Age related reference ranges of heart rate for Saudi children and adolescents

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ABSTRACT

الأهداف: وضع معايير لمعدل ضربات القلب حسب العمر للأطفال والمراهقين السعوديين الأصحاء.

الطريقة: استعملت طريقة عشوائية متعددة المراحل للحصول على عينة من أطفال ومراهقين سعوديون من الولادة وحتى 20 عام لوضع معايير لمعدل ضربات القلب للأطفال والمراهقين السعوديون. تمثل العينة المختاره أطفال السعودية من جميع المناطق. تم جمع المعلومات وإجراء البحث الميداني على جميع مناطق المملكة الثلاثة عشر. ضم البحث 10,458 طفل سعودي، وتم قياس معدل ضربات القلب باستخدام أجهزة إلكترونية اتوماتيكية، وحساب القراءات العالية والمنخفضة لمعدل ضربات القلب للأولاد والبنات حسب الطرق الإحصائية الحديثة مثل SD 2 ±. أجري البحث الميداني على مدى سنتين مابين الفترة 2004 وحتى 2005. تم تحليل البيانات و دراستها في كلية الطب – جامعة الملك سعود – الرياض – المملكة العربية السعودية.

النتائج: تم تحديد معايير لمعدل ضربات القلب من عينة تمثل الأطفال والمراهقين السعوديين الأصحاء من الولادة حتى 20عام.

خاتمة: تعطي هذه الدراسة الحالية معدل ضربات القلب للأطفال والمراهقين السعوديين حسب العمر مستعينة بعينة ضخمة. إن استخدام هذه المعايير تساعد على معرفة الأطفال الذين يعانون من معدل ضربات قلب غير طبيعي.

Objectives: To evaluate the resting heart rate to define reference values for healthy Saudi children and adolescents.

Methods: To establish representative heart rate (HR) reference values for Saudi Arabian children and adolescents, a sample of children, and adolescents was selected by multi-stage probability sampling of the Saudi population from birth to 20 years of age. The selected sample represents Saudi children from the whole country. Data were collected by a house-to-house survey of all selected households in all the 13 regions in the country. A total of 10,458 Saudi children were included in the study. The HR was measured by oscillometric-automated devices. Upper and lower reference values of the HR in boys and girls were calculated as mean ± 2 SD. The study is cross-sectional, community based, and conducted over 2 years (2004-2005). Data management and analysis were performed in the College of Medicine, King Saud University, Riyadh, Kingdom of Saudi Arabia.

Results: Determination of the HR values in a sample representing healthy Saudi children and adolescents from birth to 20 years of age.

Conclusion: The present study provides age-specific reference values for heart rate (HR) of Saudi children and adolescents based on a large study sample. The use of these standards should aid the identification of children with abnormal HR.

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The importance of heart rate (HR) measurement during pediatric examination is not obvious for many physicians although it is useful not only for assessment of the severity of acute illness in children, such as infectious diseases, which are usually associated with tachycardia, but also slow HR aids in

the identification of children with subclinical chronic illnesses, such as malnutrition, hypothyroidism, and congenital heart block.[1-4] The HR correlates with blood pressure (BP) and can predict the development of hypertension in adolescence with normal BP values.[5] Fast HR has been associated with increased risk of cardiovascular and non-cardiovascular deaths.[2,6] The HR is a specific marker of sympathetic activity that may have clinical applications.[7] The recorded HR during clinical examination of the child must be compared with a reference range in order to derive meaningful information. The HR ranges may vary in children due to genetic, ethnic, and socio-economic factors.[2,8] Based on these variations, reference ranges developed for one particular population may not be applicable to others.[2,9] The local reference data are essential to evaluate any observed HR values. There is limited HR reference data available for Arab children based on a nationwide survey. Therefore, the objective of this report is to provide age related HR reference standards for healthy resting Saudi children and adolescents.

