

Objectively measured daily physical activity related to left ventricular seize in young children

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Abstract

Introduction: Training studies in children have revealed that endurance training can give enlargement of the left ventricle. This relationship has not been studied on a population-based level in young children with objective methods.

Materials and methods: Cross-sectional study of 248 children (140 boys and 108 girls), aged 8 to 11 year, from a population-based cohort. Left ventricular end-diastolic diameter (LVDD) and left atrial end-systolic diameter (LA) were measured with echocardiography and indexed for body surface area (BSA). Physical activity was assessed by accelerometry and the duration of vigorous activity per day (VPA) was calculated.

Results: Acceptable accelerometer and echocardiography measurements were obtained in 228 children (boys=127, girls=101). Univariate correlations between VPA and LVDD indexed for BSA ($r=0.27$, $P<0.05$) in boys and in girls ($r=0.10$, ns). Multiple regression analysis showed that independent factors for LVDD indexed for BSA for boys were age and VPA. LA indexed for BSA was not related to physical activity variables in either gender.

Conclusion: An independent, weak, relationship exists between LVDD and daily physical activity in boys, but not in girls. This suggests that a modest left ventricular remodelling due to the volume exposure secondary to a high amount of physical activity begins early in life in boys.

Introduction

In adults, intense endurance training leads to enlargement of left ventricular end-diastolic and left atrial end-systolic diameters (Pluim et al., 1999; Pellicca et al., 2002; Pellicca et al., 2005; Maron & Pelliccia, 2006). Whether alteration of cardiac dimensions secondary to high level of activity begins early in life has been debated. Studies of cardiac dimensions in young athletes compared to non-athletes have shown diverging findings, a majority of studies suggest that young athletes have larger cardiac dimensions compared to non-athletes (Allen et al., 1977; Medved et al., 1986, Obert et al., 1998; Triposkiadis et al., 2002; Ayabakan et al., 2006), but not all studies (Telford et al., 1988; Rowland et al., 1994). Furthermore, the results of various types of short-term endurance training programs have also been diverging, with no change in cardiac size (Ricci et al., 1982), whereas others have reported alterations in cardiac size (Geenan et al., 1982; Obert et al., 2001; Obert et al., 2003). The hypothesis that increased amount of daily physical activity may result in alterations of cardiac dimensions has also been evaluated in young subjects from the general population (Janz et al., 1996; Eisenmann et al., 2000), with diverging findings. Previous investigations (Janz et al., 1996; Eisenmann et al., 2000) have, however, used self-report methods to assess daily physical activity. Self-report methods are known to have limited accuracy in the measurement of daily physical activity in subjects of all ages and are considered inappropriate to use in children under the age of 10-12 years (Kohl et al., 2000; Harro & Riddoch, 2000; Sallis & Saelens, 2000). In this study accelerometers were used to obtain objective measurements of body movements per se (Troost, 2001) and then related to cardiac size. The purpose of the present investigation was to evaluate and for the first time present the relationship between cardiac dimensions and objectively measured daily physical activity in an urban sample of children.

Materials and Methods

Subjects and anthropometric measures

Recruitment of the study cohort has been presented previously (Dencker et al., 2006a, b, c; Dencker et al., 2007). In brief, 477 children (259 boys and 218 girls) in four different schools in Malmö, Sweden, received an invitation to participate in the study and 248 (140 boys and 108 girls) accepted the invitation. Standard height and body mass were measured in the laboratory with the child dressed in light clothing. Height was measured to the nearest 1.0 cm and body mass was measured to the nearest kg. Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared (kg/m^2). Height and body mass of all invited children were retrieved from the general health data registered by the school nurses, in order to evaluate if a selection bias had occurred. Body surface area (BSA) was calculated according to Du Bois and Du Bois (Du Bois and Du Bois, 1916). Puberty status was assessed by self-evaluation according to Tanner (Duke et al., 1980). The institutional ethics committee of Lund University, Sweden, approved the study. Written informed consent was obtained from the parents of all participating children.

