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特集
エネルギー代謝と体温

日本人の代謝基準値の再評価

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日本では，古くから基礎代謝および活動時のエネルギー代謝に関する研究が行なわれ，それらを土台として，日本人の栄養所要量や食事摂取基準におけるエネルギーの必要量の基準値が策定されてきた．本稿では，まず，エネルギーの必要量の歴史についてふれた後，最近の見直しの中でヒューマンカロリメーターがどのように関与してきたかを述べる．

1. 総エネルギー消費量の内訳

体重変化のない成人の場合，1日当たりの総エネルギー消費量（total energy expenditure：TEE）がそのまま，エネルギーの“必要量”（かつては，エネルギーについても“所要量”と呼ばれていた）となる．TEEは，一般に以下のように大別される．

TEE＝基礎代謝量（basal metabolic rate：BMR）＋食事誘発性体熱産生（diet-induced thermogenesis：DIT）＋身体活動量

他にも，場合によっては，寒冷刺激による熱産生，運動後の代謝亢進などが加わる．このうち，DITはTEEの約10%といわれており，その絶対量や個人間差は，BMRや身体活動量と比べて，相対的に小さい．そのため，「第五次改定日本人の栄養所要量」[1]までは，BMRと身体活動量を求め，それらの和を0.9で除すことによってTEEを推定し，それをエネルギー必要量の推定値としていた．

「第六次改定日本人の栄養所要量―食事摂取基準―」[2]以降は，

TEE＝BMR×身体活動レベル（physical activity level：PAL）

としており，DITは身体活動量とともにPALの中に含まれている．

このように，以前より現在に至るまで，“BMR”と“身体活動量”がTEE推定の二大要素である．ただし，それ以外の要素（DITや寒冷刺激による熱産生，運動後の代謝亢進など）についてどのように考えるかによって，TEEの推定法が異なってくる．

2. BMRの推定

1）基礎代謝基準値の確立

1919年にHarris-BenedictによるBMR推定式が公表され[3]，1920年，内務省に栄養研究所が設立された直後に，日本におけるBMRの測定がはじまったようである[4]．1941年には，主として栄養研究所で測定されたデータに基づいた日本人の基礎代謝の標準値を利用して，栄養研究所と公衆衛生院が合併してできた厚生科学研究所国民栄養部が「日本人栄養要求量標準」を報告している．その後，昭和34（1959）年の栄養所要量改定に

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おいて，戦前・戦後にわたって男女それぞれ900名程度を対象に測定された値をもとにして，大幅な見直しがされている．

しかし，昭和44（1969）年改定の栄養所要量でさらに本格的に見直しがなされ，そこで決められた基礎代謝基準値が，現在まで最も重要な位置を占めている．長崎大学の藤本らによる文部省総合研究「日本人発育期の基礎代謝研究」は，Benedictらの方法に準じて，測定条件を厳格に規定した[4,5]．それに従って，主に長崎大学，徳島大学および昭和医科大学で，約6,500人の測定を実施し，1951年から1966年の16年間において，約60の文献で結果が報告された．それをもとにして，性・年齢階級別基礎代謝基準値が設定された．

ちなみに，健常人に対して国際的に最も用いられているのは，Schofieldの式[6]やWHO/FAO/UNUの式[7]である．これらは1930～1950年頃に発表された世界各国からの114の文献（英文で発表された日本人の結果を含む）中の値から作成されており，対象者数は7,000人強であるが，軍人・警察官を中心としたイタリア人が半数近くを占めている．日本の基礎代謝基準値も，それに近い人数の日本人での測定に基づいており，対象者の偏りのなさや条件の均一性も考えると，国際的に優れたものであるといえる．

その後，昭和50（1975）年の改定で，それまで体表面積当たりで表されていた基礎代謝基準値（kcal/m^2/時）が，体重当たり（kcal/kg/日）で表されるようになった．その算出方法は，

体表面積当たりの基礎代謝基準値×基準体位における体表面積÷基準体重×24

である．この方法は，その後も採用され続けた．第六次改定まで，少しずつ基礎代謝基準値の値が変わっていたのは，基準体位が毎回変更されるのに伴って，上記の換算がなされていたためである．

体重当たりの基礎代謝基準値に変わったことにより，計算は簡単になったものの，個人における推定誤差は大きくなってしまった．そこで，昭和50年改定では，「体重当たりの基準値からの推定では，体重が大きい者のBMRを過大評価，小さい者のBMRを過小評価する」という問題を指摘した上で，体重から算出される“加算値”を用いた補正法を提案した．

2）エネルギー代謝率（relative metabolic rate：R.M.R.）

R.M.R.は，労働科学の立場から，各種作業のエネルギー消費量，ひいては1日のエネルギー必要量を推定するために考えられた指標である[8]．作業環境における安静状態からのエネルギーの増加分をBMRで除することによって，体格等の影響を除いている．

R.M.R.＝（労作時のエネルギー消費量—座位安静時代謝量）÷BMR

ここでの座位安静時代謝量は，労作強度を測定する前あるいは後に，同じ被験者について，その現場と同じ環境条件下で測定するものであるため，DITや環境温度などの影響も受ける．ただし，快適な温度環境であれば，BMRと比べ，およそ＋20％になっているものと考えられている[8,9]．

R.M.R.の測定は，さまざまな労働作業や日常生活活動，運動を対象として，主に1924年から1940年にかけて実施された．最終的に値の得られた活動の種類は，600を優に超えている．欧米では知られていないものの，国際的にみても，質・量とも優れたデータベースである．

座位安静時代謝量＝BMR×1.2

と仮定すれば，R.M.R.から

Activity factor（Af）＝当該活動のエネルギー消費量÷BMR

を算出し，要因加算法（生活時間調査）により，身体活動の強度が推定できる．これに，基礎代謝基準値から推定されたBMRを乗じ，食事による産熱効果を考慮してTEE，ひいてはエネルギー必要量を推定する方法が，第六次改定（1999年）まで続いた．

3）R.M.R.を利用したTEE推定の問題点

基礎代謝基準値およびエネルギー代謝率（R.

M.R.）は，かなり厳格な条件のもとで測定された莫大なデータベースに基づいている．しかし，これらを利用した要因加算法による推定には，記録の正確性に加え，DITやExcess of Post-exercise Oxygen Consumption（EPOC）の推定，寒冷時における代謝亢進など，さまざまな誤差要因が伴うため，TEE推定の妥当性については確信がもてない状態であった．実際，第五次改定（1994）までは，R.M.R.の中にDITが含まれているにもかかわらず，BMRと身体活動量の和をさらに0.9で除していたため，実際にはDITが二重に計算されていた．TEE推定時の仮定が多くなればなるほど，TEEの推定の正確さは保証しにくくなる．

3.「日本人の食事摂取基準（2005年版）」以降

1）二重標識水（doubly labeled water：DLW）法

1980年頃以降，日常生活におけるエネルギー消費量を最も正確かつ非侵襲的に評価できるとして，少しずつ利用されるようになってきたのは，DLW法であった[10]．DLW法とは，^{2}Hと^{18}Oという2つの安定同位体を含む水（＝DLW）を摂取し，それらの減少率の差から二酸化炭素産生量を推定する方法である[10,11]．一般に2週間程度にわたる比較的長期間のエネルギー消費量を得るのに，被験者は数回の採尿だけで済む．非常に高価で，分析も難しく機器が少ないが，1～2%程度の誤差が確認されているヒューマンカロリメーター法を基準として比較すると，約5%程度の誤差と報告されている[10]．日本では，ヒューマンカロリメーターと同じく2000年に，国立健康・栄養研究所に分析システムが導入された．

2）身体活動レベル（PAL）

第六次改定から，エネルギーの必要量は，BMRにPALの推定値を乗じることによって求めるようになった．しかし，それ以前に用いられていた生活活動強度の指数をPALに換算することは可能である．それらを比較すると，第六次では，実質上4段階のうちの1段階ずつ引き下げられていた（表1）．その理由は，十分に記述されているとはいえない．しかし，本文中の記述および，各活動におけるAfの値が，第五次改定までと比較して0.2ずつ小さくなっていることからすると，主に，「R.M.R.における座位安静時代謝量とBMRが等しい」と仮定してしまったことによるものと考えられる．その結果，DITを二重に加えていた第五次までとは逆に，第六次ではDITがまったく考慮されていないことになる．さらに，座位と立位の差の10%も無視されている．

「日本人の食事摂取基準（2005年版）」[12]においては，（独）国立健康・栄養研究所がDLW法を用いて全国4カ所で行なった，DLW法としては比較的大規模な調査結果[13]に基づいて，PALの値を決定した．その結果，PALを4分類することは難しいため3分類にし，標準の値を第六次改定の1.5から1.75へと変更した（表1）．

その後，日本を含め新たに得られたPALのデータをより厳密に吟味した．その結果，「日本人の食事摂取基準（2010年版）」[14]では，成人以外の多くの性・年齢階級で，PALの値が若干変更され，表2のようになった．PALの推定法は，現在でも大きな課題である[13,15～19]．

ちなみに，子どものPALについては，成人とは逆に，2005年版で値が大きくなっている．子どもにおける標準のPALは，第六次改定で1.7と，活動的な成人と同じ値であった．少なくとも第六次改定で明確な根拠は示されていないが，「子どもの身体活動量は多い」という仮定があったことによるようである．2005年版以降は，DLW法に基づき，1歳から成人に至るまで，年齢が上がるとともにPALの値が大きくなるように設定されている．

