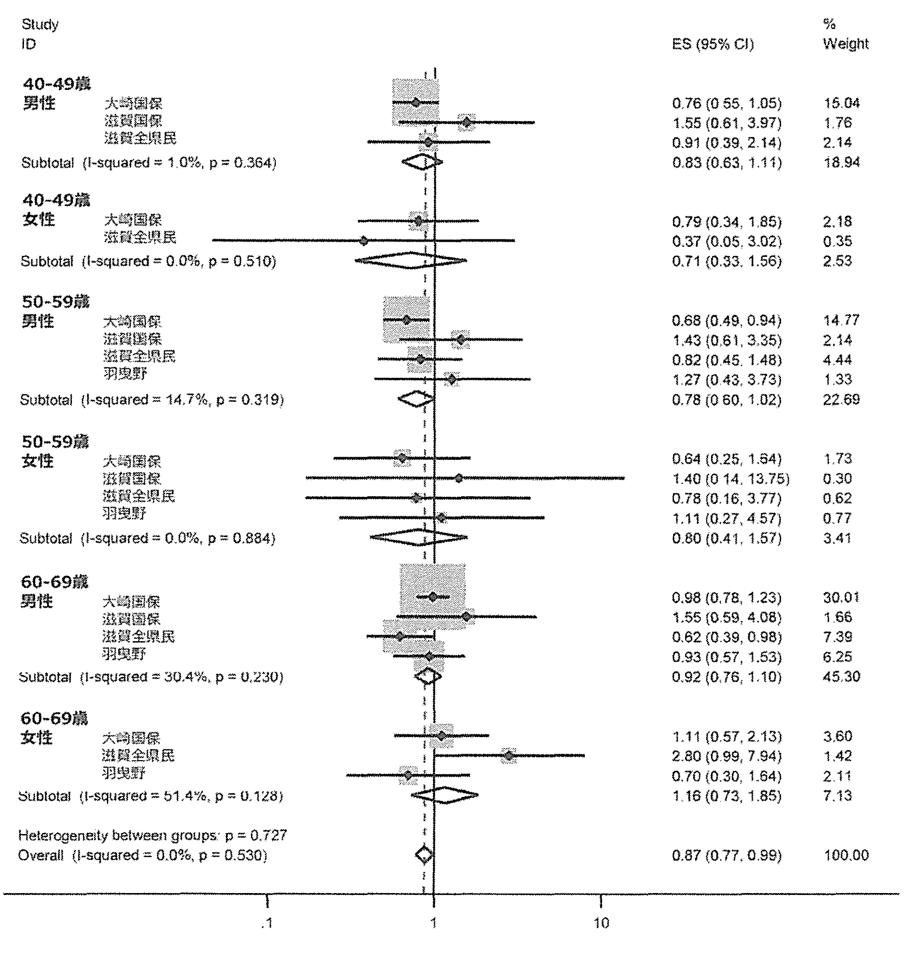
表５　喫煙習慣別、性年齢層別にみたhigh-cost riskのメタアナリシス結果（生存例のみによる副解析）

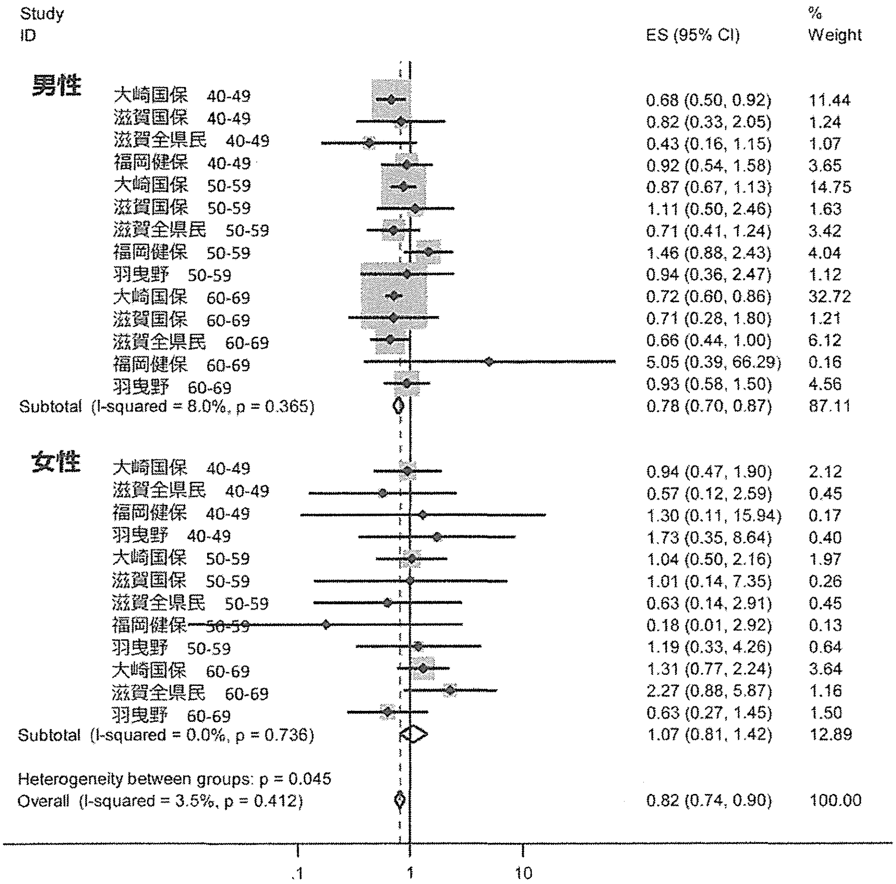
	統合コホート数（人数）	過去喫煙者		生涯非喫煙者	
		統合オッズ比（95%信頼区間）	I^2統計量	統合オッズ比（95%信頼区間）	I^2統計量
40-49歳　男性	3 (4,991)	0.83 (0.63 - 1.11)	1.0%	0.77 (0.59 - 1.00)	6.9%
40-49歳　女性	2 (3,689)	0.71 (0.33 - 1.56)	0.0%	0.67 (0.49 - 0.92)	0.0%
50-59歳　男性	4 (5,834)	0.78 (0.60 - 1.02)	14.7%	0.85 (0.69 - 1.05)	0.0%
50-59歳　女性	4 (8,228)	0.8 (0.41 - 1.57)	0.0%	0.87 (0.66 - 1.14)	0.0%
60-69歳　男性	4 (9,472)	0.92 (0.76 - 1.10)	30.4%	0.9 (0.75 - 1.08)	48.7%
60-69歳　女性	3 (14,384)	1.16 (0.73 - 1.85)	51.4%	0.76 (0.60 - 0.97)	0.0%
全性年齢層統合	4 (46,598)	0.87 (0.77 - 0.99)	0.0%	0.82 (0.74 - 0.90)	0.0%

統合にはrandom effect modelを仮定した.



※　継続喫煙者を基準（オッズ比1）とした際のオッズ比で表示

図２　性年齢層別に統合した過去禁煙者のhigh-cost riskのメタアナリシス結果（生存例のみによる副解析）



※ 継続喫煙者を基準（オッズ比1）とした際のオッズ比で表示

図３　性別により統合した過去禁煙者のhigh-cost risk のメタアナリシス結果

D．考　察

結果をまとめると、共分散分析の手法を用いて平均医療費実額の差を検討したプール解析では喫煙習慣と医療費に有意な関連は認められなかった一方、個人ごとの high-cost risk を推定し統合したメタアナリシスにおいては、禁煙した者は喫煙を継続している者よりも18%、喫煙しないものは継続喫煙者と比べ29%、近い将来に高額の医療費が発生するがそれぞれ低く、この差は統計学的に有意であることが示された。昨年度報告した大崎国保コホートにおける禁煙の高額医療費リスク減少効果が、国内の多様なコホートを統合した代表性のあるデータで追認されたことになる。

はじめにプール解析で有意な差が見いだされなかった理由であるが、これは統計手法上の限界が大きく影響していると考えられる。初年度から繰り返し述べているように医療費は正規分布から強く逸脱した分布をとっており、本来正規分布を仮定している分散分析は最適な検定法ではない。過去の研究においてはサンプル数が大きい場合の頑健性を根拠に分散分析が多用されてきたが、頑健性と検出力は異なる概念であり、有意な結果が出なかったことを持って関連がないと決定づけることはできない。医療費のような過分散かつ正の値しかとらない分布に対しては近年ガンマ分布、負の二項分布、またゼロ過剰を仮定した two-part model などが適用されつつあり、将来このような解析手法により実額の医療費と喫煙習慣の関連を明らかにすることが可能になるかもしれない。繰り返すが、本解析により「関連がないことが示された」訳ではなく、引き続き積極的に取り組むべき課題である。

しかし医療費実額を対象とした統合解析は、仮に統計学的処理が適切であっても物価や診療報酬を含めた時代背景による貨幣価値の変動が大きな障壁となる。この点を回避する考え方が、昨年度提示したhigh-cost risk analysisであった。本解析法は同時にメタアナリシスという統計学的に有用な処理を可能とし、また平均値では語られることのない一人一人のリスク（確率）を提示することで個人のヘルスプロモーションに訴えかけるという有益な副産物を伴う。この手法は時代や貨幣価値、医療制度の影響を回避できるため、諸外国との比較や統合、また時代を経ての効果の変遷を評価することにも利用可能である。無論喫煙習慣だけでなく、他のリスク因子についても同様に評価可能である。今後多方面での活用を待ちたい。

次にメタアナリシスの結果が意味するところについて考察する。今回の最大の成果は、禁煙した者は喫煙を継続した者よりも将来高額の医療費に悩まされるリスクが有意に低いことを示した点にある。しかもこの関連は死亡時の医療費高騰を含めても、逆に死亡や追跡不能例を除き、生存し続けた例のみで見ても同様に認められた。すでに禁煙者は継続喫煙者と比較して死亡リスクが低いことが本邦の大規模観察研究で示されており、これらの知見を総合すると、禁煙は死亡リスクを下げ、また長期生存する中にあっても高額な医療費の発生を抑制するということが強く示唆されることになる。したがって禁煙は健康長寿を目的とするだけでなく、医療費抑制の目的においても強く推進すべき施策となる。さらに、本研究が３～12年後という比較的近い将来の医療費への影響を示したことにより、近年増加している国民医療費に歯止めをかけるための即効性のある対応ともいえるだろう。