Measurement of physical activity

Methodology of physical activity assessment has been previously presented in detail (Dencker et al., 2006a). In brief, an MTI model 7164 accelerometer (Manufacturing Technology Inc., Fort Walton Beach, FL, USA) was worn around the hip for four consecutive days. Epoch time is the timeframe during which accelerometer counts are averaged, thus the time resolution of the activity measurement. We choose an epoch time of 10 seconds in order to capture short bursts of activity since younger children's activity pattern tends to be random, sporadic and unsustained (Bailey et al., 1995). Children were excluded if they failed to achieve at least three days with

eight hours of valid registrations, after removal of missing data. Several physical activity variables were estimated. First, the overall physical activity was called general physical activity (GPA), and considered to be the total accelerometer counts per valid minute of monitoring (mean counts/min). Secondly, the time that the child was engaged in activity of different intensities was evaluated. Age and weight-specific cut-off points exist for accelerometer counts representing activity of varying intensities (Freedson et al., 1997; Trost et al., 1998). These cut-off points made it possible to estimate roughly the number of minutes the child was engaged in activity above a specific intensity threshold. The intensity was described as METs (metabolic equivalents). The time the child spent performing 3-6 METs was considered to reflect moderate physical activity (MPA), such as walking. The time spent above 6 METs was considered to reflect vigorous physical activity (VPA), such as running. Daily accumulation of moderate to vigorous physical activity (MVPA) was assessed by summing up MPA and VPA. Cut-off points used for all children were 167-583 counts/epoch for MPA and >583 counts/epoch for VPA (Freedson et al., 1997; Trost et al., 1998).

Echocardiography

Methodology of the echocardiographic examination has been previously presented (Dencker et al., 2007). In brief, the studies were performed by highly trained echo technicians with 2-dimensional guided M-mode echocardiography obtained in the parasternal short and long-axis views, in accordance with the recommendations by the American Society of Echocardiography (Lang et al., 2005). End-diastolic left ventricular inner diameter (LVDD) and left atrial end-systolic diameter (LA) were measured and indexed for BSA (LVDDI and LAI), as suggested by Henry et al. (1978). We have previously reported low (<5%) intra- and interobserver variability (Dencker et al., 2007).

Statistics

All statistical analyses were performed using Statistica 5.0 (StatSoft Inc., Tulsa, OK, USA). Means and standard deviations (SD) were calculated for all variables. Univariate relationships between physical activity and fitness variables were assessed with Pearson correlation analysis. Student's t-test between means was used to analyse group differences. A value of $P < 0.05$ was regarded as a statistically significant difference. Multiple linear forward regression analysis was performed, if we found a univariate linear relationship, to evaluate the independent significant factors for LVDDI. Activity data (GPA, MVPA, or VPA) and potential confounders such as age and days of activity recording were introduced to the model.

Results

One hundred and eighty-three children (80%) achieved the full four days of at least eight hours of valid recording and 45 children (20%) achieved three days. Twenty children were excluded for failing to achieve at least three days of valid registrations. Echocardiography measurements were successfully obtained in all children. The final study population consisted of 228 children (Girls $n=101$, Boys $n=127$). Summary of age, anthropometrics, accelerometry, and echocardiography data for all children with valid measurements are shown in table 1. Boys were more physically active, had higher fitness level, and larger LVDD. The average time span between accelerometer evaluation and the echocardiographic examination was 8.2 ± 11.0 days. Univariate relationship between LVDDI vs. daily physical activity data for boys were; GPA ($r=0.21$, $P < 0.05$), MPA ($r=0.12$, ns), MVPA ($r=0.19$, $P < 0.05$), and VPA ($r=0.27$, $P < 0.05$). LAI was not significantly related to physical activity variables in boys; GPA ($r=0.12$, ns), MPA ($r=0.11$, ns), MVPA ($r=0.14$, ns), and VPA ($r=0.14$, ns). No significant relationships were detected between LVDDI

vs. daily physical activity data for girls; GPA ($r=-0.03$, ns), MPA ($r=-0.07$, ns), MVPA ($r=-0.02$, ns), and VPA ($r=0.10$, ns). LAI was not related to physical activity variables in girls; GPA ($r=-0.09$, ns), MPA ($r=0.03$, ns), MVPA ($r=0.00$, ns), and VPA ($r=-0.06$, ns). Multiple regression analysis in boys, with LVDDI as dependent variable and age, number of accelerometer recording days, and VPA as independent variables displayed an independent relation between LVDDI vs. VPA and age. VPA accounted for 7% of the variability of LVDDI. A summary of the regression analysis is displayed in table 2. A similar finding was found for GPA, which only accounted for 3% of the variability of LVDDI. No such independent relation was found for MVPA (data not shown). Both boys and girls were divided according to quartiles of LVDDI (lower, two middle and upper), separately. VPA data (min) for boys in the respective quartile were; 39 ± 23 , 47 ± 16 and 49 ± 16 ($P<0.05$ between lower and upper quartile). Corresponding values for girls were; 34 ± 13 , 35 ± 13 and 36 ± 16 (ns between lower and upper quartile).

