このプログラムでは，脆弱な高齢者を対象とすることを考慮して，看護師，保健師，管理栄養士，医師／疫学研究者，体育科学研究者，健康運動指導士，受付事務という多様な専門職で構成する学際的チームにより運営にあたっている。さらに，転倒事故，急病の発生に備えて加えて聖路加国際病院救命救急センターとの連携体制を整えた。本稿では2005年，2006年に実施したプログラムの経過とその評価について報告する。

Ⅱ．地域特性とアウトリーチプログラム－転倒骨折予防体操教室－の目的

中央区の人口は10万2,241人，65歳以上の人口割合は16.5%であり（平成18年11月現在），高齢者人口割合は全国と比較して高いほうではないが，後期高齢者の割合が近年増加している。

区内は京橋，日本橋，月島の3つの地域に区分され，各地域に1ヵ所の保健所・保健センター，地域包括支援センターほか，行政各機関が設置されている。本学は京橋地域に属し，区役所，保健所，地域包括支援センター，老人保健施設などの主要機関と地理的に近く，地域の情報を得やすい特徴がある。本地域には高層マンション，商店や住宅が混在しているが，両者が融合し，近隣同士の助け合いや商店，町会のつながりも強い。しかし，高齢者が安心して体操等を行える場所は多いとはいえない。

このような地域背景のもと本プロジェクトが提供する本プログラムの当初ねらいは，①本プログラムの実施を通じて，中央区という都市部に暮らす高齢者の特性を理解すること，②本プログラムの内容が安全かつ都市部高齢者のニーズに一致しているか検討すること，③本プログラムが今後都市部である本地域に密着して持続し，定着しうるか検討すること，④アウトリーチ活動を通じて，大学近隣地域のキーパーソンや，本プロジェクトのパートナーとなる区民を探すこと，⑤Community based participatory research（CBPR）をすすめる上での outcome 評価指標を検討することであった。

Ⅲ．プログラムの計画

1．日時と場所，内容の検討

第1回の企画会議では日時，回数，プログラムの内容，専門職スタッフ構成，ボランティアについて検討した。

日程は，スタッフ側の可能量と参加者の健康状態を考慮して，半日4回を1コースとして試みることとした。開催場所は聖路加看護大学2号館3階交流ラウンジとし，時間帯は13：30－15：30の2時間とした。また，内容は，体操プログラムに加え，看護の視点を付加し，健康教育として転倒予防，食事と栄養，足の手入れ（フットケア）に関する講義，参加者同士の交流の時間などを設け，参加者にとって相互交流の場にもなるようなプログラムとした（表1）。学内で活用し得る緒資源についても検討し，場所，計測機器，体操用マットなどを借用することとした。

参加者の当日の健康状態の観察と，自身が身体の状況について理解できるよう，身長，体重，肥満度（BMI），骨密度，血圧，脈拍，歩行時間などの計測結果を個別に記録した。また，個別記録用紙には体操の内容，満足度，1週間の出来事などの記録欄を設けた。個別ファイルにはこれらと配布資料などを綴じて保存できるようにした（写真1）。

表1　本プロジェクトによる転倒骨折予防プログラム

第1回		第2回		第3回		第4回	
13：30	受付開始 ・保険申し込み（2005年度のみ） ・健康観察 ・基礎体力計測	13：30	健康観察	13：30	健康観察	13：30	健康観察
		14：00	自己紹介	14：00	ミニレクチャー（フットケア）	14：00	体操プログラム ⇓
14：00	オリエンテーション	14：15	ミニレクチャー（食事と栄養）	14：15	体操プログラム ⇓	14：30	休憩 ⇓
14：10	ミニレクチャー（転倒・骨折予防）						
14：30	体操プログラム ⇓	14：30	体操プログラム ⇓	14：30	休憩 ⇓	14：55	体操プログラム
15：15	休憩 ⇓	15：00	休憩 ⇓			15：00	質疑と懇談 修了証授与
15：25	体操プログラム	15：25	体操プログラム	15：25	体操プログラム	15：25	同窓会の説明
15：30	個別記録返却、終了	15：30	個別記録返却、終了	15：30	個別記録返却、終了	15：30	個別記録返却、終了

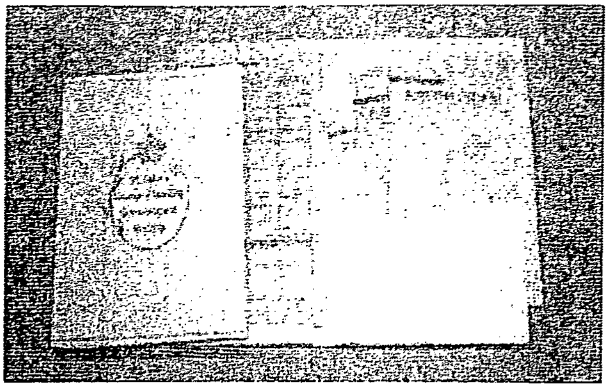

写真1　個別記録と保存用ファイル，教材

2．運営スタッフ

脆弱な高齢者を参加者集団とするため，本プログラムの運営スタッフは，本学看護教員（保健師・看護師・管理栄養士），研究員に加え，医師／疫学研究者，健康運動指導士による学際的チーム構成とした。さらに本学大学院生ボランティアを加え，参加者定員15名につき，運営スタッフは各回8～9名の体制をとることとした。

3．リスク管理

会場への往復路，プログラム参加中の転倒事故，体調変化などが予測されるため，事故発生時の速やかな受診システムを整えた。学長を通じて聖路加国際病院救命救急センターと公文書を交わし，緊急時の受診受け入れについて了承を得た。また，けが等の事故に備え，都社会福祉協議会が提供する「行事保険」に2005年参加者は強制加入した。2006年は2号館全体として傷害保険に加入したため，本プログラム参加者もそれでカバーされると判断し行事保険の加入は割愛した。会場には，受傷者搬送用の車椅子を用意した。

個人情報保護・管理に努め，特に名簿は参加者の選考，出席確認，各種計測結果の記入目的で作成し，通し番号による管理と使用後の回収・断裁を行った。

4．広　報

地域在住の高齢者への参加案内は，ポスター，パンフレット，本プロジェクトが刊行している情報誌「生き活きネット」，本学主催のWebsite「看護ネットー最新情報コーナー」を用いて行った。広報期間は1ヵ月間であった。

Ⅳ．応募者の概要と健康状態の確認

前述の広報により，2005年は22名，2006年は18名から応募があった。2005年はすべて女性，2006年は男性2名，女性16名であった。

これら応募者に対し，現在の身体・生活・健康状態（①血圧，②服薬，③受診状況，④歩行状態，⑤転倒経験，⑥同居家族，⑦本学会場までの所要時間），本プログラムへの期待について電話でインタビューし，参加可能であるか確認した。

インタビューにより得られた情報からは，応募者同士が友人，顔見知りであることが多く，2人から5人のグループで応募していることがわかった。これは地域内の人的つながりを示す情報と考えられた。参加動機や期待は，「家でできる体操を教えてほしい」「歩き方を教えてほしい」「外出する機会がほしい」「定年後は人と接することが減ったため地域とのつながりをもちたい」などであった。また民生委員，町会役員から自分が参加して，今後は地域に広めていきたいという意向があげられ，ニーズの多様さがうかがわれた。

本プログラムの情報を把握した経路は，2005年は「友人に誘われて」がほとんどで，ポスター・チラシによりプログラム開催を知った友人同士が誘いあって応募していた。2006年は，2号館「るかなび」で情報を得たとする者が多かった。本学のWebsite（看護ネット）から本プログラムを把握した者はなかった。

会場までの所要時間は，3分から50分と幅があり，平均は15分程度であった。2006年は他区や都外からの応募者もあった。運動習慣は，散歩の習慣がある者と，一方では，杖が必要であるなど，運動に補助が必要である者が含まれていた。過去の転倒経験者は，各年とも2名であった。

これら各応募者の身体状況，友人関係などを考慮し，運営スタッフの合議により2005年は14名，2006年は15名を本プログラム参加可能者と判断した。また，民生委員，町会長等からの参加の要望もあったため，今後の地域との協働を考え，各回1名ずつの参加枠を設けた。これらの者には，「参加決定通知」を郵送し，日時，服装などの案内を再度行った。

参加できなかった者に関しては，理由を電話で説明し，了承を得た。また，次回の開催予定を案内した。2005年は2名，2006年は3名が都合による参加辞退の申し出があった。

Ⅴ．プログラムの実施経過

1．参加者の概要と参加状況

2005年度，2006年度の参加者の概要は表2に示した。平均年齢は両年とも差がなく74歳前後で，年齢の範囲は65～83歳であった。内服治療中の者は65.5%であった。2006年参加者における「介護予防スクリーニングシート」（厚生労働省）項目の，「運動機能」リスク者は5名，「口腔機能」リスク者は4名，「うつ」リスク者は3名であった。またWHO-QOL26による評価では，「Ⅰ身体的領域」平均3.11，「Ⅱ心理的領域」平均3.48，「Ⅲ社会的関係」

表2　プログラム参加者の概要

項目	2005年	2006年	計
参加者数	14	15	29名
男性	—	2	2名
女性	14	13	27名
平均年齢±SD	73.9±5.5	74.4±4.5	74.1±4.9
年齢範囲	65～82	66～83	65～83
内服治療者数(割合)	9(64.3)	10(66.7)	19(65.5)
内訳　降圧剤	7(50.0)	3(20.0)	10(34.5)
その他	2(14.3)	7(46.7)	9(31.0)
平均来所所要時間(分)	10.4±7.3	20.9±18.9	15.6±15.0
介護予防スクリーニングシート(N, %)			
運動機能リスク者	—	5(33.3)	5(33.3)
口腔機能リスク者	—	4(26.7)	4(26.7)
うつリスク者	—	3(20.0)	3(20.0)
WHO-QOL26(点)			
Ⅰ身体的領域	—	3.11	3.11
Ⅱ心理的領域	—	3.48	3.48
Ⅲ社会的関係	—	3.20	3.20
Ⅳ環境	—	3.46	3.46
出席者数(N, %)			
1回目	14(100)	12(80.0)	26(89.7)
2回目	9(64.3)	12(80.0)	21(72.4)
3回目	11(78.6)	13(86.7)	23(79.3)
4回目	12(85.7)	12(80.0)	24(82.8)
独居者(N, %)	2(14.3)	5(33.3)	7(24.1)