またこの結果は政策決定者だけでなく、喫煙者個人に対しても強いメッセージを与えることが期待される。なぜなら、喫煙を継続することで寿命を縮め健康を害するのみならず、近い将来の高額な医療費という経済的に大きな痛手を被る危険が上昇することが示されたからである。これまで 50 年以上にわたり喫煙が健康を害するというエビデンスは繰り返し示されてきたが、それでもなお喫煙を継続している者にとっては、「寿命の延長」「疾病発生予防」といった、一般的にアウトカムとされていた事柄の価値が相対的に低い可能性がある。いわゆる刹那的な、老後の寿命数年よりも青壮年期の快楽に重きを置く者に対しては、これまで通りのリスク情報では禁煙行動に導くことには限界があるだろう。そのような喫煙者集団に、近い将来の高額医療費発生というアウトカムはこれまでと異なるメッセージを与えるのではないだろうか。たばこ税増税が禁煙を促したように、金銭（医療費）に関する明確なメッセージが一人でも多くの喫煙者を禁煙行動に導くことを期待したい。

そして統合オッズ比が統計学的に有意であったことと同程度に重要な成果は、この喫煙習慣と high-cost risk の関連が多様な、すなわち東西日本の国保健保をまたいだコホートの結果を統合したものであり、かつ地域や保険種による異質性の小さい、外的妥当性の高い関連であるという点である。今回の結果は、より厳密には一つ一つの性年齢層の統合オッズ比のみを検討すべきであるが、60代の一部集団を除いては異質性が軽微であり、本邦の多くの集団に当てはめることのできる結果と考えられる。

ただし男女で禁煙と high-cost risk の関連に異質性が認められた点には注意が必要である。今回データを統合することにより、女性禁煙者においても単一コホートよりも推定精度の高い信頼区間を算出することができた。また図３に示されるように女性の内部では統計学的な異質性は観察されず値に一貫性がある。したがってこの「女性においては継続喫煙者と過去禁煙者で将来の high-cost risk に差があるとは言えない」という事象は事実である可能性を考慮すべきである。その説明としては、女性

は一般に喫煙による有害事象の発生が男性よりも顕著であり、少量の過去の喫煙であっても将来の健康状態に影響が残存する可能性があげられる。こうした on-off 的な関連は、女性の非喫煙者では男性と同様に有意な高額医療費リスク低下を認めている点とも合致する。あるいは女性の喫煙経験者に共通する因子、例えば配偶者等からの濃厚な受動喫煙、が本人の喫煙習慣を凌駕して医療費に影響を与えている可能性も考えられる。いずれにせよ推論の域を出ず、女性の禁煙が与える健康および医療費に与える影響については、今後より多くのデータを統合し詳細に検討することが必要である。

今後の研究展望として、一つはより若年者における医療費解析が求められる。現実に存在する 10 代の喫煙者を含めた若年喫煙者が、非喫煙者と比較して近い将来の医療費・高額医療費リスクに差があることが示されれば、喫煙開始を抑制する情報となりうる。こうした若年者では遠い将来の寿命を論じるよりも近未来の金銭的リスクが強いインパクトを与えるであろう。特に女性においては周産期医療費や児の医療費も含め検討することで新たな知見が得られる可能性がある。もう一つ、今回対象外であったのは、医療費の大きな部分を使用している高齢者である。高齢者においては、いつまでに禁煙すれば医療費低減の恩恵が得られるのかという情報を提示することに強い意義がある。また、医療費だけでなく介護の費用を合算することで、社会保障全体に与える影響を正しく推定することができる。ただし高齢者においては上位 10%の high-cost user が消費する医療費が全体に占める割合は若年者よりも小さく、消費額のばらつきが小さい分布をとっていることが大崎国保コホートでは示されている。したがって高齢者集団を対象とする解析においては注意が必要である。また早期死亡により積算医療費は低額になることから、死亡例の取り扱いにおいても解決すべき課題が多く、今後の議論が待たれる。

E．結　論

国内 5 コホート、62,572 人（594,587 人年）のデータを統合したメタアナリシスにより、40～69 歳においてすでに禁煙していた者は、喫煙を継続していた者よりも将来高額の医療費を要する相対リスクが 18%低く、この差は統計学的に有意であることが示された。同様に喫煙経験のない者は継続喫煙者と比較してリスクが 29%低かった。この関連は中途死亡による医療費高騰の影響を除外しても認められ、またコホート間、年齢層間、保険種別間などで明らかな異質性は観察されず、外的妥当性の高い結果であると考えられた。ただし女性においては禁煙者と継続喫煙者の高額医療費リスクに有意差が認められず、男性での結果と統計学的異質性が観察された。死亡リスクだけでなく高額な医療費の発生リスクが禁煙群において有意に低いことは、禁煙が長寿達成のみならず医療費抑制のためにも推奨されるべき施策であることを示唆するものである。

F．健康危険情報

なし

G．研究発表

なし

H．知的財産権の出願・登録状況

なし

Ⅳ．研究成果の刊行に関する一覧

研究成果の刊行に関する一覧

［論文発表・単行本］

1. Nagai M, Kuriyama S, Kakizaki M, Ohmori-Matsuda K, Sone T, Hozawa A, Kawado M, Hashimoto S, Tsuji I.
   Impact of obesity, overweight and underweight on life expectancy and lifetime medical expenditures: the Ohsaki Cohort Study.
   BMJ Open, 2012;11;2(3): e000940.

2. Nagai M, Tomata Y, Watanabe T, Kakizaki M, Tsuji I.
   Association between sleep duration, weight gain, and obesity for long period.
   Sleep Medicine,. 2012 Dec 3. [Epub ahead of print]

3. Morishima T, Imanaka Y, Otsubo T, Hayashida K, Watanabe T, Tsuji I.
   Burden of Household Environmental Tobacco Smoke on Medical Expenditure for Japanese Women: A Population-Based Cohort Study.
   Journal of Epidemiology, 2013;23(1):55-62.

4. 林田賢史，村上玄樹，高橋裕子，辻　一郎，今中雄一.
   喫煙者と非喫煙者の生涯医療費.
   日本衛生学雑誌，2012;67(1):50-55.

5. 田中英夫（編）.
   事例で学ぶ禁煙治療のためのカウンセリングテクニック［エキスパート編］.
   谷口千枝．東京，看護の科学社，2012.

6. Ojima M, Hanioka T, Tanaka H.
   Necessity and readiness for smoking cessation intervention in dental clinics in Japan.
   Journal of Epidemiology, 2012;22:57-63.

7. Matsuo K, Gallus S, Negri E, Kawakita D, Oze I, Hosono S, Ito H, Hatooka S, Hasegawa Y, Shinoda M, Tajima K, La Vecchia C, Tanaka H.
   Time to first cigarette and upper aerodigestive tract cancer risk in Japan.
   Cancer Epidemiology, Biomarkers & Prevention, 2012;21:1986-92.

8. Kawakita D, Hosono S, Ito H, Oze I, Watanabe M, Hanai N, Hasegawa Y, Tajima K, Murakami S, Tanaka H, Matsuo K.
   Impact of smoking status on clinical outcome in oral cavity cancer patients.
   Oral Oncology, 2012;48:186-91.

9. Nakamura K, Sakurai M, Miura K, Morikawa Y, Nagasawa SY, Ishizaki M, Kido T, Naruse Y, Suwazono Y, Nakagawa H.
Nicotine dependence and cost-effectiveness of individualized support for smoking cessation: evidence from practice at a worksite in Japan.
PLoS One, 2013;8(1):e55836.

10. Nakamura K, Sakurai M, Nishijo M, Morikawa Y, Nakagawa H.
Characteristics of smoking cessation in former smokers in a rural area of Japan.
International Journal of Preventive Medicine, 2012;3(7):459-65.

11. Murakami Y, Okamura T, Nakamura K, Miura K, Ueshima H.
The clustering of cardiovascular disease risk factors and their impacts on annual medical expenditure in Japan: community-based cost analysis using Gamma regression models.
BMJ Open, 2013;3 (in press).

［学会発表］

1. 舟本美果，渡辺浩一，矢熊恵美子，宮松直美，杉山大典，岡村智教.
短期的な医療費上昇につながるハイリスク喫煙者同定の試み.
第 71 回日本公衆衛生学会，山口，2012 年.

2. Tanaka H.
Cost-effectiveness of smoking cessation therapy in Japan.
World Cancer Congress, Montreal, 2012.

3. 中村幸志，岡村智教，早川岳人，岡山　明，三浦克之，上島弘嗣.
動脈硬化性疾患危険因子の医療費へのインパクト.
第 44 回日本動脈硬化学会総会・学術集会，福岡，2012 年.

4. 谷原真一.
男性勤労者における糖尿病と医療費に関する追跡調査.
第 55 回日本糖尿病学会年次学術集会，横浜，2012 年.

5. 谷原真一，百瀬義人.
男性勤労者のニコチン依存度と禁煙取り組み状況及び理由に関する分析.
第 22 回日本産業衛生学会産業医・産業看護全国協議会，東京，2012 年.

6. Murakami Y, Okamura T, Miura K and Ueshima H.
Age, sex, and BMI-specific increase in medical expenditure due to the clustering of established atherosclerotic risk factors: a community-based cost analysis among 38,890 Japanese.
XVI International Symposium of Atherosclerosis 2012, Sydney, 2012.

BMJ open accessible medical research

Impact of obesity, overweight and underweight on life expectancy and lifetime medical expenditures: the Ohsaki Cohort Study

Masato Nagai,[1] Shinichi Kuriyama,[1,2] Masako Kakizaki,[1] Kaori Ohmori-Matsuda,[1] Toshimasa Sone,[1] Atsushi Hozawa,[1,3] Miyuki Kawado,[4] Shuji Hashimoto,[4] Ichiro Tsuji[1]

To cite: Nagai M, Kuriyama S, Kakizaki M, *et al.* Impact of obesity, overweight and underweight on life expectancy and lifetime medical expenditures: the Ohsaki Cohort Study. *BMJ Open* 2012;2:e000940. doi:10.1136/bmjopen-2012-000940

▶ Prepublication history for this paper is available online. To view these files please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2012-000940).

Received 25 January 2012
Accepted 12 April 2012

For numbered affiliations see end of article.

Correspondence to
Dr Masato Nagai;
m-nagai@med.tohoku.ac.jp

ABSTRACT

Objectives: People who are obese have higher demands for medical care than those of the normal weight people. However, in view of their shorter life expectancy, it is unclear whether obese people have higher lifetime medical expenditure. We examined the association between body mass index, life expectancy and lifetime medical expenditure.

Design: Prospective cohort study using individual data from the Ohsaki Cohort Study.

Setting: Miyagi Prefecture, northeastern Japan.

Participants: The 41 965 participants aged 40–79 years.

Primary and secondary outcome measures: The life expectancy and lifetime medical expenditure aged from 40 years.

