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Associations of Vigorous-intensity Physical Activity with Biomarkers in Youth

Justin B. Moore[1], **Michael W. Beets**[2], **Keith Brazendale**[2], **Steven N. Blair**[2,3], **Russell R. Pate**[2], **Lars B. Andersen**[4], **Sigmund A. Anderssen**[5], **Anders Grøntved**[4], **Pedro C. Hallal**[6], **Katarzyna Kordas**[7], **Susi Kriemler**[8], **John J. Reilly**[9], and **Luis B. Sardinha**[10]

[1]Wake Forest School of Medicine, Department of Family and Community Medicine, Winston-Salem, North Carolina, US [2]University of South Carolina, Arnold School of Public Health, Department of Exercise Science, Columbia, South Carolina, US [3]University of South Carolina, Arnold School of Public Health, Department of Epidemiology and Biostatistics, Columbia, South Carolina, US [4]University of Southern Denmark, Department of Sport Science and Clinical Biomechanics, Odense, Denmark [5]Norwegian School of Sport Science, Department of Sport Medicine, Oslo, Norway [6]Federal University of Pelotas, Pelotas, Brazil [7]University of Bristol, School of Social and Community Medicine, Bristol, UK [8]University of Zürich, Epidemiology, Biostatistics and Public Health Institute, Zürich, Switzerland [9]University of Strathclyde, Physical Activity for Health Group, School of Psychological Sciences and Health, Glasgow, UK [10]Exercise

Address correspondence to: Justin B. Moore, PhD, MS, FACSM, Associate Professor Department of Family & Community Medicine, Wake Forest School of Medicine, Wake Forest Baptist Medical Center. Winston-Salem, NC 27157, jusmoore@wakehealth.edu 336.716.3702.

ICAD Collaborators

The ICAD Collaborators include: Prof LB Andersen, University of Southern Denmark, Odense, Denmark (Copenhagen School Child Intervention Study (CoSCIS)); Prof S Anderssen, Norwegian School for Sport Science, Oslo, Norway (European Youth Heart Study (EYHS), Norway); Prof G Cardon, Department of Movement and Sports Sciences, Ghent University, Belgium (Belgium Pre-School Study); Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCHS), Hyattsville, MD USA (National Health and Nutrition Examination Survey (NHANES)); Prof A Cooper, Centre for Exercise, Nutrition and Health Sciences, University of Bristol, UK (Personal and Environmental Associations with Children's Health (PEACH)); Dr. R Davey, Centre for Research and Action in Public Health, University of Canberra, Australia (Children's Health and Activity Monitoring for Schools (CHAMPS)); Prof U Ekelund, Norwegian School of Sport Sciences, Oslo, Norway & MRC Epidemiology Unit, University of Cambridge, UK; Dr. DW Esliger, School of Exercise and Health Sciences, Loughborough University, UK; Dr. K Froberg, University of Southern Denmark, Odense, Denmark (European Youth Heart Study (EYHS), Denmark); Dr. P Hallal, Postgraduate Program in Epidemiology, Federal University of Pelotas, Brazil (1993 Pelotas Birth Cohort); Prof KF Janz, Department of Health and Human Physiology, Department of Epidemiology, University of Iowa, Iowa City, US (Iowa Bone Development Study); Dr. K Kordas, School of Social and Community Medicine, University of Bristol, UK (Avon Longitudinal Study of Parents and Children (ALSPAC)); Dr. S Kriemler, Institute of Social and Preventive Medicine, University of Zürich, Switzerland (Kinder-Sportstudie (KISS)); Dr. A Page, Centre for Exercise, Nutrition and Health Sciences, University of Bristol, UK; Prof R Pate, Department of Exercise Science, University of South Carolina, Columbia, US (Physical Activity in Pre-school Children (CHAMPS-US) and Project Trial of Activity for Adolescent Girls (Project TAAG)); Dr. JJ Puder, Service of Endocrinology, Diabetes and Metabolism, Centre Hospitalier Universitaire Vaudois, University of Lausanne, Switzerland (Ballabeina Study); Prof J Reilly, Physical Activity for Health Group, School of Psychological Sciences and Health, University of Strathclyde, Glasgow, UK (Movement and Activity Glasgow Intervention in Children (MAGIC)); Prof J Salmon, School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia (Children Living in Active Neigbourhoods (CLAN)); Prof LB Sardinha, Exercise and Health Laboratory, Faculty of Human Movement, Technical University of Lisbon, Portugal (European Youth Heart Study (EYHS), Portugal); Dr. LB Sherar, School of Sports, Exercise and Health Sciences, Loughborough University, UK; Dr. A Timperio, Centre for Physical Activity and Nutrition Research, Deakin University Melbourne, Australia (Healthy Eating and Play Study (HEAPS)); Dr. EMF van Sluijs, MRC Epidemiology Unit, University of Cambridge, UK (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people (SPEEDY)).

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and Health Laboratory, CIPER, Faculty of Human Kinetics, University of Lisbon, Cruz-Quebrada, Portugal

Abstract

Introduction—Physical activity (PA) conveys known cardiometabolic benefits to youth, but the contribution of vigorous-intensity PA (VPA) to these benefits is unknown. Therefore, we sought to determine, a) the associations between VPA and cardiometabolic biomarkers independent of moderate-intensity PA (MPA) and time sedentary, and b) the accelerometer cutpoint that best represents the threshold for health-promoting VPA in youth.

Methods—Data from the International Children's Accelerometry Database (ICAD) were analyzed in 2015. The relationship between cardiometabolic biomarkers and 4 categories of VPA estimated via 3 sets of cutpoints were examined using isotemporal substitution quantile regression modeling at the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile of the distribution of each biomarker, separately. Age, sex, accelerometer wear time, sedentary time, and MPA were controlled for while allowing substitution for light-intensity PA. Data from 11,588 youth (4-18yrs) from 11 ICAD studies (collected 1998-2009) were analyzed.

