was close to the results of Schaffer et al. Radimer et al[32] reported that non-vitamin and non-mineral dietary supplements included many herbal supplements in NHANES III, and the term "herbal" is often used loosely, including non-plant dietary supplement (i.e., enzymes, glandular extracts, choline, and fish oils). Herbal supplements were most commonly used because they were considered "healthy or good for you",[14,34,37,38] and consumers may perceive plant products as more natural than manufactured medicines.[38] Furthermore, some studies reported that herbal supplement use is accelerating, and some products might have adverse health effects.[8,32,33,38] We could not determine the reason why some individuals chose "others" types of dietary supplements. As the prevalence of "others" types of dietary supplement use was high in our study, it will be important to estimate the prevalence of this kind of product (non-vitamin and non-mineral dietary supplements) and to clarify the health effects of these products.

In our study, the prevalence of drink type dietary supplement was high, especially in males, and more than 60 % of drink type dietary supplement users were "seldom users". Hakura et al[14] also reported that high prevalence of drink type dietary supplement was observed in Japan, and many of the occasional dietary supplement users took this kind of dietary supplements to maintain or recover health. However, drink type dietary supplement was not usually described in the studies reported from the Western countries.[32-34,38] The high prevalence of drink type dietary supplement use might be one of the characteristics observed in Japan, and might be caused by broad accessibility that people can get drink type dietary supplements easily at supermarkets and convenience stores when they feel weary.

The purpose of dietary supplement use may be to compensate the shortage of nutrients from foods, but some users had excessive intake of some nutrients. The median values of Vitamin B_1 and 90 percentile values of vitamin E, Vitamin B_2, B_6, B_{12}, niacin, and vitamin C from dietary supplements in this study were more than that from food, according to the results of J-NNS 2002.[16] Some dietary supplement users consumed huge amounts of nutrients from dietary supplements.

Regarding overdoses, this study had two important findings. The first was that overdoses sometimes occurred for non-target nutrients from dietary supplements, when the primary nutrient in the dietary supplement was defined as the target nutrient. For example, according to the 6th Ed. UL, only three persons took an excess dose of vitamin A among vitamin supplement users, whereas 12 people consumed an excess dose of vitamin A among the "others" type of supplement users (Table 5). The second was that overdose sometimes occurred in users of "multiple" dietary supplements. In this study, according to the 6th Ed. UL, five people consumed an excess dose of vitamin A from "multiple" dietary supplements which belonged to different categories.

Stewart et al[31] reported that there was a wide range of intake of vitamins from dietary supplements. Subjects who took more than 10 times the Recommended Dietary Allowances (RDAs) in the US were observed for vitamin B group, vitamin C, vitamin E, niacin, and pantothenic acid intakes. Other studies reported that some dietary supplement users consumed excess doses of some nutrients as compared to the RDAs.[6-9,39,40] Rock et al[2] noted that a few women consumed potentially toxic levels of vitamin A, vitamin B_6, iron, and zinc from dietary supplements. People need to be aware that excessive use of some dietary supplements may produce undesirable health effects.[41,42] Because we did not include fortified foods and modified foods among dietary supplements in this study, nutrient intake from those foods was not included the estimation of total nutrient intake. We are apprehensive that excessive levels of nutrient intake could be more common people with in a combination of fortified foods, modified foods and dietary supplement use.

The main strength of this study is the development of the nutrient content database of more than 900 dietary supplements, and the use of this database to calculate nutrient intake from these products for more than 2,000 middle-aged and older people. Although our database of dietary supplements is extensive, a lack of information on some dietary supplements still exists. Information on the nutrient content of some products available in the marketplace had not been obtained even by the producer and/or was difficult to get,[6,7,43-45] because dietary supplements except for medicines are not required to show their nutrient contents.

APPENDIX

We succeeded in constructing the database of more then 1500 dietary supplement products in April 2006. The database has been regularly updated according to the study. We will make latest dietary supplement database generally available, but for non-profit use only, in the internet website (http://www.nils.go.jp/department/ep/index-j.html) of our institute, without a need for permission. The authors, however, request that this article be cited when a study in which the data, or even a part of it, were used is published or open to the public. We expect that this database will be useful for the prevention of excess intake of dietary supplements and contribute to the development of research on nutritional epidemiology.

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AGE-RELATED CHANGES OF POSTURAL STABILITY AND PHYSICAL FUNCTION IN MIDDLE-AGED AND ELDERLY JAPANESE

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AGE-RELATED CHANGES OF POSTURAL STABILITY AND PHYSICAL FUNCTION IN MIDDLE-AGED AND ELDERLY JAPANESE

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Abstract

The aim of the present study was to clarify the relationships between age-related changes of postural stability and physical function in middle-aged and elderly Japanese. The subjects were 640 males and 620 females who had participated in both the baseline and the 4-year follow-up surveys of the National Institute for Longevity Sciences-Longitudinal Study of Aging. Postural stability was measured using a force platform. Flexibility, muscle function, reaction time, balance and comfortable and maximal gait performance were also measured as physical function. Postural sway was increased in 4 years. Multiple logistic regression analysis controlled for age, sex, height, weight and history of diseases revealed significant relationships between decline of postural stability and sit-ups, flexibility, frequency and velocity at comfortable gait and leg extension power at baseline. These results suggest that not only greater abdominal muscle strength and leg power but also quick walking benefit the preservation of postural stability.

(Jpn. J. Phys. Fitness Sports Med. 2006, **55** Suppl : S227～S230)

key word : postural stability, abdominal muscle strength, gait performance, longitudinal study, middle-aged and elderly

INTRODUCTION

Postural instability was observed in elderly people[1]. However, few population-based longitudinal studies have been presented in the literature. Previous studies suggested that poor balance is one of the risk factors of falls, which is a serious problem for the elderly[2,3]. It is important to investigate the relationship between age-related changes of postural stability and other physical function such as physical fitness and gait performance in order to develop effective strategy for maintaining balance or preventing falls. The aim of the present study was to estimate the changes of postural stability in 4 years and to clarify the relationships between age-related changes of postural stability and physical function in middle-aged and elderly Japanese.

METHODS

Subjects : The data of this study were collected as part of the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA). In this project, the normal aging process has been assessed using detailed questionnaires and examinations including clinical evaluations, blood chemistries, anthropometrical measurements, physical fitness tests, nutritional analysis, and psychological examinations. Details of the study are reported elsewhere[4]. The initial survey of NILS-LSA involved 2267 males and females aged 40～79 years. They were gender- and decade age-stratified random samples living in Obu-shi and Higashiura-cho Aichi Prefecture, Japan. The subjects for this study were 640 males (mean age at baseline ; 58.0±10.3 years) and 620 females (56.8±10.2 years) who had participated in both of the baseline and the 4-year follow-up surveys. Written informed consent was obtained from all the participants. The Ethical Committee of the National Center for Geriatrics and Gerontology has already approved all procedures of the NILS-LSA (Approval number : 175).

