Hyperdynamic Circulation and the Insulin Resistance Syndrome ("Syndrome X")

Michael P. Stern, Philip A. Morales, Steven M. Haffner, and Rodolfo A. Valdez

The insulin resistance syndrome ("syndrome X") consists of hyperinsulinemia, glucose intolerance, dyslipidemia, and hypertension, although the inclusion of hypertension has been challenged. Insulin has biological effects that could produce a hyperdynamic circulation. We therefore postulated that an insulin-induced hyperdynamic circulation is an early feature of the insulin resistance syndrome and that this circulatory abnormality leads to later fixed hypertension. The San Antonio Heart Study cohort, a population-based cohort of 3,301 Mexican Americans and 1,857 non-Hispanic whites, was used to define individuals who were hyperdynamic (pulse pressure and heart rate in the upper quartile of their respective distributions), intermediate, and hypodynamic (pulse pressure and heart rate in the bottom quartile). The characteristics of the insulin resistance syndrome were then examined according to these three hemodynamic categories. We also examined the 8-year incidence of hypertension and of type II diabetes according to these hemodynamic categories. A hyperdynamic circulation was associated with statistically significant increases in body mass index (BMI) (p<0.001), subscapular-to-triceps skinfold ratio (p=0.042), triglyceride (p=0.002), 2-hour glucose (p=0.002), and fasting and 2-hour insulin (p=0.019 and 0.006). When hemodynamic status was examined separately in lean (BMI <27 kg/m²) and obese (BMI ≥27 kg/m²) individuals, the above effects persisted, although they were somewhat attenuated. The odds ratio for the hyperdynamic state as a predictor of future hypertension was 1.66, although this was not statistically significant (p=0.304). The odds ratio for predicting future type II diabetes was 3.97, which was statistically significant (p=0.047). Hyperdynamic individuals display many of the features of the insulin resistance syndrome, although hyperdynamic circulation was not predictive of future hypertension. It was, however, highly predictive of type II diabetes, itself a principal outcome of the insulin resistance syndrome. (Hypertension 1992;20:802-808)

KEY WORDS • blood circulation • insulin resistance • glucose • hyperinsulinism • diabetes mellitus, non-insulin-dependent

In his 1988 Banting Lecture, Reaven1 introduced the term "syndrome X" to describe a syndrome consisting of insulin resistance, compensatory hyperinsulinemia, glucose intolerance, hypertriglyceridemia, low levels of high-density lipoprotein (HDL) cholesterol, and hypertension. Because insulin resistance was postulated to be the underlying metabolic defect responsible for the other manifestations of the syndrome, we have chosen to call it the insulin resistance syndrome.2 Obesity and an unfavorable distribution of body fat (upper-body, centralized adiposity, or both) are also associated with this syndrome. Reaven1 also postulated that type II diabetes and coronary artery disease were long-term consequences of the syndrome.

The inclusion of hypertension as part of the syndrome has been controversial.3-5 Although a number of studies have documented the presence of insulin resistance in patients with essential hypertension,8-12 such cross-sectional relations by no means prove cause and effect. There are, however, several known biological effects of insulin that could provide a theoretical basis whereby hyperinsulinemia could contribute to hypertension. These include the ability of insulin to stimulate sympathetic activity, particularly norepinephrine release;13 to promote renal sodium retention; and to stimulate smooth muscle proliferation.17 However, despite the rise in norepinephrine levels with insulin infusion, there does not appear to be any increase in peripheral vascular resistance. In fact, many studies of regional muscle blood flow (forearm and leg) have shown that insulin infusion produces vasodilation, increased regional blood flow, and decreased vascular resistance;15,18,19 although there have been a few contrary studies.20,21 It has been argued that the vasodilatory effects of insulin preclude a role for it in the pathogenesis of hypertension.