Discussion

The main finding of the present study was that an independent, although weak, relationship between LVDDI and daily physical activity existed in boys. No such relation could be detected in girls or for LAI in either gender. The cross-sectional design gives, however, no information about causality. Furthermore, genetic and hormonal factors have been linked to cardiac size at a young age (Verhaaren et al., 1991; Janz et al., 1996). These factors may modify the relation between LVDDI and physical activity. It is not possible for the present study to address this since we have not data to present. It is reasonable to presume that hormonal factors shouldn't be of major importance since very few of the children had entered puberty.

Previous investigations on the effects of training on cardiac dimensions during childhood have

shown diverging findings. Some studies indicate that some cardiac dimensions are greater in young athletes than in non-athletes (Allen et al., 1977; Medved et al., 1986, Obert et al., 1998; Triposkiadis et al., 2002; Ayabakan et al., 2006). Others have not found such differences (Telford et al., 1988; Rowland et al., 1994). Furthermore, the results of various types of short-term endurance training programs have been diverging where some studies have shown alteration of various cardiac dimensions (Geenan et al., 1982; Obert et al., 2001; Obert et al., 2003), but not all studies (Ricci et al., 1982). It is perhaps not surprising that different studies generate different results and this could in part be related to sample size, selection criteria, and in intervention studies to type of exercise protocol. One also has to keep in mind that any alteration of a given cardiac dimension secondary differences in physical activity levels may be of a modest magnitude at a young age, and therefore difficult to detect if appropriate sample size is not applied.

Few population studies on younger children exist in which the relationship between daily physical activity and cardiac size have been evaluated (Janz et al., 1996; Eisenmann et al., 2000). No relationship was found ($r=0.00$ in boys and -0.09 in girls, both ns) between left ventricular mass indexed for BSA (LVMI) and questionnaire assessed physical activity in 124 children aged 8-12 years participating in the Muscatine Study (Janz et al., 1996). Eisenmann et al. (2000) found that questionnaire-estimated energy expenditure related to echocardiographic LVMI in 74 boys aged 9-12 years ($r=0.24$, $P<0.05$), whereas no such relation was found for MVPA. No relation was found between LVMI and questionnaire-estimated energy expenditure and MVPA in 53 girls. Neither study reported data on LVDDI or LAI (Janz et al., 1996; Eisenmann et al., 2000).

Several authors have speculated about a “critical threshold” of exercise intensity that may exist

for inducing cardiac enlargement (Telford et al., 1988; Janz et al., 1996; Eisenmann et al., 2000). Only one study has examined the influence of intensities on the development of cardiac enlargement (Eisenmann et al., 2000). Eisenmann et al. (2000) found that questionnaire-estimated energy total expenditure related to LVMI in boys, not time in MVPA. The present investigation only partly supports the “critical threshold” hypothesis. We found an independent relation between LVDDI vs. GPA or VPA, but not for MPA or MVPA, in boys. This finding suggests that it is not only volume of activity but also intensity of activity that may lead to alteration of LVDDI. However, VPA accounted only for 7% of the variability of LVDDI in boys, if this represents a biologically significant relation is not clear. The fact that an independent relation only existed in boys and only for GPA or VPA, could have been attributed to significantly higher physical activity level among boys. We did not find any relation between LAI and physical activity variables for neither gender. The lack of association between physical activity and LVDDI in girls and LAI in both genders contradicts the findings in adult endurance-trained athletes of both genders (Pluim et al., 1999; Pellicca et al., 2002; Pellicca et al., 2005; Maron & Pelliccia, 2006). Only one older study on young athletes (Medved et al., 1986) and only one smaller recent study (Triposkiadis et al., 2002) have found enlargement of LA. No intervention study or population-based study on physical activity, including ours, have found enlargement of LA. This suggests that there are, in younger boys, differences in the susceptibility between LVDD and LA for dilatation secondary to high amounts of physical activity. A possible explanation to this finding is the fact that the LA mainly serves as a conduit, since LA contraction has minimal contribution to left ventricular filling in younger children.

