Table 3
Mean (SD) for angular excursion (deg) and rate of excursion (deg/ms)

	Knee abduction		Internal tibial rotation	
	Excursion	Rate	Excursion	Rate
Single limb landing	6.6 (3.6)	0.12 (0.05)	21.4 (6.4)	0.15 (0.06)
Plant and cutting	9.8 (3.8)**	0.13 (0.04)	26.8 (6.8)**	0.22 (0.07) **
Both limb jump landing	11.2 (3.6)	0.14 (0.05)	12.1 (4.9)**	0.14 (0.05)

*: $p<0.05$, **: $p<0.01$.

To each subject, 25 reflective markers of 9 mm diameter were secured to the lower limb using double-sided adhesive tape, as described in a previous study [14]. The markers were used to implement the Point Cluster Technique (PCT) [18]. We calculated knee kinematics using the joint coordinate system proposed by Grood and Suntay [19]. For PCT, the skin markers are classified into two groups: a cluster of points representing a segment and points representing bony landmarks. For a cluster of points, 10 and 6 markers were attached respectively to the thigh and shank segments. The bony landmarks were the great trochanter, the lateral and medial epicondyles of the femur, the lateral and medial edges of the tibia plateau, the lateral (fibula) and medial malleoli, and the fifth metatarsophalangeal joint.

2.4. Data analysis

The coordinate data obtained from the markers were not smoothed because of the expected noise-cancelling property of the PCT. In each trial, we calculated the angular displacements of flexion/extension, abduction/adduction, and external/internal tibial rotation using the PCT. The reference position for these measurements was obtained during the static trial. We analyzed each variable at the time of foot contact and the peak value from the foot contact to 200 ms thereafter. Additionally, angular excursion for knee abduction and internal tibial rotation was calculated. A rate of excursion for knee abduction and internal tibial rotation was also calculated.

All dependent variables were calculated for each trial, then averaged across the three trials. A repeated measures one-way ANOVA was used to test for task differences in joint angle at the foot contact and peak joint angle. The alpha level was set at $p<0.05$. A post hoc Bonferroni multiple comparison test was performed for each variable to determine differences among tasks. Intraclass correlation coefficients (ICC (1, 3)) were calculated to determine the measurement consistency.

3. Results

Acceptable ICC (1, 3) values at the time of foot contact and a peak value were established for knee abduction/adduction (0.98, 0.97), external/internal tibial rotation (0.93, 0.98), and flexion/extension (0.96, 0.89). Fig. 2 portrays mean time course comparisons across tasks for the three angular displacements of the knee (abduction/adduction, external/internal tibial rotation, and flexion/extension).

Means, standard deviations and observed power for all variables at the time of foot contact are presented in Table 1. The adduction angle in plant and cutting was significantly larger than that for either single-limb landing or both-limb jump landing ($p<0.01$, respectively); that in single-limb landing was significantly larger than that of both-limb jump landing ($p<0.05$). The external tibial rotation angle in plant and cutting was significantly larger than for either single-limb landing or both-limb jump landing ($p<0.01$); that in single-limb landing was significantly larger than that of both-limb jump landing ($p<0.01$). The flexion angle in both-limb jump landing was significantly larger than that of either single-limb landing or plant and cutting ($p<0.01$); that in plant and cutting was significantly larger than that of single-limb landing ($p<0.01$).

Means and standard deviations of peak values for all variables are presented in Table 2. The peak abduction angle in both-limb jump landing was significantly larger than that of either single-limb landing or plant and cutting ($p<0.01$ and $p<0.05$, respectively). During single-limb landing or plant and cutting, their knee was abducted from foot contact with time. However, even at their peak, it is adducted. The peak internal tibial rotation angles in plant and cutting and both-limb jump landing were significantly larger than that of single-limb landing ($p<0.05$ and $p<0.01$, respectively). The peak flexion angle in plant and cutting was significantly smaller than both-limb jump landing ($p<0.05$).

The angular excursion and velocity for knee abduction and internal tibial rotation are presented in Table 3. The excursion for knee abduction in plant and cutting and both-limb jump landing was significantly larger than that for either single-limb landing ($p<0.01$, respectively). The rates of excursion for knee abduction among three tasks were not significantly different. The excursion for internal tibial rotation in plant and cutting was significantly larger than for either single-limb landing or both-limb jump landing ($p<0.01$, respectively), whereas that in single-limb landing was significantly larger than that of both-limb jump landing ($p<0.01$). The rate of excursion for internal tibial rotation in plant and cutting was significantly faster than that for either single-limb landing or both-limb jump landing ($p<0.01$, respectively).

4. Discussion

The primary purpose of this study was to analyze the biomechanical characteristics of the knee joint during several athletic tasks, and to examine what tasks present a risk for ACL injury. A plant and cutting manoeuvre is a movement that commonly causes ACL injury, of which most situations were single-foot push-offs [5]. However, biomechanical characteristics of plant and cutting and several athletic tasks are unknown. Therefore, to compare a plant and cutting and normal single-limb landing as well as both limb landing, we can understand these athletic tasks and examine what tasks are risky for ACL injury. The results of this study showed that greater excursion and more rapid knee abduction occur in plant and cutting than that which occurs in single-limb landing, in addition to greater internal tibial rotation. Furthermore, compared to similar single-limb tasks, both-limb jump landing knee flexion and knee abduction were greater; external tibial rotation at the foot contact was smaller.

4.1. Plant and cutting versus single-limb landing

Some recent studies have compared biomechanical characteristics across different athletic tasks [8,15,20]. Nevertheless, these studies present some limitations. Although Chappell et al. [8] compared knee kinematics of forward, vertical, and backward stop-jump tasks, they did not examine lateral movement. Sell et al. [15] compared two-legged stop-jump tasks in three different directions. Although their results indicate that lateral jumps are the most dangerous of the stop-jumps, all tasks were two-legged tasks, not single-leg tasks. Besier et al. [20] compared the joint load during running, sidestep cutting, and crossover cutting. They inferred that external moments applied to the knee joint during the stance phase of the cutting tasks place the ACL and collateral ligaments at risk of injury, but they did not analyze joint kinematics and the frequency of the motion analysis system was too slow to support examination of high-speed athletic tasks. Therefore, the results of this study, along with those of the prior study, provide some implications of mechanisms causing ACL injury.

The results of this study showed that, during plant and cutting, external tibial rotation at the foot contact and peak internal tibial rotation were greater than during single-limb landing. During plant and cutting, from foot contact, subjects rotated the tibia more rapidly and to a greater degree toward internal tibial rotation than during single-limb landing. Previous studies [8,15,16] that examined the mechanism of ACL injury have not analyzed tibial rotation during high-risk movement, probably because of technical issues. In this study, we analyzed tibial rotation using PCT. An anatomical study has demonstrated that internal tibial rotation increases the strain of ACL [21]. Therefore, biomechanically and anatomically, plant and cutting presents a high risk for ACL injury.

During plant and cutting, subjects demonstrated more increased knee adduction at foot contact than during single-limb landing. After foot contact, during single-limb landing, subjects showed twin peaks of knee abduction. During plant and cutting, subjects moved toward knee abduction with time, although subjects did not exhibit a great magnitude of knee abduction. Consequently, during plant and cutting, excursion of knee abduction was greater than during single-limb landing. Therefore, during plant and cutting, greater excursion of knee abduction occurred than during single-limb landing combined with greater internal tibial rotation to push off their body to the other side and change direction.

4.2. Both-limb jump landing versus single-limb tasks

Some studies have analyzed kinematics or kinetics during bilateral landing to examine ACL injury mechanisms [11,12,22]; other studies have screened risks for ACL injury [13] or lower limb injury [23,24]. However, few studies have examined the characteristics of bilateral landing in comparison to single-limb landing. Only Pappas et al. [16] compared bilateral and unilateral landings. Their results indicated that, in unilateral landings, subjects performed high-risk kinematics with increased knee valgus, decreased knee flexion, and decreased relative hip adduction. However, they showed no peak knee valgus or tibial rotation during landing.

