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Why socially deprived populations have a faster resting heart rate: Impact of behaviour, life course anthropometry, and biology – the RECORD Cohort Study

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ABSTRACT

Although studies have shown that resting heart rate (RHR) is predictive of cardiovascular morbidity/mortality, few studies focused on the epidemiology and social aetiology of RHR. Using the RECORD Cohort Study (7158 participants, 2007–2008, Paris region, France), we investigated individual/neighbourhood socioeconomic variables associated with resting heart rate, and assessed which of a number of psychological factors (depression and stress), behaviour (sport-related energy expenditure, medication use, and alcohol, coffee, and tobacco consumption), life course anthropometric factors (body mass index, waist circumference, and leg length as a marker of childhood environmental exposures), and biologic factors (alkaline phosphatase and gamma-glutamyltransferase) contributed to the socioeconomic disadvantage–RHR relationship. Combining individual/neighbourhood socioeconomic factors in a socioeconomic score, RHR increased with socioeconomic disadvantage: +0.9 [95% credible interval (CrI): +0.2, +1.6], +1.8 (95% CrI: +1.0, +2.5), and +3.6 (95% CrI: +2.9, +4.4) bpm for the 3 categories reflecting increasing disadvantage, compared with the lowest disadvantage category. Twenty-one percent of the socioeconomic disadvantage–RHR relationship was explained by sport practise variables, 9% by waist circumference, 7% by gamma-glutamyltransferase, 5% by alkaline phosphatase, and 3% by leg length. Future research should further clarify the mechanisms through which socioeconomic disadvantage influences resting heart rate, as a pathway to social disparities in cardiovascular morbidity/mortality.

Introduction

Studies have shown that high resting heart rate (RHR) increases the risk of cardiovascular and total mortality in the general population and of fatal prognosis in coronary heart disease patients (Benetos, Rudnichi, Thomas, Safar, & Guize, 1999; Cook & Hess, 2009; Cook, Togni, Schaub, Wenaweser, & Hess, 2006). Thus, certain authors recently asked whether the artificial lowering of an abnormally high RHR through medication may aid primary and secondary prevention of coronary heart disease (Cook et al., 2006).

Despite this ongoing debate, few studies examined population variations (Gillum, 1988; Zhang & Kesteloot, 1999) and disparities between socioeconomic groups (McGrath, Matthews, & Brady, 2006) in heart rate, while almost no study explored the mechanisms contributing to such disparities. Accordingly, we had three objectives. First, we constructed an individual/neighbourhood multilevel socioeconomic risk score of RHR to improve risk stratification of populations.

Second, we investigated whether the following factors were associated with RHR: psychological factors (depression and stress), medication use (beta-blockers; other RHR-lowering medications; thyroid medications; drugs used in nicotine, alcohol, and opioid dependence; antipsychotics; anxiolytics; hypnotics and sedatives), other health behaviour (overall sport practise; energy expenditure associated with medium, high, or very high intensity activities; and alcohol, coffee, and tobacco consumption), life course

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anthropometric factors (body mass index, waist circumference, and leg length as a marker of growth retardation in early childhood attributable to negative environmental circumstances (Frisancho, 2007; Gunnell, Smith, Frankel, Kemp, & Peters, 1998; Li, Dangour, & Power, 2007; Wadsworth, Hardy, Paul, Marshall, & Cole, 2002)), and specific biologic factors (gamma-glutamyltransferase and alkaline phosphatase) previously shown to be associated with RHR (Zhang & Kesteloot, 1999) and involved in the atherosclerotic process (Emdin, Pompella, & Paolicchi, 2005; Tonelli et al., 2009).

Third, to gain mechanistic insight, we examined which of these psychological, medication, behavioural, life course anthropometry, and biologic factors contributed to the observed individual/neighbourhood socioeconomic disparities in RHR.

