Research Article

Application of Principal Component Analysis (PCA) in a Nutritional Intervention Program Performed in Overweight and Obese Pediatric Patients

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Abstract

Introduction: Childhood obesity is a serious public health problem in Mexico. A nutritional intervention program (NIP) and the construction of nutritional status index for its prevention, can prevent non-communicable diseases in adulthood; and communicable ones such as COVID-19.

Objective: Apply a Principal Component Analysis (PCA) to evaluate the effect of a NIP in overweight and obese pediatric patients.

Methodology: 50 children between the ages of 7 and 13 years old participated. A clinical record and a nutritional diagnosis were prepared. A descriptive analysis was made using measures of central tendency, dispersion, and variable association; Pearson's correlations, Student's "t" tests for paired samples, univariate analysis of variance (ANOVA), multivariate (MANOVA) and a Cluster analysis were performed to form groups of children with similar multivariate behavior. A nutritional index (NI) was obtained for the patients using a PCA.

Results: The NIP showed a statistically significant effect ($p \leq 0.05$) on anthropometric response variables. The weight mean decrease 9.7 ± 0.3 Kg. The intestinal habit and age significantly affected ($p \leq 0.01$) the "Change in Weight" and the "Change in BMI" variable. The fast-food intake frequency and sweetened drinks decreased. Using the PCA, two components were selected that explained 94.9% of the total nutritional variation observed in the patients.

Conclusion: At the end of the NIP, the multivariate behavior of pediatric patients changed positively and the dispersion of children in the variables involved decreased.

Keywords: Childhood Obesity; Principal-component-analysis; Eating-habits; Nutrition-intervention; COVID-19

Introduction

Obesity is a multifactorial chronic disease (genetic, metabolic, psychosocial, and environmental factors) that often begins in childhood or adolescence. Defined by an imbalance between daily energy intake and expenditure, characterized by excessive accumulation of fat, weight gain, and body volume [1-3].

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Several studies have established that childhood obesity is a risk factor linked to higher cardiovascular disease, hypertension, hypercholesterolemia, and type II diabetes cases in adults [4,5]. Moreover, obesity is a risk factor that can aggravate COVID-19 symptoms in young patients. The first scientific evidence reported from the United States and Canada confirms that more than 20% of [6,7] young patients (6 years and older) admitted to pediatric intensive care units for COVID-19 had obesity [8]. Rivas-Ruiz., *et al*. (2020) report that children positive for SARS-CoV-2 in Mexico had a statistically higher obesity percentage [9].

The National Health and Nutrition Survey 2018-2019 in Mexico showed 8.1% and 17.5% of overweight and obesity prevalence (respectively) in children between 5 and 11 years old. Children and adolescents between 12 and 19 years old revealed 23.8% and 14.6% of overweight and obesity prevalence. In recent years, statistics indicate that a third of the population between 5 and 11 years old has excess body weight (overweight plus obesity), becoming a serious public health problem. In addition, Mexico is among the top 10 countries with the highest obesity prevalence in children of 5 to 19 years old. Thus, a big challenge poses in institutions responsible for Public Health and Child Welfare to help mitigate factors that affect the health and quality of life of the most vulnerable children [10-13].

In recent years, community strategies for nutritional surveillance and health promotion have been developed through the acquisition of healthy eating habits [1,4]. Nutritional intervention programs (NIPs) have been designed, organized, and implemented to gradually achieve the nutritional model fitting towards a healthier profile [12], to promote better nutrition education, and in turn, prevent noncommunicable diseases in adulthood [14]. Besides, contribute to decreasing obesity as a risk factor that aggravates diseases, such as COVID-19 [3,7].

Body mass index (BMI) is the most common tool used to diagnose obesity. However, the current concept and measurement analysis present inaccuracies and biases. Therefore, new assessment and screening alternatives should include a multifactorial analysis that involves more variables. Principal Component Analysis (PCA) is applied to explore the relationship between elements of a population to predict whether this relationship is somehow influenced by a set of variables or by the properties of the elements themselves [15].