Methods. This study was part of the Health Profile of Saudi Children and Adolescent Project. It was approved ethically and funded by King Abdul-Aziz City for Science and Technology (KACST). The project was based on a house-to-house survey of selected household from all the regions in the Kingdom of Saudi Arabia, including urban, and rural areas. The households were randomly selected by a multi-stage probability sampling procedure from a stratified listing based on the updated 2000-2001 census. This process was completely computerized. It was performed with the assistance of the General Directorate of Statistics, Ministry of Planning that provided all details of the selected households in cities and villages including road and street maps. All randomly selected 14,000 households were covered whether on the top of high mountains in the south (Faifa, Gizan), or in the middle of the desert of the Riyadh region (Mashthobah). A sub-sample was selected randomly from the original main sample to measure BP and HR. Workshop training of field teams was conducted in each region of the country. The workshop included oral presentations, small group training in the procedure of locating the selected households, explanations of the questionnaire, family consultations, and clinical examinations of the children as well as taking the measurements and recording the data. Practical demonstrations to all the members of the field teams on how to use and maintain BP and HR measurement devices were performed. Specific guidelines written in Arabic and English were provided to the members of the teams. Each team consisted of one physician and one to 2 female nurses.

The clinical examination of the children and adolescents was performed by the physicians to determine the eligibility for measurements. The study included all healthy Saudi children and adolescents from birth to 20 years old in the selected sample as determined by consultation and clinical examination. All children with acute or chronic diseases detected by history or examination were excluded from the study. Children who had echocardiogram reports carried out previously or after referral to hospitals indicating innocent murmurs were included in the study. Children with obesity or significantly underweight detected by clinical examination or body measurement were also excluded. The survey questionnaire was designed to provide needed basic information on the subject, including birth date, prenatal history, nutrition, childhood illnesses, socio-economic status of the family and body measurements. The exact birth date was considered to be particularly important and acceptable only when it was completely recorded from an official document. The exact date of measurement was also noted; both dates are essential for the determination of the exact age at the time of measurements. We evaluated: HR, BP, weight, height, body mass index, head circumference, liver span, and socio-cultural level. Further details on the study design, sampling procedures, body measurements, and examinations have been reported in the growth charts for Saudi children,[10] and symptomatic congenital heart disease in Saudi children and adolescent project.[11] Electronic devices using oscillometric techniques were used in the study (Accutor Plus, Datascope corporation, NJ, USA). The devices used fulfilled the American Association for the Advancement of Medical Instrumentations (AAMI). Two readings were performed for each subject with an interval of 5 minutes at the end of the consultation and the physical examination with the presence of both parents. For children below 2 years the readings were taken in the supine position, and for children above 2 years the readings were taken in the sitting position. The lower of the 2 readings was recorded for the final analysis. The HR measurements were carried out during the evening time when all household members were available. A pilot study was performed to test all the components of the project before the actual start of the main study.

The data collection was performed over 2 years (2004-2005) by house-to-house visits. Precautions were taken to ensure reliability and accuracy of measurements. In addition to the use of equipment known for high accuracy, intra- and inter-observer reliability were tested by selection of 1% of the children to be re-measured by the same or another observer. Multiple frequency analysis was used to detect any