Methods

Population

The RECORD Cohort Study ("Residential Environment and COROnary heart Disease", www.record-study.org) includes 7290 participants recruited in 2007–2008 (Chaix et al., 2010, 2011, in press; Havard, Reich, Bean, & Chaix, 2011; Leal, Bean, Thomas, & Chaix, 2011). The participants benefitted from a free medical check-up offered by the French National Health Insurance System for Salaried Workers. Participants were recruited without *a priori* sampling during these 2-hour-long preventive check-ups conducted by the Centre d'Investigations Préventives et Cliniques in 4 of its health centres located in the Paris metropolitan area. Eligibility criteria were age 30–79 years, ability to fill out French study questionnaires, and residence in 1 of the 10 (out of 20) administrative divisions of Paris or 111 other municipalities of the metropolitan area selected *a priori*. Participants were accurately geocoded based on their residential address in 2007–2008. The study was reviewed by the French Data Protection Authority.

Measures

Resting heart rate

During the health check-up, trained nurses measured RHR in bpm by electrocardiogram, using a Cardionics CardioPlug device. The measurement was made in a quiet room after a 5- to 7-mn rest period in the supine position (Benetos et al., 1999).

Circumstances of RHR measurement

As RHR is sensitive to measurement conditions (Gillum, 1988), we considered the day of the week (from Monday to Friday) and the hour of the day (8:00–10:00 am, 10:00–12:00 am, 0:00–2:00 pm, and 2:00–4:00 pm) on which the check-up was scheduled; the number of times each participant was previously seen at the health centre since 1995 (0, 1, 2 or more) and the last year he/she was seen (to assess whether participants were used to RHR measurement in the health centre); and the maximum daily temperature, atmospheric pressure, and relative humidity averaged over the previous 10 days.

Individual demographic and socioeconomic variables

Demographic variables included age (continuous), gender, marital status (living alone or not), and retirement status (retired or not).

Individual socioeconomic variables included personal education, parental education, occupation, perceived situation of overwork, household income, perceived financial strain, ownership of dwelling, and reporting no holidays over the previous 12 months.

Education was divided into four classes: no education; primary education and lower secondary education; higher secondary education and lower tertiary education; and upper tertiary education. For parental education level, we created a variable by adding the mother's and father's education level and divided the resulting score into three classes. Regarding occupation, four categories were distinguished: blue-collar workers; low-white collar workers; intermediate occupations; and high white-collar workers. Household income adjusted for household size was divided into four categories. Separate binary variables were determined for perceived overwork, self-reported financial strain, dwelling ownership, and reporting holidays or not over the previous year.

Neighbourhood socioeconomic variables

Following previous work (Chaix et al., 2010), neighbourhood education (proportion of residents with a tertiary education in the 2006 Population Census) was employed as a proxy of neighbourhood socioeconomic status (see Supplementary material A2 online for sensitivity analyses using other indicators).

First, neighbourhood education was assessed within census block group areas (Chaix et al., 2008). The median number of residents in these 1911 neighbourhoods was 2536 in 2006.

Second, as administrative neighbourhood delimitations may be arbitrary (Chaix, Merlo, & Chauvin, 2005; Chaix, Merlo, Subramanian, et al., 2005), we determined neighbourhood education within circular areas centred on the exact residential building of participants, using individual-level data of the Census geocoded at the residential addresses (the variable was computed on different scales, with a circular radius from 100 to 10,000 m around the residential building).

Health status

Variables from the questionnaire indicated whether participants had had a myocardial infarction, a cerebrovascular disease, and whether they had a heart murmur, angina pectoris, or another heart condition.

Potential mediators of the socioeconomic disadvantage–RHR relationship

Factors investigated as possible mediators of the socioeconomic status–RHR association included medication use (beta-blocker use; other RHR-lowering medications; thyroid medications; drugs used in nicotine, alcohol, and opioid dependence; antipsychotics; anxiolytics; hypnotics and sedatives), other health behaviour (coffee consumption, overall sport practise, energy expenditure associated with recreational physical activity, alcohol consumption, and smoking), anthropometric variables (body mass index, waist circumference, standing height, trunk length, and leg length), biologic variables (alkaline phosphatase, gamma-glutamyltransferase), and psychological variables (depression and stress).

By merging SNIIR-AM data for all reimbursed healthcare consumption in participants, we created separate binary variables indicating whether individuals had been reimbursed over the previous year for the medications listed above (statistics on infrequently used RHR-lowering drugs are reported in Supplementary material A5 online).

Coffee consumption was coded in three classes (0; 1–4; >4 cups per day). Alcohol consumption was coded in four categories: never drinker, former drinker, light drinker, and drinker (>2 glasses per day for women and >3 glasses per day for men). We distinguished between non-smokers, former smokers, and current smokers.