Results—Only 32 of 360 significant associations were observed. Significant, negative relationships were observed for VPA with waist circumference and insulin. Replacing light intensity PA with VPA (corresponding to at the 25^{th} to 90^{th} percentiles of VPA) was associated with a .67 (-1.33, -0.01; P = .048) to 7.30cm (-11.01, -3.58; P < .001) lower waist circumference using Evenson and ICAD cutpoints (i.e., higher CPM). VPA levels were associated with 12.60 (-21.28, -3.92; P = .004) to 27.03 pmol/l (-45.03, -9.03; P = .003) lower insulin levels at the 75^{th} to 90^{th} percentiles using Evenson and ICAD cutpoints when substituted for light PA.

Conclusions—Substituting light PA with VPA was inversely associated with waist circumference and insulin. However, VPA was inconsistently related to the remaining biomarkers after controlling for time sedentary and MPA.

Keywords

Movement; cardiometabolic; adiposity; insulin

Introduction

Emerging research utilizing international samples (7, 17) has indicated that many children globally are spending an insufficient amount of time engaging in physical activity (PA) and an excessive amount of time engaging in sedentary behaviors. Engaging in international guideline recommendations (38) of 60 minutes per day (min/day) of moderate-to-vigorous physical activity (MVPA) is inversely associated with biomarkers of cardiometabolic health (13, 25) including lower rates of obesity (17) independent of time spent sedentary. While the benefits of MVPA are well established cross-sectionally (7) and longitudinally (6), few studies of PA in youth have examined the contribution of specific intensities to the association, despite a growing body of literature that suggests that vigorous-intensity physical activity (VPA) may be more important for the prevention and amelioration of

cardiometabolic risk factors (13, 39). A small number of studies have employed an objective measure of PA to examine associations with cardiometabolic biomarkers. These studies suggest that VPA is independently associated with cardiorespiratory fitness (positive) (23), BMI (negative) (17), adiposity (negative) (32), HDL cholesterol (positive) (22), fasting glucose (negative) (31), and fasting insulin (negative) (1). However, an extensive examination of the literature suggests that the relationship between VPA and cardiometabolic biomarkers is inconsistent, potentially due to small samples, definition of VPA, and other methodological limitations (11).

Complicating examinations of the relations between VPA and cardiometabolic biomarkers is an issue of measurement of VPA, or more specifically, the threshold for which VPA occurs. While imperfect, accelerometers are still considered one of the best objective measures available for epidemiological studies of PA (5, 28), but the processing of data generated by accelerometers (e.g., “counts”) lacks uniformity or consistency across studies (18), which can lead to misclassification of exercise intensity (12) and/or lack of comparability across studies (3, 4). Since the choice of cutpoint is a de facto selection of an intensity threshold with all other sources of variability held constant (e.g., monitor brand, epoch), and no standard exists for the VPA cutpoint, it is imperative to consider a range of accelerometer cutpoints for VPA if the relationship between VPA and cardiometabolic biomarkers is to be studied.

The benefits of MVPA in youth are well established, but little research has been conducted to examine the contribution of PA intensity in cardiometabolic health in youth. Therefore, the objective of the present investigation was to determine, a) the associations between VPA and cardiometabolic biomarkers independent of moderate physical activity (MPA) and sedentary time, and b) the accelerometer cutpoint that best represents the threshold for health-promoting VPA in a diverse sample of youth.

Materials/Subjects and Methods

Study Design

Data were utilized from the International Children’s Accelerometry Database (ICAD, http://www.mrc-epid.cam.ac.uk/Research/Studies/), which was established to pool data on PA from studies in youth worldwide. A comprehensive description of the ICAD can be found elsewhere (34). Briefly, in 2008 19 studies were identified from a PubMed search that used an Actigraph (Actigraph, LLC, Pensacola, FL, USA) accelerometer and included a minimum of 400 participants aged 3 to 18 years. Six additional studies were identified through professional colleagues, with 21 studies ultimately contributing data to the final database (7, 34). For the current study, 11 studies were included (7, 34), which are presented in brief with the variables each contributed in Table 1 [details of the Avon Longitudinal Study of Parents and Children (ALSPAC) are available at www.bris.ac.uk/alspac and including the data that are available via a fully searchable data dictionary (http://www.bris.ac.uk/alspac/researchers/data-access/data-dictionary)]. Ethical approval for the present study was attained from participating institutions, and data-sharing agreements were established prior to contribution of data.

Participants

Data from 11,588 youth (4-18yrs), representing 11 studies from Brazil, Europe, and the United States from the ICAD were analyzed. Data from studies conducted between 1998 and 2009 were included in the present analyses if the dataset contained PA, age, sex, and at least one biomarker of a cardiometabolic risk [defined as "A characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention" (2)].

Measurements

Physical activity—A comprehensive description of the measurement of PA has been published previously (34). ICAD data were reanalyzed to allow for comparability across studies by aggregating data to a 60-second epoch. The criterion of 60 minutes of consecutive zeros was utilized to designate non-wear time, with a tolerance for 2 minutes of nonzero epochs (35). Participants with three or more days with 600 minutes of valid wear time were included in analyses. VPA was defined by cutpoints from Pate (26), Evenson (8), and the ICAD workgroup (7, 34). These cutpoints were selected because they represent the most generous, lowest threshold defining VPA [Pate ≥ 3,365 counts/min (CPM)], a medium threshold (Evenson ≥ 4,012 CPM), to the most stringent, highest threshold for VPA (ICAD ≥ 6,000 CPM).

Cardiometabolic biomarkers—Eight cardiometabolic biomarkers reflecting a diverse array of health indices were collected, including; waist circumference [as a proxy for adiposity (30)]; systolic and diastolic blood pressure (hemodynamics); high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, fasting triglycerides (lipid metabolism); fasting glucose and fasting insulin (glucose metabolism). Details of data collection procedures can be found elsewhere (7, 34). Waist circumference (WC) was assessed midway between the lower rib margin and the iliac crest using a metal tape (10), except in the NHANES (National Health and Nutrition Examination Survey) where WC was measured just above the iliac crest at the mid-axillary line using similar equipment (36). Resting blood pressure was measured using standard procedures, reported previously (7). Markers of lipid and glucose metabolism were assessed using standard clinical procedures described in detail elsewhere (36).

