***Research Article***

**GLYCEMIC INDICES AND GLYCEMIC LOADS OF SOME COMMONLY CONSUMED TRADITIONAL DIETS IN NORTHWESTERN, NIGERIA**

**ABSTRACT**

**Aim:** This research was conducted to evaluate glycemic index (GI) and glycemic load (GL) of some commonly consumed traditional diets in Northwest, geopolitical zone, Nigeria.

**Study design:** A cross sectional study was conducted, questionnaires were administered across the local government areas (LGAs) of the selected states (Jigawa, Kano and Katsina), to sample individuals from different sectors of the community.

**Place and Duration of Study:** Jigawa, Kano and Katsina states for the period of six (6) months.

**Methodology:** Research involves administration of questionnaire/consent form using random sampling technique across the local government areas of Jigawa, Kano and Katsina states (Phase I). Based on respondent’s responses most commonly consumed traditional diet types mentioned by the respondents were documented from which three categories viz; most highly-, moderately- and the least- consumed diets were selected for the study. Diets were prepared according to recipe mentioned by the respondents and most common method of processing/cooking of the commonly consumed diets was also adopted based on their responses. Two hundred and eighty (280) consented subjects were used for the study, twenty (20) subjects were used for the GI test of each prepared diets (twelve diets, four for each state) and forty (40) subjects for the standard diet (glucose). Phase II involves determination of fasting blood glucose for 2hours at interval of 30 minutes for the calculation of glycemic index and load (GI/GL). Fasting blood glucose of the volunteers was determined using standard methods.Results obtained are mean ± standard error of the mean. All data were subjected to analysis of variance (ANOVA) and independent samples test using SPSS software version 20.0 with P value <0.05 considered significant.

**Results:** GI and GL of all the prepared commonly consumed traditional diets were found to be high that is >70 and >20 respectively.

**Conclusion:** The high GI and GL observed may promote overconsumption of energy together with sedentary life style leading to a greater risk of developing obesity and consequently diabetes mellitus later in life within the study area.

**Key words:** Glycemic Index, Glycemic Load, Traditional Diets, Standard diet, Northwest Geopolitical Zone.

**INTRODUCTION**

“Nigeria is a country in west Africa bordering Niger in the North, Chad in the Northeast, Cameroon in the East and Benin in the West. Nigeria's latitude and longitude is 10° 00' N and 8° 00' E, total area of about 973,768km2 and 200,962,417 people” [1]. “It comprises thirty-six states (and one Federal Capital Territory) divided into six geopolitical zones according to economic, political and ethnical preferences viz: North-Central, North-West, North-East, South-South, South-East and South-West. Northwest geopolitical zone constitutes seven states; Jigawa, Kano, Katsina, Kebbi, Sokoto and Zamfara” [2]. The zone consists of Hausas and Fulani’s and the religion in the region is Islam. This zone is the most populated in Nigeria with over 35,786,944 people and covers a land area of 213, 345 km2 [3]. The occupation of the zone is predominantly farming.

The concept of a dietary Glycemic Index (GI) came under discussion as a factor that should be controlled to prevent chronic diseases and has been reported as a way of identifying foods that might be useful in the disease management. According to a study by [4] “Nigeria has 5.77% pooled prevalence of diabetes mellitus across the six geopolitical zones, with south-south having the highest prevalence (9.8%) and north-west accounting for 3.0%. The increasing prevalence of non-communicable diseases (NCDs) causes premature deaths owing to changes in diet and lifestyle. Therefore, numerous strategies for prevention and control have been developed in order to delay the spread of these diseases” [5]. “The GI of food is a categorization based on the effect of a food on blood glucose level” [6]. Glycemic Index(GI) is defined as “the incremental area under the blood glucose response curve expressed as a percentage of the response to the same amount of carbohydrates from a standard food taken by the same subject” [7]. “The standard food is usually white bread or glucose. The glycemic index (GI) provides a measure of how quickly blood sugar levels rise after eating a particular type of food” [8]**. “**The effect that carbohydrate-containing foods have on blood glucose concentration, called the glycemic response of the food, varies with the time it takes to digest and absorb the carbohydrates in that food. Some foods cause a rapid rise and fall in blood glucose levels, whereas others cause a slower and more extended rise with a lower peak level and a gradual fall. The concept of the glycemic index of a food was developed to provide a numerical value to represent the effect of the food on blood glucose levels. It provides a quantitative comparison between foods. Glycemic Load (GL) considers both the quantity and the quality of the carbohydrate in a meal. The GL equals the glycemic index times the grams of carbohydrate in a serving food. The higher the GL, the greater the expected elevation in blood glucose and insulinogenic effect of the food. Long-term consumption of a diet with a relatively high GL is associated with an increased risk of type two diabetes and coronary heart disease” [9]. “The longer and higher the elevation of blood glucose, the greater the risk of developing chronic diseases and obesity” [10], [11]. There is lack of comprehensive information on GI and GL of most commonly consumed traditional foods in northern Nigeria, making it difficult to advice relevant group of population on diets. The main focus of this research is to provide glycemic index and glycemic load of some commonly consumed traditional diets in northwest geopolitical zone, Nigeria.

