Tricuspid Annular Plane Systolic Excursion (TAPSE) and Cardiac Z Score Values in 827 Healthy Turkish Children: Single Center Results

Sağlıklı 827 Türk Çocuğunda Triküspid Anüler Düzlem Sistolik Hareketi (TAPSE) ve Kardiyak Z Skoru Değerleri: Tek Merkezin Sonuçları

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ABSTRACT Objective: The evaluation of right ventricular systolic function is an established component of echocardiographic examinations. The aim of the present study is to determine tricuspid annular plane systolic excursion (TAPSE) and cardiac z scores among a large cohort of healthy Turkish children. **Material and Methods:** This prospective study included 827 healthy children, ranging in age from 0 to 17.5 years (mean 6.04±4.98). Right ventricular systolic function was examined by TAPSE during a routine echocardiographic examination. **Results:** The mean TAPSE was 17.44±4.15 mm and the mean indexed TAPSE (TAPSE/m^2) was 25.34±11.01 mm/m^2. The mean TAPSE z- score and the mean TAPSE/m^2 z score were -0.062 and 0.229, respectively, across all age groups. TAPSE, minimum, maximum, standard deviation, TAPSE/m^2 ve percentile values were specified according to age groups and body surface area. **Conclusion:** The TAPSE, TAPSE/m^2 and z-score values reported in the present study represent the first comprehensive set of reference values in the Turkish pediatric population. This study will inform future studies and clinical evaluation of both healthy children and children with congenital heart disease affecting right ventricular systolic function.

Key Words: Child; tricuspid valve; ventricular function, right

ÖZET Amaç: Sağ ventrikül sistolik fonksiyonlarının değerlendirilmesi klinik pratikte ekokardiyografik incelemenin bir parçasıdır. Bu çalışmanın amacı kardiyak açıdan sağlıklı Türk çocuklarında tricuspid annular plane systolic excursion (TAPSE), percentil ve z skorlarını belirlemektir. **Gereç ve Yöntemler:** Bu çalışma prospektif olarak düzenlendi. Yaşları 0-17.5 yıl (ortalama 6,04±4,98) olan, 827 sağlıklı çocuk çalışmaya alındı. Rutin ekokardiyografik inceleme yanı sıra sağ ventrikül sistolik fonksiyonları TAPSE ile değerlendirildi. **Bulgular:** Ortalama TAPSE 17.44 (5,44-30,6, ±4,15) mm, ortalama indexlenmiş TAPSE (TAPSE/m^2) 25.34 (7,37-76,09, ±11,01) mm/m^2 olarak hesaplandı. Katılımcılar yaş gruplarına göre ele alındıklarında TAPSE ve TAPSE/m^2 z skorları ortalaması sırası ile -0,062 ve 0,229 idi. TAPSE, minimum, maksimum ve standart deviasyon, TAPSE/m^2 ve percentil değerleri, yaş gruplarına ve vücut yüzey alanlarına göre belirlenen gruplar için tablolarda gösterildi. **Sonuç:** Bu çalışma ile belirlenen TAPSE, TAPSE/m^2 ve z skoru değerleri Türk çocuklarında sunulan ilk kapsamlı çalışmanın referans değerleridir. Bu çalışma gerek sağlıklı çocuklarda, gerekse sağ ventrikül sistolik fonksiyonlarının etkilendiği konjenital kalp hastalıklı çocukların ele alındığı kontrollü, geniş kapsamlı çalışmalara da ışık tutacaktır.

Anahtar Kelimeler: Çocuk; triküspid kapak; ventriküler fonksiyon, sağ

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Tricuspid annular plane systolic excursion (TAPSE) distance, a measurement which is obtained easily, precisely, and non-invasively using most echocardiographic systems, is an important component of the evaluation of right ventricular systolic function. The American and Euro-

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pean guidelines state that evaluation of right ventricular systolic function must be a part of all echocardiographic examinations.[1,2] TAPSE reference values for both children and adults have been reported previously.[1-6] No comprehensive data on TAPSE percentile and z-scores among healthy Turkish children are currently available. The aim of the present study is to determine the distribution of TAPSE distances and z-scores among a large cohort of healthy Turkish children. This is the first comprehensive study of its kind to be conducted in this population.