However, current studies that use PCA for the analysis of nutritional intervention outcomes are scarce. Therefore, this research aimed to apply Principal Components Analysis to evaluate the effect of a Nutritional Intervention Program on pediatric patients with overweight and obesity who attend their medical appointments in a Health Center in Chihuahua, Mexico.

Materials and Methods

Method and study subjects

For this observational, descriptive, cross-sectional epidemiological study, 50 children aged between 7 and 13 years old, with obesity and overweight, participated.

Health Center authorities, parents, and/or legal guardians of the minors were previously informed about the research whereabouts. The Ethics and Research Committees of the Faculty of Nursing and Nutriology of the Autonomous University of Chihuahua, Mexico, issued a favorable opinion (official letter 115). Also, the Health Center Human Resources Department granted a permit to carry out the study, besides the parent's or guardians' informed consent to guarantee data protection and confidentiality. The study was carried out for six months, monitoring patients each month. With an approximate 20–30-minute consultation time.

On the first appointment, a clinical record was constructed, including personal information, pathological diseases, hereditary family history, 24-hour reminders, and frequency of fast-food intake. We investigated eating behavior (appetite, intake, swallowing) and bowel habit (normal, constipation, or diarrhea). An appointment schedule was delivered to participants, explaining the program's whereabouts to elaborate a nutritional diagnosis. Anthropometric measurements were made following the protocol established in the Data Collection Procedure Manual, specifically elaborated for the WHO (COSI) [16], International Society for the Advancement of Kinanthropometry (ISAK), technical recommendations [17], carried out by two previously trained nutritionists from the pediatrics area. During the measurements, the parents or guardians were always present with the minors.

Body weight was measured in kg using a digital scale (Health-o-meter model BFM 580-01, Shanghai, China), with a 0.1 kg sensitivity. Body height was measured in cm, standing, using a portable

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stadimeter (Avanutri 312, Mexico). BMI was calculated using the following equation: weight (Kg) divided by height squared (m2). Instruments were calibrated for every 25 weight and height measurements. We also provided a list of healthy snacks and examples for physical activation involving the whole family. At each appointment, we provide teaching material to parents or guardians regarding: "Basic food handling and preparation practice", besides adjusting the nutritional plan according to the patients' requirements. We use a similar procedure for the following four appointments.

Patients who improved their anthropometric measures: appetite habits, and fast-food intake, were dismissed, providing their nutritional diagnosis results and evolution during the study period. Patients who did not achieve the objectives were invited to resume the NIP.

Statistical analysis

- A descriptive analysis was performed using central tendency, dispersion, and association statistics between pairs of variables.

- Pearson correlations and Student's t-tests were estimated to compare variables means measured before and after the intervention.

- Univariate analysis of variance (ANOVA) was performed to test differences in changes by the effect of various classification factors (gender, age, appetite, initial conditions, habits, and intake).

- A Principal Component Analysis was applied to obtain a patient's nutritional status index and to observe changes in multidimensional variability.

- Cluster analysis was performed to obtain children's groups with similar multivariate behavior. And univariate Analysis of Variance (ANOVA) and multivariate Analysis of Variance (MANOVA) was run to test differences between the groups formed. Data were analyzed using Minitab version 17 and SAS version 9.0 statistical programs.

Results

The descriptive statistics results for the sample of 50 pediatric patients are shown in table 1. BMI initially calculated showed a 98% obesity prevalence and 2% overweight prevalence at baseline (P95 to P99, obesity conditions). These results are consistent with percentile values found in CDC growth charts (Centers for Disease Control and Prevention) in children of the same age and gender, where the overweight is determined as a BMI between the 85th and 95th percentile; obesity is defined as a BMI in the 95th percentile or higher (18). At the end of the intervention, it was observed that children (boys and girls) are in lower percentiles P47 and P88 (healthy weight and overweight values).

The Ward linkage method was used to form four groups of children hierarchically and systematically. A stratification of groups of children (Appointment 1 and Appointment 5) was performed (Figure 1 and 2). Wilks' Lambda statistic showed a multivariate statistical difference between groups (p ≤ 0.0001) [19,20].