平均3.20，「Ⅳ環境」平均3.46であった。

プログラム各回の出席状況は，2005年は64.3～100%，2006年は80.0～86.7%で，欠席者の欠席理由は本人の体調不良や家族を介護するため，失念などであった。全ての回数参加できた者は2005年9名（64.3%），2006年9名（60.0%）であった。

独居者は2005年2名，2006年5名であった。

各回とも，民生委員あるいは町会役員が1名ずつ参加した。

2．プログラム内容

1）健康観察

第1回参加時に，BMI・血圧・脈拍・骨密度・握力・開眼片足立ち・10m 歩行速度（2006年のみ）・問診により基礎体力を観察した。2回目以降の参加時には，体重・血圧・脈拍測定と測定結果の説明，服薬の確認，当日の症状の有無，前回参加後の身体状態（筋肉痛等）の問診を行い，当日のプログラム参加が可能か判断し，また指導する体操強度の参考に用いた。

基礎体力の結果は表3に示した。血圧は平均146.5／85.4mmHg であるが，収縮期血圧160 mmHg を超える者は6名（20.7%）あった。脈拍は平均80.9（±13.6）bpm であった。

BMI は両年平均23.9（±3.5）で，判定は「標準」22名（75.9%），「肥満」7名（24.1%）であった。

骨密度スティフネス年齢比較（A-1000InSight, GE Healthcare 社製）は，平均65.4（±12.8）%で，判定は「問題なし」3名（10.3%），「骨減少症疑い」12名（41.4%），「骨粗鬆症疑い」12名（41.4%）であった。

握力（ハンドグリップメーター 握力計6103，TANITA 社製）は，左右とも平均20kg 程度であったが，2006年は男性が2名含まれているため，2005年参加者に比較して，2006年参加者の方が有意に高かった（$p<0.05$）。

開眼片足立ち時間（利き足）は，平均30.3（±30.3）秒で，同年代平均（平成16年度文部科学省[16]）より低い。文部科学省得点判定別では「10－9点」3名（10.3%），「8－7点」7名（24.1%），「6－5点」7名（24.1%），「4－3点」9名（31.0%），「2－1点」2名（6.9%）と，判定が3～8点の者が多かった。

歩行速度（2006年のみ計測）は男性平均115.2（±21.5）m/min，女性平均98.7（±13.3）m/min で，年代別では両者とも同年代よりも早い傾向である[17]。年齢別判定[17]は「ランクA」12名（80%）「ランクC」1名（6.7%）であった。

降圧剤を服用している者が11名で，ほかに血液抗凝固剤，安定剤，睡眠剤，痛風薬，消化剤，抗コレステロール剤，抗甲状腺剤，気管拡張剤の服用／吸入など何らかの薬物治療を受けているものがほとんどであった。血圧

表3　基礎体力結果

項目	2005年 n=14	2006年 n=15	全体 n=29
血圧(mmHg)	152.1±18.3/85.4±11.8	140.9±18.7/85.4±4.1	146.5±19.0/85.4±8.6
脈拍(bpm)	83.4±11.1	78.6±15.7	80.9±13.6
BMI	24.3± 3.8	23.4± 3.3	23.9± 3.5
BMI 判定(N, %)			
標準	10(71.4)	12(80.0)	22(75.9)
肥満	4(28.6)	3(20.0)	7(24.1)
骨密度スティフネス (%)	64.4±11.9	66.5±14.0	65.4±12.8
骨密度判定(N, %)			
問題なし	1(7.1)	2(13.3)	3(10.3)
骨減少疑い	6(42.9)	6(40.0)	12(41.4)
骨粗鬆疑い	7(50.0)	5(33.3)	12(41.4)
非測定	−	2(13.3)	2(6.9)
握力(kg)			
左	18.1± 4.0 *	22.7± 7.3 *	20.4± 6.3
右	17.9± 3.2 *	24.9± 7.7 *	21.4± 6.8
開眼片足立ち時間(利き足)(sec)	19.8±17.5	40.7±37.0	30.3±30.3
開眼片足立ち得点判定(文部科学省)(N, %)			
10−9	−	3(20.0)	3(10.3)
8−7	4(28.6)	3(20.0)	7(24.1)
6−5	3(21.4)	4(26.7)	7(24.1)
4−3	5(35.7)	4(26.7)	9(31.0)
2−1	2(14.3)	−	2(6.9)
不明	−	1(6.7)	1(3.4)
性別歩行速度(m/min)	−	男性 (n=2) 115.2±21.5 女性 (n=13) 98.7±13.3	
年代別歩行速度(m/min)	−	65−69歳 (n=2) 102.7± 3.7 70−74歳 (n=6) 105.5±19.8 75歳以上 (n=6) 95.5±10.5	

*；$p<0.05$

値が普段の値よりも30mmHg以上上昇していたため安静後再測定した者が各回とも2〜3名程度あった。参加前の問診では，朝の服薬忘れ，腰や膝などの痛み，急いで会場に来たため血圧が上昇したなどがあった。前回参加後に筋肉痛が生じたり，身体の痛みが増強した者はなく，体操参加に影響を与える自覚症状の訴えはみられなかった。

測定結果は個別ファイルに記録して本人に返却した。前回参加後の1週間に行った体操や感想などを自己記入欄に記載している者は5名であった。体重変動は，プログラム初回から第4回までの参加中に1.0kgの上下変動があった。

2) 健康教育

第1回は医師から転倒しやすい場所，転倒や骨折を予防するポイントと本プログラムの趣旨について，第2回は管理栄養士から良質なたんぱく質とカルシウムを摂取するための食事と栄養，低栄養の予防について，第3回は看護師より足と爪の手入れを中心としたフットケアについて15分程度の健康教育を行い参考資料も配付した。

3) 体操プログラム

健康運動指導士によって各回60分程度の時間で体操を行った。

第1回は，上半身，体幹，下肢ストレッチ，正しい歩き方と歩行のチェック（写真2），腿上げ，バランス立ち，つま先上げなどを実施した。また，マットを利用して腓腹筋・腿・股関節などを中心とした下肢ストレッチ（写真3），上半身，体幹ストレッチを行った。

第2回は，敏捷性，移動性，調整力を高めるレクリエー

写真２　正しい歩き方

写真３　下肢ストレッチ

写真４　調整力を高める体操

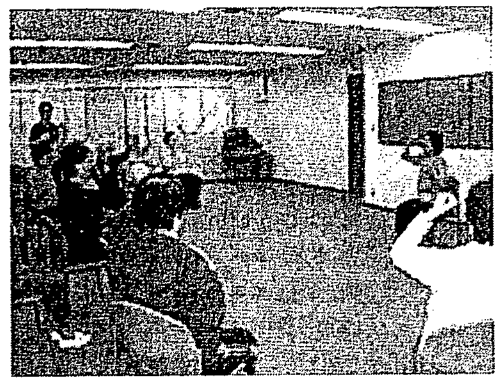

写真５　座位による上肢の体操

ションを取り入れた体操（写真４），1回目と同様に歩行姿勢のチェック（腿上げ，バランス，つま先上げ），マットを利用した腓腹筋・腿・股関節ストレッチを行った。

第3回は，座位で肩，背，胸，上肢，大腿前後部を中心とした体操を行い（写真５），リズム運動，歩幅をかえた歩行，膝あげ歩行，横歩き，後ろ歩きなどを行った。

第4回は座位で腿上げ，つま先上げ，リズムを取る運動，音楽に合わせたバランス体操，臥位による腹筋，腰部，下肢ストレッチとリラクゼーションなどを行った。体操の強度は個別に声をかけ，各参加者が無理のない範囲で実施した。運営スタッフも共に体操に参加しながら，周囲の参加者に声をかけたり，人数調整のためにペアに入るなど，全体を見渡しながら進めた。上・下肢の複雑な組み合わせによる動きもあったが，始終和やかな雰囲気で進められていた。休憩時間には，水分補給を全員に勧め，その間にも参加者同士で体操や転倒の怖さについて話しているなど，情報交換の場にもなっていた。懸念された転倒などによる事故やけがは生じなかった。

4）参加者の交流談話会と修了証授与

最終回には30分程度の時間を各講師への質問と今後も体操を継続していく上での参加者同士の懇談にあてた。「走ることは良いのか」などの質問があり，健康運動指導士，医師がその安全性と危険性を回答した。今後も各自が体操を続けることに関しては，表４のような意見と課題があげられた。区に体操できる場所の借用を頼んでも，「介護保険対象者でないと利用できない」といわれ，

表４　参加者の意見：体操を継続する上での課題

・体操を継続したいと思うが，場所がないので皆で集まれない
・70歳以上でも元気なお年寄り（要介護認定されない）がいることを区は分かっていないのではないか
・行政の問題として，場所の利用の申請をしても年齢で切られてしまい，年齢が該当しない虚弱な人は運動できない
・運動したいと思っても一人で行うのは難しい。行政に言っても分かってもらえない。住民はもっと声を出すべきだ
・高齢者は閉じこもりになりやすいから，誘い出していくことが必要
・運動を継続するには，精神面が非常に大きい
・今後も継続したいが，なかなかできることではない。仲間が必要だと思った
・今回は，ここに来ることが楽しかった
・専門の先生に教えてもらえてよかった。なかなか講師に教えてもらう機会は少ない

場所がないことが体操継続上の問題であることがあげられていた。身近な場所に，集団で体操ができる場所が得られないことは，都市部での問題であることがうかがわれた。修了証を手にした参加者は，「(賞状を手にしたのは）小学校卒業以来はじめて」と表情を和ませていた。