MATERIAL AND METHODS

PATIENTS

This prospective study included 827 otherwise healthy children admitted to the Pediatric Cardiology Department of an intermediate-sized private hospital between May 2011 and October 2013 with cardiac murmur, chest pain or fatigue, between the ages of 0 and 17.5 (mean 6.04±4.98) years. The patients with chronic lung disease, diabetes mellitus, hypertension, obesity, structural heart disease, and cardiac rhythm dysfunction were excluded from the study. Patients with cardiac murmur and normal telecardiography and electrocardiography results were referred for echocardiographic examination. The patients complaints such as chest pain and fatigue were assessesed as nonspesific and the cardiac murmur was evaluated as innocent murmur.

ECHOCARDIOGRAPHY

Routine transthoracic echocardiographic examination was conducted using the S4-2 or S8-3 mHz Broadband Sector Array transducers with ©Philips Medical System Nederland BV 2005 according to the segmental analysis method. Heart rate, body weight, height, and sex were recorded during study. All echocardiographic imaging was performed by a single pediatric cardiologist (SP). The study group consisted of patients with normal echocardiography findings and patent foramen ovale shunt ≤3 mm**.** The most recent echocardiography data were utilized in patients who had undergone repeated examinations.

TAPSE was measured by M-mode echocardiography, obtained by placing the cursor on the lateral tricuspid annulus at the level of the right ventricular free wall in the apical 4-chamber view in two-dimensional echocardiography. The patient was positioned on the left side for the examination. Patients were not sedated during the examination.

STATISTICAL ANALYSIS

SPSS 15.0 software was used for all statistical analysis. An Independent sample t-test was used for the comparison of parametric values. Pearson correlation test and linear regression analysis were used to evaluate correlation between variables. Weak, medium, and strong correlation are defined as having a correlation coefficient less than 0.3 (<0.3), between 0.3 and 0.7 (0.3-0.7), and greater than 0.7, respectively. The average differences between independent groups were evaluated using the Independent sample t-test. All values are reported as mean±standard deviation (SD). TAPSE and indexed TAPSE (TAPSE/body surface area: TAPSE/BSA: TAPSE/m^2) values (mm and mm/m^2 respectively); z scores ±2 SD were presented in the tables below.

RESULTS

Three hundred thirty seven of 827 patients were female (40.7%) and 490 (59.3%) patients were male. The basic characteristics of all patients are presented in Table 1. Patients were categorized by body surface area (BSA) into eleven groups and were divided into eight groups according to age.

The mean TAPSE distance was 17.44±4.15 mm (Range: 5.44-30.6) mm, and mean TAPSE/m^2 was 25.34±11.01 mm/m^2 (Range: 7.37-76.09 mm/m^2). When the subjects were evaluated according to gender, these findings were obtained: the mean TAPSE distances were 17.08±3.78 mm and 17.68±4.38 mm, the mean indexed TAPSE were 25.19±10.98 mm/m^2 and 25.15±11.05 mm/m^2 , the mean TAPSE z scores were -0.07±0.96 and -0.07±1.06, the mean indexed TAPSE z scores were 0.21±0.99 and 0.23±1.00, the former ones symbolized females and the latter symbolized males. There was no significant difference between girls and boys.

TABLE 1: Anthropometric features of patients.

	Min	Max	Mean	SD
Age (year)	0,00	17,50	6,04	4,98
Weight (kg)	2,34	108,00	25,91	19,84
Height (cm)	45,00	193,00	11,92	35,96
BSA (m^2)	0,15	2,30	0,86	0,48
HR (/min)	44,00	160,00	97,90	21,66
EF (%)	59,90	88,10	70,83	5,44
FS (%)	28,50	55,00	39,12	4,39
TAPSE (mm)	5,44	30,60	17,44	4,15
TAPSE/BSA (mm/m^2)	7,37	76,09	25,35	11,01

Min: Minimum; Max: Maximum; SD: Standard deviation; BSA: Body surface area; HR: Heart Rate; Min: Minute; EF: Ejection fraction; FS: Fractional Shortening; TAPSE: Tricuspid annular plane systolic excursion.

There was a mid-negative correlation between TAPSE and heart rate (r= -0.64, p= 0.005). The mean, median, and SD of TAPSE and TAPSE/m^2 are presented by age group in Table 2, and are presented according to BSA in Table 3. TAPSE percentile values were reported according to age and BSA category in Tables 4, 5.

The analyses of bivariate correlation and linear regression of TAPSE values according to age and BSA were reported in Figure 1 and 2 (r=0.67 and 0.70, p=0.001 and p=0.01, respectively). There was a strong correlation between indexed TAPSE (TAPSE/m^2) z-score values and both age and BSA. A statistically significant negative correlation between age and indexed TAPSE z-score (r=-0.85, p=0.01) and BSA and indexed TAPSE z-score (r=-0.87, p=0.01) were identified. The distribution of TAPSE and TAPSE/m^2 z score averages according to age groups and BSA was presented in Figures 3, 4.