Variables :

1) Postural stability (baseline, follow-up)

The measurements of postural stability were carried out using a force platform (GE Yokogawa Medical Systems Co., Japan) in quiet upright bipedal

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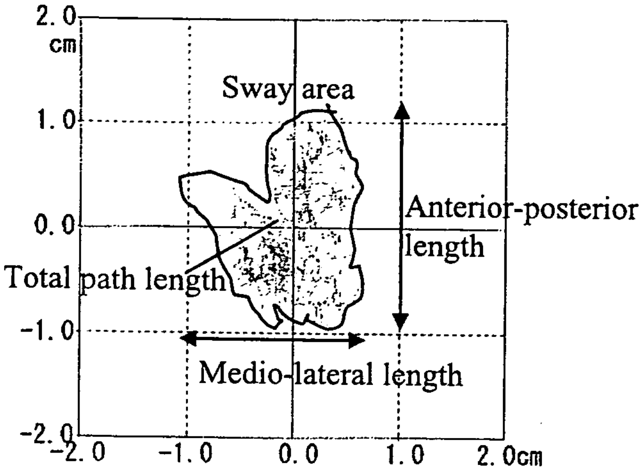

Figure 1. Examples of sway trajectory and output parameters.

stance under the eyes open and closed condition for 60 seconds. Output parameters to examine the amount of motion were the sway area, maximum anterior-posterior and medio-lateral length and total path length in both eyes conditions (Figure 1). The Romberg ratio (sway with eyes open/sway with eyes closed) was calculated in sway area and total path length.

2) Physical function (baseline)

Flexibility, grip strength, one-leg balance, reaction time, leg extension power, sit-ups, knee extension strength (Takei Co., Japan), step length, step frequency, and velocity during 10 m comfortable and maximal gait (Yagami Co., Japan) were measured as physical function.

3) Covariates (baseline)

Height and weight were measured using a digital scale. Body mass index was calculated as weight divided by height squared (BMI ; kg/m^2). Body fat mass was assessed by dual X-ray absorptiometry (DXA ; QDR-4500A, Hologic, USA). Medical histories such as stroke, hypertension and diabetes mellitus were determined by questionnaire and interview.

Statistical analysis : Measurements of postural stability were compared by paired-t test between baseline and follow-up. Percent changes in the postural stability variables were calculated as the (change/baseline value) × 100. Multiple logistic regression analysis was performed to assess the relationships between changes of postural stability and each physical function. Odds ratios were calculated from the change of sway area with eyes closed (case : change> =2 s. d., control : change<2 s. d.) per 1 s. d. increase of each physical function controlled for age, sex, height, weight and history of diseases. Significant probability levels were less than 0.05. Statistical testing was performed using Statistical Analysis System release. 8.2 (SAS Institute Inc. NC, USA).

RESULTS

The characteristics of the subjects were summarized in Table 1. Subjects who reported history of diseases such as stroke, hypertension or diabetes mellitus were 29.7% of male and 25.2% of female. Four-year changes in postural stability were showed in Table 2. Postural sway significantly increased over the follow-up period excluded medio-lateral length with eyes open and total path length in both eyes conditions ($p<0.05$). Romberg ratio significantly decreased over follow-up period in both sway area and total path length ($p<0.05$). Mean percent changes in postural stability were showed in Figure 2. Mean percent change in the sway area with eyes closed (20.2%) was the greatest of all parameters. Therefore, the sway area was decided as an indicator of decline in postural stability. The relationship between decline in postural stability and physical function was shown in Table 3. Multiple logistic regression analysis controlled for age, sex, height, weight and history of diseases revealed significant relationship between

Table 1. Charactaristics of subjests.

		Male (n=640)	Female (n=620)
Height	(cm)	165.0 ± 6.2	152.4 ± 5.8
Weight	(kg)	62.8 ± 8.8	53.0 ± 8.0
BMI	(kg/m^2)	23.0 ± 2.7	22.8 ± 3.1
% Body fat	(%)	21.2 ± 4.1	31.2 ± 4.9
History of deseases†	(%)	29.7	25.2

Mean ± S. D.

†: Subjects who had, stroke, hypertention or diabetes mellitus.

Table 2. Four-year changes in postural stability.

		Baseline	Follow-up	Absolute change
Eyes open				
Sway area*	(cm^2)	2.26 ± 1.17	2.34 ± 1.16	0.08 ± 1.09
Anterior-posterior length*	(cm)	2.44 ± 0.74	2.78 ± 0.82	0.34 ± 0.85
Medio-lateral length	(cm)	1.99 ± 0.60	1.98 ± 0.58	-0.01 ± 0.61
Total path length*	(cm)	78.88 ± 16.50	72.01 ± 19.69	-6.87 ± 14.53
Eyes closed				
Sway area*	(cm^2)	3.80 ± 2.37	4.20 ± 3.01	0.40 ± 2.21
Anterior-posterior length*	(cm)	2.97 ± 0.95	3.09 ± 1.05	0.12 ± 0.98
Medio-lateral length*	(cm)	2.57 ± 0.90	2.76 ± 1.00	0.19 ± 0.89
Total path length	(cm)	107.60 ± 36.67	106.83 ± 44.76	-0.74 ± 29.59
Rombelg ratio				
Sway area*	-	0.69 ± 0.34	0.66 ± 0.31	-0.02 ± 0.41
Total path length*	-	0.76 ± 0.13	0.71 ± 0.14	-0.05 ± 0.14

Mean ± S. D., * $p < 0.05$; paird-t test.

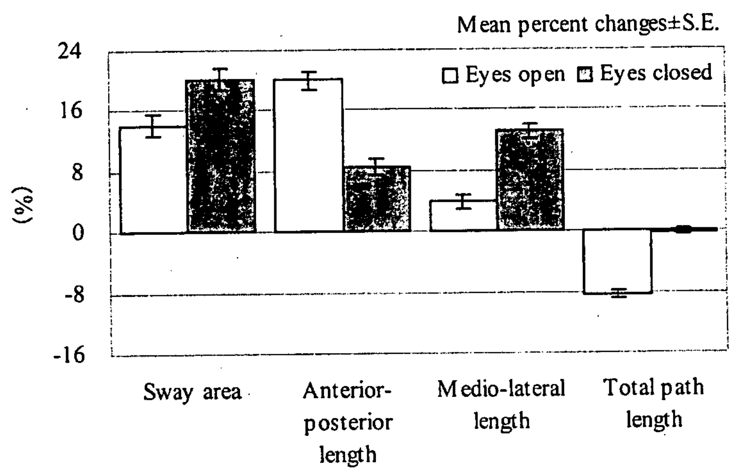

Figure 2. Mean percent changes in postural stability.

Table 3. Relationship between baseline physical function and postural stability change.

		Odds ratio†	95% CI	p-value
Flexibility		1.048	1.008 - 1.090	<0.05
Grip strength		1.002	0.938 - 1.069	
One-leg balance with eyes closed		0.972	0.933 - 1.013	
Reaction time		1.440	0.049 - 42.022	
Leg extensor power		0.997	0.994 - 1.000	<0.05
Sit-ups		0.921	0.850 - 0.998	<0.05
Knee extensor strength		0.962	0.918 - 1.008	
Comfortable gait	step length	0.987	0.944 - 1.032	
	step frequency	0.967	0.940 - 0.995	<0.05
	velocity	0.965	0.936 - 0.995	<0.05
Maximum gait	step length	0.975	0.934 - 1.018	
	step frequency	1.004	0.981 - 1.027	
	velocity	0.986	0.960 - 1.012	

† : Odds ratios of remakable change of away area with eyes closed (case : change > = 2 s. d., control : change < 2 s. d.) per 1 s. d. increase of each physical function controlled for age, sex, height, weight and history of diseases (stroke, hypertension or diabetes mellitus).

increased postural sway and sit-ups (Odds ratio per 1 s.d. = 0.921, 95% confidence interval = 0.850-0.998), flexibility (1.048, 1.008-1.090), step frequency (0.967, 0.940-0.995) and velocity (0.965, 0.936-0.995) at comfortable gait and leg extension power (0.997, 0.994-1.000).

