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Body size influences heart rate in children aged 6 to 18 years old

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Abstract

Previous research established age-related normal limits for children's heart rates (HRs). However, children of the same age can have significantly different HRs, depending on whether they are overweight or underweight, tall or short. Studies on children HR have failed to find a clear correlation between HR and body size. The goal of our study was to create *Z* scores for HR based on weight (W), height (H), body mass index (BMI), and body surface area (BSA) and compare them to normal age-related HR limits. Electrocardiograms were recorded from a total of 22,460 healthy children ranging in age from 6 to 18 years old using BTL machines. A comparison was made between different age groups, in function of W, H, BMI, and BSA, based on the HR that was automatically detected by using the digitally stored electrocardiogram. *Z* scores were computed for each of the categories that were mentioned. Incremental *Z* score values between –2.5 and 2.5 were calculated to establish upper and lower limits of HR. The BSA's estimation of HR is the most accurate of the available methods and can be utilized with accuracy in clinical practice. *Z* scores for HR in children differ in function of the age, W, H, BMI and BSA. The best estimation is based on BSA. The novelty of our study is that we developed *Z* scores for HR in relation to body size, age and sex, producing a standardized, consistent, and reproducible result without requiring practitioners to learn and remember cutoff values for a wide range of variables across age groups and sexes. *Z* scores minimize observer and institutional bias, hence generating uniform and reproducible standards.

Abbreviations: BMI = body mass index, BSA = body surface area, ECG = electrocardiogram, H = height, HR = heart rate, W = weight.

Keywords: body size, ECG, heart rate (HR), height (H), nomograms, screening, weight (W), *Z* scores

1. Introduction

Heart rate (HR) studies on children have failed to establish a link between HR and body size. Despite their significance, several studies on HR appear to have knowledge gaps that must be filled by additional research. Some studies, for instance, only covered a small number of age groups, had small sample sizes for pediatric subjects, or did not investigate reference values in children at all. In the study of Paech et al, the HRs of obese children were not elevated and remained within normal age and gender ranges. Akyüz et al[1] compared 67 obese with 70 lean children and found no association between HR and

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Informed consent was obtained from the parents of the subjects involved in the study.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the University of Medicine and Pharmacy Cluj-Napoca.

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weight (W) or body mass index (BMI). Furthermore, Evans et al found no significant relationship between body size (BMI, W, height [H] and body surface area [BSA]) and HR in 34 patients.

However, in animals, the link is well recognized, the HR of mice being lower than that of rabbits, which is lower than that of elephants.[2] Most likely, the lack of a significant correlation in children is attributable to the narrow range in BSA or BMI values compared to that of small and big animals. When there is little variance, the association with another variable is also weaker, as evidenced by a lower correlation index. To reduce bias, therefore we propose a large-scale research.

As a child develops from infancy to adolescence, his or her HR fluctuates based on a number of factors. Consequently, standard values for the HRs of children based on their age, H, and W are crucial. For these reasons, *Z* scores were developed in children. In adults, however, a single "normal range" of 60 to 100 beats per minute is commonly used in primary care settings.[3,4] Nevertheless, we urge that such conventional normal range HRs be replaced with age-, gender-, H-, and W-specific values in children depending on their body size. In this regard, we consider that tables and graphs of *Z* scores may be useful for pediatricians evaluating the HR of children.

2. Materials and methods

A retrospective analysis of 22,460 electrocardiograms (ECGs) taken from children aged 6 to 18 years old in 12 primary schools located in northwestern Transylvania was carried out. The Iuliu Hatieganu University of Medicine and Pharmacy in Cluj-Napoca has a dedicated Ethics Committee that has given their blessing to the project. The outpatient clinic is where the ECGs were taken. Screening of the pediatric population was one of the indications that ECGs should be obtained. Every child received a flyer with important information, and it was up to the parents to determine whether their child could take part in the research. The flyer made it clear that this was an epidemiological study, and that the researchers were looking for children who were free of any acute or chronic illness and were not taking any medications. During the medical examination, it was determined that each child was in good health with no noteworthy findings.

The ECG was recorded using a BTL-08 MT Plus (BTL Industries Limited UK) with a standard 12-lead tracing at 25 mm/s speed, 10 mm/mV amplitude, and a sampling rate of 2000 Hz. The ECG was obtained between March 2015 and November 2015 with the patient at rest in the supine position. ECGs were discarded if they were missing important information or had poor signal quality. Only the first ECG from each patient's set that was included in the dataset was used for the analysis, even if that patient had >1 recorded ECG. HR was measured based on 6 seconds ECG recordings.