一方，基礎代謝基準値についても，2010年版において，1980年代以降に報告された値から，測定から約50年が経過した現在でも通用するかどうかが検証された．その結果，18～29歳の女性では，23.6kcal/kg/日から22.1kcal/kg/日

表 1 最近の栄養所要量・食事摂取基準における生活活動強度・身体活動レベル（PAL）の比較

第五次改定		第六次改定		日本人の食事摂取基準（2005年版/2010年版）	
生活活動強度とPAL	日常生活の内容	生活活動強度とPAL	日常生活の内容	身体活動レベルとPAL	日常生活の内容
Ⅰ（軽い）1.50	通勤，買い物など1時間程度の歩行と軽い手作業や家事などによる立位のほかは，大部分座位で事務，勉強，談話等をしている場合	Ⅰ（低い）1.3	散歩，買い物など比較的ゆっくりした1時間程度の歩行のほか，大部分は座位での読書，勉強，談話，また座位や横になってのテレビ，音楽鑑賞などをしている場合	Ⅰ（低い）1.50（1.40～1.60）	生活の大部分が座位で，静的な活動が中心の場合
Ⅱ（中等度）1.67	通勤，買い物のほか仕事などで2時間程度の歩行と事務，読書，談話による座位のほか，機械操作，接客，家事等による立位時間の多い場合	Ⅱ（やや低い）1.5	通勤，仕事などで2時間程度の歩行や乗車，接客，家事等立位での業務が比較的多いほか，大部分は座位での事務，談話などをしている場合	Ⅱ（普通）1.75（1.60～1.90）	座位中心の仕事だが，職場内での移動や立位での作業・接客等，あるいは通勤・買物・家事，軽いスポーツ等のいずれかを含む場合．
Ⅲ（やや重い）1.94	農耕，漁業，建築などで座位，立位，歩行のほか，1日のうち1時間程度は重い筋作業に従事している場合	Ⅲ（適度）1.7	生活活動強度Ⅱの者が1日1時間程度は速歩やサイクリングなど比較的強い身体活動を行なっている場合や，大部分は立位での作業であるが1時間程度は農作業，漁業などのような強い作業に従事している場合	Ⅲ（高い）2.00（1.90～2.20）	移動や立位の多い仕事への従事者．あるいは，スポーツなど余暇における活発な運動習慣をもっている場合
Ⅳ（重い）2.22	1日のうち2時間程度は激しいトレーニングや木材の運搬，農繁期の農耕作業などのような重い作業に従事している場合	Ⅳ（高い）1.9	1日のうち1時間程度は激しいトレーニングや木材の運搬，農繁期の農耕作業などのような強い作業に従事している場合		

第五次改定のPALは生活活動指数より換算．

表 2 日本人の食事摂取基準（2010年版）における身体活動レベル（男女共通）

身体活動レベル	レベルⅠ	レベルⅡ	レベルⅢ
1～2（歳）	−	1.35	−
3～5（歳）	−	1.45	−
6～7（歳）	1.35	1.55	1.75
8～9（歳）	1.40	1.60	1.80
10～11（歳）	1.45	1.65	1.85
12～14（歳）	1.45	1.65	1.85
15～17（歳）	1.55	1.75	1.95
18～29（歳）	1.50	1.75	2.00
30～49（歳）	1.50	1.75	2.00
50～69（歳）	1.50	1.75	2.00
70以上（歳）	1.45	1.70	1.95

へと引き下げられたものの，他の性・年齢階級については，そのままで問題ない，あるいは，変更するに足るだけの根拠がないと判断された（表3）．

4. 食事摂取基準に対するヒューマンカロリメーターの貢献

1）PALの値の確認

国立健康・栄養研究所に国内ではじめてヒューマンカロリメーターが設置されたのは，2000年であった．先述のように，「第六次改定日本人の栄養所要量―食事摂取基準―」[2]で，PALの値，ひいては，ふつうに相当する成人のエネルギー必要量の値が引き下げられた直後のことである．そ

表３　日本人の食事摂取基準（2010年版）における基礎代謝量

年齢	女性			男性		
	基礎代謝基準値 (kcal/kg/日)	基準体重 (kg)	基礎代謝量 (kcal/日)	基礎代謝基準値 (kcal/kg/日)	基準体重 (kg)	基礎代謝量 (kcal/日)
1～2（歳）	59.7	11.0	660	61.0	11.7	710
3～5（歳）	52.2	16.2	850	54.8	16.2	890
6～7（歳）	41.9	22.0	920	44.3	22.0	980
8～9（歳）	38.3	27.2	1,040	40.8	27.5	1,120
10～11（歳）	34.8	34.5	1,200	37.4	35.5	1,330
12～14（歳）	29.6	46.0	1,360	31.0	48.0	1,490
15～17（歳）	25.3	50.6	1,280	27.0	58.4	1,580
18～29（歳）	22.1	50.6	1,120	24.0	63.0	1,510
30～49（歳）	21.7	53.0	1,150	22.3	68.5	1,530
50～69（歳）	20.7	53.6	1,110	21.5	65.0	1,400
70以上（歳）	20.7	49.0	1,010	21.5	59.7	1,280

こで，設置されたばかりのヒューマンカロリメーターで，DLW 法と並行して測定を実施し，DLW 法での結果が出る前に，第六次改定の値が妥当かどうか検討するのに利用された．その際，1 時間の歩行や 1 時間の立位，15 分の踏み台昇降を含む 24 時間の生活を再現した[20]．この生活内容は，生活活動強度Ⅰ（低い：PAL = 1.3）とほぼ対応すると考えられる（表 1）．しかし，実際の測定値から求めた PAL の平均値はおよそ 1.5，運動がまったくない生活における PAL を推定すると 1.3 台であった．これらのことから，第六次改定の生活活動強度に対応する PAL の値は，ほぼ一段階ずれていると考えられた．これは，その後に出た DLW 法の結果と整合性のあるものであり，第六次改定で最も下の生活活動強度に対応する PAL（1.3）は，室内生活に限定されない健常人の日常生活では得られにくい値と考えられた．また，第六次改定で標準と考えられていた 1.5 は，PAL が小さい方から 1/4 の集団の代表値となり，「ふつう」の代表値は 1.75 となった[12]．

ただし，約 1 時間の自転車漕ぎと 1 時間の立位，踏み台昇降を含んでも PAL は約 1.5 であるのに対し，日常生活の 1.75 に到達するまでには，およそ 300kcal/ 日程度の身体活動が必要である．それが何かは，今もって明確になっているとは言い難い．

2）身体活動量推定法の妥当性

先に述べたように，生活活動記録に基づく要因加算法は，TEE，ひいてはエネルギー必要量の推定にとって最も活用されてきた方法である．しかし，身体活動量の評価や各種熱産生に関する仮定については不安が残る．そこで，要因加算法の妥当性について，ヒューマンカロリメーターで検討した[21]．その結果，Af あるいはメッツなどを用いた要因加算法で，推定値と実測値の平均値は一致すること，ただし，BMR の実測値を用いても ±300kcal/ 日以上の誤差を生じることが明らかとなった．

食事摂取基準に直結するものではないが，当研究所では，加速度計を用いた身体活動量の推定法にもヒューマンカロリメーターを利用している[22]．その成果を土台にして，新たな加速度計による身体活動評価法の開発にもつながっている[23,24]．

3）睡眠時代謝量および BMR の推定

かつて日本の栄養所要量では，睡眠時代謝量は BMR より 10％低いとされていたが，これは短時間の計測によるものであった．一方，第六次改定

では，睡眠時代謝量はBMRと等しいと解釈されていた．しかし，日本人について，睡眠時間全体のエネルギー消費量を計測したデータはかつてなかった．その点について，当研究所のヒューマンカロリメーターで検討したところ，8時間の睡眠時間におけるエネルギー消費量（kcal/日）は，実測BMRの1.03 ± 0.08倍であった[20]．一方，Kumaharaら[25]は，ローザンヌ在住の日本人を対象に，0.95 ± 0.08倍という値を報告している．その後，Ganpuleら[26]も，8時間の睡眠時間全体および最小の3時間に分けて報告している（それぞれ，1.01 ± 0.09と0.94 ± 0.07）．報告によって値に若干の差がみられるのは，睡眠中のエネルギー消費量は変化するのに対し[27]，どの時間帯を利用して睡眠時代謝量を計算しているか（特に，相対的に値の大きい，就寝直後の値が含まれているかどうか）によるところが大きいと考えられる．

Ganpuleら[26]は，睡眠時代謝量およびBMRの個人間差が，これまで報告されているより小さいことを報告するとともに，それらの推定式も求めた．そのうちBMRの推定式については，2010年版[14]で，日本人におけるBMR推定式としてとりあげられ，その後，妥当性が優れていることを報告している[28]．

4）身体活動によるエネルギー代謝の亢進

運動習慣やこれといった身体活動がみられなくても，DLW法に基づくPALを求めると，1.8から2.0以上の高い値が得られることがしばしばある．その原因のひとつとして，日常生活においてそれほど高強度ではないものの頻繁に行なわれる身体活動によって，安静時代謝が高くなっている可能性を否定できないと考えた．実際，米国の食事摂取基準[29]では，ベースとなる最低限の身体活動（約30分の歩行や着替えなどの身の回りのこと）を想定し，それを上回る身体活動については，たとえ低強度でも，身体活動中のエネルギーに15%を付加してTEEに加算することとしている．そこで，15分/回×11回/日の速歩といった頻回の身体活動による，速歩の時間以外におけるエネルギー消費量の亢進について，ヒューマンカロリメーターで検討した[30]．その結果，速歩中心の場合でも，あるいはそれと同程度のエネルギーに相当するジョギングを中心に付加した場合でも，30kcal/日程度の亢進しかみられなかった．この値は，少なくともTEEの推定にとっては無視できる量である．そのため，「日本人の食事摂取基準（2010年版）」[14]では，米国の食事摂取基準のように身体活動による代謝亢進を加算することはしないこととなった．