DISCUSSION

The present study estimated the changes of postural stability in 4 years and the relationship between age-related changes of postural stability and physical function, corrected for age, sex, height, weight and history of diseases, based on a random sample of the middle-aged and elderly Japanese.

Previous cross-sectional studies suggested that the decline in postural stability associated with aging[1,5~7]. However, little is known about the contribution of age on postural stability in a population-based longitudinal study. In one follow-up study, Baloh et al suggested that static sway test was relatively insensitive for identifying age-related increased in sway than dynamic tests[6]. However, our results revealed that postural sway, excluding sway length was increased in 4 years. Age-associated impairment of postural control on static condition was demonstrated in the study.

The sway under the eyes closed condition was increased remarkably. The proprioceptive system or vestibular system may deteriorate with aging. Gill et al suggested that eye closure reduces the availability of visual information and shifts postural mechanisms towards vestibular and proprioceptive control, which may be unfavorable to the postural control in elderly subjects[7]. Our result is supported by previous studies[2,3,7].

In the logistic regression analysis, increased sway was negatively associated with sit-ups, leg extensor power and comfortable gait, and was positively associated with flexibility. Although Load et al indicated that increased body sway on the foam was associated with reduced quadriceps and ankle dorsiflexion strength[8], there were few studies to assess the relationship between components of physical fitness and postural stability. Our results suggest that not only greater abdominal muscle strength and leg power but also quick walking and lower trunk flexibility may benefit the preservation of postural stability.

In conclusion, the findings indicate that postural sway increased with aging in community dwelling middle-aged and elderly. Greater abdominal and lower extremity muscle strength and quick walking were associated with the preservation of postural stability.

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第 47 回日本老年医学会学術集会記録
〈老年医療における Controversy〉

3．高齢者の生活習慣はどこまで是正すべきか（Pro）

下方　浩史

日本老年医学会雑誌　第43巻　第４号　別刷

第 47 回日本老年医学会学術集会記録
〈老年医療における Controversy〉

3. 高齢者の生活習慣はどこまで是正すべきか (Pro)

下方　浩史

要　約　健康長寿を目指すためには生活習慣の改善が最も重要である．喫煙や飲酒のコントロール，肥満防止，栄養改善，運動習慣などの生活習慣の改善は，寝たきりを防止して健康寿命を延ばしていくためには不可欠である．生活習慣の是正は小児期から必要であり，青年期，中年期から老年期まで，生涯にわたって必要であるが，ライフステージごとに方法や目標は異なる．75 歳以上の後期高齢者では肥満よりも痩せの危険が高いことを認識し栄養指導を行うことが必要である．喫煙による循環器疾患や呼吸器疾患への影響としては急性の不整脈の誘発や，末梢血管の収縮，気道への刺激などもあり，禁煙は高齢者でも有用と考えられる．また代謝予備力が落ちているために飲酒量も減らすことが望ましい．運動習慣は高齢者の身体活動能力を維持するだけでなく，代謝機能を高め，鬱を予防するなど心身の健康維持に重要であり，運動教室などを利用して積極的な介入を行っていくべきであろう．

Key words：生活習慣，老年病，予防，栄養，喫煙

（日老医誌　2006；43：462–464）

高齢者の生活習慣への介入

生活習慣病は，食事，肥満，身体活動，喫煙，飲酒などの生活習慣に起因する疾患であり日本人の死因の大部分を占めるがん，心臓病，脳卒中がその代表的疾患である[1]．また高齢者に多い痴呆や骨粗鬆症も生活習慣が重要な因子である場合が多い．生活習慣病は，性別や年齢，遺伝的素因，さらには職業や教育など社会的要因が相互に作用しあって発症する．したがって，これらの背景要因を考慮し，生活習慣への介入を行って疾病の発症予防，進行の予防，そして再発の予防を行うことが重要である．

生活習慣病の予防には小児期，青年期，中年期，老年期のそれぞれのライフステージに応じたストラテジーが必要である（図 1）．小児期，青年期には将来の疾患発症を予防するための一次予防に重点を置いた指導が行われる．小児期には基本的な生活習慣が形作られるため，それに対応しての家庭や学校での健康教育が重要である．塩味や油の多い食事への嗜好なども小児期に形成される．青年期には栄養や運動など一生にかかわる生活習慣が確立する．また喫煙や飲酒の習慣もこの頃から始まることが多い．中年期には疾患の早期発見・早期治療を目指す二次予防も重要となる．効率的な健診の体制作りが必要だろう．さらに老年期には再発の予防を中心とした三次予防も重要である．

75 歳未満の前期高齢者は元気である．多くの人が職についており，また積極的に社会参加をしている．喫煙や飲酒のコントロール，肥満防止，栄養改善，運動習慣などの生活習慣の改善は，寝たきりを防止して健康寿命を延ばしていくためには不可欠である．一方，75 歳以上の後期高齢者では加齢による身体機能の変化に対応し，10 年先，20 年先のことよりも現在の生活の質（Quality of life；QOL）を考慮した生活習慣への介入が必要だろう．

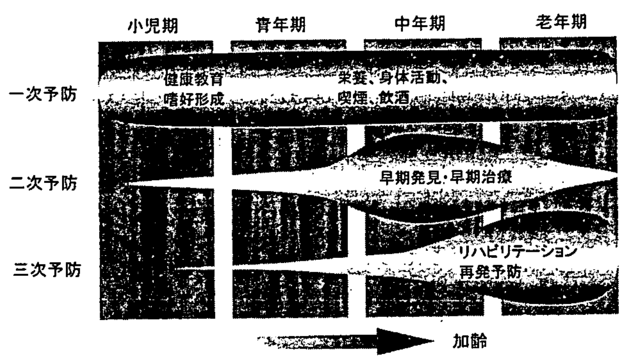

図 1　ライフステージ別にみた生活習慣病の予防
生活習慣病の予防には小児期，青年期，中年期，老年期のそれぞれのライフステージに応じたストラテジーが必要である．

肥満と老化

食餌制限と寿命との関係については，1930 年代の McCay によるラットを使った有名な実験があり[2]，自由

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無制限の食餌を与えたラットより食餌を制限したラットの方が長生きするという結果は基礎老化の研究者の間ではよく知られている[3][4].

人間ではやせていればいるほど健康にいいのか．もしそうでないなら，どの程度の体重であるのが医学的には理想なのか．Andresは米国の生命保険会社のデータから，体重（kg）を身長（m）の二乗で割って求めたBody Mass Index（BMI）を身長とは無相関の肥満の指標として用い，各年代ごとに最も死亡率の低いBMIをもとめた[5]．この結果死亡率を縦軸，BMIを横軸にとった時，きれいなU字を描くことを示した．BMIの小さいやせた人では，肺炎や結核などの感染症の発病率が高く，BMIの大きな太った人では糖尿病や心臓病などの発病率が高くなる．男女別に，各年齢毎にこのようなグラフを作成し，死亡率の最も低い肥満度を求めてみると，この理想的な肥満度の値は加齢とともに大きくなっている[6]．男女で大きな差はなく年齢とともにほぼ直線的に理想的なBMIの値が大きくなっていく．

BMIによる高齢者の肥満評価には，加齢に伴う椎間の狭小化，椎骨の圧迫骨折による脊椎前弯の増強などにより身長が年齢とともに低下し，BMIは本来あるべき値よりも，大きくなっていることにも留意せねばならない．