missing data, inconsistencies, and other types of errors. All questionable data were double-checked and either corrected or deleted. Data management and analysis were carried out at the College of Medicine, King Saud University, Riyadh, Saudi Arabia. The data were analyzed using the statistical package for social sciences (SPSS). Mean age and gender-specific HR values were calculated. Upper and lower reference values were calculated as mean ± 2 SD.
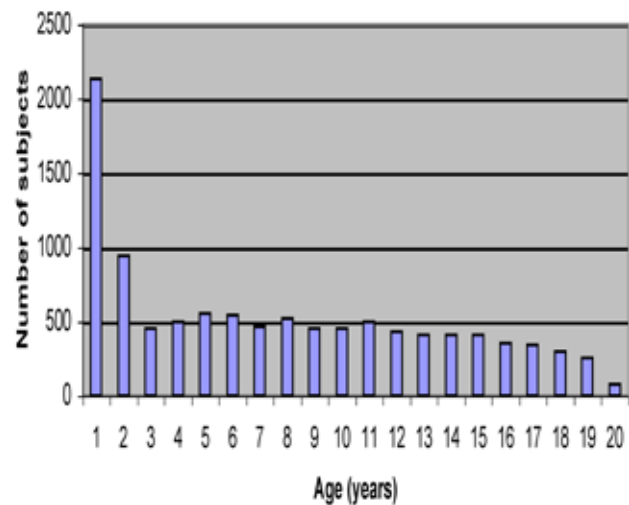
Results. A total of 10,458 Saudi Arabian children from birth to 20 years were examined for HR values in this study. There were 5,155 girls and 5,303 boys. The age distribution of the subjects is shown in **Figure 1**. The distribution of gender and age is summarized in **Table 1** (throughout these results, each year group refers to the period from the day of that birthday to the day after the

previous birthday). Data were treated initially for the main study of growth charts as 37 separate frequency distributions, 22 groups from birth to 60 months, and 15 groups from 5-20 years. A minimum of 200 children were required for each group in each gender, however, this was necessary to plot growth charts of Saudi children since both height and weight vary considerably with age, while for standard HR values we divided them into 23 groups, 4 groups from birth to 12 months, and 19 groups from 2-20 years. The reference values of HR for these children according to age and gender are shown in **Table 1**. The values are shown as integers, upper and lower reference values were calculated as mean ± 2 SD. The mean HR values are shown in **Figure 2** indicating higher rates in girls than boys. The results were not significant for children less than 5 years ($p>0.05$) and were highly significant for children between age 5-20 years ($p=0.00001$). The gender difference increased with age due to more rapid and prolonged decline of HR with age in boys. In both genders, the mean HR fell with increasing age until 16 years, subsequently it changed little.

Discussion. This report establishes HR reference values for Saudi Arab children and adolescents by electronic devices using oscillometric techniques. Our study was compared with 2 school-based studies.[12,13] The first was reported by Rabbia et al in 2003,[12] who selected 2230 adolescents aged 12-18 years, and the HR was estimated by calculation of the mean of 3 radial pulse measurement after 5, 10, and 15 minutes of being in the sitting position.[12] The reliability of such methods depends on the accuracy of the measurement of radial pulse by the physician especially, in young

Table 1 - Mean heart rate in the different age and gender groups with the standard deviation (SD) given in brackets.

Age	Boys	Girls	Boys	Girls
	Number		mean (SD)	
Less than one month	65	70	130 (6)	130 (5)
2-3 months	175	173	128 (4)	126 (4)
4-6 months	299	290	122 (4)	123 (4)
7-12 month	527	530	117 (4)	118 (3)
2 years	476	466	118 (3)	118 (3)
3 years	209	246	114 (3)	115 (3)
4 years	238	254	107 (3)	110 (3)
5 years	290	263	102 (2)	105 (3)
6 years	281	255	98 (2)	102 (2)
7 years	226	236	98 (2)	100 (2)
8 years	262	259	94 (2)	98 (2)
9 years	234	222	92 (2)	95 (2)
10 years	228	220	91 (2)	94 (2)
11 years	244	254	88 (2)	93 (2)
12 years	228	201	87 (2)	92 (2)
13 years	221	190	87 (2)	91 (2)
14 years	225	187	86 (2)	90 (2)
15 years	199	206	80 (2)	90 (2)
16 years	195	161	81 (2)	90 (2)
17 years	173	168	78 (2)	88 (3)
18 years	152	139	78 (2)	87 (2)
19 years	124	124	78 (2)	87 (2)
20 years	32	41	79 (5)	90 (5)
Total	**5303**	**5155**		

Figure 1 - Age distribution.

