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Real-Time Technology Video-Coding Tools for Programming Multisensory Interventions Incorporating Exotic Local Fruits and Vegetables in Early Childhood: Implications for Pediatric Obesity Prevention Research

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SCIENTIFIC BACKGROUND

Promoting fruit and vegetable (henceforth referred to as F&V) intake in early childhood is significant to public health now and in the future. One of the goals of Healthy People 2020 (i.e., Goal NSW-15) is to increase the variety and contribution of vegetables in the dietary habits of the population, including its youngest members (U.S. Department of Health and Human Services, 2014). Education efforts fostering the consumption of fruits and vegetables in young children serve as a catalyst for efforts to combat childhood obesity by helping promote shifts in dietary patterns with decreased intake of energy-dense foods high in fat and sugars to foods high in vitamins, minerals, and phytonutrients. In our work with the U.S. federal food assistance program, Head Start, in the New England region of Western Massachusetts, we found that children were not achieving the recommended F and V intake, and that overweight and obesity, as well as micronutrient deficiencies (vitamins A and C, and iron) may be prevalent. Although the direct correlation between F and V consumption, and lowering of obesity is yet to be established in this early life-stage, F and V, especially exotic varieties are low-calorie, low-fat sources of vitamins (vitamin C, carotenoids), minerals, and fiber and provide an array of phytonutrients and antioxidants, and anti-inflammatory benefits.

SENSORY MESSAGING FOR EXOTIC FRUIT-VEGETABLE EDUCATION IN EARLY CHILDHOOD SETTINGS

Early childhood researchers and practitioners addressing obesity prevention should consider introducing exotic varieties of F&V with diverse sensory qualities. In this novel intervention effort, educators must consider utilizing messaging that involves engagement of the five senses (sight, smell, touch, taste, texture) and integrate the combination of all senses in children’s food perceptions and sensory-based food education activities. Introducing a variety of F and V in positive, engaging activities highlighting their sensory characteristics such as color, shape, texture, and taste, increases the likelihood that young children will taste and eat a wider variety of these health-promoting foods. Frequent experience with foods through sight, smell, and taste exposures are critical to achieving acceptance of these items in preschool age, as this experience has been shown to influence the hedonic preferences for exotic vegetables (swede, rucola) and berries (bilberry, lingonberry, and sea buckthorn) among children.

However, what is lacking is research assessing the correlation between preschool children’s sensory exploration, and mediators of exotic F and V consumption, such as willingness...
to taste and preferences. In the U.S, Cooperative Extension programs teach children about the diversity of F and V by engaging the children in multisensory activities in the classroom. A French ‘Glasses du Goût’ (Sapere taste education), developed for school-aged children, is a widely accepted sensory education method. In Finland, project funding has been available for training day care personnel and various sensory-based activities have been implemented in many kindergartens.\(^1\)\(^2\)\(^3\)

**BRIDGING THE CLASSROOM FEEDING PARAMETERS ASSESSMENT GAP WITH VIDEO OBSERVATIONS OF SENSORY INTERACTIOS**

Several studies have successfully used video recordings of infant feeding sessions through the application of the Feeding Infants: Behaviour and Facial Expression Coding System (FIBFECS) to document a clear and valid means of measuring *liking* and *wanting* in infants at the time of complementary feeding.\(^1\)\(^2\)\(^3\)\(^4\)\(^5\)\(^6\)\(^7\)\(^8\)\(^9\)\(^10\) This type of analysis represents an interesting avenue for future research.

**PROCESSING EARLY CHILDHOOD SENSORY NUTRITION EXPLORATIONS DATA WITH VIDEO-CODING OBSERVATIONS**

With the global rise in the use of sensory based approaches to address healthy eating, the availability of reliable and valid measures of observation in early childhood classroom settings is critical for program developers, child care providers, and parents, and researchers. Since preschool is a particularly important stage in the development of eating habits and a period in which assessment of *liking* and *wanting* is difficult or subjective, the development of systematic, and reliable methods to assess *liking* and *wanting* of foods is warranted. A particular area that needs improvement is the validation of tools assessing the developmentally relevant multisensory food education interactions, and early childhood activities such as sorting and categorizing based on perceptual properties. Measures appropriate for assessing the quality of sensory interactions in child care settings are scarce. Currently available measures often focus more on the environment and are valid only for certain types of settings, and for the simultaneous assessment of both feeding related behaviors and facial expressions observed during the maternal-child feeding process.\(^1\)\(^2\)\(^3\)

Can we expand existing video based assessment methodology utilized with infants, to validate willingness-to-taste and taste measures in individual preschool and elementary school age children in circle-time/group naturalistic settings (e.g., Head Start, early Head Start, elementary school classrooms)? Central to this question is how we define and measure the quality of sensory explorations, and engagement in an early childhood environment context. Our current definition of sensory assessment and evaluation includes a variety of tools. We propose the implementation during classroom circle-time of video recordings to observe and code young children’s’ “real-time” truthful reactions to foods combined with the more detailed examination of early childhood sensory behavior and facial expression coding, anchored in assessment and ratings of engagement in sensory activity, and willingness to taste. Reliably collecting video-recordings of food-based sensory exploratory observations, and coding and analyzing such behavioral data within children’s peer-circle time settings is an exciting venue for research.

The advantages of the proposed video recording approach are that the same assessor (s) can repeatedly observe the recordings which are not possible in real time observations. However, to code these video recorded sessions, it is important to know what behaviors to search for and systematically code and document based on the videotaped observations of the sensory measures of engagement/exploration/willingness/avoidance/circle-time behaviors. The circle time peer interactions and facial expressions included in the coding analysis should be evidence-based, and must include consultation with early childhood teachers, linguists, nutritionists, caregivers, and scientific experts. Clearly the assessment of other behaviors such as peer interactions, interactions with caregiver, verbal skills/literacy/vocalization, will offer value-added analytical benefits as facial expression alone may not capture all the information observed during circle time. Therefore, facial expressions in combination with other feeding related behaviors such as physical body and mouth movements indicating approach or avoidance engagement, exploration, willingness, and acceptance could provide a detailed and reliable method of assessing responses to novel foods in early childhood. Other unique aspects of the video-coding evaluation urgently needed are the assessment of the sensitivity of the coding scheme to feeding interventions, and triangulation with direct observations by trained raters, and with pre-post food waste measures. Finally, there is a need to develop STEM evidence-based and child-outcomes focused protocols for video-coding sensory observations and peer interactions in the context of a classroom sensory intervention aimed at children’s engagement with and consumption of locally available exotic F/V.

**SIGNIFICANCE OF INCORPORATING VIDEO-OBSERVATION CODING TECHNOLOGY IN SENSORY INTERVENTIONS**

The importance of incorporating technology in sensory intervention studies assessing early F and V acceptance is high. Preschool classrooms and circle time settings serve as unique early education settings for technology driven evaluation of developmentally appropriate responses to promotion of local F and V in young learners. The combination of coding both sensory interactive feeding behaviors and facial expressions can be useful to professionals and caregivers in recognizing sensory expressions linked to willingness-to-try and willingness-to-taste and consumption in early childhood. Recognizing the diverse sensory engagement cues
in conjunction may help caregivers to facilitate healthy eating and responsive feeding as young children appear to move naturally through developmental stages of food acceptance. While sensory-based food education activities may promote a willingness to eat vegetables and fruits and child-centered test methods are important for evaluating the effects of dietary interventions among children, reliable and valid tools are essential for the long term success of such interventions. Another application of the video coding protocol involves the validation of constructs and domains from relevant theoretical frameworks. For a nutrition intervention to be effective, research shows that it should be based on sound theoretical principles. The social cognitive theory (SCT) postulates that children’s behavior is influenced by several factors. Personal (e.g., knowledge), behavioral (e.g., skills), and environmental (e.g., visual reinforcement) factors are believed to influence children’s health-related behaviors, such as dietary choices. While systematically incorporating the framework domains and constructs through sensory activities implemented in the classroom, the video-codes could perhaps track changes in children’s self-efficacy in the context of exotic F and V consumption in response to sensory interventions.

DEVELOPMENT OF THE VIDEO-CODING SYSTEM ASSESSING WILLINGNESS TO ENGAGE, EXPLORE AND TASTE

In our ongoing work, facial and behavioral (verbal/non-verbal) expression coding along with coding of developmental milestones aligned with STEM guidelines and State-specific early learning standards are being evaluated with Teaching Strategies GOLD® assessment system. We are also comparing available software such as Dedoose, Noldus and others to identify reliable and robust online tools for observational coding. The children’s circle-time sensory behaviors will be extracted, and then applied and tested to assess structural validity and inter-observer reliability for assessing Willingness to Engage, Explore and Taste, along the continuum of the Willingness Rating Scale (Table 1 and Figure 1).

QUANTIFYING REAL-TIME VIDEO RECORDINGS

To standardize the extraction of quantitative data from the raw video recordings, a customized coding scheme must be developed using video annotation software such as ANVIL 5.0. There is a need to define the assessment categories based upon the respective sensory observations chosen to be mutually exclusive. To establish inter-rater reliability, coding of the videos must be divided

1. Not willing  
2. Examined but would not taste or smell  
3. Willing to smell  
4. Willing to lick/taste ➔ tongue  
5. Willing to eat ➔ put in mouth, chewed

5A. spit out  
5B. consumed  
5C. finished serving  
5D. asked for more

Used to evaluate the enjoyment of the selected fruit

| Table 1: Range of willingness rating scale for the assessment of children’s circle-time sensory engagement, explorations and interactions. |
between at least three (trained) researchers, and coding variables must be established using robust criteria. The video footage must be watched and coded by highly trained, independent raters (process described below) for outcomes based on the state-specific early learning metrics and early learning and development standards, using the Teaching Strategies GOLD Assessment System and State-specific Learning and Development Standards, Child Assessment Portfolio Objectives must be matched (example: shows curiosity and motivation, and explores and investigates to make things happen).

For example, as shown in the Figure, children would be rated on a Level ranging from 0-9 to observe the results of their explorations, which is a basic science skill. Triangulated Data (trained research observers’ notes) will be integrated with objective intake data representing pre-post consumption (grams) of exotic fruits and vegetables introduced during the sensory intervention.

**TRAINING SENSORY CODERS AND Raters**

There is a need to standardize sensory coding, and training is extremely important. With sufficient training, the video-coding system can be used to explore sensory engagement and willingness-to-taste parameters in early childhood. A comprehensive training manual will be developed detailing the description of possible sensory behaviors and facial expressions including pictures/video extracts with information and assessment domains, including possible misinterpretations. Coding schemes and decision-trees must be developed and validated for the scientifically robust measurement of children’s facial expressions as markers of willingness and acceptance. For each cue assessed, we will evaluate and establish test-retest reliability, and examine a range of validity measures. Sensory data will be coded using factor analysis, and quantified using rating scales.

**APPLYING EARLY LEARNING AND DEVELOPMENTAL MILESTONE STANDARDS TO CODE THE VIDEOS**

Based on current interest in designing Policy, System, and Environmental (PSE) interventions for food insecure such as Head Start populations, we recommend that classroom videos documenting F-V sensory exploration by children be evaluated using state-specific early learning and developmental milestone standards, and validated with willingness and preferences for each F and V at baseline, during intervention and at follow-up. Utilizing currently available definitions for sensory measures, the video coding of acceptance data would potentially span a 7-point scale, ranging from 0 to 6 (Table 1). Specifically, coding of data will assess the children’s responses to classroom educational activities along the domains of early learning such as: verbal skills, conceptual and language skills, memory, and sensory exploration.

**SELECTION OF SUITABLE SOFTWARE, MATCHING MEASURES WITH DEVELOPMENTAL MILESTONES AND ADAPTING A HYBRID FIBAC APPROACH WITH MANUAL CODING**

Suitable media player tools available for playing back the videos with ease (easily accessible, free to download, various visual effects such as zoom, color/contrast, frame by frame view and slow motion must) be utilized. There is an urgent need for accurate and affordable methods for evaluating sensory responses and we recommend a hybrid tool combining paper-based manual assessment with online ratings, as coders cannot rely only on software tools.

