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Heart Rate-Determined Physical Activity In New Zealand School Children: A Cross-Sectional Study

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***Abstract*—**The aim of this study was to examine current levels of physical activity determined via heart rate monitoring. A total of 176 children (85 boys, 91 girls) aged 5-13 years wore sealed Polar heart rate monitors for at least 10 hours per day on at least 3 days. Mean daily minutes of moderate to vigorous-intensity physical activity was 65 ± 43 (mean ± SD) for boys and 54 ± 37 for girls. Daily minutes of vigorous-intensity activity was 31 ± 24 and 24 ± 21 for boys and girls respectively. Significant differences in physical activity levels were observed between school day and weekends, boys and girls, and among age and geographical groups. Only 36% of boys and 22% of girls met the New Zealand physical activity guideline. This research indicates that a large proportion of New Zealand children are not meeting physical activity recommendations.

***Keywords*—**activity guidelines, moderate activity, sedentary, vigorous activity

I. Introduction

CONTEMPORARY research indicates that regular participation in physical activity provides a range of physiological and psychological health benefits for children and adolescents [1]-[3]. Establishing adequate physical activity patterns in childhood is important to health in adulthood given the evidence that activity patterns are likely to track into adolescence, and subsequently adulthood [4], and maintaining sufficiently high levels of activity from youth to adulthood lowers the risk of chronic diseases such as obesity [5].

Benchmarks for healthy physical activity levels in New Zealand children have been established as national guidelines and have lately been revised becoming more stringent. In 1997, the New Zealand Ministry of Health adopted a guideline that recommended children aged 2-12 years accumulate 30-60 minutes (min) of moderate-intensity physical activity per day. In 2007 these guidelines were superseded by recommendations that stated 5-18 year olds should accumulate at least 60 min per day of moderate to vigorous physical activity [6].

Over the previous decade various studies have attempted to assess the physical activity levels of New Zealand children with self-reported interview and questionnaire techniques [7]-[9]. However questionnaires and interviews, particularly for paediatric populations, are problematic due to young people's inability to accurately recall activity behaviour [10]. In addition, such questionnaires typically use duration and frequency of leisure-time physical activity with little attention given to the intensity of activity, thereby neglecting an important aspect of total physical activity. In many cases, these questionnaires also failed to account for non-leisure-time physical activity (e.g. active transport, chores and cultural activities) which probably resulted in underestimation of overall activity levels.

As indicated by Bassett [11], heart rate monitoring is an effective tool to measure physical activity as heart rate is related to energy expenditure and oxygen consumption. It is recognised that heart rate is not a direct measure of physical activity, though it reflects the stress placed on the cardiovascular system by physical activity [12]. Since heart rates can also be influenced by other factors such as body temperature and emotional state, heart rate monitoring is considered only to be a valid tool for assessing moderate to vigorous levels of physical activity [13].

Over the last decade Armstrong has assessed the physical activity patterns of British school children vindicating the use of heart rate monitoring by depicting heart rate as indicative of physical activity volume and intensity [12]. Calvert (1999) [14] emulated Armstrong's research methodology on a small sample of New Zealand children from the Canterbury region and determined that the proportion of children meeting the then, Ministry of Health (1997) activity guidelines was 53%, much lower than previously reported by questionnaire techniques (69%) [7]. The purpose of this study was to use heart rate monitoring as an objective tool to investigate the physical activity patterns of a large cross-section of New Zealand children. In addition, the extent to which New Zealand children meet the physical activity guidelines was assessed along with activity differences between different population groups (age and geographical), and different days of the week.

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II. METHODS

The study was approved by the Christchurch College of Education Ethics Committee and conformed to the standards set by the Declaration of Helsinki. Informed voluntary written consent was obtained from participants prior to the start of the study. Participants were children involved in two large studies (The Primary Schools Physical Activity Project and the Southland Primary School Physical Activity Study) conducted in three geographical diverse areas (Auckland, Christchurch and Southland) between 2003 and 2004 in New Zealand. Demographic data (age, gender) was collected from all children who were randomly selected from each year level from each of the 21 participating schools. Subjects were asked to wear the heart rate monitors (Polar Electro, S610, Oy, Finland) for at least 6 days (5 weekdays and 1 weekend day). The monitors stored children's heart rate every 60 seconds.

