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RESEARCH ARTICLE

Time trends in mid-upper-arm anthropometry from 1982 to 2011 in male children and adolescents from Kolkata, India

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Abstract

The aim of this study was to investigate inter-generational changes in selected mid-upper-arm measurements of boys from Kolkata, India. The analysis was based on the anthropometric measurements of two cohorts of Bengali boys aged 7–16 from middle-class families, in 1982–83 and 2005–11. The two cohorts were compared in terms of their mid-upper-arm circumference (MUAC) and mid-upper-arm area (MUAA), mid-upper-arm muscle area (MUAMA), mid-upper-arm fat area (MUAFA) and Arm Fat Index (AFI). The significances of the differences were determined using two-way ANOVA. All features differed significantly between the examined cohorts and all showed a general positive secular trend. In most cases, the biggest differences were noted for 14- and 16-year olds and the smallest for the youngest boys. The contemporary boys seemed to have more favourable overall developmental conditions, probably related to socioeconomic progress in India over recent decades.

Keywords: Mid upper arm; Secular trend; Anthropological measurements

Introduction

Anthropometric characteristics defining the dimensions and proportions of the human body are widely used to diagnose overweight/obesity, as well as to accurately assess the tissue composition of the body (Gharib & Shah, 2009; Debnath *et al.*, 2017). They particularly important in field research as they do not require the use of additional, special devices such as DEXA scanners (dual-energy X-ray absorptiometry), which are both expensive and difficult, or even impossible, to transport. In addition, the anthropometric method is extremely practical in world regions such as India where other techniques cannot be used, or their use is exceptionally hard (Mondal & Sen, 2010; Sen & Mondal, 2013; Debnath *et al.*, 2017; Kryst *et al.*, 2019a).

Mid-upper-arm anthropometry can undoubtedly be of great importance in determining abnormalities in body weight and tissue composition. For example, upper-arm girth is characterized by 90% sensitivity and specificity as an indicator of overweight/obesity (Jaiswal *et al.*, 2017). Also, the correlation of MUAC (mid-upper-arm circumference) with both body weight and level of adiposity has been confirmed in previous studies for the Indian population. Kryst *et al.* (2019b) showed that children with higher BMI and adiposity values are generally characterized by greater upper-arm circumferences. A similar relationship was observed in a study in South Asia (Dasgupta *et al.*, 2010). Thus, MUAC can be used not only as a tool for the diagnosis of undernutrition, but also as a predictor of level of adiposity (Mazıcıoğlu *et al.*, 2010; Chaput *et al.*, 2017). In addition to the arm circumference itself, other anthropometric features of the mid-upper-arm, such as area of fat or muscle tissue, are crucial predictors of nutrition level, body weight and adiposity (Debnath *et al.*, 2017). It has even been suggested that the fat area of the upper arm is the most suitable index to monitor obesity in prepubertal and pubertal children and adolescents (Cândido *et al.*, 2011). In addition, the muscle area of the arm can be successfully used as an indicator of overall muscle mass (Monir *et al.*, 2008).

Mid-upper-arm anthropometry has been widely used to assess levels of nutrition, but little research has been done on the changes in mid-upper-arm circumference between subsequent generations (Bolzan *et al.*, 1999; Chowdhury & Ghosh, 2009; Çiçek *et al.*, 2009; Basu *et al*, 2010; Debnath *et al.*, 2017). However, secular trends can provide important information, especially in developing countries such as India (International Statistical Institute, 2017). Developing countries are subject to economic and social changes that can have significant impacts on the growth and development of children and adolescents (Eveleth & Tanner, 1976; Komlos & Baten, 2004; Bielicki *et al.*, 2005). The analysis of the direction and pace of inter-generational changes is one of the methods most often used to study the impact of socioeconomic factors on these processes (Dasgupta *et al.*, 2008; Kryst *et al.*, 2012; Mori, 2016). The anthropometric features of the upper arm are an accurate reflection of nutrition level, body weight and composition. Therefore, their changes with time are particularly interesting in the context of the so-called 'double burden' of over- and under-nutrition seen in India in recent years. This is the co-existence of an increasing prevalence of overweight and obesity (especially in the last 10 years) and high levels of underweight and undernutrition (Dasgupta *et al.*, 2008; Singhal *et al.*, 2010; Arora *et al.*, 2017; UNICEF and WHO, 2017).