**CONCLUSION: METHODOLOGICAL STRENGTHS AND FUTURE RESEARCH**

We have made tremendous strides incorporating technology in the assessment of and understanding the impact of nutrition education interventions and generating observation-driven hypotheses related to patterns of sensory responses, of promising relevance to early childhood educational practices. Future work will focus on advancing sensory data collection, assessment, processing and interpretation tools, developing analytical methods, and creating an educational design framework that promotes practice of sensory skills for fun learning in early childhood.

There is a broad range of exciting interdisciplinary research and training opportunities spanning technological and database tools, theoretical models, early learning and developmental milestones, and population studies. Data analytical frameworks, tools and techniques are essential for unraveling the mysteries of children’s multiple sensory modalities simultaneously, tuning effort and perception to gain what is useful in a given multisensory nutrition education context.

Scientific journals will continue to play a crucial role by providing the basic and translational research communities many opportunities to disseminate this innovative work. The potential opportunity to familiarize educators with viable technological tools, and sensory programming of interventions addressing pediatric health is an exciting and timely area for exploration.
CONFLICTS OF INTEREST

All authors declare that there is no conflicts of interest.

REFERENCES


Physical Activity Assessment in an Italian Adult Population using the International Physical Activity Questionnaire

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ABSTRACT

Introduction: The international physical activity questionnaire (IPAQ) was developed as an instrument for cross-national monitoring of physical activity (PA) and inactivity. The aim of this study was to determine the PA level in a sample of Italian population.

Methods: In total 957 adults (56% women) aged 19-65 years were randomly recruited. PA was assessed using the long form of the IPAQ (IPAQ-L). Lifestyle, body weight and height were obtained by questionnaire.

Results: The total PA was 1610 MET-min/week: subjects were physically more active in the domestic and garden domain, contrary to transportation and leisure domain. Classifying the activities on the basis of the intensity, significant differences between sexes were detected for moderate and vigorous activities; moreover subjects aged 18-30 years had the lowest levels of PA, while subjects aged >50 had the highest levels. The 86% of the examined population spent at least 30 minutes of moderate PA on 5 days of the week, adhering to the international recommendations.

Conclusions: Differences in PA between sexes and among age groups were observed. Strategies for increasing PA should be addressed especially to the young adults.

KEYWORDS: Physical activity assessment; IPAQ; Subjective methods; Community-based research.


INTRODUCTION

Physical activity (PA) has been regarded as one of the most important habitual behaviours, which leads to a healthy life by preventing diseases and increasing health benefits. Regular and adequate levels improve muscular and cardiorespiratory fitness, bone and functional health, reduce the risk of non-communicable diseases and depression and are a key determinant of energy expenditure, thus fundamental to energy balance and weight control.1-4 For these reasons, in 2010 World Health Organization (WHO) developed the global recommendations on PA for health:1 people aged >18 years should accumulate at least 150 minutes of moderate intensity aerobic PA throughout the week or do at least 75 minutes of vigorous intensity aerobic PA throughout the week or an equivalent combination of moderate and vigorous intensity activity.

Nevertheless, physical inactivity has been identified as one of the biggest public health problems of the 21st century.5 As reported by WHO, insufficient PA has been identified as the
fourth leading risk factor for mortality, as well as the main cause for approximately 21-25% of breast and colon cancers, 27% of diabetes and approximately 30% of ischemic heart disease burden. About 3.2 million people die each year because they are not active enough and the levels of physical inactivity increase across the world. In 2012, it was estimated that 31.1% of the adult global population did not meet the physical activity recommendations.

Notwithstanding physical inactivity is considered a global health concern, as no standardized approaches to measurement exist, international comparisons and global surveillance are difficult.

In a recent review of adult physical activity levels across Europe is underlined that because of the large variety in the assessment methods used to assess physical activity, the reported outcome variables and the presented physical activity levels per study, absolute physical activity population levels in European adults are currently unknown.

Several routine instruments are available, all of which having well-known limitations; consequently there is currently no perfect gold-standard criterion. Objective methods, as movement sensors, due to their high costs, are not usually practical in large-scale cohort studies. While the self-report questionnaire is the most commonly used instrument.

Several questionnaires have been proposed and among them the international physical activity questionnaire is widely used. This questionnaire was developed in the late 1990’s to obtain internationally comparable data on health-related PA and several studies have shown its acceptable validity and reliability for population-based studies. In particular, the long form of IPAQ (IPAQ-L) measures frequency, duration, and intensity of PA in four domains of life: work, transport, domestic and garden, leisure-time.

To the best of our knowledge, there has been no population-based study in Italy, which examined all four domains of PA. The aim of this study is to determine PA levels in a sample of adult Italian population using the IPAQ-L.

**METHODS**

**Sampling**

One-thousand and sixty-two healthy volunteers (482 males and 580 females), aged 18-65 years, were recruited in the North, the Centre and the South of Italy. After being informed about the purpose of the study, they gave their written consent. All the subjects underwent lifestyle questionnaire administration and PA evaluation. From the original sample, after cleaning the data for missing and out-of-range values according to the IPAQ Research Committee, 957 (422 men and 535 women) subjects represent the final sample of the study.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ‘Sapienza’ University of Rome Ethics Committee. Written informed consent was obtained from all the subjects.

**Lifestyle Questionnaire and Anthropometry**

The lifestyle questionnaire was administered to each participant by trained personnel and consisting of a package of questions specifically designed to obtain different information about sociodemographic (marital status, education and occupation) and anthropometric characteristics (height and body weight), smoking habits and alcohol consumption. In order to verify the validity of self-reported body anthropometric data, on a subsample of 300 subjects the fasting weight and height were also measured by a trained observer under standardized conditions. A calibrated computerized digital scale (K-Tron P1-SR; K-Tron SA, Hanse Division, Colombier, Switzerland; capacity 150 kg, graduation 10 g) and a wall-mounted Holtain stadiometer (Holtain Ltd, Crosswell, Crymych, UK), with height being recorded to the nearest 0.1 cm, were used. Both self-reported and objectively measured weight and height were used to calculate body mass index (BMI, kg/m^2^), and consequently the prevalence of obesity and overweight, using the cut-off points proposed for adult population: underweight <18.5 kg/m^2^; overweight 25.0-29.9 kg/m^2^ and obesity ≥ 30 kg/m^2^.

The mean difference between self-reported and objectively measured BMI was 0.3 kg/m^2^ for men and 0.2 kg/m^2^ for women and can be considered negligible.

**Evaluation of Physical Activity**

For estimating the level of PA, the original English version of IPAQ-L was translated into Italian, then back translated into English and the Italian version was administered by trained personnel in a face-to-face interview. The IPAQ-L, designed to assess the levels of habitual PA, consists of 27 questions referred to the previous 7 days covering 4 domains of PA (work-related PA, transport-related PA, domestic and gardening activities, and leisure-time PA). The items in IPAQ are structured to provide separate domain-specific scores for walking, moderate-intensity and vigorous-intensity activity within each domain.

The results were presented as the estimation of energy expenditure in metabolic equivalent-minutes per week (MET-minutes/week), made by using the compendium of physical activities, which provides a classification of specific activities in MET. One MET represents the resting energy expenditure during quiet sitting and is commonly defined as 3.5 ml O2•kg−1•min−1 or ~ 250 mL/min of oxygen consumed, which represents the average value for a standard person (70 kg). Obviously the oxygen consumption increases with activity intensity level, therefore the MET value increases with the intensity of PA (e.g. 1 MET = the rate of energy expenditure while at rest (sitting quietly), 2 MET = walking at 3 km/h would require twice the energy that an average person consumes at rest). According to
IPAQ scoring protocol. MET-minutes/week of specific activity (walking or moderate intensity activity or vigorous intensity activity) is computed by multiplying MET value of particular activity (3.3 for walking, 4.0 for moderate intensity activity, and 8.0 for vigorous intensity activity) with hours spent in that particular activity (e.g., walking MET-minutes/week at work=3.3×walking minutes×walking days at work). Computation of the total scores for the long form requires the summation of the duration (in minutes) and frequency (days) for all the types of activities in all domains. Only the activities lasting at least 10 minutes were taken into account. Domain specific scores or activity specific sub-scores may be calculated. Domain specific scores require the summation of the scores for walking, moderate-intensity and vigorous-intensity activities within the specific domain, whereas activity-specific scores require the summation of the scores for the specific type of activity across domains.  

The PA was categorized using the IPAQ scoring protocol. The cut-off levels, reported in Table 1, are based on the current guidelines for PA, which state that every adult should be active on most, preferably all days of the week, at moderate intensity accumulating 30 minutes of PA. In terms of how the IPAQ measures activity, this would be equal to 600 MET-minutes/week, which is the lowest limit for the moderately active category. The cut-off limit for moderately active category also allows a person to be vigorously active for three days per week for 20 minutes. As the IPAQ measures PA across all domains and the guidelines are based mainly on studies assessing leisure time PA, the cut-off for reaching the moderately active category should be viewed as the absolute minimum of PA for some health benefit. The higher category aims to include persons that are doing intentional PA three days per week or more, accumulating 1500 MET-minutes/week or that are accumulating 3000 MET-minutes/week. Subjects in this category are believed to be sufficiently active for health benefits across all domains.

### Statistical Analysis

Normality of distributions of variables was tested by Shapiro-Wilk test. Median, 95% confidence interval (CI) for median, and interquartile range (IQR) were calculated for each domain of PA separately, as well as for total PA, for sex and for 4 age groups of participants (18-30 years, 31-40 years, 41-50 years, 50 years and older). The student t-test was used to evaluate the differences in physical characteristics between sexes, while differences of PA between age groups and sexes were tested by the non-parametric Kruskal-Wallis test. Differences among prevalence were tested by the chi-square test. Additionally, multiple regression analysis was conducted to identify socio-demographic and anthropometric factors related to PA levels. In the regression model, age, BMI and educational level were used as independent variable, while each of the 4 PA domain scores and total PA score as dependent variable. The level of significance for all analyse was set at \( p<0.05 \). Statistical analysis was performed by STATISTICA software (release 8; 135 StatSoft Inc, Vigonza PD, Italy).

### RESULTS

The sample included a total of 957 (422 men and 535 women) participants, whose physical characteristics are reported the physical characteristics in Table 2.

There were significant differences for all the variables between men and women \((p=0.000)\). The mean BMI was 26.0±3.8 kg/m² for men (indicating an overweight status) and 24.5±5.3 kg/m² for women \((p=0.000)\). There were statistically significant differences between sexes \((\chi^2=63.61, p=0.001)\) in BMI categories: 60.7% of women was normal weight and 55.8% of men was overweight or obese; moreover, the percentage of obese subjects is similar between men and women (14%) (data not shown).

<table>
<thead>
<tr>
<th>Physical activity category</th>
<th>Cut-off levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Those individuals who not meet criteria for Categories 2 or 3 are considered to have a ‘low’ physical activity level.</td>
</tr>
</tbody>
</table>
| Moderate                   | The pattern of activity to be classified as ‘moderate’ is either of the following criteria:  
  a) 3 or more days of vigorous-intensity activity of at least 20 minutes per day OR  
  b) 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day OR  
  c) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum Total physical activity of at least 600 MET-minutes/week. |
| High                       | The pattern of activity to be classified as ‘high’ is either of the following criteria:  
  a) vigorous-intensity activity on at least 3 days achieving a minimum Total physical activity of at least 1500 MET-minutes/week OR  
  b) 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum Total physical activity of at least 3000 MET-minutes/week. |

Table 1: Physical activity categories and cut-off levels based on the IPAQ scoring protocol.
In Table 3 are reported socio-demographic variables of the sample by gender. There were not significant differences in marital status, while regarding educational level, about 70% of the sample (74% of men and 66.6% of women) had a secondary education and, on the whole, there were slight differences ($\chi^2 = 7.54$, $p = 0.05$). The majority of the sample stated to be engaged in some form of work activity; the difference between sexes ($\chi^2 = 103.27$, $p = 0.001$) depends on the high percentage of housewives in the sample, which are included in the “unemployed” category.