**MATERIALS AND METHODS**

**Documentation and Selection of Commonly Consumed Diets**

Documentation and selection of commonly consumed diets in each state (Jigawa, Kano, Katsina) were done by administration of questionnaire.

**Selected diets**

Based on respondent’s responses most highly-, moderately- and the least- consumed diets were selected for the study (Table 1).

**Quantity of Recipe and Processing Method**

Recipe, quantity and type of processing applied to the recipe and most common method of cooking the commonly consumed diets in each state were also adopted based on their responses (Table 2).

**Table 1: Selected Commonly Consumed Traditional Diets of Jigawa, Kano and Katsina States with their codes**

|  |  |  |  |
| --- | --- | --- | --- |
| Codes | State | Selected diets | Symbol |
| 001 | Jigawa state | *Tuwon masara* using white maize served with *kuka* soup | TMW SWKS |
| 002 | Jigawa state | *Tuwon masara* using yellow maize served with *kuka* soup | TMY SWKS |
| 003 | Jigawa state | *Danwake* served with groundnut oil and pepper | *Danwake* SWGOP |
| 004 | Jigawa state | Moimoi | - |
| 005 | Kano state | *Tuwon masara* using white maize served with *kuka* soup | TMW SWKS |
| 006 | Kano state | *Tuwon masara* using yellow maize served with *kuka* soup | TMY SWKS |
| 007 | Kano state | Rice and beans served with groundnut oil and pepper | Rice and Beans SWGOP |
| 008 | Kano state | *Danwake* served with groundnut oil and pepper | *Danwake* SWGOP |
| 009 | Katsina state | *Tuwon masara* using white maize served with *kuka* soup | TMW SWKS |
| 010 | Katsina state | *Tuwon masara* using yellow maize served with *kuka* soup | TMY SWKS |
| 011 | Katsina state | *Danwake* served with groundnut oil and pepper | *Danwake* SWGOP |
| 012 | Katsina state | *Dambu* | *-* |