Statistical Analysis

Descriptive analyses of accelerometer-derived estimates of min·day^{-1} spent in sedentary, MPA, and VPA were computed across all studies using three sets of cutpoints to define PA intensities. To evaluate the cross-sectional association of cardiometabolic biomarkers and time spent in VPA, a series of isotemporal substitution quantile regression models were estimated for each set of cutpoints separately (20, 21, 40). Quantile regression models were employed since biomarkers are often non-normal in their distribution, and quantile regression models are not influenced by normality and are free from distributional assumptions (19). Individual models for each biomarker as the dependent variable were estimated. Time spent in VPA, defined by one of the 3 sets of cutpoints, separately, served as the primary independent variable. Because of its non-normal distribution, min·day^{-1} spent in

VPA was placed into 4 categories – none (0mins/d – reference category), low (lower 33%), middle (middle 33%), and high (upper 33%) – based on the distribution of VPA for each of the 3 sets of cutpoints. The relationship between cardio-metabolic biomarkers and 4 categories of VPA min/d [none (0 min/d – reference category), low (7.2_{Pate}, $4.0_{Evenson}$, 1.5_{ICAD} min/d), medium (18.6_{Pate}, $11.0_{Evenson}$, 3.5_{ICAD} min/d), and high (42.7_{Pate}, $28.9_{Evenson}$, 11.9_{ICAD} min/d)] estimated via 3 sets of cutpoints [Pate: sedentary = 0 - 152 counts/min (CPM), MPA = 1677 – 3364, VPA = ≥ 3,365 CPM; Evenson: sedentary = 0 - 100 CPM, MPA = 2296 – 4011, VPA = ≥ 4,012 CPM; and ICAD: sedentary = 0 - 100 CPM, MPA = 3000 – 6000, VPA = ≥ 6,001 CPM] —were examined using isotemporal substitution quantile regression modeled at the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles of the distribution of each biomarker. Included in each model were age (years), sex, average total daily wear time, and min·day^{-1} in sedentary and MPA distilled using the corresponding cutpoint for VPA. Since light PA (LPA) was the only intensity excluded from the models, all estimates are interpreted as substituting “x” amount of LPA with VPA. Separate models were estimated for each study and for each set of cutpoints used to define VPA within each study. An example of the modeling approach is: insulin serving as the dependent variable, with 3 separate models using VPA levels (i.e., low, middle and high, with no VPA as the referent group) reduced with each of the sets of cutpoints for each study, run separately. Statistical significance was set at P = .05.

Meta-analytical techniques were used to combine the quantile regression model coefficients and standard errors for each biomarker across the 11 studies for each of the 3 sets of cutpoints, separately. Random effects inverse variance weighting was used to pool effects across studies and within study for each set of cutpoints. The study served as the unit of analysis for each quantile and category of VPA. For instance, the VPA estimates representing the lowest 33^{rd} of the distribution of VPA regressed on the 10^{th} quantile of insulin were combined across all studies for a given biomarker. All quantile regression analyses were conducted in 2015 using Stata (v.13.0, College Station, TX) and all meta-analytic analyses were conducted using Comprehensive Meta-Analysis (v2.2, Englewood, NJ).

Results

Descriptive information for each study is presented in Table 2. The average amount of VPA min·day^{-1} for each set of cutpoints (highest to lowest) by tertile ranged from 1.5 to 7.2 min/day for the lowest tertile, the medium tertile 3.5 to 18.6 min/day, and the highest tertile 11.9 to 42.7 min/day. The results of the pooled meta-analytic effects for each quantile and level of VPA across each cardiometabolic biomarker are presented in the supplemental table (see Table, Supplemental Digital Content 1, Results of meta-analytical combination of quantile regression model coefficients and standard errors for each risk factor across the 11 studies for each of the three sets of accelerometer cutpoints)

Relationship of volume of VPA with cardiometabolic biomarkers

Substituting LPA with VPA was inconsistently related to systolic/diastolic blood pressure, fasting triglycerides, HDL, or LDL after controlling for time sedentary and MPA at all

tertiles of VPA volume, with only 32 of a possible 360 associations statistically significant ($P < .05$). Independent of min·day^{-1} spent sedentary and in MPA, substituting LPA with VPA was associated with a .67 to 7.30 cm smaller waist circumference at the 50th to 90th percentiles. Relationships were observed for all three tertiles of VPA, but relationships at the lowest tertile of VPA volume were significant at only the highest cutpoint value (i.e., ICAD). Substituting LPA with VPA was associated with 12.6 to 27.0 pmol/l lower insulin values at the 75th to 90th percentiles. Relationships were observed for all three tertiles of VPA, but relationships at the lowest tertile of VPA were significant at only the highest tertiles of VPA volume for the highest cutpoint value (i.e., ICAD).

Influence of cutpoint

Independent of min·day^{-1} spent sedentary and in MPA, substituting LPA with the high volume of VPA defined via Pate cutpoints was associated with a smaller waist circumference only at the 90th percentile. For VPA determined via Evenson cutpoints, substituting LPA for medium and high VPA levels were associated with a smaller waist circumference at the 25th to 90th centiles. Substituting LPA with the lowest, medium, and highest volumes of VPA reduced via ICAD cutpoints was associated with a smaller waist circumference at the 50th to 90th, the 75th and 90th, and the 25th to 90th, respectively. Across all other biomarkers (i.e., SBP, DBP, HDL, LDL, glucose, and triglycerides), no consistent associations or patterns were observed, with only 9 significant associations observed from a possible 270 tested (<5%; see Figure).

