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REFERENCE RANGE OF POST-EXERCISE HEART RATE AFTER THREE-MINUTE STEP TEST FOR ASSESSMENT OF CARDIORESPIRATORY FITNESS IN CHILDREN

Physiotherapy

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ABSTRACT

Cardiorespiratory fitness which is a key parameter of children's health, should be an important aspect in evaluation and promotion of physical activity and healthy lifestyle. This study aimed to develop a reference range of post-exercise HR ($HR_{post-ex}$) after a 3-min step test used to screen the cardiorespiratory fitness of 6- to 9-year-old children (≥6 years to <9 years). The study included 489 children (245 boys and 244 girls) of age 6–9 years from different schools of various cities across Gujarat, India. These children were subjected to the 3-min Kasch Pulse Recovery Test (KPR Test). The reference range for the classification of cardiorespiratory fitness was developed based on the age-specific percentile distribution of $HR_{post-ex}$ in 6- to 9-year-old children. This study showed that the 3-min KPR Test is easy to perform by school-age children. As such, it can constitute a useful tool for health promoters and educators. The presented age- and gender-specific reference range of $HR_{post-ex}$ enables the assessment and monitoring of submaximal exercise-induced changes in the cardiovascular system and, consequently, the physical fitness of a given individual.

KEYWORDS

Post-exercise heart rate, 3-min step test, Cardiovascular fitness

INTRODUCTION

Physical activity during childhood is imperative for optimal growth and development. Despite substantial evidence linking the importance of physical activity to optimal child development, physical activity has been replaced by modern day conveniences and engineered out of most aspects of daily life. Additionally, childhood sedentary behavior is a complex system problem that emerged during the economic growth and globalization of the marketplace.(Brewer & Jalongo, 2018)

Childhood obesity is major concern of public health in the 21st century. The problem is global and is affecting not only high-income countries but also many low- and middle-income countries. It is an undeniable fact that childhood obesity is on the rise also in India. (Sahoo et al., 2015) A large research by University of Washington's Institute for Health Metrics and Evaluation analysed data from various sources to estimate the prevalence of overweight and obesity in 195 countries and change of trend from 1980 to 2015. As per this study, China and India have the highest number of obese children. India has the second highest number of obese children in the world, with prevalence of 14.4 million according to this study. China, with 15.3 million obese children, was ranked first in the list.(GBD 2015 Obesity Collaborators et al., 2017) Another systemic review from India, analyzed the pooled data after 2010 and estimated a combined prevalence of 19.3 % of childhood overweight and obesity which was a significant increase from the earlier prevalence of 16.3 % reported in 2001-2005.(Ranjani et al., 2016) The multitude of serious comorbidities associated with childhood obesity necessitates effective and timely interventions. (Kumar & Kelly, 2017)

Physical fitness, which includes cardiorespiratory fitness (aerobic fitness), is a key parameter of children's health. Cardiorespiratory fitness is one of vital aspect of body functions, and its assessment should be an important aspect in evaluation and promotion of physical activity. The standard methods to measure cardiorespiratory fitness remain laboratory-based assessments with gas analysis. However, laboratory-based testing is costly and not feasible for large population-based assessments with large samples. Also these methods need a special environment and special conditions(Jankowski et al., 2015; Lang et al., 2018; Li et al., 2007). Evaluation of cardiorespiratory fitness for population screening requires easy, reproducible screening tests that can be conducted under the conditions of an epidemiologic study. Such examination can provide parents, teachers, and physicians with valuable information concerning the lifestyle and general health status of the child. One of the most typical places in which a simple, quick screening test can be used is the school. This can be a way of preventing negative behaviors and can give us information about needs in training of children with impaired cardiorespiratory fitness.(Hayes et al., 2019; Jankowski et al., 2015)