**Table 2: Recipe for Commonly Consumed JG, KN and KT Diets with Their Quantities and Type of Processing Involved.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Code | Recipe | Quantity of ingredients (g)  Jigawa (JG) Kano (KN) Katsina (KT) | | | Processing  Method |
| 001, 002, 005, 006, 009, 010 | Maize powder | 400 | 400 | 400 | Grinding |
| Groundnut oil | 13.46 ml | 13.50 ml | 9.30 |  |
| Onion | 70.13 | 69.03 | 67.09 | Blending |
| Hot pepper | 32.37 | 31.77 | 32.56 | Blending |
| Meat | 244.32 | 242.20 | 241.72 | Slicing |
| Salt | 1.00 | 1.00 | 1.00 |  |
| Seasoning agent | 16.39 | 16.42 | 15.97 |  |
| *Daddawa* | 22.67 | 21.45 | 20.59 | Grinding |
| Potash | 0.15 | 0.15 | 0.15 |  |
| *Baobab* leaf | 20.13 | 20.00 | 20.13 | Grinding |
| Tomato | - | - | 9.47 | Blending |
| Water for TMW | 1914.16 ml | 1914.16 ml | 2028.63 ml |  |
| Water for TMY | 1914.16 ml | 1914.16 ml | 2028.63 ml |  |
| Water for *kuka* soup | 1910.20 ml | 1525.62 ml | 2028.63ml |  |
| 003, 008, 011 | Wheat | - | 54.75 | 68.70 | Grinding |
| Guinea corn | 112.87 | 27.59 | 63.29 | Grinding |
| Beans | 105.72 | 26.09 | 58.27 | Grinding |
| Cassava | 150.15 | 149.93 | 109.76 | Grinding |
| Bambaranut | - | 29.60 |  | Grinding |
| Mixed flour | 368.74 | 288 | 300 |  |
| *Boabab* leaf | 34.66 | 30 | 30 | Grinding |
| Potash | 17.03 | 18 | 18 |  |
| Groundnut oil | 31.50 | 34.44 | 24.75 |  |
| Pepper | 150.21 | 222.61 | 222.61 | Grinding |
| Seasoning Agent | 64.43 | 115.97 | 115.96 |  |
| Salt | 6.45 | 7.00 | 7.00 |  |
| Pepper mix | 7.25 | 6.12 | 3.47 |  |
| Water | 3265.04 ml | 3828.32ml | 3828.32 ml |  |
| 004 | Beans | 245.58 | - | - | Soaking, blending |
| Hot pepper | 36.58 | - | - | Blending |
| Onions | 40.26 | - | - | Blending |
| Seasoning agent | 19.33 | - | - |  |
| Salt | 0.99 | - | - |  |
| Palm oil | 21.64 | - | - |  |
| Groundnut oil | 10.12 | - | - |  |
| 16 nylon | 5.41 | - | - |  |
| Water | 2498.49 ml | - | - |  |
| 007 | Rice |  | 354.53 | - |  |
| Beans |  | 158.02 | - |  |
| Potash |  | 0.2 | - |  |
| Groundnut oil |  | 34.29 ml | - |  |
| Pepper |  | 222.61 | - | Grinding |
| Seasoning agent |  | 115.97 | - |  |
| Salt |  | 7.00 |  |  |
| Mixed pepper |  | 3.81 |  |  |
| Water |  | 1914.16 ml |  |  |
| 012 | Maize granules | - | - | 472.16 |  |
| Groundnut | - | - | 100.00 | Grinding |
| *Moringa* leaf | - | - | 114.49 |  |
| Onion | - | - | 94.54 | Slicing |
| Hot pepper | - | - | 28.76 | Blending |
| Seasoning agent | - | - | 34.14 |  |
| Salt | - | - | 0.50 |  |
| Oil | - | - | 46.48 |  |
| Water | - | - | 2871.24 ml |  |

**2.3 Recipe Preparation**

All the recipe ingredients were purchased from the main markets in each of the three states that constitutes the Northwest zone Nigeria (Jigawa from Kachako market, Kano from *Dawa*nau and ‘Yan kaba markets and Katsina from Dutsin-ma market) from months of January - February, 2019 and used for food preparations. The diets were prepared, dried and grounded into powder using mortar and pestle and used for the amino acids analysis. The powdered samples were kept in tight plastic containers at room temperature prior to analysis.

**2.4 Subject: Inclusion and exclusion criteria and Data collection**

Only consented Subject(s) were considered and those with blood glucose level above the normal range (65-120mg/dl) or under the age of 18 years were excluded for the study.

**2.5 Subjects Preparation and Food Administration**

A total of two hundred and eighty (280) individuals who consented for the study around Kano metropolitan specifically Bayero University, Kano, BUK using consent sort form participated in the study. Some basic and simple information such as age, sex, previous meal taken the previous day were obtained from the subjects. Subjects fasted for 12 hours (fast from the time they took their last meal to the morning of the study) and all reported to the GI testing venue at 8:00am. The reporting time and venue of both the test and reference food’s is the same. Weight of subjects were taken using standard scale without their shoes or any heavy objects such as phone, bag, watch etc. Height was taken using standiometer. Body Mass Index (BMI) was calculated as weight (in Kg) divided by height (in m2) of the subject.

**Test Foods:** A total of two hundred and forty (240) subjects were given an equivalent measured amount of 50g available carbohydrate of test food in which 20 subjects were given for each diet (twelve diets). The time each subject started taken the meal was recorded. Blood samples were collected at 0, 30, 60, 90 and 120th minutes with the glucose concentrations measured and recorded accordingly with previous meal of each respondent also documented.

