172 - BUILDING REFERENCE CENTILES BY LMS METHOD: A SYSTEMATIC REVIEW OF ANTHROPOMETRIC STUDIES

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Introduction

LMS method has been used to build curves of anthropometrics measures such as height and skinfold thickness. This method allows building patterns of physical growth and as well as provides reference values for monitoring growth and for nutritional status assessment (COLE *et al.*, 1998; COLE *et al*, 1999; COLE *et al*., 2000; CONDE and MONTEIRO, 2006).

LMS assumptions are related to Box-Cox transformation for positive independent values for age groups in order to normalize skewed distributions (COLE, 1989; COLE, 1990), typically found in indicators of body composition (COLE, 1989; COLE, 1990; CONDE and MONTEIRO, 2006). LMS method summarizes data for age specific groups by three parameters by smothering estimators:

The parameter M is the median of the observed index value in each age group; parameter S is the coefficient of variation in each age group and the parameter L is coefficient from Box-Cox transformation used for normalizing data in each age. The coefficient L should assume the value that minimizes the sum of squares (COLE *et al*., 2000).

The sample, for each sex, must be separated into age groups adding up to 100 or more subjects, considered the minimum accepted value for LMS method (CONDE and MONTEIRO, 2006). Conde and Monteiro (2006) have used a three-month subdivision aiming to represent multiple aspects of the growth speed and to add up at least 100 subjects, in each stratum. Parameters L, M and S are calculated for each age and theirs curves are adjusted by polynomial equations in each sex group. By interpolation, based on the arithmetic mean, the monthly value of the distribution is calculated (CONDE and MONTEIRO, 2006).

With these three parameters (L, M and S), it is possible to construct the new curve for any desired centile desired by the use of the formula:

$$C(z) = M\,(1 + LSz)^{1/L}\,,\ se\ L \neq 0$$
$$C(z) = M \exp(Sz)\,,\ se\ L = 0$$

Where C(z) is the desired centile according to z value from N(0,1) curve. Values L, M and S are the corresponding values for each curve for a specific age; z is the number of standard deviations from normal distribution according to the area equivalent to the desired centile for each age.

Table 1 presents an example of LMS method. It comes from the study by Conde and Monteiro (2006), and shows values for L, M and S according to sex and age, constructed based in BMI distribution taking into account 2 to 19 years old.

Table 1 - Values for L, M and S parameters of the body mass index distribution for a Brazilian reference population aged 2 to 19 years, by age and sex

Age (month)	Male			Female		
	L	M	S	L	M	S
24.0	0.1791	16.9476	0.0939	0.1228	16.7003	0.0990
24.5	0.1551	16.9242	0.0935	0.0970	16.6730	0.0985
30.5	-0.1155	16.6587	0.0892	-0.1906	16.3666	0.0936
36.5	-0.3564	16.4192	0.0864	-0.4427	16.1042	0.0903
42.5	-0.5691	16.2071	0.0848	-0.6613	15.8899	0.0884
48.5	-0.7549	16.0233	0.0843	-0.8487	15.7212	0.0878
54.5	-0.9153	15.8687	0.0847	-1.0069	15.5927	0.0882
60.5	-1.0519	15.7438	0.0859	-1.1381	15.4984	0.0895
66.5	-1.1659	15.6492	0.0877	-1.2442	15.4331	0.0915
72.5	-1.2588	15.5852	0.0899	-1.3273	15.3937	0.0941
78.5	-1.3321	15.5519	0.0926	-1.3893	15.3791	0.0972
84.5	-1.3870	15.5491	0.0955	-1.4321	15.3907	0.1006
90.5	-1.4250	15.5767	0.0985	-1.4575	15.4316	0.1043
96.5	-1.4475	15.6341	0.1016	-1.4675	15.5062	0.1080

Source: Conde e Monteiro (2006)

For better understanding the application of the method and the use of parameters L, M and S in the formula, we present an example using the values of the study by Conde and Monteiro (2006). We wish to find the value of BMI at the 91st centile for a male, 24 months old. The z score corresponding to the area for 91st centile is 1.33. Thus:

Parameters and values	Example
(C_{91}) = Centile 91st for BMI Age (months): 24 Sex: Male L = 0.1791 M = 16.9476 S = 0.0939 z = 1.33	**Formula : C(z) = M [1 + LSz]1/L** *by substitution:* $C_{91} = 16.94 \times (1 + 0.1791 \times 0.0939 \times 1.33)^{1/0.1791}$ **C_{91} = 19.16697 kg/m^2**

One observes that the value of BMI at the 91st centile for a male, 24 months year old is 19.16697 kg/m^2

Since the first works published by Tim Cole (COLE, 1989; COLE, 1990), in which the method LMS is presented and discussed, several papers have been published centile references for innumerous physiological and anthropometrical variables.