Discussion

The present study is the first of this scope (e.g., sample size, diversity of national origin) to examine the relationship between VPA and cardiometabolic biomarkers in youth. The results are consistent with previous studies using more homogeneous samples, such as Carson et al. (6) where no association was found between diastolic blood pressure and VPA, but a significant negative association was reported between waist circumference and VPA in children of the 2nd and 3rd quartiles (relative to the 1st). The more nuanced analyses presented here, taken with those of Carson et al. (6), provide additional insight into the complex relationship between VPA and cardiometabolic biomarkers (11, 25). The results suggest that substituting modest amounts of LPA for VPA may have cardiometabolic benefits above and beyond those conveyed by MPA and avoidance of sedentary behavior (24). Of potentially greater importance, the current results suggest that these health supportive associations are most pronounced in those who have undesirable levels of these biomarkers, specifically those with relatively large waist circumference or fasting insulin levels. If these relationships are found to be robust in longitudinal and experimental studies, then a specific frequency and duration of VPA could be incorporated as a distinct component of a PA “prescription” for youth (24). However, it must be noted that VPA was independently associated with only two of the markers examined. Therefore, while VPA may relay meaningful health benefits, the number of markers exhibiting those benefits may be few relative to less intense movement.

These results, taken with a growing body of literature demonstrating the independent health benefits of VPA for youth (6, 11, 14, 16, 17, 23, 24, 37), support the assertion that this intensity should be considered when setting policy recommendations for PA of youth. For example, it has been shown previously that as little as 9 (15) to 14 minutes (17) of VPA per day is associated with less adiposity in Canadian (15) and multinational samples of youth (17). These previous findings, derived from independent samples, are consistent with the present findings showing an association of substituting 11.9 to 42.7 min/day of LPA for VPA. While this is a considerable range, with the top end (42.7 min/day) potentially impractical, consistent benefits were seen for VPA defined by the ICAD cutpoints, which even in the high volume category represented 11.9 min/day of VPA, is potentially achievable for most youth (39). Therefore, the present findings suggest a modest duration (e.g., approximately 10 min) of high intensity PA may be related to health benefits in youth who exhibit undesirable levels of insulin or waist circumference.

While the present study has a number of strengths, including an objective measure of PA, a large sample size, a diverse and international sample, and an advanced analytical approach, the present results should be considered in light of a number of limitations. First, all data were cross-sectional in nature, therefore causality cannot be assumed. For example, it is possible that children with smaller waist circumference are more vigorously active because it is less cumbersome for them to do so. However, the nature of our analyses, which examined the relationship of VPA and waist circumference at different quantiles of waist circumference, is less supportive of this possibility. Second, while these cross-sectional results are supportive of VPA specific PA recommendations for youth, it is unknown if changes in youth VPA levels will result in meaningful changes in diastolic blood pressure, HDL, cholesterol, insulin or adiposity. While a recent study is supportive of the latter three (29), the literature is mixed on the relationship between increased VPA and blood pressure (9, 11, 27, 33), and very few studies have examined the responsiveness of insulin or other markers of glucose metabolism (11, 13). Third, the database we utilized lacks standardized dietary data or genetic data that might confound the observed relationships. For example, children with higher levels of VPA may consume fewer calories, or possess a genetic make-up supportive of a positive biomarker profile. This possibility cannot be ruled out using the currently available data. Despite these limitations, this study represents one of the largest to date that examined VPA in relation to cardiometabolic biomarkers in youth.

In summary, the present results suggest few significant or clinically meaningful associations between VPA and most cardiometabolic biomarkers studied in youth, but health promoting associations were observed between VPA and select cardiometabolic biomarkers (i.e., insulin, waist circumference), with the associations observed at higher levels of the biomarkers and higher volumes of VPA. As such, VPA may have unique metabolic health benefits beyond those conveyed by MPA or minimizing time spent sedentary. The present results also suggest that higher VPA cutpoints represent an intensity that is associated with healthier insulin levels and waist circumference. Future longitudinal and intervention studies are needed to determine the temporal relationship between these variables, the modifiability of VPA, and the effect of increased VPA on biomarkers in youth. If these results are indeed robust, then a less time consuming, more intense dose of PA may be a viable option for youth seeking to achieve or maintain cardiovascular health.

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Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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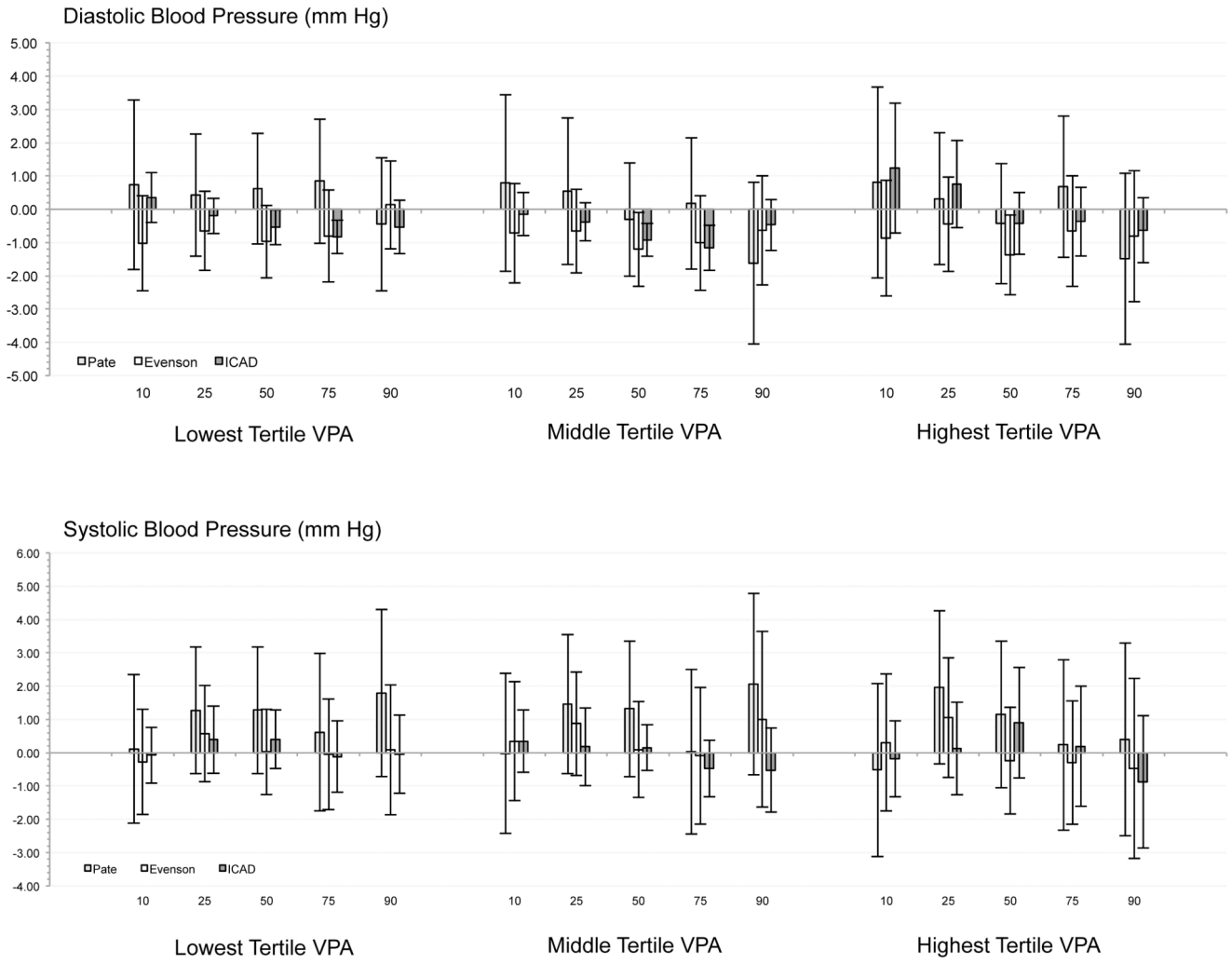