The results of this study demonstrated that, during both-limb jump landing, knee flexion at foot contact was greater than for single-limb landing and plant and cutting, and that peak knee flexion was greater than plant and cutting. These results were consistent with those of a previous study [16]. Pappas et al. [16] speculated that subjects might attempt to prevent falls by limiting excessive knee flexion during unilateral landing compared to bilateral landing, while simultaneously increasing the forces in ACL. Additionally, in slight knee flexion, i.e. less than 30 , contraction of the quadriceps strains the ACL [21,25,26]. For that reason, slight knee flexion is inferred as a risk factor of ACL injury. During a process of prevention training leading athletes to increased knee flexion can decrease the incidence of ACL injury. On the other hand, during both-limb landing, external tibial rotation at the foot contact was less than that during single-limb landing and plant and cutting, while peak internal tibial rotation was not significantly different with plant and cutting. Unilateral landing has a greater excursion of tibial internal rotation than bilateral landing. As described above, an anatomical study has demonstrated that internal tibial rotation increases the ACL strain [21]. Consequently, characteristics of unilateral landing that have less knee flexion and greater internal tibial rotation present a higher risk for ACL injury than bilateral landings.

During both-limb jump landing, peak knee abduction was greater than for either single-limb landing or plant and cutting, while knee adduction at foot contact was smaller. These results did not support our hypothesis. We speculate that knee abduction was limited compensatory for greater internal tibial rotation and smaller knee flexion to prevent ACL injury during single-limb tasks. The possibility of ACL injury arose when subjects allowed greater knee abduction during single-limb tasks. Another reason might be that, because ACL injury occurs not only in single-limb situations but also in both-limb jump landing, the latter also poses a risk for ACL injury. Krosshaug et al. [27] analyzed videos of ACL injury situations and reported that ACL injury occurred during two-legged landing in 9 of 22 cases of female player situations, although it occurred in only four cases of one-legged landing. Therefore, it is thought that both-limb landing with greater knee abduction might also pose a risk for ACL injury.

Greater knee abduction was apparent during a both-limb jump landing task. For screening of ACL injuries, we detected knee abduction well in this task. It is difficult to detect a risk demonstrating greater knee abduction during single-limb tasks because of these characteristics, which demonstrate limited knee abduction. Moreover, knee abduction during both-limb landing can be evaluated using a two-dimensional approach, which uses a video recorder and analyzes a frontal projected knee valgus angle [17]. Some studies have been conducted using comparable methods [23,28]. Consequently, considering convenience and efficiency, both-limb jump landing is thought to be valuable for screening the risk of ACL injury.

4.3. Limitations

This study has important limitations. Influences of the hip and ankle have recently been suggested [9,29]. However, the present study analyzed the kinematics of the knee only. Additionally, although joint kinetics holds great importance for analyses of athletic tasks and for examination of the mechanisms of injuries, we only analyzed knee kinematics because we have not developed a joint-moment calculation system corresponding to PCT. Future studies should examine the relation between kinematic data and kinetics data to assess the ACL injury mechanism.

5. Conclusion

We compare the biomechanical characteristics of the knee joint for several athletic tasks to elucidate the characteristics of single-limb landing, plant and cutting and both-limb landing, and to examine what tasks present a risk for ACL injury. The results indicate that, in plant and cutting, knee abduction combined with internal tibial rotation poses a risk of causing ACL injury. Both-limb landing with greater knee abduction might also pose risks for ACL injury.

6. Conflict of Interest

No author of this manuscript has any conflict of interst.

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卒後
研修講座

変形性膝関節症のリスクファクター*

大森　豪**

はじめに

変形性膝関節症（膝OA）は年齢に伴う膝関節の退行性疾患であり，日常診療の場において変形性関節症の中では腰椎に次いで頻度が高い．本症の病態は，関節軟骨の変性と摩耗を主体として骨や軟骨下骨，滑膜，半月板，靱帯といった関節構成体に炎症反応や増殖性変化，変形性変化が生じ，結果的に関節破壊の進行にいたる一連の過程として理解される．膝OAは“common disease”であり，その発症と進行には多数の因子が関与している．これらの因子は，膝関節に限局する局所因子と全身性因子あるいは遺伝要因と環境要因などに区分され，疫学や生体力学，生化学，画像解析などさまざまなアプローチで研究が行われている．

膝OAの治療や予防を考えるうえでリスクファクターを理解することはきわめて重要であり，本稿では膝OAの発症・進行因子について，これまでに明らかになっているものおよび残された課題を含めて概説する．なお，ここで述べる膝OAとはX線像にて診断されたradiographic OAであり，膝痛などの症状を有するsymptomatic OAではない．

1 年齢と性別

男女とも40歳代以降年齢とともに膝OAの頻度は増加し，70歳代では男性で30～40%，女性で50～60%に達する[1]（図1）．40歳以降の各年代では女性が1.5～2.5倍発症率が高くなっており，これらの点から加齢および女性は膝OAの危険因子といえる．興味深いのは40歳以下の年代では，Lawrenceら[2]は男性で5.5%，女性で3.9%，NHANES-I[3]でも35～44歳の群で男性1.75%，女性1.44%と逆に男性の発症率がわずかながら高く，比較的若年者の膝OA発症に靱帯，半月，軟骨損傷といった膝外傷が潜在的に影響している可能性を示唆する所見と考えられる．

2 人　種

これまでの報告では，欧米の白人，日本人，中国人における年代別の膝OA発生率はいずれも男女とも加齢とともに増加する（図1）．また，NHANES-I[3]では米国内の黒人は白人に比べて男性で1.4倍，女性で2.8倍膝OAに対する危険度が大きいことも示されている．近年，異なる二つの人種を同一の解析手法で比較した研究が行われ，Zhangら[4]はFramingham studyのプロトコルを用いて調査を行い，中国人女性が白人女性に比べて有意に膝OAが多いことを示した．また，Yoshidaら[5]も同様の手法で日本人女性は白人女性に比べて1.9倍膝OAの危険度が高いと述べており，今後，同様の研究がすすむに従い人種間の相違や特徴が明らかになることが期待される．

Key words：medial knee osteoarthritis, risk factor, review

* Risk factor of knee osteoarthritis

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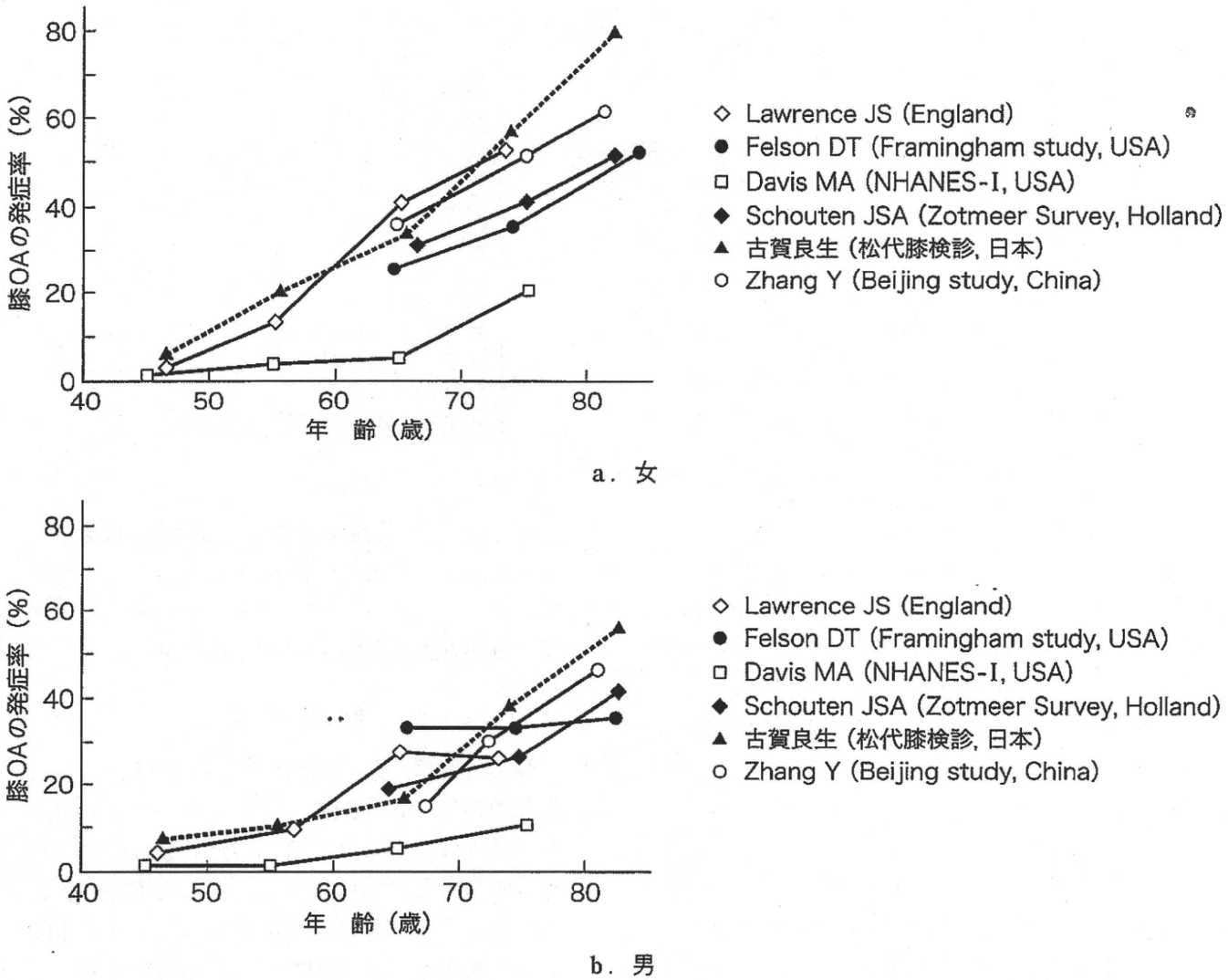