The aim of this paper is, by a systematic review, to identify and to describe the main characteristics of studies in witch the LMS method was used for construction of reference centile curves, in the last 5 years.

Method

A Systematic review has been carried out from 20 to 25 of January of 2007, using the National Library of Medicine (MEDLINE) electronic database and the key-word LMS method as search strategy. The "limits adjusted" in the MEDLINE contemplated human beings, men and women and articles published in the last 5 years. 40 studies that fulfilled these criteria were identified. To define which of these they would be part of the review, the study had to mention in its headings or in its summary the use of LMS method for the construction of references centiles curves for a specific anthropometrical characteristic. Articles using LMS as acronym for Least Mean Square or Learning Management Systems were excluded leading to 31 studies in the systematic review. The search of the papers was carried out using facilities from the Federal University of Santa Catarina available in an international and national network system by a Brazilian Institution - CAPES.

Results and Discussion

Table 2 shows 31 studies published in last the 5 years using the LSM method for construction of references centiles curves. Information about authors, year of the publication, the country where the study was conducted, age groups and the anthropometrical variable under investigation were extracted. Studies were carried out in countries such as India, China, Japan, Korea, Taiwan, Iran, Israel, Turkey, Morocco, Australia, Great-Britain, Italy, Denmark, Holland, Bangladesh, Ireland, The United States, Brazil and Argentina. The majority of them constructed references centiles curves for children and adolescents and anthropometrical characteristics such as body mass, height and body mass index (BMI) (STYLES et al., 2002; FREDRICKS et al., 2003; FREDRICKS et al., 2004; LEE and HUANG, 2004; MARWAHA et al, 2006; RAZZ)

Some studies constructed reference curves for BMI as the one by Inokuchi et al. (2006) for children and Japanese adolescents from 1 to 19 years old; Huerta et al (2006) for 6-12 children years from Israel; Conde and Monteiro (2006) with a sample of Brazilian children and adolescents from 2 to 19 years old; Baratta et al. (2006) for adolescents from 11 the 15 years from Sicily; and Bubdak et al. (2006) who worked with Turkish children and adolescents from 6 to 18 years of age. Reference centiles curves have been also constructed using LMS for waist circumference (EISENMANN, 2005; FREDRICKS et al., 2005; INOKUCHI et al., 2006), head circumference (ANZO et al., 2002; STYLES et al., 2002; KALANDA et al., 2005; SAUNDERS et al., 2006), sitting heigth (DANGOUR et al., 2002; FREDRICKS et al., 2005), arm circumference (KALANDA et al., 2005; FOK et al., 2005), length of inferior limbs (DANGOUR et al., 2002; FOK et al., 2005; FREDRICKS et al., 2005) and hip circumference (FOK et al., 2005; FREDRICKS et al., 2005).

Table 2. Studies that using the LMS method for construction of reference centile curves, in the last 5 years.

