Table 4. Prediction equations of SMI in the development group (Men: n=185, Women: n=673).

		Prediction equatios (kg/m^2)	R^2	SEE	F value	p value
Men	One variable	SMI = 0.220 × BMI + 2.991	0.56	0.35	231.21	<0.0001
	Two variables	SMI = 0.363 × BMI − 0.058 × Waist C + 4.523	0.65	0.38	172.41	<0.0001
	Three variables	SMI = 0.326 × BMI − 0.047 × Waist C − 0.011 × Age − 5.135	0.68	0.40	128.31	<0.0001
Women	One variable	SMI = 0.141 × BMI + 3.377	0.45	0.14	559.9	<0.0001
	Two variables	SMI = 0.133 × BMI + 0.045 × Handgrip strength + 2.409	0.56	0.15	426.9	<0.0001
	Three variables	SMI = 0.156 × BMI + 0.044 × Handgrip strength − 0.010 × Waist C + 2.747	0.57	0.17	295.4	<0.0001

SMI, skeletal muscle index: Waist C., waist circumference

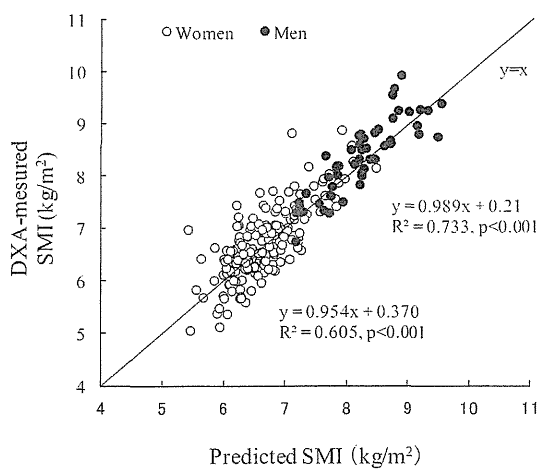

Fig. 5 Relationship between DXA-measured and predicted SMI (skeletal muscle index) in the cross-validation group.

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原　著

加速度計で求めた「健康づくりのための運動基準2006」における身体活動の目標値(23メッツ・時／週)に相当する歩数

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Daily steps corresponding to the reference quantity of physical activity of Exercise and Physical Activity Reference for Health Promotion 2006 (EPAR2006) assessed by accelerometer

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Abstract The purpose of this study was to determine daily steps corresponding to the reference value for the quantity of Physical Activity and Exercise for Health Promotion 2006 (23 METs·h/wk) considering non-locomotive activities. Two hundred and thirty one men and 224 women wore a tri-axial accelerometer for two weeks. We analyzed the data in each age group (young (less than 40 years), middle-aged (40 to 59 years), and elderly (60 years or more) groups), also. There were significant relationships between daily steps and locomotive activity ($r = 0.762$ to 0.820, $p < 0.001$) and total (locomotive and non-locomotive) physical activity ($r = 0.706$ to 0.824, $p < 0.001$) with intensity of 3 METs or more in all groups. The daily steps corresponding to 23 METs·h/wk, calculated using regression lines between the daily steps and total physical activities with intensity of 3 METs or more in men and women were 6,534 steps/d and 6,119 steps/d. On the other hand, the daily steps corresponding to 23 METs·h/wk, calculated using regression lines between the daily steps and locomotive activities with intensity of 3 METs or more in men and women were 7,888 steps/d and 8,584 steps/d. These results suggest that non-locomotive activity should also be taken into consideration in the case of assessment of a daily physical activity.

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Keywords : daily steps, physical activity, Exercise and Physical Activity Reference for Health Promotion 2006, accelerometer, non-locomotive activity

緒　言

日常生活が活動的な者において，生活習慣病の発症リスクが低いことが報告されている[1]．適度な活動量を維持するためには，現状の身体活動量を知り，個人のライフスタイルに応じて日常生活の中に運動を取り入れていくことが必要である．

これまで，身体活動を定量的に評価する方法として，質問紙法，歩数計法，加速度計法，心拍数法，二重標識水法（DLW法）などが用いられてきた[2]．中でも歩数計は，その簡便性と指標のわかりやすさから，我が国の国民健康・栄養調査[3]をはじめ，多くの研究で用いられて

いる．日本から発信された「1日1万歩」という目標値についても，国内外を問わず，その妥当性に関して議論がなされており[4]，わが国においても，1993年に出された「健康づくりのための運動指針」では1日の合計歩数は1万歩が目標とされた[5]．さらに平成12年から取り組まれてきた健康日本21においても，現状の歩数＋1,000歩が1日の身体活動の目標値として掲げられている[6]．

一方，2006年に厚生労働省が策定した「健康づくりのための運動基準2006～身体活動・運動・体力～（以下，運動基準2006）」[7]では，生活習慣病予防の観点から，歩行に限らず，仕事や家事などの日常生活活動を含む中等度以上の活動強度の必要性を強調している．また，健康の維持・増進に必要な身体活動・運動量として，強度が3メッツ以上の身体活動を23メッツ・時／週以上，そのうち運動を4メッツ・時／週以上実践することが推奨されている．23メッツ・時／週の身体活動量とは，3メッツ以上の強度の身体活動を1日あたり約60分行うことに相当し，歩行中心の活動で考えると，約6,000歩（10分あたり1,000歩で60分）に，低強度で意識されない歩数約2,000～4,000歩を加えた1日あたり8,000～10,000歩が目安になると示されている[7]．しかしながら，これはあくまでも試算したものであり，23メッツ・時／週と1日あたり8,000～10,000歩が日常生活環境下で実際に一致するかどうかは検討が必要である．

日常生活の中で，歩行は代表的な身体活動の一つであるが，歩行以外にも掃除機かけや洗濯などの家事活動のように上半身も動かす複雑な活動を行っている．運動基準2006では，体力の維持・向上を目的として計画的・意図的に実施する運動だけではなく，これらの家事活動などをも含めた身体活動の総量についての基準値が設けられている．そのため，日常生活における身体活動量を，より正しく捉えた上で23メッツ・時／週がどの程度の歩数に相当するのかを明らかにすることが必要である．そこで本研究では，歩行以外の生活活動も評価可能な3次元加速度計を用い，性・年齢階級別に加えて，身体活動を強度が3メッツ以上の歩行活動のみに限定した場合と歩行以外の生活活動も含めた場合の23メッツ・時／週に相当する歩数について明らかにすることを目的とした．

方　法

対象　主に京都市近郊に在住し，事前のアンケート調査により，健康診断等で医師から内科的または整形外科的な疾患によって運動制限されていないことが確認された男性231名，女性224名の計455名を対象とし，若年者群（40歳未満の男性84名，女性81名），中年者群（40歳以上60歳未満の男性100名，女性93名），高齢者群（60歳以上の男性47名，女性50名）の3群に分けて検討を行った（Table 1）．主な職種と人数は，男性で自営業25名，事務職106名，技能職21名，営業職41名，無職または主夫38名であり，女性で自営業12名，事務職61名，技能職31名，営業職38名，無職または主婦82名であった．

歩数および身体活動量の測定　歩数と活動量の測定には，データメモリ機能を有するオムロンヘルスケア社製の活動量計Active Style Pro（HJA-350IT）を用いた．本装置は，幅74×高さ46×奥行き34mm，質量が60gであり，腰部にクリップで装着して計測する仕様となっている．3軸の加速度データをもとに歩数と活動量をそれぞれ独自のアルゴリズムで演算するが，歩数については，加速度波形の振幅の大きさが予め決められた閾値以上になり，かつその動きが2秒間続いた場合に歩行と認識され，カウントされる[8]．また，活動量の演算にあたっては，活動強度にかかわらず，加速度信号の重力加速度成分の変化から，活動時に上半身の傾斜変化がみられない歩・走行などの歩行活動と，活動時に上半身の傾斜変化を伴う荷物運びや掃除機かけなどの生活活動に分類され，それぞれの身体活動時における合成加速度と活動強度の関係式を用いて歩行活動強度および歩行以外の生活活動強度が計測されるという特徴を有している[9,10]．

活動量計は2週間装着してもらい，1日の歩数および

Table 1.　Physical characteristics in different age groups.