a．女

b．男

図 1．疫学調査による膝 OA の年齢別発症率

3 肥　満

膝関節には立位で体重の 1～1.5 倍，階段昇降で 2～3 倍，ジャンプ動作では 4～6 倍の荷重がかかるとされ，機械的要因の観点から体重と膝 OA の関連性は明らかである．疫学調査においても膝 OA と肥満の有意な関連を示す報告は多く，肥満の指標として BMI［body mass index：体重（kg)/身長（m)^2］を用いた欧米の調査[3,6]では BMI が 25 以上で 1.8～3.8 倍，BMI が 30 以上で 3.8～4.8 倍，35 以上の超肥満では 4～7.8 倍の相対危険度が報告されている．日本では，われわれが行った調査（松代膝検診）[7]において BMI が 24 以上で危険度が 2.1 倍に高くなり，また Yoshimura ら[8]は和歌山県のコホートに対し case-control-study を行い，過去の肥満の既往が膝 OA 発症に関連することを述べている．男女差については，男性のほうが肥満の影響が大きいとする報告と女性のほうが大きいとする報告があり一定の見解は得られていない．また，肥満が膝 OA に影響するメカニズムとして膝関節への荷重負荷増大による機械的作用と高脂血症や糖尿病などの代謝性疾患による作用が考えられているが，次項に述べるように代謝性疾患による影響は少なく機械的作用が主体と考えられる．

4 代謝性疾患

偽痛風の原因であるピロリン酸カルシウム結晶（CPPD）やほかのカルシウムリン酸結晶（BCP）と膝 OA との関連性は古くから指摘されており，膝 OA の 50～60% に関節液中に

表 1. 職業および日常活動性の膝 OA への影響

職業および日常活動性	膝 OA への影響
炭鉱労働者	男で影響あり
港湾労働者	男で影響あり
膝屈曲を要する職業（大工，トラック運転手など）	男で 2.5，女で 3.5（OR*）
力を要する職業（農夫，大工など）	男で 1.8，女で 3.1（OR）
膝屈曲＋力仕事	男で 2.2，女で 0.3（OR）
しゃがみ込み動作（1 日 30 分以上）	6.9（OR）
膝つき動作（1 日 30 分以上）	3.9（OR）
階段昇降（1 日 10 段以上）	2.7（OR）
しゃがみ込み動作（1 日 1 時間以上）	女で 1.2（OR）
階段昇降（1 日 30 段以上）	女で 1.19（OR）
椅子の腰掛け（1 日 2 時間以上）	女で 0.77（OR）
しゃがみ込み動作（1 日 2 時間以上）	女で 2.4（OR），男で 2.0（OR）

*OR：オッズ比

CPPD が存在するといわれている[9]．しかし，全身的な高尿酸血症の影響については明らかになっていない．また高脂血症，糖尿病，高血圧についても関連性があるとする報告とないとする報告があり一定の見解は得られておらず，現時点で代謝性疾患の膝 OA への直接的な関与は少ないと考えられる[10,11]．

5 喫　煙

これまでの疫学調査では，タバコおよび葉巻の喫煙習慣と膝 OA の発症は逆相関が認められ，喫煙は膝 OA に無関係とするものから予防的効果の可能性すら指摘する報告もある[12,13]．しかしニコチンやタール，アンモニアといったタバコに含まれる成分が膝関節に及ぼす生物学的な影響についてはまったく解明されていない．

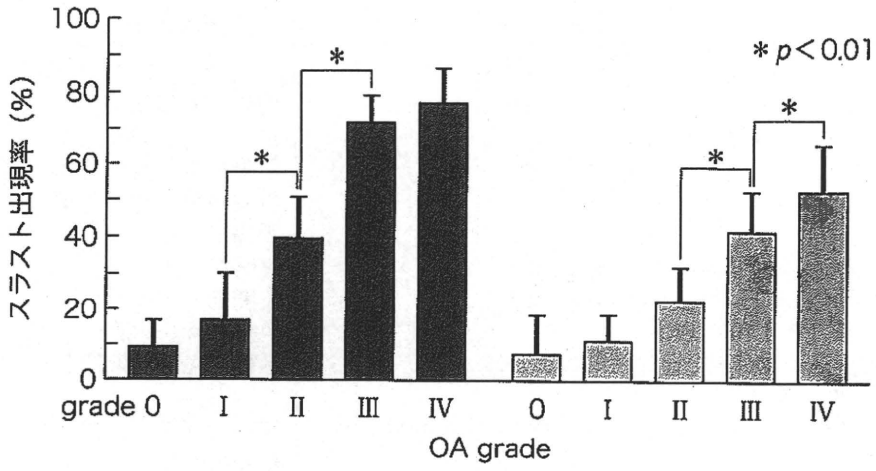
6 職業，生活様式，日常活動性と運動

職業や日常動作と膝 OA との関連性については多数の研究があり，膝の屈伸を伴う重労働の影響が大きいとする報告が多い（表 1）．地域での生活習慣については，グリーンランドの狩猟民族やジャマイカの裸足生活者には膝 OA が多いという報告もある[14,15]．

運動と膝 OA との関連では，ジョギングのように軽度～中等度の負荷にとどまる場合は影響が少ないとされている[16]．これに対し膝関節への負荷が増大する運動強度の高い種目では，次項に述べる半月板損傷や軟骨損傷，靱帯損傷といった膝外傷の合併との関連で検討され，膝 OA に大きく影響するといった報告が多い．Sandmark ら[17]の行った調査によると，クロスカントリースキーやアイスホッケーでは，男性で 2.9 倍相対危険度が増すと述べている．

7 膝 外 傷

膝 OA に影響する外傷としては靱帯損傷，半月板損傷，軟骨損傷，骨折があるが，未治療の膝外傷については診断が明確とならないため特定することは困難である．半月板損傷の影響は，生体力学研究により半月板切除による膝関節への著明な応力集中が証明されているが[18]，臨床的には治療として行った切除術後の OA 変化を検討するものが多く，変性半月板断裂，半月板切除量が多いことが成績不良因子としてあげられている[19]．また，前十字靱帯損傷に関しては，保存的治療例または放置例において受傷後 10～20 年の経過で高率に膝 OA が発症することが報告されている[20,21]．しかし，これらの臨床研究では対象者の年齢が 40～50 歳と比較的若いこと，X 線像上の OA 所見のわりに臨床症状が少ないことが指摘されている．われわれも膝半月板切除後 30 年以上の長期経過例を評価し，膝 OA 発症例に臨床症状が少なく可動域が良好な例が多いことを経験している[22]．さらに，既述した膝 OA の発症率が 40 歳代までは男性が女性より多くその後逆転することを考えると，膝外傷後にみられる膝関節の OA 変化は外傷に対する関節の生体変化である可能性が示唆される．そして，これが最終的に真の膝 OA となりさらに進行するかどうかは，



a. 女　　b. 男

図 2. 膝 OA grade とスラスト運動出現率

その個人のもつ膝 OA のリスクファクターによって左右されると考えられる．しかし，この点に関する科学的なエビデンスはなく今後明らかにすべき課題である．

8 下肢筋力

大腿四頭筋力が膝 OA の進行に伴い低下することは，疫学的な横断調査や患者を対象とした臨床研究において多数の報告がみられ，両者に関連性があることは明らかであるが，因果関係については不明な点が多い．最近の研究では単なる大腿四頭筋力低下ではなく，日常生活動作（ADL）における大腿四頭筋反応時間[23]や，膝屈筋とのバランス[24]，関節位置覚[25]，スラスト運動を含めた関節安定性[26]などほかの要素を含めて膝 OA との関連性を述べたものが多い．われわれは松代膝検診における縦断解析より，大腿四頭筋力低下が後述するスラスト運動を介して膝 OA 発症に影響することを明らかにしている[27]．また大腿四頭筋力と膝 OA の進行との関係については，これまでのところ有意な関連性を示した基礎研究は見当たらず，大腿四頭筋力強化により疼痛や ADL が改善したという臨床研究がみられるのみである．

