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ORIGINAL COMMUNICATION

# Waist circumference, body mass index, hip circumference and waist-to-hip ratio as predictors of cardiovascular disease in Aboriginal people

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**Objective**: To investigate waist circumference (WC), waist–hip ratio, hip circumference and body mass index (BMI) as risk factors for cardiovascular disease in Aboriginal Australians.
**Methods**: This cohort study included 836 adults aged 20–74 y in a remote Aboriginal community. WC, waist–hip ratio, hip circumference and BMI were obtained from a screening program. The participants were followed for up to 10 y for cardiovascular events. A Cox regression model was used to calculate the rate ratio (RR) and 95% confidence interval (CI) for the first-ever cardiovascular event (fatal and nonfatal).
**Results**: RRs for the first-ever cardiovascular event were 1.31 (95% CI: 1.11, 1.54), 1.29 (95% CI: 1.09,1.53), 1.28 (95% CI: 1.08, 1.52) and 1.10 (95% CI: 0.93, 1.30) per standard deviation increase in WC, BMI, hip circumference and waist–hip ratio, respectively, after adjustment for diabetes mellitus, total cholesterol, systolic blood pressure and smoking status. WC, BMI and hip circumference were significantly associated with cardiovascular risk, independent of other cardiovascular risk factors. Dividing each of the four parameters into quartiles, WC had the highest likelihood statistics (12.76) followed by BMI (11.45), hip circumference (10.57) and waist–hip ratio (3.15) for predicting first CV events.
**Conclusion**: WC, BMI and hip circumference are associated with cardiovascular outcome, independent of traditional risk factors. However, WC appears to be a better predictor for cardiovascular risk than other parameters. Waist–hip ratio is not as useful as other measurements.
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**Keywords:** cardiovascular disease; waist circumference; body mass index; hip circumference; waist-to-hip ratio

## Introduction

The prevalence of obesity in Aboriginal Australians has increased during the last decade (McDermott *et al*, 2000). In one remote Aboriginal community, the prevalence of obesity is about 24–29% for 25–44-y-old females, which is higher than older Aboriginal and non-Aboriginal counterparts (Wang & Hoy, 2003). Obesity has been shown to be a risk factor for coronary heart disease (Manson *et al*, 1990). However, the relative importance of overall and abdominal obesity is still debatable. Several anthropometric measures have been used to investigate the association between adiposity and cardiovascular disease. Body mass index (BMI) is perhaps the most commonly used measurement. Waist-to-hip ratio has been reported as a better predictor of coronary heart disease than BMI (Rimm *et al*, 1995; Rexrode *et al*, 1998). However, waist-to-hip ratio is considered an artificial term with no biological meaning, and it does not usefully reflect fat distribution or health better than waist circumference (WC) alone (Lean & Han, 2002). Several studies have shown that WC is more closely associated with visceral adipose tissue mass, than is either waist-to-hip ratio or BMI (van der Kooy & Seidell, 1993; Pouliot *et al*, 1994), and that WC is independently associated with increased risk of coronary heart disease (Rimm *et al*, 1995; Rexrode *et al*, 1998; Iwao *et al*, 2001) and stroke (Dey *et al*, 2002). Seidell *et al* (2001) suggest that people with a narrow WC and a large hip circumference have a lower risk of cardiovascular disease.

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Large hip circumference is found to be associated with a lower risk of diabetes, independent of BMI and WC (Seidell *et al*, 1997; Snijder *et al*, 2003).

No studies on this topic are available in Australian Aboriginal people, who experience higher cardiovascular disease death rates than other Australians (Mathur & Gajanayake, 1998). The cardiovascular risk profile in Aboriginal people is different from that of the general Australian population (Wang & Hoy, 2003). Aboriginal people have a higher prevalence of smoking, diabetes and hypertension, and a lower prevalence of abnormal total cholesterol. Characterized by long-leggedness and low sitting height to stature ratio, Aboriginal Australians have a body shape different from that of other populations (Norgan, 1994).

A number of questions remain to be answered in this population. Is WC a better indicator of cardiovascular risk than BMI? Does hip circumference add to the predictive power of WC or BMI? In this community-based cohort study, we assessed and compared the predictive values of four anthropometric parameters, WC, waist-to-hip ratio, hip circumference and BMI, on the risk of cardiovascular disease.

## Methods

In 1992, a community-wide screening program was started in a remote Northern Territory Aboriginal community. Participants were offered testing at baseline between 1992 and 1995. A total of 870 adults aged 20–74 y were included in this study. In all, 34 were excluded because of the known pre-existing cardiovascular events in the hospital records. A total of 836 participants (414 females and 422 males) were included in the analysis, representing over 80% of the adult population.

