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RESEARCH ARTICLE

RELATIONSHIP BETWEEN BODY MASS INDEX AND BODY FAT PERCENTAGE, ESTIMATED BY BIOELECTRICAL IMPEDANCE ANALYSIS AND SKIN FOLD THICKNESS, IN A GROUP OF SRI LANKAN ADOLESCENTS: A CROSS SECTIONAL STUDY

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ABSTRACT

Background: Body Mass Index, isoften used in clinical practice as well as in epidemiological studies.However, it is not clear how strong the relationship between BMI for age Z score (BMI – Z) and body fat percentage (BF %) among children.The study determined the (BMI – Z) and (BF %) relationship, in a group of South Asian adolescentsand to examined the influence of age, gender in this relationship andassessed its' linearity or curvilinearity. **Methodology:** A cross-sectional study was conducted on 1374 adolescents. BF% was estimated by Bioelectrical Impedance analysis (BIA) and Skinfold thickness (SFT).Pearsons' correlation coefficient(r) was calculated to see the relationship between (BMI – Z) score and (BF %). Multiple regression analysis was performed to determine the effect of age and gender in the relationship and polynomial regression was carried out to see its' linearity. **Results**: Of the total sample 50.3 % (690) were girls. A significant positive correlation was observed between BMI – Z and BF% by SFT (Boys -r =0.87, p < 0.01; SEE = 4.42, Girls - r =0.78, p < 0.01; SEE = 4.17) and between BMI – Z and BF% by BIA (Boys -r =0.74, p < 0.01; SEE = 4.33, Girls - r =0.88, p < 0.01; SEE = 2.71). Effect of age and gender in the BMI – Z and BF%, relationship was significant (p < 0.001). Curvilinear relationship between BMI – Z and BF%, was found. **Conclusion:** BMI - Z is strongly correlates with BF % estimated by BIA and SFT in this study group. The both relationships studied were curvilinear in nature. The effect of the age and gender of an individual were significant.

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INTRODUCTION

Overweight and Obesity among children is a global public health concern and its prevalence, especially in the urban settings, shows an upward trendworldwide regardless of the economic standing of the individual counties (http://www.who .int/dietphysicalactivity/childhood/en). World Health Organization (WHO) defines Overweight and Obesity as abnormal or excessive accumulation of fat in the body that may impair health (http://www.who.int/dietphysicalactivity/ childhood/en). Excessive body fat increases the risk of having cardiovasculardiseases, impaired glucose tolerance, insulin resistance and type 2 diabete (Freedman *et al*., 2007; Whitlock *et al*., 2005; Fortuño *et al*., 2003). Therefore, the accurate measurement of adiposity is important tomanage the health consequences related to the excess body fat (McCarthy *et al*., 2006).

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Underwater weighing (densitometry), Dual X – ray absorptiometry (DXA) and magnetic resonance imaging (MRI) are some of the most accurate measurements of body fat which are more expensive and time consuming[6]. Therefore those methods are impractical in the clinical practice and in epidemiological studies (Dehghan *et al*., 2005). Body-mass index (BMI), skinfold thickness (SFT) measurements and bioelectrical impedance analysis (BIA) are the widely used feasible methods of assessing body composition in children and adolescents (Dehghan *et al*., 2005). BMI is the one of the most widely used for classifying overweight and obesity in adults (Mei *et al*., 2002) as well for screening overweight and obesity in children and adolescents (Himes and Dietz, 1994). It has been used as a proxy for estimating the body fat percentage (BF%) and associated health risks (De Wilde *et al*., 2013). However BMI cut-offs have not yet been adjustedfor south Asianchildren and adolescents, even though their cardiometabolic risks are higher at a lower BMI than in children of European descent (Whincup *et al*., 2002). For all ethnic groups theuniversal BMI-cut-offs for ages 2–18 years (Cole *et al*., 2000), or the WHOChild Growth Standard 0–5 years (WHO, 2006) and the WHO GrowthReference 5–19 years (Onis *et al*., 2007) are still recommended (Wang and Chen, 2012). In the current study we have usedBMI for age (BMI – Z), the WHO growth Reference 5 – 19 years, since it have been scrutinized and implemented by many countries worldwide (De Onis *et al*., 2007). Measurements of skin fold thicknesses can be used to estimate the body fatness, which correlate reasonably well with body fatness[16]. There are several regression equations which have been developed and cross validated to calculate body composition by using SFT (Wickramasinghe *et al*., 2008; Slaughter *et al*., 1988; Deurenberg *et al*., 1990; Rodriguez *et al*., 2005). Out of them, equations proposed by Slaughter *et al*. (1988) or prepubertal, pubertal and postpubertal males and females are the most commonly used (Orta Duarte *et al*., 2014; Pecoraro *et al*., 2003).