When the study subjects were evaluated according to age group, the average TAPSE and TAPSE/m^2 z scores were -0.062 (range: -2.95 to 3.11, SD: 1.0) and 0.229 (ranging from -1.40 to 4.84, SD: 1.0), respectively. When the study subjects were evaluated according to BSA the mean TAPSE z score was -0.074 (range: -4.14 to 3.11, SD: 1.02)

DISCUSSION

Echocardiographic evaluation of right ventricular functions has been the subject of many studies. The right ventricle has historically been ignored in clinical practice due to its localization in the thorax as well as its features of contraction. Right ventricular function, evaluated by echocardiography, radionuclide and magnetic resonance imaging in modern clinical practice, have recently included the measurement of TAPSE, a non-invasive, practical, and easily applicable echocardiographic method.[3,4,7-11]

TABLE 2: TAPSE and indexed TAPSE values according to age.

			TAPSE (mm)			TAPSE/m^2 (mm/m^2)		
Age	Group	n	Mean	Median	SD	Mean	Median	SD
0-30 days	1	54	9.06	9.26	1.80	41.34	41.26	8.96
1-3 months	2	37	12.10	12.20	2.21	42.34	42.43	7.08
3-6 months	3	45	13.44	13.60	2.12	39.07	37.95	6.63
6-12 months	4	67	15.41	15.50	2.34	37.71	37.47	6.09
1-2 years	5	58	16.52	16.30	2.22	33.25	32.49	4.41
2-4 years	6	88	17.09	16.90	2.20	27.93	27.13	4.65
4-6 years	7	103	18.11	17.80	2.27	23.91	23.62	3.89
6-8 years	8	95	18.77	18.40	2.45	19.49	19.72	3.16
8-10 years	9	90	19.56	19.15	2.78	17.37	17.17	2.90
10-13 years	10	97	20.30	20.40	2.88	14.82	14.58	2.83
13-17.5 years	11	93	21.52	21.20	3.61	12.70	12.53	2.37

SD: Standard deviation.

TABLE 3: TAPSE and indexed TAPSE values according to body surface area (BSA).

			TAPSE (mm)			TAPSE/m² (mm/m²)		
BSA	**Group**	**n**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
0-0.25 m²	1	57	9.27	9.35	1.90	43.04	42.67	8.36
0.26-0.5 m²	2	178	14.39	14.30	2.62	38.03	37.68	6.09
0.51-0.75 m²	3	164	17.42	17.10	2.30	27.81	27.13	4.58
0.76-1 m²	4	131	18.19	17.80	2.41	20.82	20.75	3.08
1.01-1.25 m²	5	110	19.51	19.35	2.55	17.47	17.42	2.45
1.26-1.5 m²	6	77	20.66	20.40	3.11	15.06	14.93	2.34
1.51-1.75 m²	7	67	21.04	20.80	3.23	12.97	12.96	1.95
1.76-2.3 m²	8	43	21.89	22.20	3.64	11.53	11.15	2.02

SD: Standard deviation.

TABLE 4: TAPSE percentile and indexed TAPSE percentile according to age groups.