**Standard/Reference Food (D-Glucose):** After analysis for fasting blood glucose 0 hr., a glucose solution made from 50g glucose and 200ml of water was given to each participant (40). After the start of the consumption of the glucose solution (the reference sample), blood glucose concentration of the consented subjects was measured at 30, 60, 90 and 120th min and recorded accordingly with previous meal of each respondent also documented.

**2.6 Blood collection**

All the subjects had their thumbs disinfected by swabbing with methylated spirit. The thumb was pricked with sterile lancet, a rounded drop of blood was obtained by squeezing the finger gently, with drop of blood placed on the blood glucose test strip which was inserted into a calibrated glucometer (Accu-CHECK Active) that gives direct reading after 45 second based on the glucose oxidase assay method [12] to determine the blood glucose.

**2.7 Calculation of:**

**a. Glycemic index:** Blood glucose response curve was plotted, which in turn was used to calculate the GI. Glycemic index was calculated from the blood glucose response curve at 0-120 min, the incremental area under the blood glucose response curve of test meal was obtained by summing up the surface triangles, rectangles and trapeziums under the glucose response curve. The GI of test meal was then calculated by dividing the Incremental Area Under Curve (IAUC) of the test meal by IAUC of control food (glucose) multiplied by hundred.

**b. Glycemic Load:** GL was calculated by dividing the GI of the meal by 100 and multiply it by the gram of available carbohydrates in the consumed meal. Mathematically represented as:

**2.8 Statistical Analysis**

Results were presented as mean ± standard error of the mean. All data were subjected to analysis of variance (ANOVA) and independent samples test using SPSS software version 20.0 with P value <0.05 considered significant.

**3.0 RESULTS AND DISCUSSION**

Table 1 shows the glycemic index and glycemic load of prepared diets commonly consumed in Jigawa, Kano and Katsina States, Nigeria as well as age and BMI of the consented subjects that participated in the study. *Danwake* SWGOP was found to have higher GI (91.61 ± 2.22) and GL (45.81 ± 1.11) values while TMW SWKS have the least GI (77.55 ± 1.89) and GL (38.77 ± 0.95). The GI and GL of KN TMW SWKS was slightly higher than that of JG TMW SWKS and KT TMW SWKS though not statistically significant (P>0.05). BMI and age of the participated subjects were within the range of 18.96 ± 0.26 – 22.30 ± 1.35 and 22.90 ± 0.62 – 42.50 ± 2.00 respectively. However, there is significant difference (P<0.05) between the ages of the consented subjects used for the study for the three state diets. There is significant increase (P<0.05) between GI and GL of JG TMY SWKS and KN TMY SWKS as well as the age and BMI of the consented subjects. There is also significant increase (P<0.05) between GI, GL and BMI for JG TMY SWKS and KT TMY SWKS consented subjects. Significant decrease (P<0.05) was observed between GI and GL of JG *Danwake* SWGOP Vs KN *Danwake* SWGOP and JG *Danwake* SWGOP Vs KT *Danwake* SWGOP respectively.

**Table 3:** **Glycemic Index and Glycemic Load of Prepared Diets Commonly Consumed in Jigawa State, Nigeria**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Code** | **GI** | **GL** | **AGE** | **BMI** |
| 001 | 77.549  ±  1.891 | 38.775  ±  0.946 | 35.600  ±  2.519 | 21.994  ±  0.729 |
| 002 | 78.436  ±  1.258 | 39.218  ±  0.629 | 24.250  ±  0.512 | 18.961  ±  0.257 |
| 003 | 91.609  ±  2.224 | 45.805  ±  1.112 | 25.850  ±  0.769 | 20.938  ±  0.636 |
| 004 | 83.590  ±  1.872 | 41.795  ±  0.936 | 22.900  ±  0.615 | 19.977  ±  0.420 |