The aim of this study was to compare the time trends in mid-upper-arm anthropometry characteristics of two cohorts (1982–83 and 2005–2011) of Bengali boys aged 7–16 years from Kolkata, India.

Methods

The study data comprised two series of anthropometric measurements of 2063 Bengali boys aged 7–16, from predominantly middle-class families (classified on the basis of per *capita* monthly family expenditure, parental occupation, parental education, school affiliation, household assets and housing condition). Both studies were cross-sectional in design. The cohort examined in 1982–83 consisted of 758 individuals and the 2005–11 cohort included 1305 individuals (Table 1). For both cohorts, measurements were made on the subjects' birthdays (±3 days, verified through hospital discharge certificates). Only boys of good overall health and whose parents gave their consent were included in the study.

Measurement of the mid-upper-arm circumference (MUAC) was taken using a measuring non-stretchable tape-measure (0.5 cm accuracy). Intra- and inter-observer errors for this measurement were 0.044 and 0.152 cm, respectively. Triceps skinfold thickness (TSF) was measured on the left arm using a Lange skinfold calliper (Beta Technology, USA) with a constant standard pressure of 10 g/mm^2 (1 mm accuracy). Intra- and inter-observer errors for this measurement were 0.223 and 0.806 mm, respectively. The measurement methods were analogous in both surveys and full details, as well as the exact characteristics of the study sample, are available in previous publications (Dasgupta *et al.*, 2015; Das *et al.*, 2016).

From the direct measurement of the mid-upper arm circumference and triceps skinfold thickness the following indicators were calculated, according to the formulae of Frisancho (1990):

$$\text{Mid-upper-arm area (MUAA)} = \text{MUAC}^2/(4\pi)$$

$$\text{Mid-upper-arm muscle circumference (MUAMC)} = \text{MUAC}-(\pi\times\text{TSF}/10)$$

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Table 1. Distribution of Bengali boys aged 7–16 by age group and cohort

Age group	Cohort 1982–83 *n*	2005–2011 *n*
7	58	121
8	82	123
9	93	129
10	64	116
11	90	123
12	91	140
13	91	153
14	88	136
15	70	126
16	31	138
Total	**758**	**1305**

$$\text{Mid-upper-arm muscle area (MUAMA)} = \text{MUAMC}^2/(4\pi)$$

$$\text{Mid-upper-arm fat area (MUAFA)} = \text{MUAA–MUAMA}$$

$$\text{Arm Fat Index (AFI)} = (\text{MUAFA/MUAA}) \times 100$$

The measurements for the 1982–83 cohort were taken from the results of the Kolkata Growth Study-1 (KG-1) (Pakrasi *et al.*, 1988; Dasgupta & Das, 1997).

The statistical significance of the differences between both cohorts was assessed using two-way ANOVA, with statistical significance at $p \leq 0.05$, performed using Statistica 12.0.

Results

Both age and cohort significantly differentiated MUAC (Table 2). A statistically significant, positive secular trend was present in all age groups. The largest differences were noted in 14- and 16-year-olds, while the smallest were observed in the youngest boys (Table 3, Fig. 1).

Due to the secular increase in arm circumference, contemporary boys were also characterized by a higher mid-upper-arm area (MUAA) (Fig. 2). This was significantly different between the two age groups and for both cohorts. Also, the interaction of these factors significantly differentiated MUAA (Table 2). Again, the greatest differences were observed in the oldest age groups (Table 3, Fig. 2).

The change of the overall arm area (MUAA) was also found to be associated with significant differences in the areas of individual tissues. Mid-upper-arm muscle area (MUAMA) differed between the age groups and cohorts, and also in the interaction of these factors (Table 2). In all age groups, boys examined in 2005–2011 had a higher muscle area than those from the earlier cohort. These differences were significant in almost all age groups, and were largest, once again, among 14- to 16-year-olds (Table 3, Fig. 3).

