Dyslipidemia and abdominal obesity:
an assessment in three general populations
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Abstract
Several studies show a relationship between abdominal obesity and cardiovascular diseases, partially mediated through an altered metabolism of dyslipidemia. The present study was aimed at testing the robustness of this association across three contrasted populations and at assessing the performances of abdominal obesity as a screening tool for dyslipidemia. Data were drawn from three population health surveys recently conducted in two regions of a developed country (Switzerland, mostly of Caucasian origin, \(n = 2650\)) and in a less developed country (Seychelles, Indian Ocean, mostly of black descent, \(n = 806\)). Dyslipidemia was defined as a ratio of total cholesterol to high-density lipoprotein cholesterol (TC-HDL) greater than 5. Two anthropometric circumference measurements, waist-to-hip ratio (WHR) and waist circumference (WC), were used to define abdominal obesity either as WHR > 0.9 in men and WHR > 0.8 in women or as WC > 94 cm and WC > 80 cm, respectively. A consistent direct association between abdominal obesity and dyslipidemia (odds ratios varying from 1.85 to 4.56) was found in the three populations, independently of gender, age, body mass index, blood pressure, and smoking. This consistency across ethnicities and environments strengthens the hypothesis of a common etiopathological mechanism. The sensitivity for detecting dyslipidemia was generally higher for abdominal obesity, based on either WHR or WC, than for criteria based on the other risk factors under study. In addition, the sensitivity was higher in the study populations with a low prevalence of dyslipidemia (Swiss women and Seychellois of both sexes) than in the others. These findings support that WHR and WC may be useful as simple and inexpensive screening tools to select individuals eligible for more sophisticated and costly serum lipid determinations, especially in developing countries. © 2000 Elsevier Science Inc. All rights reserved.

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1. Introduction
The prevention of cardiovascular disease (CVD) is an important challenge for public health in developed countries and, increasingly, in developing countries as well [1]. Dyslipidemia is an independent and modifiable risk factor for CVD, together with high blood pressure, smoking, and sedentary habits. Prevalence of dyslipidemia is high and not decreasing in most developed countries [2]. Moreover, prevalence seems to increase in many developing countries due to the Westernization of diet and other lifestyle changes [3,4]. As far as blood lipid levels are concerned, it is increasingly recognized that the ratio of total cholesterol (TC) to high-density lipoprotein (HDL) ratio better predicts the occurrence of CVD events than measurements of total cholesterol or HDL alone [5,6].

One preventive approach, the so-called “high risk strategy” [7], seeks to identify those individuals with dyslipidemia in order to provide them with individualized counseling and treatment with the view to reduce their cardiovascular risk. This can be achieved, for example, by measuring blood lipids in patients attending routine medical visits [8].

Reeder et al. [9] explored various screening strategies to detect dyslipidemia with the aim of reducing the number of blood samples to be collected. The authors found that the waist-to-hip circumference ratio (WHR), a measure of abdominal obesity (centrally distributed body fat, android-type adiposity) [10–12], effectively identified individuals with a high TC/HDL ratio in a representative sample of the adult population in Saskatchewan (Canada). These results are in accordance with a suggestion first made in the 1950s [13] and then confirmed by several epidemiological studies [14–18]: abdominal obesity as measured by WHR or other similar anthropometric indicators (waist circumference/height ratio [19,20], waist circumference [15,16], abdominal diameter [21], waist-to-tight ratio [22], etc.) is generally a better predictor of CVD mortality and morbidity and/or
related metabolic disturbance than body mass index (BMI) [13,23–34]. Such a link has been found among both children [35] and adolescents [36].

Moreover, based on the good predictive performance of WHR, Reeder et al. suggested its use within a two-stage screening strategy of dyslipidemia in the general population of Saskatchewan [9] (i.e., the use of high WHR as a criterion for the selection of individuals eligible for blood lipid assessment).

The purpose of the present study is to assess the validity of the relationship between abdominal obesity and dyslipidemia in three different populations, namely two Swiss regions and the Seychelles Islands (Indian Ocean). A specific purpose of the inclusion of the latter population is the emerging epidemic of CVD, which is partially related to an increasing prevalence of dyslipidemia [37]. Screening strategies based on simple inexpensive anthropometric measures may be specially relevant in areas with limited health care resources.

2. Methods

The three surveys were performed with similar methods and tools. The surveys in Vaud-Fribourg and in Ticino were part of the MONICA study and, therefore, had to follow a strict protocol for data gathering and measurement. The Seychelles survey was strongly inspired by the MONICA framework, although it was not formally part of it. More details are given below.