The methodology to assess physical activity mimicked that established by Armstrong [12], and monitors were initially fitted to children between 0800–0900 on the first day and parents were encouraged to come along and use this time as a training session. Children and parents were provided with an instruction sheet on the heart rate monitors along with a help-line phone number. Children were asked to attach the monitor immediately upon rising from bed in the morning and detach the monitor just prior to going to bed at night.

As with other heart rate monitoring research [15], the heart rate data contained aberrations. These aberrations are typically caused by electrical interference, causing spikes in the data that typically transpire at >200 beats per min, or loosening of the transmitter electrodes from the chest that result in a heart rate recording of zero. Utilising the same technique as the above authors, aberrations (heart rate recording more than 215 or less than 45 beats per min) were initially screened by a customised Excel Visual Basic macro to exclude these non-physiological heart rates [15]. Excluded heart rates were replaced by the average of the preceding and subsequent values [15]. The data was split into time periods including; all day, before school, during school, after school, and lunchtime. No files were analysed if the total number of aberrations in a time period exceeded 10% of the data. For the 'all day' time period, from which we determined the proportion of children meeting activity guidelines, only children who had at least three days of data of at least 10 hours in length were used, as previously recommended by Trost et al (2000) [16]. Treating the data in this way produced datasets on 176 children (49 children for 3 days, 74 children for 4 days, 38 children for 5 days, 8 children for 6 days and 7 children for 7 days) which represents adherence rates similar to previous research [17]. Well-established heart rate cut-offs [12] (more than 139 beats per min and more than 159 beats per min for moderate to vigorous and vigorous-intensity physical activity respectively) were used in this study. Total minutes in which the heart rates were above the moderate to vigorous and vigorous-intensity thresholds were calculated along with the proportion of children meeting the current and previous New Zealand physical activity guidelines. For the current guidelines [6] children were required to accumulate at least 60 min of moderate-intensity physical activity (in our case 60 min with heart rate above 139 beats per min) each day. For the previous guidelines [18] children needed to accumulate at least 30 min of moderate-intensity physical activity on at least 71% of the recorded days per week (the equivalent of 5 of 7 days per week). We chose to investigate both guidelines to compare the proportions of children meeting the old and new recommendations and to contrast results with previous studies [14], [19].

Heart rates were analysed using the mixed modelling procedure (Proc Mixed) in the Statistical Analysis System (Version 9.1.3 SAS Institute, Cary, NC). Unpaired unequal variances t-tests were used to analyse the differences in accumulated min above heart rates of 139 and 159 beats per min between groups. A type I error of 5% was chosen for the declaration of statistical significance and precision of estimates is represented by the 95% confidence limits (CL, the likely range of the true value). Differences in the proportion of children meeting physical activity guidelines were analysed using the general linear modelling procedure (Proc Genmod), and given as relative risks.

III. RESULTS

Overall Total Activity Duration

On average over a week, children spent almost 1 hour per day with their heart rate above the moderate-intensity physical activity cut off (Table I). Children were significantly more active on schools days than on weekend days at both moderate to vigorous and vigorous-only exercise intensities ($p < 0.01$). Boys accumulated over 1 hour of moderate-intensity physical activity on school days (69 ± 40, mean ± SD) and slightly less on weekends (51 ± 49), whereas girls were less active than boys on school days (57 ± 37, $p < 0.01$) and on weekends (43 ± 39, $p < 0.05$). Mean physical activity duration decreased with age regardless of intensity such that 11-13 year olds accumulated approximately 63-66% of the activity duration of the 5-6 year olds. Compared to children at urban schools, children that attended rural schools were significantly more active during school days but not in weekends.