One may also inquire about the direct effects on blood pressure of hyperinsulinemia produced by a euglycemic insulin infusion. Although in some studies such infusions have produced increases in blood pressure,13,22,23 this result has not been universal.15,20,24 Moreover, most insulin infusion studies have been relatively acute. Hall et al25-27 performed a series of more...
prolonged infusions of insulin into dogs lasting 7-28 days and found that such infusions produced, if anything, a transient fall in blood pressure. On the other hand, the same investigators showed that 5-day euglycemic infusions of insulin into conscious rats did raise arterial blood pressure.\textsuperscript{26}

Euglycemic insulin infusions have also been accompanied by increases in cardiac output, cardiac contractility, and heart rate.\textsuperscript{13,22,23,28-32} It thus appears that insulin can contribute to a hyperdynamic circulation, which in turn has been postulated to be a risk factor for future fixed hypertension.\textsuperscript{33-35}

In view of the above considerations, we postulated that a hyperdynamic state manifested by a widened pulse pressure and tachycardia might represent an early stage of the IRS and that fixed hypertension might be a later feature. To address this question, we used the cohort examined in the San Antonio Heart Study (SAHS) to define three groups of individuals who differed in their hemodynamic status and then asked whether individuals with a more hyperdynamic circulation were more likely to display features of the insulin resistance syndrome than those with a less hyperdynamic circulation. We also determined whether, after 8 years of follow-up, some of the long-term sequelae of the insulin resistance syndrome (namely, diabetes and hypertension) were more likely to develop in hyperdynamic individuals.

Methods

The sampling design, field procedures, response rates, and principal results of the SAHS have been described in detail in previous publications.\textsuperscript{36-46} Briefly, the SAHS cohort was enrolled in two phases, the first from 1979 to 1982 and the second from 1984 to 1988. In both phases, households were randomly selected from three types of neighborhoods: low-income barrios, middle-income "transitional" neighborhoods, and high-income suburbs. All men and nonpregnant women 25-64 years old residing in the selected households were considered eligible for the study. Ethnic group, either Mexican American, non-Hispanic white, or other, was assigned on the basis of a previously published algorithm.\textsuperscript{43} Only Mexican Americans and non-Hispanic whites are included in the present report. A total of 5,158 participants (1,288 Mexican Americans and 929 non-Hispanic whites from phase I and 2,013 Mexican Americans and 928 non-Hispanic whites from phase II) were enrolled in the study, representing 60-70% of eligible individuals identified at the time the randomly selected households were enumerated. Beginning in 1987, an 8-year follow-up study was begun. The follow-up of the phase I (1979-1982) cohort has now been completed. Vital status has been ascertained on 97.8% of the original participants, and 80.3% of the survivors (1,673 individuals) participated in the 8-year follow-up examination. Measurement procedures in the follow-up examination were identical to those used 8 years earlier in the baseline examination. A full description of the follow-up examination has been published previously.\textsuperscript{44}

Height, weight, subscapular and triceps skinfold, and systolic (more like diastolic) blood pressures were measured on all subjects. Training of blood pressure technicians followed the Hypertension Detection and Follow-up Program (HDFP) guidelines, including matching proper cuff size to upper arm circumference.\textsuperscript{45} This training was carried out at approximately 6-month intervals throughout the duration of field work by an individual who had had extensive experience in training HDFP field and clinic staff and who had access to all HDFP training materials. Heart rate was counted for 15 seconds after a 5-minute rest. Fasting blood specimens were obtained from all subjects for determination of serum total, low density lipoprotein (LDL) and HDL cholesterol, serum triglyceride, serum insulin, and plasma glucose concentration. Plasma glucose concentration 2 hours after a standardized oral glucose load was also measured on all subjects. Waist and hip circumferences and 2-hour serum insulin concentrations were measured only in phase II, and the data presented for these measurements refer to phase II subjects only. The procedures for all of these measurements have been described in detail elsewhere.\textsuperscript{36-42}

Body mass index (BMI) (weight in kilograms divided by height in meters squared) was used as an index of overall adiposity. The ratio of subscapular to triceps skinfold was used as an index of central adiposity, and the ratio of waist to hip circumference was used as an index of upper-body adiposity.

Diabetes was diagnosed according to the World Health Organization (WHO) plasma glucose criteria.\textsuperscript{46} Individuals who gave a history of diabetes and reported current treatment with either insulin or oral antidiabetic agents were also considered to have diabetes regardless of their glucose level. Hypertension was diagnosed according to the HDFP screening criteria (diastolic blood pressure greater than or equal to 95 mm Hg, current treatment with antihypertensive agents, or both).\textsuperscript{45} The 490 prevalent cases of diabetes and the 550 prevalent cases of hypertension were excluded from the present analysis, leaving a total of 4,118 individuals.

