

To Run or Not to Run: A Post-Meniscectomy Qualitative Risk Analysis Model for Osteoarthritis When Considering a Return to Recreational Running

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Abstract: The increased likelihood of osteoarthritic change in the tibiofemoral joint following meniscectomy is well documented. This awareness often leads medical practitioners to advise patients previously engaged in recreational running who have undergone meniscectomy to cease all recreational running. This literature review examines the following questions: 1) Is there evidence to demonstrate that runners, post-meniscectomy, incur a great enough risk for early degenerative OA to cease all running? 2) Does the literature yield risk factors for early OA that would guide a physical therapist with regard to advising the post-meniscectomy patient contemplating a return to recreational running? Current literature related to meniscal structure and function, etiology and definition of osteoarthritis, methods for assessing osteoarthritis, relationship between running and osteoarthritis, and relationship between meniscectomy and osteoarthritis are reviewed. This review finds that while the probability for early osteoarthritis in the post-meniscectomy population is substantial, it is a probability and not a certainty. To help guide a physical therapist with regard to advising the patient for a safe return to running following a meniscectomy, a qualitative risk assessment based on identified risk factors for osteoarthritis in both the running and the post-meniscectomy populations is proposed.

Key Words: Recreational Running, Meniscectomy, Tibiofemoral Osteoarthritis, Qualitative Risk Analysis

Recreational running, meniscectomy, and knee osteoarthritis (OA) meet at a busy intersection. Which has the right of way? Running is a very popular sports activity. There are an estimated 15 to 35 million active recreational runners in the United States^{1,2}. Meniscal injury is common in the general population with an estimated frequency of 61 per 100,000³, and meniscectomy is one of the most commonly performed arthroscopic procedures^{4,5}. The American Academy of Orthopedic Surgeons has estimated that 850,000 meniscectomies are performed yearly³.

The knee is, arguably, the most frequent site of injury among runners. Van Mechelen⁶ reviewed the literature on

the epidemiology of injuries among recreational runners, examining studies involving more than 500 subjects. The yearly incidence for all running-related injuries was between 37% and 56%; 25% of these injuries were related to the knee. Taunton et al⁷ conducted a retrospective case control analysis of injuries in 926 male and 1076 female runners with a mean age of 36 years. Knee pain was the most common complaint, present in 42.1% of the study population. Koplan et al⁸ followed 326 male and 209 female runners for 10 years. Knee injury was the most common injury with 32% of males and 28% of females reporting at least one knee injury over the 10-year period.

Individual commitment to running varies but as a group, runners may be dedicated seemingly beyond logic to their sport. A “fully committed runner,” as Lutter¹⁰ remarked, will “follow treatment for any problem, provided it does not have as its goal cessation of running,” making them a difficult group to treat successfully⁹⁻¹¹. However, runners who suffer injuries resulting in meniscectomy are commonly advised to

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limit or stop running by health care providers due to the potential risk of subsequent degenerative knee OA¹¹. These recommendations are generally based on the current understanding of the load-bearing and force-distribution functions of the meniscus¹²⁻¹⁷ and the assumption that repetitive loading of the meniscectomized knee with running may predispose the patient to early osteoarthritic degeneration.

This literature review examines the following questions:

- Is there evidence to demonstrate that runners, post-meniscectomy, incur a great enough risk for early degenerative OA to cease all running?
- Does the literature yield risk factors for early OA that would guide a physical therapist with regard to advising the post-meniscectomy patient contemplating a return to recreational running?

Methods

To assist in answering these questions, this paper will review current research on:

- Key features of meniscal structure and function in load bearing, force distribution, and knee joint stability.
- The etiology of OA, problems related to its definition, and risk factors in the general population.
- Methods for assessing presence of OA, measurement tools for determining post-meniscectomy outcomes, and the reliability of these instruments.
- The relationship between running and OA.
- The relationship between meniscectomy and post-surgical outcome.