Regarding physical activity, we first considered an overall sport practise variable (not regularly; 1–2 times per week; ≥3 times per week). Second, based on the detailed list of sport activities performed over the previous 7 days and on the duration of activities and intensity of activities in metabolic equivalent (MET), we determined three separate variables for the energy expended over the previous 7 days in (i) medium intensity activities (3–6 MET); (ii) high intensity activities (6–8 MET); and (iii) very high intensity activities (>8 MET).

Height (using a wall-mounted stadiometre) and weight (using calibrated scales) were recorded by a nurse. Body mass index (in kg/m^2) was divided into three categories (normal: <25, overweight: 25–≤30, obese: ≥30). Waist circumference was measured in cm using an inelastic tape placed mid way between the lower ribs and iliac crests on the mid-axillary line, and divided into three categories (<94, 94–≤102, >102 among men; <80, 80–≤88, >88 among women).

Height was also measured in the sitting position with a specific stadiometre. Participants were instructed to sit erect on a flat wood stool facing forward with the head in the Frankfurt plane position, with their back against the vertical stand of the stadiometre and their thighs parallel. The measure was performed at the maximum point of a quiet respiration. Trunk length was calculated by subtracting the stool height (45 cm) to the sitting height. Leg length was determined as standing height minus trunk length (Davey Smith et al., 2001; Li et al., 2007; Wadsworth et al., 2002), and was divided into four categories based on the quartiles.

Biologic parameters including alkaline phosphatase and gamma-glutamyltransferase were measured under fasting conditions. They were categorised based on the quartiles.

Finally, we used the 4-item Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) (score >6 or not) to identify individuals who felt overwhelmed by life events, and the 13-item QD2A scale (score >6 or not) for depressive symptoms (De Bonis, Lebeaux, De Boeck, Simon, & Pichot, 1991).

Statistical analysis

We excluded 132 participants with missing information for RHR, resulting in a sample of 7158 individuals.

Socioeconomic stratification of RHR

To account for within-neighbourhood correlation in RHR, individual/neighbourhood predictors of RHR were analysed with multilevel linear regression models (Chaix et al., 2007a, 2007b). Only the individual/neighbourhood variables associated with RHR were retained into the model.

Based on this model, we performed a sensitivity analysis to determine the spatial scale (i.e., the size of the radius of circular areas) on which it seemed most relevant to measure neighbourhood socioeconomic status (Chaix, Merlo, & Chauvin, 2005; Chaix, Merlo, Subramanian, et al., 2005; Leal et al., 2011). It was *a priori* decided to choose the spatial scale based on two predetermined criteria: (i) the combination of fit to the data and complexity of the model; and (ii) the strength of the association with RHR as assessed primarily with the coefficient associated with the most extreme neighbourhood socioeconomic category (i.e., the lowest vs. the highest quintile of neighbourhood education).

The estimated coefficients for the individual/neighbourhood socioeconomic effects were used to compute a multilevel socioeconomic disadvantage risk score of RHR for each participant. We reestimated a model for RHR in which the various individual/neighbourhood socioeconomic variables were replaced by the socioeconomic disadvantage score into categories (see Supplementary material E online for estimation issues).

Mediation analyses

Possible risk factors of RHR were further entered as categorical variables into the model, only retaining factors associated with RHR. Blood pressure, cholesterol, glycaemia, and triglycerides were not introduced into the model for RHR, because bidirectional relationships exist between RHR and these variables or both are determined by common causes (e.g., sympathetic overactivity). However, Supplementary material C online provides analyses showing that the socioeconomic disadvantage–RHR relationship persisted after adjustment for these factors.

We then conducted a path analysis to quantify the share of the association between socioeconomic disadvantage and RHR that was statistically explained by each of the mediating factors (Ditlevsen, Christensen, Lynch, Damsgaard, & Keiding, 2005). Potential intermediary factors were retained as mediators in the final model only if the two following conditions were met: (i) socioeconomic disadvantage had to be associated with the intermediary variable; and (ii) the potential mediator had to be related to RHR after adjustment for the other risk factors.