Age	**n**	**Percentil**	**P 5**	**P 10**	**P 25**	**P 50**	**P 75**	**P 90**	**P 95**
0-30 days		TAPSE	6.35	6.68	8.16	9.26	9.69	10.70	11.62
	54	TAPSE/m²	27.60	30.78	37.22	41.26	45.33	49.47	54.71
1-3 months		TAPSE	6.97	9.34	10.85	12.20	13.70	14.30	16.01
	37	TAPSE/m²	24.50	35.04	38.94	42.43	46.24	51.09	53.90
3-6 months		TAPSE	9.80	10.38	12.20	13.60	14.60	15.88	17.59
	45	TAPSE/m²	29.21	32.04	34.91	37.95	42.20	49.23	52.31
6-12 months		TAPSE	11.42	12.44	13.60	15.50	16.70	18.40	19.94
	67	TAPSE/m²	28.57	29.35	33.61	37.47	42.26	46.44	47.32
1-2 years		TAPSE	13.28	13.90	15.00	16.30	17.95	19.40	21.53
	58	TAPSE/m²	27.17	28.02	30.10	32.49	35.67	38.80	43.43
2-4 years		TAPSE	13.99	14.33	15.36	16.93	18.48	20.20	21.83
	88	TAPSE/m²	21.36	23.45	24.28	27.13	31.37	34.02	36.46
4-6 years		TAPSE	14.60	15.24	16.70	17.80	19.40	21.10	22.18
	103	TAPSE/m²	18.01	19.36	21.23	23.62	26.30	29.33	31.00
6-8 years		TAPSE	15.26	15.96	17.10	18.40	20.20	21.80	23.62
	95	TAPSE/m²	14.72	15.82	17.34	19.72	21.10	24.01	25.44
8-10 years		TAPSE	15.21	16.30	17.33	19.15	21.47	23.78	24.60
	90	TAPSE/m²	12.53	13.48	15.84	17.17	18.54	21.04	23.11
10-13 years		TAPSE	15.50	16.24	18.10	20.40	22.15	24.24	25.91
	97	TAPSE/m²	9.81	11.23	13.37	14.58	16.30	18.45	20.24
13-17.5 years		TAPSE	15.10	16.26	19.30	21.20	24.10	25.80	28.16
	93	TAPSE/m²	9.22	9.62	10.96	12.53	14.40	15.78	16.94

TAPSE is used to correlate right ventricular contractile function with right ventricular ejection fraction in adult patients. TAPSE values less than 18 mm are highly significant, specific indicators of abnormal right ventricular function.[12] High TAPSE values are indicative of normal right ventricular function in adult subjects. TAPSE values less than 20 mm indicate right ventricular ejection fraction less than 40% in adults.[13,14] Changes in systolic volume and diameter during the cardiac cycle are conventionally used for the evaluation of right ventricular systolic function in children. The measurement of systolic longitudinal right ventricular function is evaluated by the combination of tricuspid annular plane peak systolic velocity (TAPSV) and TAPSE.[15]

TABLE 5: TAPSE percentile and indexed TAPSE percentile according to BSA.

BSA Groups	n	Percentil	P 5	P 10	P 25	P 50	P 75	P 90	P 95
0-0.25 m^2		TAPSE	6.35	6.75	8.22	9.35	9.94	11.50	12.55
	57	TAPSE/m^2	30.49	31.25	38.30	42.67	47.19	54.28	56.59
0.26-0.5 m^2		TAPSE	10.18	11.17	12.50	14.30	16.00	17.71	18.73
	178	TAPSE/m^2	28.70	30.08	33.79	37.68	42.10	46.40	48.77
0.51-0.75 m^2		TAPSE	14.22	14.30	15.65	17.10	18.92	20.50	22.10
	164	TAPSE/m^2	20.94	22.67	24.11	27.13	31.00	33.81	35.99
0.76-1 m^2		TAPSE	15.06	15.50	16.60	17.80	19.80	21.80	22.92
	131	TAPSE/m^2	16.36	16.69	18.50	20.75	22.57	25.32	26.45
1.01-1.25 m^2		TAPSE	15.86	16.70	17.96	19.35	21.00	22.78	23.98
	110	TAPSE/m^2	13.84	14.59	15.93	17.42	18.68	20.78	22.17
1.26-1.50 m^2		TAPSE	15.45	16.64	18.60	20.40	23.00	24.86	26.09
	77	TAPSE/m^2	10.91	11.69	13.38	14.93	17.76	18.33	19.29
1.51-1.75 m^2		TAPSE	15.18	15.78	18.80	20.80	23.10	25.08	26.60
	67	TAPSE/m^2	9.49	9.68	12.04	12.96	14.17	15.53	16.20
1.76-2.30 m^2		TAPSE	14.70	17.24	19.30	22.20	24.60	26.22	27.98
	43	TAPSE/m^2	7.54	9.21	9.95	11.15	12.95	14.30	15.43

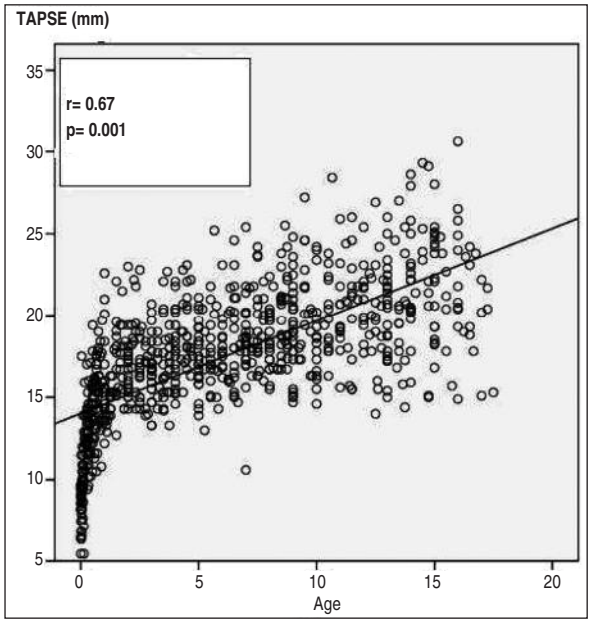

FIGURE 1: Patients TAPSE values distribution by age.