It is beyond the scope of this paper to exhaustively review the structure and function of the meniscus and articular cartilage. The inter-relationship between the meniscus, articular cartilage, and underlying bone remains an evolving and ongoing area of study with detailed information readily available elsewhere in the literature. However, a review of the meniscus's role in load bearing, load and force distribution, joint stability, and proprioception^{3,12-20} should assist the reader in understanding from a pathophysiologic perspective the possible relationships between meniscectomy, running, and OA. Likewise, the etiology and definition of OA, recognized risk factors, methods of assessment, and outcome measures are summarily reviewed to assist the reader in both understanding the relevant research discussed here and to underscore the difficulty in systematically analyzing the literature.

The author searched the electronic databases PubMed, Ovid, MD Consult, and EBSCO Host for post-meniscectomy outcome studies. The search was limited to human English-language studies conducted between 1990 and 2006. Earlier

research, seminal to the investigation of tibiofemoral osteoarthritis, has also been included.

Meniscus Structure and Function

The menisci are asymmetric fibrocartilaginous structures located on the tibial plateau. The meniscus is thick peripherally where it attaches to the joint capsule and tapers to a thin, freely mobile edge centrally^{19,21}. This triangular or wedge cross-section deepens the tibial articular fossa; enhances load-bearing, force distribution, and joint stability functions; and influences the stress and strain on the meniscus during function^{12,21,22}. The cross-sectional wedge shape of the anterior horns resists posterior translation of the tibia; similarly, the posterior horns resist anterior tibial translation³. Studies by Jorgensen et al²⁰ on 101 post-total meniscectomy subjects and by Hede et al²³ on 173 subjects, both post-partial and post-total meniscectomy, found some degree of either anteroposterior or mediolateral instability. However, it should be noted that neither study clearly delineated the degree of instability that was present.

Because the menisci also increase the contact area for the femoral condyles, they help decrease focal contact pressure on articular cartilage^{3,12,13}. Following meniscectomy, articular surface contact pressures increase significantly¹²⁻¹⁷. How this affects load transmission on subchondral structures is less well understood. McKinley et al²⁴ measured *in vitro* changes in tensile, compressive, and shear forces on trabecular bone, with the meniscus intact and following partial and total meniscectomy. Following partial meniscectomy, no significant differences were noted in load transfer through to trabecular bone. In contrast, total meniscectomy caused significant changes in all three types of forces, measured at all levels of the trabecular bone.

Knowledge of the meniscus's collagen arrangement is also important in understanding the potential relationship between meniscectomy and OA. Meniscal collagen is arranged circumferentially and is bound together by oblique and radial fibers, an arrangement conducive to resisting tensile forces^{18,25}. Tensile loads occur when axial forces are transmitted onto the meniscus from the femur. These loads are generally perpendicular, but they also have radial components^{3,18,26}. The radial component of this load extrudes the meniscus peripherally²⁷. This tensile or extrusive stress, known as "hoop" stress, is resisted in part by the tensile stiffness of the circumferential collagen bundles, which helps to dissipate the axial forces within the meniscus, thereby decreasing the load on the underlying cartilage surfaces.

Load transmission is also influenced by osteokinematic relationships. Genu valgum increases compressive forces on the lateral femoral condyle and lateral tibial plateau whereas genu varum increases compressive stress on the medial tib-

ial plateau and medial femoral condyle²¹. The influence of lower extremity alignment on the progression of OA, predisposition to injury in runners, and outcome following meniscectomy has been addressed in the literature. Ahlback²⁸ found increased prevalence of weight-bearing varus deformity with medial compartment degeneration and increased prevalence of weight-bearing valgus deformity with lateral compartment degeneration. Of course, such correlational findings do not indicate which factor is the cause and which the effect. Van Mechelen⁶ found studies that assessed the relationship between lower extremity malalignment and running injury to be “scarce and contradicting.” Studies relating meniscectomy to OA have assessed varus/valgus alignment via radiograph^{29,30}, observation or clinical measurement³¹⁻³⁶, pre- or post-surgically, or not at all³⁷⁻⁴⁰. Of note is the fact that definition of alignment has not been consistent across studies. Rockborn and Gillquist^{31,32} described a knee as “varus if the inter-condylar space exceeded the inter-malleolar space and vice versa in valgus knees.” Maletius and Messner³³ measured the angle formed by the anterior superior iliac spine, center of the patella, and the midpoint between the “epicondyles” of the ankle. Angles $>$ or $<$ 4° were defined as “varus” or “valgus,” respectively. Maletius and Messner found varus alignment to be a significant risk factor for medial compartment degenerative change and valgus alignment to be a significant risk factor for lateral compartment degenerative change following partial meniscectomy. In contrast, four other studies^{31,34-36} found no significant correlation between post-surgical alignment and outcome.

