotherapy, Federal Medical Centre, Asaba, Delta State, Nigeria.

2.1.4 Meter rule

Two transparent meter rules (50 cm long each) were purchased.

2.2 Protocol

Ethical approval was obtained from the Research and Ethics committee of the college of Health Sciences, Delta State University, Abraka, Delta State. Before investigation, a Consent form was also administered to participants in order to have their permissions. Those whose permission was not granted were left without contempt.

2.3 Selection Criteria

Selection of subjects for participation was based on the findings that:

i. Upper respiratory tract infections pose a slowdown effect on reflex responses [8].
ii. Alcohol is a potent inhibitor of reflex responses [1].
iii. Caffeine decreases reflex reaction time [9].
iv. Use of Calcium channel blockers (e.g. Diltiazem) inhibits signal transduction at N-M Junctions10.
v. Reaction time and GMS are gender dependent [11]. Using this criterion, each group was sorted by into male and female genders.
vi. With age > 60, there is a gradual decrease in active muscular performance and endurance [12].

2.3.1 Inclusion criteria

A subject was neither screened out by height, nor was religion, tribe, race and/or geopolitical routes used. Only subjects who had fasted for 12 hours at least, were included. For GMS tests, Dexterity and Preference for handedness was considered [13] before including any subject for participation. The reason for this is that, upon

tactile contact on the right shoulder, left handed individuals (for example) were involuntarily expected to swiftly respond from their contra-lateral limb, and vice versa.

2.3.2 Exclusion criteria

Based on above findings, Prejudice was made against Subjects with upper respiratory tract ailments, subjects who took little to high dose of alcohol, Caffeine addicts, Subjects undergoing treatments with Calcium channel blockers, and Subjects With age > 60.

2.4 Study Limitation

Majorly funding, we actually intended to run this study with the mean haemoglobin value (glycosylated haemoglobin test) of Diabetics. This would have given huge precisions on the actual blood sugar value of any tested individual. However, logistics for conducting such tests were not readily within reach. Where found, cost of funding it for a sample size as 387 subjects was on a high side. Hence, the need for fasting blood sugar.

2.5 Procedure

First, subjects were categorized into two main groups; Experimental and Control. Based on glucometer readings < 70 mg/dl, 70 – 100 mg/dl, and ≥ 101 mg/dl, Experimental group was subdivided into hypoglycaemic group A, and hyperglycaemic group C; while Normo-glyceamic group B served as the control. The choice for so adopting above values while grouping subjects were based on specified standards of the American Diabetes Association [14].

2.5.1 Testing the Fasting Blood Sugar (FBS)

To obtain the fasting sugar value, we adhere strictly to Guides from the glucometer's manufacturer manual.

2.5.2 Testing the Grip Muscle Strength (GMS)

After a subject's fasting sugar status was measured (low, normal or high), a hand grip dynamometer was placed in their non-dominant hand. They were then made to stand in a position where the hand's grip muscles will rest in the direction of gravity. This gravitational–directional flow was necessary to obtain an optimum force from the limbs upon abduction beyond 90 degrees [15]. Participants were then asked to squeeze the dynamometer with as much force as possible, being careful to squeeze only once for each measurement. Three trials were made with a pause of about 10-20 seconds between trials; in order to avoid the effects of muscle fatigue. In each case, the result of each trial was read, approximated to kilogram (kg), and recorded as such. Where the difference in scores was within 3 kgs, the test was accepted. However, where the difference between any two measures was more than 3 kg, the test was repeated once more after a rest period. In the end, only the best 3 measurements (i.e. the highest three) were reported in the data sheet.

2.5.3 Testing the reaction time

To be accurate or near accurate, this test was divided into two phases. While the first phase used one meter rule to determine reflex reaction time (phase I), the second made use of two rulers for the same purpose (phase II). In the end, results from phases I and II were added. The average taken (after three successful repetitions) is what was recorded in data sheet.

2.5.4 Phase I (One ruler)

Here, subject sat on a chair with his/her dominant hand over the edge.