Kasch (1961) designed 3-min step test, which belongs to a group of step tests used to estimate exercise capacity based on heart rate (HR) post-exercise values. This test is known as 3-min Kasch Pulse Recovery Test (KPR Test).(Kasch, 1961) In 1970, the test used in this study was adopted by the YMCA as an "excellent cardiorespiratory test". The 3-minute step test can be used very successfully in mass-testing situations. This is an excellent cardiorespiratory test for mass testing and minimal equipment is required. Furthermore, it is used in epidemiologic studies and in health training programs. (Beunen et al., 1983; Golding & Myers, 1989; McArdle et al., 2010)

Physical fitness can be characterized by the post-exercise heart rate (HR), considered as an indicator of cardiorespiratory fitness. Individuals with high values of peak oxygen uptake ($VO2_{max}$) are characterized by the ability to restore all pre-exercise reactions rapidly and a low HR during submaximal exercise. (T. Rowland et al., 2000) Consequently, the value of post-exercise HR obtained with the step test is considered to be an indicator of cardiorespiratory fitness. (Fitchett, 1985; Golding & Myers, 1989) Thus, value of post-exercise HR obtained with the step test is suggestive of cardiorespiratory fitness; it gives idea of habitual physical activity and can be useful diagnostic and prognostic health indicator. As physical inactivity and obesity are growing health problems in children, it is necessary to evaluate the temporal trends in obesity and exercise capacity among children. Impaired post-exercise HR in children can be signal of a need for preventing negative behaviours or lifestyle.

This study aimed to develop a reference system of post-exercise HR ($HR_{post-ex}$) after a 3-min step test used to screen the cardiorespiratory fitness of 6- to 9-year-old children (≥6 years to <9 years) in Gujarat, India.

MATERIALS AND METHODOLOGY

This study was normative descriptive study conducted at different schools of various cities across Gujarat, India. Total 489 Children of 6-9 years age group (≥6 years to <9 years) were included in the study from major cities. Cities from each zone of Gujarat (Central, North & South zones, Saurashtra & Kutch) and schools from the different cities were selected by lottery method. Based on lists of students in each of the schools, a proportional sample of children by age and sex was decided and then children were then chosen by systematic sampling method.

Children with cardiovascular or respiratory co-morbidities or absolute contraindications to physical exercise were excluded from the study. These exclusions were decided based on a parent or caregiver interview, physical examination, and data from medical records. For each participant, due consent was taken from the parents or legal guardian and assent was taken from child after due explanation about procedure. This study was approved by Institutional Ethics committee. Anthropometric measurements; Height, weight and triceps skin fold were measured. Height was measured by stadiometer in centimetre to nearest 0.1 cm. Weight was measured by digital weighing scale with 0.1 kg sensitivity. Body mass index of child was calculated with help of "BMI Percentile Calculator for Child and Teen" by centre for disease control and prevention (CDC)(CDC, 2019). Triceps skinfold thickness was measured following recommended protocols.(Addo & Himes, 2010; Ramírez-Vélez et al., 2016) Skinfold thickness was measured using a BASELINE skinfold calliper, at triceps; halfway between the acromion process and the olecranon process of both sides.(Moreno et al., 2002)

The participants were asked to perform a 3-min Kasch Pulse Recovery Test (KPR Test). In the KPR Test participants have to climb a 0.305-meter (12 inch) step at a rate of 24 steps up and down per minute. The rate of climbing was defined by a metronome set at 96 beats (signals) per minute. The heart rate (HR) was recorded with IBP electronic pulse analyser. Throughout the test, HR was monitored continuously (i.e., during 3 min of exercise [step test] and during 1 min and 5 sec of recovery [seated position]). Only the values of post-exercise HR (i.e., the values recorded 1 min after completion of the test [no later than 5 sec]) was included in the further analysis. HR during restitution were recorded continuously with the participant in the seated position; participants were instructed to sit still, breath normally, and not engage in conversation. The test was considered incomplete whenever instructions are not properly followed (e.g., due to an improper climbing rate, conversation, or refusal to exercise) or if child feels too tired or breathing difficulty or pain. The test was discontinued if the exercise HR exceeded 180 beats per minute for more than 15 seconds and participants were excluded from the study. No repeat test was offered to children who could not complete the test due to any of above reasons.