Results: In spite of their shorter life expectancy, obese participants might require higher medical expenditure than normal weight participants. In men aged 40 years, multiadjusted life expectancy for those who were obese participants was 41.4 years (95% CI 38.28 to 44.70), which was 1.7 years non-significantly shorter than that for normal weight participants (p=0.3184). Multiadjusted lifetime medical expenditure for obese participants was £112 858.9 (94 954.1–131 840.9), being 14.7% non-significantly higher than that for normal weight participants (p=0.1141). In women aged 40 years, multiadjusted life expectancy for those who were obese participants was 49.2 years (46.14–52.59), which was 3.1 years non-significantly shorter than for normal weight participants (p=0.0724), and multiadjusted lifetime medical expenditure was £137 765.9 (123 672.9–152 970.2), being 21.6% significantly higher (p=0.0005).

Conclusions: According to the point estimate, lifetime medical expenditure might appear to be higher for obese participants, despite their short life expectancy. With weight control, more people would enjoy their longevity with lower demands for medical care.

ARTICLE SUMMARY

Article focus

- Obese people have higher needs and demands for medical care.
- Obesity is associated with an increased risk of mortality.
- In view of the decreased life expectancy in obese participants, it is unclear whether lifetime medical expenditure increases or decreases as a result.

Key messages

- In spite of their short life expectancy, obese men and women had approximately 14.7% and 21.6% higher lifetime medical expenditure in comparison with normal weight participants, respectively.
- With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

Strengths and limitations of this study

- This is the first study to have investigated the association between body mass index, life expectancy and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population.
- There was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants because the Japanese population has a low prevalence of body mass index≥30.0 kg/m^2.

INTRODUCTION

Obesity is closely associated with an increased risk of cardiovascular disease, cancer, hypertension, diabetes mellitus and other medical problems. Previous studies have reported that obese and overweight people have higher needs and demands for medical care than normal weight people.[1–5] However, it is unclear whether obese people have higher lifetime medical expenditure than those of the normal weight people because the former have a comparatively shorter life expectancy.[6–10] Additionally, underweight people have a higher risk of mortality and thus also tend to have higher medical expenditure per month or per person, based on a 10-year follow-up.[1 4]

Although four previous studies have examined the association between obesity and lifetime medical expenditure,[10–13] the results were inconsistent. One study showed that obese people had lower lifetime medical expenditure than those of the normal weight people,[11] whereas the others indicated that obese people had higher lifetime medical expenditure.[10 12 13] In addition, two of the four studies estimated lifetime medical expenditure from excess risk of cause-specific mortality and mean medical expenditure for the index disease.[10 11] Only the other two studies calculated lifetime medical expenditure on the basis of individual medical expenditure and mortality.[12 13] However, one of those studies followed up the participants for only 2 years[12] and the other calculated lifetime medical expenditure for elderly participants aged 70 years or over.[13] Therefore, the association between body mass index (BMI) and lifetime medical expenditure remains to be fully clarified.

We therefore conducted a 13-year prospective observation of 41 965 Japanese adults aged 40–79 years living in the community, which accrued 392 860 person-years. We examined the association between BMI and lifetime medical expenditure, based on individual medical expenditure and life table analysis.[1 14–17] We collected data for survival and all medical care utilisation and costs, excluding home care services provided home health aides, nursing home care and preventive health services in participants of this cohort study.

MATERIALS AND METHODS

Study cohort

We used data from the Ohsaki National Health Insurance (NHI) Cohort Study.[1 14 16–18] In brief, we sent a self-administered questionnaire on various lifestyle habits between October and December 1994 to all NHI beneficiaries living in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan. A survey was conducted of NHI beneficiaries aged 40–79 years. Among 54 996 eligible individuals, 52 029 (95%) responded.

We excluded 776 participants who had withdrawn from the NHI before 1 January 1995, when we started the prospective collection of NHI claim files. Thus, 51 253 participants formed the study cohort. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. The participants who had returned the self-administered questionnaires and had signed them were considered to have consented to participate in this study.

For the current analysis, we also excluded participants who did not provide information about body weight and height (n=3543), were at both extremes of the BMI range: lower than the 0.05th percentile for BMI (below 14.41 for men; below 13.67 for women) or higher than the 99.95th percentile for BMI (above 58.46 for men; above 62.00 for women; n=48), those who died within the first year (n=454) or those who had a history of cancer (n=1533), myocardial infarction (n=1233), stroke (n=831) or kidney disease (n=1646). Thus, a total of 41 965 participants (20 066 men and 21 899 women) participated.

Body mass index

The self-administered questionnaire included questions on weight and height, and BMI was calculated as weight divided by the square of height (kilograms per square metre). We divided the participants into groups according to the following BMI categories: <18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (overweight) and ≥30.0 kg/m^2 (obesity). These BMI categories correspond to the cut-off points proposed by the WHO: normal BMI range (18.5–24.9 kg/m^2), grade 1 overweight (25.0–29.9 kg/m^2), grade 2 overweight (30.0–39.9 kg/m^2) and grade 3 overweight (≥40.0 kg/m^2).[19]

The validity of self-reported body weight and height has been reported earlier.[1] Briefly, the weight and height of 14 883 participants, who were a subsample of the cohort, were measured during basic health examinations provided by local governments in 1995. The Pearson correlation coefficient (r) and weighted κ (κ) between the self-reported values and measured values were r=0.96 (p<0.01) for weight, r=0.93 (p<0.01) for height and r=0.88 (p<0.01) and κ=0.72 for BMI categories.

Health insurance system in Japan

The details of the NHI system have been described previously.[1 4 14 16 18] Briefly, everyone living in Japan is required to enrol in one health insurance system. The NHI covers 35% of the Japanese population for almost all medical treatment, including diagnostic tests, medication, surgery, supplies and materials, physicians and other personnel costs and most dental treatment. It also covers home care services provided by physicians and nurses but not those by other professionals such as home health aides. The NHI covers inpatient care but not nursing home care. Also, it does not cover preventive health services such as mass screening and health education. Payment to medical providers is made on a fee-for-service basis, where the price of each service is determined by a uniform national fee schedule.

If a participant withdrew from the NHI system because of death, emigration or employment, the withdrawal date and the reason for withdrawal were coded in the NHI withdrawal history files. We recorded any mortality or migration by reviewing the NHI withdrawal history files and collected data on the death of participants by reviewing the death certificates filed at Ohsaki Public Health Center. We then followed up the participants and prospectively collected data on medical care utilisation and its costs for all participants in the cohort from 1 January 1995 through 31 December 2007.

Statistical analysis

We conducted the same analysis as the previous study about the association between walking, life expectancy and lifetime medical expenditure.[16] Briefly, we divided the age groups (×) from 40 years according to the following categories: 40–44, 45–49, 50–54, 55–59, 60,64, 65–69, 70–74, 75–79, 80–84 and ≥85 years. Based on person-years and the number of deaths from 1996 until 2007, the multiadjusted mortality rates for each age category were estimated from a Poisson regression model. The dependent variable was mortality, and independent variables were age groups, categories of BMI and the following covariates: smoking status (current and past smoker or never smoker), alcohol consumption (current drinker consuming 1–499 g/week, current drinker consuming ≥450 g/week or never and past drinker), sports and physical exercise (≥3 h/week or <3 h/week), time spent walking (≥1 h/week or <1 h/week) and education (junior high school, high school or college/university or higher). We did not adjust for hypertension and diabetes mellitus in the multivariate models because these variables are considered to occupy an intermediate position in the etiologic pathway between BMI and mortality.

We separately calculated medical expenditure for participants who survived through the index year and for those who died because previous study showed that medical expenditure increased before death.[20] The multiadjusted medical expenditure per year was estimated using a linear regression model adjusted for the above covariates in survivors and decedents.

The estimates of multiadjusted mortality and medical expenditure were used for estimating life expectancy and lifetime medical expenditure from 40 years of age. To estimate life expectancy and lifetime medical expenditure, we constructed life tables per 100 000 persons using Chiang's analytical method on the basis of the latest published complete life tables of Japan for the year 2000.[21 22] Then, life expectancy (e_x) and lifetime medical expenditure (M_x) for each age groups (x) were estimated using the numbers of survivors (l_x), deaths (d_x), static population (L_x), multiadjusted medical expenditure for survivors (a_y) and multiadjusted medical expenditure for the deceased (b_y) as follows:

$$\sum \text{is sum of} y = x$$

$$e_x = \frac{\sum L_y}{l_x}$$

$$M_x = \frac{\sum (L_y \cdot a_y + d_y \cdot b_y)}{l_x}$$

The 95% CIs were estimated using a Monte Carlo simulation based on a Poisson regression model and linear regression model. We repeated 100 000 times, and all analysis were used the SAS V.9.1 statistical software package (SAS Institute Inc., 2004). All p values <0.05 were accepted as statistically significant.

We used a purchasing power parity rate of UK£ 1.00= JPN\140.[16]

RESULTS

After 13 years of follow-up, we observed 5159 deaths (3356 men and 1803 women) among the 41 965 participants (20 066 men and 21 899 women).

The mean medical expenditure per year for survivors in men was £2393 in underweight, £2055 in normal weight, £2231 in overweight and £2334 in obesity, respectively. In women, it was £2375 in underweight, £1972 in normal weight, £2317 in overweight and £2733 in obesity, respectively. These differences of mean medical expenditure per year for survivors are statistically significant in men and women (ANOVA; p<0.0001). Also, the mean medical expenditure in the year of death for participants in men was £15 445 in underweight, £16 973 in normal weight, £17 811 in overweight and £17 878 in obesity, respectively. In women, it was £12 833 in underweight, £15 584 in normal weight, £17 059 in overweight and £19 635 in obesity, respectively. These differences of mean medical expenditure in the year of death for participants are statistically significant in only women (men, p=0.2241; women, p=0.0059).

Baseline characteristics by BMI category

The baseline characteristics of the study participants according to the BMI categories are shown for men and women (table 1), among whom 3.3% and 3.9% were underweight, 23.6% and 28.4% were overweight and 2.0% and 3.6% were obese, respectively.

Mean age in men decreased linearly with increasing BMI category. In women, mean age was highest in the underweight category. The proportions of men and women who were current and past smokers decreased with increasing BMI, and this tendency was especially marked in men. The proportions of men who had never and past drinker were highest in the underweight category. The proportions of men who did ≥3 h sports and physical exercise per week decreased with increasing BMI. The proportions of men and women who walked ≥1 h/day were the lowest in underweight men and obese women. Educational background increased linearly in men and decreased linearly in women as the BMI category increased. These characteristics showed statistically significant difference.

Mortality in terms of categories for BMI

Figure 1A for men and figure 1B for women show the mortality (per 1000 person-years) in each of the age groups according to the categories of BMI.

In underweight participants, there was a tendency that the mortality was the highest in each age group.

