Preparing Diet List Suggestion with Fuzzy Expert System

Okan UYAR[*1]

Abstract: Proportion of disease is growing due to the malnutrition and sedentary life. In this work, a diet list is proposed to the user by calculating the necessary amount of calorie according to gender, weight, height, age and activity level. Diet list are prepared for seven days of a week as divided by six meals. Parameter assessment of users and offering recommendations are made via fuzzy expert system. Prepared diet list are constituted considering calories of nutrients and based on the dieticians' general diet list proposals. Developed software also includes some functions such as nutrition advices, calculation of ideal weight, information about benefits of several nutrients and calorie evaluation of some daily activities. Thus, nutrition suggestion software carried out against for growing obesity and healthy eating problems in order that people would educate themselves about wellness.

1. Introduction

European office of World Health Organization (WHO) pointed out in "European Food and Nutrition Action Plan 2015–2020" that malnutrition, obesity and unhealthy diets lead to noncommunicable diseases (NCDs). Also, these cause economic and social costs for individuals, families and countries. In the same report, about %57.4 of people over the age of 20 are reported as overweight or obese. Action plan that further analyzes given in this report is about implementation of healthy diet and controlling the food productions with the aid of governments [1]. Besides all these, diabetes, hypertension and high cholesterol are among the top 10 causes of death in the world [2].

Every nutrition plays an important role for supporting daily activities of the people. Therefore, a balanced diet should be in proportion to the values of carbohydrate, protein, fat, vitamins and minerals. Values of these nutrients should be calculated by taking into account taken and consumed energy. Nevertheless, people do not prefer allowing time to go dietitian because of their habits and busy schedule. To overcome this problem, web or pc based expert systems that have input parameters such as current diseases, activity level and age should be used.

There are many studies which are focused on diet planning for humans. Some of them are focused on a specific region or a situation. Kljusurić et al. [3] presented a nutrition planning system using fuzzy logic modeling method for boarding schools in Croatia. Daily menu price, meal preference, nutritional and energy value of foods considered input parameters. They take meal preference as input since nutrition habits are different in various places of Croatia. Their software is suitable for planning of menu which has optimal cost and adequate nutrient intake. Kurozumi et al. [4] proposed a Japanese diet evaluation system that uses Fuzzy

Markup Language and food exchange list published by Japan Diabetes Society. Dietary healthy level is evaluated by calculating the nutrient percentages of foods selected for menu and proposed method according to the Japanese dietician database. Another region specific work is presented by Şahiner et al. [5]. They examined how to prepare a sample weekly menu for a young person who has a business environment that requires intensive physical activity and his revenue determined by Türk-İş (Confederation of Turkish Trade Unions) on the edge of hunger.

Faiz et al. [6] implemented an approach that gives diet and exercise recommendations for diabetes by using Web Ontology Language and Semantic Web Rule Language as a specific human case application. Similarly, Li et al. [7] proposed automated food ontology for diabetes that cares necessary nutrient values and limitations. They used Hierarchical Clustering Algorithms, Class Naming by intersection naming and instance ranking by granular ranking and positioning so as to construct various food groups (diet lists). Another work considers the diseases were presented by Chen et al. [8]. An diet recommendation was offered by using Fuzzy Rules and Knapsack Method that utilizes users' height, weight, activity level, renal function, hypertension, high cholesterol and preference data. Mamat et al. [9] proposed Fuzzy Multi-Objective Linear Programming application that provides an optimum diet list includes enough nutrients for a day with reasonable price. Decision Support System also used in this work to recognize the type of disease according to the symptoms obtained from the users.

Main method used in the diet assessment systems is Fuzzy Logic and its derivatives. Lee et al. [10, 11] produced Type-2 Fuzzy Ontology based on Type-2 Fuzzy Food Ontology and Fuzzy Markup Languege-2(FML2). Similarly, they presents to the user healthy level of the foods in diet with semantic expressions by developing FML2 based agent. Mamat et al. [12] made a balanced diet planning using Fuzzy Linear Programing approach. In this planning, assessment of carbohydrate and fat amounts in the food that eaten every day, food prices and the amount of nutrients that required to take a day are for 30 years old sedentary woman considered. Mák et al. [13] have presented an equation that define dietary and physical activity advisory problem. Proposed equation expressed as "Hierarchical Multi-Objective Dietary Menu

_____

Electric & Electronic Engineering, Selcuk University,
Technology Faculty, Konya, TURKIYE
* Corresponding Author: Email: okanuyar@selcuk.edu.tr

Planning Problem with Harmony" allows the formalization of any diet and physical activity planning problem.