Ⅵ．評　価

1）参加者アンケートによる評価

本プログラムの終了にあたり，任意による自記式アンケートの記載を依頼し，回収した（2005年回収数12，最

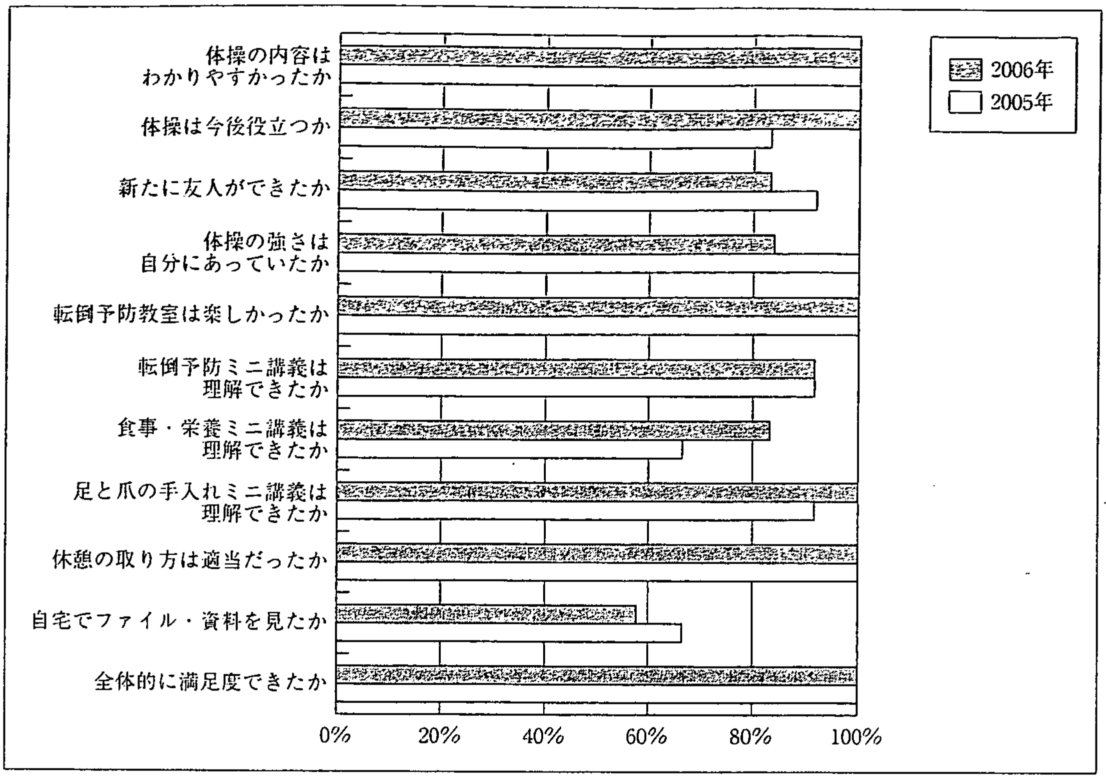

図1　転倒骨折予防体操プログラム参加者アンケート結果

終回参加者中の回収率100%，2006年度回収数12，最終回参加者中の回収率100%）。

結果は，図1に示したとおり，「体操内容がわかりやすかった」「教室は楽しかった」「休憩の取り方」などはほとんど肯定的な回答であった。ほとんどの参加者から，本プログラムの延長・継続を求める声があげられていた。

健康教育については，理解できたとした者は67～92%とばらつきがみられた。ファイルや資料を自宅で毎回見たとした者は，60%程度であった。

良かったプログラムの内容としては，「骨密度」「足と爪の手入れ」「足の体操」「歩き方」「ストレッチ」が上位であり（図2），当初からニーズにあげられていた内容についての評価が高かった。

自由記載では，「参加して気持ちが明るくなった」「家庭でも思い出しながら続けたい」「教室に来るのが楽しかった」「大変なお世話をおかけしていることと思いますが，この後もぜひやらせていただけたらとても幸せと思います」などがあった。

意見としては，「自宅で復習するときのために，体操の絵が書かれているものがほしい」という者があったため，2006年3月に体操ビデオを製作し，看護ネット日本型高齢者ケアプロジェクト（http://www.kango-net.jp/project/04/04_2/p04_12.html）で配信を開始した。また，2006年のプログラムでは，体操を紹介した小冊子教材を作成し，配布するという対応を行った。全体的な満足度は，「とても満足」75%，「満足」25%であり，「不満」とした者はなかった。

2. スタッフによる評価

各回の終了時には反省会を行い，次回に改善するようにした。また，2005年の改善策を2006年に生かしてプログラムを検討した。

第1回の各種計測は項目が多いため，場所によっては待ち時間が生じていた。特に骨密度の測定は時間を要したため，2006年度は2回に分けて計測をすることに変更し，2006年は待ち時間が全体的に改善された。

運営上，開始や終了の区別を明確にすることが，事故の予防にとっても重要であるため，2005年の2回目からは休憩やお茶の時間をはっきりとさせることとした。2006年はスタッフもプログラムに慣れ，プログラム自体の運営がスムーズであった。

体操自体の強度は多少強いものもあったが，参加者は自分に可能な強さで行っており，後日に痛みの症状があった者もなかったため，参加者自身がコントロールできているものと考えられた。体操の種類も豊富であり，立位，座位，臥位，歩行などがあり適切であったが，片足立ちなどの体操では，転倒予防上スタッフが参加者の近くにつくべきであったと考えられた。

参加者数が15名程度であると運営スタッフも参加者の顔と名前を覚えることができ，地域の情報なども得られたため，会場の物理的広さを考慮しても適切な人数であったと考える。

町会長，民生委員などの参加者も興味深く参加していた。また，「資料が良かったので友人にも配りたい」と持ち帰った参加者もあり好評であった。

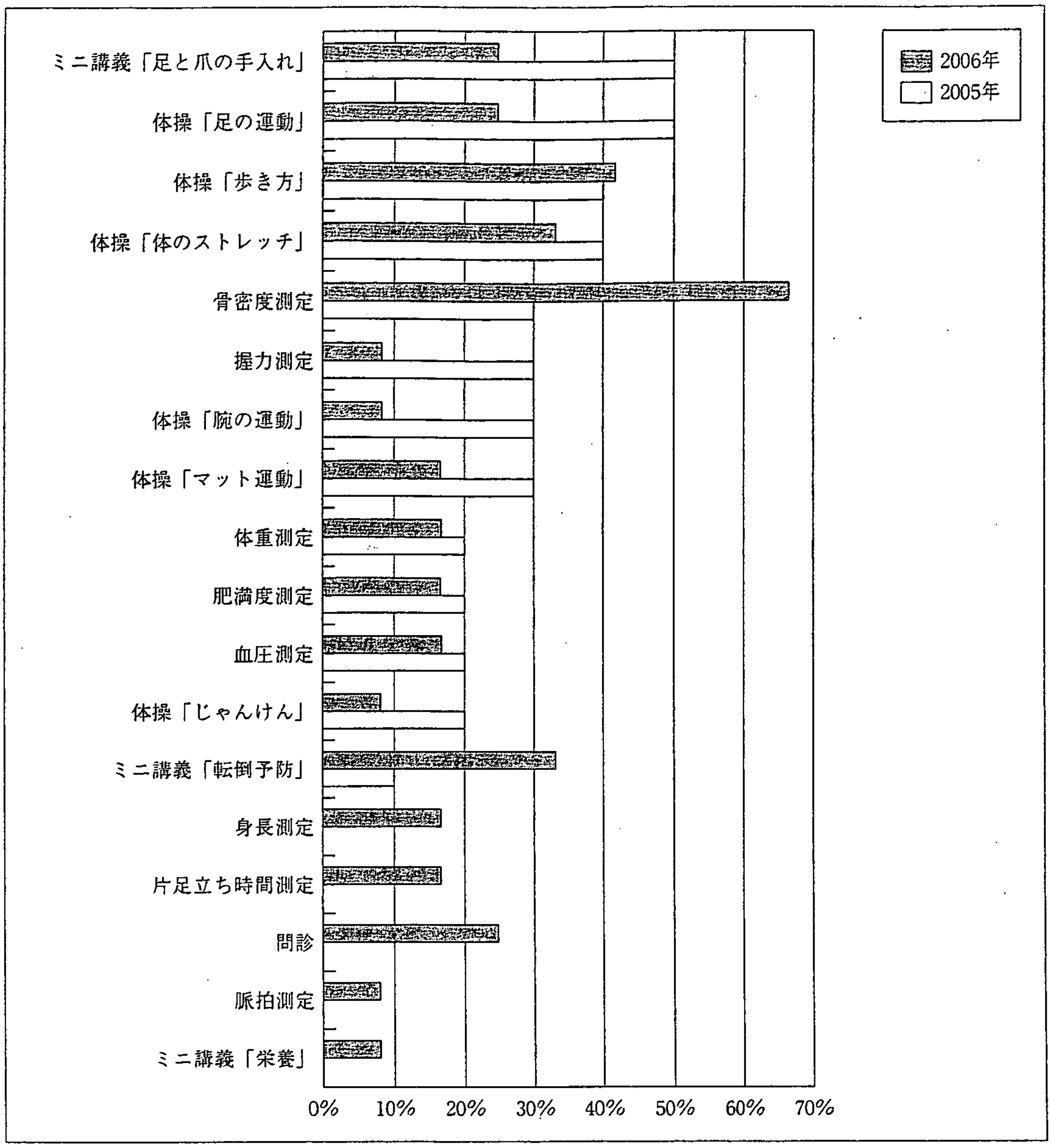

図２　良かったと思うプログラム

骨密度計の測定結果と，ファイルにある基準値が異なるものであったため，質問のあった参加者には個別に回答したが，基準値は統一する必要がある。

本プログラムを評価する outcome 指標については，本プロジェクトの最終目標である「地域の高齢者の尊厳ある意義深い健康生活の維持」「情報収集と資源のセルフコントロールと自己決定」「健康に関する知識，技術の向上」に加えて，「転倒を予防すること」をあげてきたが，さらにプログラム開発と評価のための Program Action-Logic model[18]（図３）を用いて Imput（資源，時間，スタッフ，費用等），Output（実践内容，参加者中の目標到達者），Outcomes-Impact（短期成果，中期成果，長期成果）の枠組みにより，開発した本プログラムの評価を行ったところ，これらの目標に向かっていると評価された。

Ⅶ．総　括

今回の転倒予防プログラムの運営を通じ，準備から実施に至るまで運営スタッフはリスク回避を常に考慮した。脆弱な高齢者を対象とするために予測しうるリスク管理，すなわちプログラム中の転倒，体調変化，往復路の安全など，体操前後にわたるモニタリングの重要性があげられる。途中での参加辞退者の中には，入院，通院が必要となった者も各年1名ずつみられていた。本プログラム参加との因果関係は不明であるが，常に参加者の健康状態に留意する必要がある。

一方，本プログラムを通じて地域に在住する高齢者や民生委員，町会長と交流することができ，地域のキーパーソンと今後の協働への道筋がつけられた。中央区という都市部で生活する今回の参加者は，近隣や友人とのつながりを大事にしていることや，健康に良いことは継続す