School going children of 6 to 9 years of age were selected for this study. The reference range for the classification of cardiorespiratory fitness was developed on the basis of an age-specific percentile distribution of $HR_{post-ex}$ in children 6 to 9 years of age. The values of $HR_{post-ex}$ used in the reference range were determined based on gender-specific percentile of $HR_{post-ex}$ calculated for entire age bracket. (Jankowski et al., 2015; Hayes et al., 2019; Kasch, 1961; Fyffe et al., 2020; Jacks et al., 2008; Mitchell et al., 2012; Starkoff et al., 2011; Simhaee et al., 2013)

Statistical Analysis

All statistical analyses were conducted with IBM SPSS® 20 package. Mean and standard deviation were calculated for anthropometric measurements (height, weight, body mass index, triceps skin-fold measurement) and for post-exercise heart rate. The values of percentiles (5th, 10th, 15th, 25th, 50th, 75th, 85th, 90th, and 95th) were calculated for each year age bracket (6-6.99, 7-7.99 , 8-8.99) separately for the boys and the girls. Usage of percentiles enables an easy practical assessment of the scale and are easier for both parents and children to understand.

RESULTS

Data was collected from different schools of Gujarat, India. Data of total 489 children (245 boys, 244 girls) of 6-9 years age group (≥6 years and <9 years) was included in Analysis. Seven children were excluded from study due to excess heart rate. Following table (Table-1) presents mean and standard deviation for height, weight, body mass index, triceps skin-fold measurement, post-exercise heart rate and percentage of children in each weight category (%). About 17% children belonged to either obese or overweight category.

The sample size and the percentile distributions of gender- and age-specific post- exercise HR for the 5th, 10th, 15th, 25th, 50th, 75th, 85th, 90th, and 95th percentiles of all the examined children are presented in Tables 2 and 3. Such tables that are simple to use allow evaluator (teacher, physician, school nurse) to easily assess results of performed test for children ages 6–9 years.

Table 2 & 3 show detailed percentile information that can be used during cardiorespiratory fitness screening test of children and assessment of changes in fitness level after sports training. These tables offer easy-to-use, age & sex-specific information of fitness level for teachers, coaches, and physicians.

Table: 1 Demographic Data, BMI, TSFM and post-exercise HR of study population

Parameter	Boys (n=245)	Girls (n=244)	Total (N=489)
Weight (kg) (mean ± SD)	22.28 ± 4.38	22.33 ± 5.28	22.30 ± 4.84
Height (cm) (mean ± SD)	118.89 ± 7.77	118.35 ± 8.80	118.62 ± 8.30
BMI (kg/m^2) (mean ± SD)	15.67 ± 1.95	15.81 ± 2.27	15.74 ± 2.11
TSFM (mm) (mean ± SD)	8.93 ± 3.44	9.37 ± 3.54	9.14 ± 3.49
Post-Exercise HR (beats/min) (mean ± SD)	99.68 ± 10.87	99.06 ± 9.48	99.37 ± 10.20
Weight category (%) -Underweight -Healthy weight -Overweight -Obese	15.1% 69.4% 10.6% 4.9%	21.3% 59.4% 13.1% 6.1%	18.2% 64.4% 11.9% 5.5%

Table 2: Percentile distribution of step test post-exercise heart rates of 6- to 9-year-old boys.

Age (years)	N	Percentile								
		5th	10th	15th	25th	50th	75th	85th	90th	95th
6	65	85	88	88	92	102	106	108	113	116
7	83	81	86	88	93	100	105	109	115	119
8	97	76	82	87	91	100	108	112	114	117

Table 3: Percentile distribution of step test post-exercise heart rates of 6- to 9-year-old girls.

Age (years)	N	Percentile								
		5th	10th	15th	25th	50th	75th	85th	90th	95th
6	66	86	87	90	96	104	106	110	113	116
7	80	85	87	89	92	100	104	107	112	118
8	98	80	86	87	90	98	104	108	110	114

Additionally, shorter version of the charts is also presented in Table 4, that can be used for quick screening of their physical fitness in schools & primary health care settings.