When we interpret the proposed works we deduced that there is a necessity for a software support to the diet list preparation. Another argument is usefulness of fuzzy logic based expert system since input parameters for diet and outcome presentation are verbal. Also, diet is a multi-parameter process should vary according to the individual and cultural characteristics. In this paper, we calculated   adequate calories in proportion to the person's gender, weight, height, age and activity level parameters by using fuzzy logic. After calorie determination software presents one diet list that previously prepared. This diet list arranged according to the food culture and presence in related area.

2. Nutrition and basal metabolism

A. Nutrition

Nutrition is a conscious activity, taking nutrients needed by the body adequately and on time, to protect the health and improve the quality of life. Taking every item of the energy and nutrients that essential for growing-regeneration and working of the body and proper use of them in the body is called "Adequate and Balanced Nutrition" [14].

Nutrients that we need for healthy and balanced diet can be collected in 5 main groups as shown in Fig. 1.

When we examine the pyramid, we should say that grains are most preferred nutrient group. Hereinafter vegetables and fruits come. Milk and dairy products with meat group foods follows this group. We should consume fat and sugar group at least [14].

We can group the animal and plant nutrients according to the chemical properties as follows:
- Carbohydrates
- Proteins
- Fat
- Vitamin
- Minerals
- Water

There are similar or different features of each food group which are necessary for the body. Healthy eating achieved by taking these nutrient groups adequately and balanced as mentioned before.

1) Carbohydrates

Carbohydrates are used as primary energy source of body and it is important for brain functions and nervous systems. The building blocks of carbohydrates are glucoses. It can be divided as monosaccharaides, disaccharides and polysaccharides. Also while the most common dietary disaccharides can be divided as are maltose, lactose, and sucrose, the most common forms of digestible polysaccharides are amylose and amylopectin. Monosaccharaides and disaccharides are found in such food as fruits, vegetables, milk, milk productions, sugar and sugar products. And, as for polysaccharides, they are found in such food as cereals, bread, pasta, rice and potatoes. Glucose is stored as the form of glycogen in the liver and mostly skeletal muscle [15, 16].

2) Proteins

Proteins are related with all forms of plant and animal life and 20 percent of our body is composed of protein. Proteins form the structure of each cell of our body tissue, muscle, internal organs, tendons, skin, hair and nails. And it also used for energy productions as a fuel in such metabolic formation activations as growth, formation of new tissue and repairment of tissue damaged. Besides it is necessary for the production
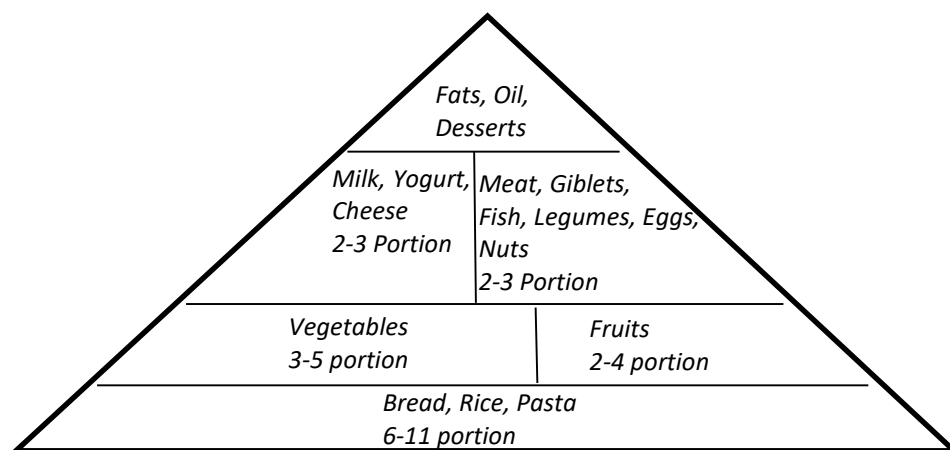

Fig. 1 A healthy eating pyramid [15]

of many enzymes, hormones (adrenaline and insulin) and neurotransmitters. In addition to that it has important role in the protection of fluid balance in tissues, the transition of nutrients into cell sand out and making the blood. Protein is composed of 20 amino acids and these amino acids are grouped as essential amino acids and non-essential amino acids [15, 16].