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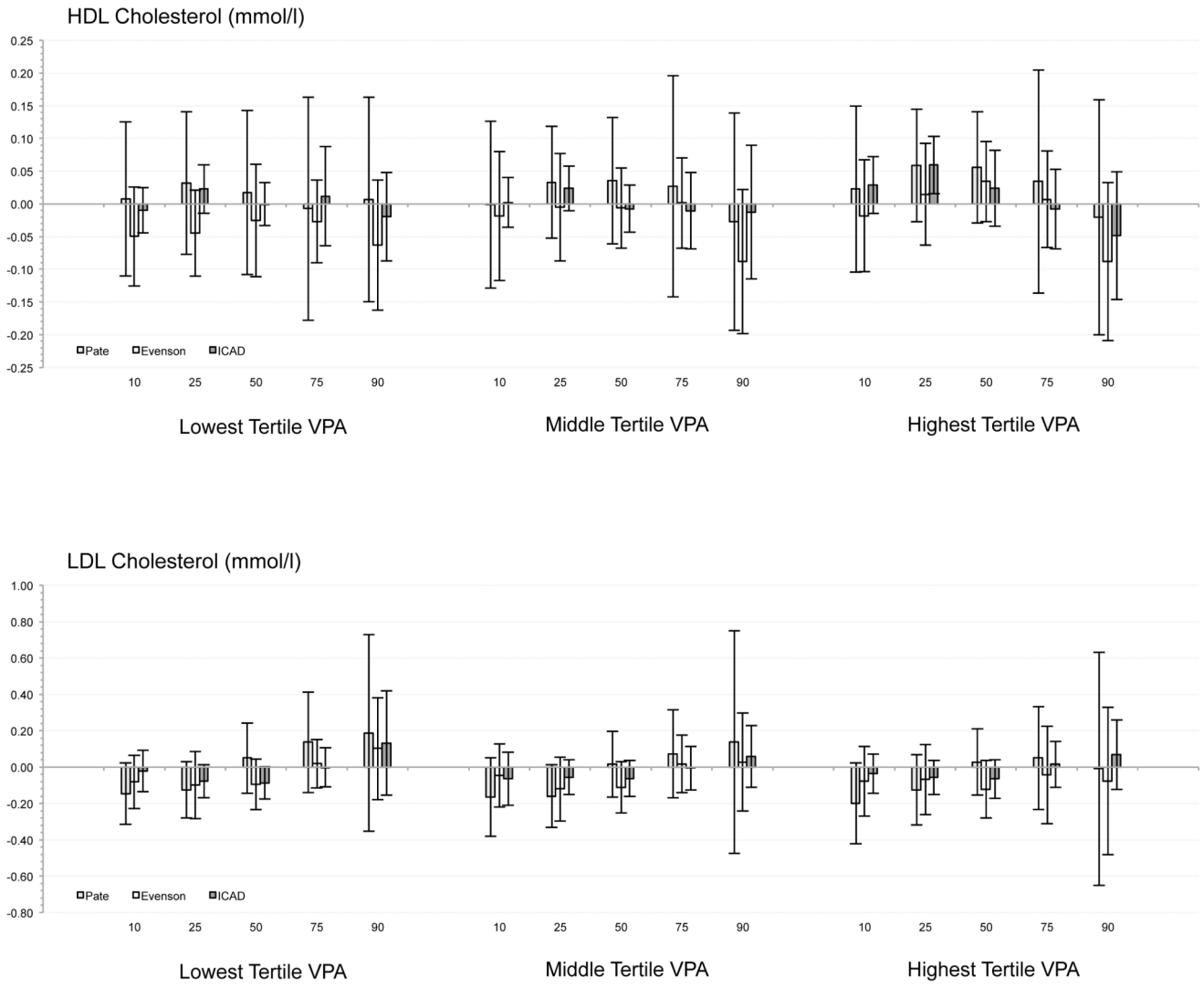