2.1. Subject

Swiss data were collected as part of the international MONICA project (MONItoing trends and determinants in Cardiovascular disease) [38]. Among the 40 regions in 25 countries taking part in this project, two Swiss regions (cantons Vaud-Fribourg and canton Ticino) were included. The present study is based on data from the 1992–93 survey. A two-stage sampling procedure was used and consisted, firstly, of drawing a sample of 51 out of the 651 communes after stratification according to their size and, secondly, of drawing the subjects from the population files of the communes. The selected persons were invited to attend to a limited physical examination and to answer a self-administered questionnaire about their sociodemographic and health-related characteristics. In the Vaud and Fribourg cantons, 3299 individuals aged 25–74 years were invited to participate in the study, and 1742 (53%) attended. Corresponding figures in the Ticino canton were 2000 invitees aged 35–64 years and 1510 (76%) participants.

Methods used in the Seychelles Heart Study have been reported elsewhere [37]. The population survey took place in 1994 and was based on a random one-stage sample stratified by age and sex. Twelve hundred and eighty subjects aged 25–64 years were drawn from the resident population on the island of Mahé, which accounts for 90% of the total population of the Seychelles. Overall 1067 (87%) of the 1226 eligible individuals attended the survey. A questionnaire about socioeconomic status and health was administered by trained health professionals and a limited physical examination was also performed.

For the purpose of comparison, the analysis was restricted to age groups common to the three regions (35–64 years). This resulted in the selection of 1140 individuals in Vaud-Fribourg, 1510 in Ticino, and 806 in the Seychelles.

2.2. Measures and cutoff

Blood samples were obtained from nonfasting participants. For the MONICA-Switzerland study, total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) were measured on serum in the Institute of Hematology and Clinical Chemistry, St-Gallen, Switzerland. TC was determined enzymatically (test kit from Boehringer, Mannheim, Germany). The same method was applied to HDL-C after precipitation with magnesium phosphotungstate. The WHO Regional Lipid Reference Center for Europe, in Prague, Czech Republic, organized continuous external quality control by sending blind sets of lyophilized samples periodically to the laboratories of all MONICA collaborating centers. In both Swiss regions, systematic errors ranged between −2.1% and +1.6% for TC, and +0.7% and −6.9% for HDL-C (i.e., within the range of errors accepted by MONICA study [±5% for TC, ±7.5% for HDL-C]).

For the Seychelles Heart Study, analyses were performed at the Lipid Laboratory, University Medical Policlinic, Lausanne, Switzerland. TC was analyzed using the enzymatic colorimetric test CHOD/PAP method (reagents supplied by Roche, Basle, Switzerland) and a Cobas-Mira Centrifugal Analyzer (Roche). HDL-C was measured similarly to TC in the supernatant obtained after precipitation of non-HDL-C lipoproteins with phosphotungstate and MgCl₂ (reagents by Boehringer). External controls by the Swiss Center for Quality Control were performed monthly. In 1994, mean percentage variations between our results and the reference values were −5.3% and \( r = 0.95 \) for TC, and +14% and \( r = 0.90 \) for HDL-C.

In this article, the indicator of dyslipidemia was the TC/HDL-C ratio. The cutoff point was defined for a TC/HDL-C ≥ 5, as in the article from Reeder et al. [9].

Height and weight were measured with participants standing without shoes and heavy outer garments. Body mass index (BMI) was calculated as weight divided by height squared (kg/m²). Waist circumference was measured at a level midway between the lower rib margin and the iliac crest in centimeters (cm) rounded up to the nearest centimeter (Switzerland) or to the nearest half-centimeter (Seychelles). Hip circumference was measured as the maximal circumference over the buttocks. Cutoff points for overweight and high WHR were defined as in the Reeder article [9] (i.e., BMI ≥ 27 kg/m² and WHR ≥ 0.9 in men, WHR ≥ 0.8 in women).

According to some articles [15,39–43] suggesting the superiority of waist circumference (WC) over WHR in terms of correlation with abdominal fat and metabolic complications of CVD, the performance of WC as a screening crite-
rion for dyslipidemia was tested as well as WHR. Cutoff points were defined as WC $\geq$ 94 cm in men and $\geq$80 cm in women, according to published studies [15,39].

Regular cigarette smoking was defined as smoking at least one cigarette per day. Blood pressure (BP) was measured at least 15 min after the subjects had been sitting in a quiet environment. BP values were recorded to the nearest 2 mmHg with diastolic BP being determined at the beginning of Korotkoff phase V. In Switzerland, measurements were made with a standard cuff (12 $\times$ 34 cm) and with a random zero mercury sphygmomanometer. In the Seychelles, measurements were made with a standard or large cuff for an arm circumference respectively up to or higher than 33.9 cm, with a standard mercury sphygmomanometer. BP values used in this study were the average of two measures (Switzerland) and the average of the second and third out of three measures (Seychelles). High BP was defined as a diastolic BP equal to or greater than 90 mmHg and/or treated hypertension.