予備力が低下している後期高齢者では無理な減量はかえって健康を害することが多い．しかし複数の代謝性合併症を有するメタボリック・シンドローム，下肢の骨関節障害を有する高度肥満，睡眠時無呼吸症候群を有する高度肥満などでは高齢者においても減量は必要であると考えられる[7]．

一方で，高齢者では骨格筋萎縮に伴う基礎代謝の低下，味覚などの感覚器機能低下，ジギタリス製剤等の食欲を低下させる副作用のある薬物の使用，味気ない減塩食や老人食，ACE阻害剤などの薬剤による亜鉛欠乏症等により，食欲が低下していることが多い．慢性的に栄養不良の高齢者も多く，肥満よりもむしろやせのリスクに注意する必要がある[8]．

喫煙と老年病

喫煙により消化器の運動が低下する．口腔の衛生状態が悪くなり，歯周病のため歯牙が脱落する．喫煙で口がまずい，味覚障害などから食欲も低下する．1本のタバコを吸うと約10キロカロリーが使われる[9]．1パック20本の喫煙では200キロカロリーが消費される．これは1時間の歩行とほぼ同等のエネルギー消費である．このため喫煙は体重減少の要因となる．

喫煙はさまざまな老年病の危険因子でもある．アルツハイマー病についてはハワイ在住日系人ではリスクは2.4倍と報告されている[10]．喫煙による痩せ，エストロゲン抑制，骨カルシウム代謝障害などが骨粗鬆症の要因になる[11]．また喫煙は老人性難聴[12]，老人性白内障[13]，加齢に伴う記銘力障害[14]の要因でもある．慢性気管支炎，肺気腫の閉塞性肺疾患は高齢者に多くみられ，また喫煙との関連が強い．多くの化学物質が直接に気道に作用し，刺激により炎症反応を引き起こす．慢性閉塞性肺疾患による肺機能低下は禁煙によって回復しないが，禁煙をすることで，それ以上の悪化を防ぐことはできる．むしろ禁煙が進行を予防する唯一の手段である．

一般にがんは発がん物質に曝露されてから，実際にがんが見つかるまでの期間が長い．このため若い頃から喫煙を継続している高齢者が禁煙をしても，若い成人と同じようにがんのリスクを下げるような効果があるかどうかは不明である．

喫煙による循環器疾患や呼吸器疾患への影響は急性の不整脈の誘発や，末梢血管の収縮，気道への刺激など急性の影響もあり，禁煙は，高齢者でも有用と考えられる．しかしFramingham Studyでの18年間の観察で65歳以上の群では禁煙による虚血性心疾患のリスク低下は認められなかったとする報告もある[15]．

喫煙者の近くで，副流煙・排出煙を吸わされる受動喫煙は，主流煙を吸う喫煙者本人よりも有害である．家族，主として夫の喫煙による妻への影響，あるいは子どもや孫への影響も重要である．特に小さな子どもや妊婦への影響は大きい．大家族で暮らすことの多い日本では，高齢者の喫煙に関して，こうした家庭での環境についても考慮が必要であろう．

高齢者の飲酒

適量の飲酒は，血清脂質，耐糖能，インスリン抵抗性を改善させる．しかし少量の飲酒でも高血圧の要因となりうるので要注意である．飲酒は高齢者の脳出血のリスクを上げる．加齢に伴いアルコール代謝機能が低下し，顔面紅潮などの頻度が高くなる．飲酒量を一般成人よりも減らすことも重要であろう．もちろん慢性肝炎・肝硬変では高齢者でも禁酒は必要であろう．

高齢者の身体活動

身体活動は加齢に伴う耐糖能を改善させ，骨粗鬆症を予防し，高齢者の循環器機能を維持するためきわめて重要である．我々は高齢者の身体活動が，うつを予防する効果のあることを報告している[16]．

高齢者の身体機能の維持・改善，QOLの向上を目指し，介護予防を行っていくためにも生涯にわたっての介入が望ましい．積極的なソーシャル・サポートや家族からの支えによって，閉じこもりや，寝たきりを防止していくことも重要であろう．

しかし運動指導には，高齢者に多い循環器疾患，骨関

節疾患，呼吸器疾患などに留意し，個人ごとの対応が必要である．

おわりに

健康長寿を目指すためには，人の一生を通じて生活習慣の是正が欠かせない．しかし，その目標や方法は加齢の進行によって異なる．特に75歳以上の後期高齢者では現在のQOLを重視した生活指導が行われるべきである．高齢者では肥満よりも痩せが問題になる．健康の維持のためには食欲の低下による栄養不良，体重減少を予防していくことが必要であり，食事の制限や減塩などはどうしても必要な場合に限るべきであろう．喫煙は高齢者でも避けるべきであり，過度の飲酒も好ましくない．また，高齢者では心身の健康の維持のために運動習慣への積極的な介入が必要である．

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How far should life-style be corrected in the elderly?

Hiroshi Shimokata

Abstract

To ensure a healthy elderly population, correction of life-style is one of the most important approaches. Smoking cessation, regulation of alcohol intake, prevention of obesity, improvement of nutrition, promotion of physical activity are key factors for prevention of bed-ridden and extension of healthy life span. Although corrections of life-style are essential in childhood, adolescence, and the middle-aged and elderly periods, the methods and purpose are different in each life stage. The risks of emaciation and malnutrition are more important rather than that of obesity in the elderly aged 75 years or over. As for the influence of smoking in cardiovascular and respiratory diseases, smoking can be a trigger for arrhythmia, peripheral vascular constriction, and irritation of the respiratory tract in the elderly. Smoking cessation is necessary even among elderly people. It is also necessary to decrease the amount of alcohol intake, because the ability of metabolize alcohol is limited in the elderly. Physical activity in the elderly people is fundamental not only to maintain the ability of daily living, but also to improve metabolic function and to prevent depression. Vigorous intervention to increase physical activity such as exercise class is recommended, especially in the elderly.

Key words: *Life-style, Geriatric disease, Prevention, Nutrition, Smoking*
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ORIGINAL ARTICLE

Can you diagnose for vertebral fracture correctly by plain X-ray?

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Abstract *Introduction:* A wrong diagnosis of latent vertebral fracture is often made when it is based on plain X-ray imaging. Magnetic resonance imaging (MRI) has a high degree of accuracy for the definite diagnosis. This study was designed to identify ways to support improvements in the diagnostic accuracy of plain X-ray (X-P). *Methods:* We studied X-P and MRI images of 120 women and men (age range: 50–96 years). Five orthopedists and two radiologists interpreted front and lateral thoracolumbar X-Ps and MRI images. The correct diagnosis rate for the presence and location of incident vertebral fractures and the correct diagnosis rate according to morphological classifications were analyzed. *Results:* A correct diagnosis of incident fractures was made in 51.5% of cases overall. Diagnoses of non-incident fracture based on X-P in those cases with incident fracture based on MRI (false positive) occurred in 24.8% of the patients, while diagnoses of incident fracture based on X-P in those cases without incident fracture based on MRI (false negative) occurred in 6.5% of the patients. The application of morphological classifications (the primary osteoporosis diagnostic criteria and Yoshida's classification) resulted in the correct diagnosis rate being significantly higher in the group without prevalent fracture even when there were morphological changes (wedge, indented, protruding type) in the anterior bone cortex. Odds ratios were investigated for factors that would affect the correct diagnosis rate, including age, body weight, lumbar vertebrae bone mineral density, and examiner ability. In an overall investigation, age (OR=0.660), body weight (OR=2.082), and examiner ability (p=0.0205) affected the correct diagnosis rate. *Conclusion:* The correct diagnosis rate for incident vertebral fractures with X-Ps was low (24.8%) and in cases with prevalent fractures, the rate was even lower (16.8%), but the number of prevalent fractures and BMD did not exert an effect. One key improving the correct diagnosis rate may be to pay attention to morphological changes in the anterior bone cortex.

