

Determination of reference values for tricuspid annular plane systolic excursion in healthy Turkish children

Fahrettin Uysal, Özlem Mehtap Bostan, Ergun Çil

Department of Pediatric Cardiology, Faculty of Medicine, Uludağ University; Bursa-Turkey

ABSTRACT

Objective: Tricuspid annular plane systolic excursion (TAPSE) is an echocardiographic measurement used for evaluating right ventricular systolic function. While established reference values of TAPSE exist for the adult population, only a limited number of studies have attempted to evaluate reference values for the pediatric population. The aim of the present study was to determine the reference values for TAPSE in healthy children in Turkey.

Methods: A total of 765 healthy children aged between 0 and 18 years, all of whom were referred to our clinic with cardiac murmurs, were evaluated prospectively. Patients with no cardiac pathologies or other disorders were excluded from the study. The measurement of TAPSE was obtained using a 2D-guided M-mode technique with echocardiography, and the relationship between age and surface area with TAPSE was investigated. The statistical analysis was carried out using the SPSS 20.0 software package (SPSS Inc., Chicago, IL, USA, 2012).

Results: The mean TAPSE value was found to be 19.56 ± 5.54 mm, and no significant difference was identified between male and female children. TAPSE values showed a positive correlation with increasing age and surface area. The mean TAPSE value was 9.09 ± 1.36 mm in newborns and 25.91 ± 3.60 mm in the 13-18 years age group. A negative correlation was seen between TAPSE and heart rate.

Conclusion: In the present study, the reference values for TAPSE in healthy Turkish children were presented in percentile tables and the corresponding z-scores were determined. These reference values may be useful in daily practice for the evaluation of right ventricular systolic function in children. (*Anatol J Cardiol* 2016; 16: 354-9)

Keywords: TAPSE, percentile, healthy children, right ventricle systolic function

Introduction

Our understanding of the right ventricle is limited when compared to our understanding of the left ventricle. The right ventricle's complicated geometry, thick and trabeculated endocardial surface, and location of the inlet tract on a different plane to the outflow tract prohibits the use of standard measurement techniques used for the evaluation of function (1-3). The presence of an accompanying congenital cardiac disorder further complicates the geometry; however, it is particularly important to determine right ventricular function in these patients both before surgery and during postoperative follow-up (4, 5). Accordingly, an applicable and reliable means of measurement of right ventricular systolic function is required in daily practice. The tricuspid annular plane systolic excursion is a simple, reproducible, and applicable measurement technique that provides important information regarding right ventricular function. Recent studies using cardiac magnetic resonance imaging (MRI) suggest that TAPSE values correlate well with right ven-

tricular ejection fraction (6, 7). The reference values of TAPSE have been determined for adults (8, 9); however, only a limited number of studies have been conducted to determine the reference values of TAPSE in the pediatric age group (10, 11). The aim of the present study is to evaluate the reference values of TAPSE in healthy Turkish children.

Methods

Subjects

This prospective study included 765 healthy children aged between 0 and 18 years, who were referred to the pediatric cardiology outpatient clinics with cardiac murmurs between January 25, 2013 and December 31, 2013; they had no other health problems. The children were divided into 9 groups according to age: 0-1 month, 1-3 months, 3-6 months, 6-12 months, 1-3 years, 3-5 years, 5-9 years, 9-13 years, and 13-18 years. Body surface area was measured using the formula $\sqrt{(\text{height (cm)} \times \text{weight (kg)})/3600}$.

Address for Correspondence: Dr. Fahrettin Uysal, Uludağ Üniversitesi Tıp Fakültesi, Pediatrik Kardiyoloji Bölümü, Bursa-Türkiye Phone: +90 224 295 04 49 Fax: +90 224 442 81 43 E-mail: fahrettin_uysal@mynet.com

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For the purposes of the study, patients with a patent foramen ovale <2 mm and those with normal findings on echocardiography were evaluated.

Premature babies and patients who were referred due to congenital cardiac disorder; arrhythmia, palpitation, chest pain, or syncope other than cardiac murmur; large patent foramen ovale (>2 mm); growth/developmental retardation; and any non-cardiac disorders were excluded from the study.

The study was approved by the ethics committee; the parents of the patients provided informed consent for their children's participation in the study.

Echocardiographic evaluation

An echocardiographic evaluation was carried out with standard views in the supine and left decubitus positions using 3-8 MHz transducers and Vivid-6 GE® (GE Healthcare, USA) and HP/SONOS 5500® (Philips Medical Systems, USA) devices. In addition, color, continuous-wave (CW), and pulse-wave (PW) doppler techniques were used for all patients. The left ventricular end-diastolic diameter, ejection fraction (EF), fractional shortening, and septum thickness were evaluated using a parasternal long-axis view in M-mode.