The median (95% CI) of PA, expressed as median of MET-minutes/week, is reported in Table 4 for men and women separately and for the total sample and indicated for the 4 domains separately (work, transport, domestic and garden, and leisure-time) and for the specific activities (walking or 155 moderate intensity activity or vigorous intensity activity).

The median (95% CI) of total PA for the whole sample was 1610 MET-min/week, without significant differences between men and women. Regarding the individual domains of PA, subjects were physically more active in the domestic and garden domain (223 MET-min/week), as opposed to transport and leisure domain (85 MET-min/week each one). Moreover, there were statistical differences between sexes in the median value of MET-min/week in the work (31 MET-min/week for men and 0 MET-min/week for women, $p = 0.000$), in domestic and garden (69 MET-min/week for men and 617 MET-min/week for women, $p = 0.000$) and in leisure time (198 MET-min/week for men vs. 57 MET-min/week for women, $p = 0.000$); no significant differences were observed in the domain of transport. Classifying the activities based on the intensity, significant differences between sexes were detected for moderate (319 MET-min/week for men vs. 814 MET-min/week for women, $p = 0.000$) and vigorous activities (103 MET-min/week for men vs. 0 MET-min/week for women, $p = 0.000$), while no significant differences were found for walking.

Stratifying the sample by age, all the differences were statistically significant, except for the vigorous activities (Table 5). As a general remark, PA increased with age: subjects aged 18-30 years had the lowest levels of PA (1154 MET-min/week), while subjects aged >50 had the highest levels (3639 MET-min/week). Moreover, the oldest subjects were highly involved in transport (236 MET-min/week) and domestic and garden (1260 MET-min/week) domains, while in leisure-time the most active group was aged 18-30 years (170 MET-min/week).

The multiple regression analysis between BMI (calculated using self-reported weight and height) and socio-demographic characteristics (age and educational level) as independent variables with PA as the dependent variable is reported in Table 6. Total PA, as well as moderate PA, was positively correlated with age ($p = 0.000$) and negatively with educational.
<table>
<thead>
<tr>
<th></th>
<th>Men (n=422)</th>
<th>Women (n=535)</th>
<th>Total (n=957)</th>
<th>p value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>Median 31</td>
<td>0</td>
<td>0</td>
<td>0.000</td>
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<tr>
<td></td>
<td>95% CI 5181-5931</td>
<td>2998-3380</td>
<td>4255-4654</td>
<td>509</td>
</tr>
<tr>
<td></td>
<td>IQR* 1393</td>
<td>137</td>
<td></td>
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<tr>
<td>Transport</td>
<td>Median 58</td>
<td>113</td>
<td>85</td>
<td>n.s.</td>
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<td></td>
<td>95% CI 808-925</td>
<td>624-704</td>
<td>724-792</td>
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<tr>
<td></td>
<td>IQR* 453</td>
<td>462</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic and garden</td>
<td>Median 69</td>
<td>617</td>
<td>223</td>
<td>0.000</td>
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<tr>
<td></td>
<td>95% CI 1694-1940</td>
<td>2210-2492</td>
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<td></td>
<td>IQR* 377</td>
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<td>Leisure-time</td>
<td>Median 198</td>
<td>57</td>
<td>85</td>
<td>0.000</td>
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<td></td>
<td>95% CI 1107-1268</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>IQR* 728</td>
<td>354</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>Median 283</td>
<td>255</td>
<td>269</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>95% CI 1871-2141</td>
<td>1354-1527</td>
<td>1638-1792</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IQR* 1110</td>
<td>790</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate activities</td>
<td>Median 319</td>
<td>814</td>
<td>549</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>95% CI 2763-3163</td>
<td>2725-3073</td>
<td>2804-3067</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IQR* 1251</td>
<td>2314</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vigorous activities</td>
<td>Median 103</td>
<td>0</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>95% CI 3965-4539</td>
<td>2110-2379</td>
<td>3186-3485</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IQR* 1120</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total physical activity</td>
<td>Median 1573</td>
<td>1657</td>
<td>1610</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>95% CI 5979-6845</td>
<td>4014-4527</td>
<td>5089-5567</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IQR* 4312</td>
<td>3578</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Interquartile range (IQR) in MET-minutes/week calculated according to the IPAQ protocol.
†Statistical analysis: Kruskal-Wallis test; n.s.=not significant.

Table 4: Physical activity expressed in metabolic-equivalent-minutes per week (MET-min/week) by gender (median; 95% CI; IQR∗).

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Median (n=323)</th>
<th>31-40 (n=267)</th>
<th>41-50 (n=258)</th>
<th>&gt;50 (n=109)</th>
<th>Total (n=957)</th>
<th>p value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>2676-3124</td>
<td>4458-5285</td>
<td>4666-5549</td>
<td>4781-6250</td>
<td>4255-4654</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>226</td>
<td>408</td>
<td>707</td>
<td>1175</td>
<td>509</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>128</td>
<td>42</td>
<td>63</td>
<td>236</td>
<td>85</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>561-655</td>
<td>636-754</td>
<td>783-931</td>
<td>878-1148</td>
<td>724-792</td>
<td></td>
</tr>
<tr>
<td></td>
<td>363</td>
<td>347</td>
<td>462</td>
<td>767</td>
<td>456</td>
<td></td>
</tr>
<tr>
<td>Domestic and garden</td>
<td>99</td>
<td>309</td>
<td>321</td>
<td>1260</td>
<td>2091-2288</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>1080-1260</td>
<td>2042-2421</td>
<td>2393-2846</td>
<td>2481-3244</td>
<td>1234</td>
<td></td>
</tr>
<tr>
<td>Leisure-time</td>
<td>170</td>
<td>63</td>
<td>57</td>
<td>57</td>
<td>85</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>1096-1279</td>
<td>767-910</td>
<td>903-1075</td>
<td>843-1102</td>
<td>970-1061</td>
<td></td>
</tr>
<tr>
<td></td>
<td>656</td>
<td>519</td>
<td>426</td>
<td>693</td>
<td>548</td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>269</td>
<td>170</td>
<td>285</td>
<td>679</td>
<td>269</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>1249-1458</td>
<td>1741-2064</td>
<td>1747-2078</td>
<td>1506-1968</td>
<td>1638-1792</td>
<td></td>
</tr>
<tr>
<td></td>
<td>698</td>
<td>929</td>
<td>999</td>
<td>1443</td>
<td>924</td>
<td></td>
</tr>
<tr>
<td>Moderate activities</td>
<td>274</td>
<td>617</td>
<td>750</td>
<td>1976</td>
<td>549</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>1751-2043</td>
<td>2907-3347</td>
<td>2790-3317</td>
<td>3504-4580</td>
<td>2804-3067</td>
<td></td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1787</td>
<td>2359</td>
<td>3471</td>
<td>2059</td>
<td></td>
</tr>
<tr>
<td>Vigorous activities</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1846-2155</td>
<td>3105-3682</td>
<td>3851-4579</td>
<td>3534-4619</td>
<td>3186-3485</td>
<td></td>
</tr>
<tr>
<td></td>
<td>411</td>
<td>457</td>
<td>308</td>
<td>411</td>
<td>411</td>
<td></td>
</tr>
<tr>
<td>Total physical activity</td>
<td>1154</td>
<td>1636</td>
<td>2113</td>
<td>3639</td>
<td>1610</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>3174-3705</td>
<td>5169-6128</td>
<td>5393-6413</td>
<td>6036-7890</td>
<td>5089-5567</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2074</td>
<td>3674</td>
<td>4559</td>
<td>5596</td>
<td>3763</td>
<td></td>
</tr>
</tbody>
</table>

*Intraquartile range (IQR) in MET-minutes/week calculated according to the IPAQ protocol.
†Statistical analysis: Kruskal-Wallis test; n.s.=not significant.

Table 5: Physical activity expressed in metabolic-equivalent-minutes per week (MET-min/week) by age (median; 95% CI; IQR∗).
level ($p=0.000$). PA in work domain was inversely related to educational level and positively to BMI, opposite to leisure-time domain. PA in transport domain was negatively related to BMI and positively to age. Finally, PA in domestic and garden domain was positively related to age and negatively to educational level.

In Table 7 are reported the PA categories of the sample on the basis of the IPAQ scoring protocol. Overall, the 86% of participants reached the levels of at least 30 minutes of moderate PA 5 days a week, which could be considered as the lowest level of PA for achieving health benefits, according to the recommendations.

**DISCUSSION**

The aim of the study was to evaluate the PA in a sample of adult Italian population, using the IPAQ-L, which can be considered as an acceptable instrument for monitoring population levels of PA among 18-65 years old adults in different settings. Results show that the majority of respondents (86%) reached the levels of at least 30 minutes of moderate PA 5 days a week, which could be considered as the lowest level of PA for achieving health benefits, according to the recommendations. The total PA of the sample is 1610 MET-min/week, without gender differences. This is because women are mainly involved in moderate activities while men do vigorous activities. Additionally, it is important to notice that patterns of PA were also considerably different for men and women. Indeed, men reported more PA at work and leisure-time, while women at domestic and garden. Moreover, there were age differences, with participants aged >51 years having the highest level of PA and youngest participants having the lowest.

Literature studies conducted in Italy and considering all four domains of PA are lacking. Similar studies conducted in other European countries considered the short version of IPAQ, more simple to be administered (7 questions in the short version compared with 27 questions in the long version) or other **ad hoc** questionnaires with study-specific items and time references, severely limiting the potential for comparisons across different studies. European Activity Surveillance System (EUPASS) project, designed to contribute to a European health monitoring system, measured PA in 8 European countries, finding a median of 19.6 MET-hour/week (i.e. 1176 MET-min/week) for Italy. Eurobarometer published the survey “Sport and physical activity” finding that in Italy 65% did not do any vigorous PA in the previous seven days and 54% did no moderate PA at all. In the “Multipurpose survey on households: aspects of daily life” conducted by the Italian National Statistics Institute, the proportion of sedentary people in Italy was 41.2% in 2013 (36.2% of men and 45.8% of women). The “Passi study” conducted from 2011 to 2014 reports 31% of sedentary people; this condition increases with age (25.7% of sedentary people aged 18-34 years, 30.8% of 211 sedentary people aged 35-49 years and 35.4% of sedentary people aged 50-69 years) and decreases with higher socio-economic conditions.

Even if IPAQ-L is less pleasant and more confusing in comparison with the short form and PA estimated using the long version may be higher because the short version systematically underestimates PA level, it has been demonstrated that results obtained by different versions can be compared. Moreover, beyond the identification of the total PA, it is also important to study the contribution of the different domains. In most studies recommended levels of PA have been determined by the age, body mass index, and educational level. The following table shows the results of a multiple regression analysis between these variables and physical activity:

<table>
<thead>
<tr>
<th>Age</th>
<th>Body Mass Index</th>
<th>Educational level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$p$ value</td>
<td>$p$ value</td>
</tr>
<tr>
<td>Work</td>
<td>0.06 n.s.</td>
<td>0.07</td>
</tr>
<tr>
<td>Transport</td>
<td>0.16 0.000</td>
<td>-0.07</td>
</tr>
<tr>
<td>Domestic and garden</td>
<td>0.19 0.000</td>
<td>-0.03</td>
</tr>
<tr>
<td>Leisure-time</td>
<td>0.04 n.s.</td>
<td>-0.07</td>
</tr>
<tr>
<td>Walking</td>
<td>0.10 0.005</td>
<td>-0.04</td>
</tr>
<tr>
<td>Moderate activities</td>
<td>0.17 0.000</td>
<td>-0.01</td>
</tr>
<tr>
<td>Vigorous activities</td>
<td>0.06 n.s.</td>
<td>0.06</td>
</tr>
<tr>
<td>Total physical activities</td>
<td>0.16 0.000</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 6: Multiple regression analysis between anthropometric and socio-demographic characteristics (independent variables) and physical activity (dependent variable).