A positive secular trend was also observed for the fat tissue area of the arm, as indicated by the mid-upper-arm fat area (MUAFA). This differed significantly between age groups and cohorts

Table 2. Two-way analysis of variance comparing the anthropometric characteristics of Bengali boys in the 1982–83 and 2005–2011 cohorts

		MUAC	MUAA	MUAMA	MUAFA	AFI
Age group	SS	6556.4	6.5×10^8	6.3×10^8	4.0×10^5	122.2
	F	75.2	66.9	71.0	14.3	17.5
	p-value	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
Cohort	SS	3772.0	3.7×10^8	3.5×10^8	5.9×10^5	29.3
	F	389.3	344.6	353.5	189.8	37.8
	p-value	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001
Interaction	SS	95.0	2.3×10^7	2.1×10^7	2.4×10^4	3.6
	F	1.1	2.4	2.4	0.8	0.5
	p-value	0.367	0.011	0.011	0.578	0.866

SS: sum of squares.

(Table 2). Again, the differences were greatest among the oldest boys. The differences were statistically significant for all age groups, except for 7-year-olds (Table 4, Fig. 4).

It can be concluded that, in the contemporary boys, the observed increases in the circumferences and areas of the arm resulted from greater muscle mass and adiposity. It also can be noted that the secular growth of the amount of both tissues was proportional because no statistically significant differences in the Arm Fat Index (AFI) were observed between the two cohorts, or between any of the age groups (Table 4, Fig. 5). However, both age groups and cohorts significantly differentiated the value of the Arm Fat Index (Table 2).

Discussion

Positive time trends in the mid-upper-arm anthropometry of Indian boys were observed in this study for almost all of the studied traits. In the contemporary population, the total mid-upper arm circumference, as well as the area of the arm, and muscle tissue content and adiposity, had increased.

A similar tendency was observed in a previous study conducted using data from newborns in India (Bhalla & Kaur, 2016), which found a positive secular trend in MUAC. Sousa *et al.* (2012) observed an increase in the total circumference of the mid-upper arm in contemporary children from Portugal, but no significant changes in boys' triceps skinfold thickness. Similar inter-generational changes have also been observed in Polish children and adolescents (Kryst *et al.*, 2018).

An important finding in the current study was that these changes were particularly pronounced in boys (Kryst *et al.*, 2018). Likewise, Sedlak *et al.* (2017), in their research of pre-school children in the Czech Republic, noted an increase in the overall level of body fat in the more recent population. In this case, however, unlike in the present research, the total circumference of the arm also decreased. This suggests that in these Czech children there was also a negative secular trend in the amount of muscle tissue in the arm, which was also different from the results observed in the present Indian population. This may be related to differences in the levels of economic development in the two countries. According to the World Bank, the Czech Republic is a high-income country, while India is currently classified as a middle-income country. Those socioeconomic differences are also seen in mean life expectancy at birth and GDP (Gross Domestic Product) (World Bank, 2018a, b). An inter-generational increase in MUAC co-existing with a slight increase in general body fat has also been observed in Croatian children, between cohorts from

Table 3. Results of Tukey's *post hoc* (HSD) test comparing MUAC, MUAA and MUAMA for the 1982–83 and 2005–2011 cohorts by age group