We defined three categories of individuals on the basis of their heart rate and pulse pressure: "hyperdynamic," "intermediate," and "hypodynamic." Hyperdynamic individuals were defined as individuals whose heart rate was greater than or equal to 80 beats per minute, whose pulse pressure (systolic minus diastolic blood pressure) was greater than or equal to 50 mm Hg, and whose diastolic pressure was less than 90 mm Hg (n=318). These cutoff points correspond approximately to the upper 25% of the heart rate and pulse pressure distributions, respectively. Hypodynamic individuals were defined as individuals whose heart rate was less than 70 beats per minute and whose pulse pressure was less than or equal to 35 mm Hg (n=381). Again, these cutoff points correspond approximately to the lowest 25% of the respective distributions. We also defined a group of individuals who were intermediate; these individuals had heart rates greater than or equal to 70 but less than 80 beats per minute and pulse pressures greater than 35 but less than 50 mm Hg (n=1,742). Individuals who did not fall into any of these three categories (4,118-318+381+1,742)=1,677 were excluded from the present analysis.

The effect of a hyperdynamic circulation on anthropometric, physiological, and metabolic variables was tested by two-way analysis of covariance (ANCOVA).\textsuperscript{47} The grouping variables were one of the three hemodynamic categories and sex, ethnic group, or BMI, the
latter categorized as above or below 27 kg/m². Age was a covariate in these analyses. In the analysis involving ethnic group, no interactions were observed between ethnic group and hemodynamic status, indicating that the effect of the three hemodynamic states on the dependent variables (anthropometric, physiological, or metabolic) was similar in both ethnic groups. The ethnic-specific analyses are therefore not presented, and the ethnic groups were pooled in subsequent analyses. To further reduce the impact of any minor ethnic differences among the three hemodynamic states, ethnic group has been entered as a second covariate (in addition to age) in all analyses. Moreover, the ethnic distribution was quite similar in the three hemodynamic categories. Fasting and 2-hour insulin and triglyceride differences among the three hemodynamic states, ethnic differences in the prevalence of this condition.

Table 2 compares hypodynamic, intermediate, and hyperdynamic men and women with respect to features that are characteristic of the insulin resistance syndrome. There was a statistically significant trend, stronger in women, toward higher BMIs with a more hyperdynamic circulation. A similar trend was seen for unfavorable body fat distribution that was statistically significant for subscapular-to-triceps skinfold ratio, and fasting glucose and fasting insulin.

**Results**

Table 1 shows that the prevalence of a hyperdynamic circulation rises with advancing age, but there are no ethnic differences in the prevalence of this condition.

Table 2 compares hypodynamic, intermediate, and hyperdynamic men and women with respect to features that are characteristic of the insulin resistance syndrome. There was a statistically significant trend, stronger in women, toward higher BMIs with a more hyperdynamic circulation. A similar trend was seen for unfavorable body fat distribution that was statistically significant for subscapular-to-triceps skinfold ratio, and fasting glucose and fasting insulin.

**Table 1. Number and Percent of Hyperdynamic Individuals by Age and Ethnic Groups**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mexican American</th>
<th>Non-Hispanic white</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>25–34</td>
<td>56/859</td>
<td>6.5</td>
</tr>
<tr>
<td>35–44</td>
<td>40/777</td>
<td>5.1</td>
</tr>
<tr>
<td>45–54</td>
<td>51/566</td>
<td>9.0</td>
</tr>
<tr>
<td>55–64</td>
<td>46/568</td>
<td>12.5</td>
</tr>
<tr>
<td>Total</td>
<td>192/2,570</td>
<td>7.5</td>
</tr>
</tbody>
</table>

**Table 2. Age- and Ethnic Group-Adjusted Anthropometric, Physiological, and Metabolic Variables According to Sex and Hemodynamic Status**