Firstly, visual responses were tested as follows: While Ruler was held (through assistance) between the outstretched index finger and thumb of participant's dominant hand, subject was worn a pair of eye shade for reason of blurring his/her vision. He or She was then instructed to grab the ruler (rested at 0 cm level with the thumb) as fast as possible immediately its release. Though no sound or gesture was told them as of release, the rationale was to have them react to the visual stimulus of picking a falling ruler at the blurriest possible vision. The centimetre mark on which the falling metre rule was picked (by subject) was recorded and saved against previously read parameters (FBS and GMS). The procedure was repeated three more times at different position, and mean values were recorded.

Secondly, auditory reactions were tested in a similar fashion. However, without wearing a pair of eye shade, only dominant hand was tested in similar way. Here, subject was asked to pick the ruler at the sound of "Release". The rationale was to have them react to the auditory stimulus

of hearing "Release" whether or not the ruler was truly released. Upon response, the centimetre mark on the ruler was read and recorded as usual. Procedure was repeated three times, switching places per subject, and in each case recording the mean value after three trials.

Thirdly and lastly, tactile reaction was tested in similar way. This time, subjects were instructed to react to a tactile touch from behind on the shoulder of his/her non-dominant arm as the ruler drops. Here, the rationale was, whether or not the ruler actually drops, subject should react at any slight touch. Procedure was repeated three times as before with appropriate centimetre readings were recorded.

2.5.5 Phase II (Two rulers)

Procedures for this phase were similar to those of phase I. however, two meter rule were used to determine auditory and visual responses (no tactile response was measured). For visual response, both rulers were held the same time unknowing to subject without subject which will be dropped in advance, but attempting to pick the correct one as fast as possible. Thus, offsetting planned responses at stimulation. To avoid cheating, subjects were told in advance not to squeeze both hands, but one (the dormant one), attempting to pick the ruler as it fell. Procedure was repeated three times each for auditory stimulation, with mean values recorded (as in phase I).

2.5.6 Distance-time conversions

To obtain reaction times (AUD, TAC and VIS), all meter rule values (read in centimetres) were converted to time (in seconds), indicating how long it took for an object (the ruler) to fall a certain distance and the corresponding saving time (subject's response time). This distance-to-time conversion was made, using the second equation of motion, given as:

$$S = ut + \tfrac{1}{2}gt^2 \quad (1)$$

Were →

S = distance measured in centimetres,
U = initial velocity before free fall (always zero),
g = the acceleration due to gravity constant (980 cm/sec2), and
t = time in seconds.

Recall that for any object placed in the earth's gravitational flux, initial velocity (U) of motion is always zero. So, equation 1 above becomes:

$$S = \tfrac{1}{2}gt^2 \quad (2)$$

And finally,

$$t = \sqrt{2S/g} \quad (3)$$

Equation 3 above became the final equation on which centimetres to seconds conversion was made, were all symbols retained their usual meanings.

2.6 Statistical Analysis

Using Microsoft's Excel (version 14.0.4760.1000), Evaluation of collected data for statistical significance with ANOVA was made between groups; while Pearson Product Moment Correlation (PPMC) was used to establish relationship between measured parameters from the field. P-values less than 0.05 were judged to be statistically significant.

3. RESULTS

Firstly, we present results in tabular form as obtained for all groups.

Fig. 1 compares FBS in males (of all groups) to the mean values of their reaction times (AUD, VIS and TAC). The curve explains that, hypoglycaemic males (y-axis with FBS < 69) had a maximal FBS of about 62mg/dl in 1+ second, as against 93 mg/dl and 138mg/dl for the normoglycaemic and hyperglycaemic males respectively. in each case, these values appears to be the peak sugar range for which RRT was highest, indicative of a slowdown in nerve-muscle signalling. This may be useful in predicting the onset of possible nerve-muscle damage (neuropathy) as seen in chronic diabetics.

Fig. 2 compares FBS in females (of all groups) to the mean values of their reaction times (AUD, VIS and TAC). As opposed to males however, females had 69mg/dl, 99mg/dl and 143mg/dl in hypoglycaemic, normoglycaemic, and hyperglycaemic cases respective.