School Day Activity Duration

Since young people spend a relatively high proportion of their time at school, and because of the likelihood that children's physical activity may be influenced through interventions and programmes developed at school (e.g. health and physical education curricula) we separated the data further into periods within the school day (Table II). During a school day, children accumulated most of their activity at school (62% moderate to vigorous activity, 68% vigorous activity) rather than before or after school. During school hours, boys accumulated significantly more physical activity above the cut points compared to girls ($p < 0.01$). Children from urban schools accumulated significantly less activity than their peers from rural schools either while at school or after school.

TABLE I
HEART RATE DETERMINED PHYSICAL ACTIVITY (MIN PER DAY) AND PROPORTION OF CHILDREN MEETING PHYSICAL ACTIVITY RECOMMENDATION

		All days min‡		School days min		Weekend days min		% Meeting recommendation	
	N	>139	>159	>139	>159	>139	>159	30-min† (%)	60-minŁ (%)
All	176	59±40	27±23	63±38	30±23	47±44	19±22	74	29
Sex									
Male	85	65±43[a]	31±24[a]	69±40[a]	34±24[a]	51±49[a]	20±24[a]	86[a]	36[a]
Female	91	54±37[b]	24±21[b]	57±37[b]	26±21[b]	43±39[a]	17±20[a]	64[b]	22[b]
Age (yr)									
5-6	30	75±45[a]	32±24[a]	77±39[a]	34±22[a]	70±59[a]	27±28[a]	97[a]	43[a]
7-8	40	59±39[b]	25±19[b]	63±40[b]	27±20[b]	45±32[b]	17±16[b]	73[b]	30[a]
9-10	55	62±40[b]	31±25[a]	66±38[b]	34±24[a]	50±45[b]	21±26[a,b]	78[a,b]	36[a]
11-13	51	47±36[c]	22±22[b]	52±35[c]	25±23[b]	33±35[c]	13±16[c]	59[c]	12[b]
Locality									
Rural	106	64±40[a]	30±24[a]	68±39[a]	33±23[a]	48±40[a]	20±22[a]	81[a]	33[a]
Urban	70	55±40[b]	23±22[b]	55±36[b]	25±21[b]	47±49[a]	17±23[a]	64[b]	24[a]

Values are means ± SD. ‡All day data is school day and weekend data combined. †Adherence definitions based on children accumulating 30 min of activity with their heart rates elevated above 139 beats per minute on at least 71% of the recorded days (e.g. 5 out of 7 days). ŁAdherence definitions based on children accumulating 60 minutes of activity with their heart rates elevated above 139 beats per minute on each of the recorded days. >139 min, with heart rate above 139 beats per minute (moderate to vigorous activity combined). >159 min, with heart rate above 159 beats per minute (vigorous activity only). [a, b, c] Groups with different letters differ at $P < 0.05$.

Prevalence of adherence to physical activity guidelines

Using the 30-min per day guideline, approximately 74% of the children in this study achieved the recommended amount of activity (Table 1). Boys were 2.5 (1.4-4.6) times (Relative Risk [RR], and 95% confidence interval [CI], $p < 0.01$) more likely than girls to achieve this recommendation. Younger children were also more likely than older children to meet the guidelines with 97% of 5-6 year-olds compared to 59% of 11-13 year-olds achieving the guidelines. Children from schools in rural areas were 1.9 times (CI = 1.1-3.1, $p = 0.01$) more likely to meet the guidelines compared to children from schools in urban areas. When analysing the data using the latest guidelines of 60 min per day, the total proportion of children meeting the guideline decreased considerably (to approximately 29%).

IV. DISCUSSION

This study is unique in that it is the first to collect heart rate data on a large New Zealand sample of children from different age and geographic groups. It is also the first study to analyse heart rate data over the various periods of the day (before, during, after school) allowing not only comparison with other international studies but giving us an in-depth understanding of when and where children are active.

The mean standard error of measurement (typical error) from the day-to-day heart rate recording was 33 min (95% Confidence Limits = 31-36 min) for the moderate to vigorous-intensity physical activity and 18 min (95% CL = 17-19 min) for the vigorous-intensity activity. This is the average typical variation in these measures for this population and suggests considerable day-to-day variation in accumulated activity levels. Typically, children will vary their activity levels considerably from day to day according to external (weather, temperature, facilities) and internal (fatigue, state of anxiety, feelings of confidence) factors which would account for the large typical errors.