Accelerometer-measured physical activity represents a substantial improvement compared to

self-report methods (Kohl et al., 2000; Harro & Riddoch, 2000; Sallis & Saelens, 2000). Children of this age tend to have a highly intermittent activity pattern (Bailey et al., 1995) and the use of a short epoch should be of advantage to capture short bursts of VPA. One limitation of using the shorter epoch is that this type of accelerometer can only record for four consecutive days, thus the price for a higher time resolution is a shorter observation time.

Many previous studies that have evaluated left ventricular size in the context with physical activity have used left ventricular mass (LVM) as measure. This is problematic since M-mode measured LVM has been shown to have poor reproducibility. Considerable intra- and interobserver variability of 15-30% has been reported (Gottdiener et al., 1995; de Simone et al., 1999; Muiesan et al., 2006), and this has been suggested as a major limitation for measurement of LVM on an individual basis. In contrast, substantially lower intra- and interobserver variability for measurement of LVDD and LA have been reported (Pellicca et al., 2002; Pellicca et al., 2005). Our practice of only using the diameter measurement should have been of advantage when it comes to acquiring an accurate measurement. Since we restricted our measurements to the diameter of the left ventricle, this study provides information only on this aspect of remodelling and not on the mass aspect.

The inclusion frequency in this study of 52% might be considered somewhat low, but a separate study of anthropometric data from all children that received an invitation to participate in the study showed no significant differences in height, body mass or BMI between the children that chose to participate and those who did not (Dencker et al., 2006c). This suggests that no fundamental selection bias occurred and a fairly representative cross-sectional sample of urban Swedish children, aged 8-11 years, participated.

Perspective

The findings from this population-based cohort of young children show that an independent, weak, relationship exists between heart size and amount of vigorous daily physical activity in boys. No such relation was found for total amount of daily physical activity or activity of lower threshold. This suggests that heart muscle remodelling due to the volume exposure secondary to a high amount of vigorous physical activity may begin early in life in boys. For girls, physical activity had no significant relation to cardiac size suggesting a gender difference at this age. Left atrial size had no significant relation to physical activity variables in neither boys nor girls.

References

Allen H, Goldberg S, Sahn D, Schy N, Wojcik R. A quantitative echocardiographic study of champion childhood swimmers. *Circulation* 1977; 55:142-145.

Ayabakan C, Akalin F, Mengütay S, Cotuk B, Odabas I, Oziak A. Athlete's heart in prepubertal male swimmers. *Cardiol Young* 2006; 16: 61-66.

Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc* 1995; 27: 1033-1041.

Dencker M, Thorsson O, Karlsson M.K, Lindén C, Svensson J, Wollmer P, Andersen L.B. Daily physical activity in Swedish children aged 8-11 years. *Scand J Med Sci Sports* 2006a; 16: 252-257.

Dencker M, Thorsson O, Karlsson M.K, Lindén C, Svensson J, Wollmer P, Andersen L.B. Daily physical activity and its relation aerobic fitness in children aged 8-11 years. *Eur J Appl Physiol* 2006b; 96: 587-592.

Dencker M, Thorsson O, Karlsson M.K, Lindén C, Eiberg S, Wollmer P, Andersen L.B. Daily physical activity related to body fat in children aged 8-11 years. *J Pediatr* 2006c; 149: 38-42.

Dencker M, Thorsson O, Karlsson M.K, Lindén C, Eiberg S, Wollmer P, Andersen L.B. Gender differences and determinants of aerobic fitness in children aged 8-11 years. *Eur J Appl Physiol* 2007; 99: 19-26.

de Simone G, Muiesan ML, Ganau A, Longhini C, Verdecchia P, Palmieri V, Agabiti-Rosei E, Mancia G. Reliability and limitations of echocardiographic measurement of left ventricular mass for risk stratification and follow-up in single patients: the RES trial. Working Group on Heart and Hypertension of the Italian Society of Hypertension. Reliability of M-mode Echocardiographic Studies. *J Hypertens* 1999; 17: 1955-1963.

Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known. *Arch Intern Med* 1916; 17: 863-871.

Duke PM, Litt IF, Gross RT. Adolescents' self-assessment of sexual maturation. *Pediatrics* 1980; 66: 918-920.

Eisenmann JC, Katzmarzyk PT, Theriault G, Song TM, Malina RM, Bouchard C. Cardiac dimensions, physical activity, and submaximal working capacity in youth of the Quebec Family Study. *Eur J Appl Physiol* 2000 81: 40-46.

Freedson PS, Sirard J, Dehold E, Pate R, Dowda M, Trost S, Sallis J. Calibration of the Computer Science and Applications, Inc. (CSA) accelerometer. *Med Sci Sports Exerc* 1997; 29 (suppl): S45.

Geenan D, Gilliam T, Crowley D, Moorehead-Steens C, Rosenthal A Echocardiographic measures in 6- to 7-year-old children after an 8 month exercise program. *Am J Cardiol* 1982; 49:1990-1995.

Gottdiener JS, Livengood SV, Meyer PS, Chase GA. Should echocardiography be performed to assess effects of antihypertensive therapy? Test-retest reliability of echocardiography for measurement of left ventricular mass and function. *J Am Coll Cardiol* 1995; 25: 424-430.

Harro M, Riddoch C. Physical activity. In: Armstrong N, van Mechelen W, eds. *Paediatric exercise science and medicine* (pp 77-84). Oxford University Press, Oxford, UK, 2000.

Henry WL, Ware J, Gardin JM, Hepner SI, McKay J, Weiner M. Echocardiographic measurements in normal subjects. Growth-related changes that occur between infancy and early adulthood. *Circulation*. 1978; 57: 278-285.

Janz K, Burns T, Mahoney L Predictors of left ventricular mass and resting blood pressure in children: The Muscatine Study. *Med Sci Sports Exerc* 1996; 27:818-825.

Kohl III HW, Fulton JE, Caspersen CJ. Assessment of physical activity among children and adolescents: a review and synthesis. *Prev Med* 2000; 31: S54-S76.

Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, Picard MH, Roman MJ, Seward J, Shanewise JS, Solomon SD, Spencer KT, Sutton MS, Stewart WJ; Chamber Quantification Writing Group; American Society of Echocardiography's Guidelines and Standards Committee; European Association of Echocardiography. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in

conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am Soc Echocardiogr* 2005; 18: 1440-1463.

Maron BJ, Pelliccia A. The heart of trained athletes: cardiac remodeling and the risks of sports, including sudden death. *Circulation* 2006; 114: 1633-1644.

Medved R, Fabecic-Sabadi V, Medved V. Echocardiographic findings in children participating in swimming training. *Int J Sports Med* 1986; 7: 94-99.

Muiesan ML, de Simone G, Ganau A, Longhini C, Verdecchia P, Mancia G, Agabiti-Rosei E; Working Group on Heart and Hypertension of Italian Society of Hypertension. Inappropriate left ventricular mass: Reliability and limitations of echocardiographic measurement for risk stratification and follow-up in single patients. *J Hypertens* 2006; 24: 2293-2298.

Obert P, Mandigouts S, Nottin S, Vinet A, N'Guyen LD, Lecoq AM. Cardiovascular responses to endurance training in children: effect of gender. *Eur J Clin Invest* 2003;33: 199-208.

Obert P, Mandigout S, Vinet A, N'Guyen LD, Stecken F, Courteix D. Effect of aerobic training and detraining on left ventricular dimensions and diastolic function in prepubertal boys and girls. *Int J Sports Med* 2001; 22: 90-96.

Obert P, Stecken F, Courteix D, Lecoq AM, Guenon P. Effect of long-term intensive endurance training on left ventricular structure and diastolic function in prepubertal children. *Int J Sports Med* 1998; 19: 149-154.

Pelliccia A, Maron BJ, De Luca R, Di Paolo FM, Spataro A, Culasso F. Remodeling of left ventricular hypertrophy in elite athletes after long-term deconditioning. *Circulation* 2002; 105: 944-949.