N	Author / Year	Country	Age group	Anthropometrical characteristic
1	Marwaha *et. al* (2006)	India	5-18 years	Body mass, height, BMI
2	Fok *et al.* (2006)	China	Newborns (31 to 42 weeks of pregnancy)	Triceps and subscapular skinfold thickness
3	Inokuchi *et al.* (2006)	Japan	6-18 years	Waist circumference
4	Inokuchi *et al.* (2006)	Japan	1-19 years	BMI
5	Saunders *et al.* (2006)	Argentina	0-6 years	Waist-to-hip ratio, Head circumference-to-height ratio
6	Razzaghy Azar *et al.* (2006)	Iran	6-17 years	Body mass, height and BMI
7	Huerta *et al.* (2006)	Israel	6-12 years	BMI
8	Jackson *et al.* (2006)	Great Britain	4-24 years	Arterial pressure
9	Conde and Monteiro (2006)	Brazil	2-19 years	BMI
10	Wang *et al.* (2006)	China	20-45 years	BMI
11	Baratta *et al.* (2006)	Italy	11-15 years	BMI
12	McCarthy *et al.* (2006)	England	5-18 years	Fat percentage (bio-impedance)
13	Gultekin *et al.* (2006)	Turkey	7-17 years	Body mass and height
14	Bubdak *et al.* (2006)	Turkey	6-18 years	BMI
15	Kalanda *et al.* (2005)	England	Newborns (35 to 42 weeks of pregnancy)	Body mass, recumbent height, head and arm circumference,
16	Kim *et al.* (2005)'	Korea	Girls from 8-18 years	BMI
17	Eisenmann (2005)	Australia	7-17 years	Waist circumference
18	Fok *et al.* (2005)	China	Newborns (28 to 42 weeks of pregnancy)	Anthropometrical measurements of superior and inferior limbs
19	Olsen *et al.* (2005)	Denmark	0-1 years	Body mass and recumbent height
20	Fok *et al.* (2005)	China	Newborns (24 to 42 weeks of pregnancy)	Anthropometrical measurements chest, hip, abdominal circumferences and length of external bone.
21	Fredricks *et al.* (2005)	Holland	0-21 years	Anthropometrical measurements chest-head height, measurements of superior and inferior limbs and sitting heigth to height ratio
22	Banerjee *et al.* (2005)	Bangladesh	11-17 years	BMI
23	Fredricks *et al.* (2005)	Holland	0-21 years	Waist, hip and abdominal circumferences

• 24	• Lee and Huang (2004)	• Taiwan	• 7-18 years	• Body mass, height and BMI
• 25	• Fredricks *et al.* (2004)	• Holland e Morocco	• 0-20 years	• Body mass, height and BMI
• 26	• Reichman *et al.* (2003)	• Australia	• 1-12 years	• Total energy waste
• 27	• Fredricks *et al.* (2003)	• Holland e Turkey	• 0-20 years	• Body mass, height and BMI
• 28	• Binkley *et al.* (2002)	• USA	• 5-22 years	• Bone density, mineral bone density, total bone area
• 29	• Anzo *et al.* (2002)	• Japan	• 0-18 years	• Head circumference
• 30	• Styles *et al.* (2002)	• United Kingdom and Ireland	• 0-18 years - Down's syndrome	• Body mass, height and head circumference
• 31	• Dangour *et al.* (2002)	• England	• 0-25 years	• Inferior limb length, sitting heigth

McCarthy et al. (2006) published reference centiles for assessment of the body composition for English children and adolescents from 5 the 18 years old, based on the fat percentage estimated by bioelectrical impedance.

From the total revised studies, only Fok et al. (2006) suggest reference centiles for triceps and subscapular skinfold thickness using LMS method. However this study has a different approach compared to studies presented before.

Fok et al. (2006) presented reference centiles to assess Chinese breastfeeding babies born in pregnancies with gestational length from 31 to 42 weeks very different from others that used chronological age and sex. Another similar study by Kalanda et (2005), involving English newborns with 35 to 42 weeks of gestation used reference centiles related with the gestational period, body mass, sitting height, head and arm circumferences.

Fok et al. also published two similar studies (FOK et al., 2005a; FOK et al, 2005b), in which they constructed reference centiles for inferior and superior limbs length and measures of the trunk. In these, they used gestational period in a different feature compared to studies with samples of children and adolescents, related to age and sex.

Not only for anthropometrical variables has LSM method been used but also for physiological variables. Jackson et al (2006) created reference centiles for arterial blood pressure (ABP) in children, adolescents and young adults from Great-Britain. In this study subjects from 4 the 24 years old were involved making available centiles for systolic and diastolic blood pressure, and average blood pressure.

Reichman et al (2003) created reference centiles for the evaluation of total energy expenditure for Australian children aged 1-12 years. Another variable related to body composition that has been also studied using LMS method is bone density. Binkley et al (2002) constructed reference centiles taking into account mineral bone content and the total bone area working with a sample of American children, adolescents and young adult from 5 the 22 years of age. The study carried out by Styles et al (2002) also has a differential, for they considered reference centiles for the evaluation of the body mass, height and head circumference of children and adolescents from 0 the 18 years of age with Down's Syndrome, based upon a study with children and adolescents conducted in the United Kingdom and Northern Ireland.