Physical activity was assessed by a questionnaire asking the participants to categorize their physical activity at work and during leisure time. Physical inactivity was defined by a sedentary type of work (most often sitting down) and less than 1 h of walking per day and less than 20 min of sport per week.

### 2.3. Data analyses

Data analyses performed in this article have been made to compare the present results with those published by Reeder et al. [9], all variables were dichotomic (except age and cutoff points).

Multiple logistic regression analysis was performed to quantify the association between abdominal obesity (as measured by high WHR or WC) and dyslipidemia, independently of several potentially confounding factors (gender, age, smoking, high BMI, high BP, and sedentary habits). Because of the strong collinearity between WHR and WC, they were analyzed in two separate regression models: model 1 with WHR and the confounding factors mentioned above, and model 2 with WC and the same factors. As in the article from Reeder et al. [9], all variables were dichotomized in multiple logistic regression models, except for age, which was taken as a continuous variable. Multivariate odds ratio were used as the measure of association between dyslipidemia and each of the factors under study, controlling for other confounding factors in the equation.

Sensitivity and specificity were used to assess the validity of the screening test. Positive and negative predictive values were used to assess the performance of the test in the three populations.

### 3. Results

Table 1 presents selected characteristics of the three populations under study. There were more young participants in the Vaud-Fribourg sample than in the two others.

Prevalence of dyslipidemia (TC/HDL-C ratio $\geq$ 5) was around 60% in Swiss men and 21–24% in Swiss women and Seychellois of both genders. This pattern results from the differential distribution of TC and HDL-C. Among men, prevalence of high TC was similar in the two Swiss regions (85% with TC $\geq$ 5.2 mmol/l, 40% with TC $\geq$ 6.5 mmol/l), but higher in Switzerland than in the Seychelles (60% and 23%, respectively). Prevalence in Swiss women was lower than in Swiss men but similar to that found in Seychellois women. Prevalence of low HDL-C ($<0.9$ mmol/l) was much lower in Seychellois men (6%) than in Swiss men (12–13%), whereas it was similar in Swiss and Seychellois women (2–3%).

Table 1 also shows the mean values of WHR, WC, and BMI, as well as the corresponding prevalence of high values. Prevalence of high WHR was higher in Swiss men than in Swiss women, but higher in Seychellois women than Seychellois men. In all populations, prevalence of abdominal obesity tended to be higher than prevalence of overweight. Prevalence of abdominal obesity was similar in Swiss men and Seychellois women (about two thirds), and was higher in these categories than in Swiss women and Seychellois men. In all regions and in both genders, prevalence of abdominal obesity was similar irrespective of WHR or WC, except for Seychellois men.

The prevalence of other cardiovascular risk factors is also shown in Table 1. In both genders there is a higher prevalence of high BP in the Seychelles than in Switzerland, consistent with previous studies [44].

Results of the two logistic regression models relating the TC/HDL-C ratio to other risk factors are presented in Table 2 and are expressed as odds ratios (OR) adjusted for the other factors shown in the table. In the three regions and for both genders, dyslipidemia was significantly associated with high WHR and high WC. A significant association was also found for age, male gender, and high BMI (except for Seychellois women in model 2). Smoking was positively and significantly related to dyslipidemia only in the two Swiss regions; in the Seychelles, the OR of smoking was significantly less than 1. High BP and sedentary habits were significantly associated with dyslipidemia only in specific regions (Ticino and Vaud-Fribourg, respectively), but in both models.

The magnitude of the adjusted odds ratios can be compared directly because all variables are dichotomic (except age) and cutoff values similarly defined. In Switzerland, male gender was the highest OR observed, generally followed by one indicator of central obesity or by high BMI. High WC reaches a remarkably high value in the Seychelles (OR = 4.56); high WHR ranked second after high BMI in the Seychelles.

The sensitivity and specificity of each variable for detecting dyslipidemia are presented in Table 3. Sensitivity was similar for high WHR and WC (63–89%), and was usually higher than that of the other indicators, except for high WC in Seychellois men (with a low 48%). Overweight (high BMI) ranked third (48–69%), with an exception for Seychellois women (69%). A major difference between the Swiss and Seychellois populations was high BP of which
the sensitivity (57–63%) was close to that of high WHR in the Seychelles, and greater than those found for high WC and overweight.