	Group	N	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m²)
Men	Young	84	31.1 ± 5.5	173.1 ± 7.2	74.2 ± 16.3	24.7 ± 4.9
	Middle-age	100	47.5 ± 5.4 *	169.9 ± 6.3 *	72.0 ± 11.8	24.9 ± 3.6
	Elderly	47	66.3 ± 4.2 *†	166.1 ± 5.9 *†	68.0 ± 9.7 *	24.7 ± 3.3
Women	Young	81	32.3 ± 5.1	159.7 ± 5.5	63.7 ± 15.6	24.9 ± 5.8
	Middle-age	93	48.7 ± 5.8 *	157.8 ± 5.0 *	63.8 ± 11.3	25.6 ± 4.1
	Elderly	50	65.0 ± 4.1 *†	153.2 ± 5.1 *†	57.5 ± 8.2 *†	24.5 ± 3.5

Values are mean ± SD.
BMI indicates body mass index.
*: Significant difference from Young group ($p<0.05$).
†: Significant difference from Middle-age group ($p<0.05$).

MVPA（moderate-to-vigorous physical activity）の指標として，強度が3メッツ以上の歩行活動量（locomotive MVPA）と生活活動量（non-locomotive MVPA），その合計値（total MVPA）を算出した．対象者には，睡眠および活動量計が水に浸かる活動（入浴や水泳など）以外の全ての時間に活動量計を装着するように指示した．2週間の装着後に活動量計を回収し，専用ソフトを用いて解析を行った．日々の活動量のデータは，1分ごとに加速度信号の有無を確認し，1日あたり合計10時間以上の加速度信号が検出された日を装着日とし，平日2日，休日1日の計3日以上の装着日があったデータを解析に採用した．

倫理面への配慮　本研究は，独立行政法人国立健康・栄養研究所「研究倫理審査委員会－疫学研究部会」の承認を得て実施した．測定にあたって，対象者に測定の目的，利益，不利益，危険性，データの管理や公表について説明を行い，書面にて同意を得た．データは慎重に管理し，外部に流出することがないようにした．測定に伴う危険性はない．

統計処理　解析結果は，平均値±標準偏差で示した．男女間の差の検定には，対応のないｔ検定を用いて解析した．年齢階級別の3群間の平均値の比較には，一元配置分散分析法を用い，その後の多重比較にはTukeyのpost-hoc検定を用いた．また，歩数と活動量との関連性は，ピアソンの相関係数によって検討し，単回帰により回帰直線を求めた．解析にはSPSS15.0Jを使用し，統計学的有意水準はすべて5％未満とした．

結　果

対象者の身体特性をTable 1に示した．男女ともBMIを除くすべての指標において，年齢階級間で有意な差が認められた（p＝0.04～p＜0.001）．1日あたりの歩数は男性が平均7,293±2,815歩／日，女性が平均6,607±2,315歩／日であり，女性に比較して男性で有意に高値を示した（p＝0.005）．男女別年齢階級別にみたところ，男女ともに年齢階級別の3群間で有意な差は認められなかった（Table 2）．

強度が3メッツ以上の生活活動は，男性が平均8.1±7.2メッツ・時／週，女性が平均12.4±8.5メッツ・時／週であり，男性に比較して女性で有意に高値を示した（p＜0.001）．年齢階級別での検討では，女性においてのみ3群間で有意な差が認められ，若年者群で他の群よりも低値を示した．また，強度が3メッツ以上の歩行活動は，男性が平均19.9±11.6メッツ・時／週，女性が平均14.0±7.9メッツ・時／週であり，女性に比較して男性で有意に高値を示した（p＜0.001）．年齢階級別での検討では，男女ともに3群間で有意な差が認められ，男性では高齢者群で他の群よりも低値を示し，女性では若年者群で他の群よりも高値を示した．さらに，強度が3メッツ以上の生活活動と歩行活動を合計した総活動量は，男性が平均28.0±14.2メッツ・時／週，女性が平均26.4±11.7メッツ・時／週であり，男女間で有意な差が認められなかった．年齢階級別での検討では，男性においてのみ3群間で有意な差が認められ，高齢者群で他の群よりも低値を示した．

また，強度が3メッツ以上の総活動量に占める歩行活動の割合は，男性が平均70.2±19.0％，女性が53.6±19.0％であり，女性に比較して男性で有意に高値を示した（p＜0.001）．年齢階級別での検討では，男女ともに3群間で有意な差が認められ，男性では高齢者群で他の群よりも低値を示し，女性では若年者群で他の群よりも高値を示した．

1日あたりの歩数と強度が3メッツ以上の週あたりの総活動量との間には，男女ともに有意な相関関係が認め

Table 2.　Physical activity parameter by accelerometer in different age groups.

	Group	Steps (steps/d)	Total MVPA (METs·h/wk)	Non-locomotive MVPA (METs·h/wk)	Locomotive MVPA (METs·h/wk)	% Locomotive MVPA (%)
Men	Young	7393 ± 2713	31.4 ± 15.4	8.7 ± 7.8	22.7 ± 12.0	72.9 ± 16.9
	Middle-age	7430 ± 2877	28.0 ± 13.7	7.8 ± 7.5	20.2 ± 11.4	71.9 ± 19.0
	Elderly	6821 ± 2869	21.8 ± 10.9 *†	7.5 ± 5.2	14.3 ± 9.2 *†	61.9 ± 20.5 *†
		n.s.	p=0.001	n.s.	p<0.001	p=0.003
Women	Young	6565 ± 2232	25.4 ± 10.5	9.0 ± 6.1	16.3 ± 8.7	63.1 ± 18.5
	Middle-age	6806 ± 2355	27.4 ± 12.1	14.2 ± 9.0 *	13.2 ± 7.2 *	49.3 ± 16.5 *
	Elderly	6303 ± 2383	26.1 ± 12.8	14.3 ± 9.2 *	11.8 ± 6.8 *	46.3 ± 18.3 *
		n.s.	n.s.	p<0.001	p=0.002	p<0.001

Values are mean ± SD.
MVPA indicates moderate to vigorous physical activity with intensity 3 METs or more.
Locomotive MVPA indicates MVPA during locomotive activity.
Non-locomotive MVPA indicates MVPA during non-locomotive activity.
＊: Significant difference from Young group (p<0.05).
†: Significant difference from Middle-age group (p<0.05).