The measurement of TAPSE was obtained using the M-mode technique in 2-dimensional echocardiography by placing the cursor along the lateral free wall of the tricuspid annulus in an apical four-chamber view (Fig. 1). The cursor was adjusted perpendicular to the lateral annulus as much as possible, in order to lie on the same plane as the cardiac apex. No angle correction method was used during the measurement. The analysis included the average of 3 consecutive measurements, and the heart rate was simultaneously calculated by measuring the R-R interval. The measurements were obtained while the patient was in a calm state during the procedure.

Considering interobserver variability, data were measured by 3 observers (FU, O.M.B, and E.C.) who were blinded to one another's results. Intraobserver variability was considered in 30 participants by measuring values again at >20 days after the first examination. Observer variability was low, with measured intraobserver variability of $2.2\% \pm 5$ and interobserver variability of $2.5\% \pm 7$.

Statistical analysis

Statistical analysis was carried out using the SPSS 20.0 software package (SPSS Inc., Chicago, IL, USA, 2012). The Kolmogorov-Smirnov test was used to determine whether the variables showed normal distribution, and those that did were expressed as mean \pm standard deviation. Nominal values were expressed as percentages. In statistical analysis, a Pearson correlation analysis was used to evaluate the relationship between 2 continuous variables that showed normal distribution and a Spearman correlation analysis was used to evaluate the relationship between 2 continuous variables that did not show normal distribution. A simple linear regression method was used to formulate the relationship between age and TAPSE.

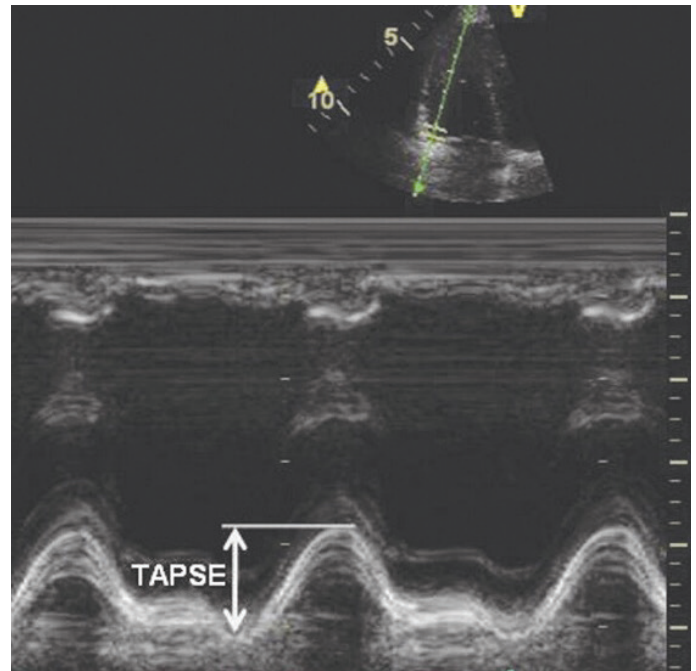


Figure 1. The measurement of tricuspid annular plane systolic excursion using M-mode technique

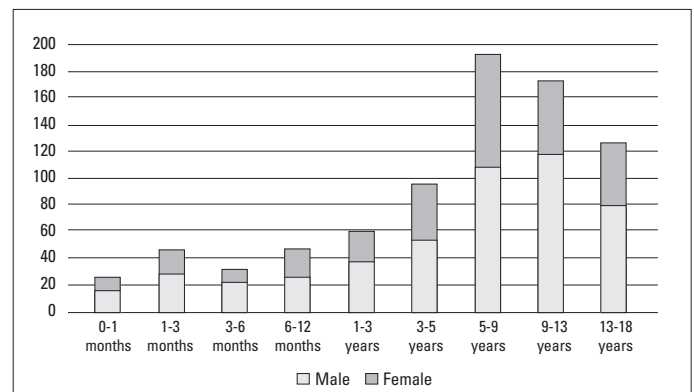


Figure 2. The distribution of age according to gender in the study population

Results

A total of 765 healthy children [312 girls (40.8%) and 453 boys (59.2%)], who were referred to the pediatric cardiology outpatient clinic and diagnosed with physiologic murmurs, were evaluated in the study. The distribution of age according to gender is presented in Figure 2; the anthropometric features of the evaluated children are summarized in Table 1.