The path analysis model was based on the simultaneous estimation of different regression models, for each mediator and RHR (see details in Supplementary material F4 online). The mediating variables were both specified as the outcomes of separate regression models and introduced as explanatory variables in the model for RHR. All regression equations were simultaneously estimated with a Markov chain Monte Carlo approach. Coefficients from the different regression equations were used to calculate indirect effects, following the product-of-effect approach (MacKinnon, Lockwood, Brown, Wang, & Hoffman, 2007). For example, to determine the indirect effect of socioeconomic disadvantage on RHR through waist circumference, we multiplied the coefficient of the association between socioeconomic disadvantage and waist circumference by the coefficient of the association between waist circumference and RHR. As explained in Supplementary material F4 online, we determined the proportion of the socioeconomic disadvantage–RHR relationship that was mediated by each of the mediators by dividing each of the corresponding indirect effects by the total effect (sum of the direct effect and all indirect effects through the mediators) (Ditlevsen et al., 2005).

As recommended (Hafeman & Schwartz, 2009; Kaufman, Maclehose, & Kaufman, 2004), interactions between the effects of the socioeconomic score and each of the mediators were tested (see Supplementary material F6 online), to assess whether the applied decomposition strategy into direct and indirect effects was valid.

Models were estimated using Winbugs 1.4.3, and compared with the Deviance Information Criterion (DIC) (Spiegelhalter, Best, Carlin, & Linde, 2002).

Results

Mean RHR was 62.8 bpm (95% confidence interval: 62.6, 63.1). Overall, 4.0% of the participants were reimbursed for beta-blockers over the previous year.

In a multilevel model including sociodemographic factors (Table 1, first column), after adjustment for measurement circumstances, a higher RHR was found among low educated participants, blue-collar workers, among those who did not own their dwelling, and among participants who reported no holidays over the previous year, while a lower RHR was documented among retired participants (see Supplementary material A1 online for variables selection).

After adjustment, RHR also increased with decreasing education level of the residential administrative neighbourhood. However, when neighbourhood education was defined in circular areas centred on individual residences (Fig. 1), the association was the strongest (as determined from the coefficient associated with the most extreme education category) and the fit to the data the best (as reflected by a lower DIC) when average education was measured within 500 or

Table 1
Associations between individual/neighbourhood sociodemographic variables and RHR expressed in bpm (adjusted for study centre), without (model 1) and with (model 2) adjustment for risk factors, estimated from multilevel models (all effects in the same column are adjusted for each other), RECORD Cohort Study, 2007–2008, Paris region, France.