られた（男性：r＝0.770，p＜0.001，女性：r＝0.726，p＜0.001）．また，男女ともに，1日あたりの歩数と強度が3メッツ以上の週あたりの歩行活動との間には強い相関が（男性：r＝0.795，p＜0.001，女性：r＝0.747，p＜0.001），生活活動との間には弱い相関（男性：r＝0.240，p＜0.001，女性：r＝0.311，p＜0.001）が認められた．年齢階級別での検討では，すべての群において1日あたりの歩数と強度が3メッツ以上の週あたりの歩行活動（r＝0.762〜0.820，p＜0.001），および総活動量（r＝0.706〜0.824，p＜0.001）との間に有意な相関関係が認められた（Fig.1，2）．一方，1日あたりの歩数と強度が3メッツ以上の週あたりの生活活動との関係については，男性の若年者群（r＝0.272，p＝0.012）および中年者群（r＝0.264，p＝0.008），女性の中年者群（r＝0.361，p＜0.001）および高齢者群（r＝0.422，p＝0.002）においてのみ有意な相関関係が認められた．

強度が3メッツ以上の週あたりの総活動量と歩数の関係によると，健康の維持・増進に必要な身体活動推奨量である23メッツ・時／週に相当する歩数は，男性で6,534歩／日，女性で6,119歩／日であった．一方，歩行活動と判定された活動のみに限定した場合に得られる23メッツ・時／週に相当する歩数は，男性で7,888歩／日，女性で8,584歩／日であった．

男女別・年齢階級別でみると，23メッツ・時／週に相当する歩数は，歩行活動と歩数との関係から算出した場合に比べ，総活動量と歩数の関係から算出した場合にお

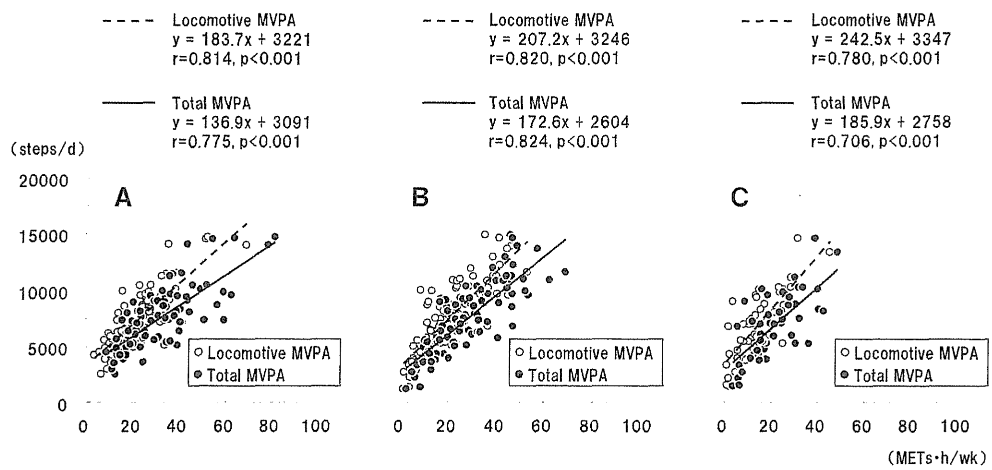

Fig 1. Relationships between daily steps and weekly MVPA in men.

MVPA indicates moderate to vigorous physical activity with intensity of 3 METs or more.
Locomotive MVPA indicates MVPA during locomotive activity.
A: Young group, B: Middle-age group, C: Elderly group.

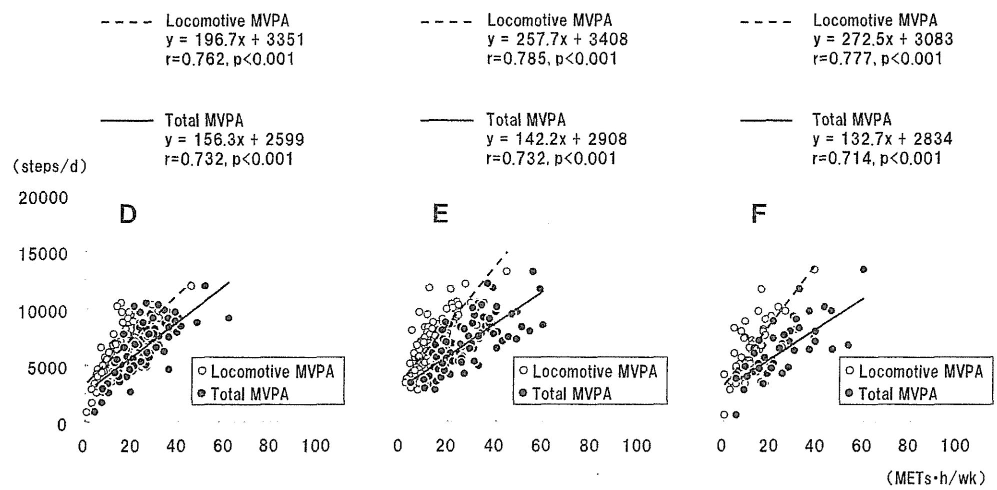

Fig 2. Relationships between daily steps and weekly MVPA in women.

MVPA indicates moderate to vigorous physical activity with intensity of 3 METs or more.
Locomotive MVPA indicates MVPA during locomotive activity.
D: Young group, E: Middle-age group, F: Elderly group.

いて，男性では若年者群で1,206歩，中年者群で1,437歩，高齢者群で1,889歩，それぞれ少なく，女性では若年者群で1,680歩，中年者群で3,156歩，高齢者群で3,463歩，それぞれ少なくなり，男女ともに加齢に伴って歩数の差が大きくなる傾向が認められた．

考　察

本研究は，3メッツ以上の身体活動量と歩数との関係について，歩行と歩行以外の身体活動を分離した計測が可能な加速度計を用いて得られた知見に基づいているという点に特徴がある．日常生活において，歩行以外の生活活動は，1日の身体活動が日本人の標準的なPAL（身体活動レベル）である1.75程度の生活では，2～4時間程度の普通歩行に相当する身体活動量にもなることが報告されている[11]．こういった生活活動を含めた身体活動量の推定に対して，加速度計が用いられているが，国内外において，1次元・3次元加速度計のいずれについても，歩行時に得られた加速度と活動強度の関係に基づく推定式が適用されることが多く，歩行以外の生活活動を過小評価する傾向にあった[12,13]．そのため，これまでにも加速度センサを用いて，歩行以外の生活活動を精度よく計測しようとする試みがなされている[14,15]．我々も独自のアプローチにより，3次元加速度の重力加速度成分の情報に基づいて上半身の傾斜の変化をとらえ，歩行系活動に加えて日常生活活動も精度よく評価できるアルゴリズムを開発した[9,10]．このアルゴリズムは，活動タイプによって加速度に対する重力加速度の寄与が異なることを利用し，歩行活動による身体活動と歩行以外の生活活動による身体活動に分類するという特徴を有している[9]．また，活動量計で得られた計測値の妥当性については，ダグラスバッグ法を基準として，歩行や家事などの12種類の動作において，それぞれ平均±6％以内の誤差で活動強度を推定できる[10]．さらに，ゆっくりとした歩行でも，歩数や強度を他機種と比べても正確に評価できることも確認されている[16]．この活動量計を用いて計測した1日の歩数と強度が3メッツ以上の週あたりの総活動量との関係式から23メッツ・時／週に相当する歩数を算出したところ，男性で6,534歩／日，女性で6,119歩／日となり，歩行中心の活動で考えた場合の目安として示されている1日あたり8,000～10,000歩[7]よりも明らかに低い値が得られた．また，年齢階級別にみても23メッツ・時／週に相当する歩数には大きな差はなかった．このことから，性・年代にかかわらず，生活活動も身体活動量の増加に貢献しており，歩行活動を高く維持することだけが必ずしも運動基準を満たす条件ではないことが示唆された．