BIA also can be used as proxy for estimating the body fat percentage as it provides a rapid, non-invasive and accurate measurement of body composition (Kyle *et al*., 2004). Validity of the BIA derived body fat percentage has been tested with a rangeof reference techniques including, total body water hydrodensitormetry, dual energy X-ray absorptiometry and air displacement plethysmography (Goran *et al*., 1996). The research on body composition of South Asian adolescents, especially Sri Lankanadolescents are limited (Wickramasinghe *et al*., 2008). Thus we studied a large sub-population of South Asian adolescents from Sri Lanka; to determine the relationship betweenBMI – Z and BF % derived from BIA and SFT and its nature, whether linear or curvilinear. Also we tried to find the prevalence of overweight and obesity among them by using deferent techniques (BMI- Z, SFT and BIA) and the effects of age and gender on relationship between BMI-Z and BF%.

MATERIALS AND METHODS

A cross-sectional study was conducted in 2016among 1374 school children (684 boys and 690 girls) aged 12 – 16 years. Sample size was calculatedwith an Anticipated population proportion of50% (for maximum sample size), at the confidence level of 95 %, and a 5% error.Thedesign effect was 3 (Thalagala *et al*., 2004). Thesamplewas recruited from 25 schools in Colombo District selected by stratified random cluster sampling (Thalagala *et al*., 2004). A class room was considered as a cluster. In a class room there are approximately 40 students and the whole sample was divided in to 35 clusters. The sample was stratified at two stages. First the sample (clusters) was divided equally into five strata according to the school grades (grades 7-11). Within each stratum the clusters were divided according to the functional type categorization of schools adopted by the Ministry of Education, Sri Lanka (1 AB, 1 C and Type 2 government schools which includes the classes grades 7 to 11 and all the Private schools which are having grades 7 -11). The number of students allocated to each grade was divided according to the Probability Proportional to the number of the student in the specific grades in different types of schools.

Measurements

Body Mass Index: Weight and height were measured by standard techniques as described by the World Health Organization (WHO, 1995). Participants were wearing only the school uniform with no school tie, badges or footwear and other accessories. Body weight was measured to the nearest 0.1 kg using calibrated electronic weighing scales (Seca 770, Digital Scales, Seca Ltd, Birmingham, UK). Height was measured using a portable Stadiometer (SecaStadiometer, Seca Ltd, Birmingham, UK) and recorded to the nearest millimeter. Participants were asked to stand with their backs straight, with the head held in the Frankfort horizontal plane and feet flat and arms hanging loosely by their sides (WHO, 1995). The z-score values for BMI-for-age were calculated using "AnthroPlus" software (WHO, 2009). Overweight (> + 1SD) and obesity (>+2SD) were defined according to the WHO child growth reference 2007 (Onis *et al*., 2007).

Skin fold thickness

SFT was measured using a Harpenden Skinfold Caliper (John Bull, British Indicators Ltd, UK) to the closest 1mm. Left triceps and subscapular (SS) SFT were measured using standard protocols (WHO, 1995). The triceps skin - fold site was located and marked as the middle point on the posterior side of thearm, over the triceps muscle between the acromion and olecranonprocesses. The subcutaneousfat 1 cm above the mark was pinched and the skinfold caliper wasapplied horizontally on the mark for about three seconds. Thesubscapular SFT was obtained by pinching the inner edgeof the shoulder blade at an angle of 45°. Both the skinfoldsites were located with the subjects in a relaxedstanding position with their arms hanging by their sides. The following equations by Slaughter *et al*. (1988) were used to estimate the percentage of total body fat driven by SFT.

White males = $1.21 \times (\text{triceps} + \text{SS}) - 0.008 \times (\text{triceps} + \text{SS})^2 - 3.4$

All females = $1.33 \times (\text{triceps} + \text{SS}) - 0.013 \times (\text{triceps} + \text{SS})^2 - 2.5$

For sum of triceps and subscapular >35 mm, the following equation was used.