Variables	Girls before intervention						Girls at the end of intervention					
	Mean	[a]**SD**	[b]**VC**	**Mín.**	**Med.**	**Max.**	**Mean**	**SD**	**VC**	**Mín.**	**Med.**	**Max.**
Size (m)	1.4	0.1	7.8	1.2	1.4	1.6	1.4	0.1	7.8	1.2	1.5	1.6
Age (years)	10.8	1.9	17.2	7	11	13	10.8	1.9	17.2	7	11	13
[c]BMI	25	2.5	9.8	19.2	25.4	29.6	20.2	2.1	10.6	16.5	21	23.5
Weight (kg)	52.2	11.9	22.9	30	54	71	42.3	10.2	24.1	26	43	60
Waist circumference (cm)	78.6	6.9	8.8	65	81	89	68.4	6.3	9.2	57	70	79
Variables	Boys before intervention						Boys at the end of intervention					
	Mean	[a]SD	[b]VC	Mín.	Med.	Max.	Mean	SD	VC	Mín.	Med.	Max.
Size (m)	1.4	0.1	9.8	1.3	1.5	1.7	1.5	0.2	10.5	1.2	1.5	1.7
Age (years)	10.3	2.2	21	7	11	13	10.3	2.2	21	7	11	13
[c]BMI	24.8	2.2	8.8	20.7	25.4	30.3	19.8	2.4	11.9	15.4	20	24.7
Weight (kg)	52.2	11.9	22.9	30	54	71	42.6	12.5	29.2	26	44	62
Waist circumference (cm)	80.6	9.2	11.5	65	80	95	71.2	9.3	13	52	72	87

Table 1: Pediatric patients sample descriptive statistcs

[a]SD= Standard deviation; [b]VC= Variation coefficient; [c]BMI= Body Mass Index.

Fuente: Directa.

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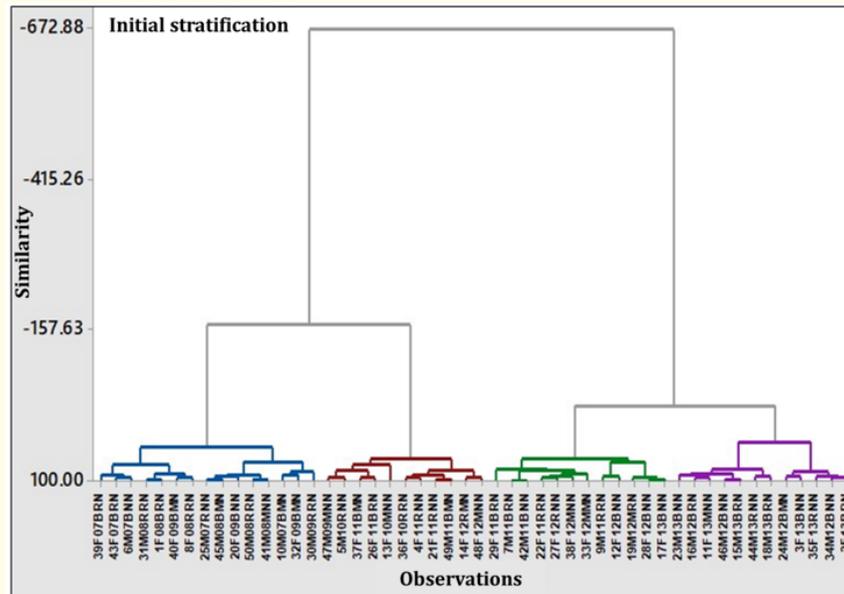
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Figure 1: Grouping dendrograms of pediatric patients based on their multivariate similarity (Beginning of NIP). Source: Table 2.