運動基準2006によれば，「3メッツ」以上の身体活動には，歩行以外に屋内の掃除，掃除機かけ，風呂掃除といった家事活動なども含まれている[7]．こういった家事活動は上半身の動作が中心となるため，歩数には反映されにくい．先行研究において，3メッツ強度の1分間あたりの歩数，即ち歩行率は，歩行活動で100歩／分前後[17]であるのに対して，家事活動では，60歩／分程度[18]，あるいは，それよりも少ない[13]ことが報告されている．このように活動の内容によって活動強度と歩行率の関係性は異なるため，少ない歩数であっても，活発な生活活動によって身体活動量を増すことが可能であると考えられる．

本研究において，3メッツ以上の活動が歩行活動のみであると想定し，1日の歩数と強度が3メッツ以上の週あたりの歩行活動との関係から，23メッツ・時／週に相当する歩数を算出したところ，男性は7,888歩／日，女性は8,584歩／日であった．これは，歩行中心の活動の場合には，1日あたり8,000～10,000歩を目安とすることが妥当であったことを示唆している．また，23メッツ・時／週に相当するかどうかにかかわらず，1日の歩数を8,000～10,000歩に維持することが生活習慣病の予防に効果がある可能性がいくつかの論文より示唆されている[19-21]ため，望ましい身体活動量としてのひとつの目標値にすることは有用かつ実践的であると思われる．その一方で，本研究での運動基準の目標値に相当する歩数は，現在，国民健康・栄養調査で得られている平均値に近い値であった．運動基準2006では，週あたり23メッツ・時／週が目標値として設定されている．しかしながら，この目標値は主に欧米人を対象として質問紙調査で評価した身体活動量に基づく疫学研究結果から出されたものである[7]．また，目標値の設定の際にレビューされた論文で用いられた質問紙を考えると，総身体活動量というよりは，余暇時間の活動量を中心に扱っており，仕事中の活動や通勤，家事などについては部分的にしか考慮されていない[7]．そのため，今後，身体活動量の目標値の妥当性について，加速度計などを用いて検証した上で歩数との関連性を調査する必要があるものと思われる．

年齢階級別に見ると，男女ともに高齢者群で歩行活動による23メッツ･時／週に相当する歩数が高値を示した．高齢者では筋力低下に伴う歩幅の減少によって歩行速度が低下することが報告されている[22]．歩幅が減少した状態で3メッツ強度の歩行を行うためには，歩行率を高めることが必要となり，特に高齢者では負担が大きくなる．このことは，本研究において強度が3メッツ以上の週あたりの歩行活動が男女ともに若年者群に比べて高齢者群で有意に低値であったことからも明らかであり，特に歩数や歩行活動を中心とした身体活動による目標値を設定する場合には，性・年齢などを考慮する必要があると思われる．

先行研究では，成人男女92名を対象として，加速度セ

ンサを用いて歩数および強度が3メッツ以上の活動量を測定することで23メッツ・時／週に相当する歩数を算出し，10,652歩／日と本研究の結果に比較して高い値が報告されている[23]．また，Tudor-Lockeら[24]は，6つの研究のレビュー結果に基づき，1日あたり30分の中等度から高強度の身体活動（Moderate to vigorous physical activity: MVPA）は，7,000～8,000歩／日に相当すると報告している．先行研究において身体活動量のガイドラインに相当する歩数が，本研究の結果よりも高い傾向となっている要因の一つとして，先行研究で用いられた加速度計による活動強度の算出式が，歩行時に得られた加速度と活動強度の関係式に基づいて作成されたもの[25]であることがあげられる．加速度と活動強度の関係性は，歩行と生活活動とで異なるため，歩行時に得られた加速度と活動強度の関係式を用いると，歩行以外の生活活動を過小評価する傾向にあることが報告されている[12,13]．そのため，強度が3メッツ以上の歩行活動と歩行以外の生活活動を合わせた総活動量も過小評価してしまうことが推測され，それによって23メッツ・時／週に相当する歩数も大きな値となっている可能性が考えられた．

歩数と強度が3メッツ以上の歩行活動または総活動量との関係式から算出した23メッツ・時／週に相当する歩数の差についてみたところ，男女ともに大きな差が認められ，その差は女性および高齢者群で顕著であった．また，強度が3メッツ以上の総活動量に対する歩行活動の割合についても同様に男性よりも女性で小さく，男女ともに高齢者で低値を示しており，ライフスタイルの違いが，これらの結果に影響していることが示唆された．家事などの生活活動では強度の高い活動は少なく，1回の継続時間も短い場合がほとんどである．一回の身体活動の継続時間について，アメリカスポーツ医学会とアメリカ心臓学会が作成した身体活動ガイドラインでは，一回当たりの運動継続時間が10分間の場合と30分間の場合とで効果に差がないという報告に基づいて，10分以上の継続が明記されているものの[26]，わが国の運動基準2006では規定されていない．そのため，本研究のように，1分単位で活動強度を評価する方法は，運動基準2006に対応していると考えられる．先行研究では，日常生活での細切れの身体活動の蓄積と，30分以上の連続的な身体活動を比較し，同程度の運動量の実施では$\dot{V}O_2max$の改善効果に差がなかったこと[27]や，3分間×10回の運動は，食後高脂血症や血圧の改善に対して30分×1回の運動と同等の効果であったこと[28]が報告されている．また，運動に対するコンプライアンスについても1回にまとめて実施するよりも，複数回に分けて実施するほうが高いことが報告されている[29]．そのため，ウォーキングを中心とした身体活動のみでなく，日常生活での家事活動の増加などによって活動量を増やすことも有効かもしれない．今後，家事活動などの歩行以外の活動によってどの程度，身体活動量を増加させせることが可能か，さらに増やすことによる身体機能に対する効果はどうか，といったことを検討する必要があると思われる．

本研究の限界として，対象者が都市部の一部地域に限定されている点が挙げられる．また，事前のスクリーニングによって，医師から運動制限されていない者を抽出したため，特に高齢群においては一般集団よりも健康集団であり，相対的に身体活動量が多かった可能性が考えられる．そのため，幅広い地域の集団に対しても同様の結果が当てはまるとは限らない．今後，調査地域を拡大し，対象者をランダムに抽出した上でのさらなる検討が必要であると思われる．最後に，本研究で用いた活動量計の身体活動量は，歩行と歩行以外の身体活動量を加味したアルゴリズムで演算されたものである．そのため，本結果を他の歩行を前提にエネルギー消費量を算出した加速度計で得られた結果にあてはめることはできない．用いる歩数計および活動量計の機種によって計測アルゴリズムが異なるため，結果も異なる可能性があることに留意する必要がある．

ま と め

歩行以外の生活活動も評価可能な3次元加速度計を用い，健康の維持・増進に必要な身体活動量として推奨されている23メッツ・時／週に相当する歩数を検討した結果，男性で6,534歩／日，女性で6,119歩／日であった．一方，身体活動量を強度が3メッツ以上の歩行活動のみに限定して考えた場合，23メッツ・時／週に相当する歩数は男性で7,888歩／日，女性で8,584歩／日であった．このことから，歩行以外の生活活動も身体活動量の増加に貢献しており，身体活動量を評価する際に考慮すべきことが示唆された．

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Chair-rising and 3-min walk: A simple screening test for functional mobility

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ABSTRACT

Aging induces decrease of locomotor capacity and its decrease is associated with an increased risk of falls. Several lines of evidence indicate that both change in muscle power and aerobic fitness are causative. Mobility tests are usually based on a maximal exercise stress test; however, this test is often difficult and sometimes frightening to older persons. Therefore, the objective of this study was to examine age and gender differences in 3-min walk distance test (3WDT), and time of chair-rising test (CRT) of functional mobility. 153 men and 159 women aged from 20 to 78 years were recruited as subjects of the present study. The body composition measured the height, body mass (BM), body mass index (BMI), lean tissue mass (LTM), and waist circumference (WC). The Functional mobility tests measured the peak oxygen uptake (V_{O2peak}), 3WDT, leg extension strength (LES), and times of CRT. Both in men and women, height and BMI, WC decreased and increased, respectively, with age. Height, BM, LTM, WC in men are higher than in women. We found no correlation between ages and 3WDT in women and a significant, negative correlation in men. All parameters of fitness performance were negatively correlated with age. Both in men and women, all parameters of fitness performance were positively correlated with sex. Both in men and women, V_{O2peak}, 3WDT, and LES decreased with age. All parameters of fitness performance in men are higher than in women. Both in men and women were observed for the correlation between 3WDT and V_{O2peak}, LES and CRT respectively. Although as the correlation coefficient between 3WTD and V_{O2peak}, LES and CRT were low (r = 0.28 - 0.38), an error may occur, this study shows that 3WDT and CRT test can be a feasible method of providing the information for muscle power and aerobic fitness, possibly avoiding the need for a maximal stress test.