All males = $0.783 \times (\text{triceps} + \text{subscapular}) + 1.7$
All females = $0.546 \times (\text{triceps} + \text{subscapular}) + 9.7$

BIA: Total body fat percentage wasestimated by using a commercially available single-frequency, 8 electrode bio impedance analyzer system (BC-418, Tanita Corp, Tokyo, Japan). All measurements were taken during morning hours (0830–1200), before the students' lunch break. According to the manufacturer's instructions the students had no alcohol or vigorous exercise within12 hours prior to measurement, no excess food or drink than usual on the day before measurement and any food or drink within 3 hours prior to measurement. Furthermore, they were instructed to urinate before the measurement. The BIA system consisted of two handgrips with two electrodes each and a footplate with four electrodes. Participants stood on the footplate and gently grasped the two handgrips with arms held straight forward at 90 degrees. During the measurement, the instrument recorded whole body impedance from the hands to the feet by applying an electric alternating current flux of 0.8mA at an operating frequency of 50 kHz. Finally, %BF was estimated from the whole body impedance value and was recorded to the nearest 0.1% (Kyle *et al*., 2004). The percentage of BF derived from the SFT and BIA was classified according to the children's sex-specific centile curves of %BF references by McCarthy *et al.* (2006). Underfat, overfat andobese, wereset at the 2nd, 85th and 95th centiles respectively.

Statistical Analysis

The statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) version 16.0 (SPSS Inc.USA). Basic descriptive statistics for subject data were expressed as means ± standard deviations. Differences between means were analyzed by independent sample t test. We have analyzed two relationships; relationship between BMI Z and BF% - SFT and the relationship between BMI Z and the BF% - BIA. Pearson's correlation coefficients (r) were calculated to assess the degree of relationship between BMI- Zand BF% driven by both BIA and SFT, in both girls and boys. Multipleregression analysis was performed to examine the effect of age on the both relationships separately. Then gender was further added to the modelsto see its' effect. BMI - Z, age and gender were taken as independent variables and BF% - SFT and BIA were the dependent variables.The statistical significance was set at $p<0.05$. Polynomial regression analysis examined the linearity of the BMI-Z -BF% (SFT and BIA) relationships. After analyzing with General linear models it was extended to examine nonlinearity by including a quadratic term for BMI-Z (BMI^2) in both relationships

Ethical Approval: Ethical clearance was obtained from the Ethics Review Committee of the Faculty of Medical Sciences, University of Sri Jayewardenepura. Permission to implement the study was taken from the Ministry of Education, Provincial and Zonal education Office and other relevant stakeholders (Principals and the relevant class teachers) of schools. Informed written consent from the parents or the guardians and the assent/consent from the students were obtained prior to the start of the study.

RESULTS

Baseline group characteristics: The sample of 1374 schoolchildren was composed of 49.7% boys (n = 683) with a mean age of 13.7 (±1.4SD) years and 50.3% girls (n = 691) with a mean age of 13.8 (±1.3SD) years.A significant difference was observed between boys and girls regarding BMI for age z scores, height, triceps and subscapular SFT, percentage of body fat by BIA and SFT, whereas it was not significant considering weight (Table 1).

Relationship between BMI – Z and BF% derived from BIA and SFT: There was a strong and significant positive correlation between BMI- Z and BF% - SFT in boys ($r = 0.87$, $p< 0.01$; SEE = 4.42) and in girls ($r =0.78$, $p < 0.01$; SEE = 3.85). Similarly, the correlation between BMI- Z and BF% - BIA was also significant and positive in both boys ($r = 0.74$, $p < 0.01$; SEE = 4.33) and girls ($r = 0.88$, $p < 0.01$; SEE = 2.71). The correlation between BF% - BIA and BF% - SFT also strong and positive ($r = 0.78$, $p < 0.01$; SEE = 4.29).

Prevalence of obesity according to percentage of body fat and BMI – Z (Table 2): According to age specific BMI Z score (BMI – Z), 8% were obese and 9.6% were overweight, while 14% were overfat and 5.5% were obese according to BIA. SFT showed 13% and 10.3% of over fatness and obesity respectively. Furthermore, all three methods showed high prevalence of underweight/underfat with values ranging from 23.0%, 31.0% and 31.5% according to the measurements of SFT, BMI and BIA respectively.