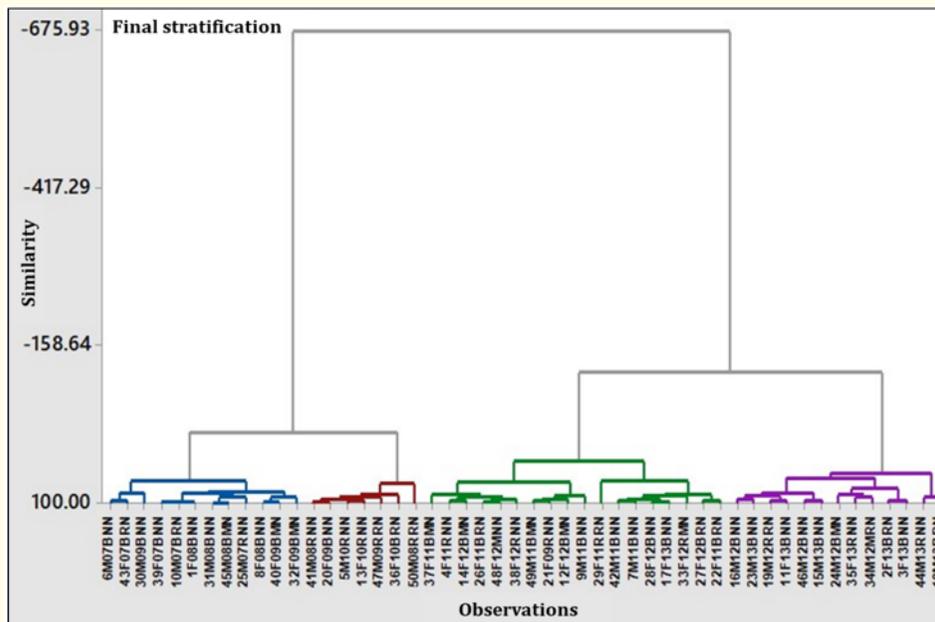**Figure 2:** Grouping dendrograms of pediatric patients based on their multivariate similarity (End of NIP). Source: Table 2.

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Initially, group 1 was composed of 53.3% boys and 46.3% girls. Like group 4, where boys were the majority (66.6%). Group 2 consisted of 90% girls, and group 3, 58.33% girls. In terms of eating habits and behavior, group 1, 3, and 4 showed good appetite (53%, 50%, 75% of boys and girls, respectively); only children of group 2 had regular appetite (45%). Fast-food intake was normal at 56%, 50%, and 58% in groups 2, 3, and 4. In group 1, fast-food intake was regular (46.6%). Swallowing resulted regular for all groups (100%). The anthropometric variables in the four groups presented high values in weight, BMI, and waist circumference, placing the children in a condition of overweight and obesity (Table 2).

ªVariables	Groups at the beginning of NIP			
	1 (15)	2 (11)	3 (12)	4 (12)
Size (m)	1.4 ± 0.04	1.4 ± 0.5	1.5 ± 0.1	1.6 ± 0.04
Age (years)	7.9 ± 0.8	10.7 ± 0.9	11.7 ± 0.7	12.7 ± 0.5
ᶜBMI	22.6 ± 1.8	24.7 ± 1.2	26.1 ± 1.7	26.9 ± 1.5
Weight (kg)	37.3 ± 3.6	49.2 ± 3.5	59.8 ± 2.7	67.3 ± 3.1
Waist circumference (cm)	69.8 ± 3.5	79.6 ± 3.2	82.5 ± 4.01	88.7 ± 4.31
Variables	Groups at the end of NIP			
	1 (12)	2 (7)	3 (18)	4 (13)
Size (m)	1.3 ± 0.10	1.4 ± 0.1	1.5 ± 0.1	1.6 ± 0.04
Age (years)	7.8 ± 0.8	9.1 ± 0.9	11.5 ± 0.6	12.6 ± 0.5
ᶜBMI	17.3 ± 0.9	18.3 ± 1.1	20.9 ± 1.04	22.3 ± 1.2
Weight (kg)	28.2 ± 2.3	32.7 ± 1.9	46.1 ± 3.6	55.8 ± 3.5
Waist circumference (cm)	59.5 ± 3.4	68.7 ± 3.9	70.7 ± 4.04	78.2 ± 4.9

Table 2: Stratification based on children initial and final condition and progress regarding the NIP.