このように，現在臨床の場において大腿四頭筋力強化が膝 OA の予防や治療として有効であると推奨されているが，そのエビデンスは意外に乏しく，今後明らかにすべき多くの課題が残されている．

9 下肢アライメント，スラスト運動

生体力学的研究から膝内反により膝関節内側の荷重負荷が増大することが証明されているが，近年，膝内反アライメントと内側型膝 OA の関連性がわれわれ[27]や Sharma ら[28]により疫学調査や臨床研究から示されている．また，スラスト運動は立脚歩行初期における急激な内反運動で，われわれは歩行解析を行った膝 OA 患者にスラスト運動が多くみられたことから膝 OA の有力なリスクファクターと考えている．松代膝検診でも膝 OA の進行とともにスラスト運動の出現が増加し，さらに縦断解析によりスラスト運動が膝 OA 発症に関与していることが明らかとなった（図 2）．欧米ではスラスト運動は膝内反モーメントとして評価され，歩行解析を用いた臨床研究から膝 OA との関連性が指摘されているが，近年，疫学研究においてスラスト運動と膝 OA との関連性を述べた報告もみられる[29,30]．

10 骨粗鬆症

従来，変形性関節症と骨粗鬆症は逆の病態と考えられ，膝 OA についても高骨密度との関連性を示した報告が多い[31~33]．しかしその一方で，高骨密度は膝 OA 発症に関与するが，膝 OA の進行には逆に低骨密度が影響するという報告[34]や，脛骨近位の内反変形と腰椎骨密度と相関するという研究[35]もみられる．また，動物

表 2. これまでに報告された膝 OA の候補遺伝子

膝 OA の候補遺伝子として報告されたもの	膝 OA および類縁疾患との関連
COMP (cartilage oligomeric matrix protein)	偽性軟骨無形成症
COL11A1 (human type-XI procollagen gene)	Stickler 症候群
COL2A1 (human type-II procollagen gene)	軟骨形成不全，脊椎骨端異形成症など多数
VDR (vitamin D receptor gene)	骨粗鬆症，骨棘形成
aggrecan	手指 OA
COL9A1 (human type-IX procollagen gene)	股関節 OA
COL9A3 (human type-IX procollagen gene)	股関節 OA
IGF1 (insulin-like growth factor 1)	手指 OA，脊椎 OA
CRTL1 (cartilage matrix protein gene 1)	手指 OA，股関節 OA
ER (estrogen receptor)	骨粗鬆症
PAPSS2 (3'-phosphoadenosine 5'-phosphosulfate synthase)	脊椎骨端異形成症
ASPN (asporin)	膝 OA
AnK	CPPD 沈着
CALM1 (calmodulin1)	股関節 OA
FRZB (serected frizzeled-related protein-3)	股関節 OA（女性）
IL-1	股関節 OA
MATN3 (matrilin 3)	手指 OA
IL-4L	股関節 OA
ADAM12 (metalloprotease)	股関節 OA

実験では骨吸収抑制薬により膝 OA にみられる骨棘形成が抑制されたという研究[36]もある．さらに Baltimore aging study[37]では，変形性関節症と骨粗鬆症の関連性は罹患関節によって異なると述べている．したがって現状では膝 OA と骨粗鬆症の関連性は示唆されるが，その作用機序は明らかではない．

11 性ホルモン

女性ホルモンであるエストロゲン（estrogen：ERT）は，骨に対しては骨吸収を抑制し形成を維持する作用がある．膝 OA に対しても ERT 補充療法が試行され，発症と進行に予防的に作用可能性を示した報告が散見されるが，統計学的な有意差は認められていない[38,39]．近年，ERT レセプターに対する遺伝子学的研究からも ERT は膝 OA に対する予防的効果が報告されており[40]，前項の骨粗鬆症との関連性においても今後の研究がまたれている．

12 微量栄養素

ビタミン A，C，E およびベータカロチンは，活性酸素による軟骨破壊の抑制と修復をうながす点で膝 OA の発症に対しては有効ではないが，進行の抑制や膝痛の軽減に効果があるという報告が多い[41,42]．近年，Wang ら[43]は 10 年間の縦断研究からビタミン C 摂取が軟骨変性に予防的に作用することを明らかにしている．また，ビタミン D は骨代謝の観点から膝 OA との関連性が研究されている．McAlindon ら[44,45]は Framingham study において血中 25-ハイドロキシビタミン D 濃度の低下は膝 OA の進行を助長すると報告したが，近年，Felson ら[46]は Framingham と Boston の二つのコホートに対する縦断調査からビタミン D と膝 OA の進行との間に有意な関連性は見出せなかったとしており，一定の見解が得られていない．

13 遺伝子

膝 OA は common disease のため遺伝形式は多因子遺伝であり，原因遺伝子よりも感受性遺伝子（susceptibility gene）として研究される場合が多い．膝 OA の遺伝性についての報告は，Kellgren ら[47]が手指遠位指節間（DIP）関節の OA である Heberden 結節と膝 OA の合併例を調べ，「generalized OA（GOA）」という疾患概念を提唱し遺伝的素因を示唆したのが最初である．その後，軟骨形成不全症や Stickler 症候群など膝 OA の一つのモデルとも考え

られる疾患の原因遺伝子としてCOMP（cartilage oligomeric matrix protein）やCOL2A1（human type-Ⅱ collagen gene）などが同定され，これを足がかりにして，変形性関節症に関する多くの遺伝子多型（genetic polymorphism）が発見された[48~50]（表2）．さらに，これらの遺伝子多型の相関解析が行われているが，膝OAに関しては近年asporinの報告があるものの，いまだ特定されてはいない．また，ビタミンD受容体遺伝子（vitamin D receptor gene：VDR）は骨粗鬆症と関連性があることから，膝OAへの影響についても注目され多くの研究が行われており[51~53]，VDR遺伝子は初期の膝OAに関連する（Chingford study）や膝関節の骨棘形成に影響する（Rotterdam study）など多くの報告がなされているが一定の結論にいたっていない．いずれにせよ，今後膝OAに対する感受性遺伝子の研究はさらに加速すると思われるが，本疾患の複雑な病態から考えると大規模な集団に対する遺伝子解析が望まれる．

おわりに

現在，わが国においてX線像上膝OAと診断される人は1,000万人を超えると推計される．膝関節は起立歩行といった人間のもっとも基本的な動作の要であり，その機能破綻はわれわれの日常生活動作（ADL）や生活の質（QOL）に大きな影響を与える．したがって，膝OAに対する予防や治療方法の確立に向けて今後も病態解明の努力が必要と考えられる．

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《シンポジウム》

骨関節疾患リハビリテーションの実学（運動器の10年）
―変形性膝関節症のリハビリテーション実学―

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内側型変形性膝関節症の発症危険因子*

新潟大学超域研究機構

大森 豪

はじめに

内側型変形性膝関節症（以下，内側型膝OA）は我が国における代表的な骨・関節の加齢性疾患であり，荷重関節である膝関節の機能が障害されるため中高年者のADL（activity of daily life）やQOL（quality of life）に大きな影響を与える．内側型膝OAの80％以上は1次性であり加齢に伴って発症するため，その病態や危険因子の解明には自然経過の把握が極めて重要である．我は，内側型膝OAの自然経過と危険因子を知る目的で長期の疫学調査（松代膝検診）を行ってきた．本稿では，この疫学研究を紹介し本研究から得られたX線上の内側型膝OAの発症危険因子について概説する．