The effect of age and gender in the BMI- Zand BF% by BIA BF% by SFT relationships: Age and gender were found to be significant predictor variables in the regression models ($p < 0.000$) (Tables 2 and 3), in both relationships. Genderhas contributed more effect to the relationship between BMI with BF% - BIA and BF% by SFT (Model 2).

Linearity/curvilinearity of the BMI -Z and BF% (SFT and BIA) relationships: Visual inspection of the scatter plot (Figure 1 and 2) showed positive correlations in both relationships, between the BMI and BF % - SFT and BMI – BF% - BIA. It is found to be that the relationships are linear and also having curvilinear nature towards the high BMI values. According to the general linear models, of the relationship between BMI and BF% - SFT, the variance of the boys and girls are 74.7% and 60.9% respectively and 55.2% of population of the boys and 76.7% of population of the girls can be described according to the relationship between BMI and BF% - BIA. Adding quadratic component of BMI, in to both relationships, accounted for an additional 1.8% (BMI and BF% - BIA) and 0.9% (BMI and BF% - SFT) of the female variances ($p < 0.000$) and 4.2% (BMI and BF% - BIA) and 4.6% (BMI and BF% - SFT) of the male variance ($p < 0.01$). In BMI and BF% - BIA relationship, female model ($R^2 = 0.78$, SEE 2.6%) provided more accurate fit than the male model ($R^2 = 0.59$, SEE 4.1%). But in BMI and BF% - SFT relationship the male model ($R^2 = 0.79$, SEE 4.0%) showed an accurate fit than the female model ($R^2 = 0.62$, SEE 3.8%).

DISCUSSION

In the current study, our aim was to determine the relationship between BMI and BF % derived from BIA and SFT and its nature, whether linear or curvilinear, the prevalence of overweight and obesity among them by using deferent techniques (BMI, SFT and BIA) and the effects of age and gender on relationship between BMI and BF%. It is to see whether BMI – Z can be used as a proxy measure of BF% in adolescents, and to identify any significance of age and sex in this prediction.The data related to these facts are very scarce for South Asians adolescents who have a different body composition compared to Caucasians, Blacks and even Asian Mongolians (Hussain *et al*., 2014; Minghelli *et al*., 2013). The use of different methods to estimate BF%; theirvalidity, reliability have been discussed in variety ofstudies (Rodriguez *et al*., 2005; Goran *et al*., 1996). In current study we used bioelectrical impedance analysismethod and Skin fold thicknesses to estimate the BF% of the subjects. BIA and SFT measurements are considered as safe, valid and feasible tools which have been validated against gold standard methods such as dual energy X-ray absorptiometry (Gutin *et al*., 1996). In the present study SFT highly correlated with both BMI and BIA. We have used the equation by Slaughter *et al*. to calculate the percentage of body fat. Similarly Goran*et al*. (1996) and Hussain *et al*. (2014) also have used the BF% values derived from Slaughter equation. Both studies have cross calibrated several body composition methods including SFT against DXA and found that fat mass measured by DXA strongly correlates with FM measured by SFT ($r = 0.87$ and 0.76 respectively). Our study confirmed the significant positive relationship between BMI – Z and BF% by SFT and BIA which was demonstrated in most of the former studies.

Table 1. Descriptive statistics of the sample

	BF% - SFT			BF% - BIA		
	Intercept/Regression coefficient/ R^2	SE	Beta	Intercept/Regression coefficient/ R^2	SE	Beta
Intercept	15.142	1.173		23.534	1.248	
BMI for age z score	3.878	0.085	0.832 (p<0.000)	3.014	0.076	0.735 (p<0.000)
Age	0.704	0.071	0.126 (p<0.000)	0.164	0.091	0.033 (p<0.000)
R^2	0.685			0.546		

Table 2. Prevalence of obesity according to percentage of body fat and BMI for age Z score