	MUAC (cm)					MUAA (mm^2)					MUAMA (mm^2)				
	1982–83		2005–2011			1982–83		2005–2011			1982–83		2005–2011		
Age	Mean	SD	Mean	SD	1982–83 vs 2005–2011	Mean	SD	Mean	SD	1982–83 vs 2005–2011	Mean	SD	Mean	SD	1982–83 vs 2005–2011
7	15.7	2.5	17.7	2.4	2.0***	1973.0	711.6	2549.0	730.8	575.9	1915.2	682.2	2466.6	699.0	551.3
8	16.5	2.8	18.8	2.9	2.3***	2214.6	869.7	2850.9	889.8	636.3*	2108.7	772.2	2751.9	846.3	643.2**
9	17.2	2.6	19.8	3.3	2.6***	2288.7	636.8	3148.7	1040.5	860.0***	2218.1	608.8	3039.7	991.3	821.6***
10	17.8	3.3	20.4	3.2	2.6***	2621.5	1054.7	3406.2	1058.1	784.7***	2532.7	1012.3	3280.2	1005.3	747.5***
11	18.2	3.1	21.1	3.3	2.9***	2660.3	896.2	3601.0	1122.4	940.6***	2562.6	831.4	3469.5	1071.7	906.8***
12	18.8	3.0	22.0	3.6	3.2***	2863.2	926.0	3698.1	1229.4	834.9***	2771.7	888.0	3569.4	1175.4	797.6***
13	19.2	2.3	22.3	3.5	3.1***	2976.7	741.6	3762.3	1064.2	785.7***	2871.2	699.0	3640.4	1017.1	769.2***
14	19.9	2.5	23.3	3.6	3.4***	3195.6	843.6	4383.5	1362.1	1187.9***	3107.3	801.9	4257.0	1314.4	1149.7***
15	21.0	2.7	24.0	3.7	3.1***	3554.4	954.7	4658.2	1424.4	1103.8***	3451.9	898.5	4521.7	1361.8	1069.8***
16	21.7	2.8	25.2	3.1	3.5***	3660.0	718.8	5110.8	1280.7	1450.8***	3569.9	690.6	4960.3	1224.6	1390.5***

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

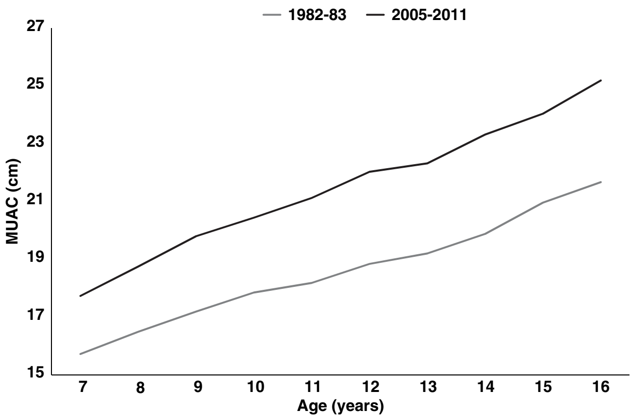

Figure 1. Mean MUAC values by age groups and cohort.

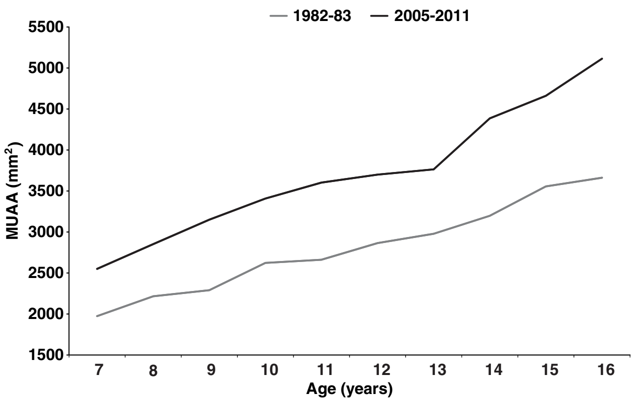

Figure 2. Mean MUAA values by age groups and cohort.

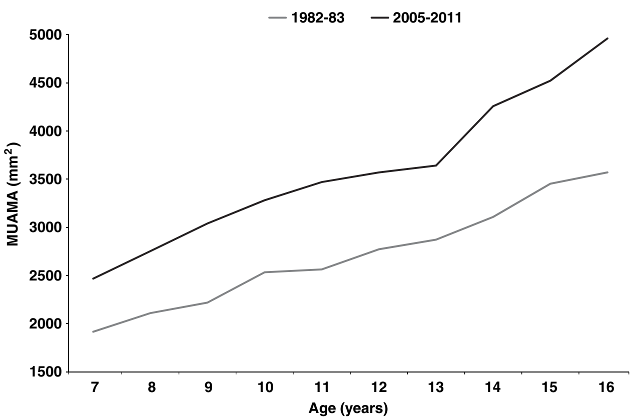

Figure 3. Mean MUAMA values by age group and cohort.