	Model 1		Model 2	
	β	95% CrI	β	95% CrI
Age (1-year increase)	+0.11	+0.08, +0.14	+0.06	+0.03, +0.09
Male (vs. female)	−1.41	−1.93, −0.91	−0.87	−1.53, −0.20
History of myocardial infarction or anger	−2.24	−4.15, −0.33	−1.45	−3.32, +0.43
History of heart murmur	−1.09	−1.87, −0.31	−1.15	−1.92, −0.39
Retirement (vs. active)	−1.09	−1.92, −0.25	−0.79	−1.61, +0.04
History of consultation at the centre (vs. not previously seen)				
Seen last time in 1995–2000	−0.65	−1.49, +0.18	−0.50	−1.31, +0.31
Seen last time in 2001–2002 – 1 time	−1.09	−1.78, −0.40	−0.77	−1.44, −0.11
Seen last time in 2001–2002 – 2 times	−1.62	−2.43, −0.80	−1.28	−2.08, −0.48
Seen last time in 2003–2006 – 1 time	−1.35	−2.66, −0.04	−1.39	−2.67, −0.11
Seen last time in 2003–2006 – 2 times	−2.30	−3.41, +1.17	−1.82	−2.92, −0.72
Hour of the appointment (vs. 8:00–10:00 am)				
10:00–12:00 am	+0.25	−0.39, +0.88	+0.17	−0.45, +0.79
0:00–2:00 pm	+1.38	+0.76, +2.01	+1.15	+0.54, +1.75
2:00–4:00 pm	+2.09	+1.36, +2.81	+1.71	+1.01, +2.43
Average maximum temperature over 10 days (vs. 4th quartile)				
2nd and 3rd quartiles	−0.01	−0.57, +0.56	−0.15	−0.71, +0.41
1st quartile	+0.87	+0.21, +1.52	+0.71	+0.03, +1.40
Medium/low education (vs. high)	+0.63	+0.10, +1.17	+0.32	−0.20, +0.84
Blue-collar worker (vs. other occupation)	+1.22	+0.42, +2.02	+0.92	+0.14, +1.71
Dwelling non-ownership (vs. ownership)	+0.95	+0.43, +1.47	+0.53	+0.02, +1.05
No vacation over 1 year (vs. vacation)	+1.47	+0.80, +2.14	+0.86	+0.20, +1.52
Neighbourhood education within 500 m (vs. 5th quintile)				
4th quintile	+0.74	+0.01, +1.49	+0.77	+0.05, +1.49
3rd quintile	+0.92	+0.18, +1.67	+0.88	+0.16, +1.61
2nd quintile	+1.03	+0.27, +1.79	+0.85	+0.10, +1.58
1st quintile	+1.66	+0.85, +2.47	+1.02	+0.22, +1.82
Beta-blocker use			−2.90	−4.08, −1.71
Drugs used in alcohol dependence			+5.35	+1.37, +9.38
Heavy drinker vs. other			+1.16	+0.30, +2.02
Smoking (vs. non-smoker)				
Former smoker			−0.74	−1.29, −0.20
Current smoker			−1.01	−1.60, −0.41
Sport practise (vs. not regularly)				
1 or 2 times per week			−1.63	−2.15, −1.11
3 or more times per week			−2.42	−3.35, −1.49
For each 100 MET-min expended in				
Medium energy expenditure activities			−0.01	−0.04, +0.02
High energy expenditure activities			−0.07	−0.09, −0.05
Very high energy expenditure activities			−0.09	−0.15, −0.04
Obesity (vs. normal or overweight)			+1.03	+0.08, +1.97
Waist circumference (vs. ideal)				
High			+0.65	+0.05, +1.24
Very high			+2.15	+1.15, +3.14
Leg length (vs. 4th quartile)				
3rd quartile			+0.50	−0.16, +1.16
2nd quartile			+1.25	+0.56, +1.94
1st quartile			+1.44	+0.61, +2.26
Alkaline phosphatase (vs. 1st quartile)				
2nd quartile			+0.50	−0.24, +1.24
3rd quartile			+0.93	+0.17, +1.67
4th quartile			+1.50	+0.73, +2.27
Gamma-glutamyltransferase (vs. 1st quartile)				
2nd quartile			+0.73	+0.07, +1.41
3rd quartile			+1.18	+0.49, +1.89
4th quartile			+2.28	+1.54, +3.01

1000 m radius areas (the DIC was only very slightly lower and the association only very slightly stronger when considering 500 m rather than 1000 m radius areas, not allowing us to clearly favour one of these scales rather than the other). The association became clearly weaker when the radius was ≤200 and ≥5000 m.

We constructed a multilevel socioeconomic disadvantage risk score based on individual education, neighbourhood education (500 m radius circular areas, choosing 1000 m radius areas leading to comparable results), home non-ownership, blue-collar occupation, and reporting no vacation. After adjustment for demographic

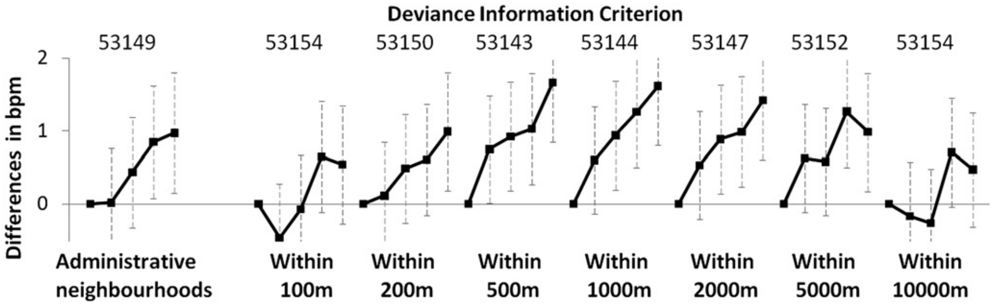

Fig. 1. Associations between neighbourhood education measured within administrative neighbourhoods or circular neighbourhoods centred on individual residences and RHR, adjusted for individual health and sociodemographic factors. Neighbourhood variables were divided into 5 categories comprising a similar number of individuals. RECORD Cohort Study, 2007–2008, Paris Region, France.

and health variables, the multilevel risk score divided into categories was strongly associated with RHR: +0.9 [95% credible interval (CrI): +0.2, +1.6], +1.8 (95% CrI: +1.0, +2.5), and +3.6 (95% CrI: +2.9, +4.4) bpm for the 3 categories reflecting increasing disadvantage, compared with the lowest disadvantage category.