Our study revealed very strong correlation Nunez-Gil et al. and Koestenberger et al. investigated TAPSE values in a large study including both patients and control subjects, including healthy children and children with tetralogy of Fallot and Atrial Septal Defect (ASD), as well as patients with pulmonary hypertension due to congenital heart disease or heart surgery in early childhood.[6,16-19]

Koestenberger et al. studied TAPSE values among 258 premature and mature infants, weighing between 530 g and 4200 g. The mean TAPSE distance was 4.4 mm (z score ±2 SD: 3-5.9) among premature patients, and 10.3 mm (z score ±2 SD: 8.5-12.1) in mature infants.[20] In the present study, the mean TAPSE distance was 9.06 mm (-2 SD: 6.35 mm, + 2 SD: 11.6 mm), and the mean indexed

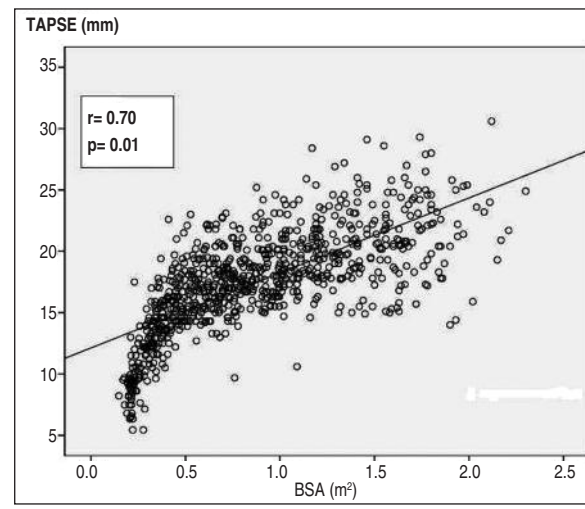

FIGURE 2: Patients TAPSE values distribution by BSA.

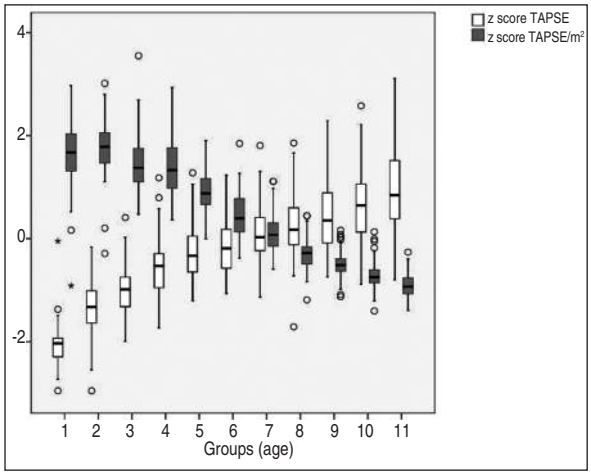

FIGURE 3: TAPSE and TAPSE/m² z score distribution according to age [White boxes (increasing) show TAPSE z score, gray boxes (decreasing) show TAPSE/m² z score].

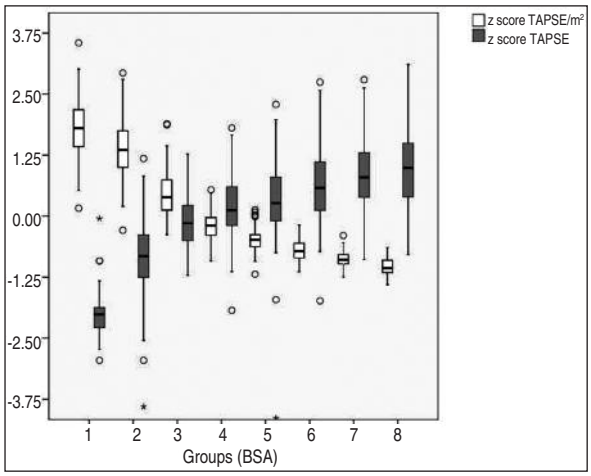

FIGURE 4: TAPSE and TAPSE/m² z score distribution according to body surface area [Gray boxes (increasing) show TAPSE z score, white boxes (decreasing) show TAPSE/m² z score].