Conclusion

The LMS method have been used in many and different studies for construction of reference centiles for anthropometrical, body composition and physiological characteristics. These reference centiles are useful for growth monitoring, assessment of nutritional status and for other diagnostics related to risk of diseases, as in the case of reference centiles for blood pressure and bone density, or diagnostic tests related to physical behavior as in the case of the total energy expenditure. Thus, considering the broad spectrum of applications, the LSM methods seems to be a useful method for the construction of centiles curves for variables asymmetrically distributed.

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BUILDING REFERENCE CENTILE WITH LMS METHOD: A SISTEMATIC REVIEW OF ANTHROPOMETRIC STUDIES

ABSTRACT

LMS method has been used to build curves of anthropometrics measures such as height. LMS assumptions are related to Box-Cox transformation for positive independent values for age groups in order to normalize skewed distributions, typically find in indicators of body composition. The aim of this paper is, by a systematic review, to identify and to describe the main characteristics of studies in witch the LMS method was used for construction of reference centiles curves, in the last 5 years. A Systematic review has been carried out using the MEDLINE database and the key-word LMS method as search strategy. The “limits adjusted” in the MEDLINE contemplated human beings, men and women and articles published in the last 5 years. 31 studies satisfied the inclusion criteria. These studies were carried out in countries such as India, China, Japan, Korea, Taiwan, Iran, Israel, Turkey, Morocco, Australia, Great-Britain, Italy, Denmark, Holland, Bangladesh, Ireland, The United States, Brazil

and Argentina. The majority of them constructed references centiles curves for children and adolescents with anthropometrical measures such as body mass, height and body mass index. Others measures so had been used such as waist circumference, head circumference, hip circumference, sitting height, Inferior limb length, as well physiological and body composition variables as arterial blood pressure, total energy expenditure and bony mineral content. These reference centiles build using the LMS method is useful for growth monitoring, assessment of nutritional status and for other diagnostics related to risk of diseases. Thus, the LSM method seems to be a useful method for the construction of centiles curves for variables asymmetrically distributed.

KEY-WORDS: LMS method, centile reference, growth, assessment of nutritional status, .

CONSTRUCTION DES CENTILES AVEC LA MÉTHODE LMS : UNE REVUE SYSTÉMATIC D´ANTHROPOMÉTRIE ÉTUDES

RESUME

La méthode LMS a été employée pour construire des courbes des mesures anthropometriques telles que l'épaisseur de la taille. Cette méthode permet de réaliser la transformation de Box-Cox ayant des valeurs indépendantes positives en catégories d'âge, afin de normaliser les distributions assymetriques lequelles sont retrouvées dans les indicateurs de composition du corp. Le but de cet article est, d' identifier et décrire les principales caracteristiques des études qui ont employée la méthode de LMS pour la construction des courbes centile de référence., dans les 5 dernières années. Une revue systématique a été effectuée sur la base de données MEDLINE, en utilisant comme stratégie de recherche le mot clé « *LMS method »* et comme limite d'ajustement l'inclusion des « l' être humain, les hommes et les femmes ». Parmi les articles contemplés par MEDLINE dans la période d'étude, 31 ont été choisis selon les critères d'inclusion. Ces études ont été effectuées dans les pays tels que l'Inde, Chine, Japon, Corée, Taiwan, Iran, Israel, Turquie, Maroc, Australie, Grande-Bretagne, Italie, Danemark, Hollande, Bangladesh, Irlande, Etats-Unis, Brésil et l'Argentine. La plupart a construit des courbes de centiles de références pour des enfants et des adolescents avec des mesures anthropométriques telles que le poids, la taille et l'indice de masse corporelle (IMC). D'autres mesures ont été employées comme la circonferénce de la taille, la circonferénce de la tête , la circonferénce du bassin, de la la taille du tronc, la circonferénce des membres et la longueur des membres inférieurs et supérieurs, et aussi quelques mesures physiologiques et de composition corporelle : la tension artérielle, la dépense énergétique totale et la teneur en minéraux osseuse. La construction de ces centiles de référence employant la méthode de LMS sont utiles pour la surveillance de la croissance, l'évaluation de l'état nutritionnel et pour certains ldiagnostics liés au risque des maladies.