3) Fat

Fat can provide more than twice the energy by weight compared to protein and carbohydrate and it is essential macronutrients which have most energy dense. Fat provides energy production, insulation against the cold, transportation of fat-soluble vitamins in the body and making the body tissue. Fat is grouped as saturated fat (butter,

margarine), monounsaturated fat (olive oil, soybean oil, fish oil) and poly unsaturated fat (sunflower, corn). Especially, saturated fat increases the amount of fat in the body. There are a lot of fat in such food as meat, fish, milk, cream, eggs, nuts, chocolate, olive, coconut, cottonseed, corn, soybean, flax and peanut [15, 16].

4) Vitamins

Vitamins, cannot be synthesized by the body, are required to support health and well-being. Vitamins are found in small amounts in foods and are designated as nutrients. They help catalyzing the numerous biochemical reactions and aren't used for direct source of energy. Vitamins are grouped as Water-Soluble Vitamins and Fat-Soluble Vitamins. B group vitamins and vitamin C are the water-soluble vitamins. Unlike the fat-soluble vitamins, they leave the body after

completing their task; they don't accumulate in the body [15, 17].

5) Minerals

Minerals, occur naturally, are inorganic solid with a specific chemical composition. The properties of minerals can be listed as follows:

- It occurs naturally.
- It has the characteristics of any part of the whole.
- It has a specific chemical formula.
- It is solid but rarely fluid.
- Inorganic.

The chemical compounds obtained synthetically in the laboratory do not considered as mineral with the technological progress. These types of solid materials are named as artificial minerals. Each mineral have different features for the body and the features of some minerals are described. Iron is the necessary element for the delivery of oxygen to tissues and the use of oxygen at the cellular and subcellular levels. Magnesium is required in a variety of cellular activities that support diverse physiologic systems. Zinc is necessary for more than 300 enzymes activity. Chromium is the essential mineral for regulation of glucose, lipid and protein metabolism [17, 18].

6) Water

The water is abundant in the world, indispensable for life, odorless and tasteless compound. The amount of fluid we need to take daily is associated the calorie we spend. 1 ml water should be taken per calorie. Water is the essential element for life and it helps to control of body temperature, use of

TABLE I
CONTENT AND CALORIES OF SOME NUTRIENTS FOR 100 GR [19]

Food	Calorie	Protein	Fat	Carbohydrate
Trout	168	18,3	10	0
Perch	93	19,2	1,2	0
Beef Meat (Low Fat)	156	19,7	8	0
Sausage	452	21,4	40,8	0
White Chicken	114	23,2	1,7	0
Broad Bean	338	25,1	1,7	58,2
Haricot Bean	340	22,3	1,6	61,3
Lentil	340	24,7	1,1	60,1
Chickpea	360	20,5	4,8	61
Pea	348	24,2	1	62,7
Sunflower Seed	560	24	47,3	19,9
Almond	598	18,6	54,2	19,5
Walnut	651	14,8	64	15,8
Hazelnut	634	12,6	62,4	16,7
Pumpkin seeds	610	30	50	10
Pear	61	0,7	0,4	15,3
Strawberry	37	0,7	0,5	8,4
Fresh Figs	80	1,2	0,4	20,4
Melon	33	0,8	0,3	7,7
Banana	85	1,1	0,2	22
Okra	36	2,4	0,3	7,6
Potato	76	2,1	0,1	17,1
Fat White Cheese	289	22,5	21,6	0
Cheddar cheese	404	27	31,7	1,4
Whole Milk	61	3,3	3,3	4,7
Oil Yogurt	61	3,5	3,3	4,7
Egg	158	12,1	11,2	1,2
Honey	315	0,3	0	78,4
Chocolate	528	4,4	35,1	57,9
Candy	385	0	0	99,5
Bulgur	357	10,3	1,2	78,1
Wheat Bread	276	9,1	0,8	56,4
Macaroni	369	12,5	1,2	75,2
Rice	363	6,7	0,4	80,4
Sunflower oil	884	0	100	0
Margarine	736	0,6	81	0,4
Olive oil	884	0	100	0
Butter	717	9	81,1	0,1
Tomato paste	98	2,7	0,4	21,3
Black olive	207	1,8	21	1,1

nutrients in the body, digestion and absorption in stomach. Fluid intake must be increased to prevent dehydrations.

