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Hans Wahrenberg, Katarina Hertel, Britt-Marie Leijonhufvud, Lars-Göran Persson, Eva Toft and Peter Arner

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# Use of waist circumference to predict insulin resistance: retrospective study

Hans Wahrenberg, Katarina Hertel, Britt-Marie Leijonhufvud, Lars-Göran Persson, Eva Toft, Peter Arner

Insulin resistance is an important pathogenic factor in common metabolic disorders. No easy clinical test exists for predicting the insulin resistance of an individual. We assessed how effectively different anthropometric measurements and biochemical markers used in clinical practice can predict insulin sensitivity.

## Participants, methods, and results

We analysed a sample of 2746 healthy volunteers (798 male) from retrospectively collected data. Ages ranged from 18 years to 72 years, body mass index ( $\text{kg}/\text{m}^2$ ) from 18 to 60, and waist circumferences from 65 cm to 150 cm (see table A on [bmj.com](http://bmj.com) for further data). We determined height, weight, waist circumference (mid-way between the lateral lower ribs and the iliac crest), and hip circumference. Results from analyses of venous plasma for glucose, insulin, lipids, and leptin concentrations were used. We used homeostasis model assessment (HOMA index) as a measure of insulin sensitivity (plasma glucose ( $\text{mol}/\text{l}$ )  $\times$  plasma insulin ( $\text{mU}/\text{l}$ )/22.5)—an established test in epidemiological studies.<sup>1</sup> We defined insulin resistance as a HOMA score  $>3.99$ , on the basis of a definition for a white population.<sup>2</sup>

We used multivariate regression models to assess the predictive power of the variables (see [bmj.com](http://bmj.com)). We used receiver operating characteristics (ROC) curve analysis to select an appropriate cut-off for variables. In the multiple regression model, waist circumference was the strongest regressor of the five significant covariates (standardised partial regression coefficients: waist circumference  $\beta_1=0.37$ ; log-plasma triglycerides  $\beta_2=0.23$ ; systolic blood pressure  $\beta_3=0.10$ , high density lipoprotein cholesterol  $\beta_4=-0.09$ ; and body mass index  $\beta_5=0.15$  ( $P<0.001$ )). The areas under the ROC curves were 0.8915 (standard error 0.008) for men and 0.8644 (0.007) for women, respectively, indicating a very good discriminating power. On the basis of the ROC curves, we set the optimal cut-off for detecting insulin resistance at 100 cm for waist circumference in both sexes. The table shows the number of true and false positives and negatives in both sexes (see also the figure on [bmj.com](http://bmj.com)). Sensitivities and specificities were between 94-98% and 61-63% respectively in both sexes. The positive predictive values in our sample were 61% in men and 42% in women (these figures depend on the prevalence of insulin resistance in the actual sample). The negative predictive value was 98% in both sexes. With a cut-off of 88 cm in women (the level cited in guidelines) the specificity dropped to 49%.<sup>3</sup>

## Comment

A waist circumference of  $<100$  cm excludes individuals of both sexes from being at risk of being insulin

### What is already known on this topic

Waist circumference is an independent risk factor for cardiovascular disease

The cut-off for high risk of cardiovascular disease is 102 cm and 88 cm in men and women respectively

### What this study adds

Waist circumference is a very good predictor of insulin sensitivity; a waist circumference of  $<100$  cm excludes insulin resistance in both sexes

resistant. Waist circumference is a strong independent risk factor for insulin resistance and the most powerful regressor in our model. It replaces body mass index, waist:hip ratio, and other measures of total body fat as a predictor of insulin resistance and explains more than 50% of the variation in insulin sensitivity alone.

Current guidelines suggest a cut-off of 102 cm in men and 88 cm in women, on the basis of the many metabolic risk factors after waist circumference is stratified in fifths.<sup>3</sup> However, with 88 cm as a cut-off in women the specificity drops markedly. In the San Antonio heart study, twice as many women as men had a waist circumference above the level given in the current guidelines, whereas the prevalence of the metabolic syndrome was similar in both sexes, thus supporting the notion that abdominal obesity is overestimated in women.<sup>4</sup> The coupling of insulin resistance with abdominal obesity suggests a biological link at the fat cell level. Hyperinsulinaemia activates  $11\beta$ -hydroxysteroid dehydrogenase in omental adipose tissue, thus generating active cortisol and promoting a cushingoid fat distribution.<sup>5</sup> Waist