The project was approved by the Joint Institutional Ethics Committee of the Menzies School of Health Research and Territory Health Services, Darwin, Australia. Informed consents were obtained at the initial data collection.

## Measurements

Deaths from cardiovascular diseases, including coronary heart disease, stroke and heart failure, during the 10-y follow-up period were identified. Cardiovascular events were identified through hospital records according to ICD-9 and ICD-10-AM codes as described in Table 1.

Only the first cardiovascular incident for each participant was included in the analysis. All participants were followed up to 31 December 2002. For those who reached an end point of a cardiovascular event during the follow-up period, their follow-up time was the time from the date of the initial anthropometric measurement to the date the first event occurred. Those who had not reached an end point were considered ‘censored’ at 31 December 2002.

Measurements of established cardiovascular risk factors, such as age, sex, smoking and diabetes, total cholesterol and HDL cholesterol levels, and blood pressures, have been described elsewhere (Wang & Hoy, 2003). WCs were measured at the narrowest point below the ribs or halfway between the lowest ribs and the iliac crests. Hip circumferences were measured at the level of the anterior superior iliac spine, where this could be felt, otherwise at the broadest circumference below the waist.

**Table 1** ICD 9 and ICD 10-AM codes for hospital diagnoses

| *Disease* | *ICD-9 code* | *ICD-10-AM code* |
|---|---|---|
| Hypertensive disease | 401–405 | I10–I15 |
| Coronary heart disease | 410–414 | I20–I25 |
| Heart failure | 428 | I50 |
| Atherosclerosis | 440 | I70 |
| Stroke | 430–438 | G45, G46 and I60–I69 |
| Peripheral vascular disease | 441–444 | I71–I74 |

## Analysis

Subjects were categorized according to quartiles of baseline anthropometric variables. Since there are no recommended ranges or cutoffs for Aboriginal people in the literature, we used quartiles to ensure equal numbers of subjects in each group. BMI among adults in the study population varied with age and gender (Wang *et al*, 2000). To control for potential confounding effects of age and sex, age–sex specific quartiles were used. Rates of cardiovascular events were calculated according to anthropometric groupings. Cardiovascular rates were obtained using the number of first cardiovascular events divided by the person-years of follow-up. Rate ratios (RRs) and their 95% confidence intervals were estimated with the lowest quartile as a reference group, using the Cox proportional hazards model adjusting for potential confounding factors such as age, sex, smoking, blood pressure, cholesterol level and diabetes status. Likelihood ratio tests were used to assess the contribution of each measurement.

To compare the strengths of linear relationship with cardiovascular events among four measurements, we calculated RRs corresponding to one standard deviation increment in each anthropometric measurement. Age–sex-specific means and standard deviations were used to convert the original scales into standard deviation scores. All analyses were performed using Stata 8.0 (StataCorp, 2003).

## Results

Correlations between study variables are presented in Table 2. WC, BMI and hip circumference were highly correlated. A positive association was found between higher WC quartiles and other traditional cardiovascular risk factors of blood pressure, total cholesterol, triglycerides and diabetes. The levels of blood pressures, total cholesterol and triglycerides

**Table 2** Correlation matrix of selected study variables

| | *Waist* | *BMI* | *WHPR* | *Hips* | *SBP* | *DBP* | *Total cholesterol* | *HDL* |
|---|---|---|---|---|---|---|---|---|
| BMI | 0.866 | | | | | | | |
| WHPR | 0.302 | 0.097 | | | | | | |
| Hips | 0.873 | 0.851 | −0.194 | | | | | |
| SBP | 0.249 | 0.230 | 0.191 | 0.161 | | | | |
| DBP | 0.283 | 0.268 | 0.174 | 0.205 | 0.626 | | | |
| Total cholesterol | 0.239 | 0.236 | 0.211 | 0.147 | 0.252 | 0.328 | | |
| HDL | −0.287 | −0.244 | −0.121 | −0.235 | 0.080 | 0.121 | 0.142 | |
| Triglycerides | 0.269 | 0.263 | 0.181 | 0.186 | 0.230 | 0.318 | 0.544 | −0.203 |

All Pearson's correlation coefficients are statistically significant ($P<0.05$).