<table>
<thead>
<tr>
<th>Physical activity categories based on the IPAQ score by gender.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men (%)</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Insufficiently active</td>
</tr>
<tr>
<td>Sufficiently active</td>
</tr>
<tr>
<td>Active</td>
</tr>
</tbody>
</table>

*Statistical analysis: $\chi^2$ test; n.s. = not significant
in relation to leisure-time PA, while other domains (work, transport, domestic and garden) were not equally considered. Self-reports are unreliable especially for housework and occupational activity; this may be particularly problematic especially in low- and middle-income countries, where transport, occupational, and housework activities often are mixed with daily life.

Total PA scores alone do not give us a complete understanding of the PA pattern. For example, health studies determining the level of PA only in the domain of leisure, while ignoring the domain of work, could possibly lead to flawed conclusions. This is supported by the studies that found a correlation between PA at work to specific aspects of health. For example, a recent systematic review highlighted the need for harmonisation and standardisation of the measurement methods and data processing used to assess physical activity in Europe, and the added value of a cross-European surveillance system including state-of-the-art physical activity measurements. Indeed, monitoring population levels of physical (in)activity provides the opportunity to track changes over time, identify and target populations with low physical activity levels, and evaluate public health policies and strategies. Internationally comparable data are especially interesting, since they allow cross-country comparisons and benchmarking.

In conclusion, taking together these findings indicate that 86% of the sample has a sufficient level of PA, with differences between sexes and among age groups. These results can provide useful baseline data in Italian population, but additional studies could be conducted to ascertain population trends over years in order to promote PA and improve public health by using a broad approach which considers the different segments of population.

Authors Contribution

The authors of the manuscripts have made the following contributions in carrying out the field work and writing of the research paper for publication: AP conceptualized, designed and supervised the study; FI conducted bibliographic research and critically reviewing the paper; DC, LB contributed to the study protocol, conducted the research and contributed to the data analysis; MZ, AT, CF contributed to the collected the data; AP,
FI, DC, LB, MZ, AT, CF drafted the paper and all authors listed reviewed the manuscript and contributed to subsequent drafts. All authors read and approved the final manuscript.

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CONFLICTS OF INTERESTS

The authors declare that they have no conflicts of interest.

REFERENCES


Body Mass Index is a Strong Predictor of Vitamin D Deficiency in Multiethnic Obese Children

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ABSTRACT

Background: Vitamin D deficiency is highly prevalent among obese children in the United States. The main objective of this study is to determine predictors of vitamin D deficiency in obese children. The main objective of this study is to determine predictors of vitamin D deficiency in obese children. Methods: Children aged 5-14 years with body mass index z-score (BMIZ)>95% were enrolled. Data included height, weight, ethnicity, season, dietary intake, serum 25-hydroxy vitamin D test: (25(OH)D), parathyroid hormone, calcium, insulin, glucose, high sensitivity C-reactive protein (CRP), lipids, aspartate aminotransferase (AST), alanine transaminase (ALT) and waist circumference. BMIZ calculation in children was categorized into ≥2.5 (high) and <2.5 (low). Serum 25(OH)D levels were dichotomized as <20 ng/mL (deficient) or ≥20 ng/mL (sufficient). Results: Ninety-one children completed the study. Mean BMIZ was 31.3±6.3 kg/m². Mean 25(OH)D level was 21.2±7.6 ng/mL. A base logistic regression model showed odds of a deficient 25(OH)D was more than 3-times higher in children with a high BMIZ (OR: 3.35, 95% CI: 1.07-10.43). African-American children were more likely than Caucasian children to have low 25(OH)D (OR: 6.68, 95% CI: 1.31-36.13). Children enrolled in seasons other than winter were less likely to have a low 25(OH)D. Adjustment for nutrients and serum cardiovascular disease risk markers did not significantly alter the relationship between low 25(OH)D and BMIZ.

Conclusions: The risk for vitamin D deficiency increases in children with severe obesity (BMIZ≥2.5 SD) and does not significantly change by season, ethnicity, nutrient intake, or cardiovascular disease risk parameters.

KEYWORDS: Vitamin D deficiency; Obesity; Multiethnic children; BMIZ; Parathyroid hormone (PTH).

ABBREVIATIONS: BMIZ: Body Mass Index Z-Score ; PTH: Parathyroid hormone; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; VDBP: Vitamin D Binding Protein; CDC: Centers for Disease Control and Prevention; FFQ: Food Frequency Questionnaire.
children. In adults, adiposity has long been known to be inversely related to circulating 25(OH)D, so it is not surprising that this association is being recognized in obese children, with studies showing that as many as 75% of obese children are vitamin D deficient.

Vitamin D deficiency is defined by the Institute of Medicine (IOM) as a serum 25-hydroxy vitamin D <20 ng/mL (<50 nmol/L). The etiology of vitamin D deficiency is multifactorial. Proposed risk factors include race/ethnicity, lack of sufficient sunlight exposure, insufficient activity, decreased consumption of vitamin D-containing foods such as fish and fortified dairy products, malabsorptive states, increased vitamin D degradation and increased body weight. Other predictors of low vitamin D status in healthy children include age, gender and socio-economic status.

In children, vitamin D is essential for skeletal health. Deficiency in children has also been linked to increased risk of allergies and asthma, and cardiovascular risk markers. In obese children, low levels of vitamin D may play a role in the pathophysiology of impaired glucose tolerance. It is therefore essential to know what factors predict vitamin D deficiency in children.

The objective of the study is to examine the association between vitamin D deficiency and BMI z-score (BMIZ) in obese children. We hypothesize that predictors of deficient serum 25(OH)D in obese children will be low dairy intake, ethnicity, season and higher BMIZ.

MATERIALS AND METHODS

Participants

Children aged 5-14 years with a BMIZ≥95% for age and gender followed at a pediatric weight management clinic were enrolled in the study from March 2011 to July 2012. Exclusion criteria were: use of vitamin D supplementation; history of hyperparathyroidism, rickets, type 1 or type 2 diabetes (T2D), renal failure, nephrolithiasis or new-on set hyperparathyroidism; and, use of prednisone, phenytoin, thiazides, statins or orlistat. Informed consent and/or assent were obtained for all participants and their caregivers prior to participation and study protocols were an Institutional Review Board (IRB) approved.

Data Collection

Fasting blood was drawn for serum 25(OH)D, parathyroid hormone (PTH), calcium, insulin, glucose, HbA1c, high sensitivity C-reactive protein (hs-CRP), lipids, aspartate aminotransferase (AST) and alanine aminotransferase (ALT). Anthropometric data were collected: height to the nearest 0.1 cm on a standard wall stadiometer, weight to the nearest 0.1 kg on an electronic scale (Scale-tronic model 6002; Wheaton, IL, USA) with children in light clothing, waist circumference (WC) measured at the level of the iliac crest, and blood pressure. BMIZ was calculated as weight in kg divided by the square of the height in meters. BMIZ percentiles were determined by using age- and gender-specific Centers for Disease Control and Prevention (CDC) growth charts.

Child age, gender, ethnicity, past medical history and family history of vitamin D deficiency, T2D and early chemical vapor deposition (CVD) were reported by parents. Season of serum collection was recorded as summer, fall, winter and spring.

Biomarker Assays

Serum 25(OH)D concentrations were determined after extraction with acetonitrile, using a standard radioimmunoassay (RIA) developed by DiaSorin, Inc. (Stillwater, MN, USA). Serum 25(OH)D was assayed using an equilibrium RIA with 125I. Lower limit of detection was 1.5 ng/mL. Serum lipids and blood glucose were measured by enzymatic methods with Cobas 8000 (Roche Diagnostics, Basel, Switzerland). hs-CRP was measured with a particle enhanced immunoturbidimetric method (Roche Diagnostics, Basel, Switzerland). PTH and fasting insulin were measured using Electro chemiluminescence immunoassay (Roche Diagnostics, Basel, Switzerland). Calcium levels were measured using Cobas method according to Schwarzenbach Roche Diagnostics is a diagnostic division of Hoffmann-La Roche which manufactures equipment and reagents for research and medical diagnostic (Roche Diagnostics, Basel, Switzerland). Hemoglobin A1c Test Normal and high chart and ranges (HbA1C) was measured using Cobas Turbimetric (Roche Diagnostics, Basel, Switzerland). AST and ALT were measured using NADH oxidation (Roche Diagnostics, Basel, Switzerland).

Dietary Assessment

Dietary intakes were assessed using the 8-page Block Kids 2004 FFQ (Nutrition Quest, Berkeley, CA, USA), incorporating approximately seventy food and beverage items. The Food Frequency Questionnaire (FFQ) has been validated for multiethnic school-age children residing in the same geographic region as the current study. It has also been specifically validated for estimating beverage, Ca and vitamin D intakes in children when compared with 3-day food diaries. Portion size pictures were used to increase the accuracy of their estimates.

The FFQs were administered by trained staff. Proxy respondents reported for 5-year-old children and proxy-assisted interviews were conducted with children 6-14 years of age. FFQs were reviewed for completion and processed through the Block Dietary Data Systems (Berkeley, CA, USA), and quantified by Nutrition Quest. Nutrient values were calculated for each item and further summarized into daily intakes of energy and nutrients using an algorithm from Nutrition Quest. Additional vitamin D contribution from foods and beverages was requested separately from Nutrition Quest. Nutrient values were determined based on updated values for fortified foods from the USDA 1998 nutrient database and adjusted for bioavailability through nutrient-equivalent estimates when relevant.
Statistical Analysis

All analysis were conducted using Stata (version 14.0, StataCorp, College Station, TX, USA). Descriptive statistics, univariate analysis, and Fisher’s exact test were employed. If continuous variables were not normally distributed, the Wilcoxon rank-sum test was employed.

Serum 25(OH)D levels were dichotomized into <20 ng/mL (deficient) or ≥20 ng/mL (sufficient). BMIZ was dichotomized into ≥2.5 (high) vs. <2.5 (low). Nutrient intakes were energy-adjusted using the residual method.22 Daily milk intake was determined with “number of milk-cup equivalents” (servings), and dairy, using “daily servings of milk, yogurt and cheese” and total dairy intake was assessed as total dairy intake in milk equivalent servings. The dietary variables were correlated with the cardiovascular markers and waist circumference and then compared by BMIZz category, using t-tests and rank-sum tests.

The month of enrollment was used as a coarse indicator of average sun exposure. Months were combined into seasons for analysis: winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November).

We computed an age- and gender- standardized WC score based on Sabo, 2012.23 For purposes of analysis, we categorized the sample into two groups above and below the median for the sample. So, the sample was split at the sample median standardized WC values, which were 3.4.

A base regression model evaluated BMIZ, adjusting for age, gender, ethnicity and season. Significance testing of their overall contribution to the model was assessed using a likelihood ratio test. Significance testing relative to the reference group, as for all other variables in the model, was conducted using a standard Wald test. In light of the restricted sample size, to account for nutritional factors, energy-adjusted nutrient variables were added singly to the base regression model. Similarly, cardiovascular disease (CVD) risk markers were evaluated as confounders by introducing each marker individually into the base model. Adjusted risk estimates are reported as odds ratios with 95% confidence intervals (CI). Significance testing was conducted at a critical level of 5%.