Table 1. Showing outcome of ANOVA test for males in each group

Parameter	Group A (Hypoglycaemics)	Group B (Normoglycaemics)	Group C (Hyperglycaemics)
FBS	43.22±12.36	84.30±6.39	118.23±11.03
GMS	35.74±4.38	34.26±3.85	42.79±3.66
VIS	0.51±0.28	0.51±0.29	0.49±0.29
TAC	0.68±0.21	0.46±0.28	0.54±0.30
AUD	0.52±0.28	0.48±0.25	0.56±0.26
ANOVA (f)	1192.39	6881.38	4570.75
F-Crit	2.39	2.40	2.41
P-Val	P > 0.05	P > 0.05	P > 0.05
Remark	Insignificant	Insignificant	Insignificant

Values are expressed as mean ± Standard Deviation (S.D). n = 193 males. Within groups (A, B, and C), ANOVA returned 1192.39 and 4570.75 for groups A and C, and 6881.38 for control group B. in either case, These values were found critical at 3.39, 2.40 and 2.41 respectively for groups A, B, and C., proving to be Insignificant as f > f-crit. at P < 0.05

Note: by saying that ANOVA proved Insignificant within groups, what is meant is that within each group (A, B, and C), an analysis was made to compare the differences in mean of measured parameters (FBS, GMS, TAC, and AUD). That is, three separate ANOVA test per group, returned insignificant results in each case.

Table 2. Showing outcome of ANOVA test for females in each group

Parameter	Group A (Hypoglycaemics)	Group B (Normoglycaemics)	Group C (Hyperglycaemics)
FBS	47.71±11.98	87.21±8.93	126.30 ±11.81
GMS	18.66±3.78	19.75±2.39	40.46±8.51
VIS	0.47±0.29	0.52±0.31	0.48 ±0.34
TAC	0.68±0.24	0.51±0.30	0.53±0.30
AUD	0.60±0.24	0.49±0.30	0.58 ±0.26
ANOVA (f)	1221.03	4277.09	3162.52
F-Crit	2.39	2.41	2.41
P-Val	P > 0.05	P > 0.05	P > 0.05
Remark	Insignificant	Insignificant	Insignificant

Values are expressed as mean ± Standard Deviation (S.D). n = 194 females, ANOVA returned insignificant values, indicating no difference between all three groups as f > f-crit. at P < 0.05

Table 3. Showing outcome of pearson product moment correlation coefficients for males in each group

Parameter	Group A (Hypoglycaemics)	Group B (Normoglycaemics)	Group C (Hyperglycaemics)
AUD	-0.01 (IP)	-0.04 (IP)	-0.07 (IP)
VIS	0.19 (DP)	0.28 (DP)	0.07(DP)
TAC	0.00 (DP)	0.09 (DP)	0.22 (DP)
GMS	**-0.09 (IP)**	0.00 (DP)	0.13 (DP)
Remark	All Weak	All Weak	All Weak

Negative values expressed as IP = Inverse Proportionality, while positive values are expressed as DP = Directly Proportional. More so, values close to +1 means positively strong, while those near -1 are taken to be weakly correlated. Pearson returned a correlation coefficient of 0.77, which was found with a P-value of 0.00 at P < 0.05

Table 4. Showing outcome of pearson product moment correlation coefficients for females in each group

Parameter	Group A (Hypoglycaemics)	Group B (Normoglycaemics)	Group C (Hyperglycaemics)
AUD	**0.29 (DP)**	-0.03 (IP)	**-0.19 (IP)**
VIS	-0.03 (IP)	-0.12 (IP)	-0.20 (IP)
TAC	**-0.06 (IP)**	0.03(DP)	**0.00(DP)**
GMS	-0.01 (IP)	-0.15 (IP)	-0.19(IP)
Remark	All weak	All weak	All weak

Negative values expressed as IP = Inverse Proportionality, while positive values are expressed as DP = Directly Proportional. More so, values close to +1 means positively strong, while those near -1 are tagged as weakly correlated. Pearson returned a correlation coefficient of -0.66, which was found insignificant with P-value of 0.00 at P < 0.05