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Table 4. Results of Tukey's *post hoc* (HSD) test comparing MUAFA and AFI for the 1982–83 and 2005–2011 cohorts by age group

	MUAFA (cm^2)					AFI				
	1982–83		2005–2011			1982–83		2005–2011		
Age	Mean	SD	Mean	SD	1982–83 vs 2005–2011	Mean	SD	Mean	SD	1982–83 vs 2005–2011
7	57.8	34.5	82.4	35.9	24.6	2.8	0.8	3.1	0.7	0.3
8	68.8	42.8	99.0	48.5	30.2*	3.0	1.0	3.3	0.8	0.3
9	71.4	40.3	109.0	53.9	37.6***	3.0	0.9	3.3	0.8	0.3
10	88.8	56.9	126.0	57.5	37.1**	3.2	1.1	3.6	0.8	0.3
11	97.7	70.1	131.5	57.9	33.8**	3.4	1.2	3.6	0.8	0.2
12	91.5	52.8	128.7	62.0	37.2***	3.1	1.1	3.4	0.9	0.3
13	89.6	47.0	121.9	47.0	32.3*	3.0	0.9	3.1	0.9	0.2
14	88.4	52.7	126.6	56.9	38.3***	2.7	1.0	2.8	0.7	0.2
15	102.5	63.8	136.5	70.8	34.0**	2.7	1.0	2.8	0.8	0.1
16	90.2	39.4	150.5	69.9	60.4***	2.4	0.8	2.8	0.9	0.4

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

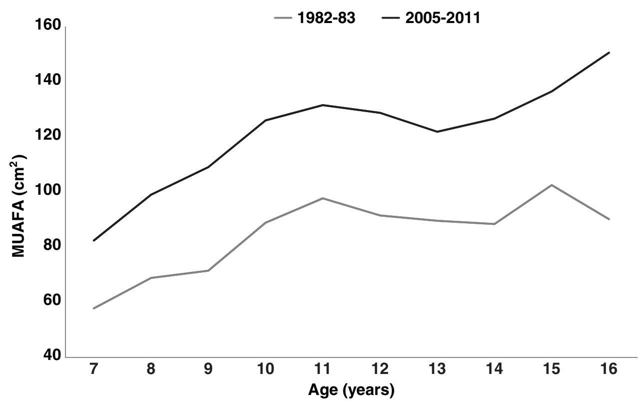

Figure 4. Mean MUAFA values by age group and cohort.

1998 and 2013 (Horvat *et al.*, 2017). What is interesting, however, is that the same study found a decrease in upper-arm adiposity, as measured by triceps skinfold thickness, between the 2003 and 2013 cohorts

An Argentinean study, similarly as in the present analysis, observed a positive secular trend rin both MUAC and upper-arm adiposity (Guimarey *et al.*, 2014). However, unlike in the current Bengali population, there was also a decrease in muscle mass. According to the authors, this was related to the increase in the intake of the energy-dense foods and the popularization of a sedentary lifestyle. In recent years, similar changes in the level of activity and diets of children and adolescents have been observed in India. Arora *et al.* (2017) and Gamit *et al.* (2015) observed that contemporary Indian teenagers preferred to travel by car or bus rather than biking or walking.

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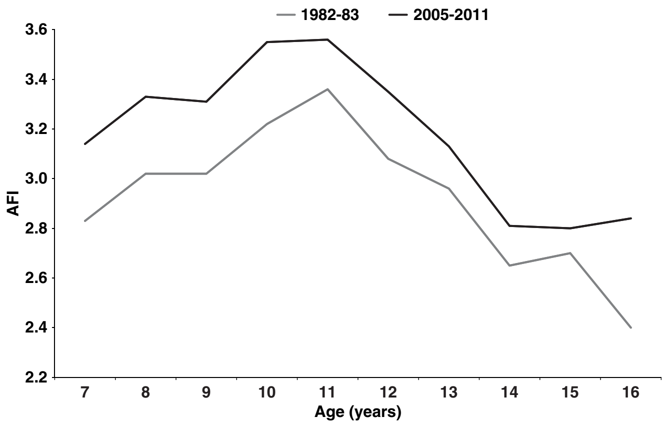

Figure 5. Mean AFI values by age group and cohort.