Keywords: Peak Oxygen Uptake; 3-Min Walk Distance Test; Leg Extension Strength; Chair-Rising Test; Mobility

1. INTRODUCTION

Aging induces decrease of locomotor capacity and its decrease is associated with an increased risk of falls. Current demographic trends show that the number of older people is rapidly increasing. In fact, mobility is essential for functional independence, reduced risk of fall, and quality of life [1-3]. In older persons, disability is caused by both change in muscle power and aerobic fitness is causative. Several studies have shown that there is a decline in the ability to perform muscle power-related tests as age increases with a significant decline commencing at approximately 40 years of age. Similarly, physical performance decrease with age. These age-related changes in the performance of functional mobility measures and physiological domains are also associated with an increased risk of falls, ongoing disability and admission into residential aged care [3,4].

Mobility tests are commonly used to assess function and frailty in older persons. Mobility tests are usually based on a maximal exercise stress test; however, this test is often difficult and sometimes frightening to older persons. 3-min walk distance test and chair-rising test are low of risk. There are little data available on the age-related changes and gender differences in the performance of these tests. The development of age stratified normative data for these commonly used functional mobility tests could assist in the targeting of interventions for people who exhibit a decline in their functional status at an early stage, prior to the occurrence of falls and the onset of disability. Therefore, the aim of this study was to provide reference data and examine age and gender differences in 3-min walk distance test, and time of rising chair without using the arms. The second aim was to provide data available on the age-related changes in the performance of these tests. The information provided is relevant to new functional mobility tests in older persons.

2. METHODS

2.1. Participants

One hundred and fifty-three men and one hundred and fifty-nine women aged from 20 to 78 years (44.3 ± 14.8 years) were recruited as subjects of the present study. None of the subjects had any chronic diseases or were taking any medications that could affect the study variables. All subjects provided written informed consent according to local institute policy before the measurement of physical fitness. All subjects were classified into six groups by sex and age: 20 to 39-year-old men, 40 to 59-year-old men, 60 to 79-year-old men, 20 to 39-year-old women, 40 to 59-year-old women, and 60 to 79-year-old women. This study has been approved by the Committee on the Use of Human Research Subjects of Matsumoto University, and also performed in accordance with the ethical standards of the IJSM [5]. Participants were fully informed of the purpose and risks of participating in this investigation and signed informed consent documents prior to testing. The participants characteristics are described in **Table 1**.

2.2. Anthropometrics

The body composition measured the height, body mass (BM), body mass index (BMI), lean tissue mass (LTM), and waist circumference (WC). Height was measured to the nearest 0.1 cm using a stadiometer (YKH-23; Yagami Inc., Japan). BM, BMI, and LTM were measured using a body composition meter (BC-118E; TANITA Inc., Japan).

2.3. Functional Mobility Tests

The four tests were administered in a single session. Timed tests were measured with stopwatch with an accuracy of 0.01 s.

2.4. Leg Extension Strength (LES)

LES was assessed using GT-330 (OG-giken, Japan). The individuals were seated in the chair of the dynamometer, and were stabilized with straps across the waist and thighs throughout the test. Bilateral reciprocal contractions at the knee were measured at a preset angle of 120°. An index of strength was determined by summing peak extension torque. The average value in two times the right and left was assumed to be measurements.

2.5. Peak Oxygen Uptake (V_{O2peak})

V_{O2peak} was measured using a maximal graded exercise test (GTX) with bicycle erometers (Monark Ergomedic 828E, Sweden). The initial workload was 30 - 60 W, and the work rate was increased thereafter by 15 $W{\cdot}min^{-1}$ until subject could not maintain the required pedaling frequency (60 rpm). Heart rate (WEP-7404; NIHON KOHDEN Corp., Japan) and a rating of perceived exertion were monitored throughout the exercise. During the progressive exercise test, the expired gas of subjects was collected, and the rates of oxygen consumption and Carbon dioxide production were measured and averaged over 30-s intervals using an automated breath-by-breath gas analyzing system (Aeromonitor AE-280S; Minato Medical Science, Japan).

2.6. Chair-Rising Test (CRT)

In this test, participants were asked to rise from a standard height (43 cm) chair without armrests, ten times as fast as possible with their arms folded. Arms are crossed in front of the chest. Participants undertook the test barefoot. The time from the initial seated position to the final seated position after completing ten stands was the test measure. Two trials were to be performed. The higher value in two trials was assumed to be measurements.

Table 1. Physical characteristic of the study subjects, mean ± SD.

	All	Age 20 - 30 years	Age 40 - 50 years	Age 60 - 70 years	All	Age 20 - 30 years	Age 40 - 50 years	Age 60 - 70 years
		Men					Women	
N	153	79	44	30	159	69	54	36
Height (cm)	169.7 ± 6.7	171.0 ± 6.6	170.5 ± 6.0	$164.9 \pm 5.7^{**\#}$	$157.6 \pm 5.6^{+++}$	159.6 ± 5.1	158.4 ± 4.3	$152.7 \pm 5.1^{***\#\#\#}$
BW (kg)	62.8 ± 7.8	62.2 ± 8.1	64.7 ± 6.5	61.7 ± 8.3	$50.8 \pm 6.1^{+++}$	50.8 ± 6.2	52.3 ± 6.4	$48.4 \pm 4.9^{\#}$
BMI (kg/m^2)	21.8 ± 2.2	21.2 ± 2.0	$22.2 \pm 1.9^{**}$	$22.6 \pm 2.7^{*}$	$20.4 \pm 2.1^{+++}$	19.9 ± 2.1	$20.8 \pm 2.1^{*}$	$20.8 \pm 2.2^{*}$
MV (kg)	50.4 ± 5.0	50.7 ± 5.1	51.5 ± 4.3	48.1 ± 5.1	$35.6 \pm 3.1^{+++}$	36.1 ± 3.2	36.3 ± 2.8	$33.4 \pm 2.2^{***\#\#\#}$
WS (cm)	77.4 ± 7.2	74.6 ± 6.8	$79.2 \pm 5.7^{***}$	$82.3 \pm 7.1^{***}$	$73.0 \pm 6.8^{+++}$	70.3 ± 5.6	$74.0 \pm 6.0^{**}$	$76.4 \pm 7.9^{***\#}$

SD = Standard Deviation; BW = Body Weight; BMI = Body Mass Index; MV = Muscle Volume; Waist Size = WS; $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$ vs Age 20 - 30 years $^{\#\#\#}p < 0.001$, $^{\#\#}p < 0.01$, $^{\#}p < 0.05$ vs Age 40 - 50 years $^{+++}p < 0.001$ vs men.