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Men</th>
<th>Women</th>
<th>Values of p for HemoD×sex interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>HypoD</td>
<td>Interm</td>
<td>HyperD</td>
</tr>
<tr>
<td>171</td>
<td>701</td>
<td>163</td>
<td>210</td>
</tr>
<tr>
<td>Mexican American (%)</td>
<td>61</td>
<td>62</td>
<td>58</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.6</td>
<td>27.2</td>
<td>27.5</td>
</tr>
<tr>
<td>STR</td>
<td>1.57</td>
<td>1.63</td>
<td>1.66</td>
</tr>
<tr>
<td>WHR*</td>
<td>0.930</td>
<td>0.940</td>
<td>0.939</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>107</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>75</td>
<td>74</td>
<td>72</td>
</tr>
<tr>
<td>Pulse pressure (mm Hg)</td>
<td>32</td>
<td>46</td>
<td>57</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>63</td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td>Total cholesterol (mg/dl)</td>
<td>208</td>
<td>205</td>
<td>202</td>
</tr>
<tr>
<td>LDL cholesterol (mg/dl)</td>
<td>131</td>
<td>135</td>
<td>131</td>
</tr>
<tr>
<td>HDL cholesterol (mg/dl)</td>
<td>44.8</td>
<td>44.0</td>
<td>43.2</td>
</tr>
<tr>
<td>Triglyceride (mg/dl)</td>
<td>123</td>
<td>133</td>
<td>144</td>
</tr>
<tr>
<td>Fasting glucose (mg/dl)</td>
<td>90.0</td>
<td>90.1</td>
<td>88.4</td>
</tr>
<tr>
<td>2-Hour glucose (mg/dl)</td>
<td>100</td>
<td>103</td>
<td>105</td>
</tr>
<tr>
<td>Fasting insulin (microunits/ml)</td>
<td>9.3</td>
<td>10.6</td>
<td>10.1</td>
</tr>
<tr>
<td>2-Hour insulin (microunits/ml)</td>
<td>44.3</td>
<td>50.3</td>
<td>54.4</td>
</tr>
</tbody>
</table>

HypoD, hypodynamic; Interm, intermediate; HyperD, hyperdynamic; HemoD, hemodynamic status; BMI, body mass index; STR, subscapular-to-triceps skinfold ratio; WHR, waist-to-hip circumference ratio; BP, blood pressure; bpm, beats per minute; LDL, low density lipoprotein; HDL, high density lipoprotein.

*Measured on phase II subjects only (n=2,941).
The effects of hemodynamic status on systolic and diastolic blood pressures, pulse pressure, and heart rate were significant, and there is no trend with waist-to-hip ratio. (Note that the latter results are based on a smaller sample size; see “Methods.”) Systolic blood pressure rose in both sexes with a more hyperdynamic circulation, but diastolic blood pressure did not. By definition, pulse pressure and heart rate rose with a more hyperdynamic circulation.

Table 3 shows trends with hemodynamic status in lean (BMI <27 kg/m²) and obese (BMI ≥27 kg/m²) individuals. Dichotomizing the BMI eliminated its association with hemodynamic status in the lean group and attenuated the association in the obese group. Thus, any trends observed in this analysis are relatively free of confounding caused by BMI. The trend of increasing subscapular-to-triceps skinfold ratio with a more hyperdynamic circulation is still present, although it is no longer statistically significant, and there is no trend with waist-to-hip ratio. The effects of hemodynamic status on systolic and diastolic blood pressures, pulse pressure, and heart rate were similar to those presented in Table 2.

As in the preceding analysis, there were no significant associations between hemodynamic status and either total or LDL cholesterol. The previous nonsignificant trend with HDL cholesterol is essentially eliminated in the present analysis. The trend of increasing triglyceride concentration with a more hyperdynamic circulation, however, is still apparent, more convincingly in the lean than the obese, although it is now of only borderline statistical significance. The trends of increasing 2-hour glucose and insulin concentrations with a more hyperdynamic circulation remain statistically significant, but the trend with fasting insulin is no longer apparent.

Table 4 shows the results of multiple logistic regression analyses with incident cases of either hypertension or type II diabetes as the dependent variables. Independently for waist-to-hip ratio. (Note that the latter results are based on a smaller sample size; see “Methods.”) Systolic blood pressure rose in both sexes with a more hyperdynamic circulation, but diastolic blood pressure did not. By definition, pulse pressure and heart rate rose with a more hyperdynamic circulation.

