F. 健康危険情報

なし

G. 研究発表

なし

表２　分析したSNPとその頻度

SNP_ID	シンボル	多型頻度			アレル頻度	
		AA	AB	BB	A	B
572	ADIPOQ	32	194	238	0.278	0.722
573	ADRA1A	335	122	11	0.846	0.154
574	ADRA1A	100	194	166	0.428	0.572
575	ADR2A	260	170	33	0.745	0.255
576	ADRB2	168	195	85	0.593	0.407
577	ADRB2	124	206	132	0.491	0.509
578	ADRB3	303	140	20	0.806	0.194
579	ADRB3	18	142	307	0.191	0.809
580	ALOX15	188	217	61	0.636	0.364
581	ALOX5	8	74	387	0.096	0.904
582	APOC3	51	233	181	0.360	0.640
583	ASIP	349	101	7	0.874	0.126
584	ATP5C1	11	121	320	0.158	0.842
585	AVPR1A	128	254	87	0.544	0.456
586	AVPR1A	20	168	280	0.222	0.778
587	BMP2	379	85	3	0.903	0.097
588	BTBD4	150	232	84	0.571	0.429
589	BTBD4	194	185	83	0.620	0.380
590	C1orf121	186	217	65	0.629	0.371
591	CLCN6	116	226	123	0.492	0.508
592	CLDN20	337	120	11	0.848	0.152
593	COCH	206	218	44	0.673	0.327
594	COL11A2		50	418	0.053	0.947
595	COL11A2	269	170	30	0.755	0.245
596	COL9A1	269	157	40	0.746	0.254
597	COL9A1	74	214	179	0.388	0.612
598	CPSF4	457	11	1	0.986	0.014
599	DDN	183	208	78	0.612	0.388
600	DFNA5	72	239	158	0.408	0.592
602	EPDR1	163	225	78	0.591	0.409
603	ESRRA	2	70	396	0.079	0.921
604	FLJ31166	85	213	169	0.410	0.590
605	FOXO1A	37	205	227	0.297	0.703
607	GCK	42	185	237	0.290	0.710
609	GJA4	204	200	65	0.648	0.352
610	GJB2	334	124	11	0.844	0.156
611	GJB2	61	233	175	0.378	0.622
612	GJB6	251	184	34	0.731	0.269
613	GJB6	216	206	47	0.680	0.320
615	GSK3B	147	231	91	0.560	0.440
616	HSD11B1	200	214	54	0.656	0.344
617	HSD11B1	329	130	10	0.840	0.160
619	IRS1		27	435	0.029	0.971
620	KCNQ4	156	225	88	0.572	0.428
621	KCNQ4	5	78	386	0.094	0.906
622	KL	347	104	14	0.858	0.142

表２　分析したSNPとその頻度（つづき）

SNP_ID	シンボル	多型頻度			アレル頻度	
		AA	AB	BB	A	B
624	LEP	306	145	17	0.809	0.191
625	LEPR	9	114	346	0.141	0.859
626	LIPG	31	174	261	0.253	0.747
627	LMNA	17	144	308	0.190	0.810
629	LPL	6	106	353	0.127	0.873
630	LRP5	36	186	246	0.276	0.724
631	MCEMP1	59	213	196	0.354	0.646
632	MECP2	288	126	50	0.756	0.244
633	MTHFR		60	407	0.064	0.936
634	MTP	290	158	19	0.790	0.210
635	MTP	10	139	319	0.170	0.830
636	MVD	388	76	2	0.914	0.086
638	MYH2	17	145	305	0.192	0.808
639	MYH9	339	109	4	0.871	0.129
640	MYO6	89	203	174	0.409	0.591
641	MYO6	5	71	392	0.087	0.913
642	MYO7A	132	235	102	0.532	0.468
643	MYO7A	100	239	129	0.469	0.531
644	NOS3	1	89	372	0.098	0.902
647	NOX4	2	40	427	0.047	0.953
648	NRF1	73	246	149	0.419	0.581
649	OLR1	26	135	305	0.201	0.799
650	PBEF1	385	82	2	0.908	0.092
651	PBEF1	379	85	2	0.905	0.095
652	PDK4	273	165	29	0.761	0.239
653	PON1	58	215	193	0.355	0.645
656	PPARGC1A	302	152	12	0.811	0.189
657	PPARGC1A	105	241	122	0.482	0.518
658	PPARGC1B	414	52	1	0.942	0.058
660	PRKAB1	443	20		0.978	0.022
661	PRKAB2	8	86	375	0.109	0.891
662	PRKAB2	169	241	51	0.628	0.372
663	PRKAG2	39	183	247	0.278	0.722
664	PRKAG2	202	205	59	0.653	0.347
665	PRKCB1	215	200	52	0.675	0.325
666	RAI1	17	122	326	0.168	0.832
667	RETN	182	223	61	0.630	0.370
668	RXRA	27	140	294	0.210	0.790
669	RXRA	19	128	317	0.179	0.821
670	RXRB	50	220	199	0.341	0.659
671	RXRB	456	12		0.987	0.013
672	RXRG	170	228	68	0.609	0.391
673	RXRG	247	180	39	0.723	0.277
674	SCD	75	211	176	0.391	0.609
676	SFRP1	1	51	398	0.059	0.941
677	SFRP2	120	241	101	0.521	0.479
678	SIRT1	363	91	6	0.888	0.112
679	SIRT1	33	190	234	0.280	0.720
680	SLC6A2	176	218	73	0.610	0.390
681	SLC6A2	259	183	24	0.752	0.248
682	SREBF2	60	224	183	0.368	0.632

表２　分析したSNPとその頻度（つづき）（今年度解析したSNPは太字で示す）

SNP_ID	シンボル	多型頻度			アレル頻度	
		AA	AB	BB	A	B
683	SREBF2	189	224	53	0.646	0.354
684	STRN3	47	208	213	0.323	0.677
685	TATDN2	219	188	60	0.670	0.330
686	TATDN2	29	146	291	0.219	0.781
687	TCFL5	86	226	156	0.425	0.575
688	TECTA	244	177	43	0.717	0.283
689	TECTA	34	192	241	0.278	0.722
690	TFAM	324	121	21	0.825	0.175
691	TFB1M	450	16	0	0.983	0.017
694	TNFA	20	143	302	0.197	0.803
695	UCP1	379	82	5	0.901	0.099
696	UCP2	93	241	133	0.457	0.543
697	UCP2	132	236	97	0.538	0.462
698	UCP3	236	187	44	0.706	0.294
699	UCP3	113	237	117	0.496	0.504
700	WFS1	10	87	369	0.115	0.885
701	WFS1	4	56	406	0.069	0.931
702	WRN	165	224	78	0.593	0.407
703	YBX2	66	218	184	0.374	0.626
711	ADRA2C	112	237	118	0.494	0.506
712	ADRA1D	355	106	6	0.874	0.126
713	ADRA1D	227	191	48	0.692	0.308
714	ADRA2B	17	106	343	0.150	0.850
721	ADRA1B	265	169	30	0.753	0.247
722	ADRA2B	57	207	203	0.344	0.656
723	ADRA1B	141	240	83	0.563	0.438

表３　分析したSNPとその頻度（つづき）

SNP_ID	シンボル	多型頻度			アレル頻度	
		AA	AB	BB	A	B
573	ADRA1A	422	132	10	0.865	0.135
574	ADRA1A	97	263	204	0.405	0.595
575	ADRA2A	297	228	39	0.729	0.271
579	ADRB3	22	186	363	0.201	0.799
585	AVPR1A	171	268	132	0.534	0.466
586	AVPR1A	32	222	313	0.252	0.748
593	COCH	233	269	67	0.646	0.354
642	MYO7A	153	279	137	0.514	0.486
643	MYO7A	123	276	171	0.458	0.542
680	SLC6A2	210	286	68	0.626	0.374
681	SLC6A2	322	209	36	0.752	0.248
711	ADRA2C	163	270	138	0.522	0.478
712	ADRA1D	441	120	7	0.882	0.118
713	ADRA1D	269	242	56	0.688	0.312
714	ADRA2B	13	137	420	0.143	0.857
721	ADRA1B	328	203	36	0.757	0.243
722	ADRA2B	77	275	214	0.379	0.621
723	ADRA1B	205	271	95	0.596	0.404