Variable	Total sample (n = 1374) Mean (SD)	Male (n = 683) Mean (SD)	Female (n = 691) Mean (SD)	P- value
Age (years)	13.7 (1.4)	13.7 (1.4)	13.8 (1.3)	0.273
Weight (kg)	43.9 (12.0)	44.0 (13.0)	43.8 (10.9)	0.674
Height (m)	154.0 (10.2)	155.5 (11.5)	152.6 (8.4)	0.000
BMI -Z	-0.7 (1.7)	-0.8 (1.8)	-0.6 (1.6)	0.005
BF% - BIA	19.3 (6.8)	16.1 (6.5)	22.3 (5.6)	0.000
Triceps SFT	13.4 (5.5)	12.5 (5.8)	14.4 (4.9)	0.000
Subscapular SFT	12.4 (5.0)	11.3 (5.2)	13.4 (4.7)	0.000
BF% - SFT	22.0 (7.8)	20.2 (8.8)	23.8 (6.2)	0.000

Table 3. Multiple regression analysis for change in BF% - SFT and BF% - BIA with BMI and age (Model 1)

Criteria		Male n (%)	Female n (%)	Total n (%)	P value
BMI – Z (WHO, 2007)[13]	Thinness	140 (20.5)	174 (25.2)	314 (22.8)	0.072
	Normal	412 (60.3)	412 (59.6)	824 (60.0)	
	Overweight	76 (11.1)	56 (8.1)	132 (9.6)	
	Obese	55 (8.1)	49 (7.1)	104 (7.6)	
BF% - SFT (Slaughter *et al*, 1988)[5, 18]	Underfat	188 (27.5)	128 (18.5)	316 (23.1)	0.000
	Normal	304 (44.5)	433 (62.7)	737 (53.6)	
	Overfat	105 (15.4)	74 (10.7)	179 (13.0)	
	Obese	86 (12.6)	56 (8.1)	142 (10.3)	
BF% - BIA**** (McCarthy *et al*, 2006)[5]	Underfat	257 (39.5)	166 (24.3)	423 (31.7)	0.000
	Normal	253 (38.9)	398 (58.3)	651 (48.8)	
	Overfat	99 (15.2)	87 (12.7)	186 (14.0)	
	Obese	41 (6.3)	32 (4.7)	73 (5.5)	

Table 4. Multiple regression analysis for change in BF% - SFT and BF% - BIA with BMI, age and gender (Model 2)

	BF% - SFT			BF% - BIA		
	Intercept/Regression coefficient/ R^2	SE	Beta	Intercept/Regression coefficient/ R^2	SE	Beta
Intercept	11.589	1.158		16.406	1.007	
BMI for age z score	3.815	0.068	0.819 (p<0.000)	2.908	0.060	0.709 (p<0.000)
Age	0.668	0.082	0.119 (p<0.000)	0.282	0.071	0.057 (p<0.000)
Gender	2.670	0.222	0.171 (p<0.000)	5.736	0.198	0.421 (p<0.000)
R^2	0.714			0.722		

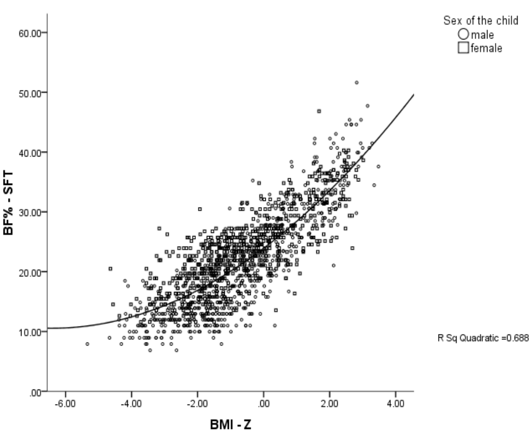

Figure 1. Scatter plot of the relationship between Body Mass Index for age (BMI - Z) and percentage of body fat by Skin fold thickness (BF% - SFT)

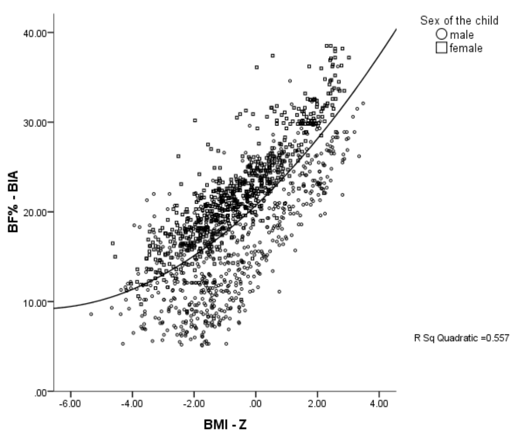

Figure 2. Scatter plot of the relationship between Body Mass Index for age (BMI - Z) and percentage of body fat by Bioelectrical Impedance Analysis (BF% - BIA)