Table 2 - The mean heart rate of boys and girls in 2 studies for all pediatric age groups.

| Age	Mean HR (Present study)		Mean HR (Semizel et al study[20])		(95% confidence interval for difference between the means) p-value			
	Boys	Girls	Boys	Girls	Boys		Girls	
Less than one month	130	130	143	158	(-45 to 19)	0.4315	(-48 to 16)	0.3356
2-3 m	128	126	154	150	(-58 to 7)	0.1217	(-56 to 8)	0.1487
4-6 m	122	123	146	145	(-56 to 8)	0.1427	(-54 to 10)	0.179
7-12 m	117	118	141	145	(-55 to 8)	0.135	(-58 to 5)	0.096
2-3 years	116	117	134	133	(-49 to 13)	0.255	(-47 to 15)	0.3117
4-5 years	105	108	105	112	(-28 to 28)	1	(-33 to 25)	0.7874
6-8 years	97	100	95	97	(-25 to 29)	0.885	(-24 to 31)	0.8308
9-12 years	90	94	88	92	(-24 to 28)	0.8808	(-24 to 28)	0.8808
13-16 years	84	90	80	87	(-21 to 29)	0.7548	(-23 to 29)	0.8216
17-20 years	78	88	-	-				

Mean HR - mean heart rate

Table 3 - The mean heart rate of boys and girls in 2 studies for all pediatric age groups.

Age	Mean HR (Present study)		Mean HR (Salameh et al study[19])		(95% confidence interval for difference between the means) p-value			
	Boys	Girls	Boys	Girls	Boys		Girls	
Less than one year	124	124	132	135	(-39 to 23)	0.6171	(-43 to 21)	0.4943
2-5 years	111	113	109	108	(-16 to 44)	0.3602	(-25 to 33)	0.7874
6-10 years	95	98	89	93	(-21 to 33)	0.6583	(-22 to 32)	0.7175
11-15 years	86	91	79	85	(-18 to 32)	0.5858	(-20 to 32)	0.6511
16-20 years	79	88	73	78	(-18 to 30)	0.62	(-15 to 35)	0.4377

Mean HR - mean heart rate
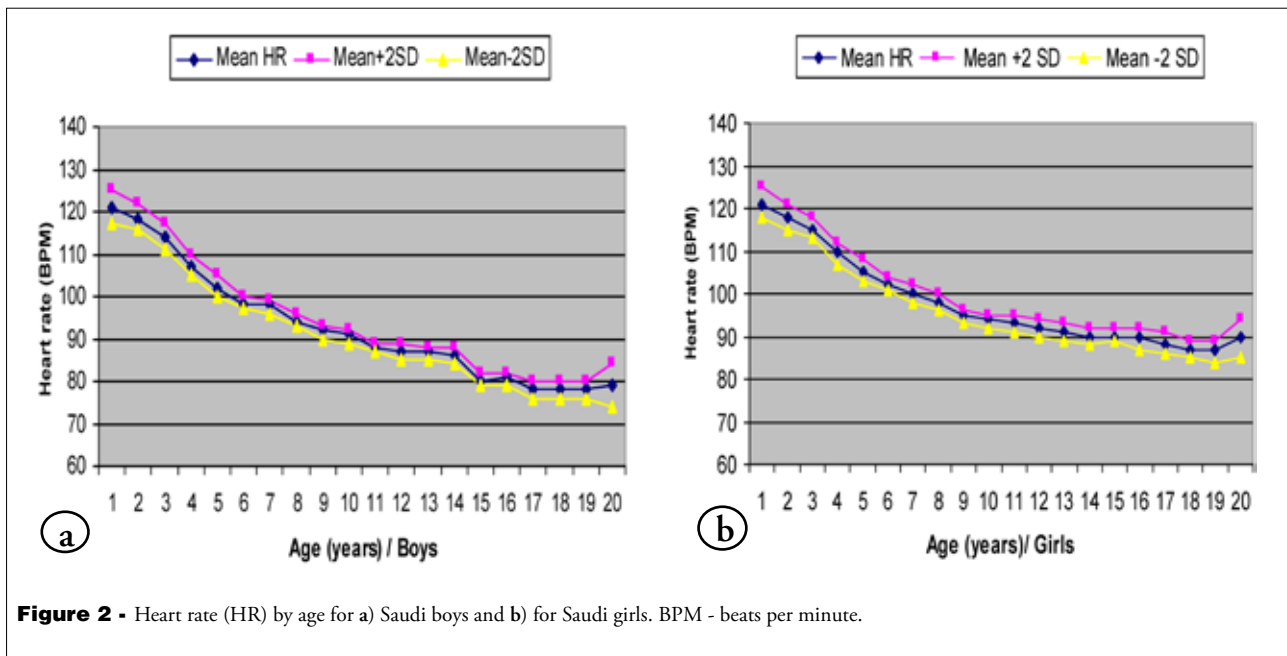
Figure 2 - Heart rate (HR) by age for **a**) Saudi boys and **b**) for Saudi girls. BPM - beats per minute.