III. 研究成果の刊行に関する一覧表

書籍

著者氏名	論文タイトル名	書籍全体の編集者名	書　籍　名	出版社名	出版地	出版年	ページ
能勢　博, 源野広和, 井澤雅子	松本市熟年体育大学（組織運営の立場から）	臨床スポーツ医学編集委員会（黒田善雄ら）	高齢社会における運動支援実践ガイド	文光堂	東京	2005	340-345
能勢　博, 根本賢一, 森川真悠子	松本市熟年体育大学（プログラムの実際）	臨床スポーツ医学編集委員会（黒田善雄ら）	高齢社会における運動支援実践ガイド	文光堂	東京	2005	346-351
能勢　博, 源野広和, 井澤雅子	産・官・学・民連携による病気予防へのモデル事業：松本市熟年体育大学	奈良昌治（監修）・山門　實（編集）	ここまでわかってきた最新の生活習慣病健診と対策のすべて：診断からフォローアップまで	ライフサイエンスセンター	横浜	2005	358-365
S. Masuki, M. Joyner, and H. Nose	Variation of α-Adrenergic Vasoconstrictor Response Changes Baroreflex Sensitivity.	H. Nose, M. Joyner, and K. Miki	Exercise, Nutrition, and Environmental Stress (vol. 4)	Cooper Publishing Group	Traverse City, MI, USA	2005	115-128
Y. Kamijo and H. Nose	Effects of Hyperosmolality on Maintenance of Arterial Pressure in Dehydrated and Exercising Men in a Hot environment	H. Nose, M. Joyner, and K. Miki	Exercise, Nutrition, and Environmental Stress (vol. 4)	Cooper Publishing Group	Traverse City, MI, USA	2005	245-256
能勢　博, 源野広和, 花岡正明, 根本賢一, 井澤雅子	運動習慣の定着に何が有効か：実践指導の経験から	太田壽城	健康寿命と運動	(財)長寿科学振興財団	大府	2006	207-217
源野広和, 能勢　博：	スポーツ	二木鋭雄	ストレス科学と健康	共立出版	東京	2007	217-221
能勢　博, 岡崎和伸	高齢者の体力測定法（持久力）	田畑　泉	健康運動指導士養成講習会テキスト	財）健康・体力づくり事業団	東京	2007	843-856
後藤正樹, 能勢　博	高齢者の体力低下：加齢と廃用の影響	田島文博ほか	リハビリテーション医療	金芳堂	京都	2007	43-49
岡崎和伸, 能勢　博	持久力の評価	渡辺　昌ほか	病気予防百科	日本医療企画	東京	2007	380-381
岡崎和伸, 能勢　博	エクササイズガイド2006	渡辺　昌ほか	病気予防百科	日本医療企画	東京	2007	392-393
岡崎和伸, 能勢　博	まだまだ，どんとこい熟年！	岡崎和伸, 能勢　博	まだまだ，どんとこい熟年！	オフィスエム	長野	2007	1-81

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Kamijo Y, Okumoto T, Takeno Y, Okazaki K, Inaki M, Masuki S, Nose H.	Transient cutaneous vasodilation and hypotension after drinking in dehydrated and exercising men.	J. Physiol (Lond.)	568	689-698	2005
Masuki S, Todo T, Nakano Y, Okamura H, and Nose H.	Reduced • •adrenoceptor responsiveness and enhanced baroreflex sensitivity in CRY-deficient mice lacking a biological clock.	J. Physiol (Lond.)	566	213-224	2005
Mitono H, Endoh H, Okazaki K, Ichinose T, Masuki S, Takamata A, and Nose H.	cute hypoosmolality attenuates the suppression of cutaneous vasodilation with increased exercise intensity.	J. Appl. Physiol.	99	902-908	2005
Ichinose T, K. Okazaki, S. Masuki, H. Mitono, M. Chen, H. Endoh, and H. Nose.	Improved cutaneous vasodilation and blunted hyperosmotic suppression sensitivity after endurance training in humans.	J. Appl. Physiol.	99	237-243	2005
Li G, Guo Z, Higuchi K, Kawakubo M, Matsumoto K, Mori M.	A locus for eosinophilia in the MES rat is on Chromosome 19.	Mamm Genome	16:	516-523	2005
Kamijo Y, Nose H	Heat illness during working and preventive considerations from body fluid homeostasis.	Industrial Health	44	345-358	2006
Yan J, Fujii K, Yao J, Kishida H, Hosoe K, Sawashita J, Takeda T, Mori M, Higuchi K	Reduced coenzyme Q10 supplementation decelerates senescence in SAMP1 mice.	Exp Gerontol.	41	130-140	2006
Mori M, Li G, Abe I, Nakayama J, Guo Z, Sawashita J, Ugawa T, Nishizono S, Serikawa T, Higuchi K, Shumiya S.	Lanosterol synthase mutations cause cholesterol deficiency-associated cataracts in the Shumiya cataract rat.	J Clin Invest	116	395-404	2006
Korenaga T, Yan J, Sawashita J, Matsusita T, Naiki H, Hosokawa M, Mori M, Higuchi K, Fu X.	Transmission of amyloidosis in affspring of mice with AApoAII amyloidosis.	Am J Pathol	168	898-906	2006
能勢　博	何故，今，ヒトか？：高齢社会にむけての生理学からの提言	基礎老化研究	30	15-21	2006
岡崎和伸，源野広和，森川真悠子，能勢　博	運動基準・指針を生かす個別プログラム，「新しい健康づくりのための運動基準・指針」	体育の科学	56	627-634	2006
後藤正樹，能勢　博	長期臥床が循環機能に及ぼす影響－起立性低血圧症を中心に－，「廃用性症候群を吟味する－無動・不動，低活動，臥床の影響の理解と予防」	MB Med. Reha	72	39-44	2006
能勢　博，根本賢一，森川真悠子，山崎敏明，源野広和，井澤雅子	活動による要介護予防への総合的取り組み－松本市熟年体育大学の試み－，「廃用性症候群を吟味する－無動・不動，低活動，臥床の影響の理解と予防」	MB Med. Reh	72	55-62	2006
能勢　博，後藤正樹	高齢者の体力低下とカウンターメジャー：松本市熟年体育大学の試み	理学療法研究・長野	34	47	2006

能勢 博	産官学連携による生活習慣病予防のモデル事業－熟年体育大学－	エスペック技術情報	46	1-11	2006
半田秀一，源野広和，花岡正明，能勢 博	生活習慣病予防のための理学療法の地域における実践とその成果	理学療法	23	807-814	2006
後藤正樹，能勢 博	高齢者の体力低下：加齢と廃用の影響	ﾘﾊﾋﾞﾘﾃｰｼｮﾝ医学	印刷中	—	2007
Zhang H, Sawashita J, Fu X, Korenaga T, Yan J, Mori M, Higuchi K	Transmissibility of mouse AApoAII amyloid fibrils: inactivation by physical and chemical methods	FASEB J	20	1012-1014	2006
Mori M, Higuchi K, Matsumoto K	A third locus for eosinophilia on chromosome 1 of the MES rats.	Exp Anim	55	497-500	2006
Nakanishi R, Shimizu M, Mori M, Akiyama H, Otsuki B, Okudaira S, Hashimoto M, Higuchi K, Tsuboyama T, Nakamura T	Secreted Frizzled-Related Protein 4 as a negative regulator of bone formation and a candidate gene affecting peak bone mineral density in mice	J Bone Mineral Res	21: 1713-1721, 2006	1713-1721	2006
Nemoto K, Genno H, Masuki S, Okazaki K, Nose H	Effects of high-intensity interval walking training on physical fitness and blood pressure in middle-aged and older people.	Mayo Clinic Proceedings	82	803-811	2007
Masuki S, Eisenach JH, Schrage WG, Johnson CP, Dietz NM, Wilkins BW, Sandroni P, Low PA and Joyner MJ.	Reduced stroke volume during exercise in postural tachycardia syndrome.	J Appl Physiol	103	1128-1135	2007
Masuki S, Eisenach JH, Schrage WG, Dietz NM, Johnson CP, Wilkins BW, Dierkhising RA Sandroni P, Low PA and Joyner MJ.	Arterial baroreflex control of heart rate during exercise in postural tachycardia syndrome.	J Appl Physiol	103	1136-1142	2007
Masuki S, Eisenach JH, Johnson CP, Dietz NM, Benrud-Larson LM, Schrage WG, Curry TB, Sandroni P, Low PA and Joyner MJ	Excessive heart rate response to orthostatic stress in postural tachycardia syndrome is not caused by anxiety	J Appl Physiol	102	896-903	2007
Mori M, Sawashita J, Higuchi K	Functional polymorphisms of the *Lss* and *Fdft1* genes in laboratory rats.	Exp Anim	56	93-101	2007
Otsuki B, Matsumura T, Shimizu M, Mori M, Okudaira S, Nakanishi R, Higuchi K, Hosokawa M, Tsuboyama T, Nakamura T	Quantitative trait locus that determines the cross-sectional shape of the femur in SAMP6 and SAMP2 mice	J Bone Miner Res.	22	675-685	2007
Ge F, Yao J, Fu X, Guo Z, Yan J, Zhang B, Zhang H, Tomozawa H, Miyazaki J, Sawashita J, Mori M, Higuchi K	Amyloidosis in transgenic mice expressing murine amyloidogenic apolipoprotein (*Apoa2*^{c}).	Lab Invest	87	633-643	2007

