Short Communication

Correspondence of two procedures to measure abdominal circumference in a convenience sample of urban, middle-class schoolchildren in Guatemala City

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Background: Given an emerging concern for juvenile overweight and obesity, even in populations of developing countries, techniques to assess central obesity, such as abdominal circumference (AC), are of increasing interest. *Objective:* To compare two procedures for measuring AC in schoolchildren from a convenience sample of middle-class, urban children aged 72 to 131 months in Guatemala City. Methods: We conducted a cross-sectional study (August 2004- April 2005) in 363 schoolchildren; 190 boys and 173 girls. The AC was recorded using both the conventional natural waist circumference (NWC) and the umbilical-level abdominal circumference (UAC) methods; each of which was measured over a thin T-shirt. Height and weight were also measured. The NWC and UAC methods were compared between genders and age groups. In addition, correlation coefficients and Bland-Altman regression were performed. A reproducibility study was performed on a subsample of 50 children. Results: Mean NWC was 63.2±10.0 cm for boys and 60.2±7.7 cm for girls (p=0.001), and mean UAC was 65.9±11.0 cm for boys and 63.2±8.8 cm for girls (p=0.008). Both measures of AC generally increased with age. The UAC - NWC difference increased with abdominal girth. The Pearson correlation coefficient of BMI vs. NWC and BMI vs. UAC was r=0.92, CV=0.46±0.27%. A high test-retest reproducibility (r > 0.98, CV= 0.50±0.24%) of the NWC and UAC measurements was found. Conclusion: Reliable NWC and UAC measurements may be obtained by applying a correction term to account for light clothing. Both measurements are applicable methodologies for the collection of data in populations with cultural limitations.

Key Words: juvenile central obesity, natural waist circumference, umbilical abdominal circumference, body mass index, Guatemala

INTRODUCTION

Overweight in children has become a matter of growing concern. A review article by Amigo, published in 2003[1] illustrates the point that overweight and obesity are becoming widespread, although in an uneven fashion across countries, in the Latin American region. He is able to project this conclusion applying variants of WHO classification features for children to a wealth of data. Information analysed from national surveys in Honduras, El Salvador, Guatemala, Colombia, Nicaragua, Brazil, Dominica Republic, Mexico, Paraguay, Chile, Bolivia and Peru, previously assembled by other authors in the region,[2-7] were included.

Researchers have raised questions not simply about the amount of weight gain and adiposity, but also about the role of fat distribution. Recent metabolic studies have shown that the specific location of fat on the body can affect health.[8-10] Visceral fat is associated with glucose intolerance, an increased risk of diabetes type 2 and coronary heart disease.[11] In adults and children, as well, there is mounting evidence linking central obesity and health related risks such as cardiovascular disease, the metabolic syndrome, serum lipoprotein concentrations and blood pressure.[11-17]

Research has suggested that the circumference of the abdomen can serve as a useful indicator of central obesity, to the degree that it reflects the deposition of visceral fat within the abdominal cavity.[8,19] Studies of adult populations have shown that waist-to-hip ratios [20] and absolute circumference of the abdomen,[21] have predictive validity for metabolic diseases. A variety of different methods and conventions have been reported in literature for measuring abdominal circumference (AC). The most conventional AC method is that using anatomical landmarks for positioning the measuring tape, as described by McCarthy and colleagues: "the waist circumference measurement was taken midway between the tenth rib and the iliac crest".[22] Another method is the so-called "natural waist circumference (NWC)" which measures the minimal distance

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Manuscript received 2 June 2009. Initial review completed 26 August 2009. Revision accepted 23 November 2009.

around the abdomen.[23] Yet a third, introduced by Norris and Wilson,[24] in the context of a British anthropometric survey, is the umbilical abdominal circumference (UAC), measured at the level of the umbilicus.