By using data collected on a number of children (n = 69) approximately 4-12 months after the initial heart rate recording we have also been able to determine overall weekly reliability of the heart rate monitoring. To do this we averaged the daily recordings from each subject at baseline and again 4-12 months later. The typical error for the average daily number of min subject's heart rates were > 139 beats per min was 18 min (95% CL = 15-22 min). The large intraclass correlation coefficient between heart rate measurements for our subjects between measurement periods (r = 0.50, 95% CL = 0.30-0.66) suggests a much higher reliability in the average daily activity levels than in the day-to-day levels. This reliability was similar to what others have reported [20] and implies the moderate to vigorous-intensity activity levels of our subjects were relatively stable over a 4-12 month period.

In early research into activity levels using heart rate monitoring, Gilliam and associates (1981) reported that 6 to 7 year old U.S. children accumulated over 60 min of moderate-intensity physical activity per day [21], whereas Sallis and colleagues (1993) reported U.S. boys and girls accumulated ~45 and ~43 min per day of moderate-intensity physical activity respectively. Sleap and Tolfrey (2001) reported

similar activity levels in U.K. children [17], whereas slightly higher levels have been observed in French school children [22]. The findings from the present study (~65 and 54 min per day for boys and girls respectively) suggest that New Zealand children are at least as active as children from other developed nations.

The proportion of New Zealand children meeting the current New Zealand physical activity guideline in the present study was 29% (36% boys, 22% girls). There are no other reported New Zealand studies to compare this figure with. However, there are a few international reports of guideline adherence but because of different methodologies used in these studies caution needs to be applied when comparing these widely varying results. Using accelerometer data recent figures for adherence in children range from 2.5% in English 11-year olds [13], through to 69% in British 9-10 year olds [23]. The large variability in the reported adherence rates signals a need for consistency in how guideline compliance is measured and compared between populations [24].

The proportion of New Zealand children meeting the old New Zealand physical activity guideline (at least 30 min of at least moderate-intensity activity on most days of week) in the present study was 74%. This is similar to 68% reported by Sport and Recreation New Zealand using proxy report questionnaires, but higher than previous research using heart rate monitoring [14]. Discrepancies between the proportion of children meeting the guideline in the current study and that of Calvert et al. (2001) is probably due to the differences in the ages of the total population sampled. Indeed, when similarly aged children from the two studies are compared (11-13 year olds) the proportion of children meeting the guidelines is similar (59% in the current study, compared to 53% in the Calvert study). The fact that the overall mean accumulated min of moderate to vigorous-intensity physical activity per day for boys and girls combined was 59 ± 40 min, but only 74% of the children met the physical activity guideline suggests that a number of children were very active but many were also very inactive.

School Days vs. Weekend days

The large differences between school days and non-schools days (weekends) as witnessed in this study has been shown previously using heart rate monitors [22]. Possible causes for such changes in activity levels between weekdays and weekends have centred on social and cultural differences between studies [22]. It's interesting to note that the opposite occurs with adults who tend to increase activity levels during the weekends [25]. The loss of structural and environmental influences that normally occur to encourage activity at school and the increased access to sedentary activities during weekends (e.g. television and computers) are probably also involved. Further research is required to uncover the reasons for the drop in activity levels in non-school days.

TABLE II
HEART RATE DETERMINED PHYSICAL ACTIVITY (MIN PER DAY) FOR SCHOOL DAYS.