2.7. 3-Min Walk Distance Test (3WDT)

The participants performed the 3WDT in a 50-m indoor corridor with marks every second metre on the side of the walkway. They were instructed to wear comfortable shoes. The instructions were to walk as many lengths as possible in three minutes, without running or jogging. To clarify the instructions, the participants were also told to walk as fast as possible. Information was given during the test by telling the participants how many minutes they had walked or minutes remaining. Finally, the total 3WDT was measured.

2.8. Statistical Analyses

Results are expressed as mean values with their standard errors. The statistical significance (p, 0.05) of differences was determined by 2-way ANOVA followed by a Tukey post hoc analysis. Correlations between a fitness performance and another fitness performance were assessed by Pearson's correlation coefficients (r).

3. RESULTS

The physical characteristic of the study is described in **Table 1**. Height decreased and BMI, WC increased in men, respectively, with age. Height, BM and LTM decreased and BMI and WC increased in women. All physical characteristic in men are higher than in women. **Table 2** reports the correlation between ages and functional mobility tests. All functional mobility tests, except for 3WDT in women, were negatively correlated with age (**Table 2**). **Table 3** reports the parameters of functional mobility tests of the study subjects. All parameters of functional mobility tests were positively correlated with sex. All parameters of functional mobility tests in men are higher than in women. Both in men and women were observed for the correlation between 3WDT and V_{O2peak}, LES and CRT respectively. **Figure 1** reports the relationship between 3WDT and V_{O2peak} in the men (n = 153) and women (n = 159). Both in men and women, 3WTD was correlated with V_{O2peak} (r = 0.31 and 0.31, respectively; $p < 0.0001$). **Figure 2** reports the relationship between LES and CRT in the men (n = 153) and women (n = 159). Both in men and women, LES was correlated with CRT (r = 0.38 and 0.28, respectively; $p < 0.001$).

4. DISCUSSION

3WDT and CRT is the simplest test of the V_{O2peak} test and leg strength, respectively. This study adds to the accumulating literature investigating the dynamic relations between body compositions and the functional mobility test in the elderly.

Body composition varies according to age, sex, and race. Older adults tend to lose fat-free mass and gain fat mass. WC is a reliable marker of mortality in older adults [6-8] and muscle mass, as represented by lean mass, is associated with survival. In the present study, height, BMI and WC were decreased and increased, respectively, with age in men and women. Moreover, Height, BM, LTM and WC in men is higher than in women.

The Functional mobility tests measured the V_{O2peak}, 3WDT, LES, and CRT. The study findings revealed significant age-related differences in all functional mobility tests examined. These findings confirm those of previous studies and indicate that when compared with young people, older people exhibit slower comfortable walking speed [5,9], reduced ability to quickly rise from a chair [3,10]. These age-related differences in functional mobility have been attributed to impaired sensorimotor function [11,12], in particular reduced lower extremity strength and power [13-15], but also increased fear of falling [8] and reduced aerobic capacity [16].

Table 2. Correlation of the variables of interest with age.

	CRT (sec)	3WDT (m)	LE (n - m)	V_{O2max} (ml/kg/min)
Women	0.19^{*}	–0.12	-0.32^{**}	-0.49^{**}
Men	0.42^{**}	-0.32^{**}	-0.32^{**}	-0.51^{**}

CRT = chair-rising test; 3WDT = 3-min walk distance test; LE = leg extension; V_{O2max} = maximum oxygen uptake; Pearsons correlation coefficients. $^{**}p < 0.001$, $^{*}p < 0.05$.

Table 3. Parameters of fitness performance of the study subjects, mean ± SD.

	All	Age 20 - 30 years	Age 40 - 50 years	Age 60 - 70 years	All	Age 20 - 30 years	Age 40 - 50 years	Age 60 - 70 years
		Men					Women	
N	153	79	44	30	159	69	54	36
V_{O2max} (ml/kg/min)	36.7 ± 9.1	40.7 ± 8.1	$35.0 \pm 7.7^{***}$	$28.6 \pm 6.9^{***\#\#\#}$	$27.8 \pm 6.4^{+++}$	30.6 ± 6.5	$27.4 \pm 5.3^{**}$	$23.0 \pm 4.4^{***\#\#\#}$
CRT (sec)	10.2 ± 2.4	9.5 ± 1.8	9.6 ± 1.7	$12.8 \pm 3.1^{***\#\#\#}$	$11.1 \pm 2.5^{+++}$	10.7 ± 2.7	11.2 ± 2.3	11.6 ± 2.5
3WDT (m)	390.0 ± 58.7	403.3 ± 58.9	390.7 ± 38.9	$353.7 \pm 68.0^{***\#\#}$	$350.6 \pm 34.1^{+++}$	351.1 ± 34.6	358.2 ± 31.6	$338.4 \pm 34.4^{\#}$
LE (n - m)	630.1 ± 137.0	669.3 ± 130.8	622.8 ± 136.5	$537.7 \pm 108.3^{***\#\#}$	$409.2 \pm 106.3^{+++}$	430.1 ± 118.8	420.3 ± 91.1	$352.6 \pm 81.7^{***\#\#}$

SD = Standard Deviation; CRT = chair-rising test; 3WDT = 3-min walk distance test; LE = leg extension; V_{O2max} = maximum oxygen uptake.

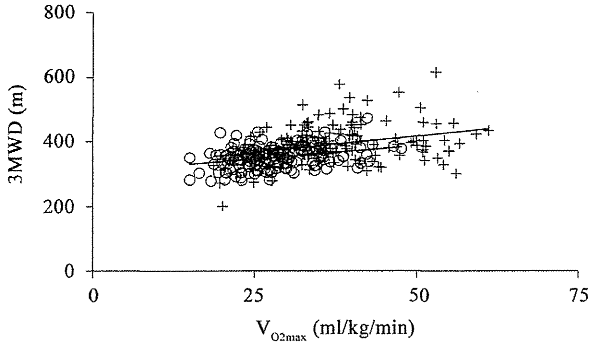

Figure 1. Relationship between 3WTD and V_{O2max} in the men (n = 153) and women (n = 159). The 3MWD was to walk as many lengths as possible in three minutes. V_{O2max} was to until subject could not maintain the required pedaling frequency (60 rpm).

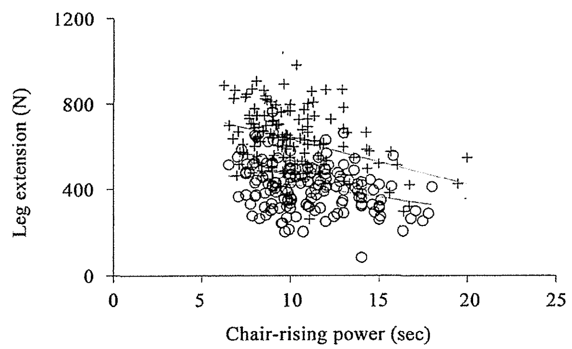

Figure 2. Relationship between LE and CRT in the men (n = 153) and women (n = 159). The LE was to the highest in four times in total the right and left two times value. Chair-rising times from the initial seated position to the final seated position after completing ten stands were the test measure.

A remarkable decline, however, was observed in the performance variables (muscle strength and aerobic capacity) assessed by the CRT and by 3WDT. The CRT was measured power during an activity which involves raising the centre of gravity. Several studies have found that performance in the CRT is a strong predictor of incident disability, mortality, falls, hospitalization and health care resources consumption. Hence, CRT can be regarded as an indicator of physical performance at old age. In the present study, both in men and women were observed for the correlation between 3WDT and V_{O2peak}, LES and CRT respectively, and the fact that this test can be a feasible method of providing the information for muscle power and aerobic fitness, possibly avoiding the need for a maximal stress test.