Yan J, Fu X, Ge F, Zhang B, Yao J, Zhang H, Qian J, Tomozawa H, Naiki H, Sawashita J, Mori M, Higuchi K	Cross-seeding and cross-competition in mouse apolipoprotein A-II amyloid fibrils (AApoAII) and protein A amyloid fibrils (AA).	Am J Pathol	171	172-180	2007
能勢　博	eヘルスプロモーションとは？	肥満と糖尿病	6	497-499	2007
能勢　博　ほか	ITでどこまでわかるか？	肥満と糖尿病	6	425-440	2007
半田秀一，根本賢一，源野広和，能勢　博	インターバル速歩による筋力増強	理学療法	24	932-938	2007
岡崎和伸，能勢　博	運動による介護予防システムの構築	体育の科学	58	51-57	2008

Ⅳ. 研究成果の刊行物・別刷

ORIGINAL ARTICLE

Effects of High-Intensity Interval Walking Training on Physical Fitness and Blood Pressure in Middle-Aged and Older People

KEN-ICHI NEMOTO, MS; HIROKAZU GEN-NO, PHD; SHIZUE MASUKI, PHD; KAZUNOBU OKAZAKI, PHD; AND HIROSHI NOSE, MD, PHD

OBJECTIVE: **To examine whether high-intensity interval walking training increased thigh muscle strength and peak aerobic capacity and reduced blood pressure more than moderate-intensity continuous walking training.**

PARTICIPANTS AND METHODS: **From May 18, 2004, to October 15, 2004 (5-month study period), 60 men and 186 women with a mean ± SD age of 63±6 years were randomly divided into 3 groups: no walking training, moderate-intensity continuous walking training, and high-intensity interval walking training. Participants in the moderate-intensity continuous walking training group were instructed to walk at approximately 50% of their peak aerobic capacity for walking, using a pedometer to verify that they took 8000 steps or more per day for 4 or more days per week. Those in the high-intensity interval walking training group, who were monitored by accelerometry, were instructed to repeat 5 or more sets of 3-minute low-intensity walking at 40% of peak aerobic capacity for walking followed by a 3-minute high-intensity walking above 70% of peak aerobic capacity for walking per day for 4 or more days per week. Isometric knee extension and flexion forces, peak aerobic capacity for cycling, and peak aerobic capacity for walking were all measured both before and after training.**

RESULTS: **The targets were met by 9 of 25 men and 37 of 59 women in the no walking training group, by 8 of 16 men and 43 of 59 women in the moderate-intensity continuous walking training group, and by 11 of 19 men and 31 of 68 women in the high-intensity interval walking training group. In the high-intensity interval walking training group, isometric knee extension increased by 13%, isometric knee flexion by 17%, peak aerobic capacity for cycling by 8%, and peak aerobic capacity for walking by 9% (all, *P*<.001), all of which were significantly greater than the increases observed in the moderate-intensity continuous walking training group (all, *P*<.01). Moreover, the reduction in resting systolic blood pressure was higher for the high-intensity interval walking training group (*P*=.01).**

CONCLUSION: **High-intensity interval walking may protect against age-associated increases in blood pressure and decreases in thigh muscle strength and peak aerobic capacity.**

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1RM = one repetition maximum; BMI = body mass index; DBP = diastolic blood pressure; HR = heart rate; RPE = rate of perceived exertion; SBP = systolic blood pressure; $\dot{V}o_{2peak}$ = peak aerobic capacity

The rapid growth in the elderly population in many countries has highlighted the importance of exercise training to decrease the likelihood of disability and age-associated disease, promote independence, and enhance quality of life.[1] Moderately paced (about 6 km/h) walking, thought to protect against disability and age-associated diseases, has been widely recommended to middle-aged and older people. However, that pace may not be intense enough to increase peak aerobic capacity ($\dot{V}o_{2peak}$) and other markers of physical fitness. Indeed, a higher intensity of aerobic exercise (>50% $\dot{V}o_{2peak}$) has been recommended in recent guidelines to increase $\dot{V}o_{2peak}$ in older people.[2] However, few regimens in the field provide this increased intensity of aerobic exercise while providing the ease of participation of walking.

Walking at submaximal velocity could be one such regimen. We found that the heart rate (HR) in older men and women walking at the maximal velocity almost reached the age-expected maximal values,[3] suggesting that $\dot{V}o_{2peak}$ would be increased in older people if walking training was performed at a higher intensity than that recommended by current guidelines.[2] Furthermore, we recently observed that cycling exercise training at moderate to high intensity increased thigh muscle strength and mass in older men,[4,5] suggesting that, like traditional resistance training, aerobic exercise training, if performed at the required intensity, can increase thigh muscle strength in older people. On the basis of these findings, we surmised that high-intensity walking training could increase $\dot{V}o_{2peak}$ and muscle mass and strength in older people. Moreover, we surmised that high-intensity walking training would lead to a greater reduction in blood pressure because the effects of aerobic training on resting blood pressure were reportedly enhanced as the intensity increased into the range of 40% to 70% of $\dot{V}o_{2peak}$.[6]

For editorial comment, see page 797

Our study examined the hypotheses that walking training at more than 70% of maximal intensity would result in greater increases in thigh muscle strength and $\dot{V}o_{2peak}$ and a greater reduction in resting blood pressure in older men and women than walking of moderate intensity. If such gains are indeed observed, it would suggest that

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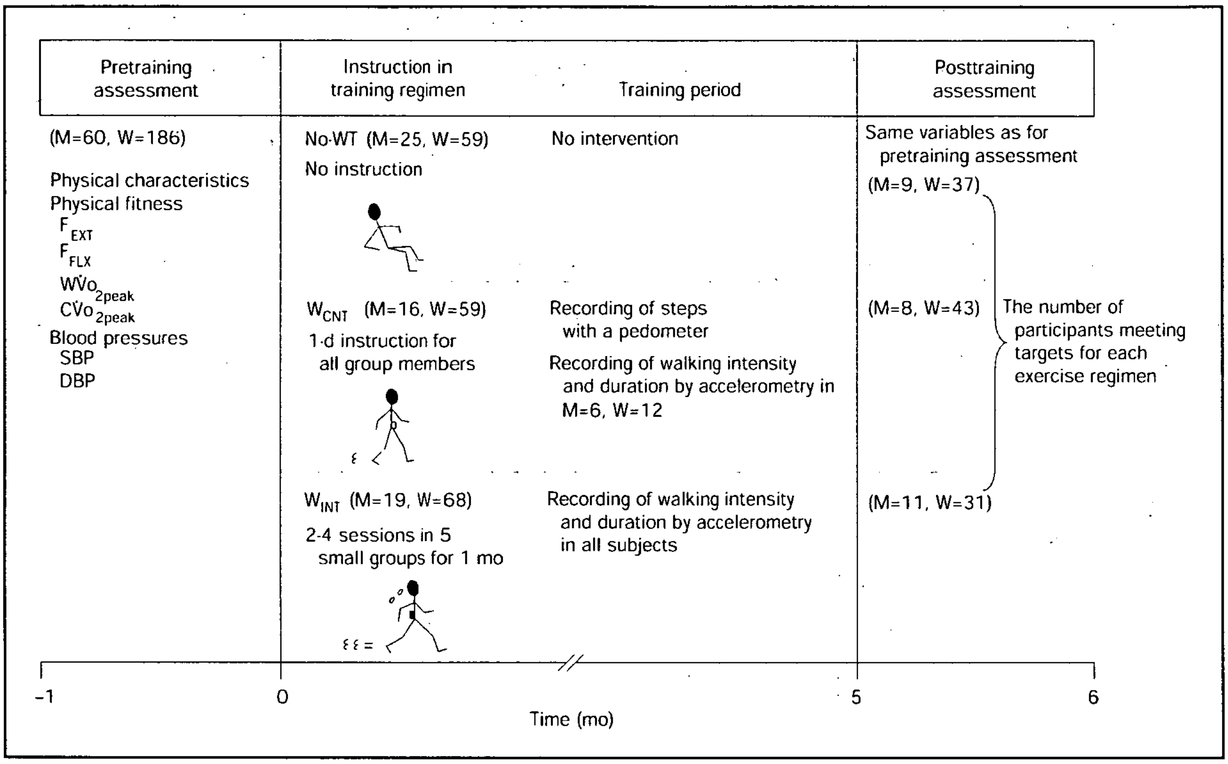

FIGURE 1. Study procedures. CVo_{peak} = peak aerobic capacity by graded cycling; DBP = diastolic blood pressure; F_{EXT} = isometric knee extension force; F_{FLX} = isometric knee flexion force; M = men; no-WT = no walking training group; SBP = systolic blood pressure; W = women; W_{CNT} = moderate-intensity continuous walking training group; W_{INT} = high-intensity interval walking training group; WVo_{2peak} = peak aerobic capacity by graded walking.

middle-aged and elderly people could participate in exercise training calibrated to their individual physical fitness to decrease disability and age-associated diseases more effectively.