Age, gender, H, W, BMI, and BSA were retroactively collected from the participants who were enrolled. The sole aspect of the electrocardiographic recordings that was taken into consideration was the HR. We did not consider patients who had known structural heart disease or who had undergone cardiac surgery in the past. A total of 22,460 people were included in the final cohort. Based on their medical histories and current physical conditions, children were assessed to have healthy cardiovascular systems.

2.1. Statistical analysis

The Shapiro–Wilk test was used to investigate whether all of the values followed a normal distribution. If the variables had a normal distribution, the results were reported as mean and standard deviation, and if they did not have a normal distribution, the results were presented as median + interquartile range. Categorical variables were reported as frequencies and percentages. To evaluate the degree of relationship between normally distributed and non-normally distributed variables, the Pearson or Spearman correlation were utilized. In all the analyses, the SPSS statistics program version 25 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp) was utilized, and *P* values with a threshold of <0.005 were regarded to be statistically significant.

3. Results

Of the 22,640 children included in the study, 11,287 (47.3%) were men, with a median age 12 years [mean 6–maximum 18 years]. There were 12,275 children aged <12 years old and 11,606 (48.6%) aged >12 years old. Mean W was 49.1+/–16.8 kg (16–135 kg), mean H 154.9+/–15.7 cm (107–207 cm) mean BMI was 20+/–4.0 kg/m^2 (14–50) and mean BSA = 1.4+/–0.3 (0.72–2.64 and HR 84+/–14.5 [32–150]). Compared to females, males had slightly increased, however statistically significant H, W and BSA (*P* an.005). Of all males, 50% were normal W, 38.7% underweight and 11.4% obese children. Of all females, 50.2% were normal W, 39.5% underweight and 10.3% obese children.

In underweight children, mean HR was 85.7 bpm, higher than in normal-weight children 84.1 bpm (*P* (m.0035) and obese children 83.9 bpm (*P* (m.0001). Furthermore, there was a significant difference in HR between normal W males: 84.8+/–14.5 bpm compared to obese males: 83.8+/–14.5 bpm (*P* (m.035) and normal-weight females: 85.5 +/–14.4 compared to obese females: 84.4+/–14.4 (*P* 4..016). However, the difference in HR is so small (1 bpm) that has no clinical relevance.

We computed therefore *Z* scores (Tables 1–5) for different age groups, W, H, BMI and BSA using the following percentiles: 50% (*Z* score 0), 15.9% (*Z* score –1), 2.3% (*Z* score –2), 0.13% (*Z* score –3), 0.003% (*Z* score –4) 84.1% (*Z* score +c1), 97.7% (*Z* score +c2), 99.87% (*Z* score +c3), and 99.997% (*Z* score +c4). Normal values are between –2 and +a2 *Z* score. Figures 1–10 demonstrate with a graphical representation the –4, –3, –2, –1, 0, +1, +2, and +n3 *Z* scores in function of age (Figs. 1 and 2), W (Figs. 3 and 4), H (Figs. 5 and 6), BMI (Figs. 7 and 8), and BSA (Figs. 9 and 10).

We found a significant correlation between HR and body size both in male HR and W *R* gh0.11, *P* .1.0001; HR and H *R* ei0.125; *P* .1.0001; HR and BMI *R* 000.06; *P* .0.0001 and HR and BSA *R* 000.12; *P* .1.0001) and also female children (HR and W *R* ei0.09, *P* .0.0001; HR and H *R* ei0.11; *P* .1.0001; HR and BMI *R* 000.04; *P* .0.0001 and HR and BSA *R* 000.125; *P* .1.0001). The best correlation coefficient was found between HR and BSA.

4. Discussion

Despite their significance, several research that attempted to establish a correlation between HR, age, and body size appear to have information gaps that require more investigation. In the study of Paech et al, the HRs of obese children were found within normal ranges: 101 bpm in obese children versus 81.7 bpm (*P* (m.29) in normal-weight, 78.7 bpm versus 76.3 bpm (*P* (m.46), and 70.3 bpm versus 73.5 bpm (*P* (m.43), for 6, 7 and 8 years old, respectively. Akyüz et al[1] compared 67 overweight (BMI 25–29.9 kg/m^2) children to 70 lean children and found no difference in HR with no correlation between HR and W or HR and BMI. Furthermore, Evans et al[5] found no significant relationship between body size and HR in 34 patients (19 males and 15 females) with no significant correlation between HR and BMI, W, H or BSA. However, these studies had relatively small sample sizes, which lacked the statistical power to detect a small effect, such as the association between HR and body size, and may have resulted in a type II error.