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As in the preceding analysis, there were no significant associations between hemodynamic status and either total or LDL cholesterol. The previous nonsignificant trend with HDL cholesterol is essentially eliminated in the present analysis. The trend of increasing triglyceride concentration with a more hyperdynamic circulation, however, is still apparent, more convincingly in the lean than the obese, although it is now of only borderline statistical significance. The trends of increasing 2-hour glucose and insulin concentrations with a more hyperdynamic circulation remain statistically significant, but the trend with fasting insulin is no longer apparent.
dent variables include age, ethnic group, and hemodynamic status. Age significantly increases the risk of both end points. Diabetes is significantly more likely to develop in Mexican Americans than non-Hispanic whites, with relative odds of nearly two, but there is no ethnic difference in incidence of hypertension. The odds of hypertension developing were 66% higher in hyperdynamic individuals than in hypodynamic individuals, but this difference was not statistically significant. In contrast, the odds of type II diabetes developing were nearly four times higher in hyperdynamic individuals than in hypodynamic individuals, and this difference was statistically significant. Individuals whose hemodynamic status was intermediate had intermediate odds of diabetes developing. When we added other established diabetes risk factors to the model for diabetes, including BMI, subscapular-to-triceps skinfold ratios, and fasting glucose and insulin, the odds ratio for a hyperdynamic circulation remained statistically significant and, in fact, increased to 6.42 for the hyperdynamic group (95% confidence interval [CI], 1.18, 34.8; p = 0.031) and to 3.95 for the intermediate group (95% CI, 1.03, 15.1; p = 0.045).

Discussion

The cross-sectional analyses presented in Tables 2 and 3 indicate that people who are more hyperdynamic tend to display many of the features of the insulin resistance syndrome. These features include increasing obesity, unfavorable body fat distribution, hypertriglyceridemia, progressive glucose intolerance, and hyperinsulinemia. A trend toward progressively lower HDL levels was also observed, but this trend was not statistically significant. In the analyses stratified by BMI, many of these effects were attenuated, indicating that the greater obesity of hyperdynamic individuals accounted for some, but not all, of their tendency to exhibit IRS-like features. Because we were careful to match cuff size to upper arm circumference, we do not believe that the relation between BMI and hemodynamic status among those with BMIs >27 kg/m² is an artifact of improper cuff size.

Because we had originally hypothesized that a hyperdynamic circulation represented an early stage of the IRS and that fixed hypertension represented a later stage, we were surprised to observe that a hyperdynamic circulation was a much stronger predictor of type II diabetes than of hypertension. Nevertheless, because diabetes is also one of the long-term outcomes of the IRS, the fact that a hyperdynamic circulation predicts this outcome as well (Table 4) adds further credence to our hypothesis that this circulatory condition may be part of the IRS. These results are also compatible with our previous report that the insulin resistance syndrome itself is a stronger predictor of future type II diabetes than of hypertension. It should also be noted that the present prospective analyses are based on the 8-year follow-up of the phase I cohort of the SAHS only. The follow-up of the phase II cohort is currently in progress, and when this follow-up has been completed, we will have greater statistical power to investigate the hyperdynamic state as a possible risk factor for hypertension.