RESULTS AND DISCUSSION

Demographics

Of 115 children enrolled, 24 were excluded for incomplete dietary data, implausible energy intake <500 or >5000 kcal/d,24 or for missing serum markers. Ninety-one children [mean age 10.9±2.6 (SD) years] had complete dietary data. The majority were female (52.7%). Of the total, 26.4% were Caucasian, 51.7% were Hispanic, and 22% were African American. The majority of participants were enrolled in the spring or summer (71.5%) (Table 1). Clinical characteristics are shown in Table 2. The mean BMIZ was 31.6±6.5 kg/m², BMIZ was 2.40±0.37. The mean standardized waist circumference was 3.7±1.5 (n=90). For subsequent analysis, BMIZ was dichotomized at 2.5 (about the 99.5%): 37.4% (n=34)≥2.5, and 62.6% (n=57)<2.5.

25(OH)D and PTH Levels

The mean 25(OH)D was 21.2±7.6 ng/mL, with 47.3% (n=43) having levels <20 ng/mL. Significant associations with 25(OH)D levels were seen with age, season and ethnicity (p<0.01) (Table 2). The prevalence of vitamin D deficiency was higher among ethnic minority and older children.

<table>
<thead>
<tr>
<th>Sample Characteristic</th>
<th>Overall (n=91)</th>
<th>VDL≥20 (n=48)</th>
<th>VDL&lt;20 (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>10.9 (2.6)</td>
<td>10.1 (2.5)</td>
<td>11.8 (2.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td>0.12</td>
</tr>
<tr>
<td>Caucasian</td>
<td>26.4 (24)</td>
<td>33.3 (16)</td>
<td>18.6 (8)</td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>22.0 (20)</td>
<td>14.6 (7)</td>
<td>30.2 (13)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>51.7 (47)</td>
<td>52.1 (25)</td>
<td>51.2 (22)</td>
<td></td>
</tr>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
<td>0.009</td>
</tr>
<tr>
<td>Winter</td>
<td>15.4 (14)</td>
<td>4.2 (2)</td>
<td>27.9 (12)</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>44.0 (40)</td>
<td>45.8 (22)</td>
<td>41.9 (18)</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>27.5 (25)</td>
<td>31.3 (15)</td>
<td>23.3 (10)</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>13.2 (12)</td>
<td>18.8 (8)</td>
<td>7.0 (3)</td>
<td></td>
</tr>
</tbody>
</table>

*among children with total calories ≥5500

Table 1: Characteristics of study sample (n=91), overall and by vitamin D Level.
Vitamin D levels were lower in the winter season of serum collection and in children with higher BMI. The effect of BMI on serum 25(OH)D may be explained by the fact that persons with high BMI may have excess body fat, potentially resulting in increased sequestration of vitamin D and low bioavailability and thus, low serum 25(OH)D levels. Other evidence suggests that excess body fat may disrupt hormonal pathways important for skeletal health. For example, leptin that binds to osteoblasts appears to activate a pathway that inhibits renal synthesis of the active form of vitamin D. Leptin levels are markedly elevated in obese individuals thereby decreasing 25(OH)D levels. Vitamin D deficiency is associated with insulin resistance, which, in turn, is inversely correlated with vitamin D binding protein (VDBP). Protein bound vitamin D is inactive, whereas non-protein bound vitamin D is the active form. We speculate that the total 25(OH)D we observed may have been counter balanced by a parallel insulin resistance-driven reduction of VDBP.

This is corroborated by potentially higher HOMA values in children with 25(OH)D <20 ng/mL vs. those with non-deficient levels.

There were no significant differences in parathyroid hormone (PTH) levels between those with 25(OH)D<20 ng/mL vs. those ≥20 ng/mL (Table 3). Our sub-analysis of the relationship between serum 25(OH)D and PTH revealed no association. As shown in Table 1, children with low 25(OH)D had higher fasting insulin (13.1 vs. 19.1 IU/ml, p<0.01), systolic (111.9 vs. 118.1 mmHg, p<0.04) and diastolic blood pressure (64.7 vs. 67.9 mmHg, p<0.03) and lower serum calcium (9.8 vs. 10.0 mg/dL, p<0.005). AST was higher in those with 25(OH)D≥20 ng/mL compared to those with 25(OH)D<20 ng/mL (median 1.1 vs. 1.4 servings; inter quartile range 1.0-1.7, p<0.05).

### Table 2: Clinical Characteristics of study sample (n=91), overall and by vitamin D level.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n=91)</th>
<th>25(OH)D≥20 (n=48)</th>
<th>25(OH)D&lt;20 (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>114.8 (10.1)</td>
<td>111.9 (8.8)</td>
<td>118.1 (10.5)</td>
<td>0.003</td>
</tr>
<tr>
<td>DBP</td>
<td>66.2 (7.0)</td>
<td>64.7 (6.2)</td>
<td>67.9 (7.5)</td>
<td>0.03</td>
</tr>
<tr>
<td>BMI≥2.5</td>
<td>37.4 (34)</td>
<td>31.3 (15)</td>
<td>44.2 (19)</td>
<td>0.28</td>
</tr>
<tr>
<td>WC≥34.4</td>
<td>51.1 (46)</td>
<td>47.9 (23)</td>
<td>54.8 (23)</td>
<td>0.53</td>
</tr>
</tbody>
</table>

SBP=Systolic Blood Pressure; DBP=Diastolic blood pressure; *Among children with total calories≥500; BMI=Body mass index by age percentile z-score; WC=waist circumference.

### Dietary Intakes

Children in the vitamin D deficient group had lower mean daily intakes of vitamin D, calcium, n-3 fatty acids (134.8 vs.173.8 IU/d, p<0.03) 657.9 vs. 763.8 mg/d, p<0.005; 0.8 vs. 1.0 mg/d, p<0.05), and total sugars (80.5±36.4 g/d vs. 110.0±58.7 g/d, p<0.005, Table 3). The median number of servings from the meat group was lower in children with 25(OH)D<20 ng/mL compared to those with 25(OH)D≥20 ng/mL (median 1.1 vs. 1.4 servings; inter quartile range 1.0-1.7, p<0.05).

### Other Clinical Measures

As shown in Table 1, children with low 25(OH)D had higher fasting insulin (13.1 vs. 19.1 IU/ml, p<0.01), systolic (111.9 vs. 118.1 mmHg, p<0.04) and diastolic blood pressure (64.7 vs. 67.9 mmHg, p<0.03) and lower serum calcium (9.8 vs. 10.0 mg/dL, p<0.005). AST was higher in those with 25(OH)D≥20 ng/mL when compared to those with <20 ng/mL (24.6±5.0 vs. 21.1±5.1 U/L; p<0.002).

### Multiple factors impacting risk for vitamin d deficiency

The base logistic regression model examining vitamin D deficiency included BMIZ (<2.5 vs. ≥2.5), gender, ethnicity, age, and season is shown in Table 4. Odds of vitamin D deficiency were more than three times higher in children with BMIZ≥2.5 compared to those <2.5 when adjusting for the other covariates (OR: 3.35, 95% CI: 1.07-10.43; p=0.04). The odds of vitamin D deficiency increased by 47% for each year of age (OR: 1.47, 95% CI: 1.17-1.83; p=0.001); African-American children were more than six times as likely as Caucasian children to have low 25(OH)D (OR: 6.68, 95% CI: 1.31-36.13; p=0.02); and, relative to winter, children entering the study during the other seasons were less likely to have lower 25(OH)D levels. Although males were less likely to have low 25(OH)D than females, this difference did not reach statistical significance (OR: 0.44, 95% CI: 0.15-1.26; p=0.13). When the base model was further adjusted for nutrient residuals, risk of Vitamin D Deficiency for those with a BMIZ≥2.5 is unchanged and remained stable regardless of the nutrient added to the base model (Figure 1). The adjust-
<table>
<thead>
<tr>
<th>Cardiovascular Measure</th>
<th>Overall (n=91)</th>
<th>VDL≥20 (n=48)</th>
<th>VDL&lt;20 (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting glucose*</td>
<td>89.7 (7.9)</td>
<td>89.7 (8.9)</td>
<td>89.8 (6.6)</td>
<td>0.94</td>
</tr>
<tr>
<td>Fasting insulin</td>
<td>15.9 (13.3)</td>
<td>13.1 (9.6)</td>
<td>19.1 (15.9)</td>
<td>0.04</td>
</tr>
<tr>
<td>PTH*</td>
<td>31.3 (11.2)</td>
<td>29.4 (8.9)</td>
<td>33.6 (13.2)</td>
<td>0.09</td>
</tr>
<tr>
<td>Ca*</td>
<td>9.9 (0.4)</td>
<td>10.0 (0.3)</td>
<td>9.8 (0.4)</td>
<td>0.005</td>
</tr>
<tr>
<td>AST*</td>
<td>23.0 (5.3)</td>
<td>24.6 (5.0)</td>
<td>21.1 (5.1)</td>
<td>0.002</td>
</tr>
<tr>
<td>ALT*</td>
<td>20.9 (8.7)</td>
<td>21.2 (7.3)</td>
<td>20.6 (10.1)</td>
<td>0.77</td>
</tr>
<tr>
<td>sCRP*</td>
<td>3.7 (4.0)</td>
<td>4.1 (4.3)</td>
<td>3.3 (3.6)</td>
<td>0.34</td>
</tr>
<tr>
<td>HOMA*</td>
<td>3.5 (3.1)</td>
<td>3.0 (2.5)</td>
<td>4.2 (3.7)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutritional Measure</th>
<th>Overall (n=91)</th>
<th>VDL≥20 (n=48)</th>
<th>VDL&lt;20 (n=43)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin D</td>
<td>155.4 (85.6)</td>
<td>173.8 (90.2)</td>
<td>134.8 (75.9)</td>
<td>0.03</td>
</tr>
<tr>
<td>Calcium</td>
<td>713.8 (306.5)</td>
<td>763.8 (320.1)</td>
<td>657.9 (284.0)</td>
<td>0.10</td>
</tr>
<tr>
<td>Magnesium</td>
<td>167.9 (76.6)</td>
<td>183.9 (82.0)</td>
<td>150.0 (66.6)</td>
<td>0.03</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>884.7 (360.4)</td>
<td>951.8 (381.2)</td>
<td>809.7 (323.9)</td>
<td>0.06</td>
</tr>
<tr>
<td>Omega-3 FA</td>
<td>0.9 (0.4)</td>
<td>1.0 (0.5)</td>
<td>0.8 (0.4)</td>
<td>0.05</td>
</tr>
<tr>
<td>MUFAs</td>
<td>17.4 (7.6)</td>
<td>18.5 (7.5)</td>
<td>16.2 (7.6)</td>
<td>0.14</td>
</tr>
<tr>
<td>PUFAs</td>
<td>9.5 (4.5)</td>
<td>10.2 (4.5)</td>
<td>8.6 (4.5)</td>
<td>0.10</td>
</tr>
<tr>
<td>Saturated fats</td>
<td>16.7 (6.8)</td>
<td>17.8 (6.9)</td>
<td>15.4 (6.6)</td>
<td>0.10</td>
</tr>
<tr>
<td>Trans-fats</td>
<td>47.4 (20.0)</td>
<td>50.6 (19.9)</td>
<td>43.7 (19.8)</td>
<td>0.10</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>165.0 (87.6)</td>
<td>175.7 (74.9)</td>
<td>153.0 (99.4)</td>
<td>0.23</td>
</tr>
<tr>
<td>Total sugars</td>
<td>96.0 (51.3)</td>
<td>110.0 (58.7)</td>
<td>80.5 (36.4)</td>
<td>0.005</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Servings²</th>
<th>Median (IQR)</th>
<th>Median (IQR)</th>
<th>Median (IQR)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>1.2 (0.8, 1.7)</td>
<td>1.4 (1.0, 1.7)</td>
<td>1.1 (0.7, 1.7)</td>
<td>0.05</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.2 (0.1, 0.4)</td>
<td>0.2 (0.1, 0.4)</td>
<td>0.1 (0.4, 0.4)</td>
<td>0.06</td>
</tr>
<tr>
<td>Dairy</td>
<td>1.7 (0.9, 2.3)</td>
<td>1.8 (1.0, 2.4)</td>
<td>1.5 (0.9, 2.0)</td>
<td>0.12</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.8 (0.4, 1.8)</td>
<td>0.8 (0.5, 1.8)</td>
<td>0.8 (0.4, 1.8)</td>
<td>0.64</td>
</tr>
<tr>
<td>Grains</td>
<td>3.2 (2.3, 4.6)</td>
<td>3.8 (2.3, 4.9)</td>
<td>2.8 (2.1, 4.2)</td>
<td>0.08</td>
</tr>
<tr>
<td>Milk</td>
<td>1.2 (0.6, 1.9)</td>
<td>1.3 (0.6, 2.1)</td>
<td>1.0 (0.6, 1.5)</td>
<td>0.08</td>
</tr>
<tr>
<td>Total Dairy</td>
<td>1.6 (0.9, 2.3)</td>
<td>1.7 (1.0, 2.4)</td>
<td>1.4 (0.9, 2.0)</td>
<td>0.11</td>
</tr>
<tr>
<td>Total Grains</td>
<td>3.5 (2.5, 4.8)</td>
<td>3.8 (2.6, 4.9)</td>
<td>3.2 (2.5, 4.1)</td>
<td>0.12</td>
</tr>
<tr>
<td>Whole Grain</td>
<td>0.3 (0.2, 0.5)</td>
<td>0.3 (0.2, 0.5)</td>
<td>0.3 (0.1, 0.6)</td>
<td>0.56</td>
</tr>
<tr>
<td>Fruit Juice</td>
<td>0.3 (0.1, 0.8)</td>
<td>0.3 (0.1, 1.0)</td>
<td>0.3 (0.0, 0.5)</td>
<td>0.05</td>
</tr>
<tr>
<td>Fish (High)</td>
<td>0.0 (0.0, 0.1)</td>
<td>0.0 (0.0, 0.1)</td>
<td>0.0 (0.0, 0.1)</td>
<td>0.55</td>
</tr>
<tr>
<td>Fish (Low)</td>
<td>0.0 (0.0, 0.2)</td>
<td>0.0 (0.0, 0.1)</td>
<td>0.0 (0.0, 0.2)</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Note: *analysis using t-tests, with unequal variances; †analysis using the Wilcoxon rank-sum test;
*VDL= total cholesterol; TG= triglycerides; HDL= high density lipoprotein; LDL= low density lipoprotein; A1C= glycated hemoglobin; PTH= parathyroid hormone; Ca= calcium; AST= aspartate aminotransferase; ALT= alanine aminotransferase; hsCRP= high sensitivity C-reactive protein; HOMA= homeostatic model assessment; SBP= systolic blood pressure; DBP= diastolic blood pressure.