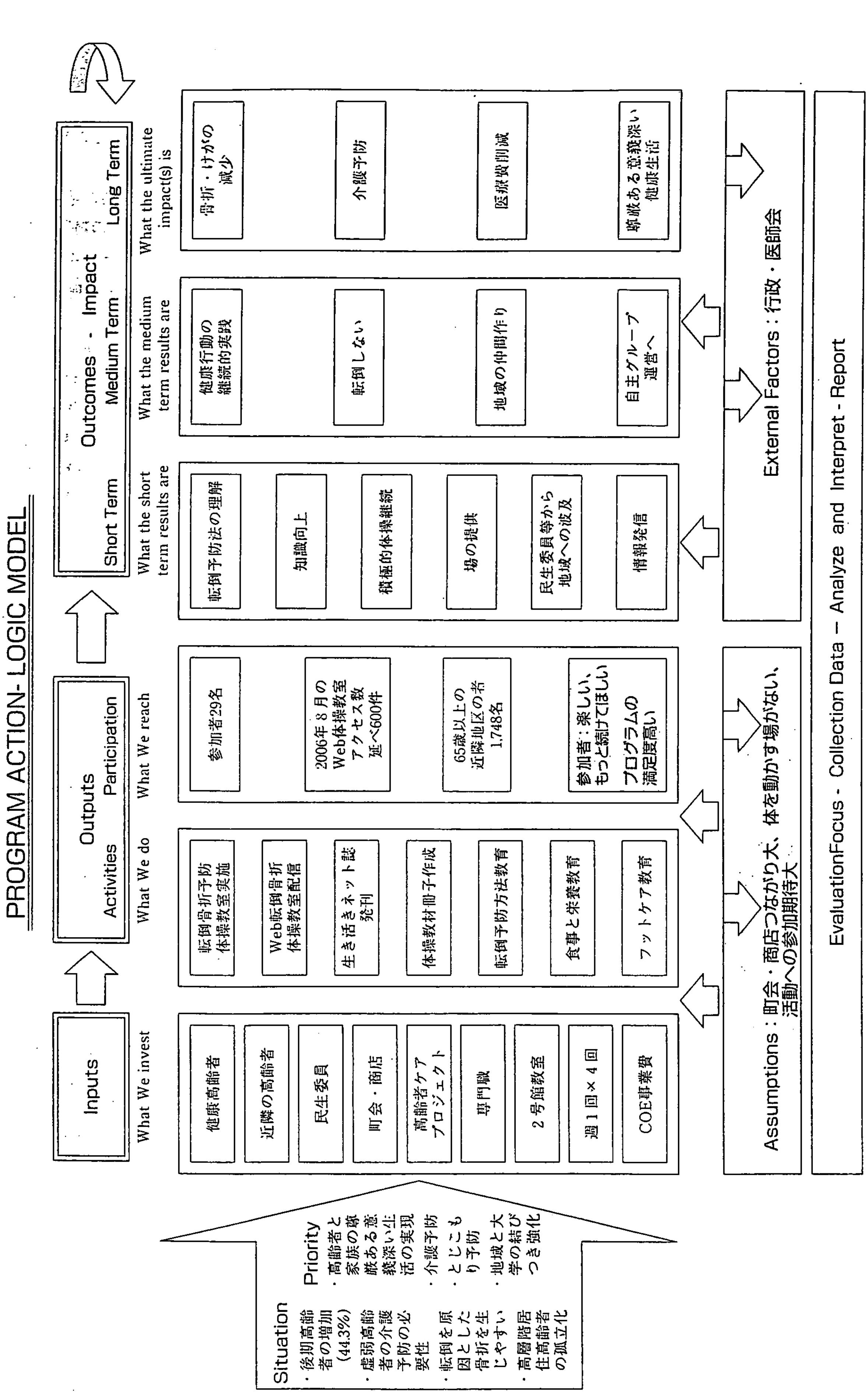

図3　Logic model を用いた転倒骨折予防アウトリーチプログラム開発の評価

注）University of Wisconsin -Extension PROGRAM ACTION- LOGIC MODEL をもとに作成

る姿勢をもっていること，また，本学の複数のプロジェクトの催しに参加し，行政へも積極的に意見を伝えている区民が存在していることが理解できた。

今回のプログラムは，安全への配慮，参加者ニーズへの適合による満足度の高さなどから判断して都市部におけるアウトリーチプログラムとしては妥当なものであったと考えられる。また，継続可能性の点からは，場所の確保と，教室卒業者，町会長，民生委員など地域の核となるメンバーとの協働が不可欠である。区民らとの協働により，大学が提供するプログラムが高齢者にとってより意味のあるものとなれば，継続性のあるプログラムになり得ると考えられる。将来は区民主導による高齢者の健康生成のためのプログラムへの発展による高齢者の健康生活と尊厳の維持に寄与することを期待している。

参加者への配布物一覧

・保存用ファイル
・転倒予防プログラム参加記録
・測定値の意味すること
・転倒骨折予防体操教室のご案内
・転倒予防のための住まいの注意点・工夫
・転倒骨折予防に効果的な食生活のポイント
・フットケアについて
・「生き活きネット」誌創刊号～第3号
・生き活き介護予防シリーズ④転倒骨折予防体操
・「老い支度」（全国訪問看護事業協会）

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引用文献

1)　新野直明．転倒リスクの多因子評価．Geriatric Medicine. 43 (1), 2005, 61－65.
2)　川上治，加藤雄一郎，大田壽城．高齢者における転倒・骨折の疫学と予防．日本老年医学会雑誌．43(1), 2006, 7－18.
3)　安村誠司，林泰史．わが国の在宅高齢者における転倒発生率　http://www2.eisai.co.jp/osteo/chapter09/chapter09_03.html〔2006－02－06〕
4)　江藤真紀．転倒の予防と看護．小玉敏江，亀井智子編著．高齢者看護学．東京，中央法規，2003，196－203.
5)　新野直明．高齢者の転倒による外傷とその関連要因．保健の科学．48(1), 2006, 26－28.
6)　西田裕紀子，新野直明，小笠原仁美他．地域在住中高年者における転倒恐怖感の要因に関する縦断的検討．日本未病システム学会雑誌．11(1), 2005, 101－103.
7)　転倒予防医学研究会　http://www.ellesnet.co.jp/tentou/aisatsu.html〔2006－02－06〕
8)　Hornbrook C, Stevens J, Wingfield J,. et. al.. Preventing falls among community-dwelling older persons: results from a randomized trial. Gerontologist. 34(1), 1994, 16-23.
9)　Tinetti ME, Baker DI, Mc Avay G, et. al.. A multifactorial intervention to reduce the risk of falling among elderly people living in the community Engl J Med. 331(13), 1994, 821－7.
10) Tinetti ME, Mc Avay G, Claus E. et. al Does multiple risk factor reduction explain the reduction in fall rate in the Yale FICSIT Trial? Frailty and Injuries Cooperative Studies of Intervention Techniques. Am J Epidemiol. 144(4), 1996, 389－99.
11) 三重県立看護大学・地域交流研究センター研究開発事業三重県における転倒予防ケアシステムの開発，転倒アセスメントツール．http://www.mcn.ac.jp/tentou/newpage72.htm.〔2006－02－06〕
12) 新野直明．高齢者の転倒予防事業．公衆衛生．69(9), 2005, 701－704.
13) 新野直明，西田裕紀子．高齢者の転倒予防活動事業に関する全国調査（Ⅱ），日本未病システム学会雑誌．12(1), 2006, 185－187.
14) 新野直明，高齢者の転倒予防活動事業に関する全国調査．日本未病システム学会雑誌．10(1), 2004, 94－96.
15) 植木章三，河西敏幸，高戸仁郎他．地域高齢者とともに転倒予防体操をつくる活動の展開．日本公衆衛生雑誌．53(2), 2006, 112－121.
16) 文部科学省．平成16年度体力・運動能力調査結果について－2．調査結果の概要．3(2)．バランス能力と歩行能力．2006.
17) 徳島県保健福祉部健康増進課　年代別体力データ http://www2.eiyo.shikoku-u.ac.jp/health/phy.html〔2006－11－09〕
18) Program Development and Evaluation-Logic Model http://www.uwex.edu/ces/pdande/evaluation/evallogicmodel.html〔2006－11－09〕

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ORIGINAL ARTICLE

Plasma fat concentration increases in visceral fat obese men during high-intensity endurance exercise

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Fat metabolism;
Free fatty acid;
Glycerol;
Fat oxidation;
Obesity phenotypes

Summary The purpose of this study was to investigate differences in fat metabolism between visceral fat obese (VF-Ob) and abdominal subcutaneous obese (SF-Ob) men during "high-intensity endurance exercise". Fourteen obese (body mass index >25 kg/m^2) men were classified into two groups according to visceral fat area using computed tomography; i.e., VF-Ob (n = 7; mean age, 52.0 ± 2.5 year) and SF-Ob (n = 7; mean age, 57.3 ± 2.8 year) groups. Plasma fat concentration and fat oxidation were measured at rest and during 60-min high-intensity (70% of peak oxygen uptake) stationary cycling exercise. Plasma concentrations of free fatty acid and glycerol were significantly higher ($P \leq 0.05$) in VF-Ob men compared with SF-Ob men during endurance exercise. However, no significant difference was found in fat oxidation between VF-Ob and SF-Ob men (697 ± 135 and 661 ± 96 kJ/h, respectively) during high-intensity endurance exercise. These results suggest that obesity phenotype affects plasma fat concentration even during high-intensity exercise. It is

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likely that plasma fat concentrations in visceral fat obese men during high-intensity endurance exercise are more increased compared with during moderate-intensity endurance exercise. Despite the difference in plasma fat concentration, total fat oxidation was similar in the two obese phenotypes.

Introduction

Visceral fat (VF) obesity is associated with metabolic abnormalities such as type 2 diabetes, hypertension, dyslipidemia, and cardiovascular diseases [1]. For improving and treating these abnormalities, it is important to prevent accumulation of VF.

Endurance exercise is beneficial in the treatment of obesity, as it promotes lipolysis, and oxidizes fat through increasing secretion of catecholamines and decreasing insulin levels [2,3]. *In vitro* studies have demonstrated that VF has a higher catecholamine-induced lipolysis [4,5], and lower insulin antilipolysis [6,7] than SF, so the lipolysis in VF during endurance exercise might be more enhanced than as compared with SF.

Previous studies [8,20]) have reported that, during moderate-intensity (45—50% maximal oxygen uptake (VO_2 max)) endurance exercise, plasma free fatty acid (FFA) concentration and fat oxidation were not different between lower-body and upper-body obese women. Another study [9] has reported that plasma fat concentration is greater in VF obese men than in SF obese men during moderate-intensity (50% VO_2 max) endurance exercise, while total fat oxidation was similar between obesity phenotypes. Although these results are not consistent, it seems that VF obesity has higher lipolytic response during moderate-intensity exercise.