ªData reported as Means $(\Re)$ ± Standard deviation. Direct source.

At the end of the intervention, groups 1, 2, and 4 consisted primarily of boys (58.3%, 57%, and 69.2%, respectively). In group 1, children registered good appetite (91%); group 2 had regular appetite (71.4%); groups 3 and 4 had a good appetite (61 - 69% respectively). Values for regular fast-food intake exhibited similarity in the four groups (58.3%, 57.14%, 50%, 61.5%, groups 1, 2, 3, and 4, respectively). Thus, the characterization of each group shows lower values for the weight, BMI, and waist circumference variables (Table 2).

The correlation analysis between anthropometric variables shows a strong and significant ($p \leq 0.001$) direct (positive) linear association between all pairs of variables, with a Pearson correlation coefficient (r) value close to 1. In addition, after the NIP, the association that involved the variable "BMI" with other variables increased in all cases. A few variables showed a slightly lower correlation, i.e., between the variables: "waist circumference" and "age, height, and weight"; table 3 shows the correlation between the study variables for data obtained in Appointments 1 and 5.

Variables	Age (years)	Size (m)	Weight (Kg)	BMI
Size$_{(i)}$	0.915			
	≤0.001			
Weight$_{(i)}$	0.938	0.952		
	≤0.001	≤0.001		
BMI$_{(i)}$	0.739	0.605	0.813	
	≤0.001	≤0.001	≤0.001	
Waist circumference (cm)$_{(i)}$	0.862	0.846	0.847	0.626
	≤0.001	≤0.001	≤0.001	≤0.001
Size$_{(f)}$	0.854			
	≤0.001			
Weight$_{(f)}$	0.935	0.896		
	≤0.001	≤0.001		
BMI$_{(f)}$	0.881	0.742	0.923	
	≤0.001	≤0.001	≤0.001	
Waist circumference (cm)$_{(f)}$	0.759	0.674	0.785	0.704
	≤0.001	≤0.001	≤0.001	≤0.001

Table 3: Linear correlation coefficients between variables and p-value associated to the beginning and the end of NIP.

ªp-value; (i)Initial conditions; (f)Final conditions.

Direct source.

The NIP effect on anthropometric response variables was proved, performing t-Student tests (paired or non-independent samples). The results presented (Table 4) indicate that for all the variables studied, we found a statistically significant effect ($p \leq 0.05$), except for the "size" variable, where the NIP effect was not significant. That may be due to short study time, which results in a lower size difference between the beginning and end of the intervention (0.01 m), contrary to the means difference recorded for the other variables.

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Final value vs Initial value	Teori-cal t	[a]Real t	p-value	[b]$\Re_f$ - $\Re_i$	[c]NIP effect
BMI$_{(f)}$ vs BMI$_i$	-28.19	2	6.13 x 10^{-32}	4.90	+
Size$_{(f)}$ vs Size$_{(i)}$	1.61	2.01	0.11	0.010	-
Weight$_{(f)}$ vs Weight$_{(i)}$	-28.93	2.01	1.8 x 10^{-32}	10.064	+
Waist circumference$_{(f)}$ vs Waist circumference$_{(i)}$	-20.58	2.01	9.15 x 10^{-26}	9.85	+

Table 4: t Student test for paired samples (non-independent) to evaluate the NIP effect

[a]t critical value (two tails); [b]Mean difference (($\Re_f$- $\Re_i$); [c](+) Effect; (-) No effect; (NIP) Nutritional Intervention Program; α=0.05.

Direct source.

The NIP impact obtained was measured with an indicator called "change variable", which was calculated as the difference between the initial and final value for each variable measured in each child. ANOVA was used to determine whether various factors (gender, age, appetite, initial conditions, habits, and fast-food intake) had a significant effect on each changing variable. The "bowel habit (normal and constipation)" and "age" of pediatric patients significantly affected (p ≤ 0.011) both the "change in weight" and "change in BMI" variables. While the "change in waist circumference" variable was not influenced by any of the study factors. Therefore, the NIP impact was the same for boys and girls, regardless of the overweight or obesity condition, or even the "Type of appetite (good, bad, and regular). It is relevant to point out that the ANOVA model included the initial values of the variables as co-variables or concomitant variables to make valid comparisons by eliminating the initial variation in the measured variables.