Table 1

***Z* scores −4 to +3 for males and females based on age: 6 to 18 years old.**

Age	Sex	−4	−3	−2	−1	0	1	2	3
6	M	65	65	65	69	80	90	121	148
	F	55	55	55	70	90	101	119	144
7	M	40	40	60	74	87	100	115	142
	F	50	50	60	74	86	100	119	140
8	M	46	46	60	74	87	100	118	147
	F	50	50	60	74	88	100	117	139
9	M	55	55	60	72	86	100	120	144
	F	53	53	61	73	86	100	120	143
10	M	50	50	60	71	85	100	118	146
	F	50	51	60	72	86	100	120	145
11	M	50	50	60	70	86	100	117	130
	F	44	46	60	72	86	100	119	139
12	M	49	49	60	73	84	99	120	134
	F	51	51	60	71	86	100	118	144
13	M	50	50	60	70	84	100	116	138
	F	49	49	60	72	85	100	120	141
14	M	44	45	59	70	82	98	117	130
	F	46	48	60	70	83	99	118	140
15	M	45	45	56	68	82	98	115	131
	F	32	41	58	70	84	98	116	135
16	M	47	47	55	67	80	97	114	135
	F	46	47	56	68	81	97	115	143
17	M	49	49	54	67	80	97	116	138
	F	45	45	57	69	80	97	111	135
18	M	45	45	52	68	80	97	114	132
	F	49	49	58	69	82	99	114	134

F = female, M = male.

Table 2

***Z* scores −4 to +3 for males and females, based on weight.**

Weight	Sex	−4	−3	−2	−1	0	1	2	3
16–25	M	40	40	60	73	87	100	120	140
	F	50	50	60	74	87	100	120	142
26–35	M	46	50	60	72	86	100	119	140
	F	50	51	60	73	86	100	118	140
36–45	M	50	50	60	71	84	100	118	132
	F	46	50	60	72	86	100	118	140
46–55	M	46	49	58	70	84	99	117	131
	F	45	47	60	70	84	99	117	139
56–65	M	46	48	56	68	82	98	116	131
	F	32	47	58	70	83	99	119	143
66–75	M	44	44	55	67	81	97	115	139
	F	48	48	56	70	83	98	116	143
76–85	M	45	45	57	68	82.5	99	116	143
	F	48	48	56	70	83	98	116	143
86–95	M	50	50	58	68	80	95	111	138
	F	49	49	59	70	83	98	120	137
96–105	M	50	50	55	70	82	100	123	136
	F	54	54	55	70	83	98	116	142
106–115	M	59	59	59	66	77	95	116	141
	F	54	54	54	61	72.5	96	119	140
116–125	M	60	60	60	67	77	100	115	139
	F	65	65	65	65	92	94	116	142
126–135	M	62	62	62	62	67	94	118	140
	F	62	62	62	62	79	93	115	140

F = female, M = male.

Nonetheless, when a larger sample size of 22,460 children was used, as in our study, the correlation between body size and HR becomes evident and statistically significant, despite the weak correlation score (R e0.2). The optimal sample size is always one that is "representative" of the population from which it is obtained. It must be large enough to include all potential features of interest and their variations within the population while limiting the research's resource requirements.

Other studies were carried out on larger populations, nevertheless, the findings are still conflicting. In the study conducted by Sarganas et al[6] on 11,986 children aged 3 to 17 years, H was inversely associated with HR only in the group of children aged 3 to 10 years, but not in the group of children aged 11 to 17 years. In addition, BMI was exclusively related with HR in females, but not in males. The HR was higher in underweight (83.1 bpm) and obese (82.7 bpm) children compared to those of