PARTICIPANTS AND METHODS

Once the study protocol (Figure 1) had been approved by the Review Board on Human Experiments, Shinshu University School of Medicine, Matsumoto, Japan, 246 healthy, nonsmoking middle-aged and older adults (44-78 years) with no history of cardiovascular or pulmonary diseases gave written informed consent and were enrolled in the study. Of the study participants, 60 were men and 186 were women. At first, we intended to divide participants randomly into 3 groups, each with 20 men and 62 women: no walking training, moderate-intensity continuous walking training, and high-intensity interval walking training. However, a few of the participants were married couples and wanted to join the same group, and others, who lived a distance from an administrative center, wished to be assigned to the interval walking group so that they could visit a local community office nearer their homes. For these reasons, minor reassignments were made, resulting in 25 men and 59 women in the no walking training group, 16 men and 59 women in the moderate-intensity continuous walking training group, and 19 men and 68 women in the high-intensity interval walking training group.

Participants in the no walking training group were instructed to maintain a sedentary lifestyle. Those in the continuous walking group were invited to the administrative center at the beginning of the program to receive training for their exercise program. They were instructed to walk more than 8000 steps per day at approximately 50% $\dot{V}o_{2peak}$ for walking for a minimum of 4 days per week. Participants used a pedometer (Omron, JH-005, Kyoto, Japan) to monitor their steps and chose a time each day to complete the exercise program. Once a month, they visited the administrative center so that their compliance with the training program could be reviewed.

The subjects in the high-intensity interval walking training group were divided into 5 subgroups of 10 to 20

TABLE 1. **Energy Expenditure During Training in Moderate-Intensity Continuous Walking and High-Intensity Interval Walking Groups***

	Moderate-intensity continuous walking group		High-intensity interval walking group	
	Men, n=6 (n=8)	Women, n=12 (n=43)	Men (n=11)	Women (n=31)
Walking days per week	4.4±0.1 (4.9±0.3)	4.5±0.1 (4.8±0.1)	4.5±0.1	4.5±0.1
Steps per day	9833±260 (10,564±267)	9439±197 (9705±180)	9166±195	7874±162†
Energy expenditure (mLO_2/day)	54.656±707	37,880±357	54.542±2539	41.003±1111
Walking time(min/day)	66±1 (66±3)	61±1 (61±1)	55±3‡	51±1†
Walking intensity (mLO_2/min)	831±13	626±9	992±15†	807±17†
Fast walking time (min/day)	NA	NA	35±2	32±1
Walking intensity during fast walking (mLO_2/min)	NA	NA	1205±22	961±26
Slow walking time (min/day)	NA	NA	20±1	18±1
Walking intensity during slow walking (mLO_2/min)	NA	NA	618±11	538±9

*NA = not applicable. Values are mean ± SE . First set of values given for each variable in the moderate-intensity continuous walking group are for the 6 men and 12 women who carried an accelerometer during walking. The values in parentheses are those for all members (8 men, 43 women) of this group included in the study. Significantly different from values in moderate-intensity continuous walking group (†$P<.001$, ‡$P=.003$).

subjects each. Before the start of the study, participants were invited to a community office near their homes and received instruction in the exercise program. They were told to repeat the following regimen 4 or more times per week: 5 or more sets of 2- to 3-minute low-intensity walking intervals (at approximately 40% of the pretraining Vo_{2peak}), followed by a 3-minute interval of high-intensity walking (>70% but <85% Vo_{2peak} for walking). The intensity and steps were monitored with a triaxial accelerometer carried on the back (Active Tracer 301, GMS, Tokyo, Japan)[3] and a pedometer, respectively. A beeping signal alerted participants when a change of intensity was scheduled. This method of instruction was continued for the first month of the regimen until the subjects had mastered high-intensity interval walking.

Once participants had learned the program, they could choose the time at which to perform it each day. Every 2 weeks the participants visited a local office, and data from the tracking devices were transferred to a central server at the administrative center through the Internet for automatic analysis and reporting. Trainers used these reports to track daily walking intensity and other parameters given in Table 1 to instruct participants on how best to achieve the target levels. If targets were not met, the trainer encouraged the participants to increase their efforts to achieve them.

In the interval walking group, all participants were equipped with the accelerometer mentioned earlier and a pedometer to measure daily walking intensity and steps, respectively. However, because we had a limited number of accelerometers, 18 (12 women, 6 men) of 75 participants in the continuous walking group carried the accelerometer for measuring walking intensity, while all had a pedometer for measuring steps. The training was performed between May 18, 2004, and October 15, 2004, during which time the average atmospheric temperature was 13° to 25°C and relative humidity was 60% to 80%.

NUMBER OF PARTICIPANTS IN THE ANALYSES

Of the participants enrolled in the study, the following completed 5 months of training and returned to the laboratory for a physical fitness test: 13 men and 46 women in the no walking training group, 13 men and 49 women in the moderate-intensity continuous walking training group, and 15 men and 53 women in the high-intensity interval walking training group. Those who completed training were asked to fill out a survey; the answers were used to determine whether they had met the criteria given to them at the beginning of the regimen.

In the no walking training group, 13 subjects were excluded from the analyses because they reported walking 30 to 60 minutes 2 to 3 days per week. In the continuous walking group, 3 subjects were excluded because they did not record their daily steps and 8 because their steps per day were fewer than 5000 and because they walked fewer than 2 days per week. In the interval walking group, 18 participants were excluded because they did not record their daily walking intensity and another 8 because they performed only moderate-intensity continuous walking, ie, taking fewer than 4000 steps a day and exercising fewer than 30 minutes a day for fewer than 2 days per week.

The criteria for inclusion in the study were met by 9 men and 37 women in the no walking training group (55% of the initial number), 8 men and 43 women in the moderate-intensity continuous walking training group (68%), and 11 men and 31 women in the high-intensity interval walking training group (48%).

MEASUREMENTS

Blood pressures, Vo_{2peak} by graded cycling exercise and by graded walking exercise, and isometric knee extension and flexion forces were measured before and after the continuous and interval walking group regimens; measurements for the no walking training group were obtained at the same time as for the other groups.

TABLE 2. **Physical Characteristics of Participants in Training Groups: Men vs Women**

	No walking (*P* value)	Moderate-intensity continuous walking (*P* value)	High-intensity interval walking (*P* value)
Age	.11	.005	.048
Height	.001	<.001	<.001
Weight	.01	.003	<.001

Peak Aerobic Capacity by Graded Walking. After baseline measurements at rest for 3 minutes, subjects with a triaxial accelerometer on their back walked for 3 minutes on a flat floor at 3 graded subjective velocities: slow, moderate, and fast. At the same time, 3-dimensional acceleration and HR with the electrocardiogram were measured at 10-millisecond intervals and recorded with 5-second memories as averaged values.[3] The total impulse from an accelerometer[7] was transferred to a computer and converted to oxygen consumption rate using a previously reported equation.[3] Peak aerobic capacity and peak HR for walking values are those for the last 30 seconds at maximal walking velocity.