		Before school min		At school min		After school min		Lunchtime min	
	N	>139	>159	>139	>159	>139	>159	>139	>159
All	176	6±9	3±5	44± 27	23±19	21±25	8±13	15±13	7±8
Sex									
Male	85	6±7[a]	3±4[a]	50±27[a]	27±21[a]	20±24[a]	8±12[a]	18±14[a]	9±9[a]
Female	91	6±10[a]	3±6[a]	37±25[b]	18±17[b]	21±26[a]	8±13[a]	13±12[a]	6±7[a]
Age (yr)									
5-6	30	5±6[a]	1±2[a]	51±26[a]	25±17[a,c]	26±31[a]	10±17[a]	21±15[a]	10±9[a]
7-8	40	8±11[a]	4±6[a]	40±23[b,c]	18±14[b]	25±27[a]	9±11[a]	16±12[a,b]	7±7[a]
9-10	55	6±9[a]	3±5[a]	46±27[a,b]	26±20[a]	21±24[a,b]	9±13[a]	15±13[a,b]	7±9[a]
11-13	51	5±6[a]	3±4[a]	39±29[c]	21±23[b,c]	16±20[b]	6±10[a]	13±12[b]	6±7[a]
Locality									
Rural	106	6±8[a]	2±4[a]	45±27[a]	25±20[a]	25±28[a]	10±14[a]	15±13[a]	7±8[a]
Urban	70	7±9[a]	3±6[a]	40±27[b]	18±17[b]	16±19[b]	6±10[b]	16±8[a]	7±8[a]

Values are means ± SD. >139 min with heart rate above 139 beats per minute (moderate to vigorous activity combined). >159 min with heart rate above 159 beats per minute (vigorous activity only). [a, b, c] Groups with different letters differ at $P < 0.05$.

Gender

Most research into physical activity indicates boys are more active than girls, with one researcher suggesting boys to be approximately 15-25% more active than girls [10]. This study found that boy's moderate to vigorous intensity physical activity levels were approximately 20% higher than girls during weekdays and 18% higher in weekends. The biggest differences in activity levels occurred while children were at school with boys accumulating approximately 33% more moderate to vigorous-intensity and 50% more vigorous-intensity activity compared to girls. Such large differences, particularly in vigorous-intensity activity between boys and

girls, probably represent the different types of activities boys and girls participate in. Such large differences in overall, but in particular vigorous-intensity activity, suggests a greater need for specific activity intervention programmes for girls.

Age

International studies consistently report a reduction in physical activity with age [13]. This trend is also apparent in New Zealand, with older children's (16-17 year olds) physical activity levels decreasing substantially [19]. The pattern for younger children is less obvious. New Zealand national data suggest children are most active at the age of 9-12 years and younger (5-8 year olds), or older (13-15 and 16-17 year-olds) children are less active. A similar pattern was found in the heart rate data of this study with the youngest children being the most active and the oldest children least active. The gradual drop in activity levels of children as they age is not fully understood. Research by Van Mechelen and colleagues (2000) suggests that this decrease is due to a reduction in non-organised sport as children age [26], whereas others using animal models suggests that at least part of this decline is a natural biological phenomenon [27]. Environmental, social and psychological factors are undoubtedly involved in this consistent pattern of activity decline in children, and highlights the need to have specific recommendations and guidelines for this population.

Geographical Location

Overall, children from rural schools were found to be more active than children from urban schools during school days but not in the weekends. Previous self-reported physical activity research reported similar results [28], but others have found no differences between these populations [29]. Factors associated with increased activity in rural children are likely to be due to chore-related activity levels and differences in socioeconomic status. For a full discussion on this topic see Hodgkin et al (2010) [30].

Limitations

Although heart rate monitoring has been used to successfully determine levels of habitual physical activity [11] some researchers have questioned the efficacy of using heart rate monitoring in physical activity studies because the rate reflects a number of factors, including the underlying metabolism, postural and psychological changes, atmospheric conditions, and the specific muscle groups used during the activity, ultimately making interpretation of the data, particularly at low intensities, difficult. The current study has not analysed low-intensity activity but concentrated on moderate-to vigorous intensity activity which may alleviate some of these problems.

In summary, this study provides the first national heart rate data for New Zealand children, indicating differences in physical activity across sex, age, and geographical groups. Children were significantly more active on school days compared to weekend days with most moderate and vigorous-intensity activity taking place during school hours. Furthermore, the results of this study offer additional evidence that significant numbers of New Zealand children are not achieving minimal physical activity standards which may potentiate significant health problems later in life. These finding support the development of a variety of policies and strategies to target the physical activity levels of young people.

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