Keywords Anterior bone cortex · Bone mineral density · Diagnosis rate · Latent fractures · Spinal fragility fractures

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Introduction

Elderly outpatients with complaints of severe lumbar back pain in almost all cases undergo plain X-ray (X-P), from which a diagnosis of the underlying condition should be made. At such times an existing lesion of vertebral disk degeneration or osteoporosis can often conceal a latent incident spinal fracture, with the result that a delayed diagnosis can make it difficult to prevent post-fracture sequelae or other problems [1]. However, reports are occasionally received that an accurate diagnosis of the existence or location of the incident fracture is difficult with X-P images only and that X-P screening images are not effective for low back pain [2, 3]. Meanwhile, many reports have stated that magnetic resonance imaging (MRI) has a high degree of accuracy for the definite diagnosis of incident spinal fracture, and it continues to be used as the more useful tool [4–6]. However, due to limitations in equipment and considerations that must be given to the economics of medical treatments, it is not possible to use MRI with all patients. In the present study, therefore, with diagnosis by MRI taken to be the correct diagnosis, we conducted a multi-lateral analysis of the diagnostic accuracy of several orthopedic surgeons and radiologists who based their diagnoses on X-P images, in order to identify ways to support improvements in diagnostic accuracy. This is a cross-sectional study.

Materials & methods

Participants

The subjects were patients above the age of 50 who were examined at the authors' hospitals between May 1999 and January 2004, and who had undergone MRI within 4 weeks of the initial examination. A non-incident fracture group consisted of patients without incident vertebral fractures, while an incident fracture group consisted of patients with incident vertebral fragility fractures caused by weak external force, such as that sustained in falls from a standing position. One hundred twenty-three patients had these conditions. After excluding patients who had a history of primary or metastatic bone tumor, infectious disease, hematological disorders, or compression fracture within the previous year, which would leave spots with high signal intensity on the MRI images (three patients), the final number of subjects for the study was 120, of whom 112 were women and eight were men, with ages ranging from 50 to 96 years (mean age: 75.6 years).

Measurements

Five orthopedists and two radiologists from our hospital interpreted anterioposterior (A-P) and lateral thoracolumbar X-Ps taken during the initial examination. They did not question the patients or have access to physiological findings, and the images were arranged by a third party with the patients' IDs and names concealed. The correct diagnoses were taken to be those of two radiologists not involved in the treatment of the patients who, in consultation with each other, reached the same conclusion based on MRI [1.5T, T1-weighted images (SE: TR/TE = 400/15 ms); T2-weighted images (SE: TR/TE = 2500/120 ms)]. In this study, a definition of a fracture based on the MRI image also included a bone bruise without deformity as an incident fracture. Differences in the ability of the five orthopedists to interpret spinal X-P images were investigated in advance. The subjects of this investigation were 89 healthy community residents who underwent thoracolumbar spine X-P for the purpose of a long-term longitudinal epidemiological study at out hospital. Each orthopedist classified the vertebral spines (Nathan's classification [7]) on an A-P thoracolumbar image, after which intraclass correlation coefficients were calculated using SAS (Statistical Analysis Software, Cary N.C.) ver. 8.2, and the level of coincidence was observed. The results revealed no significant difference in the ability of the orthopedists to interpret radiographs, with intra-class correlation (ICC) = 0.739 [95%CI for ICC: 0.679–0.799]. Accordingly, assuming that there was no difference in the ability to interpret spinal X-P images, the correct diagnosis rate for the presence and location of incident spinal fractures and the correct diagnosis rate according to the morphological classifications (classifications of Genant et al. [8] and Yoshida [9]) of the incidental fractured vertebral body were analyzed, and subjects were divided into three groups for the analysis of factors affecting correct diagnosis: (1) non-incident fracture group with and without prevalent fractures (non-incident fracture group); (2) incident fracture group without prevalent fractures; (3) incident fracture group with prevalent fractures. Bone mineral density (BMD) was measured using dual energy x-ray absorptiometry (DPX; Lunar, GE Healthcare, UK) in bones of the entire body, the lumbar vertebrae, and the femoral neck. The density for the lumbar vertebrae (L2–4) was adopted for the present study.

Table 1 Baseline data (means ± standard deviation)

1	Fracture group	Incident fracture group		Non-incident fracture group[a]	
		Without prevalent fracture	With prevalent fracture		
[a]Number	67	24	43	53	
Age (year)	79.9±7.9	76.8±7.2	81.1±7.9	68.9±9.6	
Weight (kg)	43.4±8.3	46.1±9.1	42.2±7.7	49.9±7.3	
Height (cm)	146.3±7.1	148.1±5.5	145.5±7.6	148.39±6.2	
Lumbar BMD(g/cm^2)	0.74±0.19	0.84±0.18	0.70±0.27	0.90±0.24	
One new fracture	50	21	29	-	
Two new fractures	9	2	7	-	$p<0.0001$
Three new fractures	7	1	6	-	
More new fractures	1	0	1	-	

Values are means±SD
[a]Significant differences were seen in age, height, weight, and lumbar vertebrae BMD

Statistical analysis

SAS ver. 8.2 was used for the accumulation and analysis of data. In comparing the correct diagnosis rate for fractured vertebral body morphology, adjustments were made using the Cochran-Mantel-Haenszel method for variations in age, body weight, lumbar spine bone mineral density, and examiner ability, and analysis was conducted with ANOVA, Tukey's multiple comparison test, and logistic regression analysis.

Results

Number of patients and fractured vertebras

Of the 120 patients, 67 patients were diagnosed with incident fractures with and without prevalent fractures in 95 vertebrae, including single incident fractures in 50 patients and two or more incident fractures in 17 patients. There was non-incident fracture with and without prevalent fractures in 53 patients. The group of incident fractures without prevalent fractures consisted of 24 patients and 28 vertebrae, and with prevalent fractures, of 43 patients and 67 vertebrae. Significant differences were seen in age, height, weight, and lumbar vertebrae BMD ($p<0.0001$) (Table 1).

A breakdown of correct and incorrect diagnoses

A correct diagnosis of incident fracture was made in 51.5% of cases overall. A breakdown shows that in cases when non-incident fracture was seen by MRI the correct response of non-incident fracture (true negative) was made in 37.7% of cases and the correct diagnosis of incident fracture (true positive) was judged to have occurred in 13.8% of cases. The location of incident fracture was mistaken in 17.2% of the cases. Responses of non-incident fracture on X-P images in cases with incident fracture (false negative) occurred in 24.8% of the cases, while responses of incident fracture on X-P images in cases of non-incident fracture (false positive) occurred in 6.5% of the cases (Table 2).

The overall rate of correct diagnosis

Non-incident fracture group

We next compared the correct diagnosis rate of incident fractures by the five examiners in each of the three groups. The correct diagnosis rate of the five examiners was high overall, reaching 85.3% (73.6–92.5%) in the non-incident fracture group. The overall diagnosis rate was also high with no significant variation between the five examiners (p=0.486).

Incident fracture group without prevalent fractures

The overall correct diagnosis rate for the incident fracture group without prevalent fractures was 39.3% (21–58.3%), and significant variation was seen between the five examiners ($p = 0.04$).