Risk factors of RHR and medication variables were then introduced into the model (Table 1, column 2). Practising sports decreased RHR. After adjustment for this global sport variable, a greater energy expenditure in sport activities over the previous 7 days was also associated with a lower RHR. Interestingly, a given energy expenditure (i.e., 100 MET-min per week) had a stronger RHR-lowering effect when achieved through high than through medium, and a still stronger effect when achieved through very high intensity activities. RHR increased strongly and regularly with waist circumference.

We estimated models including separately or simultaneously standing height and its components (Table 2).

When variables were included in separate models, RHR increased with decreasing height, leg length, and trunk length (the latter effect was not significant). The model with leg length led to a better fit to the data (as shown with the DIC). When height and leg length were introduced together, only leg length was negatively associated with RHR. When trunk and leg lengths were modelled simultaneously, only the latter was associated with RHR.

After adjustment, RHR regularly increased with both alkaline phosphatase and gamma-glutamyltransferase. Complementary analyses (Supplementary material F6 online) indicated that there was an interaction between the effects of socioeconomic disadvantage and gamma-glutamyltransferase, with stronger effects of gamma-glutamyltransferase on RHR at high levels of socioeconomic disadvantage.

As in a previous study based on the same cohort in which a lower systolic blood pressure was observed among both current smokers and former smokers (Chaix et al., 2010), a lower RHR was documented in these 2 groups, a phenomenon that contradicts previous literature (Zhang & Kesteloot, 1999).

The path analysis model depicted in Fig. 2 was used to examine which variables mediated the association between the multilevel socioeconomic disadvantage score and RHR.

As shown in Supplementary material F3 online, higher socioeconomic disadvantage was associated with a larger waist circumference, shorter leg length, higher alkaline phosphatase, higher gamma-glutamyltransferase, and decreased odds of overall sport practise and intense or very intense physical activity over the previous days. These seven risk factors each contributed to increase RHR in low socioeconomic groups (see Fig. 2 for the magnitude of the indirect effects). All the other initially considered risk factors were not associated with both socioeconomic disadvantage and RHR, and were therefore not retained as mediators in the path analysis model.

According to the proportion of the association explained by risk factors (Fig. 2), overall sport practise and reporting an intense sport activity over the previous days were the most significant contributors to the socioeconomic disadvantage–RHR relationship, accounting for 11% and 9% of the association, respectively. Waist circumference explained an appreciable share (9%) of the socioeconomic disadvantage–RHR relationship. The higher gamma-glutamyltransferase of disadvantaged participants also contributed in a non-negligible way to their higher RHR (to 7% of the association in a model disregarding the interaction between the effects of gamma-glutamyltransferase and socioeconomic disadvantage). As detailed in Supplementary material F6 online, due to this interaction, gamma-glutamyltransferase explained a larger share of the socioeconomic disadvantage–RHR relationship at higher than at lower levels of socioeconomic disadvantage. Finally, alkaline phosphatase and leg length also contributed respectively to only 5% and 3% of the association.

After controlling for these mediators, the direct effect of socioeconomic disadvantage on RHR (probably attributable to

Table 2
Associations between standing height, leg length, and trunk length[a] and RHR expressed in bpm, estimated from multilevel models adjusted for study centre and all individual/neighbourhood variables and risk factors listed in Table 1 (effects listed in the same line are adjusted for each other), RECORD Cohort Study, 2007–2008, Paris region, France.