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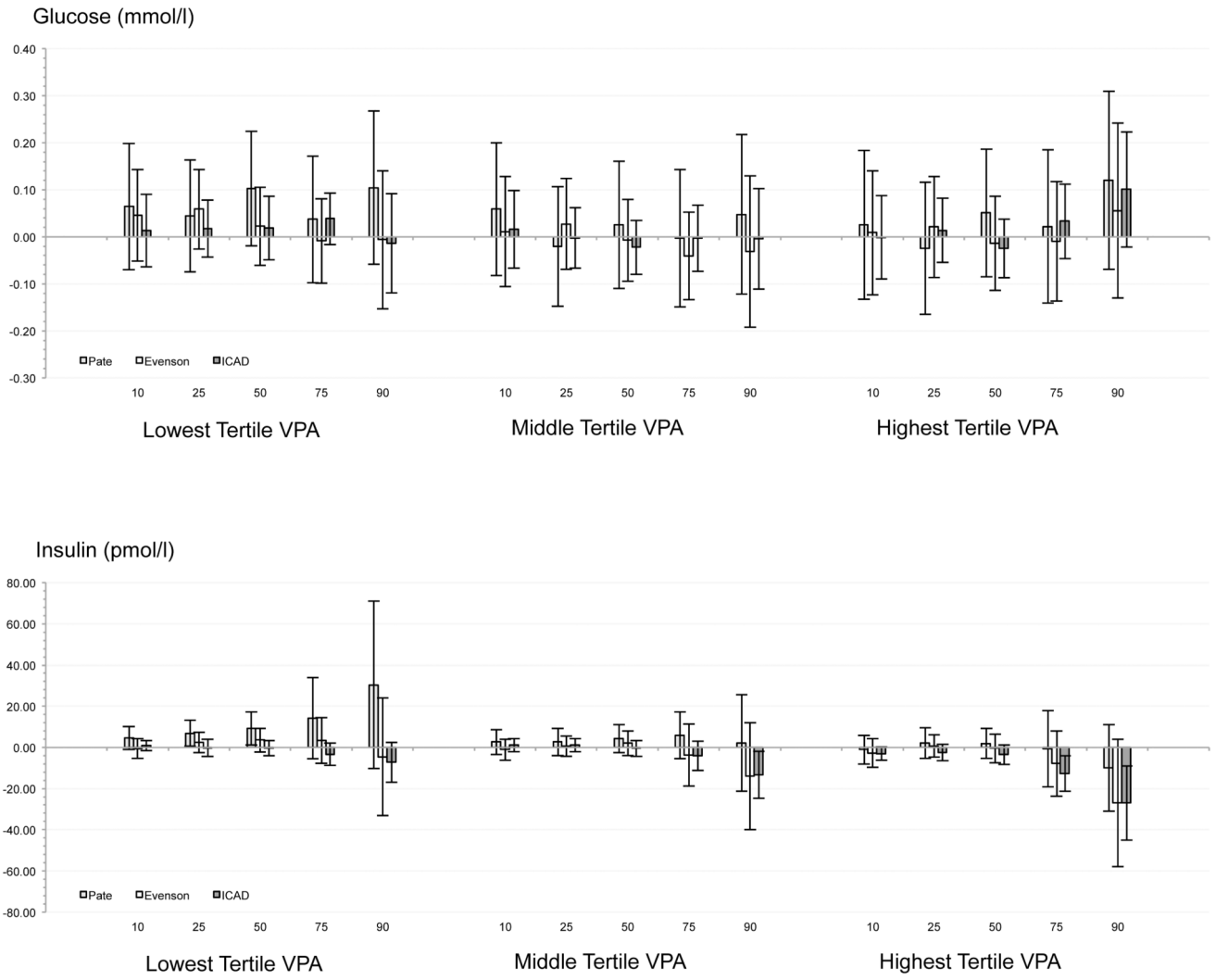

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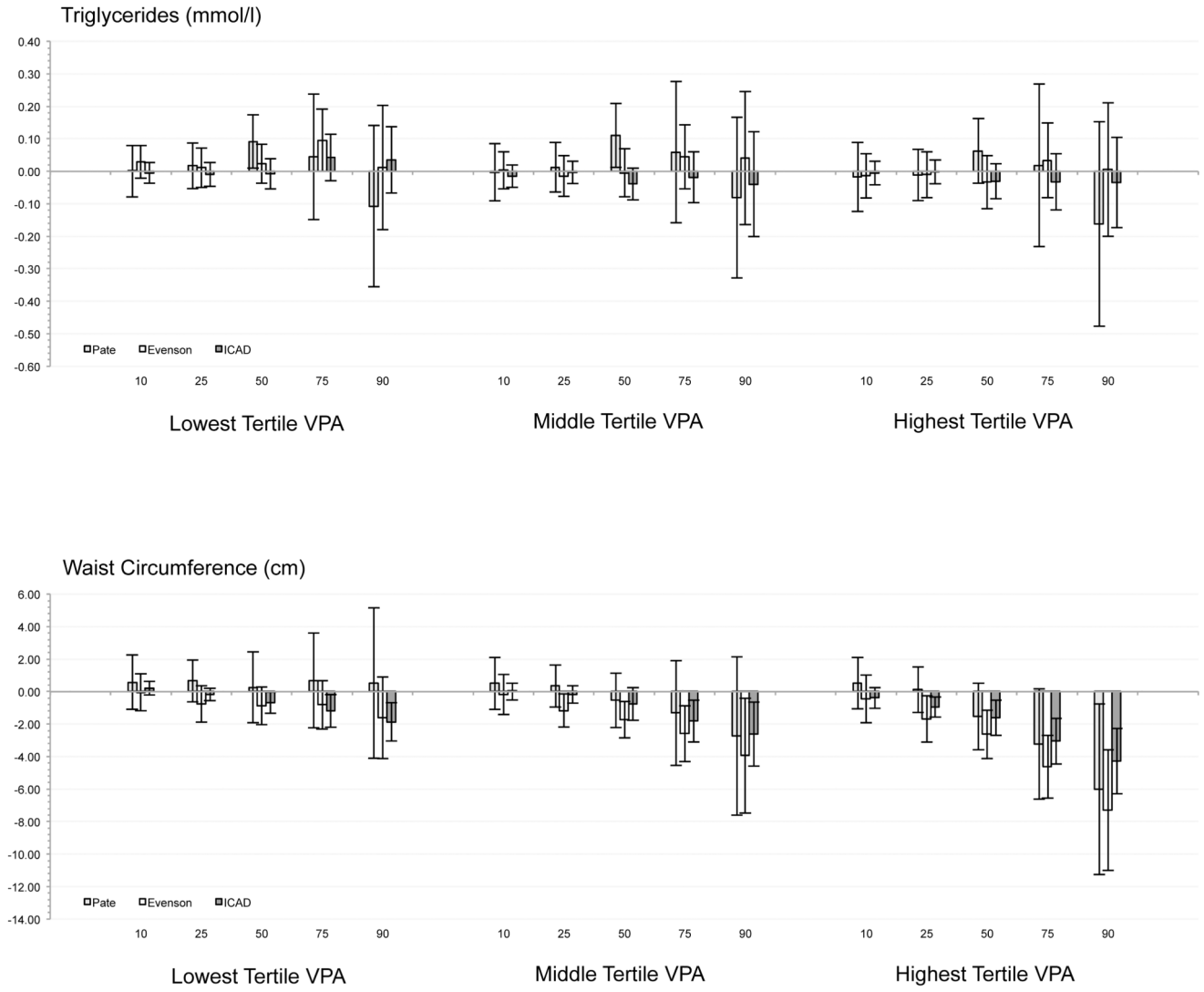

Figure.