Exercise intensity may affects the difference in lipolytic response between VF and SF obesity, since an increment in exercise intensity enhances the secretion of catecholamines and represses the secretion of insulin. Accordingly, plasma fat concentration could increase to a greater extent and fat could be more oxidized in VF obesity than in SF obesity during high-intensity exercise. This may be supported by previous intervention studies [10,11], both of which resulted in the preferential loss of VF induced by high-intensity endurance exercise among obese men. Moreover, American College of Sports Medicine [12] has recommended that exercise training intensity should be eventual progression to higher intensities (50—75%Vo_2 reserve or heart rate reserve) for effective treatments of obesity, because high-intensity exercise can produce a more negative energy balance (body fat loss) in reasonable amount of time. Therefore, it is helpful for supporting these ACSM's guideline to elucidate physiological metabolic response on VF obesity during "high-intensity" endurance exercise. However, fat metabolism in each obesity phenotype during "high-intensity" endurance exercise has not been investigated. With this in mind, the present study was undertaken to investigate whether obesity phenotype influenced fat metabolism during "high-intensity" cycling endurance exercise in obese men.

Methods

Participants

Fourteen middle-aged obese men (body mass index [BMI] >25 kg/m^2) [13] participated in this study. Participants were recruited through advertisements in local newspapers. Participants were classified into two groups (visceral fat obesity [VF-Ob] group and abdominal subcutaneous fat obesity [SF-Ob] group) based on visceral fat area (VFA) at the level of the umbilicus using a CT scan. VFA for classification was 150 cm^2; namely, the VF-Ob group ($n = 7$) had a VFA greater than 150 cm^2, and the SF-Ob group ($n = 7$) had a VFA less than 150 cm^2. Participants were not involved in regular exercise training. No participant was smoking, and was on any medications known to affect fat metabolism. All participants were weight-stable (<3 kg weight change) for at least the previous 2 months. The aim and design of the study were explained to each participant before they gave their written informed consent. This study conformed to the principles outlined in the Helsinki Declaration, and was approved by the Graduate School of Comprehensive Human Sciences, University of Tsukuba Review Board.

Body composition and abdominal fat area

Whole-body fat mass (FM) and fat-free mass (FFM) were measured by the bioelectrical impedance method (HBF-300, Omron, Tokyo, Japan). Visceral fat area (VFA) and abdominal subcutaneous fat area (SFA) were measured by CT scan (SOMATOM ARC, Siemens, Germany) performed in the supine position. A single 5-mm scan with a scanning time of 5 s was obtained, centered at the level of the umbilicus (fourth and fifth lumbar vertebrae), because it was found that VFA from a single scan highly correlated with overall visceral volume [14]. VFA and SFA were calculated using the Fat Scan computer software program (N2system, Osaka, Japan) [15].

Peak oxygen consumption

Vo_2 peak for each participant was determined using a graded exercise test with a cycling ergometer (818E, Monark, Stockholm, Sweden) [9]. Briefly, following a 2-min warming-up at 0 Watt (W), workload was increased every 1 min by 15 W until volitional exhaustion. During the test, ventilations and gas exchanges were measured using indirect calorimetry (Oxyconα, Mijnhardt, Breda, The Netherlands), and heart rate was monitored using electrocardiography (Dyna Scope, Fukuda Denshi, Tokyo, Japan).

Protocol

Participants were not allowed to perform strenuous exercise for 48 h before each measurement. They were instructed to consume a standard meal (50% carbohydrate, 30% fat, 20% protein) on the evening before the study and recorded the meal on the diary. Following more than 12 h overnight fast, participants arrived at the Higashi Toride Hospital. An exercise trial was started at 9:00 a.m. for each participant. Upon each participant's arrival at the examination room, a catheter was placed in an arm vein to allow withdrawal of blood samples at rest and during exercise.

Participants performed a cycling exercise for 60 min at a work rate corresponding to 70% of predetermined Vo_2 peak. Gas exchanges were measured at rest and at 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 min of exercise using indirect calorimetry (Oxyconα, Mijnhardt, Breda, The Netherlands). Substrate oxidation rates were calculated from respiratory exchange ratio (RER) [16]. Energy expenditure and substrate oxidation were calculated every 5 min from measurement of gas exchanges. Total energy expenditure and substrate oxidation were defined as the sums of every 5 min energy expenditure and substrate oxidation.

Blood analysis

Blood samples were collected to measure plasma concentrations of FFA, glycerol, epinephrine, norepinephrine, and insulin. Plasma concentrations of FFA were analyzed by an enzymatic colorimetric method (ACS-ACOD). Plasma concentrations of insulin were measured by a radioimmunoassay (RIA). Plasma concentrations of glycerol were determined by an enzymatic colorimetric method (GPO-DAOS). Plasma concentrations of epinephrine and norepinephrine were quantified by high performance liquid chromatography (HPLC).

Statistical analysis

All data were expressed as means ± S.E. An unpaired *t*-test was used to test significance of differences in anthropometric variables, total energy expenditure, and fat oxidation during endurance exercise between VF-Ob and SF-Ob men. A repeated measures two-way ANOVA, with group and time as factors, was used to determine differences in metabolite concentrations and RER kinetics between VF-Ob and SF-Ob men during endurance exercise. When a significance interaction was obtained, an unpaired *t*-test such as a *post hoc* comparison test was performed (if there was no homogeneity, a Mann—Whitney test was used) to

Table 1 The characteristics of participants in the VF-Ob and SF-Ob groups

	VF-Ob (n = 7)	SF-Ob (n = 7)
Age (years)	52.0 ± 2.5	57.3 ± 2.8
Height (cm)	168.6 ± 1.8	167.5 ± 2.1
Body weight (kg)	81.0 ± 3.2	75.4 ± 1.5
Body mass index (kg/m^2)	28.4 ± 0.7	26.9 ± 0.2
Body fat mass (kg)	22.4 ± 1.2	21.5 ± 1.3
Body fat-free mass (kg)	58.6 ± 2.5	53.9 ± 1.8
VO_{max} (mL/kg/min)	31.1 ± 1.7	30.5 ± 1.6
Abdominal fat area		
Total fat area (cm^2)	380.8 ± 16.7	332.7 ± 21.1
Visceral fat area (cm^2)	193.0 ± 13.0[a]	133.5 ± 5.1
Subcutaneous fat area (cm^2)	187.7 ± 13.3	199.3 ± 18.9

Values are mean ± S.E.
[a] Significantly different from SF-Ob ($P \leq 0.05$).

locate significant differences. Level of significance was set at $P \leq 0.05$.

Results

Physical characteristics of VF-Ob and SF-Ob groups are presented in Table 1. Mean VFA was significantly higher in the VF-Ob group ($193.0 \pm 13.6\,cm^2$) than in the SF-Ob group ($133.5 \pm 5.1\,cm^2$). No significant difference was found in any other variables between the VF-Ob and SF-Ob groups.

There were no differences in absolute (Vo_2) and relative intensity (%Vo_2 peak) between the VF-Ob and SF-Ob groups during exercise.

Plasma hormonal kinetics during endurance exercise are shown in Fig. 1. Plasma concentrations of epinephrine and norepinephrine progressively increased in the two groups during endurance exercise. There was a significant group × time interaction in plasma concentration of norepinephrine kinetics. Plasma insulin concentration progressively decreased in the two groups, but there was a no significant difference in plasma insulin concentration between the two groups during exercise.

Plasma FFA and glycerol concentration kinetics during endurance exercise are shown in Fig. 2. Plasma FFA concentration progressively increased in both VF-Ob (from 0.74 ± 0.06 mmol/L at rest to 3.21 ± 0.50 mmol/L at end of exercise) and SF-Ob men (from 0.55 ± 0.08 mmol/L at rest to 1.64 ± 0.20 mmol/L at end of exercise). A significant group × time interaction was observed in plasma FFA concentration during the exercise bout. After the first 40 min of exercise, plasma FFA concentration was significantly greater in VF-Ob men than in SF-Ob men. Plasma glycerol concentration also progressively increased in both groups. There was a significant group × time interaction in plasma glycerol concentration during the exercise bout. After the first 20 min of exercise, plasma glycerol concentration was higher in VF-Ob men than in SF-Ob men. Changes in RER during endurance exercise are shown in Fig. 3. RER initially increased during the first 5 min of exercise, and then progressively decreased. Changes and values in RER during exercise were not significantly different between the two groups. Total energy expenditure and fat oxidation during endurance exercise are shown in Fig. 4. There was no difference in total energy expenditure between the VF-Ob (2282 ± 144 kJ/h) and SF-Ob (1969 ± 119 kJ/h) groups. In addition, no difference was found in fat oxidation during exercise between the two groups (VF-Ob men, 697 ± 135 kJ/h; SF-Ob men, 661 ± 96 kJ/h).

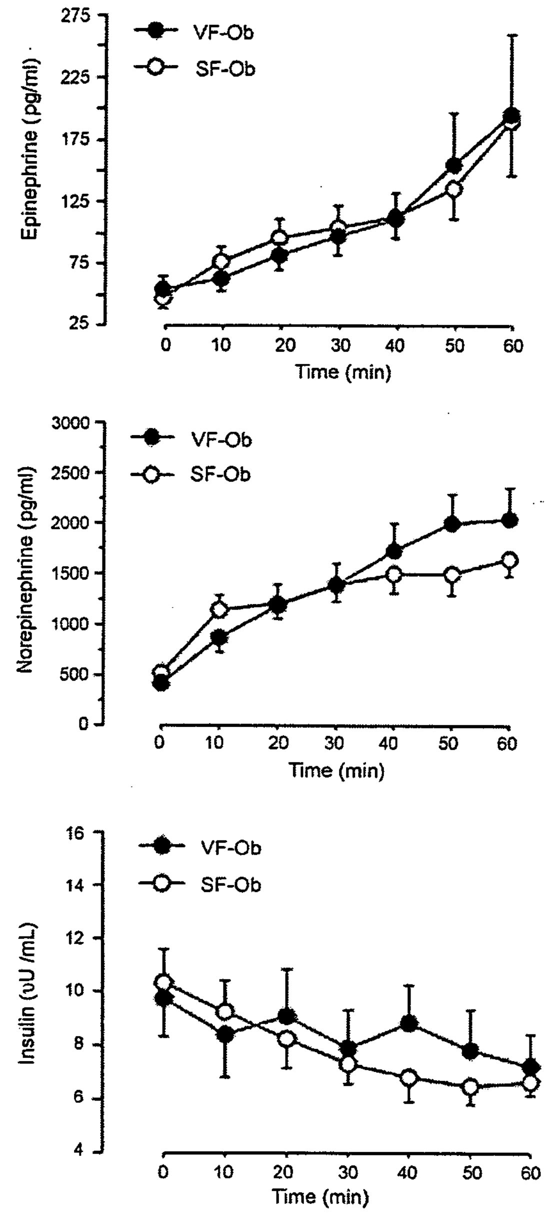

Figure 1 Changes in plasma concentrations of epinephrine (upper graph), norepinephrine (middle graph) and insulin (lower graph) in VF-Ob and SF-Ob men during 60-min high-intensity endurance exercise. There was a significant group × time interaction ($P \leq 0.05$) in plasma concentration of norepinephrine. Values are means ± S.E.