To the extent that Guatemala was a traditionally agrarian society in Central America, now transitioning toward an increasing urbanization with a growing middle-class, we might anticipate the emergence of excess weight conditions in childhood. In a cross-sectional anthropometric study among middle-class children in private schools and vacation camps of Guatemala City, aimed primarily at assessing the body mass index (BMI), Alvarado and colleagues[25] took the opportunity to measure AC's using two distinct measurement approaches. The aim of the current study was to compare NWC measurements, considered as the gold standard, with UAC measurements in the same individuals.

MATERIALS AND METHODS

Subjects

The general aspects of this study's design and features have been presented earlier.[25] Seven schools in Guatemala City located in the same area (Zone 11) and serving families of the urban middle-class, as well as five urban vacation camps, serving the same constituency, were invited to participate in our survey. Of these, we obtained the collaboration of four schools and four vacation camps, with the remaining citing incompatibility of our measurement agenda with the institutions' schedules and activities. We visited each location in advance to arrange for a proper physical setting to collect anthropometric measurements. The protocol had been previously approved by the Human Subject Committee of Centre for Studies of Sensory Impairment, Aging and Metabolism (CeSSIAM).

The teachers presented the general purposes of the study to the children and distributed informational sheets and informed consent forms to be considered by their families. Children with physical impairments, outside of the specified age range (no younger than 72 mo, and no older than 131 mo based on parental reporting of birth dates), or with irregular class attendance were excluded. Measurements were only obtained from students who assented orally to participate in the study and had parental or guardian signatures on the informed consent forms. We enrolled and measured a total of 443 children at the sites. A total of 80 children were excluded from the final analysis for the reasons mentioned above or abnormal abdominal distension on the day of measurement. The final sample comprised of 363 schoolchildren; 173 boys and 190 girls.

Data collection

Data were collected from August 2004 to April 2005. All measurements were preformed by one researcher, therefore standardization was not necessary.

Height was measured to the nearest 0.1 cm using a centimeter tape vertically affixed to a wall for the measurement. Children were measured barefoot and asked to stand on a firm, flat horizontal surface with their heels, buttocks, scapulae and head against the wall and their arms hanging loose at their sides. A carpenter's square was lowered onto the crown of the head, with the child's gaze in the Frankfort horizontal plane.[23]

Weight was measured to the nearest ounce using a calibrated, digital; electronic scale read in pounds (Detecto, Model CN2OL, Webb City, MO, USA), with a capacity of 130 lb x 0.1 lb; this was calibrated on each day of the study with a 5-lb reference weight. For weighing, children were asked to take off their shoes, sweaters or jackets, and to take out heavy objects out of their pockets.

NWC was measured in the standing position during normal respiration. This measurement was taken with the children dressed in their recreational clothing (T-shirt, shorts). Out of respect for cultural norms of modesty for young children in a congregate setting, children were not asked to expose their skin of their abdomen for the measurement. Rather the tape extended around the child while wearing the T-shirt of the recreation class. The narrowest point of the trunk was encountered by applying constant tension tape obtaining the minimal reading. We recorded our measurements to the nearest 0.1 cm.[23] For UAC measurement, the same posture and respiration conditions were applied. To locate the umbilical level, we asked the children to place their index finger to indent their T-shirt and indicate the location of their "belly button". Applying a constant tension to the tape measure, we made the UAC to the nearest 0.1 cm.

Test-retest reproducibility sub-study

In a sub-group of 50 children, 25 boys and 25 girls from one of the participating schools, we tested the reproducibility of each method for evaluating waist circumference by repeatedly measuring individuals within our sample population. The subjects involved in our cross-sectional study were measured an additional two times under identical conditions on consecutive days.

Data analysis

Body weight measurements in pounds were converted into metric expressions of kilograms, using a 2.2-to-1 conversion factor. A BMI was calculated for each participant by dividing weight in kilograms by height in meters squared. Children were classified as underweight (<5th percentile), risk of overweight (85th to <95th percentile) or overweight (>95th percentile) based on CDC cut-off points[26] using EPI Info (Center for Disease Control and Prevention, Atlanta, GA, USA).