Table 3

***Z* scores –4 to +3 for males and females, based on height.**

Height	Sex	–4	–3	–2	–1	0	1	2	3	4
100–110	M	50	50	62	74	86	100	120	144	146
	F	60	60	60	60	92.5	102	118	145	146
111–120	M	57	59	62	72	89	104	116	146	148
	F	58	58	60	74	88	105	129	149	151
121–130	M	40	43	60	73	87	100	115	142	147
	F	50	50	60	74	87	100	115	141	146
131–140	M	46	48	60	73	86	100	118	148	150
	F	50	50	60	74	86	100	120	144	146
141–150	M	50	51	60	72	85	100	118	140	142
	F	46	50	60	72	86	100	120	134	142
151–160	M	46	49	60	71	85	100	117	132	133
	F	45	47	59	70	84	100	118	141	148
161–170	M	46	48	56	70	83	99	120	136	138
	F	32	50	60	70	84	99	117	143	146
171–180	M	45	47	55	68	81	97	114	129	136
	F	49.4	58	69	81	97	114	132	144	153
181–190	M	44	45	55	67	80	97	114	128	135
	F	49	49	55	67	80	98	122	134	145
191–200	M	55	56	57	69	80	92	112	126	132
	F	60	60	60	67	88	93	113	127	133

F = female, M = male.

Table 4

***Z* scores –4 to +3 for males and females, based on body mass index.**

BMI	Sex	–4	–3	–2	–1	0	1	2	3
14–15.9	M	52	53	60	72	86	100	120	136
	F	50	52	60	72	86	100	120	140
16–18.49	M	46	49	60	70	84	100	118	134
	F	46	50	60	72	85	100	118	140
18.5–19.9	M	45	46	59	70	84	100	117	134
	F	42	47	59	70	84	100	118	144
20–21.9	M	44	49	57	70	84	98	114	137
	F	32	45	60	70	84	100	116	138
22–23.9	M	45	46	58	70	82	99	114	130
	F	49	50	58	70	84	120	143	146
24–25.9	M	49	49	57	70	84	100	118	133
	F	49	49	57	70	84	98	119	134
26–27.9	M	49	49	57	69	84	100	118	134
	F	50	50	59	70	83	97	117	132
28–29.9	M	54	54	60	70	83	99	120	136
	F	48	48	59	70	84	98	125	141
30–31.9	M	50	50	59	70	80	93	120	136
	F	50	50	58	70	84	100	125	142
32–33.9	M	54	54	57	66	82	98	115	128
	F	54	54	54	70	86	100	115	126
34–34.9	M	65	65	65	77	95	106	117	130
	F	60	60	60	66	80	100	115	131
35–35.9	M	53	53	53	68	78	90	114	130
	F	60	60	60	70	82	99	116	133
36–37.9	M	59	59	59	65	82	93	118	136
	F	54	54	54	65	81	100	122	141
38–39.9	M	60	60	60	62	74	103	124	142
	F	70	70	70	70	84	97	117	133
>40	M	80	80	80	80	87	99	116	134
	F	62	62	62	65	89	111	116	138

BMI = body mass index, F = female, M = male.

normal W (81.6 bpm). However, although the difference is statistically significant, it has no clinical relevance, as the variation across categories is minimal 1 bpm. In our study, the correlation between HR and age is consistent for all ages between 6 and 18 years old, and BMI was associated to HR both in females and males. Our findings are different to those of Sarganas et al, the HR was higher in underweight compared to normal-weight and obese children.

In the study of Cavarretta et al[7] on 2151 healthy adolescents soccer players, mean age 12.4 years, H and W were assessed based on age groups 7 to 8, 9 to 10, and 17 to 18. Compared to our study, the mean W was 49.8 +/–14.8 kg. Mean H was 156.9+/–15.9 cm. Both W and H increased with age, as expected. However, HR decreased with age, from 80.8 in group 7 to 8 years old to 59.5 in group 17 to 18 years old. In our study the decrease was less pronounced probably

Table 5

***Z* scores −4 to +3 for males and females, based on body surface area.**

BSA	Sex	−4	−3	−2	−1	0	1	2	3
0.8–1.19	M	40	50	60	73	86	100	119	147
	F	50	50	60	73	86	100	119	140
1.2–1.59	M	46	50	60	70	84	100	117	130
	F	42	48	60	70	84	100	117	138
1.6–1.99	M	44	47	56	68	81	98	115	135
	F	32	49	58	70	83	98	118	143
2.0–2.39	M	50	50	58	69	82	97	113	141
	F	54	54	55	68	81	97	113	140
2.4–2.79	M	62	62	62	67	77	77	89	126
	F	65	65	65	66	78	85	102	128

BSA = body surface area, F = female, M = male.