The mean TAPSE value was 9.09 ± 1.36 mm in newborns and 25.91 ± 3.60 mm in the 13-18 years age group. A strong positive correlation between age, weight, height, and body surface area with TAPSE values was identified; a strong negative correlation between heart rate and TAPSE value was identified (Table 2). The equation that best describes the relationship between age and TAPSE value using linear regression method is $TAPSE = 0.0763 \times \text{age (months)} + 12.927$.

Table 1. The demographic features of the children

	Total	Female	Male
N	765	312	453
Age, months	86.98±60.62	80.64±59.68	91.35±60.94
Weight, kg	27.64±18.47	25.35±17.21	29.21±19.15
Height, cm	115.66±33.89	111.53±33.07	118.51±35.44
Body surface area, m ²	0.91±0.44	0.85±0.41	0.95±0.45
Heart rate	97.97±24.69	10176±23.17	95.37±25.38
TAPSE, mm	19.56±5.54	18.86±5.39	20.05±5.59

TAPSE - tricuspid annular plane systolic excursion

Table 2. Correlation between age, weight, height, body surface area, heart rate, and TAPSE

TAPSE		Age	Weight	Height	Body surface area	Heart rate
Male	R	0.856	0.860	0.858	0.866	-0.710
	P	<0.001	<0.001	<0.001	<0.001	<0.001
Female	R	0.828	0.830	0.844	0.853	-0.690
	P	<0.001	<0.001	<0.001	<0.001	<0.001

TAPSE - tricuspid annular plane systolic excursion, Statistical analysis-Pearson and Spearman correlation analysis. p<0.05; statistical significance. r: correlation coefficient

The ±2 and ±3 z-scores for TAPSE values according to the age groups of patients are presented in Table 3 and Figure 3; the reference values of TAPSE according to body surface area are illustrated in Figure 4.

Table 4 and 5 indicate TAPSE z-scores according to body surface area in boys and girls, and the relationship between TAPSE and heart rate is shown in Figure 5.

Discussion

The present study revealed a strong correlation between TAPSE value and height, weight, and body surface area; the reference values of TAPSE were determined according to both age group and body surface area.

Although the physiological significance of the right ventricle is often underestimated, it is essential to evaluate the right ventricular function in various diseases to predict prognosis (12, 13). The right ventricular dimensions and functions in patients with pulmonary hypertension determine severity of the disease and act as an important indicator of survival (14). Similarly, right ventricular function is an important indicator of prognosis in conditions affecting left ventricular function. An impairment in right ventricular function in patients with myocarditis has been associated with a higher risk of mortality and higher rates of transplantation compared with patients with normal right ventricular function; impairment is suggested to be the most important indicator for a poor prognosis (15). The chances of survival are lower in patients with idiopathic cardiomyopathy with proven biventricular dysfunction in angiography when compared to

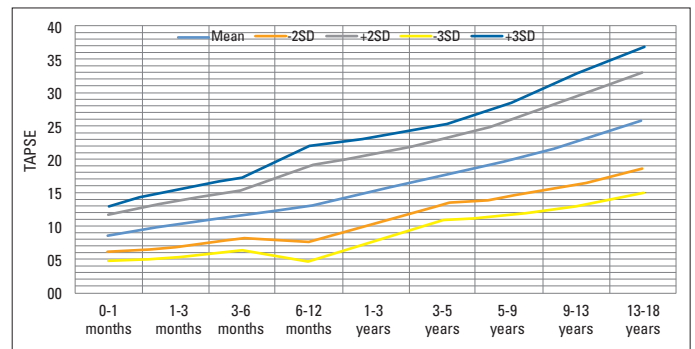


Figure 3. The ±2 and ±3 z-scores for the TAPSE values according to the age groups of the patients