Thirsty feel can be seen late in children and recommended amount of fluid are as follows to avoid of fluid loss for children:

Up to 10 kg bodyweight →100 ml / kg / day

Up to 20 kg bodyweight →50 ml (added for each kg) / kg / day

Up to 30 kg bodyweight →25 ml (added for each kg) / kg / day [15, 18].

Calorie, protein, fat and carbohydrate values of some nutrients can be shown in Table I.

B. Basal Metabolism

All the chemical changes that occur in the cell to sustain life is called "metabolism". Metabolism covers all cell construction and demolition events. Mandatory energy expenditure for working of the organs, keeping body heat and keep living in the case of complete rest is called "Basal Metabolism" [20].

Several prediction equations were presented. Harris-Benedict equation created in 1919 was the most known. Mifflin St Jeor equation used for our work as follows:

$$P = \left(\frac{10*m}{1\,kg} + \frac{6.25*h}{1\,cm} - \frac{5*a}{1\,year} + s\right) \qquad (1)$$

Where s is +5 for males and −161 for females, P is the total heat production at complete rest, m is the mass (kg), h is the height (cm) and a is the age (years).

Daily energy expenditure of individual determines his/her required energy intake for a day. Energy requirements for a normal person should be calculated by summing of the basal metabolism, need for daily physical activity and thermic effects of the foods. Energy need for sportive activities should be add this value for athletes. Thermic effect of the foods means that increase in the body's metabolic rate that is produced by the consumption, digestion, metabolism, and storage of food. Increase in the body's metabolic rate or energy consumption is about %3 for fat, %6 for carbohydrate and %16-20 for protein [15]. Energy expenditure of some activities can be shown in Table II.

3. Definition Of Fuzzy Expert System

Expert system is software that provides solutions and suggestions by using knowledge and experience of an expert has skill in any area. Fuzzy logic is beneficial for taking

TABLE II
CALORIES BURNED DURING SOME ACTIVITIES FOR A 70 KG PERSON [21]

Activity	Burned Calorie
Cycling,12-13.9 mph, moderate	563
Swimming butterfly	774
Watering lawn or garden	106
Walking 2.0 mph, slow	176
Carrying infant, upstairs	352
Playing tennis	493

linguistic values from the user. Expert systems have to include the 3

following units:

Knowledge Database is an updatable structure which information is obtained from experts, books and other literature.

Result Inference Mechanism should reach a conclusion by using rules in the knowledge database, facts and other whole information through the instrument of both forward and backward chaining method.

User Interface uses the expert system and provide interaction between the user and system. Basic structure of a Fuzzy Expert System is shown Fig. 2.
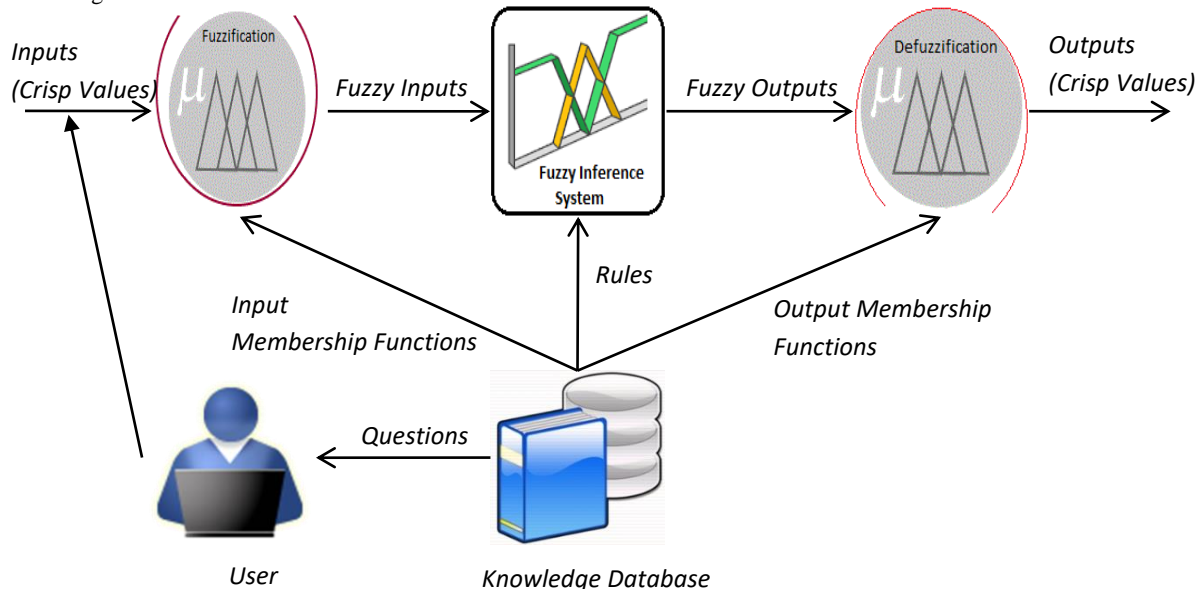
4. Program Interface and Features