Incident fracture group with prevalent fractures

Despite the low overall correct diagnosis rate of 16.8% (9.3–21%) in the incident fracture group with prevalent fractures, no significant difference was seen in the correct diagnosis rate between the five examiners, and overall the diagnosis rate was low (p=0.432).

Thus, the correct diagnosis rate for incident fractures decreased significantly in the non-incident fracture group followed by the incident fracture group without prevalent fractures, and the incident fracture group with prevalent fractures, in that order. However, a second investigation after adjusting for differences in age, weight, and lumbar vertebrae BMD revealed significant variation in all three groups (Fig. 1).

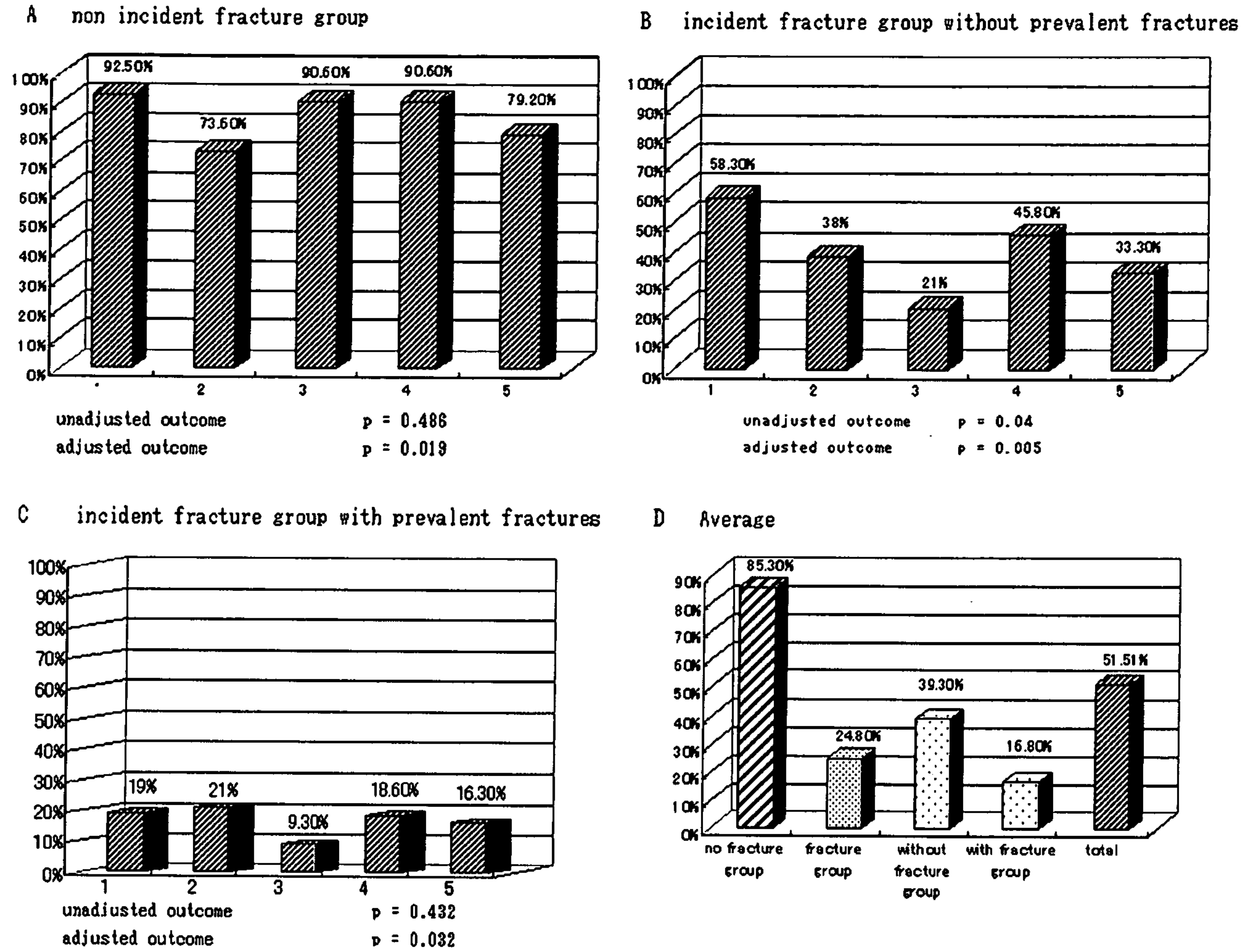
The kappa score of interexaminers

The median kappa-score of all examiners was 0.65 [0.51 (min.) to 0.81(max.)]. The median kappa-score of inter-orthopedists was 0.65 (0.51–0.72), while the kappa-score of inter-radiologists was 0.69. The median kappa-score of orthopedists-radiologists was 0.63 (0.54–0.81) (Fig. 1).

Table 2 A breakdown of correct and incorrect diagnoses[a]

	Fracture - (MRI)	Fracture +	Total		Diagnosis rate
Fracture-(X-P)	37.68%	24.83%	62.51%	→	Fx-/Fx-: 37.68%
Fracture +	6.49%	31% (Correct: 13.83%, level mistake: 17.17%)	37.495%		Fx+/Fx+: 13.83%
Total	44.17%	55.83%	100%		Total: 51.51%

[a]Fracture with a −/+ (MRI) means the correct diagnosis; fracture with a −/+ (X-P) means the examiners' answers



E

	Total	inter-orthopedists	inter-radiologists	orhtopedists-radiologists
κ score:median	0.65	0.65	0.69	0.63
(min-max)	(0.51-0.81)	(0.51-0.73)	—	(0.55-0.81)

Fig. 1 Diagnosis rate by the five examiners. **a** Significant variation was seen in the non-incident fracture group after adjustment. **b** Significant variation was seen in the incident fracture group without prevalent fractures. **c** Significant variation was seen in the incident fracture group with prevalent fractures after adjustment. **d** Average of diagnosis rate. **e** The kappa score of interexaminers. These results were moderate

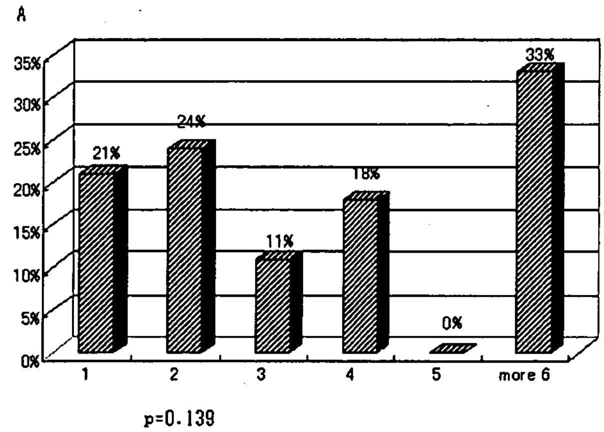
The rate of correct diagnosis based on the number of prevalent fractures

The next variable investigated was the correct diagnosis rate by number of prevalent fractures in the incident fracture group with prevalent fractures. No correlation was found between the correct diagnosis rate and the number of complicating prevalent fractures when the subjects were divided into either six groups according to the number of prevalent fractures (one fracture to six or more fractures) or two groups (one fracture vs. two or more fractures) (p=0.139, 0.284, respectively; Fig. 2).