Combination of quantile regression model coefficients and standard errors for each risk factor across the 11 studies for each of the three sets of accelerometer cutpoints.

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Table 1

List of studies contributing data with cardiometabolic biomarkers present in analytical dataset.

Study ID in the ICAD database	**1**	**4**	**5**	**6**	**9**	**10**	**11**	**12**	**14**	**15**	**20**	
Study	**ALSPAC**	**CoSCIS**	**DEYHS**	**EEYHS**	**MAGIC**	**NHANES (2005-6)**	**NEYHS**	**NHANES (2003-4)**	**Pelotas**	**PEYHS**	**KISS**	**Total # of studies contributing biomarker**
Biomarker												
Diastolic Blood Pressure (mm Hg)	•	•	•	•	•	•	•	•	•	•		10
Systolic Blood Pressure (mm Hg)	•	•	•	•	•	•	•	•	•	•		10
HDL Cholesterol (mmol/l)		•	•	•		•	•	•		•	•	8
LDL Cholesterol (mmol/l)		•	•	•		•	•	•		•	•	8
Glucose (mmol/l)		•	•	•		•		•		•	•	7
Insulin (pmol/l)		•	•	•		•		•		•	•	7
Triglycerides (mmol/l)		•	•	•		•	•	•		•	•	8
Waist Circumference (cm)	•	•	•	•	•	•	•	•	•	•	•	11
Number of Biomarkers Measured	3	8	8	8	3	8	6	8	3	8	6	

Abbreviations: ALSPAC, Avon Longitudinal Study of Parents and Children; CoSCIS, Copenhagen School Child Intervention Study; DEYHS: Denmark European Youth Heart Study; EEYHS: Estonia European Youth Heart Study; ICAD: International Children's Accelerometry Database; KISS, Kinder Sportstudie; MAGIC, Movement and Activity Glasgow Intervention in Children; NHANES, National Health and Nutrition Examination Survey; NEYHS: Norway European Youth Heart Study; Pelotas: Pelotas 1993 Birth Cohort; PEYHS: Portugal European Youth Heart Study; SPEEDY, Sport, Physical Activity and Eating Behavior: Environmental Determinants in Young People.

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Table 2

Descriptive statistics for demographic, physical activity, and cardiometabolic biomarkers variables by study.

Study	ALSPAC			CoSCIS			DEYHS			EEYHS			MAGIC			NHANES (2005-6)		
	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)
Sex (% male)	5340	52.8%		263	46.4%		1143	55.6%		436	57.8%		195	52.3%		1619	49.8%	
Age (years)	5340	11.74	(0.23)	263	9.54	(0.38)	1143	12.22	(2.95)	436	12.42	(3.00)	195	4.17	(0.31)	1619	12.54	(3.34)
Height (cm)	5312	150.68	(7.23)	262	139.78	(5.94)	1143	152.36	(16.59)	436	152.81	(17.45)	195	102.89	(4.26)	1618	152.00	(17.44)
Weight (kg)	5317	43.40	(9.84)	262	33.25	(5.59)	1143	45.30	(15.63)	436	44.56	(15.72)	195	17.26	(2.58)	1619	51.01	(20.72)
Physical Activity (min/day)																		
ICAD cutpoints																		
Sedentary time	5340	370.8	(71.3)	263	352.9	(74.6)	1143	412.0	(121.3)	436	373.5	(106.0)	195	226.4	(65.5)	1619	443.7	(127.5)
Moderate PA	5340	31.8	(17.9)	263	30.2	(14.6)	1143	25.1	(18.0)	436	33.4	(23.0)	195	23.1	(13.2)	1619	21.4	(16.0)
Vigorous PA	5340	4.0	(5.3)	263	4.7	(4.6)	1143	4.6	(6.3)	436	3.7	(5.9)	195	3.1	(3.3)	1619	4.1	(6.5)
Evenson cutpoints																		
Sedentary time	5340	370.8	(71.3)	263	352.9	(74.6)	1143	412.0	(121.3)	436	373.5	(106.0)	195	226.4	(65.5)	1619	443.7	(127.5)
Moderate PA	5340	40.5	(17.1)	263	42.3	(16.1)	1143	33.4	(19.9)	436	41.1	(24.5)	195	37.8	(16.7)	1619	30.1	(17.5)
Vigorous PA	5340	16.9	(13.1)	263	16.5	(10.9)	1143	14.8	(13.7)	436	17.9	(16.3)	195	11.3	(8.6)	1619	12.7	(12.8)
Pate cutpoints																		
Sedentary time	5340	412.3	(71.0)	263	390.0	(75.8)	1143	450.8	(120.7)	436	414.6	(108.0)	195	259.3	(69.5)	1619	483.0	(127.8)
Moderate PA	5340	58.4	(20.3)	263	66.5	(21.7)	1143	52.2	(27.9)	436	60.5	(33.0)	195	67.9	(24.2)	1619	49.7	(24.7)
Vigorous PA	5340	27.5	(17.5)	263	26.5	(14.7)	1143	22.9	(18.1)	436	28.3	(20.7)	195	19.2	(12.6)	1619	19.6	(16.7)
Diastolic Blood Pressure (mm Hg)	5250	58.69	(6.55)	262	61.36	(5.45)	1143	60.79	(6.19)	436	61.50	(7.27)	195	60.69	(6.53)	1402	57.75	(10.60)
Systolic Blood Pressure (mm Hg)	5250	105.43	(9.71)	262	103.66	(8.19)	1143	104.85	(9.99)	436	106.14	(10.80)	195	97.04	(7.63)	1411	107.06	(10.20)
HDL Cholesterol (mmol/l)	–	–	–	211	1.61	(0.35)	1088	1.51	(0.35)	430	1.43	(0.29)	–	–	–	1482	1.42	(0.34)
LDL Cholesterol (mmol/l)	–	–	–	211	2.33	(0.57)	1088	2.39	(0.64)	430	2.94	(0.70)	–	–	–	404	2.30	(0.67)
Triglycerides (mmol/l)	–	–	–	211	0.53	(0.23)	1088	0.82	(0.41)	430	0.78	(0.34)	–	–	–	404	0.90	(0.48)
Glucose (mmol/l)	–	–	–	214	4.82	(0.46)	1088	5.08	(0.39)	430	5.07	(0.38)	–	–	–	411	5.18	(0.46)
Waist Circumference (cm)	5314	67.96	(9.19)	262	61.89	(6.39)	1141	65.37	(9.16)	436	62.29	(7.94)	195	51.09	(4.07)	1602	73.35	(14.75)
Insulin (pmol/l)	–	–	–	206	5.74	(3.01)	1086	57.17	(36.76)	426	54.42	(31.83)	–	–	–	404	78.17	(56.57)