Significant correlations among all the functional mobility tests in the older group indicate that older adults who performed poorly in one test were likely to perform poorly in all the other tests. The results from the present study, the functional mobility tests of 3WDT and CRT were found to give an idea of the physical decline with age in fit elderly without any maximal exercise stress.

In conclusion, first, this study provides significant age-related differences in performance were found in tests of coordinated the V_{O2peak}, 3WDT, LES, and CRT, with older women performing worse than older men in all tests. Secondly, this study shows that 3WDT and CRT can be a feasible method of providing the information for muscle power and aerobic fitness, possibly avoiding the need for a maximal stress test.

Limit

As the correlation coefficient between 3WTD and V_{O2peak}, LES and CRT were low (r = 0.28 - 0.38), an error may occur. Accordingly, this study shows that 3WDT and CRT as estimate method for aerobic fitness and muscle power can be a feasible, if we measure many people as method briefly and in safety.

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Relationship between predicted oxygen uptake and cigarette smoking in Japanese men

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ABSTRACT

The link between cigarette smoking and predicted oxygen uptake was investigated using data for 149 Japanese men not taking medication. Cigarette smoking habits were obtained through interviews by well-trained staff. The influence of cigarette smoking on predicted oxygen uptake, predicted work rate and predicted heart rate were evaluated. Predicted oxygen uptake decreased with age. Predicted oxygen uptake and predicted work rate in men who smoked cigarettes was significantly lower than in subjects who did not, after adjusting for age. The differences in parameters did not reach significant levels after adjusting for age and physical activity evaluated by Σ[metabolic equivalents × h per week (METs·h/w)] (predicted oxygen uptake: $p = 0.0632$, predicted work rate: $p = 0.0873$). Cigarette smoking might be a modifyable factor for improving the aerobic exercise level in Japanese men.

Keywords: Cigarette Smoking; Predicted Oxygen Uptake; Metabolic Equivalents

1. INTRODUCTION

Regular physical activity has been shown to increase high density lipoprotein (HDL) cholesterol and reduce resting blood pressure, triglycerides, abdominal fat, fasting blood sugar, and insulin responses to the oral glucose challenge test [1-5]. In addition, Sandvik L. *et al.* reported that physical fitness was a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged men [6]. Maximal oxygen uptake is generally considered an accurate and reliable parameter. In the Exercise and Physical Activity Reference for Health Promotion 2006, established by the Ministry of Health Labour and Welfare Japan in 2006, maximal oxygen uptake was considered to be the most significant element of physical fitness related to health promotion and the recommended reference value for maximal oxygen uptake to prevent lifestyle-related disease was reported [7].

Cigarette smoking has become an important public health challenge, and it has been reported that 39.4% of men and 11.0% of women are current smokers in Japan [8]. Cigarette smoking is also a strong risk factor for atherosclerosis and cardiovascular disease in a dose dependent manner [9]; however, the relationship between cigarette smoking and aerobic exercise level defined by maximal oxygen uptake has not been fully discussed.

The aim of this study was to explore the link between cigarette smoking and predicted oxygen uptake in Japanese men.

2. SUBJECTS AND METHODS

2.1. Subjects

We used data for 149 Japanese men (44.1 ± 14.1 years) who met the following criteria from April 2007 to March 2010 at Okayama Southern Institute of Health, Okayama, Japan: 1) underwent anthropometric and predicted oxygen uptake measurements and evaluation of cigarette smoking voluntarily; 2) receiving no medications for diabetes, hypertension and/or dyslipidemia; and 3) provided written informed consent (**Table 1**).

Ethics approval for the study was obtained from the Ethics Committee of Okayama Health Foundation.

2.2. Anthropometric and Body Composition Measurements

Anthropometric and body compositions were evaluated based on the following parameters: height, body

Table 1. Clinical profiles of enrolled men.

	Mean ± SD	Minimum	Maximum
Number of subjects	149		
Age	44.1 ± 14.1	21	69
Height (cm)	170.2 ± 5.6	158.1	187.3
Body weight (kg)	66.4 ± 8.8	48.3	96.4
Body mass index (kg/m^2)	22.9 ± 2.9	17.2	34.7
Abdominal circumference (cm)	81.3 ± 8	63.9	104.9
Body fat percentage (%)	19.8 ± 5.6	27.3	60.4
Predicted oxygen uptake (ml/kg/min)	37.2 ± 8.7	16.5	61.9
Predicted work rate (watt)	200.8 ± 49.1	91	354
Predicted heart rate (beat/min)	178.6 ± 23.2	106	230
Daily step counts (steps/day)	8588.7 ± 3601.4	973.0	20910.9
METs·h/w	14.5 ± 10.8	0.0	63.4

Σ[metabolic equivalents×h per week (MET·h/w)]

weight, abdominal circumference and body fat percentage. Abdominal circumference was measured at the umbilical level in standing subjects after normal exhalation [10]. Body fat percentage was measured by dual energy X-ray absorptiometry (DEXA) (QDR4500; Hologic Inc., Waltham, MA, USA), which is used as an accurate standard [11]. The DEXA measurement consisted of a whole body scan using an array beam [12]. Subjects removed all metal objects and were positioned in the supine position with hands placed prone on either side of the body and with legs held 10 cm apart according to the specifications of the manufacturer. All scans were analyzed according to the manufacturer's instructions [13].

2.3. Exercise Testing

Predicted oxygen uptake was measured using a maximal graded exercise test with bicycle ergometers (Excalibur V2.0; Lode BV, Groningen, Netherlands). The initial work load was 30 - 60 watt, and the work rate was increased thereafter by 15 watt/min until the subject could not maintain the required pedaling frequency (60 rpm) [14]. During the latter stages of the test, each subject was verbally encouraged by the test operators to make their maximal effort. In addition, ECG was monitored continuously together with recording of the heart rate (HR). Expired gas was collected and rates of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured breath-by-breath using a cardiopulmonary gas exchange system (Oxycon Alpha; Mijnhrdt b.v., Netherlands). Achievement of predicted oxygen uptake was accepted if two of the following conditions were met: subject's maximal HR was >95% age-predicted maximal HR (220 – age), and the VO_2 curve showed a leveling off.

2.4. Cigarette Smoking

Data on cigarette smoking were obtained at interviews by well-trained hired staff, such as a public health nurse, in a structured way. The subjects were asked if they currently or had previously smoked cigarettes for at least 6 months and/or 100 cigarettes. When the answer was "yes", they were classified as cigarette smokers (+). When the answer was "no", they were classified as cigarette smokers (–).

2.5. Physical Activity

Physical activity was measured by the Kenz Lifecorder (LC; SUZUKEN Co Ltd, Nagoya, Japan) which is a recent addition to the growing number of uniaxial accelerometer options; it offers comparable instrument outputs with several potentially attractive features for researchers and practitioners. The LC displays reasonable estimates of physical activity intensity and energy expenditures under controlled conditions on a treadmill [15], over 24 h of typical daily activities undertaken in a respiratory chamber [15], and in a free-living environment using double-labeled water as the criterion method [16]. Furthermore, when compared with many other accelerometers, the LC can potentially simplify the data interpretation process by reducing the time spent and the need for advanced technical expertise or software programs [17]. The subjects were taught how to use the instrument, and were told to wear it on their belt or waist band at the right midline of the thigh from the moment they got up until they went to bed except while bathing or swimming, for seven consecutive days [18]. The activity monitor was firmly attached to their clothes at the waist by a clip.