The PCA at the beginning of the intervention (Appointment 1) showed that the main component 1 (CP1) controlled 85.5% of the variability, and the main component 2 (CP2), 9.47%. Both components explained 94.97% of the nutritional variation observed in 50 pediatric patients (Figure 3). All study variables were positively associated with CP1 by the correlation coefficient (r), with an equitable contribution in nutritional variance, which could perform as a general nutrition status index for patients. BMI and weight were negatively associated with CP2 (Table 5).
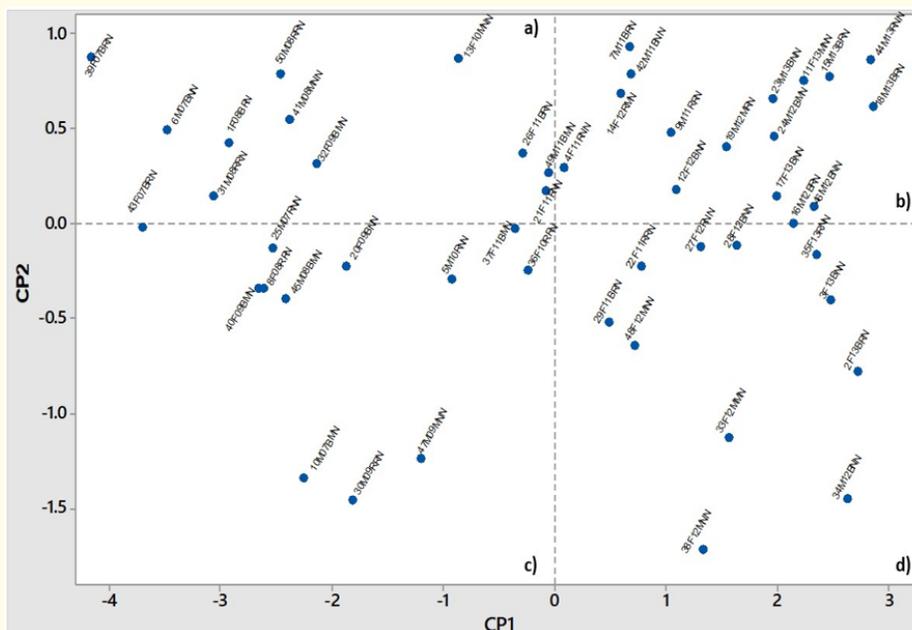

Figure 3: Distribution of the 50 pediatric patients at the beginning of NIP in two principal components (PC1 and PC2). Source: Principal Component Analysis.

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Before NIP			After NIP	
	PC1	**PC2**	**PC1**	**PC2**
Own values	4.275	0.459	4.2719	0.3536
Proportion	0.855	0.092	0.854	0.071
Cumulative	0.855	0.947	0.854	0.925
Variable	Correlation coefficient (r_{xy})			
Age	0.468	0.091	0.465	-0.139
Size	0.455	0.382	0.437	-0.368
Weight	0.477	- 0.045	0.476	-0.137
BMI	0.392	- 0.860	0.446	-0.165
Waist circumference	0.439	0.324	0.408	0.894

Table 5: Contribution of variables in the nutritional variance and correlation of variables, regarding the Principal Components.

Direct source.

After the intervention (Appointment 5), CP1 and CP2 explained 94.65% of nutritional variability. All study variables were positively associated with CP1 with an equitable contribution in nutritional variance. Thus, the same behavior and implications apply in the possible uses of CP1 as a general index for the children's nutritional health status. Unlike the variables negatively associated with CP2, the waist circumference variable had the highest contribution (89.4%) in the nutritional variation explanation (Table 5).