**Table 3** Distribution of cardiovascular risk factors in Aboriginal participants by WC

| | *Quartiles* | | | | |
|---|---|---|---|---|---|
| *Variable* | *1st* | *2nd* | *3rd* | *4th* | P-*value* |
| Number | 224 | 215 | 201 | 196 | |
| Age, mean | 34.1 (11.6) | 34.5 (12.8) | 34.0 (11.9) | 34.4 (12.0) | 0.9751 |
| Cholesterol | 4.4 (1.0) | 4.7 (1.2) | 4.8 (1.0) | 5.0 (1.2) | <0.0001 |
| Systolic BP | 116.5 (17.2) | 120.8 (19.0) | 121.3 (16.7) | 127.3 (18.2) | <0.0001 |
| Diastolic BP | 70.7 (12.8) | 74.4 (14.1) | 74.6 (11.8) | 79.0 (14.2) | <0.0001 |
| BMI | 19.2 (2.6) | 22.1 (3.3) | 24.9 (3.6) | 30.0 (4.5) | <0.0001 |
| Hip circ. | 81.0 (8.5) | 90.0 (9.9) | 96.5 (10.1) | 108.3 (11.5) | <0.0001 |
| Waist–hip ratio | 0.9 (0.1) | 0.9 (0.1) | 1.0 (0.1) | 1.0 (0.1) | <0.0001 |
| HDL | 1.19 (0.30) | 1.11 (0.23) | 1.07 (0.22) | 1.02 (0.22) | <0.0001 |
| Triglycerides, geometric mean (95% CI) | 1.4 (1.3,1.5) | 1.9 (1.7,2.1) | 2.1 (1.9,2.3) | 2.3 (2.1,2.5) | <0.0001 |
| Male, *n* (%) | 114 (50.9) | 108 (50.2) | 99 (49.3) | 101 (51.5) | 0.9729 |
| Diabetes, *n* (%) | 12 (5.4) | 23 (10.7) | 30 (14.9) | 43 (21.9) | <0.0001 |
| Smoking, *n* (%) | 179 (79.9) | 166 (77.2) | 153 (76.1) | 129 (65.8) | 0.0062 |
| Drinking, *n* (%) | 141 (62.9) | 132 (61.4) | 113 (56.2) | 102 (52.0) | 0.0956 |
| CVD events (per 1000 person–years) | 25 (14) | 42 (27) | 46 (31) | 52 (40) | 0.0002 |

Mean (s.d.) if not specified. HDL and triglyceride are only available in a subset: 178, 164, 158 and 139 for 1st, 2nd, 3rd and 4th quartiles, respectively.

monotonically increased with the increment of waist quartiles (Table 3). HDL cholesterol was inversely associated with waist quartiles. The prevalence of diabetes increased across the WC categories. A significant inverse association was found between WC and smoking status.

### Cardiovascular rates

During the follow-up period, 165 participants had confirmed first cardiovascular events, including 24 cardiovascular deaths. Cardiovascular death was the first-ever cardiovascular event for 10 participants. The CVD rate increased monotonically with WC quartiles from 14 per 1000 person–years for the lowest quartile to 40 per 1000 person–years for the highest quartile (Table 3).

### WC, BMI, hip circumference, waist–hip ratio and cardiovascular risk

The RRs are presented in Table 4. WC, BMI and hip circumference were all significantly associated with cardiovascular risk independently of traditional cardiovascular risk factors. Waist–hip ratio was not significantly associated with cardiovascular disease. WC had the highest likelihood statistic, and RRs were higher for WC than for BMI or hip circumference.

Table 5 shows estimates of population attributable risk, which suggests the proportion of population risk that would be reduced if all participants were in the lowest quartile of each index of adiposity. The highest attributable risk occurred when using WC quartiles, where 42% of population risk was attributable to higher WC quartiles.

To examine the possible linear relationship between anthropometric measurements and cardiovascular risk, we took all measurements as continuous variables to calculate RRs corresponding to one standard deviation increase. Cardiovascular events rates increased 36, 29 and 28% with one standard deviation increment in WC, BMI and hip circumference, respectively. Adjustment for traditional risk factors did not alter the order (Table 6).

We also used stepwise approaches to select anthropometric variables in Cox proportional models. Among the four variables, WC was the first variable entering the model.