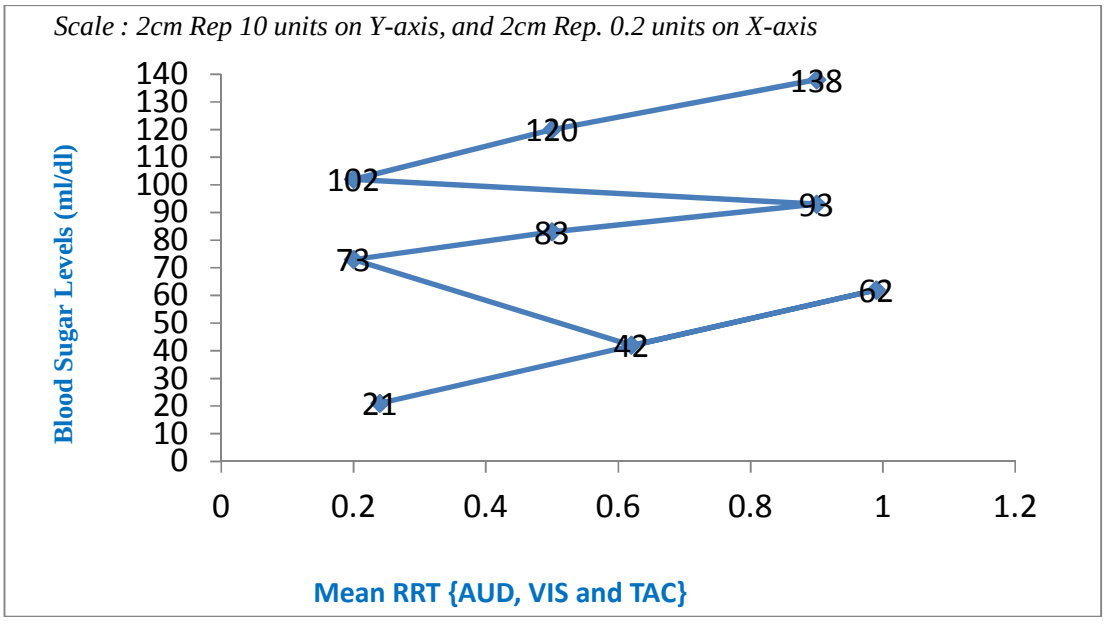

Fig. 1. Showing graph of fasting sugar (mg/dl) against mean response time in males of all groups

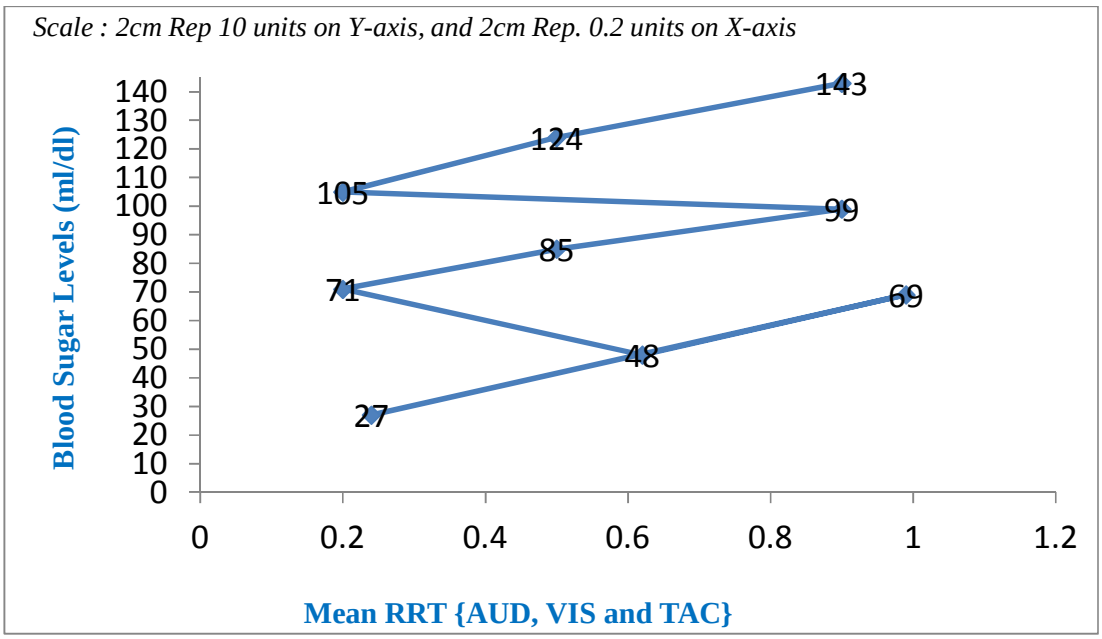

Fig. 2. Showing graph of fasting sugar (mg/dl) against mean response time in females of all groups