Table 3: Laboratory cardiovascular measures, overall and by vitamin D level (n=91).

Table 4: Logistic regression model of adjusted risk of low vitamin D level (<20 ug/mL.) (n=91).
ed odds ratios for BMI Z ranged from 2.96 when adjusting for whole grains to 3.71 when adjusting for n-3 FAs. As shown in Figure 2, most cardiovascular risk markers did not confound the adjusted odds ratio for BMI Z in the base model. Adjustment for hs-CRP increased the estimated odds ratio for BMI Z (OR=5.52; 95% CI: 1.51-20.17; p=0.01).

CONCLUSION

Our data suggests that those children with high BMI Z ≥2.5 had lower serum 25(OH)D levels as compared to those with low BMI Z <2.5. This study documented 47.3% of children studied having 25(OH)D levels <20 ng/mL. Significant associations with 25(OH)D levels were seen with older age, winter season and African American ethnicity and with higher BMI Z. Furthermore, we found that the risk for vitamin D deficiency increases in children with severe obesity (BMI Z ≥2.5 SD) and is not significantly altered by ethnicity, nutrient intake or season. Such results have not been found in other studies assessing factors affecting vitamin D status in obese children. Factors associated with a higher prevalence of Vitamin D Deficiency include poverty, winter/spring season of serum collection, lack of vitamin D supplement use, low milk intake, greater TV/computer use, and low physical activity.1 Our study suggests that although these factors are important, they do not necessarily influence the change in risk for vitamin D deficiency in this sample of severely obese children. Sample size might be one of the reasons for these differences. Our study included 91 children whereas the National Health and Nutrition Examination Survey (NHANES) study had 12,292 children in the sample. Another difference is the geographic location, as our population was mostly from Western Massachusetts.

Our study has several limitations. First, these results arise from a cross-sectional study design. As such, the associations should be interpreted as co-relational. It would be premature to assume based on these results that reducing BMI Z would necessarily increase 25(OH)D. Such evidence would need to be derived from prospective studies of change in BMI Z. Second, the limited sample size led to rather imprecise estimates, particularly for the multivariate analyses. Small sample sizes can exaggerate estimates of the odds ratios derived from logistic regression, regardless of adjustment.31 We used only a crude measure of sun exposure as a covariate in our multivariable models. Although limited, the use of season was significant in our base model and the odds ratios associated with each season appeared reasonable.

The study’s design was strengthened by the use of a validated FFQ23,24 for estimating vitamin D intake in this high-risk pediatric population and was pilot-tested in the clinical community of interest. The inclusion of a comprehensive list of multiple risk factors, as well as the use of a study population comprised of a racially and ethnically diverse sample of children from an urban location geographically at high risk for limited sunlight exposure, were other strengths of our study.

Given the numerous behavioral and environmental factors that influence sun exposure and its effect on 25(OH)D level, it is not clear that a self-reported survey would contribute more meaningfully to the model than the adjustment for season. This relationship needs further study, particularly in children. The question also arises as to whether better markers of 25(OH) D levels exist for obese children and adults, and this should be investigated in future research. Recently, Power,32 investigating both African American and White Americans, suggested that measurement of the bioavailable, 25(OH)D may provide a better marker of sufficiency compared with total 25(OH)D. It has also been proposed that serum free 25(OH)D may better reflect...
the vitamin D action than total 25(OH)D, for which an Enzyme-linked immunosorbent assay (ELISA) for serum free 25(OH)D has recently become available.33 Given the normal PTH levels in the setting of low 25(OH)D levels, and the observed increase in 25(OH)D following weight loss in many studies, it appears the treatment of low 25(OH)D levels in these adolescents and children could be weight reduction, and not supplementation. Future randomized controlled trials (RCTs) addressing this research question should be conducted. Our findings for the inverse association between BMI Z classification and vitamin D deficiency warrant more research to further elucidate the specific mechanisms by which severe obesity, and potential change in obesity status may influence serum 25(OH)D levels.

ACKNOWLEDGEMENTS

SK and CW conceived the study, received grant support, and conducted/supervised the study. PV conducted the primary analysis of the data, and facilitated data modeling and interpretations. HG managed the literature review with updated references, and incorporated revisions of the paper for critical comments from coauthors. RC contributed critical edits, with updated references from the scientific literature. MG provided scientific reference updates. All authors contributed to the review and interpretation of data, and in the editing and approval of the final paper. SK and CW had primary responsibility for the final content presented. All authors critically revised the paper for intellectual content and read and approved the final draft.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES


Measurement of Fat Content in the Human Body by Nuclear Magnetic Resonance Methods

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ABSTRACT

Aim: Characteristics of adipose tissue in the human body reflect the specifics of metabolism in the body, and therefore present an interest for the medical diagnostics. It is useful to apply the methods that allow to get such information non-invasively, namely with the help of high resolution nuclear magnetic resonance (NMR) spectroscopy and magnetic resonance imaging (MRI).

Material and Methods: In the present study, we have implemented such techniques by using the 0.5-Tesla MRI scanner Bruker Tomikon S50. Processing MRI images was carried out using graphical tools of ImageJ software.

Results: Measurements of fat content in the human body by NMR spectroscopy were carried out on the 0.5 T MRI scanners. The NMR spectra were obtained from the separate parts of the body and then combined. The peaks of water and fat were determined in this composite spectrum. Their analysis provided information about the content of fat in the human body. To spatially select the scanned volume, we applied the methods of local NMR spectroscopy with the use of non-uniform (gradient) fields. We then compared spectral data with the average density of the body for each study subject, as well as with the volume of fat found from the MR images. The correlation between these parameters was established.

Conclusion: There is an inverse relationship between the average body density and the fat-to-water ratios obtained from spectroscopy (IF/IW) and MRI (VF/V) data. For any person, the correlation between the real body fat percentage and the ratio of water and fat peaks from the whole-body NMR spectra takes place.

KEYWORDS: Local nuclear magnetic resonance (NMR) spectroscopy; Whole body magnetic resonance imaging (MRI); Fatty tissue.

INTRODUCTION

Characteristics of adipose tissue in the human body (its condition and volume) reflect the specifics of metabolism in the body, and therefore are of interest for the medical diagnostics. The simplest method to estimate these characteristics is anthropometry, which can reveal the deviations of body proportions (dimension and weight-wise) from empirically defined standards. However, this method does not provide information about biochemical and anatomical features of the adipose tissue in the body. Hence, there is an interest to the methods that allow to get this information non-invasively. These include approaches based on the phenomenon of nuclear magnetic resonance (NMR), namely high resolution NMR spectroscopy and magnetic resonance imaging (MRI). Local NMR spectroscopy performed in vivo provides information on the chemical structure of the tissues. MRI gives images of tissue slices, on which one can select and calculate the volume of tissue with physical characteristics (chemical shift, relaxation, and others) most close to the tissue of interest (adipose tissue in our case).

The above mentioned methods are most effective when the whole human body is scanned. This can be achieved by moving the body through the scanner and taking images one part of the body at a time—the one that is currently located in the magnet’s isocenter, where the magnetic field is most uniform.

The main problem of the MRI is a relatively long scan time—several minutes for one part of the body. Moreover, for each part, 2 or more scans with different parameters should be performed to identify the relaxation characteristics of the studied tissues, which further increase the total time of the study. Consequently, fast analysis methods (for example, whole body NMR spectroscopy) are of great interest, because the spectrum from the part of the body can be obtained in one second. One version of this method is proposed in the paper, which describes experiments with mice. In the mentioned paper, the correlation between the ratio of water and fat peaks in the NMR spectrum from the whole body of a mouse and the amount of fat contained in the animal body was found. These conclusions were made from the comparison of the spectral data with the results of carcass analysis based on the animal dissection with subsequent mechanical separation of fat, muscle and other tissues of the body.

This method can be justified by the fact that the proton NMR spectrum of the whole body of vertebrates contains pronounced water and fat peaks located at 0 and -3.5 ppm respectively (Figure 1). Therefore, there is a good reason to believe that similar spectral measurements may be informative for human body too.

MATERIALS AND METHODS

The main problem with the acquisition of the NMR spectrum from the whole human body is that its size is significantly larger than the region of the magnetic field homogeneity. The measurements cannot be done at once for the whole body, as for a small laboratory animal (e.g., a mouse), but only part by part. Therefore, the scanned body segment must be located within a zone with good homogeneity of the magnetic field. The easiest way to perform such a scan is to move the object gradually through this zone.

![Figure 1: Whole-body NMR spectra for different types of animals at 0.5 Tesla: top to bottom–Mollusk (slug), Crustacea (crawfish), Agnatha (lampetra), Osteichthyes (carp), Mammalia (rat).](image-url)
In the present study, we have implemented such techniques by using a 0.5-Tesla MR scanner Bruker Tomikon S50, which can work with gradient strength of up to 16.8 mT/m, and a 2-kW RF transmitter. NMR spectra were obtained slice-by-slice. Schematic of location of these slices and the corresponding spectra are presented in the two leftmost frames of Figure 2. In the combined NMR spectrum, the intensity of peaks of water IW and fat IF were measured (the third frame of Figure 2).

Since the carcass method is not suitable for human analysis, the spectral measurements were compared with the data on the average density of the body $\rho=m/V$, where $V$ is the volume of the body, and $m$ is its mass.

The mass was determined by weighing on a common scale. To determine the body volume, MRI data were used however, there are alternative methods to do it (for example, measuring the change in water level when a study subject is immersed into water bath).