**Table 4** Cardiovascular events and WC, BMI, hip circumference and waist–hip ratio

| | | Crude RR | | | Adjusted RR[a] | | |
|---|---|---|---|---|---|---|---|
| *Quartile* | | *RR (95% CI)* | *LR*[b] | *P-value* | *RR (95% CI)* | *LR*[b] | *P-value* |
| Waist circ. | 1st | 1 | 20.65 | 0.0001 | 1 | 12.76 | 0.0052 |
| | 2nd | 1.89 (1.15–3.10) | | | 1.56 (0.91–2.68) | | |
| | 3rd | 2.19 (1.34–3.56) | | | 1.81 (1.06–3.10) | | |
| | 4th | 2.8 (1.74–4.52) | | | 2.5 (1.47–4.23) | | |
| BMI | 1st | 1 | 15.2 | 0.0017 | 1 | 11.45 | 0.0095 |
| | 2nd | 1.58 (0.96–2.59) | | | 1.42 (0.83–2.43) | | |
| | 3rd | 2.08 (1.29–3.33) | | | 1.67 (0.96–2.90) | | |
| | 4th | 2.32 (1.44–3.73) | | | 2.39 (1.41–4.07) | | |
| Hip circ. | 1st | 1 | 10.54 | 0.0145 | 1 | 10.75 | 0.0132 |
| | 2nd | 1.32 (0.82–2.13) | | | 1.24 (0.73–2.10) | | |
| | 3rd | 1.88 (1.20–2.94) | | | 1.70 (1.04–2.78) | | |
| | 4th | 1.84 (1.16–2.90) | | | 2.13 (1.29–3.51) | | |
| Waist–hip ratio | 1st | 1 | 8.31 | 0.04 | 1 | 3.15 | 0.3695 |
| | 2nd | 1.01 (0.62–1.63) | | | 0.84 (0.50–1.40) | | |
| | 3rd | 1.54 (0.99–2.40) | | | 1.27 (0.80–2.01) | | |
| | 4th | 1.62 (1.04–2.52) | | | 1.08 (0.66–1.76) | | |

[a]Adjusted for age, sex, blood pressure, cholesterol, smoking and diabetes. [b]LR: likelihood ratio $\chi^2$.

**Table 5** Population attributable risk adjusting for traditional risk factors

| *Quartile* | *Waist circ.* | *BMI* | *Hip circ.* | *Waist–hip ratio* |
|---|---|---|---|---|
| 2nd | 0.09 (−0.02, 0.19) | 0.07 (−0.04, 0.17) | 0.04 (−0.06, 0.13) | −0.04 |
| 3rd | 0.12 (0.01, 0.22) | 0.12 (−0.01, 0.23) | 0.13 (0.01, 0.24) | 0.07 (−0.07, 0.18) |
| 4th | 0.21 (0.09, 0.32) | 0.19 (0.07, 0.29) | 0.16 (0.05, 0.26) | 0.02 (−0.11, 0.14) |
| Total | 0.42 (0.14, 0.61) | 0.38 (0.08, 0.59) | 0.33 (0.05, 0.53) | 0.05 (−0.31, 0.31) |

Adjusted for age, sex, blood pressure, cholesterol, smoking and diabetes.

**Table 6** RRs corresponding to one standard deviation increase in anthropometric measurements

| | Rate ratio (95% CI) | | | |
|---|---|---|---|---|
| | *Crude* | | *Adjusted** | |
| Waist circ. | 1.36 | (1.17–1.57) | 1.31 | (1.11–1.54) |
| BMI | 1.29 | (1.11–1.49) | 1.29 | (1.09–1.53) |
| Hip circ. | 1.28 | (1.10–1.49) | 1.28 | (1.08–1.52) |
| Waist–hip ratio | 1.18 | (1.02–1.37) | 1.10 | (0.93–1.30) |

Adjusted for age, sex, blood pressure, cholesterol, smoking and diabetes.

Once WC was in the model, none of the other three variables made a significant contribution.

## Discussion

WC, BMI and hip circumference are useful predictors of cardiovascular risk. Our results suggest that the risk of cardiovascular events in Aboriginal adults is related to WC independently of traditional cardiovascular risk factors. This confirms results from previous studies in other populations (Rexrode *et al*, 1998; Dey *et al*, 2002). To compare the relative importance of four anthropometric measurements, we took those measurements as categorical and continuous variables to estimate RRs, population attributable risk and likelihood ratio statistics. Findings from all approaches consistently suggest that WC is a more sensitive predictor than other measurements.