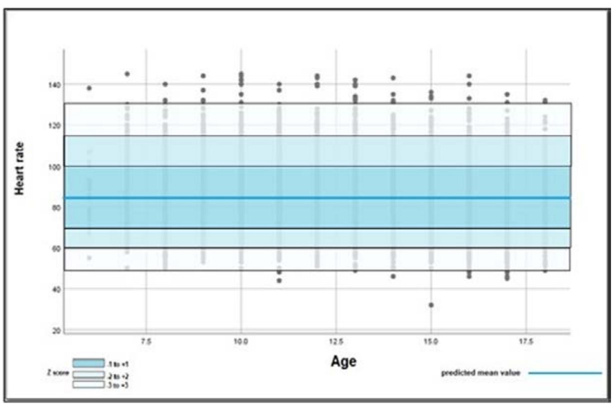

Figure 1. Distribution of heart rate in male children aged 6 to 18 years based on age.

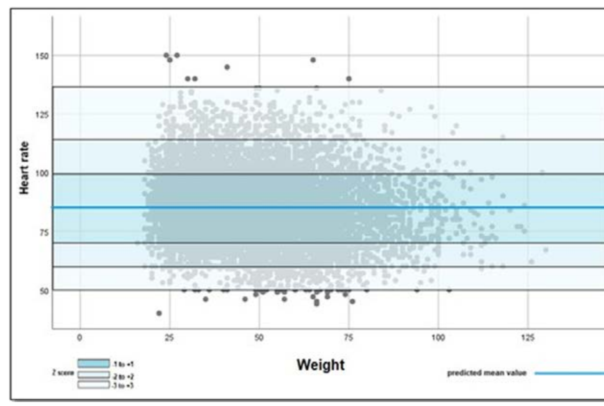

Figure 3. Distribution of heart rate in male children aged 6 to 18 years based on weight.

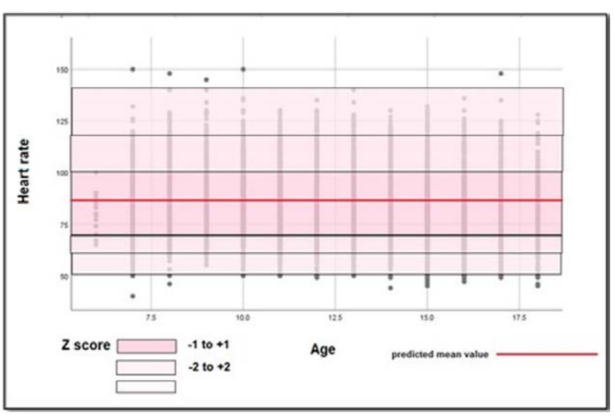

Figure 2. Distribution of heart rate in female children aged 6 to 18 years based on age.

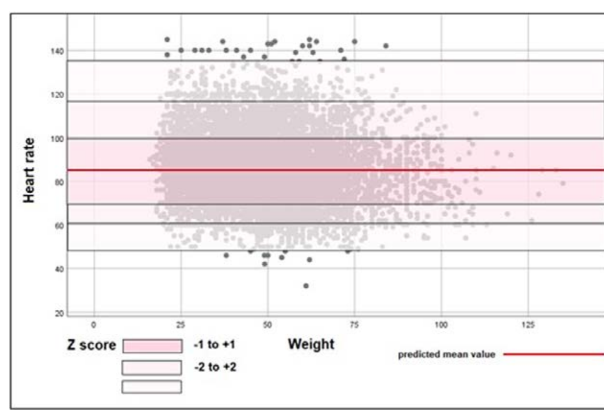

Figure 4. Distribution of heart rate in female children aged 6 to 18 years based on weight.

due to the fact that in the study of Cavarretta the patiens were highly selected, all being soccer players with 7.2 hours/week of training. The authors also provided HR charts with percentiles (0.13, 2.3, 15.9, 50, 84.1, 97.7, and 99.87) for different ages. Upadhyay et al[8] investigated 50 males aged 14 to 17 years old, 39 of them were non-obese (BMI 25 kg/ms) and 11 (22%), who were obese (BMI > 25kg/mp). Obese individuals had faster HRs than non-obese (82.27 bpm vs 75.87 bpm), and HR was significantly correlated with BMI (*R* wa0.55). Despite having a much larger number of patients in our study, there was a significant difference in HR between normal W males: 84.8+/−14.5 bpm compared to obese males: 83.8+/−14.5 bpm (*P* (m.035) and normal-weight females: 85.5 +/−14.4 compared to obese females: 84.4+/−14.4 (*P* 4..016). However, the change in HR is insignificant and has no clinical relevance. A linear link between HR and W may also be depicted: in the research of Upadhyay et al described by the formula y et0.4574x .462.307 as compared to our large cohort of children. y 2.2.5X .50. Kurane I.A et al[9] studied 2000 children with ages between 7 and 11 years old and found the incidence of 15.5% for overweight and 8.1% for obesity. Overweight was defined as a BMI of 85 to 95 centile and obesity as a BMI of > 95th percentile for children aged 7 to 11 years old. The HR was significantly lower in normal W 97.4 bpm compared to overweight 100.5 bpm and obese patients 106.7 bpm.