While meniscectomy clearly alters the biomechanics of the knee joint, it should be noted that degenerative changes in articular cartilage cannot be attributed solely to these biomechanical changes. The literature supports the paradigm that degenerative knee OA has a complex and not fully known etiology⁴¹⁻⁴⁶. Likewise, a specific definition of OA remains elusive^{22,41,42,46-48}. While biomechanical changes due to meniscectomy play a significant role, age-related tissue changes^{41,42}, trauma or wear and tear^{2,41,42,46,47,49-53}, gender^{41,44,54,55}, individual genetic predisposition for developing OA^{41,52,56,57}, and obesity⁵⁸⁻⁶² may also play a significant role.

Further complicating matters is the fact that cartilage degeneration is a salient, but not the sole, component of OA. McKinley et al²⁴ described OA as a “failure of the entire osteochondral structure.” The most recent literature^{22,41,43} has described OA as a clinical “syndrome” as opposed to a disease with a single unique characteristic. Because a broad range of characteristics defines this syndrome, comparison between studies investigating OA is challenging. However, it is generally agreed upon that progressive loss of articular cartilage, formation of osteophytes, subchondral cysts and sclerosis, joint space narrowing, and crepitus are indicators of degenerative OA^{2,22,26,28,41,43,63,66}. It is also increasingly recognized that by the time OA is visualized radiographically, significant damage may have already occurred^{22,60}.

Methods for Assessing the Presence of Knee OA

Clinical recommendations to runners related to returning to their sport are based in part on the clinician’s assessment of pre- and post-surgical radiological or magnetic resonance imaging (MRI) findings, arthroscopic data, and clinical findings indicative of OA. Research looking at incidence, prevalence, and disease progression of OA in the general population and post-meniscectomy has also used these outcome measures. However, these outcome measures are anything but standardized, validated, and consistently used across studies. This variation explains the difficulty in systematically assessing the retrieved outcome studies on meniscectomy and OA that use these varied diagnostic criteria to determine the presence of OA.

Radiographic Assessment

The most frequently reported criterion for OA is radiographic assessment^{22,28}. Standards for patient position, angle of images, and interpretation of radiographic images vary across the literature. However, there are several standards that appear most frequently in said literature. Three studies^{26,28,64} established the criteria most frequently cited in the literature when interpreting outcomes relative to risk factors for OA. Two studies^{2,65} that investigated the relationship between running and knee OA used criteria developed by Altman et al⁶⁷. Table 1 summarizes the key criteria established by these studies to interpret radiographs. Knowledge of these criteria is helpful in understanding the subsequent sections of this review related to meniscectomy and OA, and running and OA.

As evident from Table 1, each set of radiographic diagnostic criteria uses weight-bearing films, looks for evidence of joint space narrowing, and—with the exception of the criteria proposed by Fairbanks²⁶—assesses for the presence or absence of osteophytes and sclerosis. Beyond these similarities, there are considerable differences in the grading scales used. Nineteen of the studies^{2,29-40,65,78,80-82,84} investigating the relationship between either running and OA or meniscectomy and OA, as reviewed for this paper, used radiographs. Within these 19 studies, no less than 10 different rating scales or protocols were used. This variety of assessment criteria for determining the presence of knee OA compounds the difficulty in interpreting post-meniscectomy outcome studies.