Knee Extension and Flexion Forces and $\dot{V}o_{2peak}$ by Graded Cycling. No earlier than day 4 after the measurement of $\dot{V}o_{2peak}$ by walking, knee extension and flexion forces were measured on each side of the knee with a dynamometer (Biodex 3, Biodex Medical System, Shirley, NY) and the 2 measurements averaged for reporting. The validity of $\dot{V}o_{2peak}$ by graded walking determined earlier on each subject was confirmed by determining $\dot{V}o_{2peak}$ by graded cycling using expired gas analysis (AE260, Minato, Tokyo, Japan) by averaging the values for the 30 seconds at maximal intensity with peak HR by electrocardiography (Life Scope 8M, Nihon Kohden, Toyko, Japan), as described previously.[4]

These measurements before and after training were performed by the same investigator according to the same protocol.

Blood Pressures. Before $\dot{V}o_{2peak}$ by walking was determined, systolic (SBP) and diastolic (DBP) blood pressures were measured by auscultation after the participant had been sitting for 10 minutes in a room with an ambient temperature of 25°C and relative humidity of approximately 50%.

STATISTICAL ANALYSES

We used 2-way analysis of variance to determine any significant differences among the groups or between men and women in preregimen physical characteristics and training program achievements. An analysis of covariance with the pretraining values included as a covariate[8] was used to determine any significant differences among the groups in postregimen physical characteristics, cardiovascular variables, muscle strength, and $\dot{V}o_{2peak}$. Analysis of covariance was also used to determine if the changes in these values for a given group were statistically different from the changes noted for the other groups. The effects of each training regimen on these variables were tested using a 2-way (sex; before or after training) analysis of variance for repeated measures. The statistical power to detect their significant changes after training in the continuous and interval walking groups was >0.8 at α of 0.05 except for SBP in men from the continuous walking group (0.74) and DBP in men from the interval walking group (0.53). Subsequent post hoc tests to determine significant differences in the various pairwise comparisons were performed with Fisher exact test. Values are presented as means ± SE except as noted. The null hypothesis was rejected at $P<.05$.

We did not perform an intention-to-treat analysis[9] because we were unable to determine the effects of training on participants who did not return to the laboratory for a physical fitness test after training. Moreover, for our analyses, we needed to exclude the participants who did not achieve the targets set before the start of training for each of the training regimens because the purpose of this study was to assess if the high-intensity interval walking regimen, when performed as initially directed, improved physical fitness more than the moderate-intensity continuous walking regimen. As a result, we excluded approximately 40% of the participants in each group from our analyses and reconfirmed that pretraining values for physical characteristics, physical fitness, and cardiovascular variables were not statistically different among the groups.

RESULTS

Although the number of days walked per week did not significantly differ between the interval and continuous walking groups, the walking time of the interval group was only 83% of the continuous walking group (Table 1). However, despite this difference in walking time, the energy expenditure per day did not differ significantly between the 2 groups ($P=.66$) because the interval walking group exercised at a much higher intensity (>70% $\dot{V}o_{2peak}$) than the continuous walking group.

Significantly higher values for age, height, and body weight were observed for men than for women (Table 2), but differences in age in the no-training group ($P=.11$) and differences among the groups before training were not statistically significant (Table 3). After training, body weight and body mass index (BMI [calculated as weight in kilograms divided by the square of height in meters]) decreased significantly in the women in the continuous (both, $P<.001$) and interval (weight, $P=.02$; BMI, $P=.01$) walking training groups but increased significantly in the no walk-

TABLE 3. **Physical Characteristics Before and After Training***

	No walking group				Moderate-intensity continuous walking group				High-intensity interval walking group			
	Men (n=9)		Women (n=37)		Men (n=8)		Women (n=43)		Men (n=11)		Women (n=31)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Age (y)	66±5	NA	62±6	NA	67±5	NA	62±5	NA	67±4	NA	64±6	NA
Height (cm)	163±3	NA	155±6	NA	165±8	NA	154±6	NA	167±6	NA	153±6	NA
Weight (kg)	61.1±2.4	62.0±2.5	54.1±1.1	54.9±1.2†	62.5±2.7	61.8±2.7	54.4±1.0	53.2±0.9†‡	63.7±2.4	62.9±2.2	53.7±1.2	52.9±1.2§‡
BMI (kg/m²)	23.1±0.8	23.5±0.9	22.7±0.5	23.0±0.5†	23.0±1.1	22.7±1.2	22.8±0.4	22.3±0.3†‡	22.9±0.8	22.6±0.7	22.9±0.5	22.5±0.5‖¶

*BMI = body mass index; NA = not applicable. Values are mean ± SD for age and height, and mean ± SE for body weight and BMI. Significantly different from pretraining values (†*P*<.001; §*P*=.02; ‖*P*=.01). Significantly different from corresponding values in no walking training group (‡*P*<.001, ¶*P*=.004).

ing training group (*P*<.001) to levels that were significantly higher than those of women in both the continuous (both, *P*<.001) and interval (weight, *P*<.001; BMI, *P*<.004) walking groups.

Peak aerobic capacities and thigh muscle strength were significantly higher in men than in women (Table 4), but no significant differences were observed among participants in the 3 groups before training (*P*=.43-*P*=.93). Before training, SBP and DBP did not differ significantly among the groups (*P*=.13-*P*=.67), but after training a significant decrease in SBP and DBP was noted in the interval walking group (both, *P*<.001, when the values in men and women were pooled) and a significant decrease in SBP in the interval walking group compared with the no walking training group (*P*<.001). Similarly, in the high-intensity interval walking training group, knee extension and flexion forces increased significantly after training (both, *P*<.001), and these values were significantly higher than those observed in the no walking training group (*P*<.001) and in the moderate-intensity continuous walking training group (*P*<.001). Furthermore, in the high-intensity interval walking training group, $\dot{V}o_{2peak}$ by walking and cycling significantly increased after training (both, *P*<.001) to levels that were significantly higher than those observed in the no walking training group (walking, *P*<.001; cycling, *P*=.007) and in the moderate-intensity continuous walking group (both, *P*<.001). In contrast, no significant differences between the continuous walking and no walking training groups were noted for any of the variables, except for a significantly lower SBP after training (*P*<.001).

As shown in Figure 2, knee extension and flexion forces in the high-intensity interval walking training group increased significantly by 13% and 17%, respectively (both, *P*<.001), and these values were significantly higher than those of the no walking training group (both, *P*<.001) and the moderate-intensity continuous walking group (extension, *P*<.001; flexion, *P*=.004). In the high-intensity interval walking training group, moreover, significant increases in $\dot{V}o_{2peak}$ by walking (9%) and cycling (8%) (both, *P*<.001) were observed, and these values were significantly greater than those in the no walking training group (walking, *P*<.001; cycling, *P*=.005) and in the moderate-intensity continuous walking group (walking, (*P*<.001; cycling, *P*=.004). Furthermore, in the high-intensity interval walking group, $\dot{V}o_{2peak}$ by walking increased in 26 of 33 participants with increased knee extension force (79%), suggesting a close relationship between these variables.

As shown in Figure 3, SBP and DBP for the high-intensity interval walking group decreased significantly by 9 mm Hg and 5 mm Hg, respectively (both, *P*<.001), and the reduction in SBP after training was significantly greater in the high-intensity interval walking group than in the no walking training group (*P*=.002) and in the moderate-intensity continuous walking group (*P*=.01). Moreover, SBP decreased in 25 of 33 participants with increased $\dot{V}o_{2peak}$ for walking in the interval walking group (76%), suggesting a close relationship between SBP and $\dot{V}o_{2peak}$.

DISCUSSION

The major findings of this study are that high-intensity interval walking resulted in greater increases in $\dot{V}o_{2peak}$ and thigh muscle strength and a greater reduction in SBP than moderate-intensity continuous walking in older men and women.

We adopted 3 minutes as the walking interval because most participants could not continue to walk at the high intensity for more than 3 minutes because of fatigue. However, they recovered from this fatigue within 2 to 3 minutes, and so we adopted a regimen of a 3-minute interval of high-intensity walking followed by 2 to 3 minutes of low-intensity walking and instructed participants to perform more than 5 sets per day.