Discussion

The present study revealed that kinetics of plasma fat concentration during "high-intensity" endurance exercise were different between VF-Ob and SF-Ob men. Despite the fact that plasma fat concentration was different, total energy expendi-

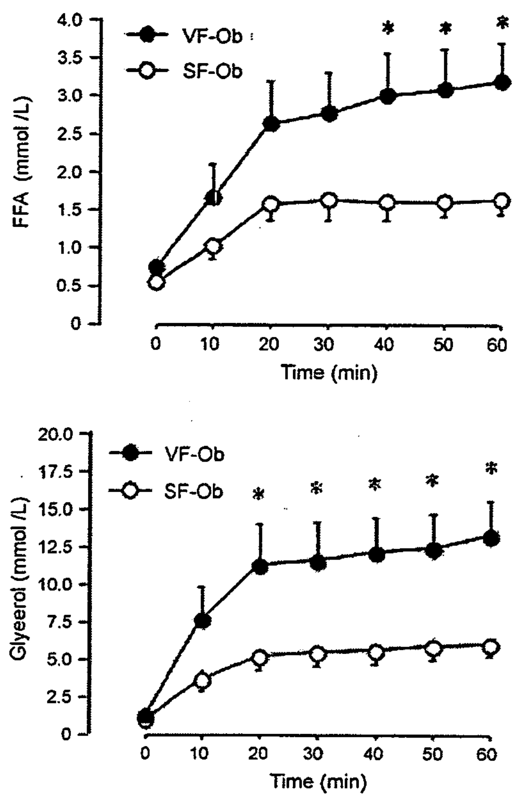

Figure 2 Changes in plasma concentrations of free fatty acid (FFA) (upper graph) and glycerol (lower graph) in VF-Ob and SF-Ob men during 60-min high-intensity endurance exercise. There was a significant group × time interaction ($P \leq 0.05$). * Significantly different from SF-Ob men ($P \leq 0.05$). Values are means ± S.E.

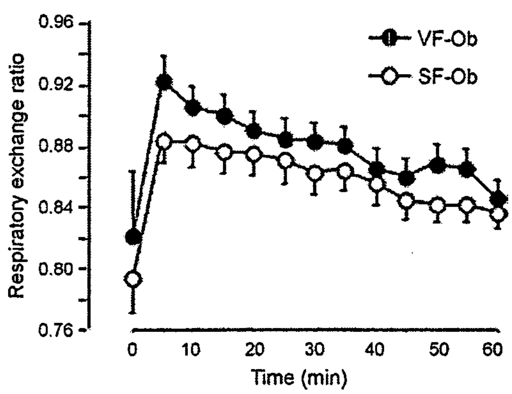

Figure 3 Changes in respiratory exchange ratio (RER) in VF-Ob and SF-Ob men during 60-min high-intensity endurance exercise. There was no significant group × time interaction ($P > 0.05$). Values are means ± S.E.

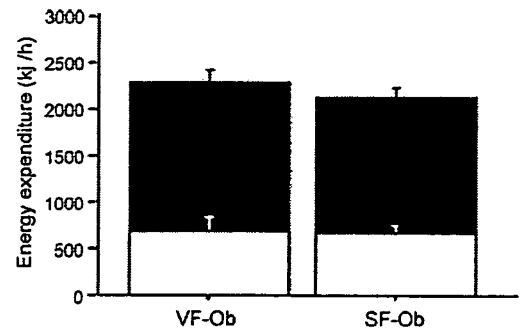

Figure 4 Total energy expenditure including fat (open bar) and carbohydrate (filled bar) in VF-Ob and SF-Ob men during 60-min high-intensity endurance exercise. There were no differences in total energy expenditure, carbohydrate oxidation, and fat oxidation between VF-Ob and SF-Ob men ($P > 0.05$). Values are means ± S.E.

ture and fat oxidation were similar between VF-Ob and SF-Ob men during "high-intensity" endurance exercise.

Despite a similar exercise intensity between the two groups, kinetics of plasma norepineprine concentration were different between VF-Ob and SF-Ob men during the high-intensity exercise bout in this study. Since plasma fat concentrations are greatly influenced by several hormones, e.g., catecholamines and insulin, both at rest and during exercise [2,3], the difference can be accounted for by differences in plasma fat concentrations between the two obese groups during endurance exercise.

It is possible that alterations in regional adipose tissue lipolysis also contributed to the differences in plasma fat concentrations during endurance exercise. *In vitro* studies have reported that lipolytic response to catecholamines was higher in visceral adipocytes than in subcutaneous adipocytes [4,5], and especially, lipolysis of VF was higher in visceral obesity than in subcutaneous obesity [17]. In addition, antilipolysis and activation of FFA re-esterification response to insulin are lower in visceral adipocytes than in subcutaneous adipocytes [6,7]. Recently, it has also been demonstrated that splanchnic fatty acid release, an indirect measure of portally drained lipolysis, accounted for 17% of systemic FFA release in obese men *in vivo* [18]. Meanwhile, Horowitz and Klein [19] suggested that the uptake of plasma fatty acid during exercise was similar in both lean and abdominally obese subjects. Thus, our results suggest that differences in plasma fat concentrations between VF and the SF-Ob men during endurance exercise might partly reflect differences in lipolytic characteristics between visceral and subcutaneous fat.

Difference in fat concentration in VF and SF-Ob men during endurance exercise observed in our study are in agreement with data from a previous study that investigated fat metabolism between two obesity phenotypes in obese men during moderate-intensity endurance exercise [9]. However, exercise intensity was different between the present and previous study [9]; that is, the intensity was 70%Vo_2 peak in the present study, and was 50%Vo_2 peak in the previous study. It is known that increasing exercise intensity changes plasma concentration of hormones, and influences lipolysis during endurance exercise [2,3]. High concentrations of epinephrine and norepinephrine were observed in this study, and difference in plasma fat concentrations between VF-Ob and SF-Ob men enlarged compared with the previous study [9]. These results suggest that high-intensity exercise could be more effective for promoting plasma fat concentrations in VF-Ob men than moderate-intensity exercise.

On the contrary, our results contradict results of previous studies [8,20]. This discrepancy may be due to differences in lipolysis in visceral fat depending on gender of participants. Previous studies were conducted in obese women, but not in obese men. Obese women have lower lipolytic sensitivity and higher antilipolytic sensitivity of visceral adipocytes compared with obese men [21]. Moreover, rate of lipolysis response to norepinephrine of visceral fat is similar to that of subcutaneous fat in obese women, but it is greater than that of subcutaneous fat in obese men [22]. These data suggest that lipolysis of visceral fat depends on gender, and these differences may be responsible for differences in plasma fat concentration between the present and previous studies. The second reason is the differences in indices used to classify obesity phenotypes. Previous studies used WHR [23] as an index for phenotype classification; UB and LB obesity [8,20]. Our study used CT, a known "gold standard" method for determination of abdominal fat accumulation [24]. Disagreement between the present and previous studies [8,20] may be due to differences in estimations of volumes between visceral and subcutaneous fat. It should be noted that differences in methodologies for evaluating abdominal fat accumulation might affect the results.

Total energy expenditure and fat oxidation during endurance exercise were similar between VF-Ob and SF-Ob men. Despite a higher exercise intensity in our study than that in previous studies, our findings are in agreement with results from previous studies [8,9,20,25]. Therefore, our data suggest that even if exercise intensity increases, total energy expenditure and fat oxidation during endurance exercise are not different between obesity phenotypes.

In summary, the present study demonstrates that plasma fat concentration is influenced by obesity phenotype even during high-intensity endurance exercise. Also, it is likely that plasma fat concentrations in visceral fat obese men during high-intensity endurance exercise are more increased compared with during moderate-intensity endurance exercise. Regardless of the increased plasma fat concentration in visceral fat obese men, total fat oxidation during high-intensity endurance exercise is similar between two obesity phenotypes as during moderate-intensity endurance exercise.

References

[1] Despres JP. Is visceral fat obesity the cause of the metabolic symdrom? Ann Med 2006;38:52–63.

[2] Romijn JA, Coyle EF, Sidossis LS, Gastaldelli A, Horowitz JF, Endert E, et al. Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. Am J Physiol 1993;265:E380–91.

[3] Romijn JA, Coyle EF, Sidossis LS, Rosenblatt J, Wolfe RR. Substrate metabolism during different exercise intensities in endurance-trained women. J Appl Physiol 2000;88:1707–14.

[4] Hellmer J, Marcus C, Sonnenfeld T, Arner P. Mechanisms for differences in lipolysis between human subcutaneous and omental fat cells. J Clin Endocrinol Metab 1992;75:15–20.

[5] Hoffstedt J, Arner P, Hellers G, Lonnqvist F. Variation in adrenergic regulation of lipolysis between omental and subcutaneous adipocytes from obese and non-obese men. J Lipid Res 1997;38:795–804.

[6] Bolinder J, Kager L, Ostman J, Arner P. Differences at the receptor and postreceptor levels between human omental and subcutaneous adipose tissue in the action of insulin on lipolysis. Diabetes 1983;32:117–23.

[7] Zierath JR, Livingston JN, Thorne A, Bolinder J, Reynisdottir S, Lonnqvist F, et al. Regional difference in insulin inhibition of non-esterified fatty acid release from human adipocytes: relation to insulin receptor phosphorylation and intracellular signalling through the insulin receptor substrate-1 pathway. Diabetologia 1998;41:1343–54.