The rate of correct diagnosis by morphological classification

The primary osteoporosis diagnostic criteria

We then looked at the correct diagnosis rate for incident fractures by morphological classification of the vertebral body in the incident fracture groups with and without prevalent fractures. The morphological classifications used were the primary osteoporosis diagnostic criteria of Genant et al. [8] and Yoshida's classification [9] (Fig. 3). Using the primary osteoporosis diagnostic criteria of Genant, the correct diagnosis rate was high for wedge-type fractures in the combined results for the incident fracture groups with and without prevalent fractures (fracture group)



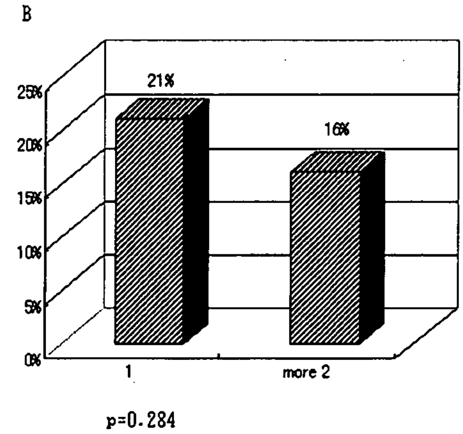


Fig. 2 No correlation was found between correct diagnosis rate and the number of complicating prevalent fractures. **a** Diagnosis rate when divided into one of six groups. **b** Diagnosis rate when divided into one of two groups

(p<0.0001). Similar results were obtained even after adjustment had been made for variation between the examiners. However, this significant difference disappeared after age, body weight, and lumbar BMD had been adjusted for. The same results were obtained in the incident fracture group with prevalent fractures, but in this case a significant difference was seen after correction in the incident fracture group without prevalent fractures (p=0.0455) (Table 3).

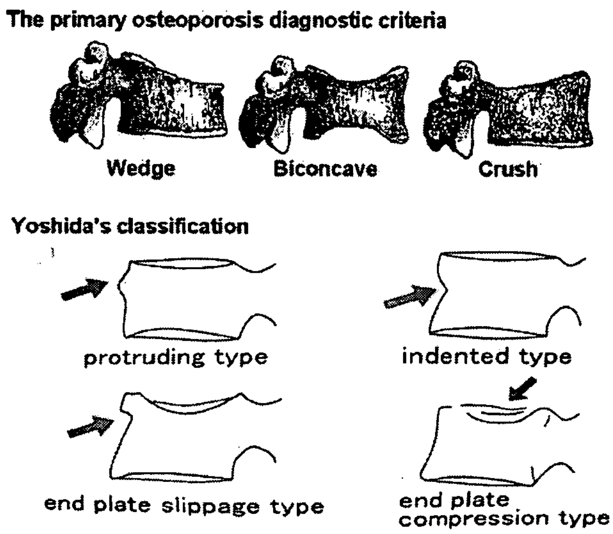


Fig. 3 The morphological classifications used were the primary osteoporosis diagnostic criteria of Genant [8] and Yoshida's [9] classification. Yoshida's criteria is for incident fractures and classified in four types as follows: protruding type, the anterior bone cortex disrupted protrudes anteriorly; indented type, the anterior bone cortex disrupted indents posteriorly; end plate slippage type, the anterior edge of the end plate disrupted displaces anteriorly; end plate compression type, the center of the end plate disrupted indents and depressed

Yoshida's classification

When Yoshida's classification was applied, the correct diagnosis rate was high for intended and protruding types of fractures (p<0.0001). The correct diagnosis rate was significantly higher in the incident fracture group without prevalent fractures even when there were morphological changes (wedge, intended and protruding type) in the anterior bone cortex. Conversely, the correct diagnosis rate was low in the incident fracture group with prevalent fractures, end plate compression and slippage type fractures with no morphological changes in the anterior bone cortex, and in "miscellaneous" cases that belonged to no category and had almost no morphological change.

Odds ratios affected the rate of correct diagnosis

Odds ratios (ORs) were investigated for factors that would affect the correct diagnosis rate, including age, body weight, lumbar vertebrae BMD, and examiner ability. In an overall investigation, age (OR=0.660), body weight (OR=2.082), and examiner ability (p=0.0205) affected the correct diagnosis rate. A younger age and greater body weight resulted in higher correct diagnosis rates, and results were also affected by the examiner's ability. None of these factors had an effect in the non-incident fracture group. Significant variation is seen in examiner's ability in Fig. 1, but not to the extent that results were affected (p=0.0709). In the fracture groups, both body weight (OR=2.206) and examiner ability (p=0.0039) affected the results. This was also seen in the incident fracture group without prevalent fractures alone, but in the incident fracture group with prevalent fractures alone only lumbar BMD had an effect (OR=1.574) (Table 4).

Discussion

The prevalence rate of spinal fracture is thought to be 117 people per 100,000 in the population [10], and the lifetime

Table 3 Diagnosis rate[a] according to the morphological classifications

Genant classification						
Fracture type	Numbers	Diagnosis rate – total fracture group	Numbers	Diagnosis rate – without prevalent fractures	Numbers	Diagnosis rate without prevalent fractures
Wedge	22	40.90%	6	63.30%	16	32.50%
Crush	9	26.70%	3	53.30%	6	13.30%
Biconcave	17	24.70%	4	40.00%	13	20.00%
Other	40	18%	12	30%	28	12.80%
a[b]	$p<0.0001$		$p=0.0011$		$p<0.0011$	
b	$p<0.0001$					
c	$p=0.9123$		$p=0.0455$		$p=0.9516$	
Yoshida's classification						
Fracture type	Numbers	Diagnosis rate – total fracture group	Numbers	Diagnosis rate – without prevalent fractures	Numbers	Diagnosis rate without prevalent fractures
End plate slippage	17	29.40%	7	45.71%	10	18.00%
Intended	8	46.70%	2	90.00%	6	40.00%
protruding	9	60%	4	80.00%	5	44.00%
End plate compression	6	10%	2	10%	4	10.00%
Other	48	16.20%	10	22.91%	38	14.21%
a[b]	$p<0.0001$		$p=0.0016$		$p=0.0173$	
b	$p<0.0001$					
c	$p=0.4708$		$p=0.0455$		p=0.6953	

[a]The correct diagnosis rate was higher in the incident fracture group without prevalent fractures even when there were morphological changes in the anterior bone cortex. In seven cases, we were unable to classify the morphology because of indistinctness

[b]a, Unadjusted p value; b, p value adjusted with examiners; c p value adjusted with age, weight, BMD and examiners

risk of spinal fracture in women over the age of 50 rises to about 40% [11]. Vertebral body fractures result in pain and functional restrictions, and provoke a marked decrease in quality of life [12, 13]. Therefore, early prevention of spinal fractures and accurate diagnosis and treatment are crucial. There are various reports on the diagnosis of incident spinal fracture [14], but a diagnostic gold standard has yet to be established. Nearly all institutions first take X-P images for patients presenting with lumbar pain. However, it is difficult to determine from X-P images the presence and location of incident fragility fractures in elderly patients with osteoporosis at the time of injury; it is even more difficult when the patient has prevalent fractures. Furthermore, incident fractures are defined as those vertebral bodies that show distinct morphologic changes or osteosclerosis change on the follow-up X-P images. Consequently, we usually cannot detect incident fractures at the early stage of diagnosis.