5）その他

ヒューマンカロリメーターは，あくまで室内生活でのエネルギー代謝に限定され，日常生活とは異なる．一方で，エネルギー消費量測定の正確性に加え，何らかの要因（食事，運動，生活習慣…）がエネルギー代謝にどの程度寄与するか実験的に検討するには適している．TEE，ひいてはエネルギー必要量の変動要因を丁寧に検討するにあたっては，今後も有用なツールではないかと考えられる．

[文　献]

1）厚生省保健医療局健康増進栄養課監修：第五次改定日本人の栄養所要量．第一出版，1994.
2）健康栄養情報研究会編：第六次改定日本人の栄養所要量—食事摂取基準—．第一出版，1999.
3）Harris JA, et al.: A biometric study of basal metabolism in man. Carnegie Institute of Washington, 1919.
4）柏崎　浩：エネルギー所要量の歴史と現状．小林修平編著，栄養所要量・基準量と食生活ガイドライン，pp61—125，建帛社，1997.
5）山本茂ほか：日本人の基礎代謝資料の評価．栄養学雑誌，59：51—59，2001.
6）Schofield WN: Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr, 39C: 5—41, 1985.
7）FAO/WHO/UNU: Energy and protein requirements, report of a joint FAO/WHO/UNU expert consultation. Technical Report Series 724, WHO, 1985.
8）沼尻幸吉：活動のエネルギー代謝 増補第2版．労

働科学研究所出版部, 1979.
9) 田中茂穂：メッツと基礎代謝. 体育の科学, 59：657—663, 2009.
10) Speakman JR: The history and theory of the doubly labeled water technique. Am J Clin Nutr, 68: 932S—938S, 1998.
11) 髙田和子：二重標識水法を用いたエネルギー摂取量評価への応用. 臨床スポーツ医学, 26：1097—1102, 2009.
12) 厚生労働省：日本人の食事摂取基準（2005年版）. 2004.
13) Ishikawa-Takata K, et al.: Physical activity level in healthy free-living Japanese estimated by doubly-labelled water method and International Physical Activity Questionnaire. Eur J Clin Nutr, 62: 885—891, 2008.
14) 厚生労働省：日本人の食事摂取基準（2010年版）. 2009.
15) 海老根直之ほか：二重標識水法を用いた簡易エネルギー消費量推定法の評価—生活時間調査法，心拍数法，加速度計法について—. 体力科学, 51：151—163, 2002.
16) Rafamantanantsoa HH, et al.: Validation of three alternative methods to measure total energy expenditure against the doubly labeled water method for older Japanese men. J Nutr Sci Vitaminol, 48: 517—523, 2002.
17) 彭雪英ほか：中年女性における簡易エネルギー消費量推定法の検討—二重標識水法との比較—. 肥満研究, 10：163—172, 2004.
18) Yamada Y, et al.: Light-intensity activities are important for estimating physical activity energy expenditure using uniaxial and triaxial accelerometers. Eur J Appl Physiol, 105: 141—152, 2009.
19) Ishikawa-Takata K, et al.: Use of doubly labeled water to validate a physical activity questionnaire developed for the Japanese population. J Epidemiol, 21: 114—121, 2011.
20) 田中茂穂ほか：ヒューマンカロリメーターを用いて測定した座位中心の生活における1日あたりのエネルギー消費量. 日本栄養・食糧学会誌, 56：291—296, 2003.
21) Yamamura C, et al.: Activity diary method for predicting energy expenditure as evaluated by a whole-body indirect human calorimeter. J Nutr Sci Vitaminol, 49: 262—269, 2003.
22) Midorikawa T, et al.: Evaluation of low-intensity physical activity by triaxial accelerometry. Obesity, 15: 3031—3038, 2007.
23) Oshima Y, et al.: Classifying household and locomotive activities using a triaxial accelerometer. Gait Posture, 31: 370—374, 2010.
24) Ohkawara K, et al.: Real-time estimation of daily physical activity intensity by triaxial accelerometer and a gravity-removal classification algorithm. Br J Nutr, 105: 1681—1691, 2011.
25) Kumahara H, et al.: The difference between the basal metabolic rate and the sleeping metabolic rate in Japanese. J Nutr Sci Vitaminol, 50: 441—445, 2004.
26) Ganpule AA, et al.: Interindividual variability in sleeping metabolic rate in Japanese subjects. Eur J Clin Nutr, 61: 1256—1261, 2007.
27) Katayose Y, et al.: Metabolic rate and fuel utilization during sleep assessed by whole body indirect calorimetry. Metabolism, 38: 920—926, 2009.
28) Miyake R, et al.: Validity of predictive equations for basal metabolic rate in Japanese adults. J Nutr Sci Vitaminol, 57: 224—232, 2011.
29) Food and Nutrition Board, Institute of Medicine: Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. pp107—264, National Academies Press, 2005.
30) Ohkawara K, et al.: Twenty-four-hour analysis of elevated energy expenditure after physical activity in a metabolic chamber: models of daily total energy expenditure. Am J Clin Nutr, 87: 1268—1276, 2008.

エネルギー代謝と加齢

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一日当たりの総エネルギー消費量（total energy expenditure: TEE）は、一般に以下のように大別される[1]。TEE＝基礎代謝量（basal metabolic rate: BMR）＋食事誘発性体熱産生＋身体活動量。このうち、食事誘発性体熱産生を独自に測定することは多くない。そのため、一般にTEEは、以下のように推定される。TEE＝BMR×身体活動レベル（physical activity level: PAL）。本稿では、高齢者のBMRとPALについて概観した後、これらと抗加齢（主に死亡率）、および最近注目されているカロリーリストリクションの影響についてふれる。

高齢者における基礎代謝量

一般に、高齢者においては、体重当たりの基礎代謝量（kcal/kg/日）は小さく、除脂肪量で補正しても差が残る（図1左）。しかし、組織・臓器重量とそれらのエネルギー代謝率を用いた推定値を用いたところ、高齢者と若年者のいずれにおいても、推定値と実測値はほぼ一致し、年齢による差はみられなかった[2]（図1右）。このことから、高齢者におけるBMR低下の原因は、主に各組織・臓器の代謝率の低下（例：骨格筋や肝臓のエネルギー代謝率（kcal/kg/日）の低下）ではなく、エネルギー消費量の高い組織・臓器の重量そのものの減少ではないかと考えられる。

高齢者における身体活動量

「日本人の食事摂取基準（2010年版）」においては、PALの「ふつう」は、70歳代でも、69歳以下と同様の値となっている（69歳まで：1.75、70歳以上：1.70）。ただし、これらは、概して外出が可能で、自立した、70歳台の高齢者を対象とした報告に基づいている。

平均年齢が80歳代のほぼ自立した高齢者においては、自宅にいる人で1.6、施設入居者で1.4という値が報告されている[3]。また、90歳以上においては、男性1.31、女性1.19という結果も報告されている[4]。欧米で蓄積した二重標識水（DLW）法による最近の報告によると、52歳頃から、およそ0.1/10年のペースで減少するという[5]。

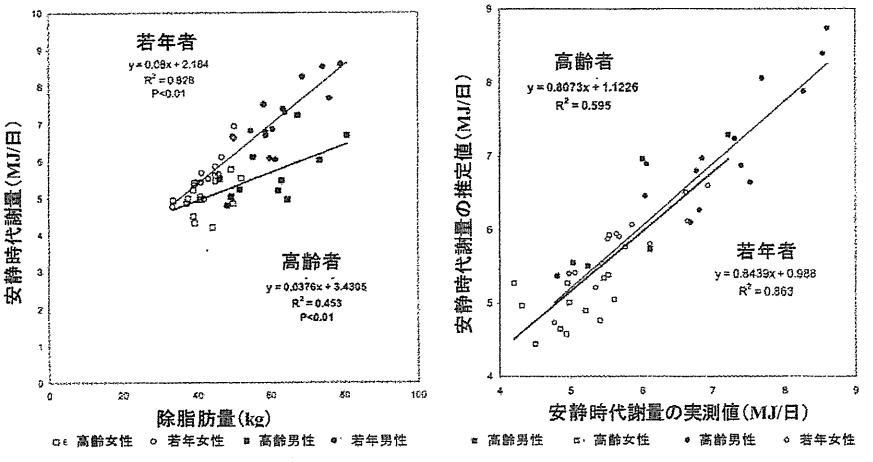

図1　高齢者と若年者における安静時代謝量の実測値と1）除脂肪量、2）各組織・臓器重量による安静時代謝量の推定値との関係　(Bosy-Westphal et al, J Nutr, 2003)

エネルギー代謝と寿命

エネルギー代謝と寿命との関係については、エネルギー代謝研究が飛躍的な進歩を遂げた20世紀初頭より意識されるようになった。Benedictは、ネズミなどの小さい哺乳類は、象のような大きい哺乳類より、体重の割に安静時代謝量が大きいが、寿命が短いことを示した[6]。