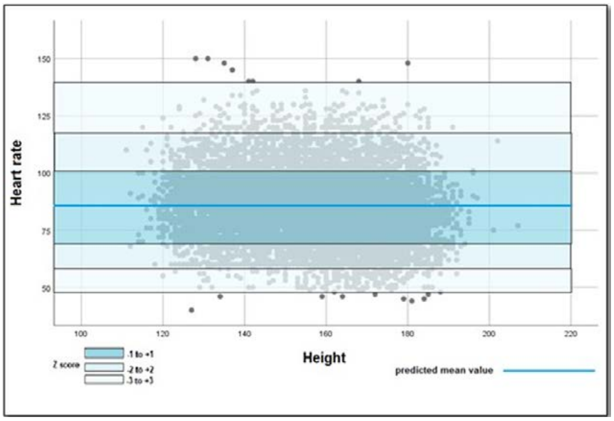

Figure 5. Distribution of heart rate in male children aged 6 to 18 years based on height.

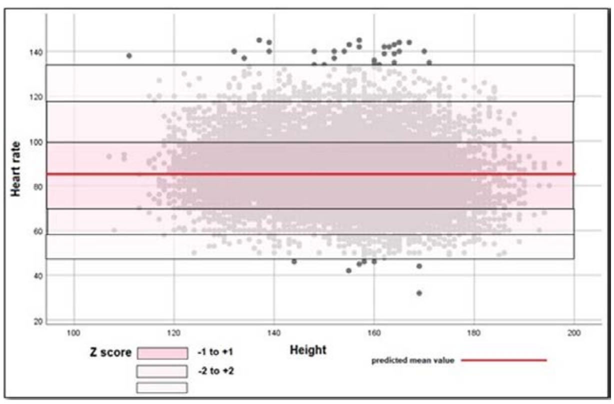

Figure 6. Distribution of heart rate in female children aged 6 to 18 years based on height.

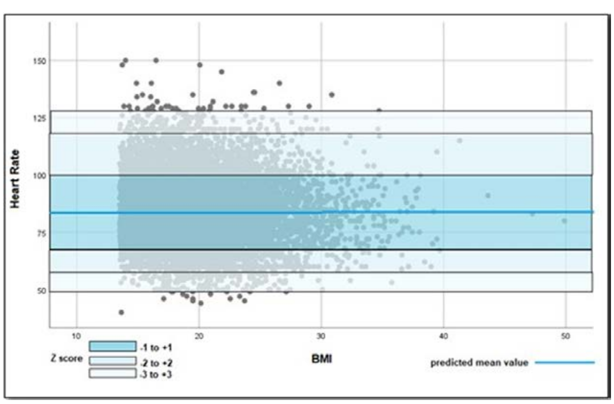

Figure 7. Distribution of heart rate in male children aged 6 to 18 years based on body mass index.

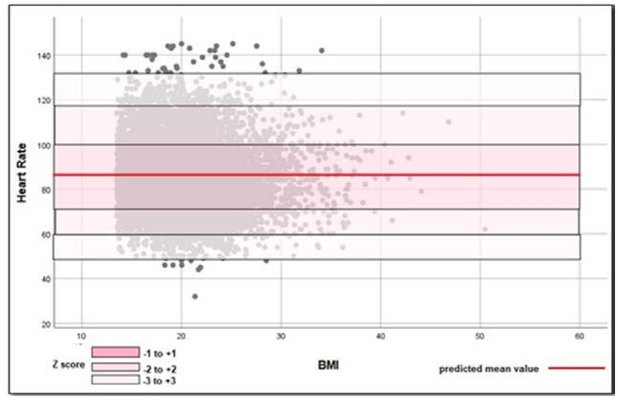

Figure 8. Distribution of heart rate in female children aged 6 to 18 years based on body mass index.