With respect to the effectiveness of X-Ps for lumbar pain disease in general, David et al. reported that 17.8% of patients in an emergency department received unnecessary lumbar X-Ps [15], while Khoo et al. reported that 90.5% of AP views on X-Ps have no benefit and were effective only in assessing the sacroiliac joint [16]. Thus, establishing a diagnosis for lumbar pain is difficult with X-P alone, and most cases require MRI. Many reports attest to the high diagnostic accuracy of MRI, and it continues to be more useful tool in diagnosing spinal fracture [4–6]. In MRI images, fractures are defined so that an acute fracture associated with hemorrhage and edema increases the focal water content and thus increases the signal on T2-images. With an osteoporotic fracture, the hemorrhage will be organized and the edema will decrease, giving a low to

Table 4 Odds ratios of factors that would affect the correct diagnosis rate

Factors	Total		Non-incident fracture group		Total fracture group		Without prevalent fractures		With prevalent fractures	
	Odds ratio	p value	Odds ratio	p value	Odds ratio	p value	Odds ratio	p value	Odds ratio	p value
Age	0.66	<0.001	0.781	0.2817	1.053	0.7098	1.02	0.9291	1.254	0.1966
Body weight	2.082	<0.001	0.661	0.0876	2.206	<0.001	3.002	<0.0001	1.42	0.1303
Lumbar BMD	1.246	0.072	1.108	0.676	1.043	00.7873	0.65	0.0584	1.574	0.0478
Ability of the examiner	-	0.0205	-	0.0709	-	0.0039	-	0.0349	-	0.1163

Results were affected by examiner ability, age and body weight intermediate signal intensity on T2-weighted images. It has already been reported that femoral neck fractures cannot be judged on X-P images and that MRI diagnosis is useful in cases of occult fracture. Pandey et al. reported that fractures are not discovered on X-P images and that even on MRI images, 30% show no fracture [17], while Rizzo et al. reported that occult fractures were detected on MRI in 36 of 62 patients (58%) [18].

With respect to spinal disease as well, Nakano et al. investigated the diagnostic accuracy of MRI for incident vertebral fractures. They took vertebral bodies showing signs of crush and bone sclerosis on follow-up X-P images to indicate true incident fractures and reported that the diagnostic sensitivity and specificity of MRI were 99.0% and 98.7 %, respectively [19, 20]. They also reported that based on diagnosis with MRI it was possible to diagnose with precision a fracture in the early period of onset. In addition, Kanchiku et al. reported that the diagnostic rate of the fractured vertebral body was 98% by MRI, which was higher than the 87% for plain radiography (p=0.006); in patients for whom no posterior wall injury was seen on X-P imaging at the time of the injury, intraspinal protrusion of the posterior wall of the vertebral body was diagnosed in 37% using MRI [21]. Eugene et al. reported that twice as many spinal diseases were detected when using MRI as when diagnosis was made from X-P imaging [2]. Thus, MRI is considered to be reliable in the diagnosis of incident fragility fracture. However, this high diagnostic accuracy also gives rise to some problems. Rupp et al. reported that in distinguishing between tumor and compression fracture on MRI images, compression fracture can only be diagnosed in those patients that have completely maintained normal marrow within the vertebrae and that it is difficult to make a distinction, due to changes in contrast effect and intensity, over multiple vertebrae or invasion to the posterior vertebral body wall [22]. In addition, Cuenod et al. reported that at 2 months after a spinal fracture is sustained, changes in brightness on MRI images have completely returned to normal in only 13% of the cases [23], indicating the possibility that old fractures can be mistaken for incident fractures. Equipment limitations at some institutions and economic problems make it impossible to conduct MRI with all patients. Jefferey et al. compared MRI in the acute phase of lumbar pain with X-P over the clinical course and concluded that no cost benefit was achieved [24]. Thus, several problems are also encountered with the use of MRI in diagnosis.

Based on all of the points raised above, we re-examined X-P diagnosis and investigated whether the correct diagnosis rate with X-P in the initial examination could be improved. To our knowledge, this type of comparison has not been carried out to date, however, a search of the literature has revealed that various data sets are available on diagnosis rates for incident fractures with X-P. In a comparison of local and central readings, Pierre et al. reported a correct diagnosis rate of 95% in the non-fracture group and 66% in the fracture group [25]. Hachiya et al. reported a correct diagnosis rate of 43%, false positives in 41% of the cases, and false negatives in 16% [26]. Nakano et al. reported a correct diagnosis rate of 51.5% [27], while Kanchiku et al. reported a high correct diagnosis rate of 87% [21]. However, factors such as unspecified measurement conditions, a small number of examiners, or non-uniform skill levels of examiners in these studies make them inadequate for the establishment of a correct diagnosis rate.

In the present study, a strict diagnosis was made together with radiologists, the ability of five orthopedists to interpret X-Ps was determined in advance to be uniform, and three groups were compared. The results of this analysis showed the correct diagnosis rate to be 51.5%, which did not differ greatly from the reports of previous investigators. However, the mean correct diagnosis rate for incident vertebral fracture group was 24.8%, and it was even lower – 16.8% – in the group with prevalent fractures. The correct diagnosis rate decreased in order of non-incident fracture group (highest), the incident fracture group without prevalent fractures, and the incident fracture group with prevalent fractures (lowest), a result which demonstrates anew the difficulty of diagnosing the location of fractures in the daily clinical setting. Moreover, after correcting for various factors, we found that there was a significant inter-examiner variation in all groups. This seems to indicate that the ability of an examiner to interpret radiographs is reflected in the correct diagnosis rate. In an examination based on the number of prevalent fractures, the correct diagnosis rate did not drop as the number of prevalent fractures increased, and no correlation was found. This finding that the number of prevalent fractures does not exert an effect is intriguing. Thus, even with prevalent fractures over multiple vertebrae, it is assumed that with diligence, incident fractures can be detected.

The previously mentioned criteria of Genant et al. were used in the analysis by morphological classification [8]. These criteria are commonly used in the diagnosis of osteoporotic vertebral body fractures. However, 45.5% of the cases in our study did not fit any type in these classifications, bringing some doubt to the judgments that have been made to date. We therefore conducted the investigation using these criteria in conjunction with Yoshida's classifications [9]. A high correct diagnosis rate was obtained for wedge type fractures with the diagnostic criteria for primary osteoporosis, and for protruding and indented type fractures with Yoshida's criteria; however, the correct diagnosis rate was low with the remaining types of fractures. Thus, a key to raising the correct diagnosis rate for incident fragility fractures may be to focus sufficient attention on morphological changes in the anterior bone cortex when diagnosing from X-P images.

In this investigation of factors influencing the correct diagnosis rate of osteoporotic vertebral body fractures, we found age, body weight, and examiner ability had an overall effect. The negative correlation seen with age, in which the correct diagnosis rate decreased as age increased, and the decrease in the correct diagnosis rate with lower body weight are understandable, but the finding that BMD did not exert an effect was intriguing. Moreover, the finding that the ability of the examiner to interpret radiographs was reflected in the correct diagnosis rate indicates the importance of continuing efforts to improve ability.

Several points remain for future study, including the facts that the present study was a retrospective study and that the diagnosis was made without questioning the patients or pathological findings. Based on the results presented here, an investigation of how repeat readings will change the correct diagnosis rate should also be made. In any case, the finding that the correct diagnosis rate was low, even when made by orthopedists experienced in reading radiographs, is a finding that should be taken into consideration in the normal diagnosis of incident spinal fragility fractures with X-Ps only, and may be important in identifying keys for the development of new diagnostic criteria and more accurate diagnoses. The present study indicates the importance of not only improving the ability of examiners to interpret radiographs but also of the attention that should be paid to morphological changes in the anterior bone cortex during examinations.

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