対象と方法

松代膝検診の概要[1-3]

松代膝検診は，新潟県十日町市松代地区において毎年7月に行われる住民の総合検診に合わせて行った．初回検診は，1979年に40～65歳の男女1,844名を対象として行い，以後基本的に同一の集団を7年毎に縦断的に評価した．初回検診の受診者は1,327名で受診率は81％であり，以後3回の検診でも受診率は70％以上と比較的良好であった（表）．また，第1回検診の受診者のうち558名（女性494名，男性64名）が以後21年間に行われた3回の検診を全て受診していた．

検診内容は問診（事前アンケートを含む），視触診および膝X線撮影とし，基本的に4回の検診とも同一内容とした．問診では，全身的な項目として職業，日常活動性，全身合併症と既往歴，喫煙習慣などを調べた．膝関節については，外傷歴や加療歴，水腫の既往および歩行・階段昇降能について聞いた．視触診では全身的に歩容と下肢アライメント，腰椎，股関節可動域，円背やHeberden結節の有無について調べ，膝関節においては歩行時のthrustの有無と膝のアライメント，可動域，関節安定性，関節裂隙の圧痛や水腫の有無について評価した．膝関節のX線撮影は立位膝関節正面像を撮影し，内側型膝OAの病期をKellgren分類[4]に準じた5段階で評価しgrade-Ⅱ以上を膝OAと判定した（図1）．したがって，本論文における膝OAの表記はX線上の定義に基

* 本稿は第44回日本リハビリテーション医学会学術集会シンポジウム「骨関節疾患リハビリテーションの実学（運動器の10年）―変形性膝関節症のリハビリテーション実学―」の講演をまとめたものである．

表1　松代膝検診における各検診毎の受診者数と受診率

	対象年齢(歳)	総受診者数(人)	女性	男性	受診率(%)
第1回検診（1979年）	40～65	1,327	1,075	252	81
第2回検診（1986年）	47～72	1,015	831	184	80
第3回検診（1993年）	54～79	1,562	907	655	87
第4回検診（2000年）	61～86	1,260	711	549	73

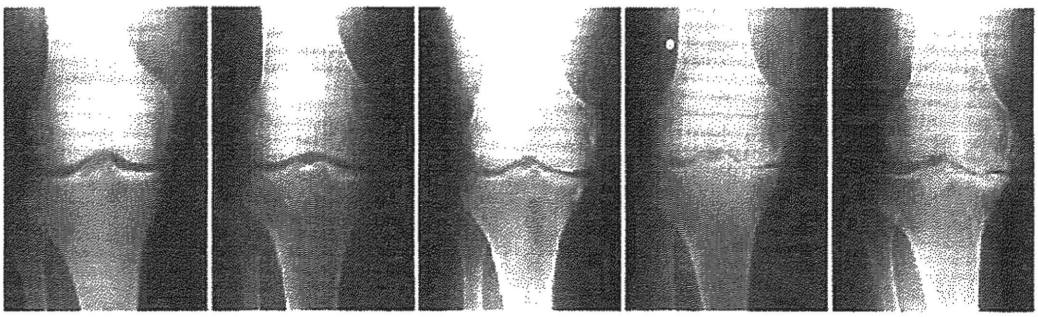

図1　Kellgren分類に準じた内側型変形性膝関節症のX線grade分類
Grade-Ⅱ以上を膝OAありと判定した.

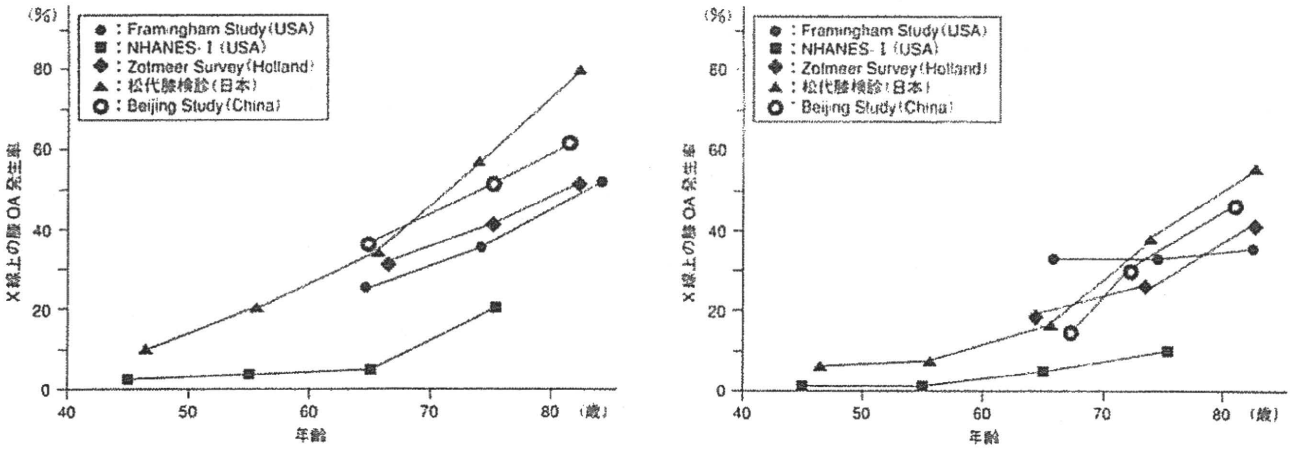

図2　松代膝検診および他の疫学調査による変形性膝関節症の発生率

づくものであり，疼痛，可動域制限や水腫といった本人の症状の有無は考慮されていない.

今回，2000年に行った第4回検診の横断的解析を行い，この結果から内側型膝OAの発症に関与する危険因子について検討した.

結　　果

1. 年齢，性別と内側型膝OAの発症

男女とも年齢の増加とともに膝OAの発生率も増加していた．女性では，40歳代で15%，50歳代で20%，60歳代で30%と増加し，70歳代では60%，80歳以上では80%以上が膝OAを生じていた（図2a）．男性でも，50歳代12%，60歳代20%，70歳代40%，80歳代60%と年齢に伴い膝OAが増加したが，その割合は女性より低くなっていた（図2b）．また，これまでに報告されている膝OAに関する代表的な疫学調査での発生率と比較すると，男女とも70歳以上の高齢域において発生率が若干高くなっていた.

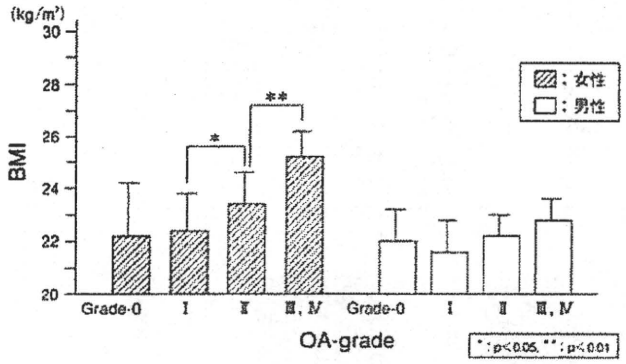

図3　肥満と内側型変形性膝関節症発生の関係
女性で膝 OA-grade の進行とともに BMI が有意に増加している.

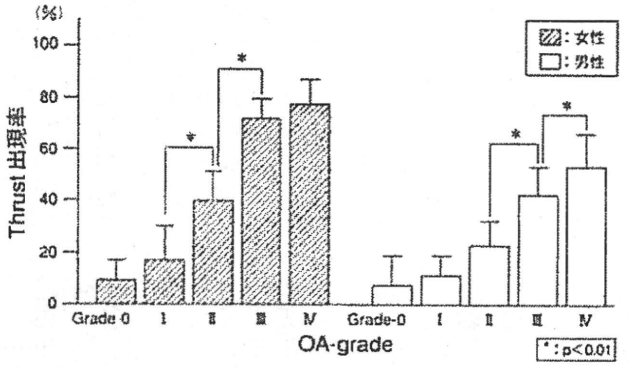

図5　Thrust 現象出現と内側型変形性膝関節症発生の関係
男女とも膝 OA-grade の進行とともに thrust 出現率が有意に増加している.