Difference of two feasible measurements to assess abdominal circumference

Since, by definition the, NWC represents the abdomen's minimal measurable circumference, the UAC will necessarily be equal to or greater than the corresponding NWC. Therefore, the difference between the two AC measurements was computed as UAC-NWC.

Correction for presence of light clothing

In order to correct for AC measurements in children wearing a thin t-shirt, a correction term was calculated. In a subsample of 40 children, 20 from each gender and four from each age-group, measurement were taken twice: once over the T-shirt, and once directly in contact with the skin. Adjustments were applied individually to each

subject's data in order to harmonize our data with finding from the published literature.

Statistical analyses

Data were analyzed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics for age, weight, height, BMI are presented by gender and for NWC and UAC by gender and age group. Student t-test was used to assess differences between genders. ANOVA was used to assess differences in UAC and NWC between age groups within each gender. Least significant difference (LSD) post hoc tests were performed to examine which differences between age groups were significant. The mean differences between UAC and NWC were compared between genders using Student t-test. In addition, one-way ANOVA followed by LSD post hoc tests were performed to examine differences between age groups.

Bland-Altman[27] plots were used to examine if there was an increase in the difference between UAC and NWC with increasing mean. Since much current discussion revolves around independent effects of total body size and the central intra-abdominal location of metabolically-active adipose tissue, we examined the association of our two AC measurements with the individual values for BMI using Pearson's correlation coefficient. MANOVA was used to compare the three repeated measurements within the same subjects. In addition, CV was used to determine the reproducibility of NWC and UAC measurements.

RESULTS

Descriptive statistics of demographic and anthropometric variables

Descriptive statistics for the total sample, and by gender, are presented for age, weight, height, BMI, NWC and UAC in Table 1. All measurements are numerically greater for boys than girls, but Student t-test showed that the differences were significant only for NWC and UAC ($p<0.05$).

Description of natural waist circumference values by age and gender

There was a progressive increase in the NWC and UAC value with age for the combined sample of Guatemalan middle-class school children enrolled in the study. The numerical values for NWC by age-groups for both genders are presented in (Table 2 upper panel). Differences with increasing age were statically significant by ANOVA ($p<0.05$). Similarly, as show in the same table (Table 2, lower panel), UAC rose with age in both genders.

Table 1. Demographic and anthropometric characteristics of the entire sample, and by gender

Demographic Characteristic	Pooled sample (n=363)	Boys (n=173)	Girls (n=190)	*p*-value*
Age (mo)	102.9 ± 16.7	104.3 ± 16.9	101.7 ± 16.5	0.131
Weigh (kg)	31.1 ± 8.8	32.1 ± 9.0	30.3 ± 8.6	0.050
Height (cm)	129.5 ± 9.3	130.0 ± 8.8	129.0 ± 9.7	0.299
BMI (kg/m^2)	18.3 ± 3.4	18.7 ± 3.6	17.9 ± 3.1	0.021
Natural Waist Circumference (cm)	61.6 ± 9.0	63.2 ±10.0	60.2 ± 7.7	0.001
Umbilical Abdominal Circumference (cm)	64.5 ± 10.0	65.9 ±11.0	63.2 ± 8.8	0.008

Values are mean±SD; **p*-value for differences between genders using independent Student t-test.

Table 2. Natural waist circumference and umbilical abdominal circumference by age groups and gender