Arthroscopic Assessment

Arthroscopic findings, including assessment of surface appearance, softness, lesion depth, diameter, and location, have also been used to identify and classify knee joint osteoarthri-

TABLE 1. Criteria for Assessing Presence of Knee OA in Radiographs

Source	Findings/Observations
Fairbanks ²⁶	<ul style="list-style-type: none"> Views utilized: Anterior-posterior; weight-bearing in full extension Assessed for presence/absence of: joint space narrowing, ridge formation at meniscal margin, generalized flattening of femoral condyle Not graded
Kellgren and Lawrence ⁶⁴	<ul style="list-style-type: none"> Views utilized: Anterior-posterior weight-bearing Assessed for presence/absence of: joint space narrowing, osteophytes, sclerosis, subchondral cysts, altered bone end shape Grades: 0 = absence of changes, 1 = doubtful presence, 2 = minimal/definitely present, 3 = moderate, 4 = severe
Ahlback ²²	<ul style="list-style-type: none"> Views utilized: Anterior-posterior (AP) weight-bearing and non-weight-bearing; lateral with knee at 45° and axial with knee at 20° Assessed for presence/absence of: joint space narrowing, osteophytes, sclerosis, cysts, articular surface attrition Not graded
Altman et al ⁶⁷	<ul style="list-style-type: none"> Views utilized: Anterior-posterior (AP) weight-bearing Assessed for presence/absence of: joint space narrowing, spurs, sclerosis Not graded

tis^{47,68-72}. The Outerbridge Scale⁷³ (Table 2), which was originally used in research of articular cartilage lesions in chondromalacia patellae, has also been used to describe arthroscopic findings related to tibiofemoral OA^{31-33,35,61}. Several authors have examined the diagnostic or prognostic accuracy of arthroscopy with regard to OA⁶⁸⁻⁷². However, the findings have been mixed.

Noyes and Stabler⁷¹ reviewed the Outerbridge Scale and other published classification systems for articular cartilage lesions. They described inconsistencies between systems regarding description and recording of surface appearance, surface quality, and depth of lesions. Hjelle et al⁴⁸ reviewed articular cartilage defects in 1,000 knee arthroscopies. The authors found that lesion classification was “highly subjective,” and they were unable to correlate the grade or stage of cartilage lesions with duration of injury, etiology, or symptoms. Brismar et al⁷⁰ compared inter- and intrarater reliability between four orthopaedic surgeons during 19 arthroscopies. The authors found significantly higher interrater agreement in knees with either normal cartilage or severe OA changes. However, intermediate cartilage changes showed poorer inter- and intrarater reliability. In contrast, in a study of 63 patients, Lysholm et al⁷² found arthroscopy to be a valuable tool for diagnosis of early OA of the knee. They noted that 58% of the patients who showed grade II Outerbridge findings at arthroscopy showed no radiographic evidence of OA. Relevant

to this review paper, this suggests that outcome studies that rely solely on radiographs to determine the presence of OA following meniscectomy may miss a large proportion of subjects with degenerative changes.

Magnetic Resonance Imaging

MRI is not widely used as an outcome measure for studies on meniscectomy and OA. Brittberg and Winalski⁶⁸ noted that there is no universally accepted classification system to interpret articular cartilage lesions found using MRI. Most grading systems have used a variation of the Outerbridge arthroscopic classification system. Two studies^{75,76} showed that Outerbridge grade I lesions (i.e., articular cartilage softening) were not reliably detected with MRI. The authors noted, however, that MRI could directly image subchondral bone and bone marrow, which could not be done arthroscopically. The ability to identify these changes makes MRI a useful evaluative tool for determining the osseous extent of articular lesions. MRI has been used in two clinical studies assessing various risk factors for OA^{49,74}.

This review of current methods for assessing cartilage lesions points toward inconsistencies among scales, limited agreement between methods, and limited prognostic value of the diagnostic tests used with regard to patient out-

TABLE 2. Outerbridge Scale⁷³ for Assessing Arthroscopic Knee Findings

Findings/Observations
Grade 1: Softening and swelling of cartilage
Grade 2: Fragmentation and fissuring $\leq 1/2''$
Grade 3: Fragmentation and fissuring $> 1/2''$
Grade 4: Erosion to subchondral bone

comes^{42,69-72}. To assist a runner in the decision regarding return to sport, it may be most informative to interpret the information obtained from arthroscopy in conjunction with information from radiographs and/or MRI. Data from arthroscopy, radiographs, and MRI used in isolation may be problematic when used to assess for the presence of early or intermediate OA, which would seem to be the stage in the syndrome when the patient may be most interested in the clinician's recommendation.