It should be noted that WC, BMI and hip circumference are highly correlated. They carry similar information of cardiovascular risk. If WC is not available, BMI and hip circumference are useful predictors. However, when WC is available, neither BMI nor hip circumference is an important predictor of cardiovascular risk. Our findings are consistent with the findings from other populations. Lean *et al* (1995) proposed WC as a simple measurement to indicate the need for weight management. Several studies found a close relation between WC and cardiovascular risk factors (Han *et al*, 1995; Seidell *et al*, 1997; Janssen *et al*, 2002). The

Framingham study suggested that the waist predicted mortality better than other anthropometric measures (Higgins *et al*, 1988). WC was also found to be associated with diabetes, stroke and coronary heart disease (Dey *et al*, 2002). Data from the Framingham study suggested that cardiovascular disease was closely linked to abdominal adiposity estimated by skinfolds and WC per inch of height (Kannel *et al*, 1991). It is reported that WC is the best anthropometric correlate of the amount of visceral adipose tissue (Pouliot *et al*, 1994). A longitudinal study revealed that the change in waist was a better predictor of the change in visceral adipose tissue (Lemieux *et al*, 1996). WC captures information on general as well as abdominal obesities including both abdominal subcutaneous fat and visceral adipose. It may also be more sensitive to weight changes due to exercise, diet, smoking and alcohol consumption (Vadstrup *et al*, 2003).

Most previous studies examining the association of WC with cardiovascular risk factors in Aboriginal people were of cross-sectional design. We used cohort data to compare the contributions of WC, BMI, hip circumference and waist–hip ratio to the actual occurrence of cardiovascular events in Aboriginal people. WC is a single measurement and a better predictor of cardiovascular risk. If confirmed in future studies, we recommend WC as a preferred risk predictor over BMI in Aboriginal people.

Although both health professionals and the general public are familiar with BMI and its acceptable range (20–25), most people cannot readily calculate their BMIs. Since two measurements, weight and height, are needed to calculate BMI, the calculation is subject to two measurement errors. WC is only a single measurement. However, there are a number of obstacles for using WC as a risk predictor. Different methods of measuring WC are currently in use. Wang *et al* (2003) compared measurement values at four commonly used anatomic sites. Although measurements using all methods were highly reproducible with intraclass correlation values $>0.99$, the values varied among sites. Therefore, efforts should be made to standardize the method. Further efforts should be made to establish cutoffs indicating need for weight management in Aboriginal people. Lean *et al* (1995) suggested that a waist circumference of 94 cm for men and 80 cm for women should be considered the cutoff for limiting weight gain, whereas 102 cm for men and 88 cm for women should be considered for reducing weight (Lean *et al*, 1995). A nationwide Australian survey of the prevalence of diabetes, obesity and other cardiovascular risk factors adopted those cutoffs (Dunstan *et al*, 2002). More Aboriginal people were classified as overweight by the above waist criteria than by BMI criteria (Wang & Hoy, 2003). Health-related cutoffs need to be established for Aboriginal Australians.

Without BMI and WC in the model, hip circumference is positively associated with cardiovascular risk. This may be because hip circumference carries some information of both overall obesity and abdominal obesity, since hip circumference is positively correlated with BMI and WCs. However, when WC was taken into account, hip circumference no longer had an independent contribution. Unlike some other studies (Lissner *et al*, 2001; Seidell *et al*, 2001), we did not find the protective effect of a large hip circumference. A relatively small sample size or imprecision of the measurements cannot be excluded as possible explanations.

Our findings suggest that waist–hip ratio is a poorer predictor than either WC or BMI. This contradicts some studies (Rexrode *et al*, 1998; Snijder *et al*, 2003). Intuitively, waist–hip ratio captures body fat distribution. However, a 7-y longitudinal study revealed that change in waist was a better correlate of the change in visceral adipose tissue than the change in the waist–hip ratio (Lemieux *et al*, 1996). Waist–hip ratio is a measure of relative accumulation of abdominal fat, while WC is a measure of absolute abdominal fat as well as total body weight. Two circumference measures are required for waist–hip ratio calculation. Both measurements are subject to measurement errors. Our data do not support waist–hip ratio as an independent risk predictor in this population.

In conclusion, WC, BMI and hip circumference are associated with cardiovascular outcome, independent of traditional risk factors. However, WC appears to be a better predictor for cardiovascular risk than other parameters. Waist–hip ratio is not as useful as other measurements. Additional analyses are needed to establish health-related cutoffs in Aboriginal people.

## Key messages

1. WC and BMI are associated with cardiovascular disease independently of traditional cardiovascular risk factors.
2. WC and BMI are highly correlated. Each is useful in predicting cardiovascular risk.
3. WC is a better predictor than BMI.
4. Waist–hip is not as useful as other measurements.
5. Efforts to standardize WC measurement and to define cutoffs for Aboriginal people should be encouraged.

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