Age (mo)	Boys					Girls				
	Waist circumference (cm)					Waist circumference (cm)				
	n	Mean± SD	Median	Confidence Interval		n	Mean± SD	Median	Confidence Interval	
				5th	95th				5th	95th
Natural waist circumference (NWC)										
72 – 83	27	58.6±10.0 ^{a}	54.0	46.7	78.0	36	55.0±4.6 ^{a}	54.3	48.6	66.1
84 – 95	32	61.3±10.0 ^{a}	58.7	44.7	81.1	33	57.5±6.9 ^{a,b}	56.0	48.6	72.0
96 – 107	30	62.1±10.2 ^{a,b}	58.5	51.8	88.4	45	60.1±7.1 ^{b}	58.5	50.3	75.1
108 – 119	46	63.9±8.0 ^{b}	63.5	52.9	76.6	42	63.8±8.0 ^{c}	62.9	52.5	77.4
120 –131	38	68.1±10.3 ^{c}	66.5	53.9	89.0	34	63.8±7.8 ^{c}	62.5	53.0	78.0
Umbilical Abdominal Circumference (UAC)										
72 – 83	27	60.9±10.7 ^{a}	56.7	47.9	81.9	36	57.2±5.4 ^{a}	56.9	48.3	68.3
84 – 95	32	64.0±11.3 ^{a}	61.4	47.7	87.8	33	60.1±8.2 ^{a,b}	57.9	49.7	75.7
96 – 107	30	64.7±11.4 ^{a,b}	60.9	53.0	93.9	45	63.1±8.5 ^{b}	60.9	51.2	82.0
108 – 119	46	66.7±9.0 ^{b}	64.9	54.2	80.1	42	67.0±8.8 ^{c}	66.3	54.9	83.5
120 – 131	38	71.3±11.0 ^{c}	70.2	55.2	92.1	34	67.7±8.5 ^{c}	65.5	56.6	83.4

Significant differences between age groups in natural waist circumference (NWC) and umbilical abdominal circumference (UAC) were found for both genders using ANOVA ($p<0.05$); Within each row, mean values bearing different superscript letters are significantly different according to LSD test at $p<0.05$.

Table 3. Difference between umbilical abdominal circumference and natural waist circumference by age groups and gender

	Boys					Girls					
	UAC-NWC (cm)*					UAC-NWC (cm)[1]					
	n	Mean± SD	Median	Confidence Interval 5th	95th	n	Mean± SD	Median	Confidence Interval 5th	95th	*p*-value†
All	173	2.8±1.7	2.4	0.5	6.0	190	3.0±1.8	2.4	0.9	6.7	0.187
Age (mo)											
72 – 83	27	2.3±1.1	1.9	0.7	4.4	36	2.3±1.4 [a]	2.0	0.0	5.1	0.998
84 – 95	32	2.7±1.9	2.4	0.0	6.7	33	2.7±1.7 [a,b]	2.3	0.8	6.4	0.838
96 – 107	30	2.6±1.5	2.2	0.2	5.7	45	3.0±1.9 [b]	2.5	0.9	7.0	0.348
108 – 119	46	2.9±1.8	2.8	0.1	6.2	42	3.2±1.7 [b]	2.7	1.4	7.3	0.388
120 –131	38	3.2±1.8	2.9	0.9	6.1	34	3.9±1.9 [c]	3.5	1.8	7.8	0.080
p-value‡					0.296						0.002

*The difference was computed as umbilical abdominal circumference (UAC) – natural waist circumference (NWC); †P-value for difference between genders using Student t-test; ‡*p*-value for difference between age groups in UAC-NWC in each genders using ANOVA. Within each row, mean values bearing different superscript letters are significantly different according to LSD test at $p<0.05$.