Table 1 Baseline characteristics by BMI categories in 41 965 participants

	Men					Women				
	BMI (kg/m^2)					BMI (kg/m^2)				
	<18.5	18.5–24.9	25.0–29.9	≥30.0	p Value*	<18.5	18.5–24.9	25.0–29.9	≥30.0	p Value
No. of subjects	666	14 278	4730	392	<0.0001	857	14 031	6226	785	<0.0001
Mean age (years)	64.0	59.1	57.4	56.1		63.7	59.8	60.7	61.2	
SD	10.4	10.5	10.2	10.2		10.9	10.1	9.1	9.5	
Smoking status (%)										
Current and past smoker	87.3	82.5	76.6	74.8	<0.0001	18.6	11.2	10.1	10.6	<0.0001
Never smoker	12.7	17.5	23.4	25.2		81.4	88.8	90.0	89.4	
Alcohol consumption (%)										
Current drinker, 1–449 g/week	49.2	61.0	61.4	50.8	<0.0001	18.2	21.8	21.4	19.3	0.0574
Current drinker, ≥450 g/week	9.6	11.7	12.6	15.0		0.6	0.8	0.5	0.9	
Never and past drinker	41.2	27.3	26.0	34.2		81.2	77.4	78.2	79.8	
Sports and physical exercise (%)										
≥3 h/week	17.5	16.1	13.8	10.1	<0.0001	9.8	11.3	11.0	10.8	0.5993
<3 h/week	82.5	83.9	86.2	89.9		90.2	88.7	89.0	89.2	
Time spent walking (%)										
≥1 h/day	41.7	51.4	45.8	42.7	<0.0001	37.9	45.1	41.0	35.6	<0.0001
<1 h/day	58.3	48.7	54.2	57.3		62.1	54.9	59.0	64.4	
Education (%)										
Junior high school	64.2	62.2	58.9	58.8	0.0013	58.3	54.2	62.7	71.3	<0.0001
High school	27.4	30.5	33.4	33.4		34.0	36.9	31.0	24.6	
College/university or higher	8.4	7.3	7.7	7.8		7.7	8.9	6.3	4.1	

*p Values were calculated by χ^2 test (categorical variables) or ANOVA (continuous variables).
BMI, body mass index.

Overweight participants showed similar mortality with normal weight participants, especially women. Overweight men showed slightly lower mortality than normal weight men. In obese participants, the mortality curve was not described smoothly because of small number of participants.

Table 2 shows the mortality ratio with 95% CIs according to the categories of BMI. In underweight participants, the multiadjusted mortality ratio was significantly higher than that in the normal weight participants (men, 1.62, 95% CI 1.41 to 1.86, p<0.0001; women, 1.46, 1.22 to 1.76, p<0.0001). In overweight participants, the multiadjusted mortality ratio was significantly lower in men and non-significantly lower in women than that in normal weight participants (men, 0.91, 0.83 to 0.99, p=0.0260; women, 0.98, 0.88 to 1.10, p=0.7841). In obese participants, the multiadjusted mortality ratio was non-significantly higher than that in normal weight participants (men, 1.14, 0.88 to 1.49, p=0.3177; women, 1.23, 0.98 to 1.55, p=0.0717).

Life expectancy and lifetime medical expenditure by BMI category

Table 3 shows life expectancy and lifetime medical expenditure with 95% CIs according to the BMI categories.

By multiadjusted analysis, obese men and women had approximately 1.7 and 3.1 years non-significantly shorter life expectancy from the age of 40 years in comparison with men and women of normal weight, respectively (men, p=0.3184; women, p=0.0724). Meanwhile, obese men and women had approximately 14.7% non-significantly higher and 21.6% significantly higher lifetime medical expenditure in comparison with normal weight participants, respectively (men, p=0.1141; women, p=0.0005).

In men, multiadjusted life expectancy was greatest for overweight, that is, 44.34 years (95% CI 43.11 to 45.54, p=0.0264), followed by normal weight (43.03 years, 42.22 to 43.73) and obesity (41.36 years, 38.28 to 44.70, p=0.3184) and was shortest for underweight (37.40 years, 35.80 to 38.87, p<0.0001). The multiadjusted lifetime medical expenditure for overweight was the highest, that is, £114 766.9 (95% CI 107 754.1 to 121 966.6, p<0.0001), followed by obesity (£112 858.9, 94 954.1 to 131 840.9, p=0.1141) and normal weight (£98 355.0, 93 615.3 to 103 010.2) and was the lowest for underweight (£93 208.7, 81 704.9 to 104 706.4, p=0.3916).

In women, multiadjusted life expectancy was greatest for overweight, that is, 52.56 years (50.67 to 54.46, p=0.7797), followed by normal weight (52.31 years,

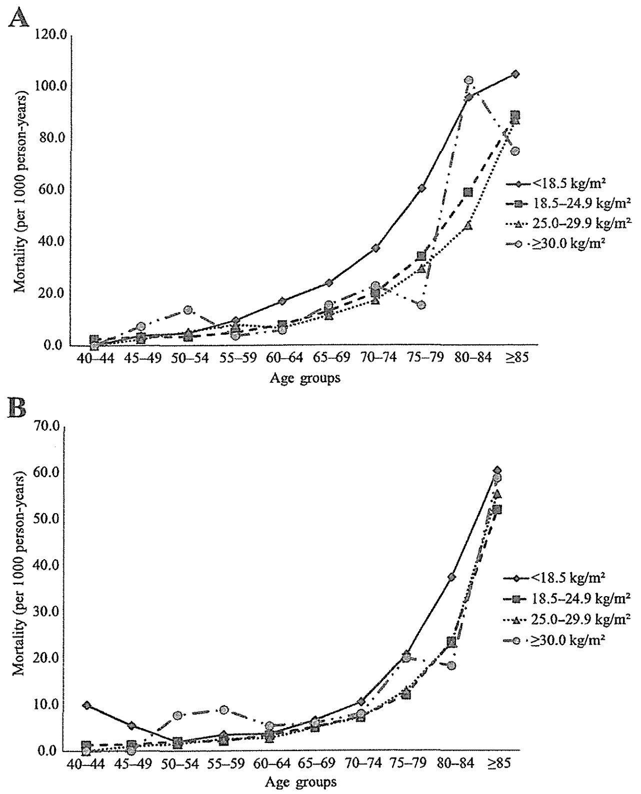


Figure 1 Multiadjusted mortality by BMI categories in each age group in men (A) and women (B).

50.79 to 53.75) and obesity (49.23 years, 46.14 to 52.59, p=0.0724) and was shortest for underweight (46.98 years, 44.63 to 49.29, p<0.0001). The lifetime medical expenditure for obesity was the highest (£137 765.9, 123 672.9 to 152 970.2, p=0.0005), followed by overweight (£129 964.6, 121 845.4 to 138 577.2, p<0.0001) and normal weight (£113 282.9, 106 668.0 to 120 054.6) and was lowest for underweight (£109 382.2, 97 996.6 to 121 008.6, p=0.5174).

DISCUSSION

The present results indicate that (1) obese men and women have 14.7% non-significantly higher and 21.6% significantly higher multiadjusted lifetime medical expenditure than those of the normal weight participants (men, p=0.1141; women, p=0.0005), even though their life expectancy is non-significantly shorter by 1.7 and 3.1 years than those of the normal weight participants, respectively (men, p=0.3184; women, p=0.0724); (2) underweight men and women have 5.2% and 3.4% non-significantly lower lifetime medical expenditure than those of the normal weight participants (men, p=0.5174; women, p=0.3916) because men and women live 5.6 and 5.3 years significantly less than those of the normal weight participants, respectively (men, p<0.0001; women, p<0.0001).

Comparison with other studies

Obese participants had shorter life expectancy than normal weight participants, as has been observed in previous studies.[6–10] Overweight participants had longer life expectancy than normal weight participants. Two of the four previous studies have reported that overweight participants had longer life expectancy than normal weight participants.[7 9] These results support our finding of an association between being overweight and life expectancy. Additionally, an association between BMI and all-cause mortality in the Japanese population has been reported by other data sets.[23–29] All seven previous studies showed that among the BMI categories, the lowest one had the highest mortality risk. These results are consistent with the fact that underweight participants have significantly the shortest life expectancy, as was observed in our study.

Thus, the association between BMI and life expectancy showed same trend with the pooled analyses of the association between BMI and all-cause mortality in Asia and Japan.[30 31]

Our present results support three of the four previous studies of lifetime medical expenditure for obese

Table 2 Mortality ratio for BMI categories in 41 965 participants

	Univariate		Multiadjusted*	
BMI (kg/m^2)	Mortality ratio (95% CI)	p Value	Mortality ratio (95% CI)	p Value
Men				
<18.5	1.69 (1.47 to 1.93)	<0.0001	1.62 (1.41 to 1.86)	<0.0001
18.5–24.9	1.00 (Reference)		1.00 (Reference)	
25.0–29.9	0.90 (0.82 to 0.98)	0.0163	0.91 (0.83 to 0.99)	0.0260
≥30.0	1.13 (0.87 to 1.47)	0.3712	1.14 (0.88 to 1.49)	0.3177
Women				
<18.5	1.50 (1.25 to 1.81)	<0.0001	1.46 (1.22 to 1.76)	<0.0001
18.5–24.9	1.00 (Reference)		1.00 (Reference)	
25.0–29.9	1.00 (0.89 to 1.11)	0.9613	0.98 (0.88 to 1.10)	0.7841
≥30.0	1.29 (1.03 to 1.62)	0.0273	1.23 (0.98 to 1.55)	0.0717

*Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking and education.
BMI, body mass index.