Ability to select insulin resistance and sensitivity among healthy men and women by using 100 cm waist circumference as cut-off. Insulin resistance was defined as a HOMA score  $>3.99$ . Waist circumference and HOMA score were available for 2648 participants

	Insulin resistance		Insulin sensitivity	
	Men	Women	Men	Women
Waist $\geq 100$ cm	277	388	176	543
Waist $<100$ cm	7	25	293	939

Means (95% binomial confidence intervals) for sensitivities, specificities, and positive and negative predictive values were, for men and women respectively: sensitivities 0.98 (0.95 to 0.99) and 0.94 (0.91 to 0.96); specificities 0.63 (0.59 to 0.68) and 0.63 (0.61 to 0.66); positive predictive values 0.61 (0.56 to 0.66) and 0.42 (0.38 to 0.45); and negative predictive values 0.98 (0.95 to 0.99) and 0.97 (0.96 to 0.98).



Further data and statistical details are on [bmj.com](http://bmj.com)

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circumference is a simple tool to exclude insulin resistance and to identify those at greatest risk (therefore those who would benefit most from lifestyle adjustments).

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Contributors: All authors contributed to the study design. KH and B-ML did all the clinical examinations. L-GP built and managed the database where all data were stored. ET, PA, and HW were responsible for the statistical analysis of the data. HW wrote the first draft of the manuscript. All authors contributed to the final version of the manuscript. HW is the guarantor for the study.

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## Mental disorders in prison populations aged 15-21: national register study of two cohorts in Finland

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Juvenile delinquency is linked to psychiatric morbidity.<sup>1 w1-w9</sup> We were interested in temporal changes in psychiatric morbidity in offenders. Criminal policy in many Western countries emphasises the need for alternative methods of punishment for adolescent prisoners.<sup>2</sup> In Finland, successful policy to diminish the number of adolescents in prisons has been internationally recognised.<sup>3</sup> We studied the changes in psychiatric hospitalisations in Finnish prisoners aged 15 to 21 to see whether a selection process occurs as the number of young prisoners decreases.

### Participants, methods, and results

We linked the unique personal identification numbers of all prisoners aged 15 to 21 years from 1984-5 and 1994-5 to the Finnish healthcare register, which includes data of all hospitalisations in Finland. We retrieved occurrences of depression, psychosis, personality disorder, and substance dependence, and we analysed temporal changes. The observation period for the first cohort was 1980-9 and for the second 1990-9. We compared hospitalisations with those of a control group, matched for sex, age, and place of birth, derived from the population register. The full method is on [bmj.com](http://bmj.com).

The earlier cohort from 1984-5 comprised 656 prisoners (719, with 63 (8.8%) missing identification numbers), and the later cohort included 370 prisoners (377, with 7 (1.9%) missing identification numbers). This temporal decrease shows the effect of the policy to reduce the number of young prisoners. The cohorts did not differ in terms of sex (Fisher's exact test,  $P=0.19$ ); in the earlier cohort there were 18 (0.03%) women, in the later 5 (0.01%).

The number of inmates with at least one hospital treatment for any mental disorder increased significantly (odds ratio 1.8, 95% confidence interval 1.3 to

### What is already known on this topic

Prisoners are more likely to have serious mental disorders than the general population, and efforts have been made to reduce the number of young prisoners

### What this study adds


More mentally ill young people end up in prison as the prison population diminishes

2.3, age adjusted) over time compared with the general population, in which we detected no increase in hospitalisations for mental disorders (1.0, 0.7 to 1.4; table). The increase in treatment for psychosis was significant between the two cohorts (2.7, 1.4 to 5.1, age adjusted) and it was significant for substance dependence (3.0, 2.0 to 4.6, age adjusted). In the control groups the changes in prevalence of these disorders were not significant (1.6, 0.7 to 3.5 and 0.9, 0.3 to 3.0).

The absolute number of prisoners who had had inpatient treatment for psychosis or substance dependence increased from the earlier to the later cohort. The odds of being hospitalised for schizophrenia in the earlier prisoner group were fourfold greater (3.9, 1.6 to 9.4) than in the control group but were eightfold greater (8.0, 2.7 to 23.5) in the later cohort.

### Comment

Relatively more mentally ill people end up in prisons as the prison population diminishes. Hospitalisations

 The full method and references w1-w9 are on [bmj.com](http://bmj.com)

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