	Standing height	Leg length	Trunk length	DIC
	β (95% CrI)	β (95% CrI)	β (95% CrI)	
Model 1	−0.07 (−0.10, −0.03)			50493.4
Model 2		−0.11 (−0.16, −0.06)		50486.6
Model 3			−0.02 (−0.09, +0.04)	50505.9
Model 4	+0.01 (−0.06, +0.07)	−0.12 (−0.21, −0.03)		50488.6
Model 5	−0.11 (−0.16, −0.06)		+0.12 (+0.03, +0.21)	50488.6
Model 6		−0.11 (−0.16, −0.06)	+0.01 (−0.06, +0.07)	50488.6

[a] The correlation between standing height and leg length was 0.91 (95% CI: 0.90, 0.91), the correlation between standing height and trunk length was 0.84 (95% CI: 0.83, 0.85), and the correlation between leg length and trunk length was 0.53 (95% CI: 0.51, 0.54).

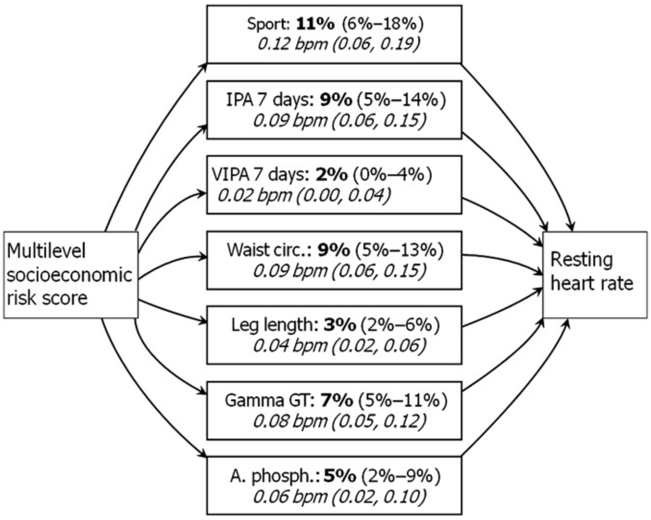

Fig. 2. Relationships mediating the association between the multilevel socioeconomic disadvantage score and RHR. We report the indirect effects of socioeconomic disadvantage on RHR through the different mediators and the percentage of the overall association attributable to these indirect effects. For example, a 1-unit increase in socioeconomic disadvantage resulted in a 0.12 (95% CrI: 0.06, 0.19) bpm increase in RHR through effects on overall sport practise. The minimum, the 10th, 25th, 75th, and 90th percentiles, and the maximum of the score were 0, 0.1, 0.8, 2.5, 3.7, and 5.5. IPA 7 days and VIPA 7 days refer to intense and very intense physical activity over the previous 7 days, waist circ. to waist circumference, gamma GT to gamma-glutamyltransferase, and a. phosph. to alkaline phosphatase. RECORD Cohort Study, 2007–2008, Paris Region, France.

unmeasured mediators) remained appreciable, accounting for 53% (95% CrI: 39%, 63%) of the overall association.

Discussion

The main study findings are the following: (i) different individual/neighbourhood variables reflecting socioeconomic disadvantage were associated with an increased RHR; (ii) among other predictors, overall sport practise, high energy expenditure activities, waist circumference, leg length, alkaline phosphatase, and gamma-glutamyltransferase were associated with RHR; and (iii) these different factors statistically explained almost half of the relationship between socioeconomic disadvantage and RHR.

Strengths and limitations

Strengths of the study include the multiple individual/neighbourhood indicators employed to capture the multidimensional influence of socioeconomic status, the numerous determinants of RHR examined, and the complex modelling framework that allowed us to generate the socioeconomic score and investigate mediating factors contributing to its association with RHR.

However, analyses were based on cross-sectional data, not allowing us to demonstrate that the temporal sequence of phenomena was coherent with the one hypothesised in Fig. 2.

Socioeconomic stratification of RHR

After adjustment for all other factors, retired participants had a lower RHR, perhaps related to their withdrawal from the stressful context of occupational life. Moreover, distinct facets of individual socioeconomic deprivation, related to knowledge and general life values, occupational exposures, and material circumstances were cumulatively associated with an increased RHR. Additionally, RHR increased monotonically with decreasing neighbourhood education measured on a rather proximate scale (500 m or 1000 m radius areas), adding evidence to the literature demonstrating neighbourhood influences on cardiovascular health (Chaix, 2009; Chaix et al., 2007a, 2007b; Diez Roux et al., 2001). Analyses combining individual/neighbourhood variables in a composite socioeconomic risk profile suggest that disadvantaged populations have a much faster RHR.