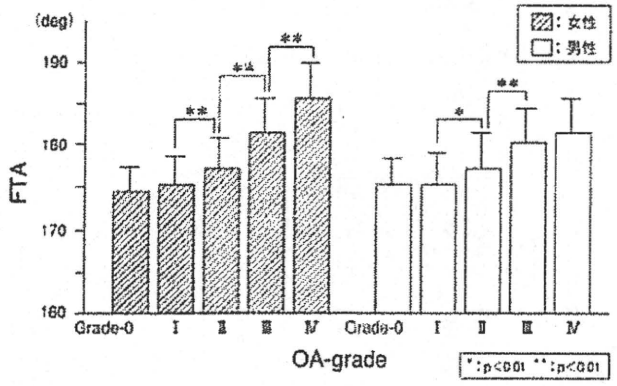

図4　膝内反変形と内側型変形性膝関節症発生の関係
男女とも膝 OA-grade の進行とともに FTA が有意に増加している.

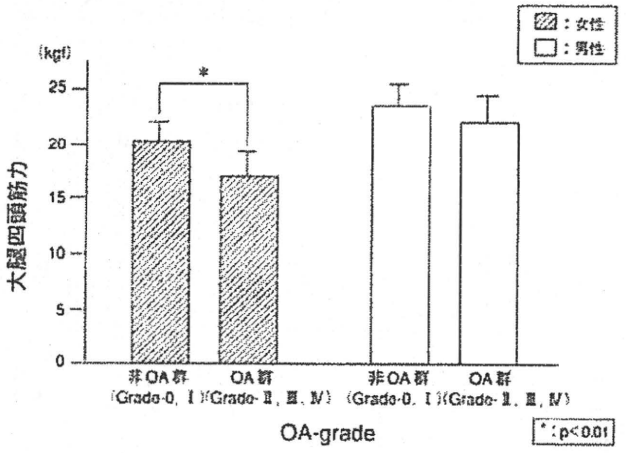

図6　大腿四頭筋力と内側型変形性膝関節症発生の関係
女性で OA 群（grade-Ⅱ，Ⅲ，Ⅳ）の大腿四頭筋力が有意に低下している.

2. 肥満と内側型膝 OA の発症

肥満の指標には BMI（body mass index）を用いた．女性では，膝 OA の grade が進行するにつれて有意に BMI が増加し，さらに grade-Ⅲ，Ⅳでは BMI の平均値が 25 kg/m² と BMI 上肥満と判定される割合も増加していた．これに対して男性では膝 OA の grade 進行に伴う BMI の増加は明らかではなく，全体的に肥満と判定される人も少なかった（図 3）.

3. 内反膝変形と内側型膝 OA の発症

内反膝のアライメントを FTA（femollo tibial angle：大腿脛骨角）で評価した．男女とも膝 OA-grade の進行とともに FTA は有意に増加して膝内反変形の増強を認め，その傾向は特に女性で顕著であった（図 4）．また，男女とも grade-ⅠからⅡの間でも FTA が有意に増加しており，内側型膝 OA において骨自体の変形が軽度な初期においても膝の内反が進行していることが明らかとなった.

4. Thrust の出現と内側型膝 OA の発症

歩行立脚初期に見られる膝の急激な内反運動（「横ぶれ」現象）である thrust の OA-grade 別の出現率を調べた．男女とも OA-grade の進行に伴い thrust の出現率が増加し，女性では grade-Ⅰ-Ⅱ間，Ⅱ-Ⅲ間で，男性では grade-Ⅱ-Ⅲ，Ⅲ-Ⅳ間で有意差を認めた．男女間の比較では，thrust 出現率は女性に多く認められた（図 5）.

5. 大腿四頭筋力と内側型膝 OA の発症

簡易筋力測定器（アルケア社製 QH-302）を用いて膝伸展筋力を定量的に測定し，これを大腿四

頭筋力として膝OA-gradeとの関係を評価した．Grade-0，Ⅰの非OA群とgrade-Ⅱ，Ⅲ，ⅣのOA群の2群間で大腿四頭筋力を比較すると，男性では差が見られなかったのに対して女性ではOA群で有意に筋力が低下していた（図6）．

考　察

疫学調査による膝OAの発症悪化要因については，欧米を中心に現在まで多方面からの研究が行われている[5-12]．これまでに報告された因子の中で，肥満，女性，非喫煙，日常生活の活動性（職業歴，運動歴），膝関節外傷の既往，人種などは膝OAとの関与がある程度明らかになっているが，一方で骨粗鬆症，女性ホルモンなどは一定した見解が得られておらず，さらにビタミンやミネラル，抗酸化物質などの微量栄養素や遺伝子の関与については不明な点が多い．

我が国においても膝OAに関する疫学調査の報告は散見されるが，いずれも対象集団が比較的小さくさらに横断調査が多いため，内側型膝OAの発症悪化要因を明らかにするにはいたっていない[13-16]．近年，人種による差に注目して，我が国や中国において比較的大規模な母集団を設定して欧米の疫学調査と比較した研究も行われ，日本人女性では肥満，膝外傷の既往，職業の影響が大きいことや，中国では外側型の膝OAの頻度が高いことなどが報告されている[17-19]．

我々が行ってきた松代膝検診は，対象集団の規模および縦断調査の期間から他に比類のない疫学調査である．今回，第4回の横断調査の解析から，加齢，女性，肥満，膝内反変形，thrust現象，および大腿四頭筋力低下が内側型膝OAと関連があることが明らかとなった．このうち，加齢，女性，肥満については他の報告と同様の結果であったが，膝内反変形，thrust現象，大腿四頭筋力低下に関しての他の研究報告は少なく，松代膝検診から得られた貴重な研究結果の1つと考えられる[20,21]．我々は，内側型膝OAの病態解明に対して疫学的手法と同時に生体力学的手法を用いて研究を行ってきた．その結果，下肢アライメントとしての膝内反変形および歩行時のthrust現象は膝関節の内側荷重を増加させることを実験的にも明らかにしている[22,23]．これらの点から内側型膝OAの発症・進行の機械的因子として膝内反変形およびthrust現象は極めて重要であり，さらに詳細な検討が必要と考えられる．今後，縦断調査の詳細な解析を行い各因子と膝OAとの因果関係を明らかにすることで危険因子を確定し，内側型膝OAの発症・進行予防法の確立を目指すことが課題とされる．

松代膝検診の解析検討に際し，以下の諸氏の多大なる協力に深謝する．古賀良生（新潟こばり病院整形外科），渡辺博史，蔦本武史，菅原治美，浜田政晴（新潟こばり病院リハビリテーション部），田中正栄，西野勝敏（新潟県スポーツ医科学センター），遠藤和男，粟生田博子（新潟医療福祉大学），速水正，日向野行正（新潟大学医学部整形外科）．

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変形性膝関節症の治療適応の選択の考え方―ADLとQOLへの影響を踏まえて―*

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池田 浩

はじめに

わが国は急速に高齢化社会へと向かっており，10数年後には4人に1人が老人（65歳以上）になると予測されている．高齢化に比例して，加齢に伴う骨関節疾患も増加し，中・高年者のADLやQOLを低下させる1つの大きな要因となっている．その主たるものが変形性関節症およびその類似疾患であり，最も多いのが変形性膝関節症（膝OA）で，患者数は1000万人以上と推測されている．

膝OAの治療は，1）非ステロイド性消炎鎮痛薬（NSAID）などの薬物療法，2）温熱，電気などの物理療法，3）筋力訓練などの運動療法[1-14]，4）足底板[15,16]などの装具療法からなる保存的治療と，関節鏡視下手術[17-20]骨切り術や人工関節置換術などの外科的治療とに大別される．しかし，外科的治療が必要となるケースはごく一部であり，大部分は保存的治療の対象となる．主症状である疼痛のコントロールにはNSAIDが用いられることが多いが，対象の多くは高齢者でありNSAIDでは副作用が懸念され，より安全な治療法が望まれる．一方，運動療法は，home exerciseとして一人で安全に行えるほか，医療費を含め経済的など多くのメリットが挙げられる．

今回，ADLやQOLへの影響を踏まえた膝OAの治療法選択に対する考え方について解説する．

膝OAの治療

治療法は，保存的治療と外科的治療とに大別さ

* 本稿は第44回日本リハビリテーション医学会学術集会シンポジウム「骨関節疾患リハビリテーションの実学（運動器の10年）―変形性膝関節症のリハビリテーション実学―」の講演をまとめたものである．

Original article

High tibial osteotomy using two threaded pins and figure-of-eight wiring fixation for medial knee osteoarthritis: 14 to 24 years follow-up results

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Abstract

Background. High tibial osteotomy (HTO) is an established surgical treatment for medial knee osteoarthritis (OA). Several studies have reported the deterioration of clinical results with time, especially after more than 10 years. The purpose of this study was to evaluate the long-term results after HTO using our originally developed fixation method and to clarify the factors affecting the long-term clinical outcome.