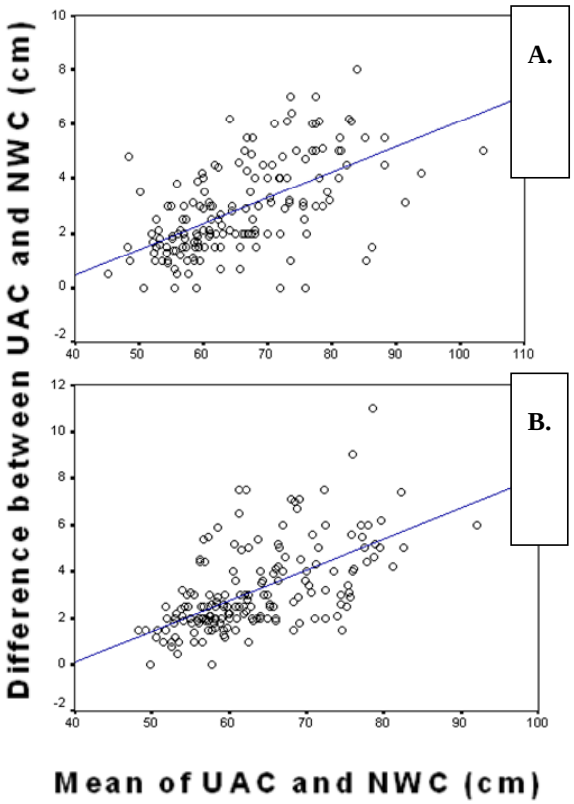

Figure 1. Altman-Bland plots for mean abdominal circumference composed of UAC and NWC pairs in cm, for the 173 boys (Panel A) and, for the 190 girls measured (Panel B) in the sample.

Application of the correction term for measurement over clothing

Based on the comparative measurements of AC over T-shirts and with direct skin contact in a sub-group of 40 children, a correction subtraction of 1.0 cm was established for NWC and 1.1 cm for UAC, for both genders.

Magnitude and consistency of the umbilical abdominal circumference minus natural waist circumference differences

As shown in Table 3, which presents mean UAC-NWC measurements by age groups and gender; our study documents consistency of the umbilical-natural waist circumference differences in boys, but not in girls. In girls, the mean difference ranged from 2.2 cm in 72-83 mo old girls to 3.9 cm in 120-131 mo old girls.

Bland-Altman plots shown in Figure 1, present a progressive increase in the within-individual difference in the circumference measurements with increasing overall AC in both sexes. The absolute difference *(y axis)* of UAC minus NWC was 2.8±1.7 cm for boys and 3.0±1.8 cm for girls, whilst the mean of both methods *(x axis),* was 64.6±10.5 cm for boys and 61.7±8.2 cm for girls.

Association of abdominal circumference measurements with body mass index

The prevalence of overweight was 20.1% for boys and 15.8% for girls. The Pearson's correlation coefficient of NWC versus BMI was 0.92 for the entire sample, 0.93 for boys and 0.91 for girls. The same values were found for the correlation between UAC and BMI.

Reproducibility of repeated measures of NWC and UAC

The mean values for the NWC for the 50 children measured three times in the reproducibility study were 61.0±8.9 cm, 61.1±8.9 cm, and 61.0±9.0 cm, for the respective measurements. MANOVA showed no difference the serial measurements. The overall mean coefficient of variation (CV) for the three measurements was 0.50± 0.24%. The Pearson correlation coefficient for the *first* versus *third* NWC measurement was 0.999. The corresponding inter-measurement correlation coefficient for the other five bivariate combinations were equally strong (data not shown) (*first* and *second* UAC measurement, *second* and *third* UAC measurement, *first* and *third* NWC measurement, *first* and *second* UAC measurement, *as well as second* and *third* UAC measurement).

The corresponding repeated means for the UAC measurements were 64.1±10.3 cm, 64.2±10.3 cm, and 64.3± 10.3 cm; again not significantly different by MANOVA. The overall mean CV for the three UAC measurements was 0.46±0.27%. The first versus third measurement, "r" was 0.999. All of the statistical and numerical relationships reported for the NWC repetitions were also seen for UAC (data not shown).

DISCUSSION

The AC variable has a close correspondence with body mass index. Our inter-variable correlation coefficient of 0.92 (for BMI versus each of our two AC measurement procedures) is numerically identical to the 0.92 found by Groeneveld, Solomons and Doak in Guatemalan children.[28] Flores-Huerta et al,[29] and Hassan and co-workers,[30] also found a strong correlation between BMI and AC in Mexican and Egyptian children; aged 5 to 17 years old and 6 to 11 respectively. Our correlation between AC and BMI was superior to the 0.87 observed by Soar and colleagues[32] in southern Brazilian schoolchildren aged 7 to 9 years. Moreover, Gomez and colleagues[33] also found a less strong correlation (r=0.84) in their study with children aged between 6 and 10 years in Mexico City. On the other hand, Hirschler and collaborators[32] found a higher correlation, r=0.96 between BMI and UAC in a studied sample with an age range from 6 to 13 years.