Table 4: Classification for ranges of reference values of post-exercise heart rates of 6- to 9-year-old children

Cardiorespiratory fitness	Boys (6–9 years) (n=245)	Girls (6–9 years) (n=244)
Excellent ($HR_{post-ex}$ < 5th %tile)	<80	<84
Very Good ($HR_{post-ex}$ 5- 25th %tile)	80-91	84-91
Good ($HR_{post-ex}$ 25-50th %tile)	92-99	92-99
Sufficient ($HR_{post-ex}$ 50-75th %tile)	100-105	100-104
Poor ($HR_{post-ex}$ 75-95th %tile)	106-117	105-115
Very Poor ($HR_{post-ex}$ > 95th %tile)	>117	>115

Both the full and short versions of the post-exercise HR distribution charts show that there were not much differences in the post-exercise HR of girls and boys in all age groups and percentiles. Pre-exercise HR cannot be used as a diagnostic tool for children and adolescents due to its rapid changes in stressful situations (e.g., performing the test).

DISCUSSION

Direct method of assessing VO_{2max} is an optimal determinant of physical fitness according to text-books(T. W. Rowland, 2004). However, such direct method is very difficult, often not possible or even necessary in average healthy children. Reaching the maximal level of exercise can be impossible for some physically inactive children who do not practice sports and are not motivated to perform this test (Dorsey et al., 2011; Rump et al., 2002). Consequently, in the course of epidemiologic studies, substitutes for this test are frequently used such as the time required for a treadmill run or the HR recorded during and after submaximal exercise(Baranowski et al., 1992; Sartor et al., 2013)

Several authors have suggested that VO_{2max} also can be estimated using step tests(Åstrand & Ryhming, 1954; Kasch, 1961). So, we have used

the KPR Test in this study which is one such step tests.
For this study the normal level of physical fitness was considered as the desirable target in determining the reference values of exercise capacity, considering future application of these reference limits in the promotion of physical activity. Using this tool to establish normal reference range for the development of fitness parameters, particularly cardiorespiratory fitness, can be a validated instrument in health promotion. It should be remembered that in addition to being informed about the percentile score, the examined subject should be aware whether his or her fitness level is desirable in the context of health status. Especially when using this test as a marker of health status, children and their parents as well as schoolteachers and managers should be given simple information about the results (i.e., good or poor status of physical fitness).

An important aspect of the testing tool was discontinuation of approximately 1-2% (7 children in this study) of tests due to an extremely high (approaching 180 beats/min) exercise HR (for safety reasons) or extreme fatigue and unwillingness to complete the test.

The protocol of the KPR Test is simple. Furthermore, it does not require an examiner with professional qualifications and uses low-cost diagnostic tools. Thus, widespread application of this test in the clinical setting as well as in schools and screening procedures should be considered.

In this study included age group of children was 6 to 9 years. Further studies should be done to include remaining age group (9-12 years) of school age children. Range of post exercise heart rate in this age group of children can be different due to rapid physical growth of this group. Such additional study would offer reference range of post exercise heart rate in age group of 9-12 years.

CONCLUSIONS

The presented age- and gender-specific reference range for post-exercise HR, determined after the KPR Test and developed based on data from a representative sample of Indian children in Gujarat would, enable the assessment and monitoring of submaximal exercise-induced changes in the cardiovascular system and, consequently, the physical fitness of a given individual. Because it is easy to perform and well tolerated by school-aged children (ages 6–9 years), the 3-min step test together with the determination of post-exercise HR ($HR_{post\text{-}ex}$) can constitute a useful tool for health promoters and educators (physicians, nurses, and teachers). This test makes it possible to estimate the exercise capacity of 6- to 9-year-old children and to monitor changes in the response of the cardiovascular system to submaximal exercise. Consequently, it enables the monitoring of biologic effects associated with physical activity. The presented tables of $HR_{post\text{-}ex}$ for various age groups of girls and boys can be used for a quick interpretation of results in the setting of a screening study as well as in primary health care. Proper interpretation of the test will enable the development of individualized health programs for children based on measurable values of $HR_{post\text{-}ex}$, providing proper daily levels of physical activity.

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