Clinical Examination

Protocols for clinical examination are again not consistent throughout the literature. Perhaps surprisingly, outcome determination in some retrospective longitudinal post-menisectomy studies^{35,37-39} and some investigations of the correlation between running and OA⁷⁷⁻⁸⁰ have not included a clinical examination at all. Some studies^{2,30,65,81} have reported using a clinical exam but they failed to specify what constituted the examination. For example, Chatain et al⁴⁰ reported using a clinical exam but described information gathered only from clinically administered questionnaires. When clinical examination was included, diverse criteria may have been assessed: palpation, joint stability, range of motion, presence/absence of swelling, presence/absence of crepitus on active or passive movement, McMurray test, strength assessment via single leg balance, tibiofemoral alignment, patellar mobility, body height, weight, and thigh girth^{29,31-34,36,82,84}. Among the studies investigating post-menisectomy OA or running and OA, little consistency was found as to what specifically constituted the clinical examination that was used.

Correlation Between Assessment Criteria

Post-menisectomy studies that measured outcomes based on patient function and/or activity level and radiographic findings^{29,31,33,34} were unable to correlate clinical and radiographic outcomes. Selected literature discussing knee injury and OA^{47,83} found attempts to correlate clinical and arthroscopic findings to be unreliable. Kujala et al⁸⁴ did find a significant correlation between radiographic OA and patient

reports of knee pain, loss of knee extension, and knee instability in a cohort of former athletes (including, but not limited to, former long distance runners). Correlations between radiographic and arthroscopic findings also remain problematic with inconsistencies in identifying osteochondral lesions^{49,75}. The lack of correlation between clinical, radiographic, and arthroscopic outcome measures makes it difficult to assess both the implications of articular cartilage degeneration^{46-48,68} and the true frequency of degenerative changes^{49,75}. This is yet another factor making for a difficult prognosis for a return to running following meniscectomy.

Relationship Between Running and OA

Before looking into the effect of meniscectomy on OA incidence, it is obviously important to understand whether running is itself a risk factor for OA. A number of studies have examined the relationship between running and knee OA^{2,65,74,77,78,80,82,84}. Typically these studies have assessed the increased likelihood of OA in runners with no reported history of knee injury or surgery. Several studies^{2,65,78,82,84} have also attempted to determine risk factors associated with development of knee OA in runners.

Lane et al² assessed the effects of aging and running on the development of OA in a 5-year prospective longitudinal study. This study paired 33 male and female runners, aged 50–73, with matched non-running controls. All subjects underwent clinical and radiographic examination initially and at 5 years. Risk factors examined included age, weight, running minutes per week, exercise minutes per week, and gender. The authors found no significant difference, assessed clinically or by radiograph, in the rate of OA progression between runners and matched controls. The best predictor of arthritic advancement at the 5-year mark, for both runners and controls, was the degree of arthritic change present on initial radiographs.

Four years later, Lane et al⁶⁵ re-examined 28 runners and 27 matched controls from the previous study² for clinical or radiographic progression of OA at the 9-year mark. The best predictors of final radiographic results, for all subjects, were the initial radiograph, body mass index, and female gender. The best predictors of OA progression, for runners, were initial radiograph findings and faster pace per mile. At 9 years, the authors concluded that a comparison of radiographs showed no significant difference in the progression of OA between the runner and non-runner groups.