McCarthy, Jarrett and Crawley,[22] who illustrated the alternative measurement approaches compared here, did not actually use either one in their serial surveys of British children. Rather, they used the circumferential level determined by the mid-point between the lowest rib and the iliac crest in the saggital plane for their measurements. They suggested, however, that NWC is effectively similar to the more conventional and laborious measure use in their surveys.[22] The average NWC observed in our sample of middle-class school children in Guatemala City, in 2004-2005 (boys=63.2 cm and girls=60.2 cm), far exceeds the age- and gender-corresponding values of their British sample enrolled in 1988 (boys=56.1 cm, girls=55.3 cm).[22] These same investigators[34] found a major secular trend toward higher AC's through the period of 1988 to 1997, with 6.9 and 6.2 cm increases in males and females, respectively.

The other measurement approach, umbilical level (UAC), has been used only sparingly in the literature.[5,24] In an Australian survey, Eisenmann[35] measured at the umbilical level and found circumference in Australian children of European descent in both genders to be similar prior age 11 years. We can draw on an increasing number of reports on AC in juvenile populations for comparative insights. In our study, there were no significant differences in either measurement of waist circumference between boys and girls of the same age groups. This agrees with the findings of Maffeis and co-workers,[36] and Ayasama and colleagues.[37] Children ranging from 3 to 11 years and 6 to 15 years were included in these surveys, respectively. There were no significant sex-related differences in age. Einsenmann[35] measured umbilical AC of 8439 Australians participants of 7-to-15 years and mean UAC increased in both genders with similar values. Meanwhile, Fernández, Reeden, Pietrobelli and Allison,[38] Soar and co-workers[31] and Fredriks and colleagues[39] found differences by sex with in their children. After evaluating 9713 subjects from 2 to 18 years of age; Fernandéz and his research team[38] concluded that "waist circumference increases in a monotonic fashion across ages but at non-constant rates and in a matter that varied across age and sex". Soar and his research group,[31] found in Brazilian children from 7 to 9 years old that there are statistically differences in waist circumference for boys and girls. On the other hand, Fredriks and collegues,[39] found the statistically differences for Dutch boys and girls start from 11 years of age.

In this study, a general and gradual increment in AC in children across ages from 7 to 11 years was found; this is confirmed by the findings reported by McCarthy and coworkers.[22] They conducted a cross-sectional study with 8355 British children, between 5 and 16.9 years were AC was measured and it increased with age. Fernández and his research group[38] found increase of AC as children became older in both sexes in three ethnic groups (American, European-American and Mexican-American) in a study with 913 children.

We acknowledge a series of methodological limitations in our study. These include the selection of a convenient sample, and cultural issues that arose in taking the waist circumference measurements. By relying on the voluntary participation of a select group of urban middle and upper class children in Guatemala City, we are only able to represent a segment of Guatemala's metropolitan population. A cultural limitation relates to the reason for measuring children over their T-shirts. In an environment lacking of the amenities of individual privacy, direct exposure of skin was proscribed. However, what we gain from this cultural peculiarity, now allows a less invasive technique for taking adequate measurement and can be applied by cultures in which undressing children is not permitted. Natural waist circumference can be measured at the narrowest point of the trunk over the clothing, and UAC can measured by asking the subject to indicate were

their umbilicus is located. Neither measurements, NWC nor UAC, require palpation or visual locations of anatomical landmarks; each provides a useful technique where cultural limitations interfere with removal of subjects clothing, as in middle class Guatemalan schools.