こうした点について、人を対象として検討された結果が、2008年に初めて報告された[7]。ボルチモア縦断研究に参加した1,227名においてBMRや死亡などを約40年間にわたり観察した結果、BMRが31.3～33.9 kcal/㎡/時で最も死亡率が低く、それより高いと死亡率も高くなっていた。この関係は、BMIや喫煙などの変数とは独立にみられた。

さらに、ごく最近、652人のPima Indianを対象として、BMRやヒューマンカロリメーター（エネルギー代謝測定室）を利用して得られたTEEについても、「性・年齢や体重を補正して得られたBMRやTEEが大きいと、死亡率が高い」という結果が得られている[8]。ここでのTEEは、運動を禁止した室内生活におけるものであるため、身体活動量の影響は、あまり受けていないと考えられる。

それに対し、日常生活において身体活動量やその影響を強く受けるTEEについても、最近、DLW法による結果が報告されている。

70～82歳の高齢者302名において、一日当たりの活動時のエネルギー（kcal/日）や身体活動レベルが高いと、約5年後の死亡率が低かった[9]（表1）。同じ対象集団において、約9年後についても報告があるが、体格等を補正したTEEが多いと死亡率が低いという結果が得られている[10]。体格等を補正したTEEは、体格等を考慮した上でのBMRの大小も反映するが、バラツキから考えると、主に「身体活動量が大きいと死亡率が低いこと」を反映していると考えられる。

また、Manini et al.[9]は、どのような身体活動が全体の身体活動量に寄与しているかも検討している。それによると、一日の身体活動のエネルギーと関連するのは、高強度の運動や歩行などではなく、階段昇降の回数と労働時間であった。身体活動のエネルギーがDLW法に基づいているのに対し、活動の種類については自己申告に基づいている点で妥当性に疑問は残るが、現時点で、最も信頼のおける結果の一つである。

表1　70～82歳の高齢者における身体活動レベルと、約5年後の死亡率

身体活動レベル	危険率（信頼区間）
～1.57	1.00
1.57～1.78	0.64（0.33 - 1.23）
1.78～	0.43（0.21 - 0.88）*

Manini, T. M. et al. JAMA 2006;296:171-179

以上のように、ごく最近、

・BMRは低い方が、寿命が長い

・身体活動量は多い方が、（代謝プロフィールの改善により）寿命が長い

という、信頼のできる結果が得られつつある。ただし、まだ報告数は限られており、今後の検討が必要である。

カロリーリストリクションとエネルギー代謝

「食事制限（カロリーリストリクション）によって、活性酸素の発生が抑制され、寿命が長くなる」という仮説は、小動物を中心に検証され、支持されてきた。

人においては、2000年代に入ってから、米国で、カロリーリストリクションの効果を検証するための大規模研究が複数スタートした。小動物やサルを対象とした研究に基づいて、寿命のバイオマーカーとして「体温が低い」「血中のインスリン濃度が低い」「血中のDHEA-Sが高い」が抽出されている[11]。それらを指標とした検討においては、カロリーリストリクションの効果が支持される結果も出ている。しかし、現時点では、まだ対象者数の割に期間が短く、最終的な結論には程遠い。

CARELIE studyでは、25%程度のカロリーリストリクションによって、身体活動のエネルギーが200 kcal/日以上減少し、PALも減少することがわかってきた[12,13]。先に述べた、寿命に対する身体活動の効果を考えると、負の効果を含んでいる可能性もある。ただし、運動を付加した群では身体活動量があまり減らないという結果も得られている[12]。それらの点についても、今後の検討が必要である。

文献
1. 田中茂穂．基礎代謝・NEATと身体活動．臨床スポーツ医学 2011; 28: 259-66.
2. Bosy-Westphal A, Eichhorn C, Kutzner D, Illner K, Heller M, Müller MJ. The age-related decline in resting energy expenditure in humans is due to the loss of fat-free mass and to alterations in its metabolically active components. J Nutr 2003; 133: 2356-62.
3. Fuller NJ, Sawyer MB, Coward WA, et al. Components of total energy expenditure in free-living elderly men (over 75 years of age): measurement, predictability and relationship to quality-of-life indices. Br J Nutr 1996; 75: 161-73.
4. Rothenberg EM, Bosaeus IG, Westerterp KR, et al. Resting energy expenditure, activity energy expenditure and total energy expenditure at age 91-96 years. Br J Nutr 2000; 84: 319-24.
5. Speakman JR, Westerterp KR. Associations between energy demands, physical activity, and body composition in adult humans between 18 and 96 y of age. Am J Clin Nutr 2010; 92: 826-34.
6. Benedict FG. Vital Energetics, a Study in Comparative Basal Metabolism. Washington, DC: Carnegie Institution of Washington. 1938.
7. Ruggiero C, Metter EJ, Melenovsky V, Cherubini A, Najjar SS, Ble A, et al. High basal metabolic rate is a risk factor for mortality: the Baltimore Longitudinal Study of Aging. J Gerontol A Biol Sci Med Sci 2008; 63: 698-706.
8. Jumpertz R, Hanson RL, Sievers ML, Bennett PH, Nelson RG, Krakoff J. 1. Higher energy expenditure in humans predicts natural mortality. J Clin Endocrinol Metab 2011; 96: E972-6.
9. 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.
10. Shahar DR, Yu B, Houston DK, Kritchevsky SB, Lee JS, Rubin SM, et al.: Health, Aging and Body Composition Study. Dietary factors in relation to daily activity energy expenditure and mortality among older adults. J Nutr Health Aging 2009; 13: 414-20.
11. Redman LM, Martin CK, Williamson DA, Ravussin E. Effect of caloric restriction in non-obese humans on physiological, psychological and behavioral outcomes. Physiol Behav 2008; 94: 643-8.
12. Redman LM, Heilbronn LK, Martin CK, de Jonge L, Williamson DA, Delany JP, et al.: Pennington CALERIE Team. Metabolic and behavioral compensations in response to caloric restriction: implications for the maintenance of weight loss. PLoS One 2009; 4: e4377.
13. Martin CK, Das SK, Lindblad L, Racette SB, McCrory MA, Weiss EP, et al. Effect of calorie restriction on the free-living physical activity levels of nonobese humans: results of three randomized trials. J Appl Physiol 2011; 110: 956-63.

Total energy for the elderly

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Total energy expenditure in the elderly tends to decline over age, due to decreased basal metabolic rate and physical activity level. The age-related decline in basal metabolic rate is attributed to a reduction in fat-free mass (FFM) and to proportional changes in its metabolically active components. There is no evidence for a decreasing organ metabolic rate in healthy aging. Recent studies suggest that higher energy turnover may accelerate aging also in humans. On the other hand, objectively measured free-living activity energy expenditure was strongly associated with a lower risk of mortality in healthy older adults. Further studies are needed to further clarify the relationship between energy metabolism and longevity in older adults. *Clinical & Functional Nutriology 2011; 3(4):180-2.*

テーラーメイドのエネルギー摂取の重要性

個々人に必要な栄養摂取量は2000年までは「栄養所要量」でしめされ、それ以後は個人のばらつきを考慮した「栄養摂取規準」で示されている。しかし、これも年齢区分ごとのエネルギー消費と運動量を考慮して大まかにカテゴリー化されている。

田中らはエネルギー消費量を体重あたりで標準化するのが良いと述べている。食事からの摂取量調査に基づくと記載もれや吸収の個体差など、過小評価される傾向にあるからである。エネルギー源の制限は痩せにつながり、それは長寿にはつながらないであろうとおもわれる。サルコペニアの一因ともなる。

桜沢如一の玄米、少食をつづけるグループは意外に長寿者が少ない。おそらく高齢になってからのエネルギー源が不足するためと思われる。個人対応の必要エネルギー源はわかりやすい指標が必要で、普通の生活をしているのなら「体重 x 0.4 単位」という値が成人ならいかなる年齢でも、男女ともあてはめられる指標である。体重kg当たり32キロカロリーなので田中らのだしたTEEとほとんど等しい。妊婦も体重が増えていくにしたがって必要単位が増えるので妊娠期に応じたカロリー摂取を足したりする必要がない。自分の日指す体重に掛ければよいので肥満解消、痩せ解消にも役立つ。(編集長)

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Original Article

Television Viewing Time is Associated with Overweight/Obesity Among Older Adults, Independent of Meeting Physical Activity and Health Guidelines

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ABSTRACT

Background: Previous studies have shown associations of sedentary behavior with cardiovascular risk, independent of moderate-to-vigorous physical activity (MVPA). However, few studies have focused on older adults. This study examined the joint associations of television (TV) viewing time and MVPA with overweight/obesity among Japanese older adults.

Methods: A population-based, cross-sectional mail survey was used to collect self-reported height, weight, time spent in TV viewing, and MVPA from 1806 older adults (age: 65–74 years, men: 51.1%). Participants were classified into 4 categories according to TV viewing time (dichotomized into high and low around the median) and MVPA level (dichotomized into sufficient and insufficient by the physical activity guideline level of ≥150 minutes/week). Odds ratios (ORs) for overweight/obesity (body mass index ≥25 kg/m^2) were calculated according to the 4 TV/MVPA categories, adjusting for potential confounders.

Results: Of all participants, 20.1% were overweight/obese. The median TV viewing time (25th, 75th percentile) was 840 (420, 1400) minutes/week. As compared with the reference category (high TV/insufficient MVPA), the adjusted ORs (95% CI) of overweight/obesity were 0.93 (0.65, 1.34) for high TV/sufficient MVPA, 0.58 (0.37, 0.90) for low TV/insufficient MVPA, and 0.67 (0.47, 0.97) for low TV/sufficient MVPA.