MRI allowed identifying the anatomical structures, to measure the body volume ($V$) and the total amount of abdominal and subcutaneous fat $V_F$ (three right frames of Figure 2).

The scanning area was a slice with the thickness of 20 cm oriented perpendicular to the direction of moving the body. The patient was placed in the usual for MRI horizontal position on a mobile platform, which was incrementally moved with the step equal to the slice thickness. It allowed moving the whole body through the magnet’s isocenter (where magnetic field is the most homogeneous) and obtaining a local NMR spectrum for each segment of the body with the thickness of 20 cm (number of such segments for adults varied between 8 and 10).

To limit the effective scanning volume, conventional slice-selective MRI method was used; the gradient field directed perpendicular to the plane of the selected slice was applied simultaneously with the frequency-selective excitation RF pulse.

The slice thickness $Z$ is determined by the equation: $Z=2\pi\Delta f/\gamma G$, where $G$–magnetic field gradient, $\gamma/2\pi=26.5$ MHz/T–gyromagnetic ratios of protons, $\Delta f$–the width of the frequency spectrum of RF pulse, which is inversely proportional to the pulse duration.

For monitoring location of a certain part of the body, one-slice (with the thickness in head-to-foot direction equal to 20 cm) images in three orthogonal planes were recorded in advance. These images were used for rough estimation of the body volume $V$.

Processing MRI images was carried out using graphical tools of ImageJ software. Calculation of the body volume was performed the following way: for each projected MRI image the contour of visualized part of the body was determined and its area was quantified by binarization method–transformation of halftone image to black-and-white image. Binarization threshold was calculated automatically using the ImageJ tools. The contour area quantified for coronal projection was multiplied by slice thickness that gave the main contribution to the measured body volume. Extra contribution determined by measuring contour areas in other two projections was subtracted from this volume. This method gives slightly overestimated results because it is hard to take into account the volume variations in the periphery of the human body (head or extremities). However, the contribution of these areas to the volume of the whole body is small. Therefore, this method of measuring body volume can be acceptable for rough fast estimates.

RESULTS

For some participants of this study, MRI images of the whole body were obtained to compare the results of the spectral measurements with the MRI data. T1- and T2-weighted images (WI) were also obtained in the Fast Spin Echo (FSE) mode with the parameters TR/TE=600/15 and 5800/100 m/sec, respectively, and ETL for FSE equal to eight. Acquisitions of the local NMR spectra and whole-body MRI were carried out by moving incrementally these participants through the zone of the magnetic field homogeneity. For MRI, 26-slice scanning

Figure 2: Measurement of body fat percentage by the local NMR spectroscopy (three left frames) and MRI (three right frames).
was performed with the resolution of 2.2×2.5 mm and the slice thickness of 10 mm. The total scan time did not exceed 30-40 min.

Fat structures on images were visually defined by comparison with anatomical atlases. A typical sign of adipose tissue is the fact that MRI-signal on T1- and T2-FSE-WI increases. This increase of the MRI signal in T1-WI is due to the fact that tissues with short relaxation time of T1 have stronger response. The reason why adipose tissues are clearly seen in T2-FSE-WI but not in T2-WI, is explained in Henkelman et al. The analysis of T2-FSE-WI did not include other clearly identifiable anatomical structures that also produce increased MRI signal on the images, such as bladder, cerebrospinal liquid, liver, kidney, brain structures, etc.

The result of such data processing (binarization of MR images and removal of the above mentioned structures from them) were the MR images similar to shown in the rightmost frame of Figure 2. On these images, the light areas, which supposedly represent adipose tissue, were measured. The total volume of adipose tissue was determined by combining the measurements for all slices.

The following Table 1 shows the results of 8 study subjects.

<table>
<thead>
<tr>
<th>No. of subject</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$ (kg/m$^3$)</td>
<td>960</td>
<td>985</td>
<td>997</td>
<td>1000</td>
<td>1014</td>
<td>1016</td>
<td>1045</td>
<td>1175</td>
</tr>
<tr>
<td>$\bar{I}_f/\bar{I}_w$</td>
<td>0.97</td>
<td>0.84</td>
<td>0.93</td>
<td>0.77</td>
<td>0.65</td>
<td>0.61</td>
<td>0.31</td>
<td>0.42*</td>
</tr>
<tr>
<td>$V_F/V$</td>
<td>-</td>
<td>0.46</td>
<td>0.42</td>
<td>-</td>
<td>0.32</td>
<td>-</td>
<td>-</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*fat peak was not identified on the background of the wide water peak.

Table 1: Results of 8 study subjects.

DISCUSSION AND CONCLUSIONS

From these results we can conclude that, in general, there is an inverse relationship between the average body density and the fat-to-water ratios obtained from spectroscopy (IF/IW) and MRI (VF/V) data. This conclusion is in agreement with the intuitive assumption that this density should decrease when the body fat percentage increases. Thus, for any person the correlation between the ratio of water and fat peaks from the whole-body NMR spectrum and the real body fat percentage takes place. This statement is in agreement with the results of work Mystkowski et al.

The comment to the Table 1 mentions the problem of differentiating broad spectral peaks in situation when the magnetic field has relatively low intensity (0.5 Tesla in our case). For comparison, in the work Mystkowski et al. the spectral measurements were performed in the magnetic field of 4.7 Tesla. So, the peaks of water and fat in their spectra were well differentiated, and NMR measurements were reduced to assessing areas under NMR line contours (integrals). In our case, the field is relatively low (0.5 Tesla) and the overlapping of the NMR lines is significant. Hence, it is hard to separate the individual contributions of water and fat lines.

Because the location of these peaks is known, math modeling allows solving this problem when the forms of the lines are known. However, the lack of reliable information about the forms of these lines makes the solution of this problem difficult. Therefore, we measured only the intensities of fat and water peaks, but not their integrals. As a result, we obtained upper limit of the $I_f/I_w$ ratio. For more accurate measurements, the human fat percentage should be evaluated by the NMR methods using MR scanners with the highest possible magnetic field (1.5 Tesla and above). In this case, the spectroscopy method may be more useful than MRI, because spectroscopic measurements can take substantially shorter time.

Obtained results demonstrate the potential of spectroscopy method for fast evaluation of fat percentage in human body. This method is simple to implement, which includes both acquisition of spectra and data processing. Because it is not associated with high RF exposure for the patient and does not take much time, this method can be easily integrated into the whole-body MRI study.

ACKNOWLEDGEMENTS

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

STATEMENT OF HUMAN AND ANIMAL RIGHTS

All applied procedures were fulfilled in accordance with the ethical standards of the responsible committee on human experimentation (Institutional and National).

CONSENT

Informed consent was obtained from all the patients for being included in the study.

REFERENCES


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Knowledge about Feeding and Practicing Physical Activity as Protective Factors of Overweight and Obesity in Students of Official Schools in the Municipality of Sopó

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ABSTRACT

Objective: To establish the knowledge of students of cycle IV of official schools of the municipality of Sopó in relation to food and adequate physical activity (AF), as protective factors of overweight and obesity.

Methodology: A descriptive cross-sectional study (diagnosis) was carried out through three phases, in the first phase, a conceptual reference was built on the competencies that would be expected to strengthen in students through the curriculum, in relation to food and adequate physical activity as prevention of overweight and obesity. In a second phase, the curricula of the areas of Natural Sciences and Physical Education were analyzed in order to establish whether or not they provide sufficient and necessary knowledge to the students in relation to the feeding and practice of physical activity as protective factors of overweight and obesity. Then in the last phase, a survey was applied to 469 students between the ages of 12 and 19 with questions associated with obesity, overweight, physical activity and adequate food.

Results: In relation to the practice of physical activity, it was established that only 10% of the students complies with the global recommendation of 60 minutes per day, in relation to physical activity, 88% is not clear which are the components to have into account during the practice of physical activity frequency, intensity and time (Organisation mondiale de la Santé, OMS, WHO 2010). With respect to the knowledge for choosing a healthy diet, it would be essential to conclude that the knowledge is insufficient, since 63% of the students include a sweet dish and other foods that are high in sugar in their diet. Regarding the overweight and obesity prevalence, only 12% are perceived as overweight and 8% come under obese, rest of the 80% are neither of the two categories. The figure that is in contrast with the nutritional status was reported by the Nutritional Surveillance System (SISVAN) of the municipality in the recent years.

Conclusions: It was possible to conclude that the curricula of the areas of Natural Sciences and Physical Education Recreation and Sports do not provide students with the necessary and sufficient knowledge when it comes to adequate diet and practice of physical activity as prevention measures of both overweight and obesity, however, they provide some guidance regarding healthy habits and lifestyles.

KEY WORDS: Feeding; Overweight; Obesity; Physical activity; Study plans.


INTRODUCTION

Overweight and obesity are the global public health problems that affects both developing and developed countries.1 Its most frequent causes are associated with genetic factors, inadequate
feeding habits and physical inactivity. Exercise as an activity to benefit the health, care and maintenance of the body, as well as the promotion of healthy lifestyles and food, have been displaced by sedentary work dynamics, low-energy leisure activities such as watching TV, playing video games and surfing on the internet, as well as eating habits of high caloric content and low protein intake. According to the World Health Organization (WHO), in 2012, about 44 million (6.7%) of children under 5 years were overweight or obese, while in 1990 they were only 31 million (5%). In Colombia, according to figures from the National Nutrition Situation Survey in 2010, 17.5% of children and young people aged 5 to 17 years are overweight. The Secretary of Health of the Municipality of Sopó in 2012 performed a nutritional screening survey in school children aged 6 to 11 years, which resulted in 13.9% overweight and 3.9% obesity; between the age of 12 to 17 years: 17.7% overweight and 3.3% obesity. In 2013, the school population aged 5 to 11 years were found to be 27% overweight and obesity, a sharp increase of 9.2% over last year. In the 12 to 17 year old students, 19% were overweight, 1.3% increase compared with the previous year. Studying overweight and childhood obesity in school contexts a strategy for their prevention and is one of the challenge that educational institutions have to incorporate into their curricula mainly with pedagogical actions inside and outside the classroom, modifying behaviors and internalizing learning. According to the National Nutrition Situation Survey, the prevalence of overweight or obesity in the population aged 5 to 17 years has increased 25.9% in the last five years and in this age group it was previously found as 17.5% nationwide. Three percent Colombians between 5 and 64 years of age do not consume fruits daily and that 5 out of 7 (71.9%) between the age 5 to 64 years do not consume vegetables daily. “Similarly,” approximately 1 in 4 Colombians (24.5%) between the age of 5 to 64 years, 25% ate fast food every week. About 22.1% of 1 in 5 Colombians between 5 and 64 years consume soft drinks on the daily basis. The following was a descriptive cross-sectional study (diagnosis): the population was constituted by 469 students of both genders residing in the municipality of Sopó, Cundinamarca, belonging to cycle IV and enrolled for the academic year 2015 in the official educational institutions of the municipality. Variables such as overweight, obesity, physical activity, study plans and healthy eating were taken into account. The procedure was developed in several stages. In the first instance, the technical documents proposed by the Ministry of National Education were analyzed through the Basic Standards for the areas of Natural Sciences and Physical Education. The next step allowed to categorize each of the contents observed in these standards. Subsequently, compared to curricula provided by educational institutions, a new matrix was created. With all the information provided, we proceeded for designing the information collection instrument based on the research questions. With knowledge regarding food and adequate physical activity as protective factors of overweight and obesity which are observed in the educational training process at the level of cycle IV in the official schools of the municipality of Sopó. When elaborated the questionnaire, validated with experts, we took into account their recommendations and suggestions and designed a pilot test of 25 questions that was applied in students of the school Delia Zapata Olivella, Suba, Bogota, Colombia with similar characteristics of cycle IV of the official schools of the municipality of Sopó, afterwards adjustments were made to some terminologies, which were not clear for a group of students and five questions were eliminated. Once the survey was consolidated, it was preceded by the application phase (questionnaire of 20 questions) and tabulation of the data obtained.