In most field studies, HR and rate of perceived exertion (RPE) have been used to monitor relative exercise intensity. However, trainers using HR and RPE methods might find it difficult to instruct participants to perform high-intensity interval walking because they would not be able

TABLE 4. **Resting Hemodynamics, Peak Aerobic Capacities, and Thigh Muscle Strength Before and After Training***

	No walking training group			
	Men (n=9)		Women (n=37)	
	Before	After	Before	After
Resting HR (beats/min)	80±3	77±4	79±1	77±2
Resting SBP (mm Hg)	143±2	141±2	142±3	141±3
Resting DBP (mm Hg)	84±2	83±2	83±2	82±2
Peak aerobic capacity for cycling (mL/min)	1502±133	1489±104	1209±40	1208±42
Peak aerobic capacity for walking (mL/min)	1481±108	1434±66	1238±25	1202±32
Peak HR for cycling (beats/min)	147±6	146±6	149±2	147±3
Peak HR for walking (beats/min)	141±7	136±6	145±2	144±3
Isometric knee extension force (N · m)	137±5	134±4	100±3	100±3
Isometric knee flexion force (N · m)	72±2	73±3	46±2	45±2

	Moderate-intensity continuous walking group			
	Men (n=8)		Women (n=43)	
	Before	After	Before	After
Resting HR, beats/min	81±3	79±3	78±1	78±2
Resting SBP (mm Hg)	141±2	138±2†	135±3	132±3‡
Resting DBP (mm Hg)	85±2	83±2§	81±2	79±1
Peak aerobic capacity for cycling (mL/min)	1560±106	1565±112	1191±35	1180±31
Peak aerobic capacity for walking (mL/min)	1507±88	1481±99	1203±28	1177±26
Peak HR for cycling (beats/min)	149±4	152±7	147±3	145±3
Peak HR for walking (beats/min)	141±3	142±5	142±3	139±3
Isometric knee extension force (N · m)	138±6	138±3	94±3	95±3
Isometric knee flexion force (N · m)	73±2	74±2	45±2	48±2§

	High-intensity interval walking group			
	Men (n=11)		Women (n=31)	
	Before	After	Before	After
Resting HR (beats/min)	75±3	74±3	81±2	78±1†
Resting SBP (mm Hg)	146±2	136±2‖¶	140±3	132±2‖‡
Resting DBP (mm Hg)	87±3	82±2†	85±2	80±2§
Peak aerobic capacity for cycling (mL/min)	1525±59	1668±72‖#**	1151±35	1222±37§
Peak aerobic capacity for walking (mL/min)	1464±56	1623±50‖#**	1186±34	1274±35†¶††
Peak HR for cycling (beats/min)	146±5	153±6	144±2	141±3
Peak HR for walking (beats/min)	142±4	137±4	144±2	139±2
Isometric knee extension force (N · m)	132±5	149±8‖#**	95±4	106±4‖¶‡‡
Isometric knee flexion force (N · m)	71±3	81±3‖#**	44±2	51±2‖#**

*DBP = diastolic blood pressure; HR = heart rate; N · m = newton meter; SBP = systolic blood pressure. Values represent mean ± SE. Significantly different from pretraining values (†*P*<.05, §*P*<.01, and ‖*P*<.001). Significantly different from the corresponding values for the no walking training group (¶*P*<.05, #*P*<.01, and ‡*P*<.001). Significantly different from the corresponding values for the moderate-intensity continuous walking group (***P*<.05, ††*P*<.01, and ‡‡*P*<.001).

to determine absolute walking intensity to a high resolution of 1 minute. For example, after a change in walking speed it takes 1 to 2 minutes for HR to reach a steady level equivalent to the new level of exercise intensity. Moreover, HR and RPE responses are influenced by adaptation to training, environmental conditions, and the physical condition of participants. For these reasons, in our study we chose to use a triaxial accelerometer to monitor exercise intensity during training.

As shown in Figure 2, significant increases in knee extension force (13%) and knee flexion force (17%) were observed in the high-intensity interval walking training group, increases that were significantly greater than those seen in the moderate-intensity continuous walking training group. The intensity of exercise training used in our study for the high-intensity interval walking training group is not as high as that recommended for increased muscle strength by the current American College of Sports Medicine guidelines for resistance training (3 sets of 8 repetitions per day at 80% of one repetition maximum [1RM], 2 to 3 days pep,week, for 3 months). However, Bemben et al[10] suggested that the same gains in muscle strength and mass of the lower extremities (approximately 30%) could be made in older women with 3 sets

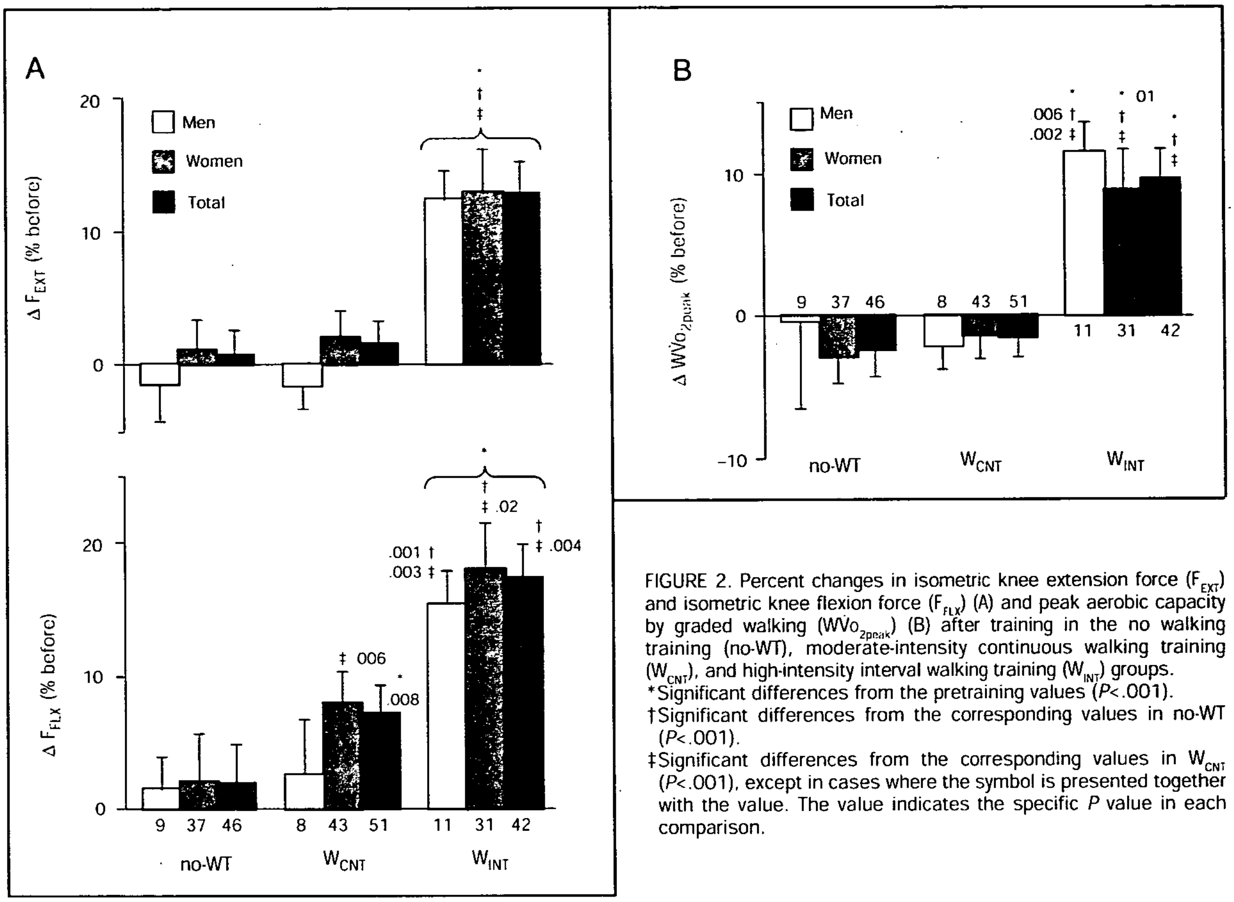

FIGURE 2. Percent changes in isometric knee extension force (F_{EXT}) and isometric knee flexion force (F_{FLX}) (A) and peak aerobic capacity by graded walking ($W\dot{V}o_{2peak}$) (B) after training in the no walking training (no-WT), moderate-intensity continuous walking training (W_{CNT}), and high-intensity interval walking training (W_{INT}) groups.
*Significant differences from the pretraining values ($P<.001$).
†Significant differences from the corresponding values in no-WT ($P<.001$).
‡Significant differences from the corresponding values in W_{CNT} ($P<.001$), except in cases where the symbol is presented together with the value. The value indicates the specific P value in each comparison.

of lower-intensity (40% 1RM) resistance training repeated 16 times per day, 3 days per week for 6 months, as with 3 sets of high-intensity (80% 1RM) resistance training repeated 8 times per day for the same period. Similar results were obtained in young subjects.[11,12] Recently, we showed that isometric knee extension could be increased by 13% and thigh muscle mass by 8.4%, as measured by magnetic resonance imaging, in older men cycling at 50% to 80% of $\dot{V}o_{2peak}$, 60 minutes per day, 3 days per week, for 18 weeks, but not in those engaging in moderate-intensity continuous walking, ie, approximately 10,000 steps per day, 6 to 7 days per week, for 18 weeks.[4,5] Thus, like traditional resistance training, higher repetitions of muscle contraction and relaxation above a given intensity may increase thigh muscle strength in older people.