CONSTRUCCIÓN DE CENTÍS CON LO MÉTODO LMS; UNA REVISIÓN SISTEMATIZADA DE LOS ESTUDIOS ANTROPOMÉTRICOS

RESUMEN

El método LMS se ha utilizado para construir curvas de las medidas antropométricas tales como la talla. Lo presupuesto para la utilización del LMS es que ello emplea la transformación Box-Cox para normalizar las distribuciones asimétricas típicas de las variables de la composición corporal. El objeto de este artículo está, por una revisión sistemática, identificar y describir las características principales de estudios de cual el método LMS fue utilizado para la construcción de las curvas centílicas, en los 5 años pasados. Se ha realizado una revisión sistemática usando la base de datos MEDLINE y la palabra clave utilizada como estrategia de la búsqueda fue "*LMS method*". También se limito la búsqueda por las palabras seres humanos, hombres y mujeres, así como por los artículos publicados en los 5 años pasados. 31 estudios cumplieran los criterios de inclusión. Estos estudios fueron realizados en países tales como India, China, Japón, Corea, Taiwán, Irán, Israel, Turquía, Marruecos, Australia, Gran Bretaña, Italia, Dinamarca, Holanda, Bangladesh, Irlanda, los Estados Unidos, Brasil y Argentina. La mayoría de ellos construyó las curvas centílicas para los niños y los adolescentes con medidas antropométricas tales como masa corporal, talla e índice de masa corporal. Otros miden así que habían sido utilizados por ejemplo circunferencia de la cintura, circunferencia de la cabeza, circunferencia de la cadera, talla del tronco, longitud del miembro inferior, también variables fisiológica y de la composición corporal como presión arterial, el gasto energético total y el contenido mineral del hueso. Constata-se que el método de LMS es útil para la supervisión del crecimiento, la evaluación del estado nutricional y para el diagnóstico relacionado con el riesgo de enfermedades. Así, el método de LSM parece ser un método bueno para la construcción de las curvas de los centiles para las variables asimétricamente distribuidas.

CONSTRUÇÃO DE REFERENCIAIS PERCENTÍLICOS PELO MÉTODO LMS: UMA REVISÃO SISTEMÁTICA

RESUMO

O método LMS é empregado na construção de curvas de distribuição de variáveis antropométricas, como peso e estatura. O principal pressuposto do método LMS é que para dados independentes, com valores positivos, a transformação *Box-Cox*, em cada idade, pode ser empregada para normalizar os dados que apresentam assimetria em sua distribuição. O objetivo dessa revisão sistemática foi levantar os estudos que utilizaram o método LMS na construção de referenciais percentílicos e verificar as principais características desses estudos, nos últimos 5 anos. Realizou-se revisão sistemática na base eletrônica de dados *MEDLINE* utilizando o termo "*LMS method"*. Os limites ajustados contemplaram humanos, homens e mulheres, e artigos publicados nos últimos 5 anos. A busca ocorreu em janeiro de 2007. Nos últimos 5 anos, foram publicados 31 artigos que satisfizeram os critérios da revisão. Esses estudos foram realizados com amostras de populações de diversos países como a Índia, China, Japão, Corréia, Taiwan, Irã, Israel, Turquia, Marrocos, Austrália, Grã-Bretanha, Itália, Inglaterra, Dinamarca, Holanda, Bangladesh, Reino Unido, Irlanda, Estados Unidos, Brasil e Argentina. A maioria desses estudos construiu referenciais percentílicos para crianças e adolescentes com variáveis antropométricas como massa corporal, estatura e IMC. Também se construiu referenciais percentílicos com variáveis como circunferência da cintura, circunferência cefálica, altura tronco-cefálica, circunferência do braço, comprimento de membro inferior, circunferência do quadril, percentual de gordura corporal estimado por bio-impedância, dobras cutâneas, densidade óssea e variáveis fisiológicas como pressão arterial e gasto energético total. Devido ao seu amplo emprego na atualidade, o método LMS parece ser um método potencial para a construção de curvas percentílicas de variáveis que demonstram característica de assimetria em sua distribuição.

PALAVRAS-CHAVE: método LMS, construção de referências percentílicas, crescimento, estado nutricional, avaliação.