Conclusions: In this sample of older adults, spending less time watching TV, a predominant sedentary behavior, was associated with lower risk of being overweight or obese, independent of meeting physical activity guidelines. Further studies using prospective and/or intervention designs are warranted to confirm the presently observed effects of sedentary behavior, independent of physical activity, on the health of older adults.

Key words: sedentary behavior; cardiovascular risk factor; obesity

INTRODUCTION

Sedentary behavior (too much sitting, as distinct from too little exercise) is related to adverse cardiometabolic risk profiles and premature mortality.[1–10] Several studies have examined television (TV) viewing time as a predominant sedentary behavior and have shown associations with obesity and other cardiovascular risk factors.[1–3,7,8,10] Furthermore, these associations between sedentary behaviors and cardiovascular risk factors were observed regardless at all levels of moderate-to-vigorous physical activity (MVPA), defined by an intensity of 3 metabolic equivalents (METs) or greater. Sugiyama et al[4] reported that adults who met current physical activity guidelines (MVPA of ≥30 min/day for 5 days/week)[11,12] but had high levels of sedentary time were about 1.5 times more likely to be overweight or obese, relative to those who met physical activity guidelines and had lower levels of sedentary time. These findings suggest that prolonged sedentary behavior elevates health risk, independent of MVPA participation.

However, few studies of the associations of sedentary behavior and physical activity with health risk have focused on older adults.[10] Older adults tend to have lower levels of physical activity[13,14] and to spend more time in sedentary behavior.[15] They also begin to lose fitness levels, and some of

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them find it difficult to adopt and maintain MVPA.[16] Because of these changes in the behavior patterns of older adults, it is important to assess how different combinations of sedentary behavior and physical activity might influence their cardiovascular health. It is important to examine if older adults could improve their health by reducing sedentary behavior, that is, by avoiding prolonged sedentary behavior and increasing light-intensity physical activity, regardless of their level of MVPA. Thus, the purpose of this study was to examine the joint associations of TV viewing time and MVPA with overweight/obesity among older adults in Japan.

METHODS

Participants and data collection

This cross-sectional study was part of a project to investigate the association between neighborhood environment and physical activity among older adults.[17] Data were collected from February to March 2010. A total of 2700 residents who were aged 65 to 74 years and living in 3 Japanese cities (Bunkyo Ward in Tokyo, Fuchu in Tokyo, Oyama in Shizuoka prefecture) were randomly selected from registries of residential addresses and stratified by sex, age (65–69 years/70–74 years), and city of residence. In total, 2700 older adults were identified, and they received invitation letters that described the content of the study. Three cities were chosen—one each from a metropolitan urban area, a suburban area, and a rural area—because this survey was originally designed to investigate the relationship of neighborhood environment with physical activity. Bunkyo is in central Tokyo. Fuchu is a suburban city located about 20 km east of the center of Tokyo. It is in the Tokyo Metropolitan Area and within commuting distance of central Tokyo. Oyama is a small regional city located about 80 km west of Tokyo.

Two weeks after the invitation, the 2700 older adults received a questionnaire and consent form. To encourage participation, a 500-yen (about 6 US dollars in 2011) book voucher was offered to respondents. During the survey, a call center was set up to answer participants' inquiries. Reminders to return the survey were mailed twice to nonresponding participants. Those who returned an incomplete survey were asked to complete the survey again. Of 2700 older adults initially identified, 2046 returned the survey. After data cleaning, 1806 participants had valid data for the analyses of this study (response rate: 66.9%). This study received prior approval from the Tokyo Medical University Ethics Committee.

Measures

Outcome variable

Body mass index (BMI) was the outcome measure of this study and was calculated from self-reported weight and height. Participants were categorized as normal weight (BMI $<25\,kg/m^2$) and overweight or obese (BMI $\geq 25\,kg/m^2$) for regression analyses.

TV viewing time and physical activity

TV viewing time was determined by asking participants to report frequency of TV viewing (days/week) and average viewing time in each day (minutes/day) over the past 7 days. This questionnaire item was a Japanese translation of an Australian questionnaire on leisure-time sedentary behaviors.[18] TV viewing time was dichotomized using median to high TV viewing (>840 min/week) and low TV viewing (≤840 min/week).

The Short Version of the International Physical Activity Questionnaire (IPAQ-S)[19,20] was used to assess moderate-to-vigorous physical activity (MVPA). Among Japanese adults, the test-retest reliability of IPAQ-S (intraclass correlation coefficient: ICC) was 0.87 and its validity as compared with accelerometry (Spearman's correlation coefficient: ρ) was 0.39.[20] Among elderly adults, reliability and validity as compared with pedometry (partial correlation coefficient adjusted for sex, age, and education: r) were reported only in a Chinese study (ICC = 0.84; $r = 0.33$).[21] Participants were asked to report the frequency and duration of 3 types of physical activity: vigorous intensity, moderate intensity (excluding walking), and walking. Total time spent in MVPA, including walking, was calculated as the sum of these 3 activities, which was then classified as insufficient MVPA (<150 min/week) and sufficient MVPA (≥150 min/week), using physical activity guidelines for health benefits.[12,22]

Sociodemographic, lifestyle, and health variables

In addition to age and sex, which were obtained from the registry of residential addresses of each city, educational attainment (years of education), working status (working hours per week), smoking habits (currently smoking or not), alcohol consumption (days/week), and physical functioning were assessed by questionnaire. Questions on smoking and alcohol were from the National Health and Nutrition Survey of Japan.[23] Physical functioning was assessed by using an item in the 8-Item Short-Form Health Survey (SF8).[24] Participants chose the most suitable response from a 5-point scale to the statement, "During the past 4 weeks, how much did physical health problems limit your usual physical activities (such as walking or climbing stairs)?". The choices were "not at all", "very little", "somewhat", "quite a lot", and "could not do physical activity".

Statistical analyses

Participants were classified into 4 groups by combinations of TV viewing time and MVPA: high TV/insufficient MVPA, high TV/sufficient MVPA, low TV/insufficient MVPA, and low TV/sufficient MVPA. Logistic regression analyses were used to calculate the odds ratios (ORs) and 95% CIs for being overweight/obese (BMI $\geq 25\,kg/m^2$) by the 4 categories (the reference category was high TV/insufficient MVPA). Two models were examined. Model 1 adjusted for sex and age. Model 2 adjusted for sex, age, education (>12 years; ≤12 years), working status (working for ≥35 hours/week; working

for 1–34 hours/week; not working), city of residence (Bunkyo; Fuchu; Oyama), smoking (current smoker; not current smoker), drinking (≥1 day/week; <1 day/week), and physical functioning (5-point scale mentioned above). Analyses were conducted first for the overall sample, then separately for men and women, and for persons who were working (>0 hour/week) and not working, because the time available for leisure activities is likely to differ between these groups. In addition, 2 subsample analyses were conducted to examine potential confounding. First, extremely low physical functioning was a potential confounder. Thus, 40 participants who answered "could not do physical activity" to the question on physical functioning[24] were excluded from analyses ($n = 1766$). Second, 127 underweight participants (BMI <18.5 kg/m^2), who were included in the normal reference category in the main analyses, were excluded from the second subsample analyses ($n = 1679$). Significance was considered to be $P < 0.05$. Analyses were conducted with SPSS Version 17.0 for Windows (SPSS Inc., Tokyo, Japan).

RESULTS

Table 1 shows the characteristics of the study sample. The mean age (SD) was 69.2 (2.9). The prevalence of being overweight/obese was 20.1% among the overall sample. The prevalence of each of the combined categories of TV viewing and MVPA was 24.6% for high TV/insufficient MVPA, 22.1% for high TV/sufficient MVPA, 17.6% for low TV/insufficient MVPA, and 18.0% for low TV/sufficient MVPA. The median (25th, 75th percentile) TV viewing time and MVPA were 840 (420, 1400) min/week and 300 (120, 630) min/week, respectively.

Table 2 shows the ORs for being overweight/obese, according to the 4 TV viewing/MVPA categories. For the overall sample, those who belonged to the most active category (low TV/sufficient MVPA) were significantly less likely to be overweight/obese, in comparison with the reference group (high TV/insufficient MVPA), after adjusting for sex and age (Model 1). After further adjustment for other potential confounders (Model 2), the 2 low-TV categories had significantly lower odds ratios of overweight/obesity: the ORs (95% CI) were 0.58 (0.37, 0.90) for low TV/insufficient MVPA and 0.67 (0.47, 0.97) for low TV/sufficient MVPA. No significant association was observed for the high TV/sufficient MVPA category (OR: 0.93 [0.65, 1.34]).

When men and women were examined separately, a significant association between TV/MVPA category and overweight was observed in the low TV/sufficient MVPA among women in Model 1, and borderline significant associations in the low TV/insufficient PA category among men and women were observed in Model 2. In the stratified analyses by working status, a significant association between TV/MVPA category and overweight was observed only among nonworking older adults. The ORs of being overweight, after adjusting for all covariates, were 0.89 (0.59, 1.36) for high TV/sufficient MVPA, 0.55 (0.33, 0.94) for low TV/insufficient MVPA, and 0.54 (0.34, 0.84) for low TV/sufficient MVPA.

The findings from 2 subsample analyses (a sample excluding those with poor physical function and one without underweight participants) showed a similar pattern: a significantly lower odds of being overweight was observed in the low TV/insufficient MVPA and low TV/sufficient MVPA categories (data not shown).