Mechanisms involved in socioeconomic influences on RHR

Regarding the underlying mechanisms, seven of the large set of potential mediators examined (overall sport practise, intense and very intense recreational activities over the past days, waist circumference, leg length, alkaline phosphatase, and gamma-glutamyltransferase) emerged as contributing to the socioeconomic disadvantage–RHR relationship.

Pathways contributing to socioeconomic disadvantage effects on physical sedentarity and abdominal adiposity may include the less prevalent health preservation values in deprived populations (Chaix, 2009), financial barriers to sport practise and healthy food consumption (Ferrie, Langenberg, Shipley, & Marmot, 2006), and a poorer spatial accessibility to related resources in disadvantaged areas (Leal & Chaix, 2011). Building on studies documenting RHR-lowering effects of sport practise and particularly detrimental effects of abdominal fat on RHR (Gillum, 1988), our work adds evidence to the notion that physical inactivity and abdominal adiposity play a major role in the genesis of social disparities in cardiovascular morbidity.

Additionally, socioeconomic disadvantage was associated with shorter leg length, which was in turn related to higher RHR. It should be kept in mind, however, that leg length only had a marginal mediating role in the relationship between socioeconomic disadvantage and RHR, only explaining 3% of the relationship. First, the observed socioeconomic disadvantage–leg length relationship is coherent with previous studies showing adult leg length to be a useful biomarker of growth retardation in early childhood attributable to negative environmental circumstances associated with socioeconomic adversity (Frisancho, 2007; Gunnell, Smith, Frankel, Kemp, et al., 1998; Li et al., 2007; Wadsworth et al., 2002). Second, our work is consistent with studies showing that short leg length (rather than trunk length) is associated with increased incidence of coronary heart disease (Davey Smith et al., 2001; Gunnell, Smith, Frankel, Nanchahal, et al., 1998; Lawlor, Taylor, Davey Smith, Gunnell, & Ebrahim, 2004) and cardiovascular risk factors (Davey Smith et al., 2001; Gunnell et al., 2003; Padez, Varela-Silva, & Bogin, 2009; Weitzman, Wang, Pankow, Schmidt, & Brancati, 2009). While no previous study investigated the relationship between leg length and RHR, our analyses suggest that the previously documented negative association between standing height and RHR (Zhang & Kesteloot, 1999) is entirely explained by leg length. These findings raise the hypothesis that environmental factors that are detrimental to growth in early childhood may have a long-term influence on RHR in later life (Frisancho, 2007; Gunnell, Smith, Frankel, Kemp, et al., 1998; Li et al., 2007; Wadsworth et al., 2002). Overall, however, it is important to emphasise that the relationship between socioeconomic status and leg length combined with the association between leg length and RHR only resulted in a weak indirect effect of socioeconomic status on RHR through leg length.

As investigated in few previous studies (Zhang & Kesteloot, 1999), RHR increased with gamma-glutamyltransferase and alkaline phosphatase. Even if gamma-glutamyltransferase has other determinants than alcohol abuse or alcoholic liver disease, the 30% increase in the effect of excessive alcohol consumption on RHR when gamma-glutamyltransferase was removed from the model suggests that high alcohol consumption is involved in the relationship between gamma-glutamyltransferase and RHR. The hypothesis that gamma-glutamyltransferase plays a role in promoting the atherosclerotic process (Emdin et al., 2005) is also coherent with its observed RHR-increasing effect. The elevation of alkaline phosphatase is used as a marker of hepatic or bone disease. However, studies have started to establish a link between abnormal bone metabolism, resulting vascular calcification, and cardiovascular mortality (Tonelli et al., 2009) that may contribute to the alkaline phosphatase–RHR association documented here. Our study is novel in showing that gamma-glutamyltransferase and alkaline phosphatase increased steadily with socioeconomic disadvantage and contributed to mediate the socioeconomic disadvantage–RHR relationship.

As slightly more than half of the relationship remained unexplained, future research should further investigate the mechanisms contributing to socioeconomic differences in RHR, which may contribute to social disparities in cardiovascular morbidity and overall mortality.

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Appendix. Supplementary data

Supplementary data associated with this article can be found online at doi:10.1016/j.socscimed.2011.09.009.

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