Changes in the level of physical activity of children and adolescents can significantly affect the bone frame. Less-active children and adolescents are characterized by a significantly lower Frame Index – an indicator of the relative robustness of the skeleton, based on elbow breadth in proportion to body height. Thus physical activity is important to maintain skeletal robustness, and therefore an appropriate body composition (Rietsch *et al.*, 2013). Moreover, Hajare *et al.* (2016) reported that over 36% of teenagers in India ate 'junk food' more than three times a week. However, the present results suggest that these activity and diet changes are not yet strong enough, at least in the West Bengal area, to negatively affect the body structure of boys. The observed positive inter-generational changes were probably, to a large extent, associated with a significant reduction in the prevalence of stunting and wasting that occurred between the years between the two examined cohorts (Rao *et al.*, 2012). This phenomenon could be due to the economic and social progress made in India over recent decades. There has been progress in various socioeconomic population characteristics, such as level of nutrition, education, parents' occupations and quality of health care (Bhalla & Kaur, 2016).

Improving environmental conditions are in turn correlated with a better realization of genetic potential, which is reflected in secular trends in the dimensions, proportions and composition of the human body (Malina, 1990). Fuller implementation of the genetic potential of the Indian population is expressed, for example, in the positive inter-generational changes in body height observed in recent years (Dasgupta *et al.*, 2015). These changes could be responsible for the differences observed between the examined cohorts in the present study. Body height can significantly influence MUAC values, as well as mid-upper-arm adiposity and muscle area (Addo *et al.*, 2017; Heymsfield & Stevens, 2017). However, according to Scheffler *et al.* (2018), fat tissue has no correlation with body height in the Bengali population.

In addition, this study's observed changes in mid-upper-arm anthropometry may be directly connected to improvements in development conditions. The sensitivity of those characteristics to the environment has been shown in studies of the Turkish population (Gültekin *et al.*, 2007; Cândido *et al.*, 2011; Çiçek *et al.*, 2014). These studies highlighted the significant impact of socioeconomic status on the muscle and fat tissue area of the upper arm. The association between the anthropometric characteristics of the mid-upper arm and developmental conditions has also been confirmed by research carried out in the National Capital Territory of Delhi by Sharma *et al.* (2007). Children were found to have significantly higher values of both MUAC and triceps skinfold thickness than the National Centre for Health Statistics standards, which are derived using data from various regions of the country. It is also interesting that the highest MUAC values in Delhi boys were observed at the ages of 12–14 years – the age at which the present study found the differences between the two cohorts to be often the greatest.

However, the positive inter-generational transformations observed in the present analysis may also be a consequence of the improved eating habits of the examined boys. Özdemir *et al.* (2014), in their study of the Turkish population, suggested that lower values of MUAMA and MUAFA could be related to a poorer and less-diverse diet. The positive impact of well-balanced eating on anthropometric dimensions of the mid-upper arm has also been confirmed by da Silva *et al.* (2014). They analysed the effectiveness of a nutrition programme on children. They found that calorie–protein adjustments can cause a significant increase in the muscle area of the arm, as well as in triceps skinfold thickness. The MUAMA is also sensitive to protein–energy malnutrition (Caballero *et al.*, 2003; Monir *et al.*, 2008). Thus, the diet of contemporary Indian boys is probably not only richer overall, but also better balanced in terms of individual nutrients. Additionally, the obtained results also suggest that between the analysed cohorts, the diet at the youngest ages has improved, for inadequate nutrition during early childhood has been proven to be associated with poor upper-arm composition, even at a later age (Monir *et al.*, 2008).

The results of this study provide some interesting and useful information about the mid-upper arm anthropometry of the Bengali population. The study of these variables, and their changes in subsequent generations, remains important and relevant, especially in developing countries. There are, of course, a wide variety of anthropometric characteristics that are accurate indicators of malnutrition, waist circumference being a good example (Kryst *et al.*, 2016). However, these alternatives can often be affected by respiratory movements and postprandial abdominal distension. In contrast, arm anthropometry is not affected by such problems, and hence may be a more reliable indicator for overweight and obesity diagnosis (Çiçek *et al.*, 2014). It is, therefore, important to obtain new information regarding the middle-upper-arm anthropometry in different populations, as this could significantly improve the process of screening for all forms of malnutrition and related health problems to help body weight and composition management.

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Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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