Main page of our software is shown in Fig. 3. Users input their personal information and desired values such as gender, workload, weight, height and age. According to this parameters required calorie determined and diet lists consonant with this value would be presented to the user. Software also includes enlightenments about several foods and vitamins. Additionally, user can calculate his ideal weight

Fig. 2 Basic structure of Fuzzy Expert System
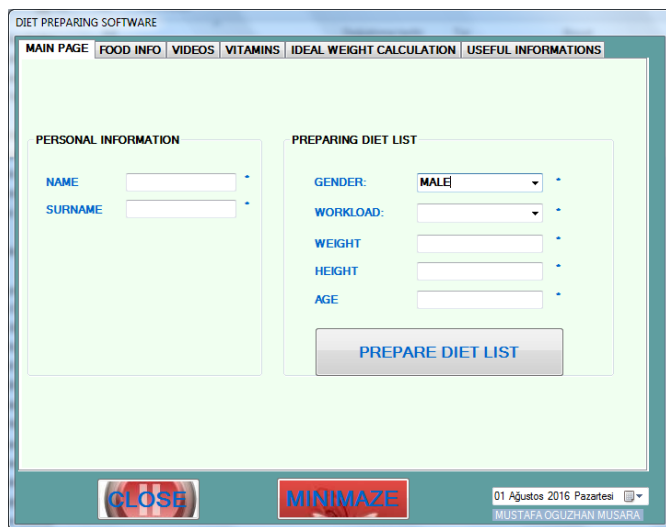
Fig. 3 Interface of developed software

Diet list are prepared for seven days of week as divided by six meals. Diet list that previously prepared taking into account the calorie values of the foods and these are classified according to the fuzzy inference outputs. After required calorie calculation, relevant list proposed to the user.

5. Conclusion

Balanced diet should help users to prevent eating disorder such as anorexia nervosa, diabetes, and obesity. This study shows that application of fuzzy logic can be used to represent recommended energy and nutrient intake adequately, as well as to present acceptable price and preferences of menu selection for people in a specific region. Diet list is proposed to the user by calculating the necessary amount of calorie according to gender, weight, height, age and activity level. These lists are prepared for seven days as divided by six meals and constituted considering calories of nutrients and based on the dieticians' general diet list proposals.
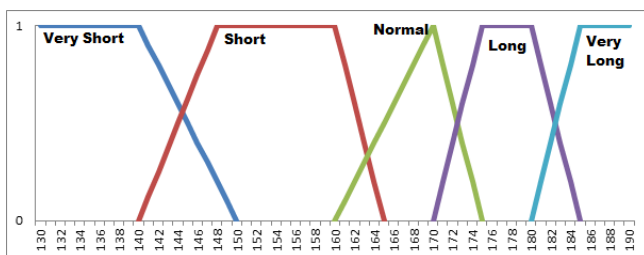
Fig. 4 Membership functions example for height

and body mass index. Membership functions of female height which is one of the diet system inputs is shown in Fig. 4.

REFERENCES

[1]   World Health Organization. *European food and nutrition action plan 2015-2020.* WHO Regional Office for Europe 2014 [cited 2016 15 July]; Available from: http://www.euro.who.int/__data/assets/pdf_file/0008/253727/64wd14e_FoodNutAP_140426.pdf.