Methods. Sixty-eight HTO treatments in 55 patients were evaluated. Eighteen patients were unable to be analyzed, thus reducing the study to 48 knees in 37 patients. The follow-up rate of the knee joint was 70.6% and the mean follow-up period was 17.1 years. The first evaluation was performed at a mean of 6.5 years postoperatively, and the most recent evaluation was done at more than 10 years postoperative follow-up. A closing-wedge osteotomy was performed, and the osteotomy site was fixed with two threaded pins and a figure-of-eight wiring technique. The Japanese Orthopaedic Association knee rating score (JOA score) was used for the clinical assessment. The change of the femorotibial angle (FTA) and progression of knee OA were radiographically analyzed. The whole knees were subsequently divided into two groups, satisfactory group and unsatisfactory group, according to the JOA score at the most recent follow-up.

Results. The mean JOA score was 59.1 before HTO and 83.1 at the most recent evaluation. In comparing the satisfactory and unsatisfactory groups, the JOA score before HTO was the same, but the JOA score of the unsatisfactory group was significantly lower at the first evaluation. The FTA in the unsatisfactory group was the same as in the satisfactory group preoperatively, but it was significantly larger after HTO. The radiographic OA was significantly progressed at the most recent evaluation, but no difference was observed in the distribution of the preoperative OA grade between the two groups.

Conclusions. HTO with two threaded pins and figure-of-eight wiring fixation showed an acceptable clinical outcome, but careful attention was needed for correction loss in early postoperative periods. In addition, the proper correction angle is necessary in order to achieve satisfactory long-term results.

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Introduction

Osteoarthritis (OA) is the most common form of degeneration of the joints. The knee joint is the key structure in the lower extremity and has much influence on the activity of daily life (ADL) and the quality of life (QOL) in elderly persons. These include standing, walking, running, jumping, stair climbing, deep knee bending such as squatting or Japanese-style sitting, and other lower extremity tasks. Approximately 10% to 15% of people aged 60 years and older have symptomatic knee OA.[1] Therefore, knee OA is a major source of chronic disability and is becoming a serious public health problem.

High tibial osteotomy (HTO) is one of the successful surgical treatments for medial compartment knee OA. HTO was first described by Jackson and Waugh,[2] and it is now widely accepted as an attractive procedure with good pain relief and preservation of knee function. Previous studies of early to midterm results of HTO have shown excellent outcomes in more than 80% of cases.[3-5] However, several studies with long-term follow-up reported that the results of HTO deteriorated with time, especially after more than 10 years. Several factors have been identified as affecting the results of HTO, but they remain controversial. These include sex, age at surgery, body weight, preoperative severity of knee OA, method of osteotomy and fixation, correction angle, amount of preoperative adduction moment, and postoperative period.[6-14]

Among these factors, the type of fixation following osteotomy remains important, and, in the past, the following methods have been reported: bone staples, blade plate with screws, one third tubular plate with a cortical screw (tension bend principle), L-buttress plate, and external fixator.[3,15-20] We developed a fixation method using two threaded pins and figure-of-eight wire and used this method for our consecutive HTO cases.

The purpose of this retrospective study was to assess the long-term results after HTO using our fixation method and to clarify the factors affecting the long-term clinical outcome.

Subjects and methods

Our indications for HTO were basically as follows: (1) degenerative change was mainly located in medial compartment (medial knee osteoarthritis), (2) normal or mild degeneration in lateral and patello-femoral compartment, (3) patient was younger than 70 years old and had relatively high activity in ADL, and (4) good range of motion and no remarkable knee joint instability. Between 1980 and 1990, HTO was performed in 68 consecutive knees in 55 cases by our senior surgeon (Y. K.). Seven patients died, 6 patients were unable to be evaluated due to the presence of other severe medical illnesses, and 2 patients were lost to follow-up. Three knees in 3 patients were converted to total knee arthroplasty (TKA) at 10 years, 12 years, and 15 years after HTO, respectively. Therefore, the remaining 48 knees in 37 cases were available for the present study, and the follow-up rate of the knee joint was 70.6%. There were 43 knees in 33 women and 5 knees in 4 men. The mean age at HTO was 59 years with a range from 40 to 69 years. The mean follow-up period was 17.1 years, but individual follow-up ranged from 14 to 24 years. The preoperative diagnosis was medial compartment knee OA in all the cases, and the preoperative Kellgren-Lawrence classification[21] showed grade II in 8 knees, grade III in 35 knees, and grade IV in 5 knees. All of the patients were evaluated initially in 1993, with a mean follow-up of 6.5 years, and evaluated at more than 10 years follow-up postoperatively. All of the patients were fully informed about the procedures and gave their informed consent.

Operative procedures and postoperative regimen

In all knees, the closing-wedge interlocking osteotomy through a lateral approach was performed according to the technique described by Ogata.[22] The correction angle was preoperatively determined to allow the mechanical axis, which is the line connecting the center of the femoral head and the ankle joint, to pass through the midpoint of the lateral compartment. The preoperative planning was performed using non-weight-bearing supine radiograph of the whole lower extremity according to Ogata et al.[23] Ogata mentioned that the relative angle of the articular surface (condylar-plateau angle) in the weight-bearing knee changed after osteotomy, and this might give unpredictable results postoperatively. He also found that the condylar-plateau angle in the postoperative standing radiograph was very similar to that seen in the non-weight-bearing supine condition, and recommended that a non-weight-bearing supine radiograph was better for preoperative planning. The femorotibial angle (FTA) that met this condition was around 165° to 168° in the majority of cases. The fibula was resected at the mid portion of the shaft. The osteotomy site was fixed with two threaded pins and a figure-of-eight wiring technique. First, two threaded pins, 2.4 or 3.0 mm in diameter, were inserted from distal and lateral of the osteotomy site to the medial corner of the proximal tibia passing through the medial half of the osteotomy line. Next, figure-of-eight wiring, 0.8 to 1.0 mm in diameter, was placed between the distal end of the pins and lateral wall of the proximal tibia. After the osteotomy site was fixed, leg alignment was checked by X-ray and cancellous bone fragments harvested from the resected bone wedge were grafted to the osteotomy site (Fig. 1). Postoperatively, the knee joint was immobilized with a cast for 6 weeks. Range-of-motion exercise was started after the cast was removed. Partial weight bearing was started 4 weeks after HTO and full weight bearing was allowed at 8 to 10 weeks postoperatively.

Clinical evaluation

All of the patients were directly interviewed and examined. The clinical result was evaluated using the Japanese Orthopedic Association knee rating score (JOA score).[24] The JOA score consisted of four categories and 100 points as full marks: pain and walking (30 points), pain and ascending or descending stairs (25 points), range of motion (35 points), and joint effusion (10 points). In this study, the preoperative JOA score was compared with the JOA score at the first evaluation in 1993 and at the most recent follow-up. Subsequently, the results of the JOA score were classified as excellent if the most recent score was 91 to 100, good if 81 to 90, fair if 71 to 80, and poor if the most recent score was less than 70 points. Furthermore, all knee joints were divided into two subgroups according to the result of the most recent follow-up. The patients who were classified as excellent and good were referred to as the satisfactory group, and the patients who were classified as fair and poor were referred to as the unsatisfactory