The increase in $\dot{V}o_{2peak}$ in the high-intensity interval walking group was greater than that in the continuous walking group. Fleg and Lakatta[13] have suggested that the age-associated decline in $\dot{V}o_{2peak}$ per kilogram of body weight may be attributable to loss of muscle mass because such declines diminished markedly to only 10% to 20% in healthy men and women aged 22 to 87 years in whom 24-hour urinary creatinine excretion, an index of muscle mass, was normalized. Using dual x-ray absorptiometry to test for a number of muscle mass indices, Proctor and Joyner[14] showed that age-associated decline in $\dot{V}o_{2peak}$ was associated with a decline in muscle mass. Taken together with our own previous reports,[4,5] these studies suggest that the greater increase in thigh muscle strength or mass in the interval walking group in our current study might have contributed to the greater increase in $\dot{V}o_{2peak}$.

In addition to the increase in thigh muscle mass, an increase in aerobic capacity per unit of muscle mass may contribute to the increase in $\dot{V}o_{2peak}$. Capillary density and citrate synthetase activity were shown to increase with an increase in mean fiber area after 12 weeks of resistance training in older men.[15] Cellular oxidative capacity was also enhanced after 6 months of aerobic and resistance training in older patients.[16] Since aerobic training in older

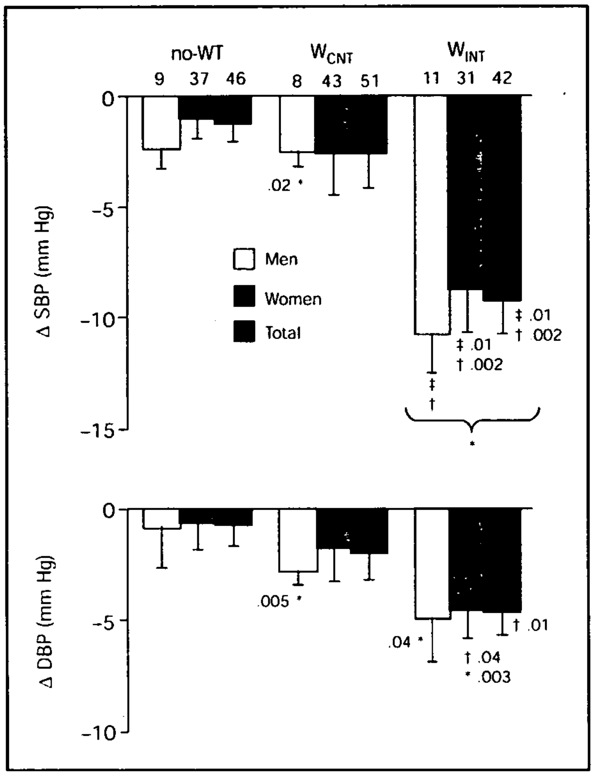

FIGURE 3. Changes in systolic blood pressure (SBP) and diastolic blood pressure (DBP) at rest after training in the no walking training (no-WT), moderate-intensity continuous walking training (W_{CNT}), and high-intensity interval walking training (W_{INT}) groups.
*Significant differences from the pretraining values ($P<.001$).
†Significant differences from the corresponding values in no-WT ($P<.001$).
‡Significant differences from the corresponding values in W_{CNT} ($P<.001$), except in cases where the symbol is presented together with the value. The value indicates the specific P value in each comparison.

men was shown not to affect blood volume[4] and cardiac stroke volume at a given intensity of exercise,[17] the increase in $\dot{V}o_{2peak}$ is likely caused by an accelerated oxygen extraction rate in thigh muscle rather than by increased oxygen delivery due to increased maximal cardiac output.

The greatest reductions in blood pressure after training were observed in the high-intensity interval walking training group (Figure 3). In a 1- to 12-year retrospective study of men and women aged 20 to 65 years with no history of hypertension, Blair et al[18] showed that subjects with low levels of $\dot{V}o_{2peak}$ were at higher risk for developing hypertension than were those with high $\dot{V}o_{2peak}$. Sawada et al[19] further showed in a 5-year longitudinal study of men aged 50 years and older that subjects with increased $\dot{V}o_{2peak}$ were less likely to have increased blood pressure after 5 years than those with unchanged or decreased $\dot{V}o_{2peak}$. In the current study, the high reduction in SBP occurred in the subjects with increased $\dot{V}o_{2peak}$. Our study is one of the first prospective attempts to test epidemiological findings, and its findings suggest that blood pressures can be decreased and $\dot{V}o_{2peak}$ enhanced by even short periods of exercise.

Our study has several potential limitations. First, different monitoring systems were used for the moderate-intensity continuous and high-intensity interval walking training groups. Because we had a limited number of triaxial accelerometers, we used pedometers in the moderate-intensity continuous walking training group, thinking that steps divided by exercise duration would give us reasonable measures of exercise intensity in this group. We thought it important to use the accelerometers in the high-intensity interval walking training group because we wanted to ensure that the desired changes in exercise intensity occurred. Thus, although 2 different monitoring systems were used, they were optimally targeted to the appropriate group and could be used to ensure that subjects meeting inclusion criteria achieved the desired exercise patterns and intensities.

Second, the subjects in the high-intensity interval walking training group, who were divided into 5 small groups, visited the center more frequently (approximately 18 times) and interacted with the trainer more, perhaps influencing the pre- and posttraining blood pressure measurements. However, members of the moderate-intensity continuous walking training group visited the center approximately 11 times and could reasonably be expected to have gained complete familiarity with the testing environment. Thus, we believe it is unlikely that the different monitoring systems and the different style of interaction with the trainer in the continuous and interval walking groups affected the main outcomes of the study.

Third, 30% of the subjects in the no walking training group, 17% of those in the moderate-intensity continuous walking training group, and 22% in the high-intensity interval walking training group did not return to the laboratory for a physical fitness test after training. Another 15% in the no walking training and moderate-intensity continuous walking training groups and 30% in the high-intensity interval walking training group did not meet the criteria for inclusion in the study. If more opportunities for a physical fitness test and for an explanation of the importance of this study had been given to participants, more of them may have returned to the laboratory. Similarly, if more opportunities to master the interval walking with an accelerometer had been given at an early stage of training, more participants may have met the targets set for that group. However, limitations in staff and facilities made it impossible to provide such opportunities in this study. Given these limitations, we did not include all randomized participants in the analysis. Therefore, the possibility exists that the study findings are influenced by selection bias.

In future studies, we will attempt to minimize inconvenience and improve attainment of study targets by use of the Internet. The Internet would allow for remote supervision by a trainer and for self-monitoring of progress by participants, obviating the need for trips to a gymnasium and making attainment of exercise targets more likely. Also, encouraged by the reduction in SBP observed in this study in participants with increased physical fitness, we will examine the effects of genetic background, blood lipid and glucose concentrations, diets, and depressive scores not only on age-associated diseases but also on health care costs.

CONCLUSION

High-intensity interval walking training might help protect against age-associated reductions in muscle strength and $\dot{V}o_{2peak}$ and increases in blood pressure. Guidelines for exercise in healthy older adults should encourage at least some higher-intensity component during walking.