4. DISCUSSION

Table 1 and Table 2 Shows outcome of ANOVA tests on differences in mean for measured parameters across groups. Notice that all groups (except female group C) had insignificant remarks with f-result greater than the critical value (*f > f-crit)*. The statistical implication of this is that very minimal (negligible) or no actual difference(s) exists between measured variables within groups *as f > f-crit. at P < 0.05.*

A careful look at Table 1 revealed hyperglycemic males as having higher GMS values than hypoglycemic males. Physiologically, this is expected as high values of blood glucose calls for increased glycolysis, resulting in increased glucose metabolism for ATP (Adenosine Tri Phosphate) generation. Availability of ATP in turn, drives the contraction process within muscle cells and strength increases by extension. This is in line with the findings of Montoye and Lamphiear [16], but disagrees with those of Kimura [17*]*

Similarly, Table 1 shows hyperglycemic males as having lower values in visual responses than normoglycaemic and hypoglycemic males. This implies that in males, visual response time decreases with hyperglycemia. A possible reason for this is traceable to glucose-galactitol inter-conversion due to hyperglycemia; leading to accumulation of galactitol if prolonged. Toxic galactitol may then impair visual reflexes in humans [18] this finding is in line with those of Ando [19].

Again, Table 1 shows that hyperglycemic males (group A) had lower tactile response than males in other groups. This is possibly linked to activation of the counter regulatory mechanisms response to high levels of circulating insulin (as seen in cases of iatrogenic hyperglycemia). This high level of circulating insulin, coupled with defective autonomic and adrenergic responses, plus failure of glucagon response can slow down tactile responses. The implication of this is that in hyperglycemic males, tactile response subtly slows down compare to normoglycaemic and hypoglycaemic males. This finding is in line with those of Stephanie [20].

Table 1 also shows that hyperglycemic males had higher auditory response time than males in other groups. The possible reason for this can be likened to Hyperglycemia's disruptive effect on psychomotor and cognitive functioning of the brain, thus impeding on reflex stimuli across the vestibular apparatus of the brain [21]. This finding is attuned with that of Kimura [17]; who asserted that auditory stimulus only takes 8-10 msec to reach the brain as against 20-40 msec for visual stimulus.

Careful observation of Tables 1 and 2 shows that, fasting blood sugar of hypoglycemic females was higher than those of males in the same group. However, this value rose from higher to highest in groups B (control) and C (hyperglycemic) respectively. The statistical implication of this is that on the mean, females had higher values in fasting blood sugar than males under hypoglycemic, normoglycaemic and hyperglycemic conditions. Physiologically, this is probably explained by the effect that male hormones may have on carbohydrate breakdown, vis-à-vis the female endocrine hormones. For this reason, glycolysis (glucose catabolism) occurs faster and higher in males than in females, necessitating that males almost immediately catabolize glucose than females. This finding is in line with that of Crewther [22].

Comparison of Tables 1 and 2 also showed that in hypoglycaemic, normoglycaemic and hyperglycaemic states, males had higher mean values than the females. This implies in spite of low sugar, that hypoglycaemic males showed high muscular strengths than their female counterparts. The explanation for this is probably linked to the metabolic effects of male steroids earlier discussed; especially, testosterone. By this, myo-tonic activities are ATP driven, depending chiefly on blood glucose availability to run6. Though no difference between males and females was found [16], some researchers however found a large gender difference in the grip and arm strengths of subjects [16,23].

4.1 Societal Advantage of Study

i Under clinical and laboratory settings, should be possible to access a subjects blood sugar range from his/her reflexes, and/or grip muscle strengths.

ii It should also be possible to test the integrity of the human nervous system without need for actual invasion, merely by having a clue on the ranges of a subject's fasting blood sugar and grip muscle strength.

5. CONCLUSION

Within the ambient of vulnerability to possible human, logical, or analytical errors, we apparently found, in humans, that there is a positive but weak AUD-FBS correlation in hypoglycaemic females and a weak negative correlation for GMS-FBS, TAC-FBS in hypoglycaemic males and females respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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