Figure 3 shows the wide distribution of pediatric patients in quadrants consisting of CP1 and CP2 (Appointment 1). In the quadrant "a", patients who presented the best nutritional status are located among age, weight, height, BMI, waist circumference, habits, and eating behavior variables. Quadrant "c" was like "a", with the exception that pediatric patients did not necessarily show the best values for the BMI variable. Quadrant "b" consisted of patients with values considered unsuitable for their nutritional status (i.e., high values in weight), but not necessarily in the BMI variable. Finally, quadrant "d" consisted of patients who obtained high values in anthropometric variables, poor eating habits, and unwanted eating behavior. Initially, a reliable index for nutritional status was constructed with values between -4 to 3 (CP1) and -1.5 to 1 (CP2).

At the end of the intervention (Figure 4), pediatric patients' distribution showed a tendency to improve in a multivariate way, and children's general dispersion decreased due to the NIP effect. Nutritional index ranges varied from -4 to 4 for CP1 and -2 to 2 for CP2.
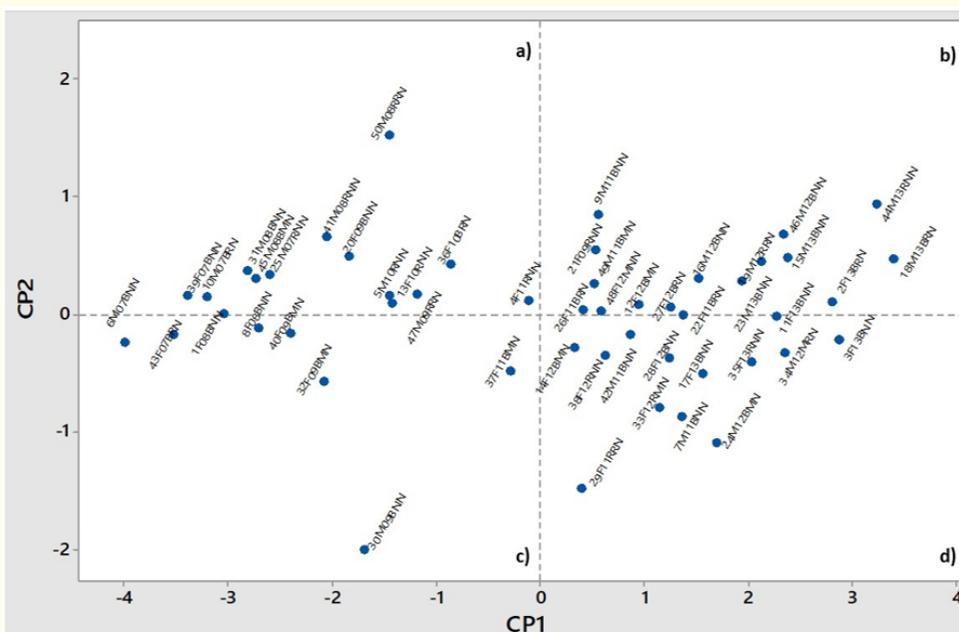

Figure 4: Distribution of the 50 pediatric patients at the beginning of NIP in two principal components (PC1 and PC2).
Source: Principal Component Analysis.

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The fast-food intake frequency showed that 48% of children consumed fresh fruit, less than 24% fish, and chicken, and meat three times a week, less than 28% vegetables daily. All the children consumed fast food more than three times a week, and more than half drank soft drinks and sugary juices. Candies showed a 100% of intake percentage. The NIP process generated positive changes, such as an increase in fruits (58%) and vegetables (36%) intake. Additionally, candy (64%) and fast food (68%) intake decreased. Dairy consumption remained constant throughout the whole NIP.

Discussion

The present study was conducted in 50 pediatric patients, within 10.8 ± 1.8 years old, with an obesity prevalence of 98% and 2% overweight prevalence at the beginning of the NIP.

Correlation analysis between the response variables involved showed a positive linear association between all variables. That is consistent with results obtained in a study conducted in Venezuela by Moya-Sifontes., *et al*. (2020), where they had a sample of children, adolescents, and university students (n = 655) and reported a positive correlation (r = 0.71) between the BMI, height, weight, waist circumference, and body fat variables (%GC) [2].