In addition, because the prevalence of meeting physical activity guidelines was high (71.3%), we conducted analyses using a different cut point for MVPA (median: 300 min/wk; data not shown in the tables) to examine the potential influence of overestimation. However, this did not substantially change the overall pattern of findings. Those in the category of "low TV viewing/insufficient PA (≤300 min/wk)" and "low TV viewing/sufficient PA (>300 min/wk)" had lower risk of overweight/obesity (OR: 0.66 [0.48–0.92], 0.67 [0.48–0.93], respectively), while no significant association between the risk of overweight/obesity and the category of "high TV viewing/sufficient PA (>300 min/wk)" was observed.

DISCUSSION

This study found that older adults who spent less time watching TV, a predominant leisure-time sedentary behavior, were less likely to be overweight or obese, regardless of their levels of MVPA. This suggests that prolonged TV viewing elevates the risk of overweight/obesity among the elderly population. Analyses also suggested that in the presence of prolonged TV viewing, a sufficient amount of MVPA, as defined by current physical activity guidelines, was not protective against overweight/obesity in this study sample. These findings could be interpreted as suggesting the importance of light-intensity activity to reduce obesity risk. A previous study showed that light-intensity activity, which is negatively correlated with sedentary time, had beneficial associations with cardiometabolic biomarkers.[25] Because some older people have difficulty in adopting and maintaining MVPA,[16] reducing sedentary behavior and increasing light-intensity activity may be an effective and practical strategy to achieve health benefits in this age group.

Associations of sedentary behavior, including TV viewing time, with obesity measures, independent of MVPA, have been consistently reported for adult samples.[2–7,9] Our study found that this was also the case with older adults. However, our study was slightly different from previous studies in that the association of MVPA with overweight/obesity seemed weaker than that of TV viewing time. A previous study on adults reported that those who spent more time in sedentary behaviors (but were sufficiently physically active) and those who were insufficiently active (but spent less time in

Table 1. Characteristics of participants by combined categories of TV viewing time and physical activity

	Overall N = 1806		High TV viewing/ Insufficient PA[b] N = 256		High TV viewing/ Sufficient PA[b] N = 544		Low TV viewing/ Insufficient PA[b] N = 262		Low TV viewing/ Sufficient PA[b] N = 744		*P* value[c]
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Sex											
Male	925	51.2	125	48.8	275	50.6	127	48.5	398	53.5	0.389
Female	881	48.8	131	51.2	269	49.4	135	51.5	346	46.5	
Age, years											
Mean (SD)	69.6 (2.9)		70.0 (3.0)		69.4 (2.9)		70.1 (3.0)		69.4 (2.9)		<0.001
City of residence											
Bunkyo	571	31.6	50	19.5	174	32.0	76	29.0	271	36.4	
Fuchu	626	34.7	74	28.9	188	34.6	77	29.4	287	38.6	<0.001
Oyama	609	33.7	132	51.6	182	33.5	109	41.6	186	25.0	
Education, years											
<13	1158	64.1	198	77.3	349	64.2	193	73.7	418	56.2	<0.001
13+	648	35.9	58	22.7	195	35.8	69	26.3	326	43.8	
Working status											
Not working	1110	61.5	200	78.1	363	66.7	163	62.2	384	51.6	
1–34 hours/wk	409	22.6	26	10.2	119	21.9	53	20.2	211	28.4	<0.001
35+ hours/wk	287	15.9	30	11.7	62	11.4	46	17.6	149	20.0	
Current smoking											
Yes	273	15.1	55	21.5	88	16.2	34	13.0	96	12.9	0.006
No	1533	84.9	201	78.5	456	83.8	228	87.0	648	87.1	
Drinking, days/week											
1+	725	40.1	88	34.4	216	39.7	87	33.2	334	44.9	0.001
<1	1081	59.9	168	65.6	328	60.3	175	66.8	410	55.1	
Limitation of physical functioning											
Not at all	1086	60.1	122	47.7	348	64.0	119	45.4	497	66.8	
Very little	337	18.7	49	19.1	99	18.2	55	21.0	134	18.0	
Somewhat	258	14.3	48	18.8	80	14.7	46	17.6	84	11.3	<0.001
Quite a lot	85	4.7	22	8.6	14	2.6	25	9.5	24	3.2	
Could not do physical activity	40	2.2	15	5.9	3	0.6	17	6.5	5	0.7	
BMI, kg/m^2											
<25	1443	79.9	193	75.4	424	77.9	216	82.4	610	82.0	0.055
25+	363	20.1	63	24.6	120	22.1	46	17.6	134	18.0	
TV viewing, min/week											
Short, ≤840	1006	55.7	0	0.0	0	0.0	262	100.0	744	100.0	<0.001
Long, 840+	800	44.3	256	100.0	544	100.0	0	0.0	0	0.0	
Median (25%tile, 75%tile)	840 (420, 1400)		1680 (1260, 2520)		1500 (1260, 2100)		420 (150, 840)		480 (255, 840)		
MVPA[a], min/week											
Insufficient, <150	518	28.7	256	100.0	0	0.0	262	100.0	0	0.0	<0.001
Sufficient, 150+	1288	71.3	0	0.0	544	100.0	0	0.0	744	100.0	
Median (25%tile, 75%tile)	300 (120, 630)		20 (0, 90)		420 (272.5, 750)		20 (0, 80)		480 (300, 840)		

[a]MVPA: moderate-to-vigorous physical activity.
[b]TV viewing time was dichotomized by the median (840 min/wk); physical activity (PA) was dichotomized by MVPA of 150 min/wk.
[c]Differences between groups were examined by chi-square tests for categorical variables and 1-way analysis of variance for age.

sedentary behavior) had similar risks of overweight.[4] In youth studies, insufficient physical activity was more strongly associated than prolonged sedentary behavior with overweight.[26,27] In light of these previous studies, it is possible to argue that the impact of sedentary behavior and MVPA on obesity risk differs with age and that prolonged sedentary behavior might be a stronger risk factor for elderly adults. The association between sedentary behavior and cardiovascular risk will be influenced by non-exercise activity thermogenesis (NEAT), which is generally a much greater component of total energy expenditure than MVPA, and by the significant role of brief yet frequent muscle contractions throughout the day, which may short-circuit unhealthy molecular signals that cause metabolic dysfunction.[28] These effects might be more pronounced among older adults, who are generally less physically active than younger adults.

The fact that significant associations of TV viewing time with overweight were found in nonworkers but not in workers suggests that light-intensity and intermittent activities during work are protective against overweight/obesity in the presence of prolonged TV viewing time. However, in nonworkers, some TV viewing may accompany other leisure-time sedentary behaviors, due to the greater amount of time available for them. An Australian study found that TV viewing time was a good marker of overall sedentary time.[29] Our findings suggest that retired older adults are at risk of overweight. Thus, retirement might be a window of opportunity for interventions that prevent and reduce sedentary time.

Table 2. Odds ratios for overweight/obesity by the combined categories of TV viewing time and physical activity

TV/PA categories[a]	Sample	Overweight /obesity, %	Model 1[b]		Model 2[c]	
			OR (95% CI)	*P* value	OR (95% CI)	*P* value
Overall						
High TV/ Insufficient PA	256	24.6	1.00		1.00	
High TV/ Sufficient PA	544	22.1	0.85 (0.60, 1.21)	0.370	0.93 (0.65, 1.34)	0.693
Low TV/ Insufficient PA	262	17.6	0.65 (0.43, 1.00)	0.052	0.58 (0.37, 0.90)	0.014
Low TV/ Sufficient PA	744	18.0	0.65 (0.46, 0.92)	0.015	0.67 (0.47, 0.97)	0.033
Men						
High TV/ Insufficient PA	125	24.8	1.00		1.00	
High TV/ Sufficient PA	275	26.2	1.05 (0.64, 1.71)	0.845	1.05 (0.63, 1.75)	0.846
Low TV/ Insufficient PA	127	18.1	0.68 (0.37, 1.25)	0.215	0.54 (0.29, 1.02)	0.057
Low TV/ Sufficient PA	398	20.9	0.77 (0.48, 1.24)	0.281	0.69 (0.42, 1.15)	0.154
Women						
High TV/ Insufficient PA	131	24.4	1.00		1.00	
High TV/ Sufficient PA	269	17.8	0.68 (0.41, 1.13)	0.136	0.83 (0.49, 1.40)	0.484
Low TV/ Insufficient PA	135	17.0	0.63 (0.35, 1.16)	0.138	0.59 (0.32, 1.10)	0.099
Low TV/ Sufficient PA	346	14.7	0.54 (0.33, 0.89)	0.015	0.66 (0.39, 1.11)	0.120
Working						
High TV/ Insufficient PA	56	23.2	1.00		1.00	
High TV/ Sufficient PA	181	24.3	1.05 (0.52, 2.14)	0.891	1.17 (0.56, 2.45)	0.681
Low TV/ Insufficient PA	99	20.2	0.87 (0.39, 1.92)	0.722	0.73 (0.32, 1.67)	0.452
Low TV/ Sufficient PA	360	22.8	0.95 (0.49, 1.86)	0.883	1.04 (0.51, 2.12)	0.906
Not working						
High TV/ Insufficient PA	200	25.0				
High TV/ Sufficient PA	363	20.9	0.79 (0.53, 1.20)	0.269	0.89 (0.59, 1.36)	0.601
Low TV/ Insufficient PA	163	16.0	0.57 (0.34, 0.97)	0.038	0.55 (0.33, 0.94)	0.030
Low TV/ Sufficient PA	384	13.5	0.47 (0.31, 0.73)	<0.001	0.54 (0.34, 0.84)	0.007

[a]TV viewing time was dichotomized by the median (840 min/wk); physical activity (PA) was dichotomized by MVPA of 150 min/wk.
[b]Model 1: adjusted for sex and age.
[c]Model 2: adjusted for sex, age, education, employment status, city of residence, smoking, drinking, and physical functioning, excluding stratified variables.