Table 3 Life expectancy and lifetime medical expenditure at age 40 years for BMI categories in 41 965 participants

	Univariate			Multiadjusted*		
BMI (kg/m^2)	Estimate	95% CI	p Value	Estimate	95% CI	p Value
Men						
Life expectancy at age 40 years (years)						
<18.5	36.72	35.10 to 38.17	<0.0001	37.40	35.80 to 38.87	<0.0001
18.5–24.9	42.70	41.91 to 43.37	Reference	43.03	42.22 to 43.73	Reference
25.0–29.9	44.09	42.89 to 45.25	0.0157	44.34	43.11 to 45.54	0.0264
≥30.0	41.23	38.16 to 44.54	0.3733	41.36	38.28 to 44.70	0.3184
Lifetime medical expenditure at age 40 years (£)						
<18.5	94 877.5	83 411.4 to 106 275.7	0.6846	93 208.7	81 704.9 to 104 706.4	0.3916
18.5–24.9	97 244.1	92 662.5 to 101 774.0	Reference	98 355.0	93 165.3 to 103 010.2	Reference
25.0–29.9	114 398.2	107 490.1 to 121 505.3	<0.0001	114 766.9	107 754.1 to 121 966.6	<0.0001
≥30.3	115 362.6	97 361.8 to 134 555.0	0.0501	112 858.9	94 954.1 to 131 840.9	0.01141
Women						
Life expectancy at age 40 years (years)						
<18.5	46.26	43.98 to 48.43	<0.0001	46.98	44.63 to 49.29	<0.0001
18.5–24.9	51.70	50.28 to 53.02	Reference	52.31	50.79 to 53.75	Reference
25.0–29.9	51.74	49.98 to 53.48	0.9582	52.56	50.67 to 54.46	0.7797
≥30.0	48.13	45.23 to 51.22	0.0272	49.23	46.14 to 52.59	0.0724
Lifetime medical expenditure at age 40 years (£)						
<18.5	108 278.3	97 142.8 to 119 593.7	0.5816	109 382.2	97 996.6 to 121 008.6	0.5174
18.5–24.9	111 512.8	105 303.4 to 117 910.4	Reference	113 282.9	106 668.0 to 120 054.6	Reference
25.0–29.9	127 869.3	120 236.3 to 135 932.3	<0.0001	129 964.6	121 845.4 to 138 577.2	<0.0001
≥30.0	134 887.1	121 318.4 to 149 383.6	0.0007	137 765.9	123 672.9 to 152 970.2	0.0005

*Adjusted for age groups, smoking status, alcohol drinking, sports and physical exercise, time spent walking and education.
BMI, body mass index.

participants.[10 12 13] In comparison to previous studies, we calculated lifetime medical expenditure from individual medical expenditure and survival data covering longest follow-up period to date. Meanwhile, one study has shown that obese participants have lower lifetime medical expenditure than normal weight participants.[11] However, that study limited the participants to non-smokers and calculated lifetime medical expenditure from the mortality of a hypothetical cohort and estimated medical expenditure from other cohort. In the present study, overweight participants were found to have higher lifetime medical expenditure than normal weight participants, as had been reported previously.[10 12 13] We consider that this was attributable to the higher medical expenditure per month or per person from the 10-year or 9-year follow-up than for normal weight participants.[1 3 4] On the other hand, with regard to underweight participants, our present findings were inconsistent with those of a previous study that examined the association between being underweight and lifetime medical expenditure.[13] However, that study calculated lifetime medical expenditure for elderly participants aged over 70 years. Elderly underweight participants have high mortality,[32] and medical expenditure increases in the 1 year prior to death.[20] Thus, lifetime medical expenditure from 70 years for underweight participants becomes higher than for participants of normal weight. Our study results are thus inconsistent with those reported previously.

We previously calculated life expectancy and lifetime medical expenditure for smokers and non-smokers from age 40 years by using the same data set as that for the present study.[17] The results indicated that lifetime medical expenditure was non-significantly lower in smokers than in non-smokers, reflecting the 3.5 years shorter life expectancy of smokers. On the other hand, the present study indicated that lifetime medical expenditure was higher for obese participants in spite of their shorter life expectancy. This difference would result from the difference in which obesity and smoking affect one's health and longevity. Previous studies of healthy and disability free life expectancy have agreed that smoking shortens life expectancy without affecting the years of life spent with ill-health or disability, while obesity shortens life expectancy and extends the years of life with ill-health or disability.[33] On the basis of these differences, Reuser *et al* summarised the situation as 'smoking kills and obesity disables'.[7] Extended years with ill-health and/or disability must result in increased lifetime medical expenditure. All these findings suggest that weight control would bring about longer life expectancy and long-term enhancement of the quality of life and a cost saving.

Strengths and limitations

A major strength of our present study is that it is the first in the world to have clarified the association between BMI and lifetime medical expenditure calculated from individual medical expenditure and mortality data over a long period in a general population from the age of 40 years.[1 14 16–18] The NHI covers almost all medical care utilisation.[1 4 14 16 18] Additionally, in order to reduce bias, we adjusted confounders by including various covariates in our Poisson regression model and linear regression mode.[16] On the other hand, several limitations of our study should also be considered. First, we used self-reported BMI which in a source of error.[34 35] We consider this error to be a non-differential misclassification. This misclassification would lead to attenuation of the true association towards the null. To address this problem, van Dam *et al*[36] studied the association between BMI and mortality using lower BMI cut-off points: 24.5 kg/m^2 to reflect a measured BMI of 25.0 kg/m^2 and 29.0 kg/m^2 to reflect a measured BMI of 30.0 kg/m^2. The association showed similar with original cut-off points. Second, the 95% CI was wide, and there was a limit to the accurate estimation of life expectancy and lifetime medical expenditure for obese participants. Additionally, we did not observe significant association in obese participants without lifetime medical expenditure in women. However, our results are consistent with those of the previous studies.[6–8 10 12 13] In Japan, prevalence of obesity is only 3%.[37] Thus, the reason for non-significant association might be β error because of the lack of statistical power due to small number of obese participants.

Conclusions and policy implication

In summary, even though we observed non-significant association between obesity, life expectancy and lifetime medical expenditure without lifetime medical expenditure in women, lifetime medical expenditure might appear to be higher for obese participants, despite their short life expectancy. With better weight control, more people would enjoy their longevity with lower needs and demands for medical care.

Author affiliations
[1]Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan
[2]Department of Molecular Epidemiology, Environment and Genome Research Center, Tohoku University Graduate School of Medicine, Sendai, Japan
[3]Department of Public Health, Yamagata University Graduate School of Medical Science, Yamagata, Japan
[4]Department of Hygiene, Fujita Health University School of Medicine, Toyoake, Japan

Contributors All authors contributed to the design of the study. MN, SK, MK, KO-M, TS and IT participated in data collection. MN, SK, AH, MK and SH participated in data analysis. MN, MK, KO-M, TS, AH, MK and SH participated in the writing of the report. SK and IT participated in critical revision of the manuscript. All authors approved the final version of the report for submission.

Funding This study was supported by a Health Sciences Research Grant for Health Services (H21-Choju-Ippan-001, H20-Junkankitou (Seisyu)-Ippan-013, H22-Junkankitou (Seisyu)-Ippan-012), Ministry of Health, Labour and Welfare, Japan. MN is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

Competing interests None.

Ethics approval The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data available.

REFERENCES

1. Kuriyama S, Tsuji I, Ohkubo T, *et al.* Medical care expenditure associated with body mass index in Japan: the Ohsaki Study. *Int J Obes Relat Metab Disord* 2002;26:1069–74.
2. Detournay B, Fagnani F, Phillippo M, *et al.* Obesity morbidity and health care costs in France: an analysis of the 1991-1992 Medical Care Household Survey. *Int J Obes Relat Metab Disord* 2000;24:151–5.
3. Thompson D, Brown JB, Nichols GA, *et al.* Body mass index and future healthcare costs: a retrospective cohort study. *Obes Res* 2001;9:210–18.
4. Nakamura K, Okamura T, Kanda H, *et al*; Health Promotion Research Committee of the Shiga National Health Insurance Organizations. Medical costs of obese Japanese: a 10-year follow-up study of National Health Insurance in Shiga, Japan. *Eur J Public Health* 2007;17:424–9.
5. Quesenberry CP Jr, Caan B, Jacobson A. Obesity, health services use, and health care costs among members of a health maintenance organization. *Arch Intern Med* 1998;158:466–72.
6. Peeters A, Barendregt JJ, Willekens F, *et al*; NEDCOM, the Netherlands Epidemiology and Demography Compression of Morbidity Research Group. Obesity in adulthood and its consequences for life expectancy: a life-table analysis. *Ann Intern Med* 2003;138:24–32.
7. Reuser M, Bonneux LG, Willekens FJ. Smoking kills, obesity disables: a multistate approach of the US Health and Retirement Survey. *Obesity (Silver Spring)* 2009;17:783–9.
8. van Baal PH, Hoogenveen RT, de Wit GA, *et al.* Estimating health-adjusted life expectancy conditional on risk factors: results for smoking and obesity. *Popul Health Metr* 2006;4:14.
9. Reuser M, Bonneux L, Willekens F. The burden of mortality of obesity at middle and old age is small. A life table analysis of the US Health and Retirement Survey. *Eur J Epidemiol* 2008;23:601–7.
10. Thompson D, Edelsberg J, Colditz GA, *et al.* Lifetime health and economic consequences of obesity. *Arch Intern Med* 1999;159:2177–83.
11. van Baal PH, Polder JJ, de Wit GA, *et al.* Lifetime medical costs of obesity: prevention no cure for increasing health expenditure. *PLoS Med* 2008;5:e29.
12. Finkelstein EA, Trogdon JG, Brown DS, *et al.* The lifetime medical cost burden of overweight and obesity: implications for obesity prevention. *Obesity (Silver Spring)* 2008;16:1843–8.
13. Lakdawalla DN, Goldman DP, Shang B. The health and cost consequences of obesity among the future elderly. *Health Aff (Millwood)* 2005;24(Suppl 2):W5R30–41.
14. Tsuji I, Nishino Y, Ohkubo T, *et al.* A prospective cohort study on National Health Insurance beneficiaries in Ohsaki, Miyagi Prefecture, Japan: study design, profiles of the subjects and medical cost during the first year. *J Epidemiol* 1998;8:258–63.
15. Kuriyama S, Shimazu T, Ohmori K, *et al.* Green tea consumption and mortality due to cardiovascular disease, cancer, and all causes in Japan: the Ohsaki study. *JAMA* 2006;296:1255–65.
16. Nagai M, Kuriyama S, Kakizaki M, *et al.* Impact of walking on life expectancy and lifetime medical expenditure: the Ohsaki Cohort Study. *BMJ Open* 2011;1:e000240.
17. Hayashida K, Imanaka Y, Murakami G, *et al.* Difference in lifetime medical expenditures between male smokers and non-smokers. *Health Policy* 2010;94:84–9.
18. Tsuji I, Takahashi K, Nishino Y, *et al.* Impact of walking upon medical care expenditure in Japan: the Ohsaki Cohort Study. *Int J Epidemiol* 2003;32:809–14.
19. World Health Organization. The use and interpretation of anthropometry: report of a WHO expert committee. *WHO Tech Rep Ser* 1995;854:312–409.
20. Breyer F, Felder S. Life expectancy and health care expenditures: a new calculation for Germany using the costs of dying. *Health Policy* 2006;75:178–86.
21. Chiang CL. *The Life Table and Its Applications.* Malabar, FL, USA: Krieger Publishing Company, 1983.
22. Statistics and Information Department Minister's Secretariat, Ministry of Health, Labour and Welfare of Japan. *The 20th Life Tables.* Tokyo, Japan: Health and Welfare Statstics Association, 2000.
23. Hayashi R, Iwasaki M, Otani T, *et al.* Body mass index and mortality in a middle-aged Japanese cohort. *J Epidemiol* 2005;15:70–7.