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Study	NEYHS			NHANES (2005-06)			Pelotas			PEYHS			KISS		
	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)	Number	M	(SD)
Sex (percent male)	274	51.1%		1507	48.8%		360	46.4%		807	51.2%		567	52.7%	
Age (years)	274	9.69	(0.32)	1507	12.71	(3.28)	360	13.32	(0.31)	807	11.28	(3.13)	567	9.94	(2.08)
Height (cm)	273	139.37	(6.39)	1496	153.52	(17.40)	360	158.18	(8.25)	806	144.24	(14.91)	564	139.81	(13.37)
Weight (kg)	273	33.20	(5.68)	1497	52.51	(20.68)	359	51.18	(12.11)	807	41.36	(14.43)	564	34.86	(10.38)
Physical Activity (min/day)															
ICAD cutpoints															
Sedentary time	274	346.5	(108.4)	1507	449.7	(134.5)	360	777.9	(107.5)	807	418.6	(105.6)	567	631.8	(181.6)
Moderate PA	274	36.2	(21.2)	1507	23.7	(17.4)	360	21.9	(16.1)	807	25.8	(19.2)	567	37.8	(18.9)
Vigorous PA	274	7.6	(10.4)	1507	4.4	(6.2)	360	0.6	(1.5)	807	2.2	(3.5)	567	5.5	(6.1)
Evenson cutpoints															
Sedentary time	274	346.5	(108.4)	1507	449.7	(134.5)	360	777.9	(107.5)	807	418.6	(105.6)	567	631.8	(181.6)
Moderate PA	274	45.6	(22.5)	1507	32.3	(17.8)	360	33.2	(20.7)	807	37.2	(21.9)	567	51.8	(18.7)
Vigorous PA	274	22.5	(17.5)	1507	14.0	(13.6)	360	7.7	(7.9)	807	11.8	(11.5)	567	20.3	(14.4)
Pate cutpoints															
Sedentary time	274	385.7	(109.0)	1507	488.5	(135.6)	360	818.0	(108.8)	807	454.9	(104.5)	567	672.8	(184.6)
Moderate PA	274	66.5	(29.5)	1507	51.6	(23.9)	360	49.5	(27.5)	807	57.8	(28.3)	567	78.9	(23.7)
Vigorous PA	274	34.0	(22.3)	1507	21.6	(18.1)	360	15.7	(12.9)	807	20.7	(17.2)	567	32.8	(18.9)
Diastolic Blood Pressure (mm Hg)	273	62.52	(5.96)	1299	57.87	(11.51)	360	68.40	(11.03)	807	55.74	(6.46)	–	–	–
Systolic Blood Pressure (mm Hg)	274	102.91	(7.76)	1315	106.20	(10.18)	360	110.71	(13.98)	807	98.23	(9.85)	–	–	–
HDL Cholesterol (mmol/l)	65	1.55	(0.32)	1420	1.42	(0.33)	–	–	–	788	1.57	(0.33)	566	1.63	(0.36)
LDL Cholesterol (mmol/l)	58	2.88	(0.96)	686	2.31	(0.69)	–	–	–	788	2.19	(0.60)	567	2.11	(0.61)
Triglycerides (mmol/l)	48	0.92	(0.33)	687	0.95	(0.54)	–	–	–	788	0.71	(0.33)	521	0.62	(0.27)
Glucose (mmol/l)	–	–	–	457	4.98	(0.48)	–	–	–	788	5.19	(0.44)	499	4.59	(0.39)
Waist Circumference (cm)	273	60.23	(5.42)	1485	74.18	(14.81)	359	68.71	(8.53)	806	64.28	(8.41)	559	59.57	(6.95)
Insulin (pmol/l)	–	–	–	448	70.75	(59.96)	–	–	–	787	36.24	(23.17)	500	7.39	(4.28)

Abbreviations: ALSPAC, Avon Longitudinal Study of Parents and Children; CSCIS, Copenhagen School Child Intervention Study; DEYHS: Denmark European Youth Heart Study; EEYHS: Estonia European Youth Heart Study; ICAD: International Children's Accelerometry Database; KISS, Kinder Sportstudie; MAGIC, Movement and Activity Glasgow Intervention in Children; NA, not available; NHANES, National Health and Nutrition Examination Survey; NEYHS: Norway European Youth Heart Study; PEACH, Personal and Environmental Associations with Children's Health; Pelotas: Pelotas 1993 Birth Cohort; PEYHS: Portugal European Youth Heart Study; SPEEDY, Sport, Physical Activity and Eating Behavior: Environmental Determinants in Young People.