There are some limitations that need to be considered in interpreting the findings of this study. First, both the dependent and independent variables were measured by self-report, which is susceptible to response bias. In particular, the percentage of participants who met physical activity guidelines was high. Overestimation of physical activity may have contributed to the weaker association of MVPA and overweight observed in this study. Although an additional analysis using a different cut point (median, 300 min/wk) produced a similar pattern of findings, reporting error and bias may have masked associations of MVPA with overweight. In addition, we used BMI calculated from self-reported weight and height. Although self-reported measurement generally has a high correlation with direct measurement,[30–35] some studies have suggested that obese and elderly persons tend to underreport their weight.[30–35] If participants tend to report their behavior and weight biased to the optimal direction, this may have reduce response variability and lead to lower statistical power and underestimation of associations.[33] Future studies should use objective measures of behaviors and

overweight/obesity, to more accurately assess the health effects of sedentary behaviors among older adults. The cross-sectional design of this study is another limitation, and the possibility of reverse causality (ie, overweight and obesity could discourage activity and lead to prolongation of TV viewing time) should be considered. Longitudinal studies are needed to examine causality. Finally, the analyses could not include information on diet, which may confound the relationship between sedentary time and overweight risk.

In spite of these limitations, the current study adds new findings on the associations between TV viewing time and overweight/obesity independent of MVPA among older adults, especially among those not working. As people get older, they typically become less active and spend more time in sedentary behaviors. Further research examining the relative importance of sedentary behavior and physical activity on health outcomes is thus warranted to inform the development of public health initiatives and guidelines for older people.

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REFERENCES

1. Jakes RW, Day NE, Khaw KT, Luben R, Oakes S, Welch A, et al. Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk population-based study. Eur J Clin Nutr. 2003;57(9):1089–96.
2. Dunstan DW, Salmon J, Owen N, Armstrong T, Zimmet PZ, Welborn TA, et al. Physical activity and television viewing in relation to risk of undiagnosed abnormal glucose metabolism in adults. Diabetes Care. 2004;27(11):2603–9.
3. Bertrais S, Beyeme-Ondoua JP, Czernichow S, Galan P, Hercberg S, Oppert JM. Sedentary behaviors, physical activity, and metabolic syndrome in middle-aged French subjects. Obes Res. 2005;13(5):936–44.
4. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Joint associations of multiple leisure-time sedentary behaviours and physical activity with obesity in Australian adults. Int J Behav Nutr Phys Act. 2008;5:35.
5. Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). Diabetes Care. 2008;31(2):369–71.
6. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009;41(5):998–1005.
7. Dunstan DW, Barr EL, Healy GN, Salmon J, Shaw JE, Balkau B, et al. Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). Circulation. 2010;121(3):384–91.
8. Thorp AA, Healy GN, Owen N, Salmon J, Ball K, Shaw JE, et al. Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers: Australian Diabetes, Obesity and Lifestyle (AusDiab) study 2004–2005. Diabetes Care. 2010;33(2):327–34.
9. Wijndaele K, Brage S, Besson H, Khaw KT, Sharp SJ, Luben R, et al. Television viewing time independently predicts all-cause and cardiovascular mortality: the EPIC Norfolk study. Int J Epidemiol. 2011;40(1):150–9.
10. Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. Diabetes Care. 2011;34(2):497–503.
11. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation. 2007 Aug 28;116(9):1081–93.
12. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans, Be Active, Healthy, and Happy! [http://www.health.gov/paguidelines/].
13. Carlson SA, Densmore D, Fulton JE, Yore MM, Kohl HW 3rd. Differences in physical activity prevalence and trends from 3 U.S. surveillance systems: NHIS, NHANES, and BRFSS. J Phys Act Health. 2009;6 Suppl 1:S18–27.
14. Hawkins MS, Storti KL, Richardson CR, King WC, Strath SJ, Holleman RG, et al. Objectively measured physical activity of USA adults by sex, age, and racial/ethnic groups: a cross-sectional study. Int J Behav Nutr Phys Act. 2009;6:31.
15. Clark BK, Sugiyama T, Healy GN, Salmon J, Dunstan DW, Shaw JE, et al. Socio-demographic correlates of prolonged television viewing time in Australian men and women: the AusDiab study. J Phys Act Health. 2010;7(5):595–601.
16. Brawley LR, Rejeski WJ, King AC. Promoting physical activity for older adults: the challenges for changing behavior. Am J Prev Med. 2003;25(3 Suppl 2):172–83.
17. Inoue S, Ohya Y, Odagiri Y, Takamiya T, Kamada M, Okada S, et al. Perceived neighborhood environment and walking for specific purposes among elderly Japanese. J Epidemiol. 2011; 21(6):481–90.
18. Salmon J, Owen N, Crawford D, Bauman A, Sallis JF. Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference. Health Psychol. 2003;22(2): 178–88.
19. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML,

Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
20. Murase N, Katsumura T, Ueda C, Inoue S, Shimomitsu T. Validity and reliability of Japanese version of International Physical Activity Questionnaire. J Health Welfare Stat. 2002; 49(11):1–9 (in Japanese).
21. Deng HB, Macfarlane DJ, Thomas GN, Lao XQ, Jiang CQ, Cheng KK, et al. Reliability and validity of the IPAQ-Chinese: the Guangzhou Biobank Cohort study. Med Sci Sports Exerc. 2008;40(2):303–7.
22. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Circulation. 2007;116(9): 1094–105.
23. The Ministry of Health, Labour and Welfare of Japan. Tokyo: The National Health and Nutrition Survey [cited 2011 May 10]. Available from: http://www.mhlw.go.jp/bunya/kenkou/kenkou_eiyou_chousa.html.
24. Fukuhara S, Suzukamo Y. Manual of the SF-8 Japanese version. Institute for Health Outcomes & Process Evaluation Research, Kyoto, 2004.
25. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. Diabetes Care. 2007;30(6):1384–9.
26. Laurson KR, Eisenmann JC, Welk GJ, Wickel EE, Gentile DA, Walsh DA. Combined influence of physical activity and screen time recommendations on childhood overweight. J Pediatr. 2008;153(2):209–14.
27. Eisenmann JC, Bartee RT, Smith DT, Welk GJ, Fu Q. Combined influence of physical activity and television viewing on the risk of overweight in US youth. Int J Obes (Lond). 2008;32(4): 613–8.
28. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. Diabetes. 2007;56(11): 2655–67.
29. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Is television viewing time a marker of a broader pattern of sedentary behavior? Ann Behav Med. 2008;35(2):245–50.
30. Gorber SC, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. Obes Rev. 2007;8(4):307–26.
31. Spencer EA, Appleby PN, Davey GK, Key TJ. Validity of self-reported height and weight in 4808 EPIC-Oxford participants. Public Health Nutr. 2002;5(4):561–5.
32. Lawlor DA, Bedford C, Taylor M, Ebrahim S. Agreement between measured and self-reported weight in older women. Results from the British Women's Heart and Health Study. Age Ageing. 2002;31(3):169–74.
33. Gunnell D, Berney L, Holland P, Maynard M, Blane D, Frankel S, et al. How accurately are height, weight and leg length reported by the elderly, and how closely are they related to measurements recorded in childhood? Int J Epidemiol. 2000; 29(3):456–64.
34. Inoue M, Toyokawa S, Miyoshi Y, Miyano Y, Suzuki T, Suyama Y, et al. Degree of agreement between weight perception and body mass index of Japanese workers: MY Health Up Study. J Occup Health. 2007;49(5):376–81.
35. Wada K, Tamakoshi K, Tsunekawa T, Otsuka R, Zhang H, Murata C, et al. Validity of self-reported height and weight in a Japanese workplace population. Int J Obes (Lond). 2005;29(9): 1093–9.

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SHORT PAPER Open Access

Joint associations of physical activity and screen time with overweight among japanese adults

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Abstract

Background: Although both insufficient physical activity (PA) and high screen time (ST) are independent risk factors for obesity, how the combination of sufficient/insufficient PA and high/low ST could increase obesity risk among the adult population of Japan is not known. This study examined joint associations of PA and ST with overweight among Japanese adults.

Methods: An Internet-based survey collected data on height, weight, self-reported time spent in PA and ST, and sociodemographic variables from 2832 adults. Respondents were categorized into sufficient PA/low ST, sufficient PA/high ST, insufficient PA/low ST, or insufficient PA/high ST categories as per public PA guidelines and the median of ST. Logistic regression analysis examined the odds ratios (OR) of being overweight (body mass index, ≥ 25 kg/m^2) according to the categories of PA and ST.

Results: In comparison with the sufficient PA/low ST category, participants in the insufficient PA/high ST category were significantly more likely overweight (OR, 1.48; 95% confidence interval [95%CI), 1.14, 1.93) after adjusting for sociodemographic variables. A significantly higher OR for overweight (including obesity) among insufficient PA/high ST category was also observed in men, but no significant association was found in women.

Conclusions: Both insufficient PA and prolonged ST contribute to overweight and obesity among Japanese adults. Public health initiatives addressing obesity in Japan need to consider both promoting PA and reducing ST, especially in men.