24. Hozawa A, Okamura T, Oki I, *et al.* Relationship between BMI and all-cause mortality in Japan: NIPPON DATA80. *Obesity (Silver Spring)* 2008;16:1714–17.
25. Kuriyama S, Ohmori K, Miura C, *et al.* Body mass index and mortality in Japan: the Miyagi cohort study. *J Epidemiol* 2004;14(Suppl 1):S33–8.
26. Matsuo T, Sairenchi T, Iso H, *et al.* Age- and gender-specific BMI in terms of the lowest mortality in Japanese general population. *Obesity (Silver Spring)* 2008;16:2348–55.
27. Miyazaki M, Babazono A, Ishii T, *et al.* Effects of low body mass index and smoking on all-cause mortality among middle-aged and elderly Japanese. *J Epidemiol* 2002;12:40–4.
28. Tamakoshi A, Yatsuya H, Lin Y, *et al.* BMI and all-cause mortality among Japanese older adults: findings from the Japan collaborative cohort study. *Obesity (Silver Spring)* 2010;18:362–9.
29. Tsugane S, Sasaki S, Tsubono Y. Under- and overweight impact on mortality among middle-aged Japanese men and women: a 10-y follow-up of JPHC study cohort I. *Int J Obes Relat Metab Disord* 2002;26:529–37.
30. Zheng W, McLerran DF, Rolland B, *et al.* Association between body-mass index and risk of death in more than 1 million Asians. *N Engl J Med* 2011;364:719–29.
31. Sasazuki S, Inoue M, Tsuji I, *et al*; Research Group for the Development and Evaluation of Cancer Prevention Strategies in Japan. Body mass index and mortality from all causes and major causes in Japanese: results of a pooled analysis of 7 large-scale cohort studies. *J Epidemiol* 2011;21:417–30.
32. Grabowski DC, Ellis JE. High body mass index does not predict mortality in older people: analysis of the Longitudinal Study of Aging. *J Am Geriatr Soc* 2001;49:968–79.
33. LaCroix AZ, Guralnik JM, Berkman LF, *et al.* Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol* 1993;137:858–69.
34. Niedhammer I, Bugel I, Bonenfant S, *et al.* Validity of self-reported weight and height in the French GAZEL cohort. *Int J Obes Relat Metab Disord* 2000;24:1111–18.
35. Gillum RF, Sempos CT. Ethnic variation in validity of classification of overweight and obesity using self-reported weight and height in American women and men: the Third National Health and Nutrition Examination Survey. *Nutr J* 2005;4:27.
36. van Dam RM, Willett WC, Manson JE, *et al.* The relationship between overweight in adolescence and premature death in women. *Ann Intern Med* 2006;145:91–7.
37. Yoshiike N, Matsumura Y, Zaman MM, *et al.* Descriptive epidemiology of body mass index in Japanese adults in a representative sample from the National Nutrition Survey 1990-1994. *Int J Obes Relat Metab Disord* 1998;22:684–7.

Sleep Medicine 14 (2013) 206–210

Contents lists available at SciVerse ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Association between sleep duration, weight gain, and obesity for long period

Masato Nagai *, Yasutake Tomata, Takashi Watanabe, Masako Kakizaki, Ichiro Tsuji

Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

ARTICLE INFO

Article history:
Received 29 May 2012
Received in revised form 13 September 2012
Accepted 14 September 2012
Available online 4 December 2012

Keywords:
Sleep duration
Weight gain
Obesity
Japanese
Long period

ABSTRACT

Background: Although previous studies showed the long-term effects of sleep duration on risk of weight gain, Western tends to gain weight irrespective of sleep duration over a long period. Conversely, it is showed that body mass index (BMI) decreases during a long period in Japanese and thus, the long-term effect of sleep duration on weight gain and obesity is still unclear in Asia.
Methods: We followed up 13,629 participants aged 40–79 years and prospectively collected data from 1995 to 2006. We divided the participants into five groups according to their self-reported sleep duration: ⩽5 h (short sleep), 6 h, 7 h (reference), 8 h, and ⩾9 h (long sleep). The main outcome was ⩾5 kg weight gain or BMI ⩾ 25 kg/m^2 (obesity). We used logistic regression analyses to derive odds ratios (ORs) and 95% confidence intervals (CIs), adjusted for several confounding factors.
Results: We observed no association between sleep duration and risk of ⩾5 kg weight gain and obesity. After stratification by BMI, long sleepers had a significantly increased risk of ⩾5 kg weight gain (OR: 1.36, 95%CI: 1.09–1.70) in obese participants.
Conclusions: Among community-dwelling Japanese, only obese long sleepers have a significantly increased long-term risk of ⩾5 kg weight gain.

1. Introduction

Obesity is increasing worldwide and its associated health problems are now widely recognized. According to the World Health Organization, Asia has a low prevalence of obesity in comparison to other areas of the world [1]. They recommended that obesity should be defined lower in Asia than Western [2]. In Japan, the prevalence of obesity is only 3%, and severe obesity almost never exists [3]. However, the percentage age of body fat is higher in Asian than in Western with the same body mass index (BMI) [4]. Meanwhile, according to the Organisation for Economic Co-operation and Development, Koreans have the shortest mean sleep duration in the world, followed by the Japanese [5].

The associations between sleep duration, weight gain, and/or obesity have been examined previously in seven meta-analyses and a systematic review [6–12]. However, almost all of the populations studied were Western, with longer mean sleep durations and higher prevalence of obesity than Asian populations. In Asia, three prospective studies, all from Japan, have examined the association between sleep duration and obesity [13–15]. However, the study participants were recruited from among people who were undergoing health checkups. The effect of sleep duration on weight gain and obesity has not yet been examined in an Asian population or recruited from the general community.

In addition, some previous studies have examined the long-term effects of sleep duration on weight gain and obesity from data accumulated over periods of at least 10 years [16,17]. Even though these studies showed that short sleepers were at risk of weight gain and obesity, Patel et al. showed that their study participants gained weight irrespective of sleep duration over a 16 year period [16]. In contrast, Matsushita et al. showed that mean BMI tended to decrease during a 10 year follow-up period in Japanese participants aged ⩾50 years [18]. Thus, the long-term association between sleep duration, weight gain, and obesity might differ between Western and Japanese populations, and the long-term effect of sleep duration on weight gain and obesity is still unclear in Asia.

In the present study, therefore, we examined the long-term association between sleep duration, weight gain, and obesity in Japanese subjects recruited from the general community based on data accumulated over 12 years.

2. Methods

2.1. Study cohort

Between October and December 1994, we distributed a self-administered questionnaire survey of various lifestyle habits to all National Health Insurance (NHI) beneficiaries aged 40–79 years

* Corresponding author. Address: Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575, Japan. Tel.: +81 22 717 8123; fax: +81 22 717 8125.
E-mail address: m-nagai@med.tohoku.ac.jp (M. Nagai).

1389-9457/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.sleep.2012.09.024

who lived in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan [19]. Among 54,996 eligible individuals, 52,029 (95%) responded. We followed-up with the participants from January 1, 1995 through December 31, 2008 and recorded any mortality or migration by reviewing the NHI withdrawal history files. On December 1, 2006, we distributed another questionnaire to all community-dwelling individuals aged over 40 years in Ohsaki City [20]. Among the 77,325 eligible individuals, 40,027 individuals who participated in the survey in 1994, were included without death or lost to follow-up until December 1, 2006. By combining the data for these two surveys, we were able to use the questionnaire responses for 16,982 participants (response rate 42.4%).

For the present analysis, we excluded 3116 participants who did not provide information about body weight and height, and 237 participants who did not provide information about sleep duration. As a result, a final total of 13,629 participants were included.

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. We considered the return of self-administered questionnaires signed by the participants to imply their consent to participate in the study.

2.2. Sleep duration

The self-administered questionnaire included question on sleep duration. Sleep duration was assessed through each participant's response to the question, "How many hours on average do you sleep per day ?" The participants entered the mean integer number representing the hours of sleep taken per day during the previous year. We divided the participants into five groups according to their sleep duration: ⩽5 h (short sleep), 6 h, 7 h (reference), 8 h, and ⩾9 h (long sleep).

2.3. Outcome measures

The main outcome measure was ⩾5 kg weight gain calculated as weight (kg) in the NHI Cohort Study minus self-reported weight (kg) recorded in the Ohsaki Cohort 2006 Study. We also assessed BMI ⩾ 25.0 kg/m^2 (obesity) calculated as weight (kg) divided by the square of height (m^2). These self-reported heights, weights, and BMI in the questionnaire were considered to be sufficiently valid [21]. The Pearson's correlation coefficient (r) between the self-reported values and measured values were $r = 0.96$ ($p < 0.01$) for weight, $r = 0.93$ ($p < 0.01$) for height, and $r = 0.88$ ($p < 0.01$) for BMI.

2.4. Statistical analysis

We used logistic regression analyses to derive odds ratios (ORs) and 95% confidence intervals (CIs) for ⩾5 kg weight gain and obesity according to each sleep duration category and to adjust for potentially confounding factors, using the SAS version 9.2 statistical software package. The 7 h sleep duration category was selected as the reference. All p values were two-tailed and differences at $p < 0.05$ were accepted as statistically significant.

We considered the following variables to be potential confounding factors: sex (men or women), age (continuous), BMI (<18.5, 18.5–24.9, 25.0–29.9, or ⩾30.0 kg/m^2), education (junior high school or less, high school, or college/university or higher), smoking status (never smoker, past smoker, current smoker consuming 1–19 cigarettes per day, or current smoker consuming at least 20 cigarettes per day), alcohol drinking (never drinker, past drinker, or current drinker), time spent walking per day (less than 1 h, or 1 h or longer), sports and physical exercise time per week (less than 1 h, 1–2 h, 3–4 h, or 5 h or longer), job status (employed, or no occupation or housewife), marital status (married or unmarried), menopausal status (premenopausal or postmenopausal), coffee consumption (never or occasionally, 1–2 cups/day, 3–4 cups/day, ⩾5 cups/day), and self-rated health (good or not good). We further adjusted for energy consumption (kcal/day) in the multivariate models 2.

In addition, we repeated analyses after excluding participants who had functional limitation, poor self-rated health, or history of disease. Physical function status was assessed using the 6 item measure of the Medical Outcomes Study (MOS) Short-form General Health Survey [22]. Participants were excluded if they stated on the MOS questionnaire that they were unable to perform moderate or vigorous activities ($n = 3576$), walk one block ($n = 25$), or perform self-care activities such as eating, dressing, bathing, or using the toilet ($n = 2$). We excluded participants who reported severe bodily pain ($n = 246$), poor self-rated health ($n = 896$), or history of cancer ($n = 160$), myocardial infarction ($n = 100$), or stroke ($n = 45$). The remaining 8579 participants were apparently healthy and their sleep duration was not affected these physical conditions.

3. Results

3.1. Baseline characteristics in terms of sleep duration categories

Table 1 shows the baseline characteristics of the study participants according to the categories of sleep duration.