[8] van Aggel-Leijssen DP, Saris WH, Wagenmakers AJ, Hul GB, van Baak MA. The effect of low-intensity exercise training on fat metabolism of obese women. Obes Res 2001;9:86–9.

[9] Numao S, Hayashi Y, Katayama Y, Matsuo T, Tomita T, Ohkawara K, et al. Effects of obesity phenotype on fat metabolism in obese men during endurance exercise. Int J Obes 2006;30:1189–96.

[10] Mourier A, Gautier JF, De Kerviler E, Bigard AX, Villette JM, Garnier JP, et al. Mobilization of visceral adipose tissue related to the improvement in insulin sensitivity in response to physical training in NIDDM. Effects of branched-chain amino acid supplements. Diabetes Care 1997;20:385–91.

[11] Ross R, Dagnone D, Jones PJH, Smith H, Paddags A, Hudson R, et al. Reduction in obesity and relate comorbid conditions after diet-induced weight loss or exercise-induce weight loss in men. Ann Intern Med 2000;133:92–103.

[12] American College of Sports Medicine. Other clinical conditions influencing exercise prescription. In: Whaley MH,

editor. ACSM's guidelines for exercise testing and prescription. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2006. p. 205–36.

[13] Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity. New criteria for 'obesity disease' in Japan. Circ J 2001;66:987–92.

[14] Borkan GA, Gerzof SG, Robbins AH, Hults DE, Silbert CK, Silbert JE. Assessment of abdominal fat content by computed tomography. Am J Clin Nutr 1982;36:172–7.

[15] Yoshizumi T, Nakamura T, Yamane M, Islam AH, Menju M, Yamasaki K, et al. Abdominal fat: standardized technique for measurement at CT. Radiology 1999;211:283–6.

[16] Peronnet F, Massicotte D. Table of nonprotein respiratory quotient: an update. Can J Sport Sci 1991;16:23–9.

[17] Busetto L, Digito M, Dalla Monta P, Carraro R, Enzi G. Omental and epidastric adipose tissue lipolytic activity in human obesity. Effect of abdominal fat distribution and relationship with hyperinsulinemia. Horm Metab Res 1993;25:365–71.

[18] Nielsen S, Guo Z, Johnson CM, Hensrud DD, Jensen MD. Splanchnic lipolysis in human obesity. J Clin Invest 2004;113:1582–8.

[19] Horowitz JF, Klein S. Oxidation of nonplasma fatty acids during exercise is increased in women with abdominal obesity. J Appl Physiol 2000;89:2276–82.

[20] Kanaley JA, Cryer PE, Jensen MD. Fatty acid kinetic responses to exercise. Effects of obesity, body fat distribution, and energy-restricted diet. J Clin Invest 1993;92:255–61.

[21] Lonnqvist F, Thorne A, Large V, Arner P. Sex differences in visceral fat lipolysis and metabolic complications of obesity. Arterioscler Thromb Vasc Biol 1997;17:1472–80.

[22] Rebuffe-Scrive M, Anderson B, Olbe L, Bjorntorp P. Metabolism of adipose tissue in intraabdominal depots in severely obese men and women. Metabolism 1990;39:1021–5.

[23] Kissebah AH, Vydelingum N, Murray R, Evans DJ, Hartz AJ, Kalkhoff RK, et al. Relation of body fat distribution to metabolic complications of obesity. J Clin Endocrinol Metab 1982;54:254–60.

[24] Chowdhury B, Sjostrom L, Alpsten M, Kostanty J, Kvist H, Lofgren R. A multicompartment body composition technique based on computerized tomography. Int J Obes Relat Metab Disord 1994;18:219–34.

[25] Swan PD, Howley ET. Substrate utilization during prolonged exercise in obese women differing in body fat distribution. Int J Obes Relat Metab Disord 1993;18:263–8.

Effects of Aerobic Exercise on Metabolic Syndrome Improvement in Response to Weight Reduction

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Abstract

OKURA, TOMOHIRO, YOSHIO NAKATA, KAZUNORI OHKAWARA, SHIGEHARU NUMAO, YASUTOMI KATAYAMA, TOMOAKI MATSUO, AND KIYOJI TANAKA. Effects of aerobic exercise on metabolic syndrome improvement in response to weight reduction. *Obesity*. 2007;15:2478–2484.

Objective: The objective was to test effects of aerobic exercise training on metabolic syndrome (MetSyn) improvement in response to weight reduction.

Research Methods and Procedures: A total of 459 overweight and obese women (age, 49 ± 9 years; BMI, 28 ± 3 kg/m^2) were recruited for a baseline examination to test the relationship between cardiorespiratory fitness and metabolic syndrome prevalence; among these, 67 subjects with MetSyn were treated with 14-week weight-loss programs, which included low-calorie diet and aerobic exercise. The MetSyn was defined according to the Examination Committee of Criteria for "Metabolic Syndrome" in Japan. Maximal oxygen uptake ($\dot{V}O_{2max}$) during a maximal cycling test was measured as an index of cardiorespiratory fitness at baseline and after the intervention.

Results: In the baseline examination, age- and BMI-adjusted odds ratios for MetSyn prevalence in the low, middle, and upper thirds of $\dot{V}O_{2max}$ were 1.0 (referent), 0.50 (95% confidence interval, 0.26 to 0.95), and 0.39 (95% confidence interval, 0.14 to 0.96), respectively (linear trend, p = 0.02). The adjusted odds ratios for MetSyn improvement in the two interventions with diet alone and diet plus exercise were 1.0 and 3.68 (95% confidence interval, 1.02 to 17.6; p = 0.04), respectively.

Discussion: These results suggest that adding aerobic exercise training to a dietary weight-reduction program further improves MetSyn (adjusted odds ratio, 3.68) in obese women, compared with diet alone. Further studies on an association between $\dot{V}O_{2max}$ change and MetSyn improvement are needed.

Key words: exercise intervention, diet, aerobic exercise, metabolic syndrome

Introduction

Metabolic syndrome is a cluster of interrelated risk factors (visceral obesity, dyslipidemia, hyperglycemia, and hypertension) (1) that increase susceptibility to cardiovascular disease (2,3) and type 2 diabetes (4,5). The National Cholesterol Education Program's Adult Treatment Panel III report (6) stated that the increasing prevalence of obesity has been accompanied by a parallel increase in the prevalence of metabolic syndrome, which together constitutes the "obesity epidemic."

Cross-sectional data indicate that high levels of cardiorespiratory fitness are associated with low prevalence of metabolic syndrome (7–9). Several prospective studies have found that cardiorespiratory fitness is a significant predictor for metabolic syndrome incidence (10,11). Another study found that 20 weeks of aerobic exercise training reduced metabolic syndrome prevalence (12). Clinical intervention studies in obese people have also revealed that regular aerobic exercise training clearly improves risk factors for metabolic syndrome (13,14).

Detecting metabolic syndrome in asymptomatic obese individuals is useful in identifying high-risk individuals for intensive primary preventive therapy (15), and lifestyle

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therapy is recognized as an important approach in the various clinical and educational settings of obesity treatment. However, little is known of the effects of diet and/or aerobic exercise training on metabolic syndrome improvement in obese individuals.

We have investigated these issues in overweight and obese Japanese women. On the basis of the studies cited above, we hypothesized that change in cardiorespiratory fitness, defined as maximal oxygen uptake ($\dot{V}O_{2max}$)[1], would be a predictor for improvement in metabolic syndrome in obese subjects during weight reduction. We first determined whether cardiorespiratory fitness was associated with metabolic syndrome prevalence at baseline. Next, we assigned subjects with metabolic syndrome to two treatment groups, which received diet therapy alone or with aerobic exercise training, and we investigated the effects of cardiorespiratory fitness change and these two treatments on metabolic syndrome improvement during weight reduction.

Research Methods and Procedures

Subjects

Participants were sedentary overweight and obese Japanese women who were recruited through advertisements in local newspapers in Ibaraki prefecture, Japan, and participated in a 14-week weight-reduction program between 2000 and 2004. Before the program, we excluded subjects who smoked, had concomitant renal, hepatic, or cardiac disease, or were being treated with hormone replacement or drugs, which could affect the variables of the study. Consequently, 459 women, 34 to 66 years of age, were chosen as subjects (Table 1) after they met the following criteria: 1) sedentariness, defined as exercise-induced energy expenditure of <60 minutes/wk, and 2) overweight or obesity, defined as a BMI of, respectively, >25 kg/m^2 and >30 kg/m^2 (16). Of these women, 185 were postmenopausal and 274 were premenopausal. Menopause was defined as the absence of menses for at least 12 months, as reported by questionnaire. This study conformed to the principles outlined in the Helsinki Declaration and was approved by the Review Board of the University of Tsukuba. The aim and design of the study were explained to each subject before she gave her written, informed consent.

Research Procedures

First, we cross-sectionally examined the relationship between cardiorespiratory fitness and metabolic syndrome prevalence in all subjects. Next, 67 subjects were diagnosed as having the metabolic syndrome according to the criteria for the Japanese population, which are described below (17). To increase subjects' adherence to the weight loss programs, the subjects' personal lifestyles (occupations, daily schedules, etc.) and preferences were taken into account, and the 67 subjects were assigned to two 14-week weight-reduction programs consisting of a low-calorie diet (n = 24; target energy intake, 1200 kcal/d) or the diet-plus-aerobic exercise (n = 43). Three subjects in the diet alone group and 5 in the diet plus exercise group were unable to complete the study successfully for personal reasons. As a consequence, 21 subjects in the diet alone group and 38 subjects in the diet plus exercise group completed the study requirements. Assays and measurements were carried out before and after the 14-week intervention period. We prospectively examined the relationship between cardiorespiratory fitness change and metabolic syndrome improvement in response to weight reduction.

Table 1. Baseline characteristics of subjects (n = 459)

Characteristic	Value
Age (yrs)	49 ± 9
BMI (kg/m^2)	27.5 ± 3.4
Waist (cm)	99.4 ± 9.5
Visceral fat area (cm^2)	96 ± 47
Systolic BP (mm Hg)	132 ± 18
Diastolic BP (mm Hg)	83 ± 11
Triglycerides (mM)	1.21 ± 0.86
HDL-C (mM)	1.64 ± 0.39
Glucose (mM)	5.49 ± 1.16
$\dot{V}O_{2max}$ (mL/kg per min)	25.2 ± 4.0
$\dot{V}O_{2max}$ (mL/min)	1714 ± 280
Visceral fat obesity (%)	42
High BP (%)	54
High triglycerides (%)	16
Low HDL-C (%)	2
High glucose (%)	13
No. of subjects with metabolic syndrome (%)	67 (15)

BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; $\dot{V}O_{2max}$, maximal oxygen uptake. Values are mean ± SD unless specified otherwise.