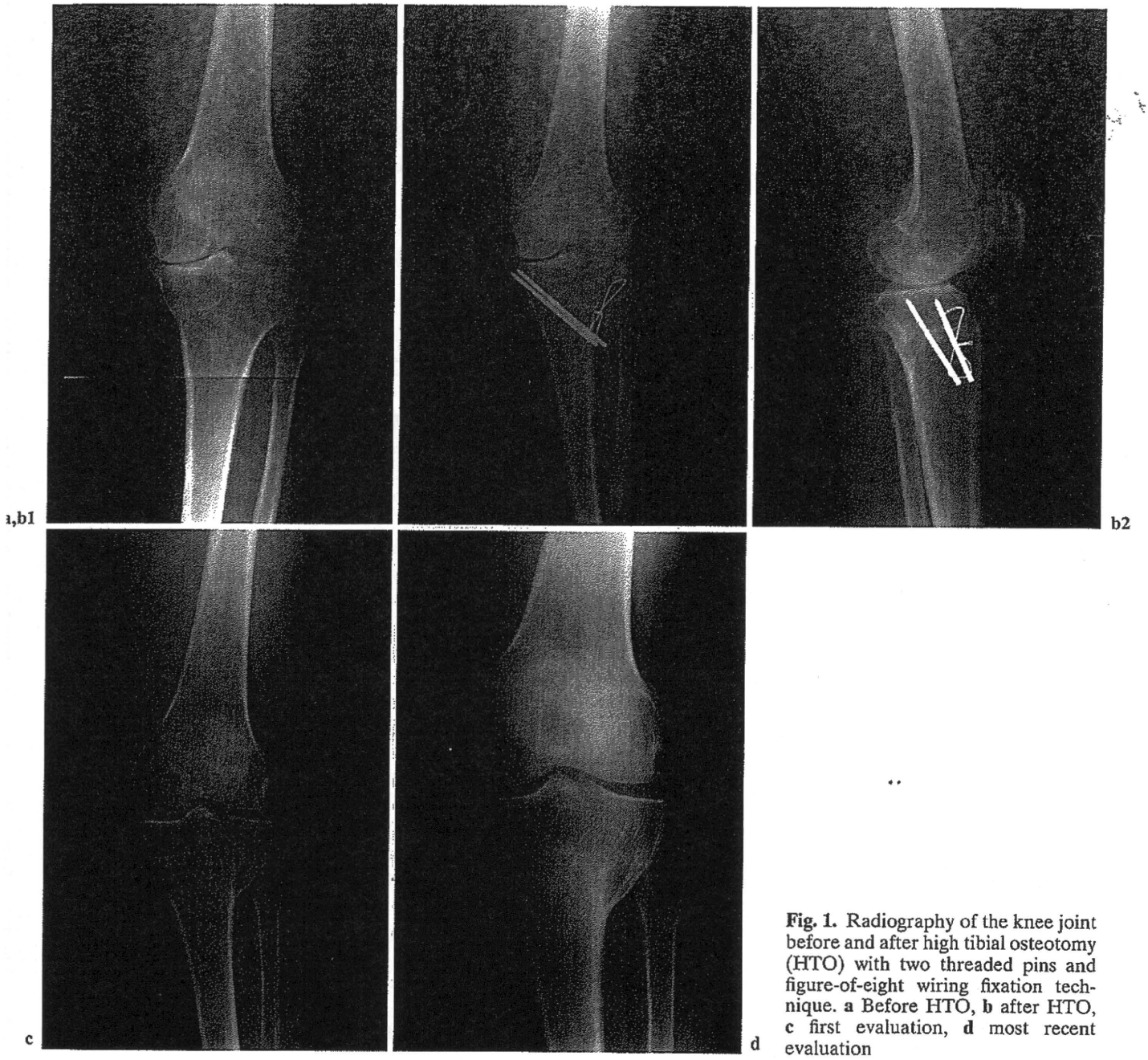

Fig. 1. Radiography of the knee joint before and after high tibial osteotomy (HTO) with two threaded pins and figure-of-eight wiring fixation technique. **a** Before HTO, **b** after HTO, **c** first evaluation, **d** most recent evaluation

group. Thirty-seven knees in 22 patients (1 male, 21 female) were included in the satisfactory group, with an average age at surgery of 57.9 ± 5.0 years and average follow-up period of 14.0 ± 2.9 years. On the other hand, 11 knees in 10 patients (3 male, 7 female) were included in the unsatisfactory group, with an average age at surgery of 60.1 ± 8.7 years and average follow-up period of 14.3 ± 3.1 years. No statistical difference was observed in the demographic data between the two groups.

Radiographic evaluation

The change of FTA and the grades of knee OA according to the Kellgren-Lawrence classification were analyzed with a standing whole-leg X-ray taken before surgery, at 1 to 3 weeks after HTO, and at each follow-up point.

Statistical analysis

The obtained data were expressed as the mean values ± standard deviation (SD). The relationships of analyzed parameters were determined using the paired *t*-test and the Wilcoxon signed rank test. In all analyses, a *P* value of less than 0.05 was considered to be significant.

Results

Clinical results

The mean JOA score of all patients improved significantly from 59.1 ± 7.6 before HTO to 86.3 ± 6.5 at the first evaluation (Table 1). At the most recent follow-up, the JOA score had slightly declined to 83.1 ± 9.3 but this change was not significant. In each category of JOA scores in all patients, the pain and walking score improved from 14.5 ± 5.2 before HTO to 26.6 ± 5.6 at the most recent evaluation, the pain and stairs score from 12.7 ± 6.6 to 20.2 ± 4.9, the score for range of motion from 25.6 ± 4.8 to 27.8 ± 4.6, and the score for joint effusion from 6.3 ± 5.7 to 8.5 ± 4.3. The mean range of motion was 9.3° ± 8.0° fixed flexion to 133.0° ± 18.1° of flexion before HTO, and 2.6° ± 4.3° to 132.5° ± 16.2° of flexion at the most recent evaluation. In comparing the satisfactory group and the unsatisfactory group, the mean JOA score was similar before HTO, but at the first and the most recent evaluation, the JOA score of the unsatisfactory group was significantly lower than that of the satisfactory group. Furthermore, in the unsatisfactory group, the JOA score had significantly declined from first evaluation to the most recent follow-up (Table 1). In the current study, there were two postoperative complications. One patient had peroneal nerve palsy and spontaneously recovered in 3 months after surgery. Another patient had delayed union and autologous iliac bone graft was performed. Final bone union was obtained at 7 months after HTO. These complications did not affect the clinical results.

Radiographic results

The mean FTA of all patients was corrected from 185.4° ± 4.4° before HTO to 168.2° ± 2.9° postoperatively, and this alignment was maintained at the most recent evaluation. In the satisfactory group, the change of FTA was almost same as the results of all patients. In contrast, the FTA of the unsatisfactory group changed from 185.3° ± 2.1° preoperatively to 170.2° ± 2.3° after HTO, and gradually increased at first evaluation and increased even more at the most recent follow-up. The FTA of the unsatisfactory group was the same as the satisfactory group preoperatively, but was significantly larger at each time of postoperative evaluation (Table 2). Seven of the unsatisfactory group (63.6%) had an FTA larger than 168° (170°: 3 cases, 172°: 3 cases, 173°: 1 case). The radiographic OA of all patients before HTO were classified as follows: 8 knees as Grade II, 35 knees as Grade III, and 5 knees as Grade IV. At the most recent evaluation, the distributions were 1 knee as Grade II, 18 knees as Grade III, and 29 knees as Grade IV. The number of Grade IV OA at the latest evaluation was significantly greater than that of before HTO (Table 3). In comparing the satisfactory group and the unsatisfactory group, no statistical difference was observed in the distribution of preoperative radiographic OA grade (Table 4). At the latest evaluation, the distributions of OA in the satisfactory group were 1 knee in Grade II, 18 knees in Grade III, and 18 knees in Grade IV. On the other hand, in unsatisfactory group, all knees were classified as Grade IV OA.

Table 1. Japanese Orthopaedic Association (JOA) score before high tibial osteotomy (HTO), at the first evaluation, and at the latest evaluation

Classification	Number of knees	JOA score		
		Before HTO	First evaluation[a]	Latest evaluation[b]
All Patients	48	59.1 ± 7.6	86.3 ± 6.5	83.1 ± 9.3
			**	
Satisfactory group	37	59.1 ± 9.1	90.0 ± 5.4	87.3 ± 4.3
			**	* **
Unsatisfactory group	11	59.1 ± 5.8	82.2 ± 7.2	69.1 ± 5.8
			**	*

Data given as mean ± standard deviation
* $P < 0.05$; ** $P < 0.01$
[a] Mean follow-up 6.5 years
[b] Mean follow-up 17.1 years