Specificity of high WHR and high WC was rather low (43–69%), except in Seychellois men for WC (with a high 86%).

### 4. Discussion

This study shows a stable association between abdominal obesity and dyslipidemia across different populations: both high WHR and high WC were associated with a high TC/HDL ratio.
Low participation rates in population surveys are likely to occur in the Vaud-Fribourg region (but not in the Seychelles). However, error in the measurement of abdominal obesity is likely to be mostly random, resulting in an attenuation of the associations observed here.

Some limits to this analysis must be considered. The surveys were not designed to address the issue under study in this article and the various measures of abdominal obesity were not standardized accordingly. Because measures of waist and hip circumference are known to be difficult to standardize [45,46], some systematic bias when comparing the populations cannot be excluded as measurements were obtained by different teams of investigators in each region. However, error in the measurement of abdominal obesity is likely to be mostly random, resulting in an attenuation of the associations observed here.

Another limit is related to the use of fixed cutoff points adopted for the variables under study. This restrictive choice was made to allow an appropriate comparison with the results from Saskatchewan [9], because the main objective of the study was to demonstrate the stability of the association. However, other indicators and/or other cutoff points may possibly increase the magnitude of the association between the considered indicators of adiposity and dyslipidemia, and improve the performance of subsequently derived screening tests.

Finally, participation rates in the surveys were low in the Vaud-Fribourg region (but not in the Seychelles). However, low participation rates in population surveys are likely to underestimate the true prevalence of overweight [47], but are not expected to alter the magnitude of the association between adiposity and dyslipidemia.

Despite these limits, one main advantage of this study is that the data are population based, thus directly relevant for assessing mass screening of dyslipidemia [9,15]. Moreover, the data were obtained in the three different populations using similar methods. Overall, several results deserve consideration.

A first point is the robustness of the association between abdominal obesity and dyslipidemia, as shown by the similar odds ratio of the multiple regression analysis obtained in the three regions (which are in turn similar to those observed in Saskatchewan [9]). This similarity is observed despite a wide variation of the frequency of CVD risk factors (Table 1) and ethnicity (a large majority of Seychellois are of black descent) among the four populations. A stable pattern across ethnic groups has been found in cross-sectional studies in the U.S. (black and white) [48], in the UK (South Asians and Caucasians) [49], and in Singapore (Malays, Chinese, and Indians) [21]. Studies in other nonwhite populations are also consistent with our findings, for example, in China [50,51], Taiwan [52], Pakistan [53], Polynesian Western Samoa [4], and among Canadian Inuit [54]. A recent study in France also suggests that this association in stable across genders, and might even explain the largest part of the differential pattern of risk factors between the sexes [55].

Thus, overall, these epidemiological findings suggest that the association between dyslipidemia and abdominal obesity is mediated through an etiopathological mechanism independent from the other known risk factors. Intraperitoneal fat has a particularly active metabolism [56], and is instrumental in increasing the flux of free fatty acids carried to the liver from enlarged deposits of mesenteric and omental fat [26]. High levels of free fatty acids interact with the secretion of the lipoproteins [25,57], modify blood levels of triglycerides and HDL-C [58], and have an influence on plasma insulin-glucose metabolism, blood pressure, and fibrinolysis [23,24,30,57,59–66].

Table 3
Sensitivity and specificity (and CI 95%) of selected characteristics for detecting dyslipidemia (TC/HDL ratio ≥5)

<table>
<thead>
<tr>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaud-Fribourg</td>
<td>Ticino</td>
</tr>
<tr>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>High WHR (M ≥0.9; F ≥0.8)</td>
<td>78</td>
</tr>
<tr>
<td>High WC (M ≥94 cm; F ≥80 cm)</td>
<td>68</td>
</tr>
<tr>
<td>BMI ≥27 kg/m²</td>
<td>51</td>
</tr>
<tr>
<td>High BP</td>
<td>31</td>
</tr>
<tr>
<td>Smoking</td>
<td>29</td>
</tr>
<tr>
<td>Sedentary habits</td>
<td>21</td>
</tr>
</tbody>
</table>

TC/HDL ratio: total cholesterol/high density lipoprotein cholesterol. WHR: waist-to-hip ratio. WC: waist circumference. BMI: body mass index. High BP: diastolic blood pressure ≥90 mmHg or current treatment. Smoking: ≥1 cigarette per day. Sedentary habits: see text.
Despite the overall consistency of the association across the considered populations, there are however intriguing variations. For example, high BP shows better sensitivity in the Seychelles than in Switzerland in predicting dyslipidemia [60% and 30%, respectively], despite a low adjusted OR in the Seychelles (Tables 2 and 3). This suggests that high BP is more strongly correlated with other risk factors in the Seychelles than in Switzerland. This corresponds to findings made in other studies [32,33], suggesting a specific physiopathological pattern of high BP among blacks [13,48]. Other studies [49] have suggested some population-specific proneness to develop determined preclinical or clinical conditions, or specific interaction between factors [13,54,67]: Indians, for example, tend to develop central obesity or low glucose tolerance more rapidly than Chinese or Malays placed in the same environment [21]. A further exploration of these different patterns of association might help identify etiopathological mechanisms [13,68,69].