[2]   World Health Organization. *Global Health Risks.* 2009 [cited 2016 July, 15]; Available from:

http://www.who.int/healthinfo/global_burden_disease/GlobalHealth Risks_report_full.pdf.

[3]   Kljusurić, J.G. and Ž. Kurtanjek, *Fuzzy logic modelling in nutrition planning-application on meals in boarding schools*, in *Current Studies of Biotechnology, Vol. III-Food*. 2003, Medicinska naklada.

[4]   Kurozumi, K., et al. *FML-based Japanese diet assessment system*. in *Fuzzy Systems (FUZZ), 2013 IEEE International Conference on*. 2013. IEEE.

[5]   ŞAHİNER, A. and G. BUZKAN, *An Application of Fuzzy Goal Programming to a Specific Diet Problem*. Journal of Natural & Applied Sciences, 2010. **14**(2).

[6]   Faiz, I., et al. *A semantic rules & reasoning based approach for Diet and Exercise management for diabetics*. in *Emerging Technologies (ICET), 2014 International Conference on*. 2014. IEEE.

[7]   Li, H.-C. and W.-M. Ko. *Automated food ontology construction mechanism for diabetes diet care*. in *2007 International Conference on Machine Learning and Cybernetics*. 2007. IEEE.

[8]   Chen, R.-C., et al. *Constructing a diet recommendation system based on fuzzy rules and knapsack method*. in *International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems*. 2013. Springer.

[9]   Mamat, M., et al., *Fuzzy Multi-Objective Linear Programming Method Applied in Decision Support System to Control Chronic Disease.* Applied Mathematical Sciences, 2013. **7**(2): p. 61-72.

[10]   Lee, C.S., et al., *Diet assessment based on type‑2 fuzzy ontology and fuzzy markup language.* International Journal of Intelligent Systems, 2010. **25**(12): p. 1187-1216.

[11]   Lee, C.-S., et al., *Type-2 fuzzy set and fuzzy ontology for diet application*, in *Advances in Type-2 Fuzzy Sets and Systems*. 2013, Springer. p. 237-256.

[12]   Mamat, M., et al., *Fuzzy linear programming approach in balance diet planning for eating disorder and disease-related lifestyle.* Applied Mathematical Sciences, 2012. **6**(103): p. 5109-5118.

[13]   Mák, E., et al. *A formal domain model for dietary and physical activity counseling*. in *International Conference on Knowledge-Based and Intelligent Information and Engineering Systems*. 2010. Springer.

[14]   Hacettepe Üniversitesi Beslenme ve Diyetetik Bölümü. *TÜRKIYE'YE ÖZGÜ BESLENME REHBERI*. 2004 [cited 2016 July, 15]; Available from: http://beslenme.gov.tr/content/files/yayinlar/kitaplar/diger_kitaplar/beslenme_rehberi.pdf.

[15]   Pehlivan, A. *Çocuk ve Genç Futbolcuda Beslenme*. 2009 [cited 2016 July, 15]; Available from: https://www.tff.org/Resources/TFF/Documents/2009DK/FGM/yayinlar/aylik-kitapcik/Sporcuda-Beslenme(Temmuz).pdf.

[16]   Litchford, M.D., *Macronutrient recommendations: protein, carbohydrate, and fat*, in *The ASMBS Textbook of Bariatric Surgery*. 2014, Springer. p. 101-109.

[17]   Lukaski, H.C., *Vitamin and mineral status: effects on physical performance.* Nutrition, 2004. **20**(7): p. 632-644.

[18]   *Mineral*. 2016 [cited 2016 July, 15]; Available from: https://tr.wikipedia.org/wiki/Mineral.

[19]   *Besinlerin Değer Cetveli*. 2011 [cited 2016 July, 15]; Available from: http://www.antrenmanyap.com/tr/blog.asp?ID=6&CID=7&AID=20&do=show.

[20]   Milli Eğitim Bakanlığı. *ENERJİ HESAPLAMALARI*. 2011 [cited 2016 July,15]; Available from: http://www.megep.meb.gov.tr/mte_program_modul/moduller_pdf/Enerji%20Hesaplamalar%C4%B1.pdf.

[21]   *Calories Burned During Exercise, Activities, Sports and Work*. 2016 [cited 2016 July, 15]; Available from: http://www.nutristrategy.com/caloriesburned.htm.