### Statistical Analysis

A database was built with the results of the survey in the program Microsoft Office Excel 2010, the variables were analyzed using descriptive statistics determining frequency distributions and percentages with the application of the SPSS program as database manager with the information obtained from the curricula of the areas of Natural Sciences and Physical Education, and a matrix was built with the main findings. The matrix for the area of Natural Sciences groups two major categories. In addition, the matrix for the area of Physical Education due to its particular structure (competencies and performances), initially addresses what was found in the curriculum of the different institutions and subsequently presents the matrix of contents suggested by the Ministry of National Education (MEN) for each degree.

### Sociodemographic characteristics

The study population consisted of 469 students between the ages of 12 and 19 years, belonging to the eighth grade 54% and ninth 46% (cycle IV). The gender distribution was taken as 53% female and 47% male. The average age was between 14 and 15 years, out of which, major population was located in the urban areas (60%) while 40% live in rural areas. As for their time in the institution, (24 years) 24% were between 1 and 2 years, 27% were between 3 and 4 years, 9% were between 5 and 6 years, 19% were between 7 and 8 and finally 21% were between 9 and 10 years.
Knowledge Related to Healthy Eating

It was possible to determine that 90% of the students (n=424) have knowledge related to healthy eating mainly referred to the consumption of fruits and vegetables. However, knowledge is insufficient when choosing the foods that make up a healthy diet. 63% (n=294) include sweets and sugary foods that are part of their diet. In this same sense, ignorance on the part of the students is observed when identifying a healthy food, since 75% (n=352) identifies through their taste and texture, 18% (n=82) agree that through the food label; while 7% (n=35) conclude that through its price (Figure 1).9,10

Knowledge regarding Overweight and Obesity as an Illness

Seventy three percent (n=340) have the necessary and sufficient knowledge to relate overweight and obesity to a non-transmissible chronic disease, while 21% (n=100) relate them to a habit. In addition, 80% (n=375) do not perceive in their body any of these chronic non-communicable diseases, such as obesity or obesity, only 8% (n=38) were perceived as overweight and 12% (n=56) were obese (Figure 2).9,11

Physical Activity

According to the results obtained with respect to physical activity AF, 10% performed AF between five and six days, 36%, one or two days, while 54% walked for three or four days a week, for ten minutes during the last seven days prior to the application of the survey. Regarding knowledge about AF 70% consider that it is a driving quality that improves health and relates to physical condition, 25% refers to exercises to improve breathing and 5% associates it with communicative skills. When asked about the components of physical activity (frequency, intensity and time), 76% considered that strength, endurance and speed are its components. 15% argued that as the stretching, exhaustion and fatigue, 9% agreed with frequency, intensity and time.

Study Plans

The curricula of the areas of Natural Sciences and Physical Education of the official schools of the municipality of Sopó were...
analyzed through a matrix. In the area of scientifiic knowledge-related aspects were identifiied in two areas, firstly, the approach to basic scientifiic knowledge, the management of knowledge of science through various environments (living environment, physical environment, science, technology and society). In the area of physical education the contents were structured by competences and performances, through which the student demonstrates the level of development of the competition through their performances, in which it manifests the meaning and their ability to perform and in the attitude towards knowledge, in changing situations of application. The performances are the observed and evaluates the manifestation of the state of development of a competition and are constructed as units of learning that enable their formation and evaluation.\textsuperscript{1,2}\textsuperscript{11} The performances are the observable and evaluable manifestation of the state of development of a competition and are constructed as units of learning that enable their formation and evaluation. They contain a formatave intention based on the characteristics of the student’s development, the complexity of the contents and the relationship with the context. The performances are expressed as statements that explain the learning actions, the conditions of realization and the meaning. They can generate relationships and interactions that contribute to the development of different competencies. The formulation of specific competences implies their utterance independently, but they integrate the totality and unity of the human being.

**DISCUSSION**

Regarding the socio-demographic component, there were no signifiicant differences in relation to gender and location (53% female and 47% male). Most participants (60%) live in the urban part of the municipality. The percentage of students in the institution between 9 and 10 years is 21%, while a student between 1 and 2 years corresponds to 24%, indicating that the curriculunm did not have impact on all the students, in the same way, since many of them come from various institutions which are official and unofficial both.\textsuperscript{14,15} As for food, a signifiicant percentage (60%) of students surveyed have the knowledge to identify healthy eating in terms of variety and balance; as a result, relating them to eating habits such as fruit and vegetables consumption (90%). However, at the time of identifying the foods that make up a healthy dish, only 25% have the knowledge to establish which food (proteins, fruits, vegetables, cereals, dairy products, fats and sugars), have a very low figure, if taken into account that 63% say that sweets and candies are part of a healthy dish.\textsuperscript{16} That is, while students have the knowledge to identify which foods are healthy or not, when given a choice, they choose not to eat healthy. When referring to overweight and obesity as a concept, 88% have enough knowledge to relate it to excess fat that can be harmful. Similarly, for 73%, it is related as a disease that afffects the current or future state of your health.\textsuperscript{17} The results show that most students are not perceived to be overweight and 80% are considered as obese. Only 12% (n=56) were perceived as overweight and 8% (n=38) with obesity. Figures that contrast with the nutritional status reported by the SISVAN of the municipality in recent years. The population aged 5 to 18, for the year 2012, represents 15.8% of overweight people, for the year 2013, 17.50% and 14% for the year 2014. Powerfully calls attention, which by the year 2014, exceeds the levels of the department and the nation, 12.9% and 13.4% respectively. One of the aspects that could inflence, is that a large part of the students 47% does not have the knowledge to identify body mass index (BMI) as an indicator to evaluate their nutritional status. Concerning the practice of physical activity, it is observed that the levels are low, only 10% of the students surveyed performed 60 minutes of daily physical activity through activities such as running, jumping and walking, while 54% performed between 30 and 40 minutes, half of what is recommended. When analyzing the curricula provided by the institutions, it is observed that in some centers (two), none exists for the area of Natural Sciences in grades six and seven, likewise, in one of the institutions, no such plan was provided for the area of Physical Education in primary school. It is established that in general the curricula in both areas integrate important elements that are part of the sciences, but they do not know others and the processes that are articulated in order to generate knowledge. For example, in basic primary content the thematic axes are developed in a disjointed way. In secondary school, they are incomplete and superficially approach some aspects related to habits, healthy lifestyles, overweight and obesity. However, through the area of physical education, a series of recreational and sports activities are promoted that allow the student to develop some skills and abilities.\textsuperscript{18}

**CONCLUSION**

Through this study, we sought to establish knowledge regarding diet and adequate physical activity as protective factors of overweight and obesity in the process of educational training of students of cycle IV of official schools of the municipality of Sopó. Overweight and obesity were addressed because of the increase in NCDs in the Juvenile population; understanding that education with all its structure should allow eradicating this type of scourge of people’s lives. In this study it was possible to establish that during the training process of the students of cycle IV of the official schools of the municipality of Sopó, the curricula of the areas of Physical Education and Natural Sciences do not provide suffcient and necessary knowledge related to adequate diet and practice of physical activity as protective factors of the overweight and obesity. They offer some guidelines in relation to healthy lifestyles, but developed them in a disjointed way taking into account that the thematic axes do not address overweight and obesity including them as important elements. Students do not have enough knowledge to identify a healthy food.\textsuperscript{19} The vast majority do it through the taste and texture and not through the label, where all the nutritional information is printed. The levels of physical activity are very low which makes it possible to classify them as inactive, since they are indulged in some leisure activity of slight intensity less than one hour a day.\textsuperscript{20} The vast majority of students are not perceived to be overweight or obese; conclusion that contrasts with the results of the nutritional monitoring carried out by the municipality through the secretaries of education and health.
CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES


ANNEXES

ANNEXES 1: Questionnaire for the Assessment of Knowledge on Food And Practice of Physical Activity as Protective Factors of Overweight and Obesity in Students of Cycle IV in Official Schools of Sopó Municipality.

Below you will find a series of questions that aim to evaluate your knowledge regarding overweight, obesity, practice of physical activity and adequate food according to the curricula of the areas of Natural Sciences and Physical Education Recreation and Sports. The questionnaire consists of 20 questions, with a single correct answer alternative. Please fill in the oval in the answer sheet, with the option that you consider correct.

BASIC DATA

Educational institution: __________________________________________________________

Grade: ______________________

Age: ______________________

Gender: Female: ___ Masculine: ___

From what grade are you in the institution: _______________

Currently lives in the area: Rural _________ Urban _________

1. Which of the following activities are basic forms of movement?

a. The force
b. The resistance
c. Walking and running

2. During the last 7 days, on how many days did you walk for at least 10 minutes in a row?

a. Two days
b. Three or more days
c. not on the way

3. Do you mean the care and grooming of the body?

a. Body hygiene
b. Mental hygiene
c. Environmental hygiene

4. Are they part of healthy lifestyles?

a. Eating and practicing physical activity
b. Positive thinking
c. Watch television and surf the internet

5. Is the body mainly hydrated?

a. Maintenance of healthy bones
b. Recover or supplement lost fluids
c. Reduce hunger and quench thirst

6. Overweight and obesity refer to?

a. An illness
b. A lifestyle
c. A habit
ANNEXES

7. One of the ways to identify a healthy food is through?
   a. Its taste and texture
   b. The label
   c. Its price

8. Physical condition refers to?
   a. A set of capacities or motor qualities that can be improved through the practice of physical activity and that serve to carry out daily activities.
   b. A set of exercises to improve muscular endurance and breathing.
   c. A set of skills and abilities to communicate in society.

9. Identify a healthy eating habit through the following actions?
   a. Consume several servings of vegetables and fruits per day
   b. Drinking soft drinks several times a day
   c. Consume products based on flour and sugars several times a day

10. Does food play an essential role in obtaining energy from humans, which of the following statements do you consider corresponds to the characteristics of healthy eating?
   a. Must be varied and balanced
   b. Must be rich in carbohydrates and proteins
   c. Must be based on dried fruits and vegetables

11. Are the main components of physical activity?
   a. Frequency, intensity and time
   b. Stretching, exhaustion, and fatigue
   c. Strength and endurance and speed

12. To prevents diseases such as being overweight and obese, is it recommended?
   a. Prepare food without excess salt, fats and sauces.
   b. Play and engage in physical activity occasionally
   c. Consume foods outweigh the number of calories we can spend on a daily basis.

13. Is the main objective of warm-up and stretching?
   a. Prepare the muscles and joints for different physical demands.
   b. Improve physical abilities for two hours.
   c. Improve the technical fundamentals of a given sport.

14. Are you currently in overweight or obese condition?
   a. Overweight
   b. Obese
   c. None of the above

15. Overweight and obesity are defined as?
   a. A disease of the central nervous system
   b. A health problem affecting children and adolescents who eat fruits and vegetables
   c. An abnormal or excessive accumulation of fat that can be harmful to health.
16. One of the functions of food sources of protein is reflected?
   a. In the formation of muscular tissue
   b. In decreasing body weight
   c. In increasing percentage of fat in the body

17. Does the “healthy dish” strategy contain the following foods?
   b. Proteins, fruits vegetables and dairy.
   c. Proteins, fruits vegetables, cereals, tubers, dairy products, fats and sugars

18. Which of the following foods do you consider to be a source of protein?
   a. Grains such as beans, lentils and chickpeas
   b. Fruits and vegetables apple and orange
   c. Soft drinks

19. Is vigorous and moderate are one of the most important characteristics of?
   a. The types of bones that run through our body
   b. The membranes of the digestive system
   c. Physical activity

20. Is the Body Mass Index (BMI) important for health because it allows?
   a. Identify sexually transmitted diseases that can impair health
   b. Identify the type of exercises a person should do to improve health.
   c. Identifying chronic noncommunicable diseases such as overweight and obesity