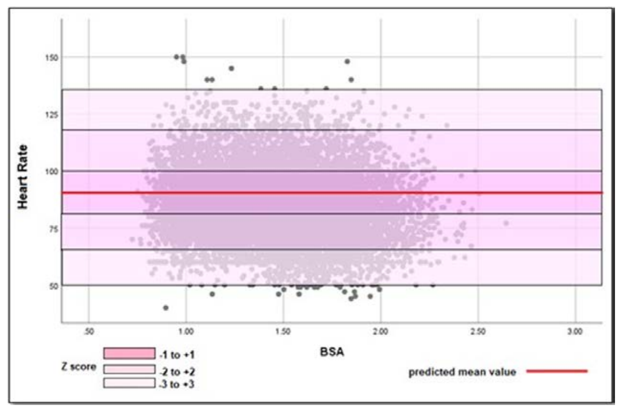

Figure 9. Distribution of heart rate in female children aged 6 to 18 years based on body surface area.

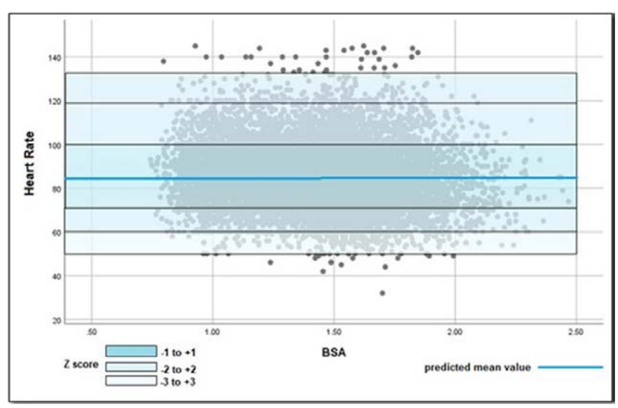

Figure 10. Distribution of heart rate in male children aged 6 to 18 years based on body surface area.

Infeld et al[10] reported a H-HR relationship on 4795 individuals using linear regression and obtained the linear formula: HR re−0.22 × H ig114 demonstrating a 0.22 bpm reduction in the HR for every 1 centimeter increase in H. In univariate analysis only BMI was a positive predictor of HR whereas W was not a predictor. We also found in our study a significant correlation between H and high rate: *R* an0.125; *P* .1.0001 with a linear formula: HR 00−0.11 × H ig101 showing a 0.11 bpm reduction in HR for every 1 cm increase in H.

In the study of Peters et al[11] on 22,843 children from Great Britain aged 9 to 11 years old, HR was positively associated to BMI and inversely associated to H. HR increases by 0.24 bpm for boys and 0.16 bpm for girls for each kg/m^2 increase in BMI and decrease by 10 bpm for boys and 0.09 bpm for girls for each cm increase in H, according to results obtained by calculating the correlation coefficient with a 95% confidence interval. However, the authors found no significant association between HR and BMI for values $<18\,kg/m^2$ but significant association between HR and BMI for values $>18\,kg/m^2$.

Santini et al[12] studied a large cohort of 24,062 students in high school, documenting the anthropometric parameters, baseline ECG findings, and principal clinical findings according to age groups divided by 2 years. The average HR decreased with age, ranging from 84 bpm at 12 to 13 years to 74 bpm at 18 to 19 years. In our study, the HR also decreased with age, the 50 percentile or matching *Z* score decreasing from 88 bpm at age 6 to 80 bpm at age 18. Another study on large population was that of O'Leary et al[9] who measured HR in 1,11,696 children presenting to the Emergency Department, including ages similar to ours: 9100 children aged 6 to 8 years old, 12,672 aged 8 to 12 years old, 6054 aged 12 to 15 years old, and 1339 aged 15 to 16 years old. On comparing our data with the work of O'Leary et al we found lower values for the resting HR quantified by the 50th percentile. One possible explanation could be the anxiety associated to the visit to Emergency Department in the study of O'Leary et al. Adhikar et al[13] studied 371 children aged 1 to 12 years old from Bangladesh (243 males and 128 females) and found significant correlation between age and HR both in male and female individuals: *r* bo–0.9 for age versus HR in all the study population; *r* in–0.89 for boys and *r* .8–0.89 for girls. A significant correlation between HR and W or H is also stated in their study, *R* is0.90 for HR versus W, and *R* a0.84 for HR versus H in males and *R* H0.88 for HR versus W and *R* W0.81 for HR versus H in females. The difference between the 2 studies is that we used a much larger population of children, approximately 24,000, and the HR was calculated from the ECG rather than the compared study's technique of palpating the carotid pulse for 1 minute. Furthermore, the children in their own study range in age from 1 to 12 years, whereas the patients in our study range in age from 6 to 18 years.