The nutritional transition[40,41] has been defined as a situation in a country or region in which the nutritional and dietary factors promoting chronic disease begin to coexist with the persistence of traditional problems of underweight and nutrient deficiencies. Although this convenience sample is far from representative of its national peer-group at large, and perhaps only partially representative of middle-class school children in private institutions in the Guatemala City, the predominance of high waist circumferences in a sub-segment of the metropolitan population provides testimony for at least the advent of nutrition transition and metabolic risk having been established in this Central American capital. Longitudinal observation studies with a more comprehensive set of variables are necessary for monitoring these changes, but our present data provide a basis and rationale for the inclusion of AC as an essential component of such an examination.

CONCLUSIONS

The use of AC as a tool in the clinical and epidemiological disciplines to screen for overweight and obesity has grown in importance, also in children. The measurement of AC is simple and practical. The two sites, natural waist and umbilical level, which can be measured over light clothing, provide an advantage over techniques for measuring body-fat that require privacy and precision equipment. The fact that UAC shows a disproportionate increase with abdominal girth illustrates the influence of subcutaneous abdominal fat in the measurement at the umbilical level. This may be useful for some diagnostic purposes. In accordance with the conjecture by McCarthy and colleagues,[22] our study suggests that the NWC is a reasonable surrogate for the conventional position for the measurement tape in the majority of juvenile surveys, and can be used as a procedure of choice were direct skin contact is inconvenient or culturally unacceptable.

ACKNOWLEDGMENTS

We wish to thank Sra Doris Elvira Chacon Sandoval head master of School Eloy Surez Cobian, children from School Eloy Surez Cobian, School Manos a la Obra and Vacations Camps: Monte María, La Auroa y EcoAventura and all the parents who made this project possible by enrolling their children in it. We are grateful to Emily Yates-Doerr and Marieke Vossenaar for editing the manuscript.

AUTHOR DISCLOSURES

None of the authors have conflicts of interest.

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Short Communication

Correspondence of two procedures to measure abdominal circumference in a convenience sample of urban, middle-class schoolchildren in Guatemala City

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以瓜地馬拉市的中產階級學童為樣本來看兩種測量腹圍方法的一致性

背景：即使在發展中國家，青少年的過重及肥胖也日益受關注。評估中央肥胖(例如：腹圍)的方法正逐漸受重視。目的：以居住在瓜地馬拉市，年齡為 72 至 131 個月的中產階級學童為樣本，比較兩種測量腹圍的方法。方法：在 2004 年 8 月至 2005 年 4 月，以 363 位學童(190 位男孩與 173 位女孩)為樣本的橫斷性研究。使用傳統的自然腰圍測量法(NWC)以及以肚臍為基準的腹圍測量法(UAC)來記錄腹圍，而測量時須穿著薄質的圓領汗衫。同時測量身高和體重。將這兩種方法測量值以性別及年齡做比較。另外，使用相關係數及 Bland-Altman 迴歸方法進行分析。並且以其中 50 位孩童為次樣本，進行再現性分析。結果：男童的平均自然腰圍為 63.2±10.0 公分，女童的平均自然腰圍為 60.2±7.7 公分(p 值為 0.001)；男童以肚臍為基準的平均腹圍為 65.9±11.0 公分，女童為 63.2±8.8 公分(p 值為 0.008)。腹圍的大小大致隨著年齡的增加而增加。自然腰圍測量值及以肚臍為基準的腹圍測量值之間的差異隨著腹圍的增加而增加。BMI 對自然腰圍與 BMI 對腹圍的皮爾森相關係數為 0.92，變異係數為 0.46±0.27%。自然腰圍測量法以及以肚臍為基準的腹圍測量法的再測量的再現性都高(相關係數大於 0.98，變異係數為 0.50±0.24%)。結論：藉由對於薄質衣料的校正可獲得可信的自然腰圍測量值及以肚臍為基準的腹圍測量值。這兩種測量方法都適合用以蒐集有文化背景限制的族群的體組成資料。

關鍵字：青少年中央肥胖、自然腰圍、以臍帶為基準的腹圍、身體質量指數，瓜地馬拉