Anthropometric Variables

Body mass was measured to the nearest 0.1 kg using a digital scale, height was measured to the nearest 0.1 cm using a wall-mounted stadiometer, and BMI was calculated as mass (kg) divided by height squared (m^2). Waist girth was measured to the nearest 0.1 cm at the level of the umbilicus with subjects in the standing position.

[1] Nonstandard abbreviations: $\dot{V}O_{2max}$, maximal oxygen uptake; CT, computed tomography; CI, confidence interval.

Visceral Fat Area by CT Scans

Visceral fat area (cm^2) was measured at the level of the umbilicus (L4–L5) using computed tomography (CT) scans (SCT-6800TX, Shimadzu, Tokyo, Japan) performed on subjects in the supine position and was calculated using a computer software program (FatScan, N2system, Osaka, Japan) (18). The intra-class correlation for repeated determinations of visceral fat area in our laboratory was 0.99.

Definition of Metabolic Syndrome

For the Japanese population, the Examination Committee of Criteria for "Metabolic Syndrome" in Japan (17) defined metabolic syndrome as the presence of visceral fat obesity (visceral fat area $\geq$100 cm^2) and two or more of the following criteria: 1) triglycerides $\geq$1.70 mM (150 mg/dL) and/or high-density lipoprotein cholesterol <1.04 mM (40 mg/dL), 2) systolic blood pressure $\geq$140 mm Hg and/or diastolic blood pressure $\geq$90 mm Hg, and 3) fasting plasma glucose $\geq$6.1 mM (110 mg/dL). Systolic and diastolic blood pressures were taken from the left arm using a sphygmomanometer after the subjects rested at least 20 minutes in a sitting position. Cuff sizes were selected based on upper arm girth and length. A blood sample of ~10 mL was drawn from each subject after an overnight fast. Triglycerides were determined enzymatically, and fasting plasma glucose was assayed by a glucose oxidase method. Serum high-density lipoprotein-cholesterol was measured by the heparin-manganese precipitation method.

Maximal Oxygen Uptake

Maximal oxygen uptake ($\dot{V}O_{2max}$, mL/kg per min and mL/min) was determined during a graded exercise test using a cycle ergometer (818E, Monark, Stockholm, Sweden). After a 2-minute warm-up, the subject started with a workload of 15 W, which was increased by 15 W each minute until volitional exhaustion occurred. Pulmonary ventilation and gas exchange were measured breath-by-breath with an online data acquisition system (Oxycon α System, Mijnhardt, Breda, Netherlands).

Diet and Exercise Regimens

Dietary Protocol. Subjects were instructed to take a well-balanced supplemental food product (MicroDiet, Sunny-Health, Nagano, Japan) every day. It was developed for very low-energy diets (170 kcal per pack) and is comprised of protein, carbohydrates, fat, various amino acids, vitamins, and minerals. Two other meals per day were allowed, consisting, on average, of 240 kcal of protein, 480 kcal of carbohydrate, and 240 kcal of fat. Subjects also kept daily food diaries during the 14-week intervention period and learned about proper daily nutrition through weekly lectures and counseling by skilled dieticians.

Exercise Protocol. In addition to restricting energy intake, the subjects from the diet plus exercise training group performed a bench-stepping exercise 3 days/wk for 45 minutes per session, supervised in the hospital by two or three physical trainers. The bench-stepping exercise is a combination exercise of low impact aerobic dance and stepping with a step bench (10 to 20 cm high) (19). The exercise started with basic steps for the first 4 weeks and then progressed to combination of basic steps and lunge steps for the next 6 weeks, and finally progressed to more advanced lunge steps for the last 4 weeks. Subjects were instructed to perform the aerobic dance at a level that raised their heart rate to 70% to 85% of the corresponding heart rate at their $\dot{V}O_{2max}$. The target Borg's scale (ratings of perceived exertion) (20) ranged from 13 (fairly hard) to 17 (very hard).

Statistical Analysis

Values are mean ± standard deviation. Paired *t* tests were used to assess differences between variables before and after the weight-reduction intervention period. Unpaired *t* tests were used to test difference in variables between the two treatment groups. Qualitative data were analyzed by a χ^2 test. We used logistic regression to estimate odds ratios and 95% confidence intervals (CIs) as an index of the strength of associations between cardiorespiratory fitness and metabolic syndrome prevalence or improvement, and between treatment (diet alone vs. diet plus exercise) and metabolic syndrome improvement. Multivariate analyses were adjusted for age (years), menopause (yes/no), BMI (kg/m^2), and body weight change (kg). General linear model analyses [repeated-measure two-by-two way (baseline vs. after treatment) ANOVA with post hoc tests] were used to test for difference in measurement variables between groups with diet alone and diet plus exercise, and between baseline and after treatment. In each statistical analysis, probability values below 0.05 were regarded as significant. The data were analyzed with the Statistical Analysis System, version 9.01 for Microsoft Windows (SAS Institute, Inc., Cary, NC).

Results

At baseline, we observed an inverse gradient (linear trend, $p < 0.05$) of age- and BMI-adjusted odds ratios for metabolic syndrome prevalence in the low (average $\dot{V}O_{2max}$, 20.8 mL/kg per min), middle (average $\dot{V}O_{2max}$, 25.2 mL/kg per min), and upper (average $\dot{V}O_{2max}$, 29.5 mL/kg per min) thirds of $\dot{V}O_{2max}$. They were 1.0 (referent), 0.50 (95% CI, 0.26 to 0.95), and 0.39 (95% CI, 0.14 to 0.96), respectively (linear trend, $p = 0.02$) (Table 2). The significant trend (linear trend, $p = 0.03$) remained after adjustment for age, BMI, and menopausal status. The adjusted risks of metabolic syndrome were 48% (−6% to 75%) and 63% (−4% to 87%) lower in the middle and upper thirds of fitness, respectively, compared with the lower third. On average, each 1 mL/kg per min increment in $\dot{V}O_{2max}$ was associated with 7% lower risk of metabolic syndrome.

Table 2. Odds ratios and 95% CIs for metabolic syndrome according to $\dot{V}O_{2max}$ (mL/kg per min)

Covariates	$\dot{V}O_{2max}$ tertile Low	Middle	High	Linear trend (p)
All (n = 459)				
No adjustment	1.0 (referent)	0.38 (0.21 to 0.68)	0.13 (0.05 to 0.28)	<0.001
Age, baseline BMI	1.0 (referent)	0.50 (0.26 to 0.95)	0.39 (0.14 to 0.96)	0.02
Age, menopause, baseline BMI	1.0 (referent)	0.52 (0.25 to 1.06)	0.37 (0.13 to 1.04)	0.03
Postmenopausal (n = 143)				
No adjustment	1.0 (referent)	0.39 (0.15 to 0.96)	0.24 (0.08 to 0.66)	<0.01
Age, baseline BMI	1.0 (referent)	0.45 (0.16 to 1.21)	0.45 (0.13 to 1.47)	0.14
Premenopausal (n = 212)				
No adjustment	1.0 (referent)	0.35 (0.09 to 1.12)	0.18 (0.03 to 0.70)	0.02
Age, baseline BMI	1.0 (referent)	0.53 (0.13 to 1.83)	0.34 (0.06 to 2.14)	0.26

CI, confidence interval; $\dot{V}O_{2max}$, maximal oxygen uptake.

Sixty-seven women (15% of all subjects) were diagnosed as having metabolic syndrome. The subjects were assigned to two groups, treated with a low-calorie diet (n = 24) or the diet-plus-aerobic exercise training (n = 43) (Table 3). Three subjects in the diet alone group and five in the diet plus exercise group were unable to complete the weight-reduction program successfully, for personal reasons. Consequently, 21 subjects in the diet alone group and 38 subjects in the diet plus exercise group were included in the final analysis. The average weight reductions in the diet group and diet plus exercise group were 6.0 kg and 8.8 kg, respectively. The prevalence of metabolic syndrome and metabolic syndrome risk factors was significantly decreased and improved in both groups. For the group treated with diet alone, of the 21 subjects with the metabolic syndrome at baseline, 15 (71%) were no longer diagnosed with the metabolic syndrome after the weight-loss treatment. For the group treated with diet plus exercise, of the 38 subjects with the metabolic syndrome at baseline, 36 (95%) were no longer diagnosed as having the metabolic syndrome after the weight-loss treatment.

We next examined whether treatment (diet alone vs. diet plus exercise) affected metabolic syndrome improvement in response to weight reduction (Table 4). The adjusted odds ratios in the groups with diet alone and diet plus exercise for metabolic syndrome improvement were 1.0 (referent) and 3.68 (95% CI, 1.02 to 17.6; linear trend, p = 0.04).

Discussion

Several organizations have recommended clinical criteria for the diagnosis of the metabolic syndrome (1,21). There are some slight differences in the criteria for diagnosis of the metabolic syndrome used by these organizations. According to the definition of the World Health Organization (22), insulin resistance is a required component and two other risk factors are sufficient for a diagnosis of metabolic syndrome. The National Cholesterol Education Program's Adult Treatment Panel III has stated that when three of five listed characteristics are present, a diagnosis of metabolic syndrome can be made (6). The criteria of the International Diabetes Federation include "central obesity" as an essential component and ethnic-specific values for waist girth (23). In the present study, we used Japanese-specific criteria recommended by the Examination Committee of Criteria for Metabolic Syndrome in Japan (17). This is in accordance with the International Diabetes Federation definition, whereas a slight difference was found in the criteria of low high-density lipoprotein cholesterol and high fasting plasma glucose between the two organizations. It is well known that Japanese individuals are likely to develop obesity-related disorders with even mild obesity (24). Inter-relations among anthropometric variables, body composition, fat distribution, and lipid/glucose metabolism, which may be affected by genetic factors, are quite different in the Japanese, U.S., and European populations. Therefore, we decided to use the Japanese-specific definition of metabolic syndrome.

A few prospective studies have revealed that physical activity and cardiorespiratory fitness are predictors of metabolic syndrome incidence (10,11). One study reported that a 20-week supervised aerobic exercise training reduced metabolic syndrome prevalence by 31% (12). The subjects in the above studies, however, were not all obese. Clinical intervention studies have shown that regular aerobic exercise training clearly improved risk factors for metabolic syndrome in obese people (13,14), but no study, to our