The mean age was highest in the long sleep category. The proportions of women decreased linearly as the sleep duration category increased. Even though the mean weight was the lowest in the short sleep category, the mean BMI showed no significant difference. The mean weight change increased linearly as the sleep duration category increased. The proportion of participants who were employed was lowest in the short sleep category, whereas the proportions of participants who were current drinkers and consumed ⩾3 cups/day of coffee were lowest in the long sleep category. The proportions of participants who walked ⩾1 h/day and did ⩾3 h/week sports and physical exercise were highest in the long sleep category. Mean energy consumption was lowest in the short sleep category.

3.2. Weight gain and obesity by sleep duration category

Table 2 shows the numbers of participants who had ⩾5 kg weight gain and obesity and the ORs of ⩾5 kg weight gain and obesity with 95% CIs according to the sleep duration categories.

We observed no association between sleep duration, ⩾5 kg weight gain, and obesity. The multivariate OR1 for ⩾5 kg weight gain was 0.93 (95%CIs; 0.73–1.19) in short sleeper and 1.05 (0.91–1.20) in long sleepers (p for trend = 0.3087). Similarly, the multivariate OR1 for obesity was 1.08 (0.77–1.52) in short sleeper and 1.06 (0.86–1.30) in long sleeper (p for trend = 0.3712). After further adjustments of multivariate ORs1 for energy consumption, the multivariate ORs2 showed associations similar to those for ORs1 (⩾5 kg weight gain; p for trend = 0.3097, obesity; p for trend = 0.3655). In addition, after stratification by BMI, the present study also demonstrated a null association between sleep duration and ⩾5 kg weight gain in normal weight participants (p for trend = 0.6236). However, among obese participants, long sleepers had a significantly increased risk of ⩾5 kg weight gain (OR: 1.36, 95%CI: 1.09–1.70).

Table 3 shows the numbers of healthy participants who had ⩾5 kg weight and obesity and ORs with 95% CIs according to the sleep duration categories. We also observed no association between sleep duration, ⩾5 kg weight gain, and obesity in participants who had no physical limitations or history of disease. The multivariate OR1 for ⩾5 kg weight gain was 0.88 (0.61–1.26) in

Table 1
Baseline characteristics by sleep duration in 13,629 participants aged 40–79 years.

	Sleep duration (h/day)					p Value[b]
	⩽5	6	7	8	⩾9	
No. of subjects	453	1831	4291	5265	1789	
Mean age (years) (SD[a])	57.5 (9.7)	56.3 (9.6)	56.2 (9.3)	58.4 (9.1)	61.9 (8.5)	<.0001
Women (%)	70.0	66.3	58.4	51.2	45.6	<.0001
Mean weight (kg) (SD)	56.9 (10.1)	57.6 (9.2)	58.7 (9.3)	58.8 (9.4)	58.5 (10.0)	<.0001
Mean BMI (kg/m^2) (SD)	23.6 (3.3)	23.6 (3.0)	23.7 (3.0)	23.7 (3.0)	23.7 (3.6)	NS
Mean weight change (kg) (SD)	0.7 (5.7)	0.8 (5.0)	1.0 (5.4)	1.1 (5.8)	1.8 (7.4)	<.0001
Education (%)						
Junior high school or less	48.9	42.8	46.2	56.7	69.7	<.0001
High school	40.7	43.9	42.4	35.7	25.9	
College/university or higher	10.5	13.3	11.4	7.6	4.4	
Job status (%)						
Employed	54.8	58.8	65.6	63.4	58.3	<.0001
No occupation or housewife	45.2	41.2	34.4	36.6	41.7	
Smoking status (%)						
Never smoker	63.7	62.9	60.6	53.1	49.0	<.0001
Past smoker	12.3	12.2	12.6	15.1	18.1	
Current smoker <20	10.8	11.4	9.3	12.8	15.3	
Current smoker ⩾20	13.1	13.5	17.5	19.0	17.7	
Alcohol drinking (%)						
Never drinker	48.7	48.4	48.6	50.6	54.1	<.0001
Past drinker	6.3	5.7	4.8	6.7	6.8	
Current drinker	45.0	45.9	46.7	42.8	39.2	
Time spent walking (%)						
⩾1 h/day	42.5	45.2	45.9	47.4	50.2	0.0054
<1 h/day	57.5	54.8	54.1	52.6	49.8	
Sports and physical exercise (%)						
⩾5 h/week	8.2	5.3	5.8	6.9	8.5	0.0083
3–4 h/week	6.1	6.5	6.2	6.2	7.0	
1–2 h/week	13.9	16.2	16.2	16.8	15.0	
<1 h/week	71.8	72.0	71.8	70.1	69.5	
Marital status (%)						
Married	77.1	83.4	86.7	86.6	84.2	<.0001
Unmarried	22.9	16.6	13.3	13.4	15.8	
Menopause status (%)						
Premenopausal	25.6	30.0	28.0	18.0	8.6	<.0001
Postmenopausal	74.4	70.0	72.0	82.0	91.3	
Coffee consumption (%)						
⩾5 cups/day	6.8	5.2	3.2	3.1	1.7	<.0001
3–4 cups/day	7.8	9.5	9.5	7.6	5.4	
1–2 cups/day	27.8	34.6	36.8	34.1	29.1	
<1 cup/day	57.6	50.7	50.6	55.3	63.8	
Self-rated health (%)						
Good	56.7	69.0	71.6	71.4	67.9	<.0001
Not good	43.3	31.0	28.5	28.6	32.1	
Mean energy consumption/day (kcal) (SD)	1405.2 (528.9)	1488.7 (550.8)	1554.3 (565.4)	1595.8 (598.4)	1572.4 (600.3)	<.0001

[a] BMI, body mass index; SD, standard deviation; NS, not significant.
[b] p Values were calculated by chi-squared test (categorical variables), or ANOVA (continuous variables).

short sleepers and 1.06 (0.88–1.27) in long sleepers (p for trend = 0.5539). Similarly, the multivariate OR1 for obesity was 0.96 (0.59–1.57) in short sleepers and 1.06 (0.82–1.37) in long sleepers (p for trend = 0.3267). After stratification by BMI, only obese long sleepers also had a significantly increased risk of ⩾5 kg weight gain (OR: 1.41, 95%CI: 1.04–1.92).

4. Discussion

The present results indicate that the association between sleep duration, ⩾5 kg weight gain and obesity showed no significant association over a long period in Japanese subjects recruited from the community. After stratification by BMI, obese long sleepers showed a significantly increased risk of ⩾5 kg weight gain (OR: 1.36, 95%CI: 1.09–1.70).

The mean age in the long sleep category was oldest and the proportion of women in the short sleep category was highest in the sleep duration categories, but the association between sleep duration, ⩾5 kg weight gain, and obesity also showed no significant associations after stratification by the age categories (<65 years or ⩾65 years) and sexes (data not shown).

There is a possibility that the long sleep category would have included participants who were bedridden due to physical limitation. Short sleep is associated with poor self-rated health [23]. Therefore, we conducted additional analysis after excluding participants who had functional limitation, poor self-rated health, or history of disease in order to eliminate any bias due to these effects. However, only obese long sleepers also showed a significantly increased risk of weight gain (OR: 1.41, 95%CI: 1.04–1.92).

These results were different from those of previous studies conducted in Japan [13–15]. However, the participants of those studies had been recruited from among individuals undergoing health checkups. Also, the previous studies had examined the short-term effect of sleep duration on obesity, whereas, the present study examined the long-term effect. On the other hand, the present results were also different from those of previous studies that had examined the long-term effects of sleep duration on weight gain

Table 2
The association between sleep duration, ⩾5 kg weight gain, and obesity.

	Sleep duration					
	⩽5	6	7	8	⩾9	*p* for trend[a]
⩾5 kg weight gain						
Total number	453	1,831	4,291	5,265	1,789	
Case	95	355	876	1113	468	
Crude	1.03(0.82–1.31)	0.94(0.82–1.08)	1.00 (reference)	1.05(0.95–1.15)	1.38(1.21–1.57)	<.0001
Age-sex adjusted ORs	0.98(0.77–1.25)	0.93(0.81–1.07)	1.00 (reference)	0.94(0.85–1.04)	1.07(0.93–1.22)	0.2032
Multivariate ORs1[b]	0.93(0.73–1.19)	0.95(0.82–1.09)	1.00 (reference)	0.94(0.84–1.04)	1.05(0.91–1.20)	0.3087
Multivariate ORs2[c]	0.93(0.73–1.20)	0.95(0.82–1.09)	1.00 (reference)	0.94(0.84–1.04)	1.05(0.91–1.20)	0.3093
Stratified analyses (BMI)						
<25 kg/m^2	0.99(0.72–1.35)	0.94(0.78–1.12)	1.00 (reference)	0.93(0.81–1.06)	0.91(0.76–1.08)	0.6236
⩾25 kg/m^2	0.86(0.58–1.29)	0.96(0.76–1.23)	1.00 (reference)	0.95(0.80–1.13)	1.36(1.09–1.70)	0.0145
Obesity[d]						
Total number	311	1,329	3,038	3,724	1,256	
Case	44	177	413	539	162	
Crude	1.05(0.75–1.47)	0.98(0.81–1.18)	1.00 (reference)	1.08(0.94–1.24)	0.94(0.78–1.14)	0.9454
Age-sex adjusted ORs	1.07(0.76–1.49)	0.98(0.81–1.18)	1.00 (reference)	1.12(0.98–1.29)	1.05(0.86–1.29)	0.3125
Multivariate ORs1	1.08(0.77–1.52)	0.99(0.82–1.20)	1.00 (reference)	1.12(0.97–1.29)	1.06(0.86–1.30)	0.3712
Multivariate ORs2	1.08(0.77–1.51)	0.99(0.81–1.19)	1.00 (reference)	1.12(0.97–1.29)	1.06(0.86–1.29)	0.3655

[a] *p* for trend values were calculated by sleep duration as a continuous variable.
[b] Multivariate ORs1 was adjusted for sex (men or women); age (continuous); body mass index (<18.5, 18.5–24.9, 25.0–29.9, or ⩾30.0 kg/m^2); education (junior high school or less, high school, or college/university or higher); smoking status (never smoker, past smoker, current smoker consuming 1–19 cigarettes per day, or current smoker consuming at least 20 cigarettes per day); alcohol drinking (never drinker, past drinker, or current drinker); time spent walking/day (less than 1 h, or 1 h or longer); job status (employed, or no occupation or housewife); marital status (married or unmarried); menopause (premenopausal or postmenopausal); coffee (never or occasionally, 1–2 cups/day, 3–4 cups/day, ⩾5 cups/day); self-rated health (good or not good).
[c] Multivariate ORs2 was further adjusted multivariate ORs1 for energy consumption/day (tertile category).
[d] Analyses of obesity excluded the 3971 participants who was obesity from the 13,629 participants.