Although not strictly proven, it is commonly supposed that hyperinsulinemia provides the mechanism linking insulin resistance to the other features of the insulin resistance syndrome. If this is the case, then there are a number of biological actions of insulin that could produce a hyperdynamic circulation. It is well known, for example, that the effects of insulin-induced hypoglycemia include adrenergic stimulation accompanied by increases in both heart rate and cardiac output.50-51 Of greater relevance to the syndrome of insulin resistance, however, are hemodynamic effects of insulin that occur in the absence of hypoglycemia. For example, insulin has been shown to increase myocardial contractility in isolated papillary muscles and perfused intact hearts in a number of animal species, including dogs, cats, newborn lambs, and piglets.79-82 These effects are independent of either glucose or catecholamines. An early study by Pereda et al23 reported that an acute infusion of insulin into dogs produced a rise in blood pressure and cardiac output within 2–9 minutes in the absence of hypoglycemia. Also in dogs, insulin infusions lasting several hours under euglycemic clamp conditions produced increased levels of both norepinephrine and epinephrine as well as increases in heart rate, mean arterial pressure, pulse pressure, cardiac output, and cardiac contractility.24 These hemodynamic effects were blocked by propranolol, indicating that they were mediated by the insulin-induced β-adrenergic stimulation. In type I diabetic subjects, insulin injected intravenously as a single bolus (7–8 units) with hypoglycemia prevented by a simultaneous glucose infusion has been reported to produce a 5 mm Hg rise in arterial blood pressure, a 16–29 beat per minute rise in heart rate, and a rise in plasma norepinephrine levels.52 Rowe et al13 have reported similar effects using continuous insulin infusions at rates of 2 and 5 milliunits • kg⁻¹ • min⁻¹. Lower infusion rates (0.5–1.0 milliunits • kg⁻¹ • min⁻¹) that fail to elicit a catecholamine response also fail to produce hemodynamic effects.24 Intravenous insulin in the absence of hypoglycemia has also been reported to produce an increased heart rate in diabetic subjects.53 In fact, although the hemodynamic effects of euglycemic insulin infusions have been somewhat variable, a rise in heart rate in both animals and humans has been a near-universal finding.13,15,25-28,52,53

A large number of studies suggest that patients with borderline hypertension, particularly if they are young, have hyperdynamic circulations manifested by high cardiac output, low peripheral resistance, and a rapid heart rate.33-35 Julius et al,39 for example, have listed 12 such studies from six different countries. It has been postulated that many of these patients eventually convert to “fixed” hypertension with normal cardiac output and elevated peripheral resistance.33-35 Although this idea is not new, there have been remarkably few prospective studies documenting the postulated transformation. Lund-Johansen30 followed 29 untreated, borderline hypertensive patients with hyperdynamic circulations, all of whom were less than 40 years of age when first examined. After 17 years, fixed hypertension requiring treatment had developed in all but seven. In the 28 patients who were restudied, cardiac output had fallen, and peripheral vascular resistance had risen. Thus, these results support the concept that a hyperdynamic circulation can contribute to later essential hypertension. There are also a number of prospective epidemiological studies suggesting that a rapid heart rate is a risk factor for future hypertension.54-56 This relation
was reported as far back as 1945, when Levy et al described 22,741 US Army officers among whom transient tachycardia noted during a routine annual physical examination predicted the development of sustained hypertension at future examinations. Similar findings were reported among former college students by Paffenbarger et al in 1968. More recently, Selby et al reported that in the Kaiser population, the effect of baseline heart rate as a predictor of future hypertension was independent of adiposity, parental history of hypertension, alcohol consumption, and heavy salt use, although it was not independent of baseline blood pressure, itself a predictor of future hypertension.

A limitation of the present analysis stems from the fact that heart rate is a highly variable physiological phenomenon. We are attempting to infer an individual’s usual (or integrated) heart rate from a 15-second sample measured under routine survey conditions that, at best, do not present a highly controlled setting. If heart rate had been a central focus of our study at the time of its design, we would no doubt have attempted to increase precision by taking multiple measurements, perhaps by using prolonged electronic monitoring. As a result of this limitation, any association between heart rate and other variables of interest is likely to be underestimated in this study. A further limitation of this analysis is that they are cross-sectional, making it difficult to distinguish cause and effect. We have stressed insulin resistance with resulting hyperinsulinemia as the prime mover because it is our intention to put forward a new hypothesis. We recognize, however, that there are other scenarios that could be contemplated. For example, it has been shown that an infusion of epinephrine can produce acute insulin resistance. Thus, it is possible to imagine that a primary disturbance in adrenergic function could produce both insulin resistance and a hyperdynamic circulation.

In summary, we have shown that hyperdynamic individuals exhibit many of the traits of the insulin resistance syndrome. Contrary to our expectation, our data do not offer much support for the concept of a transition from a hyperdynamic circulation to fixed hypertension, although, as mentioned, this may reflect low statistical power, which should improve as our follow-up progresses. On the other hand, “low” statistical power did not prevent us from observing a relation between a hyperdynamic circulation and type II diabetes, another long-term outcome of the insulin resistance syndrome. This latter finding, along with the cross-sectional results, reinforces the concept that a hyperdynamic circulation may form part of the constellation of findings that constitutes the insulin resistance syndrome.

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