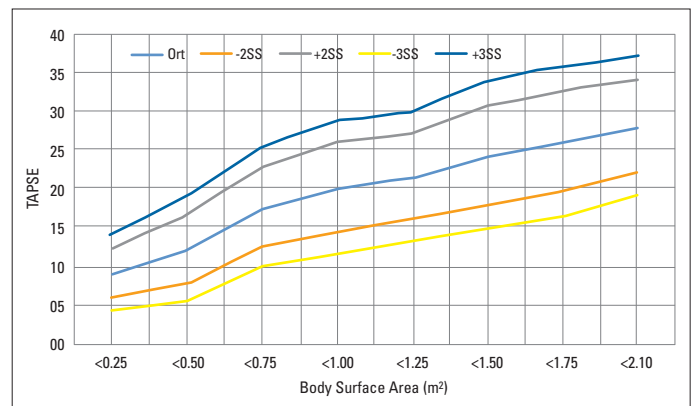


Figure 4. The reference values of TAPSE according to body surface area

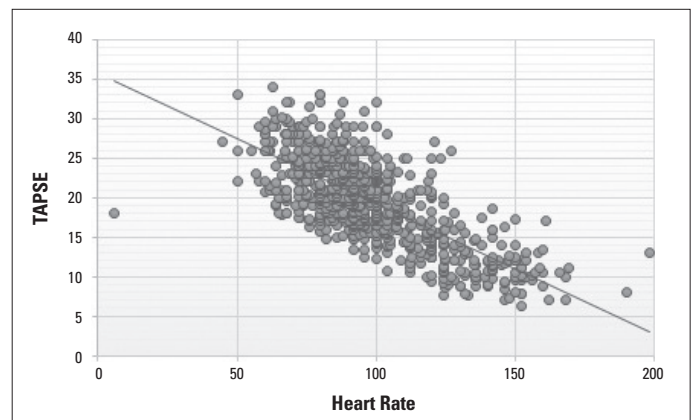


Figure 5. The association between TAPSE and heart rate
Spearman correlation analysis

patients with left ventricular dysfunction, and these patients are associated with a more severe clinical course (16). In patients with advanced congestive heart failure, a right ventricular EF of >35% not only prolongs survival but also significantly improves exercise capacity (17). Many studies have shown the importance of right ventricular function in predicting prognosis and determining the timing for the implantation of a pulmonary valve in patients with congenital cardiac disorders, particularly in patients with operated Tetralogy of Fallot (18-20).

The anatomical nature of the right ventricle limits optimal echocardiographic examination, as the measurement of right

Table 3. The ± 2 and ± 3 z-scores for the TAPSE values according to the age groups of the children

Age	n	TAPSE, mm					TAPSE mean/ BSA mean
		Mean	$\pm 2SD$ (%95)		$\pm 3SD$ (%95)		
0-1 months	22	9.09	6.36	11.82	5.00	13.18	39.53
1-3 months	42	10.49	7.08	13.90	5.37	15.61	39.51
3-6 months	28	11.94	8.27	15.60	6.43	17.44	37.55
6-12 months	44	13.46	7.73	19.19	4.87	22.05	33.24
1-3 years	57	15.71	10.56	20.86	7.98	23.43	29.82
3-5 years	92	18.09	13.34	22.85	10.97	25.22	26.65
5-9 years	189	20.10	14.54	25.65	11.77	28.43	23.06
9-13 years	169	22.96	16.32	29.60	13.00	32.92	18.99
13-18 years	122	25.91	18.71	33.12	15.10	36.73	16.15

BSA - body surface area; TAPSE - tricuspid annular plane systolic excursion. For each age group, the SD of TAPSE was taken to construct ranges of the mean ± 2 SDs and the mean ± 3 SDs. These ranges represented the expectable normal intervals of deviation for certainty levels of 95% and 99%. An index was calculated of mean TAPSE for age divided by mean BSA for each age group.

Table 4. TAPSE z-scores in boys according to body surface

BSA, m ²	Mean	-2SD	+2SD	-3SD	+3SD
<0.25	9.06	5.63	12.49	3.91	14.21
0.26-0.50	12.57	8.06	17.08	5.80	19.34
0.51-0.70	17.80	12.84	22.76	10.35	25.24
0.71-1.00	19.82	14.15	25.49	11.32	28.33
1.01-1.25	21.88	16.00	27.77	13.05	30.71
1.26-1.50	24.54	18.36	30.72	15.26	33.81
1.51-1.70	26.60	20.62	32.58	17.62	35.57
1.71-2.10	27.96	21.81	34.11	18.74	37.19

BSA - body surface area; TAPSE - tricuspid annular plane systolic excursion. For each group, the SD of TAPSE was taken to construct ranges of the mean ± 2 SDs and the mean ± 3 SDs. These ranges represented the expectable normal intervals of deviation for certainty levels of 95% and 99%. Furthermore, the mean TAPSE values were calculated for each groups.

ventricular EF and fractional area change while using conventional 2-dimensional echocardiography is complicated by the complex right ventricular anatomy. The right ventricular Tei index is valuable due to the fact that it evaluates both systolic and diastolic functions; however, measurement of the Tei index is a time-consuming procedure, particularly in younger children. Cardiac MRI, which has been considered the gold standard method for the evaluation of right ventricular function, is an expensive process, resulting in challenges in terms of reproducibility.