Table 3
The association between sleep duration, 5 kg weight gain, and obesity in healthy participants aged 40–79 years.

	Sleep duration					
	⩽5	6	7	8	⩾9	*p* for trend[a]
5 kg weight gain						
Total number	228	1185	2830	3305	1031	
Case	41	222	522	652	251	
Multivariate ORs1[b]	0.88(0.61–1.26)	1.01(0.85–1.21)	1.00 (reference)	0.95(0.83–1.09)	1.06(0.88–1.27)	0.5539
Stratified analyses (BMI)						
<25 kg/m^2	1.00(0.64–1.56)	1.07(0.86–1.33)	1.00 (reference)	0.90(0.76–1.07)	0.91(0.73–1.15)	0.2253
⩾25 kg/m^2	0.71(0.38–1.33)	0.92(0.68–1.26)	1.00 (reference)	1.06(0.85–1.32)	1.41(1.04–1.92)	0.0073
Obesity[c]						
Total number	160	852	2,041	2362	747	
Case	20	123	282	341	101	
Multivariate ORs1	0.96(0.59–1.57)	1.09(0.87–1.38)	1.00 (reference)	1.08(0.90–1.28)	1.06(0.82–1.37)	0.3267

[a] *p* for trend values were calculated by sleep duration as a continuous variable.
[b] Multivariate ORs1 was adjusted for sex (men or women); age (continuous); body mass index (<18.5, 18.5–24.9, 25.0–29.9, or ⩾30.0 kg/m^2); education (junior high school or less, high school, or college/university or higher); smoking status (never smoker, past smoker, current smoker consuming 1–19 cigarettes per day, or current smoker consuming at least 20 cigarettes per day); alcohol drinking (never drinker, past drinker, or current drinker); time spent walking/day (less than 1 h, or 1 h or longer); sports and physical exercise time/week (less than 1 h, 1–2 h, 3–4 h, or 5 h or longer); job status (employed, or no occupation or housewife); marital status (married or unmarried); menopause (premenopausal or postmenopausal); coffee consumption (never or occasionally, 1–2 cups/day, 3–4 cups/day, ⩾5 cups/day).
[c] Analyses of obesity excluded the 2417 participants who was obesity from the 8579 participants.

and obesity [16,17]. This may have been due to differences in long-term BMI or weight change trends between Japanese and Americans; the former show a decreasing long-term trend for BMI [18], and the latter an increasing long-term trend for weight increases [16]. Over short periods, short sleep is also a risk factor for obesity in Japanese [13–15]. Thus, after short sleepers have increased weight, they might show a weight reduction in the long term. Therefore, the present study found no association between short sleep and the risk of weight gain and obesity. However, we were unable to demonstrate whether our study participants exhibited such weight changes during the observation period because we only had data for their weight at the baseline and the end of follow up.

The biological mechanism responsible for the association between short sleep, weight gain, and obesity has mainly been considered attributable to a decreased leptin level and an increased ghrelin level with shorter sleep duration [24–26]. Appetite increases as the level of the satiety-promoting hormone falls and that of the appetite-promoting hormone increases. Thus, short sleep induces an increase of daily energy consumption and, thereby, weight gain. However, although we did not obtain data on leptin and ghrelin levels, daily energy consumption was lowest in short sleepers. The proportion of women in the short sleep category was higher than that in the long sleep category, but the above trend was also observed after separation of the sexes (data not shown). Manini et al. and St-Onge et al. demonstrated no association between sleep duration and energy expenditure as measured using doubly labeled water [27,28]. Therefore, the lack of association between short sleep, weight gain, and obesity in the present study might have been attributable to the lack of a relationship between short sleep duration and increased energy consumption. However, although the Nurses' Health Study also showed that daily energy consumption was lowest in short sleepers [16], lack of sleep duration was associated with a risk of ⩾15 kg weight gain. The association between changes in hormone levels, increasing daily energy consumption, weight gain, and obesity due to short sleep duration might be related to not only the above mechanism, but also other unknown mechanisms.

A major strength of the present study was that it was the first to have investigated the long-term association between sleep duration, weight gain, and obesity in an Asian general population showing different long-term trends of weight change from Western populations [16,18]. Asians have a lower prevalence of obesity and a shorter mean sleep duration than Westerners [1,5]. To exclude the effects of physical condition on sleep duration, weight gain, and obesity, we repeated our analyses after excluding participants who had functional limitation or history of disease.

On the other hand, several limitations should also be considered. First, we had no information about sleep quality, the timing of sleep, the use of sleep medication, the presence of sleeping disorders, rotating shift work, or night work that can influence sleep duration and thereby affect the risk of weight gain and obesity. Although we had no information about rotating shift work and night work, since 18.2% of our participants were housewives, 32.6% farmers, and 14.8% retired, such details would have been unlikely to have changed the results. Second, the assessment of weight was done only at the baseline and at the end of follow-up. We had no information about the trends of weight change during the follow-up period. Third, we used self-reported weight, height, and BMI. There is a systematic bias in self-reported weight and height. Because of this bias, there is possibility that we observed no association between short sleep duration, weight gain, and obesity. However, we demonstrated a high correlation and appropriate agreement between self-reported values and measured values (weight: $r = 0.96$, height: $r = 0.93$, BMI: $r = 0.88$).

In conclusion, the present study showed that only obese long sleepers have a significantly increased risk of ⩾5 kg weight gain in the long term among Japanese recruited from the community. Short sleep did not carry a risk of weight gain and obesity. Further research is needed to clarify the long-term association between sleep duration, weight gain, and obesity in Asian populations.

Conflict of Interest

This was not an industry supported study. The authors declare that they have no conflicts of interest.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2012.09.024.

Acknowledgments

This study was supported by a Health Sciences Research Grant for Health Services (H22-Junkankitou (Seisyu)-Ippan-012, H23-Junkankitou (Seisyu)-Ippan-005, H23-Junkankitou (Seisyu)-Wakate-015), Ministry of Health, Labour and Welfare, Japan. Masato Nagai is a recipient of a Research Fellowships of the Japan Society for the Promotion of Science for Young Scientists.

References

[1] World Health Organization. Global Database on Body Mass Index. <http://apps.who.int/bmi/index.jsp>.
[2] Consultation WE. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–63.
[3] Yoshiike N, Matsumura Y, Zaman MM, Yamaguchi M. Descriptive epidemiology of body mass index in Japanese adults in a representative sample from the National Nutrition Survey 1990–1994. Int J Obes Relat Metab Disord 1998; 22:684–7.
[4] Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev 2002;3:141–6.
[5] Organisation for Economic Co-operation and Development. Society at a glance 2009: OECD social indicators: Organization for Economic; 2009.
[6] Beccuti G, Pannain S. Sleep and obesity. Curr Opin Clin Nutr Metab Care 2011; 14:402–12.
[7] Grandner MA, Patel NP, Gehrman PR, Perlis ML, Pack AI. Problems associated with short sleep: bridging the gap between laboratory and epidemiological studies. Sleep Med Rev 2010;14:239–47.
[8] Horne J. Obesity and short sleep: unlikely bedfellows? Obes Rev 2011; 12:e84–94.
[9] Nielsen LS, Danielsen KV, Sorensen TI. Short sleep duration as a possible cause of obesity: critical analysis of the epidemiological evidence. Obes Rev 2011; 12:78–92.
[10] Patel SR. Reduced sleep as an obesity risk factor. Obes Rev 2009;10(Suppl. 2):61–8.
[11] Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. Obesity (Silver Spring) 2008;16:643–53.
[12] Magee L, Hale L. Longitudinal associations between sleep duration and subsequent weight gain: a systematic review. Sleep Med Rev 2012;16:231–41.
[13] Itani O, Kaneita Y, Murata A, Yokoyama E, Ohida T. Association of onset of obesity with sleep duration and shift work among Japanese adults. Sleep Med 2011;12:341–5.
[14] Kobayashi D, Takahashi O, Deshpande GA, Shimbo T, Fukui T. Association between weight gain, obesity, and sleep duration: a large-scale 3-year cohort study. Sleep Breath 2011.
[15] Nishiura C, Noguchi J, Hashimoto H. Dietary patterns only partially explain the effect of short sleep duration on the incidence of obesity. Sleep 2010;33:753–7.
[16] Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB. Association between reduced sleep and weight gain in women. Am J Epidemiol 2006;164:947–54.
[17] Hasler G, Buysse DJ, Klaghofer R, Gamma A, Ajdacic V, Eich D, et al. The association between short sleep duration and obesity in young adults: a 13-year prospective study. Sleep 2004;27:661–6.
[18] Matsushita Y, Takahashi Y, Mizoue T, Inoue M, Noda M, Tsugane S. Overweight and obesity trends among Japanese adults: a 10-year follow-up of the JPHC Study. Int J Obes (London) 2008;32:1861–7.
[19] Tsuji I, Nishino Y, Ohkubo T, Kuwahara A, Ogawa K, Watanabe Y, et al. A prospective cohort study on National Health Insurance beneficiaries in Ohsaki, Miyagi Prefecture, Japan: study design, profiles of the subjects and medical cost during the first year. J Epidemiol 1998;8:258–63.
[20] Kuriyama S, Nakaya N, Ohmori-Matsuda K, Shimazu T, Kikuchi N, Kakizaki M, et al. The Ohsaki Cohort 2006 Study: design of study and profile of participants at baseline. J Epidemiol 2010;20:253–8.
[21] Kuriyama S, Tsuji I, Ohkubo T, Anzai Y, Takahashi K, Watanabe Y, et al. Medical care expenditure associated with body mass index in Japan: the Ohsaki Study. Int J Obes Relat Metab Disord 2002;26:1069–74.
[22] Stewart AL, Hays RD, Ware Jr JE. Short-form general health survey. Reliability and validity in a patient population. Med Care 1988;26:724–35.
[23] Steptoe A, Peacey V, Wardle J. Sleep duration and health in young adults. Arch Intern Med 2006;166:1689–92.
[24] Chaput JP, Despres JP, Bouchard C, Tremblay A. Short sleep duration is associated with reduced leptin levels and increased adiposity: results from the Quebec family study. Obesity (Silver Spring) 2007;15:253–61.
[25] Spiegel K, Tasali E, Penev P, Van Cauter E. Brief communication: sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. Ann Intern Med 2004;141:846–50.
[26] Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med 2004;1:e62.
[27] Manini TM, Everhart JE, Patel KV, Schoeller DA, Colbert LH, Visser M, et al. Daily activity energy expenditure and mortality among older adults. JAMA 2006;296:171–9.
[28] St-Onge MP, Roberts AL, Chen J, Kelleman M, O'Keeffe M, RoyChoudhury A, et al. Short sleep duration increases energy intakes but does not change energy expenditure in normal-weight individuals. Am J Clin Nutr 2011;94:410–6.