Analysis of the NIP effect on anthropometric response variables showed a statistically significant change or effect ($p \leq 0.05$). Except for the variable "Size", where the effect was not significant due the study was conducted in a relatively short time (six months). Girls BMI decreased from 25 ± 2. 5 to 20.2 ± 2.1; in boys, BMI went from 24.8 ± 2.2 to 19.8 ± 2.4, which represents a decrease of 4.8 and 5 points for girls and boys respectively. Other nutritional interventions reported similar values (4.4 - 4.5 points) in pediatric patients with similar program periods [21,22].

Initially, pediatric patients had an average weight of 52. 2 Kg. After NIP, the weight recorded was 42. 3 ± 10. 2 Kg and 42.6 ± 12. 5 Kg, for boys and girls, respectively. With an average decrease of 9.7 ± 0.3 Kg, for both genders, which represents an 18.58% weight loss. Other interventions achieved a weight decrease between 0.6-10% [23,24].

The mean values for waist circumference were 78. 6 ± 6.9 cm and 80.6 ± 9. 3 cm for girls and boys, respectively. However, by the end of the intervention, the waist circumference decreased to 68.4 ± 6.3 in girls and 71.2 ± 9.3 in boys. The relevance of this achievement lies in the fact that waist circumference has a high correlation with abdominal fat (subcutaneous and visceral), total body fat, and is used as one of the best indicators of childhood obesity [25].

The NIP effect on categorical variables revealed that the number of cases of children with a "good" appetite increased from 27 to 34, ensuring the absorption of nutrients necessary for their growth; "bad" appetite decreased from 8 to 2 [26]. The number of cases with "regular" appetite was 14. The behavior for fast-food intake was as follows: initially, there were 9, 23, and 18 cases for slow, normal, and fast levels respectively. At the end of the NIP, it was possible to increase the number of cases with normal fast-food intake to 29. Likewise, fast-food intake decreased from 18 to 13 cases. Adequate fast-food intake promotes normal plasma concentrations of cholesterol, triglycerides, and lipoproteins [27]. Analysis of fast-food intake frequency showed that the intervention results were positive in this regard. Since, in boys and girls, the frequency of fast food and sweetening beverages intake decreased.

The PCA is a multivariate analysis methodology used to explain the variability source of a process and decrease data dimensionality. Achieved by transforming multidimensional information into lower variables that explain a large part of the fluctuations of the original variables, as well as their interrelations [15]. In this research, PCA was used as a statistical tool to explain patterns of nutritional status as a multivariate phenomenon. Two main components of obesity were obtained (CP1 and CP2), which summarized, represented 94.97% of the total nutritional variation observed in 50 pediatric patients. Initially, a reliable index for nutritional status was constructed with values between -4 to 3 (CP1) and -1.5 to 1 (CP2). At the end of the intervention, they range between -4 to 4 (CP1) and -2 to 2 (CP2). This nutritional status index (NI) allowed differentiation between well-nourished subjects and those that presented nutritional alteration, such as malnutrition, overweight, and obesity, through a multivariate analysis considering that the problems of obesity and overweight have multifactorial causes. Also, we could observe the positive advances achieved through nutritional intervention. With this methodology, it will be possible to establish the NI for each child who visits the Pediatrics Unit and take preventive actions if necessary to preserve their current and future health and well-being.

Conclusion

This research allowed us to evaluate the effect of a Nutritional Intervention Program in 50 pediatric patients with overweight and

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obesity in a pediatric unit in Mexico with solid statistical criteria. In addition, to a nutritional index (NI). The success obtained was due to the training, knowledge acquired, discipline, and commitment of the children and their parents. Promoting the acquisition of a healthier lifestyle and prevention of diseases in an adult stage. It is relevant to consider that obesity in children is a public health problem, not only in Mexico. But also, worldwide. In addition, the current COVID-19 pandemic situation in Mexico has caused high mortality in children [9]. Rivas-Ruiz., *et al.* (2020) reported that children in Mexico positive to SARS-CoV-2 had a statistically higher percentage of obesity.

Acknowledgements

Conflict of Interest

The authors declare no conflict of interest.

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