TAPSE value was 41.34 mm/m² (-2 SD: 27.6 mm/m², +2 SD: 54.71 mm/m²) in 54 newborns aged 4 weeks or less. TAPSE z scores ranged from -2.95 to -0.05 (mean: -2.08±0.43). Indexed TAPSE z scores ranged from -0.91 to 4.84 (mean: 1.68±0.81). All the patients in the present study were born at a gestational age of 38-40 weeks.

A study by Nunez-Gil et al. of 405 healthy children, including 30 infants aged 4 weeks or less reported a mean TAPSE distance of 10.56 mm (-2 SD: 6.6 mm, +2 SD: 14.52 mm).[6] Koestenberger et al also examined right ventricular function in healthy children, reporting a mean TAPSE distance of 9.1 mm (-2 SD: 6.8 mm, +2 SD: 11.5 mm) in 41 newborn patients.[19] The mean TAPSE value among 8 healthy newborn infants <1 month old) was 9 mm (-2 SD: 7 mm, +2 SD: 11 mm) in another study.[17]

The present study included 93 patients aged 13-17.5 years. In this group, the average TAPSE distance was 21.52±3.61 mm (- 2 SD: 15.1 mm, + 2 SD: 28.10 mm), and the average indexed TAPSE value was 12.7±2.37 mm/m² (-2 SD: 9.22 mm, +2 SD: 16.94 mm). The TAPSE z score ranged from -0.80 to 3.11 (mean TAPSE z score was 0.92±0.87), and the indexed TAPSE z score ranged from -1.39 to -0.26 (mean indexed TAPSE z score was -0.91±0.21) in the adolescent group.

The study by Koestenberger et al included 162 adolescent patients; the mean TAPSE value was 23.5 mm (-2 SD: 19.5 mm, + 2 SD: 27.5 mm) in this group.[19] Nunez-Gil et al. reported a mean TAPSE value of 20.95 mm (-2 SD: 14.41 mm, + 2 SD: 27.44 mm) among 15 patients aged 13-18 years.[6]

In the present report, the indexed TAPSE value for newborns, 41.34±8.96 mm/m² (12.75-76.09 mm/m²) was comparable to the report by Koestenberger et al (41.4 mm/m²), but lower than that reported by Nunez-Gil et al (45.91 mm/m²). In the present study, the indexed TAPSE value was 12.70±2.37 mm/m² (7.46-19.93 mm/m²) in adolescents (13-17.5 years old). Previous studies by Koestenberger et al. and Nunez-Gil et al. reported indexed TAPSE values of 13.70 mm/m² and 13.17 mm/m², respectively, among adolescents.[6,19]

Hashimato et al studied TAPSE in 953 healthy children, ranging from newborn to 22.7 years of age. TAPSE had positive correlation with age and BSA, varying from 6.0-31.4 mm (mean TAPSE 19.1±4.4 mm). Z values changed from -3.63 to 3.17. In males; TAPSE was 19.0±4.6 mm, in females 19.1±4.2 mm.[21] In our study we found that the mean TAPSE distances were 17.08±3.78 mm in girls and 17.68±4.38 mm in boys. The correlation of TAPSE with age and body surface area

(BSA) was r= 0.67, p= 0.01 and r= 0.70, p=0.01, respectively. Nunez-Gil et al reported that the correlation of TAPSE with BSA and age was r= 0.81, p<0.001 and r= 0.798, p<0.001, respectively in their study.[6] Koestenberger et al reported a strong correlation (r= 0.94, p value was unspecified) between age and TAPSE, no significant correlation was found TAPSE and BSA (r= 0.15, p= 0.09) in a control group consisting of 252 healthy children.[17]

The findings of the present study were in agreement with previous publications on the use of TAPSE to study right ventricular function in children. The results of the present study, including TAPSE, indexed TAPSE, and z-score data, will contribute to the future studies.

CONCLUSION

In the present study, Turkish children aged between 0-17.5 years, the mean TAPSE, indexed TAPSE, percentile values and z scores were determined. This study was developed for Turkish children whose specified reference values also comprehensive and in harmony with other studies were carried out. This report will be a guide to other studies hold in the future that identify right ventricular function pre/postoperative children with congenital heart disease.

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