REFERENCES

1. Haskell WL, Phillips WR. Effects of exercise training on health and physical functioning in older persons. In: Nose H, Nadel ER, Morimoto T, eds. *The 1997 Nagano Symposium on Sports Sciences*. Carmel, Ind: Cooper Publishing Group; 1998:399-417.
2. Armstrong L, Balady GJ, Berry MJ, et al. General principles of exercise prescription. In: Whaley MH, ed. *ACSM's Guidelines for Exercise Testing and Prescription*. 7th ed. Baltimore, Md: Williams &Wilkins; 2006:133-173.
3. Iwashita S, Takeno Y, Okazaki K, et al. Triaxial accelerometry to evaluate walking efficiency in older subjects. *Med Sci Sports Exerc*. 2003;35:1766-1772.
4. Okazaki K, Kamijo Y, Takeno Y, Okumoto T, Masuki S, Nose H. Effects of exercise training on thermoregulatory responses and blood volume in older men. *J Appl Physiol*. 2002;93:1630-1637.
5. Okazaki K, Kamijo Y, Takeno Y, et al. The effects of aerobic or resistance training on blood volume, thigh muscle mass, and peak aerobic power in older men [abstract] [in Japanese]. *Jpn J Phys Fitness Sports Med*. 2001;50:885. Abstract 305.
6. Armstrong L, Balady GJ, Berry MJ, et al. Other clinical conditions influencing exercise prescription. In: Whaley MH, ed. *ACSM's Guidelines for Exercise Testing and Prescription*. 7th ed. Baltimore, Md: Williams & Wilkins; 2006:205-236.
7. Bouten CV, Westerterp KR, Verduin M, Janssen JD. Assessment of energy expenditure for physical activity using a triaxial accelerometer. *Med Sci Sports Exerc*. 1994;26:1516-1523.
8. Vickers AJ, Altman DG. Statistics notes: analysing controlled trials with baseline and follow up measurements. *BMJ*. 2001;323:1123-1124.
9. Hollis S, Campbell F. What is meant by intention to treat analysis? survey of published randomised controlled trials. *BMJ*. 1999;319: 670-674.
10. Bemben DA, Fetters NL, Bemben MG, Nabavi N, Koh ET. Musculoskeletal responses to high- and low-intensity resistance training in early postmenopausal women. *Med Sci Sports Exerc*. 2000;32:1949-1957.
11. Campos GE, Luecke TJ, Wendeln HK, et al. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. *Eur J Appl Physiol*. 2002 Nov;88:50-60. Epub 2002 Aug 15.
12. Folland JP, Irish CS, Roberts JC, Tarr JE, Jones DA. Fatigue is not a necessary stimulus for strength gains during resistance training. *Br J Sports Med*. 2002;36:370-373.
13. Fleg JL, Lakatta EG. Role of muscle loss in the age-associated reduction in $\dot{V}o_{2max}$. *J Appl Physiol*. 1988;65:1147-1151.
14. Proctor DN, Joyner MJ. Skeletal muscle mass and the reduction of $\dot{V}o_{2max}$ in trained older subjects. *J Appl Physiol*. 1997;82:1411-1415.
15. Frontera WR, Meredith CN, O'Reilly KP, Evans WJ. Strength training and determinants of $\dot{V}o_{2max}$ in older men. *J Appl Physiol*. 1990;68:329-333.
16. Jubrias SA, Esselman PC, Price LB, Cress ME, Conley KE. Large energetic adaptations of elderly muscle to resistance and endurance training. *J Appl Physiol*. 2001;90:1663-1670.
17. Okazaki K, Ichinose T, Mitono H, et al. Protein and CHO supplementation during aerobic training increased plasma volume and thermoregulatory capacity in older men [abstract]. *FASEB J*. 2004;18:A1099. Abstract 704.7.
18. Blair SN, Goodyear NN, Gibbons LW, Cooper KH. Physical fitness and incidence of hypertension in healthy normotensive men and women. *JAMA*. 1984;252:487-490.
19. Sawada S, Tanaka H, Funakoshi M, Shindo M, Kono S, Ishiko T. Five year prospective study on blood pressure and maximal oxygen uptake. *Clin Exp Pharmacol Physiol*. 1993;20:483-487.

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Exercise: A Walk in the Park?

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In this issue of *Mayo Clinic Proceedings,*[1] Nemoto et al address the benefits of walking regimens and in so doing reflect a broad movement in the exercise literature and the health intervention community. Emphasis is moving away from in-termittent sweat-drenched bouts of arduous exercise to more frequent walking, whether in the park, at work, or at home

Over the past 50 years, the core messages of publications in exercise physiology have evolved similarly to those of other societal movements Two generations ago, the notion that people would pay thousands of dollars or Euros each year to sweat and feel the pain of extreme physical exertion would have been viewed as untenable. However, the exercise movement emerged, and scientists and celebrities ran hand in hand to the gymnasium. During this time, the message conveyed by exercise literature was "more is better " The oft-quoted surgeon general's report[2] well summarizes the notion that more exercise of greater intensity promises more health of greater duration. The heated debates as to whether aerobic exercise has more health benefits than strength training[3] have quieted with the growing recognition that all exercise is good, and more of it is better [4]

It is interesting that the exercise movement evolved similarly to other emotional societal movements such as those addressing racial intolerance [5,6] and homosexual discrimination.[7] In those movements too, initial vehement cries for action and debate among the scientific, intellectual, and political communities as to how best to proceed gave way to consensus and action [8]

Nemoto et al report that walking training in middle-aged and older people bestows health benefits that are akin to those provided by a gymnasium exercise program This article is 1 of many that speak to the health benefits associated with walking, whether the outcome measurement is blood pressure,[9] as in this article, diabetes,[10] other metabolic disorders,[11] cardiovascular disease,[12] joint problems, or mental health (Figure 1) [13] Collectively, these data suggest that, regardless of the study population, walking improves health This information complements physiological studies that document the role played by inactivity or sedentariness in poor health[14] and in the pathogenesis of obesity [15-17] The growing body of scientific information regarding the health benefits of walking[18] and of reversing sedentariness is mirrored by a growing public interest in walking as a means of exercise and health

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What is one to make of the mounting evidence of the health benefits of walking in light of data from the exercise movement showing the benefits of high-intensity, high-level exertion? This apparent quandary can be resolved First, individuals who are able to undertake and sustain high-duration, high-intensity exercise are, by definition, healthier than the population who rarely exercises; long-distance cyclists are inevitably healthier than people who only occasionally walk in the park Second, emerging evidence indicates that a great deal of low-intensity activity can have as many health and physiological benefits as high-intensity exercise.[19] For example, if an office worker with elevated plasma triglycerides (eg, familial hypertriglyceridemia) goes to the gym and runs for 30 minutes at 5 mph, his or her triglyceride levels will decrease to normal values for the duration of the exercise and for approximately 1½ hours afterward.[20,21] Conversely, if the same office worker walks for 30 minutes of each hour throughout the workday, his or her triglyceride levels will also decrease during and after each walk, although not to the same degree as during a 5 mph run. However, because the walking occurs throughout the day, the *cumulative* daylong decrease in blood triglycerides is greater than that seen after a single bout of running.[22] Third, walking is accessible to many more people than high-intensity exercise both in tolerance and cost. Fourth and importantly, walking exposes participants to few activity-associated injuries,[23] whereas nearly all high-intensity athletes experience sports-associated injuries.[24] Overall, the critical health benefit may be derived from the displacement of sedentariness by activity.[25] The longer a person is active, the better, regardless of what form that activity takes.

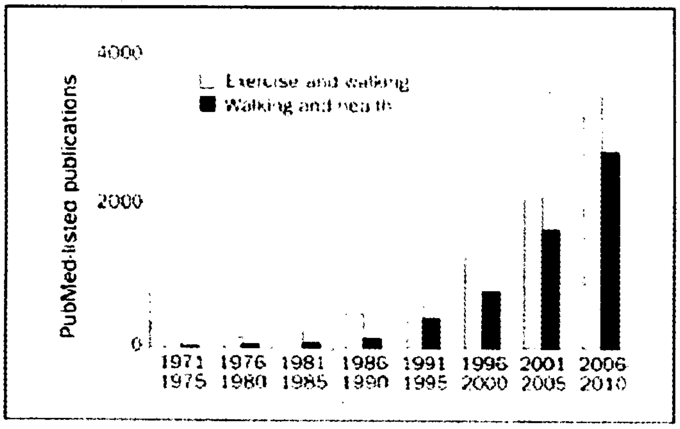

FIGURE 1. PubMed citations for *exercise and walking* and *walking and health.* Data are projected for 2010 based on 2006 data. PubMed search engine available at www.ncbi.nlm.nih.gov/entrez/query.fcgi.

In conclusion, humans evolved to walk upright over the past million years.[26] Over the past 200,000 years, people populated the earth by walking across it Our bodies evolved to walk.[27] As recent as 150 years ago, 90% of the world's population lived in agricultural regions,[28] and, like our distant ancestors, walked to work, physically exerted themselves at work, and walked home at the end of the day Water carriage, food preparation, and clothes washing were intensively manual,[29] and walking was required for socialization [30] In the short span of 150 years, we have forsaken our legs as a means of locomotion, work, and leisure. We are designed to walk all day long, and Nemoto's article suggests that we should.

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REFERENCES

1 Nemoto K, Gen-no H, Masuki S, Okazaki K, Nose H. Effects of high-intensity interval walking training on physical fitness and blood pressure in middle-aged and older people *Mayo Clin Proc* 2007;82:803-811.