2.6. Statistical Analysis

All data are expressed as the mean ± standard deviation (SD). Statistical analysis was performed using the unpaired t test and covariance analysis, with $p < 0.05$ considered significant. We used the unpaired t test to compare parameters between subjects who did and did not smoke cigarettes. Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship between continuous parameters.

3. RESULTS

The measurements of parameters in men are shown in **Table 1**. Predicted oxygen uptake in enrolled subjects was 37.2 ± 8.7 ml/kg/min. Physical activity evaluated by LC according to Σ[metabolic equivalents × h per week (METs·h/w)] was 14.5±10.8 METs·h/w. Seventy-eight men (52.3%) were defined as having a smoking habit (**Table 2**).

We evaluated the relationship between age and clinical parameters such as predicted oxygen uptake, predicted work rate, predicted heart rate, daily step counts and METs·h/w (**Table 3**). Predicted oxygen uptake, predicted work rate and predicted heart rate were significantly correlated with age (**Table 3**, **Figure 1**).

In men, there was significant difference in age between subjects who did and did not smoke cigarettes. Predicted oxygen uptake [smoking habit (+): 34.1 ± 7.5 ml/kg/min, smoking habit (–): 40.7 ± 8.7 ml/kg/min], predicted work rate and predicted heart rate in men who smoked cigarettes were significantly lower than in men who did not (**Table 4**). Significant differences of daily step counts and METs·h/w were not noted between men who did and did not smoke cigarettes. To avoid the influence of age on parameters, we used age as a covariate

Table 2. Prevalence of subjects who smoked cigarettes.

	20s	30s	40s	50s	60s	Total (%)
Smoking habit (+)	4 (13.3)	13 (43.3)	20 (66.7)	20 (64.5)	21 (75.0)	78 (52.3)
Smoking habit (-)	26 (86.7)	17 (56.7)	10 (33.3)	11 (35.5)	7 (25.0)	71 (47.7)

Table 3. Relationship between age and clinical parameters.

	r	p
Predicted oxygen uptake (ml/kg/min)	–0.554	<0.0001
Predicted work rate (watt)	–0.554	<0.0001
Predicted heart rate (beat/min)	–0.719	<0.0001
Daily step counts (steps/day)	0.114	0.1657
METs·h/w	0.124	0.1305

Σ[metabolic equivalents×h per week (METs·h/w)]

Table 4. Comparison of aerobic exercise level between men with and without a cigarette smoking habit.

	Smoking habit (+)	Smoking habit (–)	p	After adjusting for age	After adjusting for age and METs·h/w
Age	49.4 ± 12.4	38.3 ± 13.7	**<0.0001**		
Predicted oxygen uptake (ml/kg/min)	34.1 ± 7.5	40.7 ± 8.7	**<0.0001**	**0.0415**	0.0632
Predicted work rate (watt)	184.4 ± 40.8	218.9 ± 51.3	**<0.0001**	**0.0351**	0.0873
Predicted heart rate (beat/min)	172.5 ± 22.0	185.3 ± 22.6	**0.0006**	0.9942	0.6278
Daily step counts (steps/day)	8401.0 ± 3922.6	8794.9 ± 3227.3	0.5067	0.9655	0.9639
METs·h/w	14.6 ± 11.7	14.4 ± 9.8	0.9171	0.7842	

Σ[metabolic equivalents×h per week (METs·h/w)]

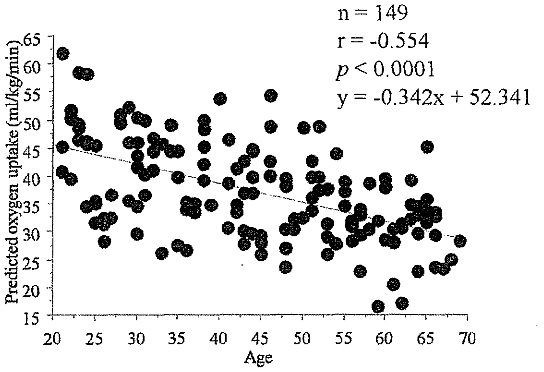

Figure 1. Simple correlation analysis between predicted oxygen uptake and age.

and compared parameters using covariance analysis. In addition, predicted oxygen uptake and predicted work rate with cigarette smoking were significantly lower than in men who did not smoke cigarettes even after adjusting for age (**Table 4**).

It is well known that the aerobic exercise level is closely linked to exercise habits [19]. To avoid the influence of age and exercise habits evaluated by METs·h/w on cigarette smoking, we finally used age and METs·h/w as covariates and compared parameters using covariance analysis. Significant differences of predicted oxygen uptake and predicted work rate between men with and without smoking habits were attenuated after adjusting for age and METs·h/w (predicted oxygen uptake: $p = 0.0632$, predicted work rate: $p = 0.0873$) (**Table 4**).

4. DISCUSSION

Impairment of pulmonary oxygen exchange [20,21], down regulation of adrenergic receptors [22] and long-term cardiac damage caused by stimulation of catecholamine by smoking [23] may also in part explain the lower maximal oxygen uptake in men who smoked cigarettes. Some cross sectional studies show that cigarette smoking is correlated with cardiovascular fitness [24-27]. Rotstein *et al.* reported that smoking retards physiological responses to submaximal exercise immediately after smoking three cigarettes [24]. Hirsch *et al.* evaluated the immediate effects of cigarette smoking on aerobic exercise capacity, which resulted in a significantly lower VO_2 max and higher heart rate after 3 cigarettes/h for 5 hours [25]. Marti *et al.* also showed that, among army conscripts, the distance covered in a 12-min endurance run was inversely related to daily cigarette consumption and years of smoking [26]. Bolinder *et al.* reported that significantly lower maximal oxygen uptake was found for smokers than non-smokers [27]. We also reported that oxygen uptake at the ventilatory threshold (VT) in women and work rate at VT in men who smoked cigarettes were significantly lower than in subjects who did not smoke cigarettes, after adjusting for age [28]. The differences of parameters at VT did not reach significant levels after adjusting for age and exercise habits in both sexes [28]. In longitudinal analysis, Sandvik L. *et al.* showed that decline in physical fitness and lung function was greater among smokers than among non-smokers among 1393 men over 7 years [29]. Moreover, moderate to heavy smoking was longitudinally and negatively related to maximal oxygen uptake, maximum treadmill slope, heat rate at sub-maximal exercise and maximum heat rate, and with increasing age, the negative relationship between smoking and the parameters described above became stronger in men [30]. In this study, we solely evaluated the relationship between cigarette smoking and the aerobic exercise level defined by predicted oxygen uptake in Japanese men. Physical activeity was accurately evaluated by LC and the aerobic exer cise level was also accurately measured by predicted oxygen uptake compared to our previous studies [28]. Predicted oxygen uptake and predicted work rate in men who smoked cigarettes were lower than in men who did not smoke cigarettes after adjusting for age and METs·h/w, but not at a significant level. Taken together, a combination of increased physical activity and giving up cigarette smoking might be considered for improving predicted oxygen uptake in Japanese men.

Potential limitations remain in this study. First, our study was a cross sectional and not a longitudinal study. Second, the 149 men in our study voluntarily underwent measurements; they were therefore more likely to be more health-conscious than the average person. Third, we could not show a clear relationship between cigarette smoking and predicted oxygen uptake because of the small sample size in this study. Fourth, the relationship between cigarette smoking and predicted oxygen uptake was not investigated in women; however, it seems reasonable to suggest that giving up smoking and increasing physical activity might ameliorate the aerobic exercise level in some Japanese men. To show this, further prospective studies of Japanese are needed.

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