OBJECTIVE — Increased BMI is a robust risk factor for type 2 diabetes. Paradoxically, South Asians have relatively low BMIs despite their high prevalence of type 2 diabetes. We examined the association between BMI and incident type 2 diabetes because detailed prospective cohort data on this topic in Asians are scarce.

RESEARCH DESIGN AND METHODS — This study was a prospective analysis of 37,091 men and women aged 45–74 years in the Singapore Chinese Health Study, using Cox regression analysis.

RESULTS — Risk of incident type 2 diabetes significantly increased beginning with BMIs 18.5–23.0 kg/m² (relative risk 2.47 [95% CI 1.75–3.48]) and continued in a monotonic fashion across the spectrum of BMI. Results were stronger for younger than for older adults.

CONCLUSIONS — BMIs considered lean and normal in Singaporean Chinese are strongly associated with increased risk of incident type 2 diabetes. This association weakened with advanced age but remained significant.

RESULTS — The associations of BMI and risk of type 2 diabetes are presented in Table 1. Those considered to be normal weight (BMI 18.5–23.0 kg/m²) had a 2.5-fold–increased risk of diabetes (HR 2.47 [95% CI 1.75–3.48]) compared with the referent category (BMI <18.5 kg/m²). The HR increased with each successively increasing BMI category. Stratification by age produced similar trends across BMI and as deciles. Hypothesized tests for interaction between BMI and age as well as sex and physical activity were performed, with only age revealing evidence (P < 0.001) for an interaction. Analyses including only validated cases and excluding cases with <2 years of follow-up time did not produce materially different results.
of obesity and type 2 diabetes, but they
for population surveillance in the case
Nonetheless, BMI cutoffs may be useful
parameters of glucose metabolism (5).
and South Asian individuals based on pa-
appropriate cutoff for obesity in Chinese
findings are consistent with a recent study
of BMI and diabetes risk by age. Our
BMI range, with strong effect modifica-
type 2 diabetes increased in BMIs consid-
dered lean and normal and continued in a
dose-response fashion throughout the
plateau for other rapidly developing regions
Asians have a relatively high susceptibility
mechanism driving diabetes risk at such
likely that the metabolic burden of abso-
other deleterious effects that could lead to
diabetes (12). However, it appears un-
likely that the metabolic burden of absolu-
te adipose accumulation would be the
mechanism driving diabetes risk at such
low BMI ranges (19–21 kg/m²) observed
in the current study. Residual confound-
ing by dietary and lifestyle factors, no as-
sement of family history of diabetes or
other measures of adiposity, and the self-
reported basis of BMI and diabetes in the
study should also be considered as limits
in interpreting the results.

In short, these findings demonstrate
that risk of developing type 2 diabetes in-
creases at low levels of BMI and continues
to increase throughout the spectrum of
BMI in Chinese Singaporeans. They also
illustrate marked effect modification by
age, as the association attenuated with in-
creasing age. Continued and further re-
search is needed to understand the associa-
tion between adiposity and type 2
diabetes and to identify an optimal and
healthful BMI range in Asians while con-
sidering diabetes and other health out-
comes. With increasing obesity and
diabetes rates in Asia, the development of
public health approaches bringing aware-
ness of and action to the issue has signif-
cy of and action to the issue has signif-
ificant potential benefits.

Table 1—HRs of type 2 diabetes by World Health Organization Southeast Asian cutoffs of BMI stratified by age

| Decile | n  | Mean BMI (minimum–maximum) | n = 16,909 | n = 13,860 | n = 3,515 |
|--------|----|----------------------------|-----------|-----------|-----------|
| <18.5 kg/m² | 3,716 | 17.6 (16.9–20.2) | 1.70 (1.20–2.42) | 2.04 (1.45–2.85) | 2.95 (2.14–4.07) |
| 18.5–23 kg/m² | 3,789 | 19.6 (18.8–21.0) | 2.15 (1.68–2.57) | 3.32 (2.49–4.58) | 3.72 (3.15–4.65) |
| 23–27.5 kg/m² | 3,943 | 21.5 (21.0–22.5) | 2.95 (2.14–4.07) | 3.72 (2.49–4.58) | 3.54 (2.95–4.25) |
| >27.5 kg/m² | 3,571 | 22.3 (21.9–22.7) | 2.95 (2.14–4.07) | 3.72 (2.49–4.58) | 3.54 (2.95–4.25) |