children and also on the cooperation of the child for measuring 3 times. The second study was reported by Wallis et al in 2005,[13] who selected 1109 children aged 4-16 years and the HR was measured for 60 seconds using a Datex S5 Lit moniter. The HR measurement by electronic device is accurate and closely correlates with HR measurement by radial artery palpation.[14] In our study, the HR was also measured by electronic device and it was reliable for the wider age range of our sample from birth to 20 years. The device is easy to use with small children, there is no need for auscultations of the heart, and its use is widely accepted in hospitals. We selected the standardized BP measurement protocol of the second task force on BP evaluation in children to measure HR since there are no standard criteria for measuring HR.[15] The HR was measured in the supine position for newborn and infants, while in the sitting position for older children and adolescents. The effect of the measurement procedure on the values of the HR and BP is not significant after 10 minutes resting time.[10,16] In our study, the HR measurements were taken at the end of the family consultation, which usually takes longer than 10 minutes. To avoid the "white coat" effect and record the real normal HR for the child, the measurement should be obtained in "the normal conditions" for the child.[17,18] We believe that the normal environment for the child is at home, which is certainly more comfortable to the child than the health hall at school or the medical center. In our study, the HR measurements were based on the lower of 2 measurements with 5 minutes intervals. We believe that there is no need for additional efforts to obtain more than 2 readings, once the child realizes, with the support of his family, the painless and benign nature of the procedure. The results of our study were compared with 2 recent studies for reference values of "Normal Heart Rate" in the pediatric age group.[19,20] There is no significant difference ($p>0.05$) in the mean values determined by our study and these 2 studies regarding all age groups for both genders (**Tables 2 & 3**). Salameh et al[19] reported normal limits of HR for children and adolescents in 2008. Although the age range was similar to our study, which is from birth to 20 years, the methodology was different. The HR was established using 24-hour ambulatory electrocardiography (Holter recordings) and the sample consisted of 616 subjects only. The gender-dependent differences in HR for children older than 10 years, with the males exhibiting lower mean HR is consistent with our study. Semizel et al[20] reported normal limits of HR for children and adolescents in 2007. The age range was from one day to 16 years, the heart rate was established from electrocardiogram recording and the sample consisted of 2241 children.

Study limitations. The HR values were not related to height to obtain reference values of HR according to height and gender, although it has been demonstrated that height is an independent determinant of resting HR values.[8] All children with acute or chronic diseases detected by history or examination were excluded from our study. Children with mild heart disease but without obvious clinical signs, like mitral valve prolapse, were likely skipped from exclusion, however, this will not affect our results due to the large sample size, and this group is small and they usually have normal HR values.

In conclusion, our data on HR measurements are the most recent, comprehensive, and representative of the Saudi Arab population of children and adolescents. The reference data should help practicing clinicians in better assessment of their patients HR than standards of other populations.

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