Mexican study performed on 74 school children has identified a significant correlation between the percentage of fat measured by the Slaughter equation and body mass index ($r = 0.85$; $p < 0.001$) and the percentage of fat measured by bio impedance analysis and body mass index ($r = 0.78$; $p < 0.001$) (Orta Duarte *et al*., 2014). A study performed on 966 Portuguese adolescent (Minghelli *et al*., 2013) aged 10 – 16 years to analyze the correlation between BMI, skinfold thickness and waist circumference to assess overweight and obesity, identified a significant correlation between BMI and skin fold thickness ($P < 0.001$, $r = 0.712$). Tyrrell *et al*. (Tyrrell *et al*., 2001). Who studied European, Maori, Pacific Islanders andAsian Indian adults also confirmed the significant positiverelationship between BMI and BF% in all these races. The present study revealed different values for the prevalence of overweight or obesity, estimated by three different methods (BMI Z Scores, SFT and BIA) ranging 17%, 23% and 20% in adolescents living in Colombo District of Sri Lanka. A nationally representative cross-sectional study on 6,264 adolescents aged 10 to 15 years, done in 2006 showed prevalence rates of underweight, stunting, and overweight were 47.2%, 28.5%, and 2.2%, respectively (Jayatissa and Ranbanda, 2006).

Therefore it is clear that the prevalence of overweight or obesity among adolescents in Sri Lanka have increased markedly during last few years. In our study the both relationships (BMI– Z and BF % - SFT and BF% - BIA) were curvilinear rather than linear (Figure 1 and 2). Some former studies have shown the relationship between BMI and BF% as linear (Tyrrell *et al.,* 2001) and some as curvilinear/ quadratic (Federico *et al*., 2011). The current study showed a significanteffect of age and gender in the both relationships (BMIZ- BF % -SFT and BMIZ – BF% - BIA).The effect of gender is more significant in the relationship between BMIZ – BF% - BIA (Beta=0.421, $p < 0.000$) rather than BMIZ- BF % - SFT relationship (Beta=0.171, $p < 0.000$). Past studies also have concluded the significant effect of the gender and age on the relationship between BMI and BF% derived from different methods (Srdić *et al*., 2012). Although in some populations, girls had greater BF% than boys (Srdić *et al*., 2012) in our study we found that BF% is higher in boys compared to girls ($p < 0.000$). Some other studies also have found a greater BF% in boys (Ochiai *et al*., 2010; Thilakarathne and Wijesinghe). We also confirmed a significant effect of the age in these relationships: but they are not very strong [BMIZ – BF% - BIA ((Beta=0.057, $p < 0.000$) and BMIZ – BF% - SFT (Beta=0.119, $p < 0.000$)]. There is lack of evidence regarding the effect of age and gender in the relationship of BMIZ and BF%. However we think it is necessary to consider this effect when describing overweight/obesity in children or adolescents, clinically and in publichealth interventions.

Conclusion

- Outcomes of the current study show that Body Mass Index for age (BMI - Z) is strongly correlates with body fat percentage (BF %) estimated by BIA and SFT in this group of SouthAsian children from Sri Lanka.
- The both relationships studied were curvilinear in nature.
- The effect of the age and gender of an individual were significant for these relationships where gender affected the most.
- Therefore we emphasize the importance of taking age and gender in to consideration when using BMI for age Z scores to predict body fat percentage/obesity, in a population.

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Declarations

Transparency Declaration: "The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted and that any discrepancies from the study as planned (and registered with) have been explained. The reporting of this work is compliant with STROBE guidelines."

Ethics approval and consent to participate: Ethical clearance was obtained from the Ethics Review Committee of the Faculty of Medical Sciences, University of Sri Jayewardenepura (Reference Number: 31/14). The study was conducted according to the guidelines set by the Declaration of Helsinki.

Availability of data and material: The datasets during and/or analyzed during the current study available from the first author (thilnilk@sjp.ac.lk) on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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