Data are incidence and HR (95% CI). *Models are adjusted for age, sex, ethnicity, year of interview (1993–1995 and 1996–1998), hypertension (yes/no), smoking history (no, former, or current), education (none, primary, or secondary or more), alcohol intake (no, monthly, weekly, or daily), dietary factors (energy intake [kcal/day], fiber intake [g/day], total meat consumption [g/day], saturated fat [g/day], soft drink consumption [glasses/week], and coffee consumption [weekly, one, two, three, or four or more cups per day]), and moderate and strenuous physical activity in hours per week (moderate e.g., walking) and strenuous e.g. jogging).

CONCLUSIONS — In this cohort of
Chinese Singaporeans, risk of developing
type 2 diabetes increased in BMIs consid-
ered lean and normal and continued in a
dose-response fashion throughout the
BMI range, with strong effect modifica-
tion of BMI and diabetes risk by age. Our
findings are consistent with a recent study
suggesting that a BMI of ~21 kg/m² is an
appropriate cutoff for obesity in Chinese
and South Asian individuals based on pa-
rameters of glucose metabolism (5).

Nonetheless, BMI cutoffs may be useful
for population surveillance in the case
of obesity and type 2 diabetes, but they
do not appear to have strict biological
meaning.

Few prospective studies have exam-
ined this question in Asians, and our data
generally confirm the dose-response asso-
ciation observed in a couple populations
(6,7); however, potentially important for
public health approaches and clinicians,
we report age-stratified results. Addition-
ally, Singapore is highly prosperous and
developed, potentially serving as a micro-
cosm for other rapidly developing regions
of Asia. Increasing evidence suggests that
Asians have a relatively high susceptibility
to type 2 diabetes based upon their an-
thropometry and how excess adiposity
may affect insulin and glucose metabo-
lism (8–11). These mechanisms are
poorly understood, but it is theorized that
excess body fat, especially visceral obe-
sity, increases insulin resistance by releas-
ing free fatty acids and cytokines that
interfere with insulin action, along with
other deleterious effects that could lead to
diabetes (12). However, it appears un-
likely that the metabolic burden of absolu-
te adipose accumulation would be the
mechanism driving diabetes risk at such
low BMI ranges (19–21 kg/m²) observed
in the current study. Residual confound-
ing by dietary and lifestyle factors, no as-
sement of family history of diabetes or
other measures of adiposity, and the self-
reported basis of BMI and diabetes in the
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In short, these findings demonstrate
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search is needed to understand the associa-
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diabetes and to identify an optimal and
healthful BMI range in Asians while con-
sidering diabetes and other health out-
comes. With increasing obesity and
diabetes rates in Asia, the development of
public health approaches bringing aware-
ness of and action to the issue has signif-
cy of and action to the issue has signif-
ificant potential benefits.

Table 2—HRs of type 2 diabetes by deciles of BMI in the Singapore Chinese Health Study

| Decile | n  | Mean BMI (minimum–maximum) | HR (95% CI) |
|--------|----|----------------------------|------------|
| 1      | 3,716 | 17.6 (16.9–18.8) | 1.0        |
| 2      | 3,769 | 19.6 (18.8–20.2) | 1.70 (1.20–2.42) |
| 3      | 3,864 | 20.7 (20.2–21.1) | 2.04 (1.45–2.85) |
| 4      | 3,794 | 21.5 (21.1–21.9) | 2.33 (1.68–3.25) |
| 5      | 3,547 | 22.3 (21.9–22.7) | 2.95 (2.14–4.07) |
| 6      | 3,729 | 23.2 (22.7–23.5) | 3.42 (2.49–4.58) |
| 7      | 3,586 | 24.1 (23.5–24.5) | 3.85 (2.82–5.26) |
| 8      | 3,769 | 25.1 (24.5–25.7) | 4.81 (3.55–6.52) |
| 9      | 3,660 | 26.5 (25.7–27.3) | 5.68 (4.20–7.68) |
| 10     | 3,657 | 29.8 (27.4–31.0) | 7.80 (5.80–10.48) |

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to this article were reported.
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