If direct measures of abdominal obesity cannot be used in an inexpensive and reliable way [70], identifying simple anthropometric tools to assess the amount of intra-abdominal fat is of great practical value [68,71]. WC might be better correlated with intra-abdominal fat [41,72,73], while WHR might be more dependent on BMI [41]. However, other conclusions have also been found [74]. This study shows similar performance of WC and WHR, unlike several studies suggesting that high WC might be more discriminant for predicting CVD [39,40,42,43] and/or the level of other risk factors for CVD [15]. There is some variation across genders in this study (sensitivity of high WHR is greater than that of high WC among men; the reverse is observed among women), but these variations are most often within the limits of the confidence intervals and, in any case, subtle in magnitude. Without definite evidence to choose between WHR and WC as a predictor of dyslipidemia, practical advantages should be taken into account. One advantage of WC over WHR is that the former uses only one measurement: in terms of precision, it is better to avoid the use of ratio and favor indicators based on single measurements [75,76].

These data may support the view that high WHR or WC is useful for mass screening of dyslipidemia. If used as a first step to identify those individuals more likely to be dyslipidemic (the second step being the blood exam), the main concern is the false negatives (i.e., the number of dyslipidemic individuals left without intervention because of normal WHR or WC). This number is related to both the sensitivity of the test and the prevalence of dyslipidemia. Both rates vary across populations, and the adoption of a specific strategy should be taken accordingly. For example, high WC is a good screening tool for Seychellois women because sensitivity is high (89%) and dyslipidemia infrequent (21%). On the contrary, high WC is not a good screening tool for Swiss men for the very opposite reasons (low sensitivity at 73–78% and high prevalence of dyslipidemia at 60%). An intermediate situation is represented by Swiss women: 39–55% of the screeners would be referred for blood sampling because of abdominal obesity (either high WHR or high WC, cf. Table 1), allowing the detection of 67–84% of dyslipidemic women (Table 3). Thus, a substantial proportion (16–33%) of the Swiss women would be left without intervention in dyslipidemia because of a low WHR. However, these false-negative individuals also show a TC/HDL ratio lower than those with a high WHR (results not shown), as in Saskatchewan [9]: this attenuates the drawback to let these persons without intervention.

In the Seychelles, routine measurement of blood lipids is less frequent and relatively costly; thus, high values of WHR or WC might be used as a single tool to provide counseling for assumed dyslipidemia. The main concern here are the false positives (i.e., normolipemic individuals who might receive a counseling related to dyslipidemia because of abdominal obesity). However, if the main message of the counseling is the weight reduction, this is beneficial in any case because weight is a risk factor for hypertension or diabetes in addition to dyslipidemia [77]. Thus, counseling for assumed dyslipidemia to persons with high values of WHR or WC is likely to have more advantages than drawbacks.

5. Conclusion

Dyslipidemia is a major risk factor for CVD. Thus, a set of strategies is needed to tackle this issue, including individual counseling for people at high risk of developing CVD. Both high WHR and WC may be useful as relatively inexpensive first-stage screening tools to detect dyslipidemic individuals. Because the overall performance of the test (in terms of sensitivity and specificity) is not very high, the practical use of WC or WHR will be most relevant in populations with low prevalence of dyslipidemia. This pattern is currently being observed in many developing countries, which may adopt this strategy. This article presents some factors in this perspective.

However, other aspects of feasibility, acceptability, impact, and costs should be evaluated before such a strategy is implemented. If measures of waist and hip have to be used as screening tools, more standardization is needed as well as more validation studies [46], also addressing possible variations across ethnic groups [78]. Abdominal obesity measurements should also be integrated regularly in population surveys, whether measured directly or self-reported (the latter appears useful for epidemiological community assessment [66,79,80]. Finally, further studies should determine which cutoff points optimize the performance of indicators of abdominal obesity as predictors of dyslipidemia [15,39], and/or which sort of combination of predictors might increase the accuracy of the screening.

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