Background

Overweight and obesity increase the risk of developing chronic diseases including cardiovascular disease, hypertension, type 2 diabetes, and certain types of cancer [1,2]. Physically inactive lifestyles are considered to play important roles in the current obesity epidemic [3]. Research has consistently shown that physical activity (PA) is inversely associated with obesity measures [4,5]. Time spent in sitting (sedentary behavior) is also known to be associated with increased risk of obesity, independent of participation in PA [6,7].

Drawing on these research findings, an Australian study has examined the joint association of PA and sedentary behavior with obesity [8]. The study found that those who met PA guideline recommendations but reported prolonged sedentary time and those with insufficient PA and lower sedentary time had similarly higher likelihood of being overweight compared with those who conducted sufficient PA and were low in sedentary time [8]. However, the combined effect of PA and sedentary behavior on obesity is not known in other countries. Japan offers a unique research opportunity in this context. Although the prevalence of obesity is relatively low in Japan compared with Western countries, it is increasing steadily [9]. In addition, partly because of easily available media-related technologies, television/video viewing and Internet use are highly prevalent and increasing among adults [10]. Since computer and Internet use has been found associated with adult overweight and obesity [11], it is of interest to examine the health impact of screen-based sedentary behavior in the presence (and absence) of PA. This study examined the joint associations of PA and screen-based sedentary behavior with overweight among Japanese adults.

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Methods

Participants

Data for this study came from an Internet-based cross-sectional survey in 2009. A total of 9418 adults were randomly selected from the database of a Japanese research service company (with approximately 264,000 registrants) and received invitation e-mails. Of these, 3000 individuals responded to the survey. Detailed methods and procedures have been reported elsewhere [12]. This study received prior approval from the Ethics Committee of Waseda University.

Outcome variable

The outcome variable of this study was body mass index (BMI) calculated from self-reported height and weight dichotomized into normal weight (< 25 kg/m^2) or overweight (including obese, ≥ 25 kg/m^2), according to the criterion of Japanese National Health and Nutrition Survey [13].

Exposure variable

Exposure variable was calculated from levels of PA and screen time (ST). For PA the Short Version of International Physical Activity Questionnaire (IPAQ-SV) was used. Total time spent in vigorous-intensity PA, moderate-intensity PA, and walking was calculated and dichotomized into "sufficient PA" (≥ 150 minutes/week) or "insufficient PA" (< 150 minutes/week) based on public health guidelines [14]. Test-retest reliability and criterion validity of the Japanese version of IPAQ-SV have been validated [15]. For ST, participants reported their time spent in the following screen-related sedentary behaviors: watching television, videos, and DVDs; Internet use (except work related); and video game use. Reasonable validity and reliability were reported [16]. The sum of the time spent in these behaviors was dichotomized into "low ST" or "high ST" using the median (21 hours/week). According to the levels of PA and ST, participants were classified into the following four categories: sufficient PA/low ST; sufficient PA/high ST; insufficient PA/low ST; and insufficient PA/high ST.

Sociodemographic variables

Data on participants' sex, age (30-39; 40-49; 50-59 years), marital status (married; unmarried), educational level (junior high and high school degree; two-year college degree or equivalent; four-year college or higher degree), job status (full-time job; not full-time job), and household income (less than 5 million yen; 5-10 million yen; more than 10 million yen) were obtained from the research company.

Data analysis

Data for 2832 adults who provided complete information for the study variables were analyzed. Logistic regression was conducted to estimate the odds ratios (ORs) of being overweight by PA/ST categories adjusted for sociodemographic variables. The sufficient PA/low ST category was the reference for this analysis. Regression analyses were performed for the whole sample, and separately for men and women, based on the gender differences have previously been found [8]. Analysis was conducted using SPSS 15.0; the level of significance was set at $p < 0.05$.

Results

Table 1 shows the sociodemographic characteristics of the total sample and the four PA/ST categories. Overall, 50% of the respondents were men and 74.5% were married. Of the total respondents, 33.6% were aged 30-39 years, 33.3% were aged 40-49 years, and 33.1% were aged 50-59 years. In addition, 47.6% of the participants had graduated from college or graduate school and 62.0% had full-time job, as well as 46.5% had 5-10 million yen income. The proportion of overweight and obese participants was 21.8% for the total sample. Correlation coefficient between PA and ST was -0.17, suggesting that these two behaviors were essentially independent from each other.

Table 2 shows ORs for being overweight or obese by combined categories of PA and ST for the total sample, for men, and for women, adjusting for sociodemographic factors. In the total sample, adults who were insufficient in PA and high in ST were 1.48 times more likely overweight compared with those who engaged in sufficient PA and were low in ST. The other categories (sufficient PA/high ST, insufficient PA/low ST) were not significantly different from the reference category. A similar pattern was observed in men. Compared with the reference category, men who engaged in insufficient PA and high ST were significantly more likely overweight. However, no significant association was found between the PA/ST categories and overweight in women.

Discussion

Japanese adults who engaged in insufficient PA and high ST were about 1.5 times more likely overweight than those with sufficient PA and low ST. Given that insufficient PA or high ST alone was not significantly associated with overweight, our findings suggest that it is the combination of lack of PA and prolonged ST that increases the risk of overweight and obesity in this sample of Japanese adults. This finding on the combined effect of PA and ST on overweight is consistent with a previous study that examined the joint association in the same manner [8]. However, our findings are different from that study in that we found the OR of being overweight was not significantly higher for sufficient PA/high ST and insufficient

Table 1 Sample characteristics by Physical Activity (PA) and Sitting Time (ST) Categories

		Combined Categories of PA and ST				
	Total	**Sufficient PA/Low ST**	**Sufficient PA/High ST**	**Insufficient PA/Low ST**	**Insufficient PA/High ST**	***p*-value**
No. (%)	2832	905(32%)	656 (23%)	702 (25%)	569 (20%)	-
Sex						< 0.001
Male	50.0%	57.5%	44.7%	50.7%	43.4%	
Female	50.0%	42.5%	55.3%	49.3%	56.6%	
Age group						< 0.001
30-39 years	33.6%	35.6%	27.7%	38.0%	31.6%	
40-49 years	33.3%	29.8%	34.3%	36.8%	33.4%	
50-59 years	33.1%	34.6%	38.0%	25.2%	35.0%	
Marital status						< 0.001
Unmarried	25.5%	20.8%	31.3%	24.5%	27.6%	
Married	74.5%	79.2%	68.8%	75.5%	72.4%	
Educational level						< 0.001
Junior high/high school	26.4%	18.6%	33.5%	25.8%	31.5%	
Two-year college	26.0%	24.7%	25.0%	25.1%	30.4%	
Four-year college/graduate school	47.6%	56.7%	41.5%	49.1%	38.1%	
Job status						< 0.001
Full-time job	62.0%	68.3%	53.7%	69.8%	52.2%	
No full-time job	38.0%	31.7%	46.3%	30.2%	47.8%	
Household income (yen p.a)						< 0.001
< 5 million	38.0%	31.3%	41.6%	36.9%	45.9%	
5-10 million	46.5%	50.4%	42.8%	48.1%	42.7%	
> 10 million	15.5%	18.3%	15.6%	15.0%	11.4%	
BMI						0.182
Normal weight	78.2%	79.4%	79.1%	78.3%	74.9%	
Overweight	21.8%	20.6%	20.9%	21.7%	25.1%	
Mean BMI, kg/m^2 (sd)	22.59 (3.53)	22.46 (3.25)	22.51 (3.49)	22.52 (3.50)	22.99 (4.02)	

Abbreviations: PA: physical activity; ST: screen time, p.a.: per annum.

PA/low ST categories. This is also inconsistent with previous studies that demonstrated associations of sedentary time with obesity measures independent of physical activity [6,7]. The inconsistency between this and previous studies may stem from behaviors that were not measured in this study such as nonscreen-based sedentary behaviors (e.g., during work and transport) and light-intensity physical activity. The latter has been shown associated with reduced metabolic risk independent of moderate-to-vigorous physical activity [17]. It is possible that those in the sufficient PA/high ST category may be low in nonscreen-based sedentary behaviors (they may afford high ST in their leisure time due to less time commitment for work or transport), and those in the insufficient PA/low ST category may be high in light-intensity activity (they may have to cut PA and ST to perform duties such as household chores). Our findings suggest potentially different behavioral

Table 2 Adjusted Odds Ratios of Overweight/Obese by Physical Activity (PA) and Sitting Time (ST) Categories

	Being overweight (BMI, ≥ 25 kg/m^2)					
	Total (n = 2832)		**Men (n = 1416)**		**Women (n = 1416)**	
	OR (95% CI)	***p*-value**	**OR (95% CI)**	***p*-value**	**OR (95% CI)**	***p*-value**
Sufficient PA/low ST	1.00 (ref.)	-	1.00 (ref.)	-	1.00 (ref.)	-
Sufficient PA/high ST	1.13 (0.87-1.46)	0.37	1.30 (0.94-1.79)	0.11	0.87 (0.55-1.40)	0.57
Insufficient PA/low ST	1.12 (0.87-1.43)	0.39	1.18 (0.88-1.59)	0.28	0.97 (0.61-1.55)	0.91
Insufficient PA/high ST	1.48 (1.14-1.93)	0.003	1.50 (1.08-2.09)	0.02	1.43 (0.92-2.23)	0.11

OR adjusted for sex (whole sample), age, marital status, educational level, job status, and household income.