TAPSE has been frequently used in recent studies due to its simplicity and ability to be unaffected by a right ventricular preload. Theoretically, right ventricular annular change is related to stroke volume. The right ventricular stroke volume index was found to be <29 mL/min/m² in patients with a TAPSE value below 1.8 cm (21). Studies of the adult population suggested that a TAPSE value of <2 cm indicates a right ventricular ejection fraction of $<40\%$ (22, 23). In contrast, TAPSE value was not found to represent global RV performance in patients with TOF (24).

Studies determining the TAPSE values in children are limited. Children with TOF and atrial septal defects (ASD) were compared

Table 5. TAPSE z-scores in girls according to body surface area

BSA, m ²	TAPSE, mm	-2SD	+2SD	-3SD	+3SD
<0.25	9.45	6.38	12.51	4.84	14.05
0.26-0.50	11.82	7.55	16.09	5.42	18.23
0.51-0.70	17.43	12.21	22.66	9.59	25.27
0.71-1.00	20.69	15.11	26.27	12.32	29.06
1.01-1.25	20.90	16.65	25.15	14.52	27.27
1.26-1.50	24.11	17.56	30.66	14.28	33.94
1.51-1.70	25.03	17.96	32.10	14.43	35.64
1.71-2.10	28.75	23.75	33.75	21.25	36.25

BSA - body surface area; TAPSE - tricuspid annular plane systolic excursion. For each group, the SD of TAPSE was taken to construct ranges of the mean ± 2 SDs and the mean ± 3 SDs. These ranges represented the expectable normal intervals of deviation for certainty levels of 95% and 99%. Furthermore, the mean TAPSE values were calculated for each groups.

with normal children in a study, and it was found that TAPSE remains unchanged in children with ASD, and decreased over the years in the postoperative period in children with TOF (25). Another study found that TAPSE values were higher than normal in patients with ASD, while they were significantly lower in children with primary pulmonary hypertension (26). In a recent study, it was determined that TAPSE correlated with functional capacity, mean right atrial pressure, and survival in children with pulmonary hypertension (27).

Reference TAPSE values are required in order to predict prognosis in children with congenital heart defects before and after surgery and in patients with pulmonary hypertension and left heart disorders. In literature, normal ranges of TAPSE have been determined for children (10, 11, 28). However, there are no established references values for children living in Turkey.

A strong correlation was found between heart rate and TAPSE. The Spearman's correlation coefficient was $r=-0.246$, when controlled for age using the partial correlation method. Based on this result, it can be suggested that heart rate decreases with increasing age and that the inverse correlation

between the TAPSE value and heart rate is in an indirect relationship.

One of the important findings of the present study is that reference TAPSE values determined in another study significantly differ from reference TAPSE values determined in the present study. For instance, in the aforementioned study, -2 z-score for TAPSE in the 13-18-year-old age group was 14.41 mm (10), while the -2 z-score for TAPSE in the same age group was found to be 18.71 mm in the present study. A similar difference is observed when TAPSE percentiles were evaluated according to body surface area. For instance, the lower limit for TAPSE was reported as 14.6 mm in the same study with a body surface area of 1.26-1.50 m², while the lower limit was found to be 17.97 mm in the present study of Turkish children. Based on these findings, it may be suggested that TAPSE values may be affected by racial and environmental factors. Accordingly, these differences must be well-understood, and each country must use its own percentile curves while evaluating TAPSE values.

Study limitations

A potential limitation of our study is that it did not assess the effects of preload variations related to respiration. It is difficult to apply respiratory gating to this method in pediatric clinical practice. The other potential limitation was that we recruited a relatively small number of healthy neonates for this study. Therefore, further studies are required to determine TAPSE percentiles of healthy newborns in Turkey.

Conclusion

The present study showed a strong positive correlation between TAPSE values and age, height, weight and body surface area, while also determining reference TAPSE values in children living in Turkey.

Conflict of interest: None declared.

Peer-review: Externally peer-reviewed.

Authorship contributions: Concept - FU., Ö.M.B., E.Ç.; Design - FU., Ö.M.B., E.Ç.; Supervision - FU., Ö.M.B., E.Ç.; Materials - E.Ç., FU.; Research - E.Ç., Ö.M.B.; Data collection &/or processing - FU.; Literature search - FU.; Writing - FU.; Critical review - Ö.M.B., E.Ç.

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