**Values are mean ± sem. n= 20. Key: GI: Glycemic Index, GL: Glycemic Load, BMI: Body Mass Index.**

**Table 4: Glycemic Index and Glycemic Load of Prepared Diets Commonly Consumed in Kano State, Nigeria**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Code** | **GI** | **GL** | **AGE** | **BMI** |
| 005 | 81.878  ±  1.329 | 40.939  ±  0.665 | 30.100  ±  2.027 | 21.291  ±  0.319 |
| 006 | 83.845  ±  1.960 | 41.923  ±  0.980 | 42.500  ±  2.003 | 21.502  ±  0.765 |
| 007 | 80.819  ±  0.921 | 40.409  ±  0.460 | 24.950  ±  1.215 | 21.462  ±  0.651 |
| 008 | 78.148  ±  1.655 | 39.074  ±  0.828 | 35.800  ±  2.896 | 21.314  ±  1.259 |

**Values are mean ± sem. n= 20. Key: GI: Glycemic Index, GL: Glycemic Load, BMI: Body Mass Index.**

**Table 5: Glycemic Index and Glycemic Load of Prepared Diets Commonly Consumed in Katsina State, Nigeria**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Code** | **GI** | **GL** | **AGE** | **BMI** |
| 009 | 78.064  ±  1.515 | 39.032  ±  0.757 | 23.450  ±  0.613 | 21.449  ±  0.980 |
| 010 | 82.155  ±  1.327 | 41.077  ±  0.664 | 23.950  ±  0.344 | 21.747  ±  1.013 |
| 011 | 79.783  ±  1.636 | 39.891  ±  0.818 | 27.700  ±  2.787 | 22.296  ±  1.354 |
| 012 | 79.678  ±  1.522 | 39.839  ±  0.761 | 29.800  ±  2.757 | 19.416  ±  0.339 |

**Values are mean ± sem. n= 20. Key: GI: Glycemic Index, GL: Glycemic Load, BMI: Body Mass Index.**

The GI/GL concept has been reported as a way of identifying foods that might be useful in the disease management [13]. GI has been transformed from a potentially useful tool in planning diets for diabetic patients to a key player for the prevention and management of diabetes, dyslipidemia, cardiovascular diseases and certain types of cancers [13]. GI and GL of the commonly consumed traditional diets in all the three states studied were found to have high GI and GL values as compared with GI scale (low GI: ≤55, medium GI: 56-69 and high GI: ≥70) and GL scale (low GL ≤10, medium GL 11-19 and high GL: ≥20). In contrast, Nnadi and Keshinro [14] reported low GI/GL values of three commonly consumed meals in Enugu, Nigeria whereas Omoregie and Osagie [15] reported high glycemic index and load values of some Nigerian foods while Dereje *et al*. [16] established low and high GI values of Selected Ethiopian Foods. It has been established that different food processing techniques affect the digestibility of starch which has some implications on the GIs [13]. Plant foods are usually processed before they are consumed by man hence according to Omoregie and Osagie [15] “processing (grinding, sieving etc) the seeds removes the fiber-rich outer bran, the vitamin and mineral rich inner germ leaving endosperm. This treatment caused reduction in particle size and faster gelatinization of starch, thereby increasing the GI/GL. Therefore, processing of foods using high temperatures could induce gelatinization, thereby permanently disrupting the amylose-amylopectin structure of the starch complex, making it more readily accessible to digestive enzymes” [13]. “Gelatinized starch are more susceptible to degradation by α-amylase than are native starch granules. High GI and GL diets may contribute to the risk of weight gain leading to hyperinsulinemia and insulin resistance via increase in the blood glucose concentration. This leads to greater carbohydrate oxidation, less fat oxidation, and greater storage of energy in adipose tissue. The high insulin response causes large fluctuations in blood glucose, and, as a consequence, the feeling of hunger may return sooner than usual, leading to earlier initiation of the next meal”[17]. Therefore, these effects on blood glucose may promote overconsumption of energy leading to a greater risk of developing obesity and consequently diabetes mellitus later in life in the study area.

Though beans are the main ingredients used in preparing moimoi (code 004, Table 3) , it high GI/GL value when compared to GI/GL scale may be due to consumption of carbohydrates rich diets by the majority of subjects used for the study as observed in their previous meals (24hr recall not included in this paper) and also high content of all the glycogenic amino acids (except Alanine and Cysteine) in moimoi compared to the other prepared diets as revealed by the amino acid profile of the prepared diets (published in NAJNFR)). However, the lower GI/GL of TMW SWKS and TMY SWKS as compared with moimoi may be due to speculation that, combining carbohydrates rich diets (in this case maize) with leafy vegetables (Baobab leaf used in preparing the *kuka* soup), protein (meat used in preparing the *kuka* soup) and fat may lower the GI value of a diet [13].