Pelliccia A, Maron BJ, Di Paolo FM, Biffi A, Quattrini FM, Pisicchio C, Roselli A, Caselli S, Culasso F. Prevalence and clinical significance of left atrial remodeling in competitive athletes. *J Am Coll Cardiol* 2005; 46: 690- 696.

Pluim BM, Zwinderman AH, van der Laarse A, van der Wall EE. The athlete's heart. A meta-analysis of cardiac structure and function. *Circulation* 1999; 100: 336-344.

Ricci G, Lajoie D, Petitclerc R, Peronnet F, Ferguson RJ, Fournier M, Taylor AW. Left ventricular size following endurance, sprint, and strength training. *Med Sci Sports Exerc* 1982; 14: 344-347.

Rowland T, Unnithan V, MacFarlane N, Gibson N, Paton J Clinical manifestations of the “athlete's heart” in prepubertal male runners. *Int J Sports Med* 1994; 15: 515-519.

Sallis JF, Saelens BE. Assessment of physical activity by self-report. Status, limitations, and future directions. *Res Q Exerc Sport* 2000; 71: 1-14.

Telford R, McDonald I, Ellis L, Chennells M, Sandstrom E, Fuller P. Echocardiographic dimensions in trained and untrained 12-year-old boys and girls. *J Sports Sci* 1988; 6: 49-57.

Tripodiadis F, Ghiokas S, Skoularigis I, Kotsakis A, Giannakoulis I, Thanopoulos V. Cardiac adaptation to intensive training in prepubertal swimmers. *Eur J Clin Invest* 2002; 32: 16-23.

Trost SG. Objective measures of Physical activity with youth: Current Issues, Future Directions. *Exerc Sport Sci Rev* 2001; 29: 32-36.

Trost SG, Ward DS, Moorehead SM, Watson PD, Riner W, Burke JR. Validity of the Computer Science and Applications (CSA) activity monitor in children. *Med Sci Sports Exerc* 1998; 30: 629-633.

Verhaaren HA, Schieken RM, Mosteller M, Hewitt JK, Eaves LJ, Nance WE. Bivariate genetic analysis of left ventricular mass and weight in pubertal twins (the Medical College of Virginia twin study). *Am J Cardiol* 1991; 68: 661-618.

Table 1. A summary of age, anthropometrics, accelerometry, and echocardiography data for all children with valid measurements (n=228). Values are mean \pm SD. General physical activity (GPA), moderate physical activity (MPA), moderate to vigorous physical activity (MVPA), vigorous physical activity (VPA), end-diastolic left ventricular inner diameter (LVDD), and left atrial (LA) diameter.

Variable	Girls (n=101)	Boys (n=127)	P-value
Age (yrs)	9.8 \pm 0.6	9.8 \pm 0.6	0.42 ns
Height (cm)	140.7 \pm 7.9	140.8 \pm 6.8	0.90 ns
Body mass (kg)	34.8 \pm 7.6	34.7 \pm 7.7	0.93 ns
BSA (m ²)	1.17 \pm 0.14	1.17 \pm 0.14	0.96 ns
Duration of accelerometer recording (days)	3.8 \pm 0.4	3.8 \pm 0.4	0.98 ns
Duration of accelerometer recording per day (h)	11.9 \pm 1.3	11.9 \pm 1.4	0.75 ns
GPA (mean count/min)	618 \pm 154	752 \pm 2442	<0.001
MPA (min)	156 \pm 30	165 \pm 36	0.047
MVPA (min)	190 \pm 38	210 \pm 51	0.001
VPA (min)	35 \pm 13	46 \pm 20	<0.001
LVDD (mm)	40.9 \pm 3.0	42.1 \pm 3.4	0.007
LA (mm)	27.4 \pm 2.8	28.0 \pm 3.7	0.18 ns

Table 2. Summary of multiple regression analysis for boys (n=127) with left ventricular end diastolic diameter indexed for body surface area (LVDDI) as dependent variable and age, number of accelerometer recording days, and minutes of vigorous activity per day (VPA) as independent variables.

Value	BETA	SE BETA	Accumulated r ²	p-value
Age	-0.270	0.083	0.08	0.001
VPA	0.255	0.083	0.15	0.002