We favored *Z* scores because they are a consistent method for determining how much an anatomic or physical measurement deviates from the mean of a size- or age-specific population. Using a method based on *Z* scores minimizes observer and institutional bias, hence generating uniform and reproducible standards. The *Z* scores may be traced back to a French mathematician named Abraham de Moivre, who defined the bell-shaped distribution.[14] He came to check the probability of multiple coin flips and described a normal distribution mathematical equation. Lambert Quetelet, a Belgian physicist, later discovered a relationship between W and H distribution and the normal curve defined by de Moivre.[15] Edward Altman, a professor at New York University, invented and launched the *Z* scores to anticipate firm insolvency in the late 1960s. Altman improved his *Z* score over time, eventually reaching an accuracy of between 82 and 94 percent. In 2012 the Altman *Z* score Plus was released, as an improved version of the *Z* score.[16] Using a standard *Z* score approach will provide a uniform foundation across investigators and institutions to establish disease-specific guidelines, automated interpretation programs, a reduction in unnecessary referrals and sports restrictions from screening efforts. *Z* scores ranging from –2 to 2 correspond to the 2.3rd and 97.7th percentiles and aid in the interpretation of data by defining a reliable limit of generally acknowledged normal and abnormal values. A *Z* score result outside the range of –2 to 2 does not imply the presence of a particular illness or disease; rather, it merely gives a reproducible standard cutoff number showing that a variable is outside the norm, not present in 95.4% of the investigated population. A *Z* score <–2 or >2 does not indicate the presence of a specific disease. It does, however, provide the field as well as the instruments to evaluate the accuracy of these parameters in predicting underlying cardiac problems.[17]

Bratincsák et al[18] developed normative standards for a group of 27,085 individuals divided in 16 distinct age groups. BSA increased with age, as expected, and *Z* scores were calculated for different age categories including 6 to 7 years, 8 to 9 years, and 16 to 17 years. The corresponding –2 *Z* scores ranged from 33 to 49 bpm and +2 *Z* score ranged from 106 to 128 bpm. In our study –2 *Z* scores ranged from 55 to 65 and +2 *Z* score from 89 to 119 bpm. Furthermore, Bratincsak et al promoted charts with –2.5 to +2.5 *Z* scores of HR based on BSA and also charts for predicted HR based on the age from 6 to 7 years and 16 to 17 years old children.

When compared with the systematic review of Fleming[19] our data show a good agreement for 50th centile and corresponding *Z* score for children aged 6 to 16 years old. We also compared our data to that of Bonafide et al[20] who studied 14,014 children from general medical and surgical wards from 2 tertiary children hospitals. The 50th centile was higher in the study of Bonafide, probably related to the diseases of the children hospitalized. The 50th centile and *Z* score remain robust and valid measurements for HR in outpatient clinic or hospital settings.

Comparing HR based on cutoff values obtained from large datasets is a viable option, although not the most accurate in terms of result precision. As a result of the growing process, the *Z* score is especially sensitive to small variations in several factors such as W, H, BMI, and BSA, which are constantly evolving. To compare the HRs of children of different ages, we must also "standardize" them by placing them on the same scale. The *Z* score becomes essential at this stage.

4.1. Limitations

Our cohort consists entirely of children aged 6 to 18 years old. Probably, a considerably stronger association would exist between BMI or BSA and HR for younger ages, which cannot be inferred from our findings. HR was manually measured from the children's ECGs displayed on a computer screen, with the enlarged image, rather than directly on paper, and there may be discrepancies between the interpretations of the 2 methods. Although there is a statistically significant difference between the HRs of normal W and obese males (84.8+/–14.5 bpm vs 83.8+/–14.5 bpm, *P* m.035), in practice, 85 bpm is not clinically different from 84 bpm when measured by palpation near the bed of a child.

5. Conclusions

On a large cohort of children, we provided *Z* scores for HR based on body size, sex and age. When compared to the most recent contribution, our dataset competes because of its larger sample size and because we transformed HR, W, H, BMI, and BSA values into *Z* scores, producing a standardized, consistent, and reproducible result without requiring practitioners to learn and remember cutoff values for a wide range of variables across age groups and sexes. Using a method based on *Z* scores minimizes observer and institutional bias, hence generating uniform and reproducible standards.

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