Comparison between GI and GL of similar diets from the three states of the northwest zone studied revealed KN TMW SWKS and KN TMY SWKS (Table 4) had higher GI/GL compared to JG TMW SWKS (Table 3) and KT TMW SWKS & TMY SWKS (Table 5) which had the higher crude fiber content with decrease GI and GL. According to David *et al.* [18] digestion, absorption, nature of the starch, cooking method, particle size, and presence of ﬁber, fat, and proteins were found to result in variances in the glycemic index of foods. JG *Danwake* SWGOP (Table 3) had the higher GI and GL while that of KN had the lowest and the differences may be to the different types of ingredients used in their preparations (Table 2); Presence of bambaranut (with high protein and fat content) and wheat (with high protein content) in KN Danwake in addition to all ingredients of JG Danwake (Table 2) may contribute to the decreased GI of KN Danwake. Also the higher crude fiber contents of KN Danwake and the ingredients used in preparing the selected diets were purchased from different state under study may explain the observed difference. According to Eleazu [13] variety is one key factor that affects the GI of foods and stated that even within the same variety, glycemic indices may vary probably due to differences in accessions within the same variety.

This study showed that, there is no association between GI/GL and age or BMI of the consented subjects that participated in the study. According to Galarregui *et al*. [19] and Helle *et al*. [17], a diet with a high glycemic index (GI) and glycemic load (GL) may contribute to the risk of weight gain because such a diet can lead to hyperinsulinemia and insulin resistance via increases in the blood glucose concentration. Evidences suggest that chronic consumption of high glycemic index (GI) foods may lead to high Oxidative stress (OS) and insulin resistance (IR) (Galarregui *et al.* [19]; Arikawa *et al.* [20]. “Therefore, it has been demonstrated that carbohydrate quality plays a signiﬁcant role in the onset of several chronic diseases, such as diabetes and heart disease” (Galarregui *et al.* [19]. “OS is recognized as a contributor to the pathogenesis of obesity, type 2 diabetes, atherosclerosis, and non-alcoholic fatty liver disease among others” [21]. OS is the disturbance in the balance between the production of reactive oxygen species (free radicals) and antioxidant defense system in body cells [19] which has been linked to IR, a pathological condition where a normal or elevated insulin level produces an attenuated biological response [19].

“Humans can be fattened on a predominantly carbohydrate diet due to the apparent ease by which carbohydrate can be converted to fat. However, human lipogenesis from glucose and weight gain from carbohydrate is thought to be caused by sparing lipolysis rather than direct carbohydrate lipogenesis. Glucose is the precursor for both the glycerol and the fatty acid components of triacylglycerols. The glycerol portion can be formed from dihydroxyacetone phosphate (DHAP) which is then converted to glycerol 3-phosphate by glycerol 3-phosphate dehydrogenase and NADH to which CoA-activated fatty acids attach in the course of triacylglycerol synthesis. Another reaction, which links glucose metabolism to fatty acid synthesis, is that of the pyruvate dehydrogenase complex which converts pyruvate to acetyl CoA, the starting material for the synthesis of long-chain fatty acids as well as a variety of other lipids” [22].

**4.0 CONCLUSION**

The GI/GL concept has been reported as a way of identifying foods that might be useful in the disease management. GI and GL of the commonly consumed traditional diets studied in northwest geopolitical zone, Nigeria was found to be high as compared with GI and GL scale. The higher the GI/GL, the greater the expected elevation in blood glucose and insulinogenic effect of the food, and the greater the risk of developing chronic diseases. High GI and GL diets may contribute to the risk of weight gain leading to hyperinsulinemia and insulin resistance via increase in the blood glucose concentration.Therefore, overconsumption of these high glycemic index traditional diets together with sedentary life style may lead to weight gain, obesity and consequently diabetes mellitus in the study area.

**Ethical Apporval**

Approval/Ethical clearance was obtained from the research and ethics committee of Kano State Ministry Of Health (MOH/OFF/797/T.1/1079) (Appendix I).

Disclaimer (Artificial intelligence)

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APPENDIX I