Konradsen et al⁸² compared 30 male runners who had been active at a competitive level with a group of matched controls. Weekly mileage, over at least four decades, averaged 21–42 kilometers per week. Pain at rest and during weight-bearing activities, range of motion, and joint alignment were assessed. Weight-bearing anterior to posterior (AP) and lateral radiographs were assessed for changes according to the Ahlback scale²⁸ (Table 1). No significant difference in radio-

graphic findings was found with regard to degenerative changes or osteophytes. The authors concluded that 40 years of running at 20–40 kilometers per week did not lead to osteoarthritic degeneration in individuals without underlying problems from pre-existing lower extremity injury.

Sohn and Micheli⁷⁷ surveyed 504 male and female college varsity cross-country runners and used 287 college swimmers as controls. Data regarding knee pain or alterations in daily activities due to pain was taken as indicative of OA. No significant difference was found between runners and swimmers.

Kujala, Kaprio, and Sarna⁷⁹ studied the incidence of hospital admission for OA of the hip, knee, and ankle in 1282 elite male athletes as compared to 777 matched controls. In the group of long-distance runners, 2.5% were admitted for knee arthritis as opposed to 1.3% of the general population. Long-distance runners were 1.84 times more likely to be admitted for OA (of the hip, knee, or ankle) than controls. The study did not report on hospital admissions for knee arthritis separately. It should also be noted that the average age at hospital admission for distance runners was 71.3 versus 61.2 years of age for the control group. When groups were controlled for body mass index (BMI), subjects with a higher BMI at age 20 and at the time of the study were 2.12 to 2.41 times more likely to be admitted to the hospital.

Kujala, Kettunen, Paananen, et al⁸⁴ investigated the incidence of knee OA in 117 male former athletes, aged 45–69, including 28 long-distance runners. Risk factors assessed included BMI at age 20 and at the time of study, occupation, physical activity level, and ongoing participation in sports. Patients were examined clinically for joint stability and range-of-motion loss in extension. Radiographs were assessed according to the criteria developed by Kellgren and Lawrence⁶⁴ for changes at either the tibiofemoral or patellofemoral joints. Using multivariate analysis, the authors did not find long-distance running to be a significant risk factor for early knee OA. They did, however, find that elevated BMI and previous knee injury were associated with increased risk for early knee OA.

Hohmann et al⁷⁴ used MRI to assess the hips and knees of eight male runners immediately before and after a marathon. One subject had undergone an ACL reconstruction 18 months previously. Post-race scans showed no significant difference in marrow edema or periosteal stress when compared to pre-race scans, suggesting that long-distance running did not damage articular or subchondral structures.

While not without disagreement, the literature does not point to running, in and of itself, on healthy knees as a significant risk factor for OA. Rather, pre-existing OA, high BMI, and female gender is correlated with a higher risk for degenerative changes^{2,65,79,80,84}.

Relationship between Meniscectomy and Post-Surgical Outcome Measures

Using the literature search strategy as described above, the author was not able to identify any research that specifically examined the three-sided relationship between meniscectomy, a return to running, and OA. Considering this absence of relevant research data, the author reviewed, in an attempt to answer the questions related to decision-making on a return to running post-meniscectomy, studies that examined post-meniscectomy outcomes for various populations, athletic and general. Although the search strategy used identified numerous post-meniscectomy studies, there were a limited number that focused specifically on athletic populations. Table 3 groups the studies as follows: 1) smaller sample size, longer-range follow-up, active population; 2) smaller sample size, short-term follow-up; 3) medium to large sample size, longer-term follow-up; 4) medium to large sample size, short-range follow-up. These studies were reviewed with the intent of identifying consistent risk factors, within the post-meniscectomy population, for post-surgical OA.

Current evidence suggests that meniscectomy may be, in itself, a strong risk factor for an increased rate of knee joint degeneration^{29-34,36,38-40}. It is also clear, however, in many cases, that an increased rate of degeneration following meniscectomy is not a certainty^{30,32,34,36,38-40,47,81}. What determines this spectrum of post-surgical outcomes?

As previously discussed, the mechanism(s) responsible for degenerative changes in the knee joint following meniscectomy are unclear⁴⁷. Studies have examined a host of biomechanical and histopathological risk factors or variables including changes in load distribution^{12-17,24,85-87}, changes in articular cartilage as a result of meniscectomy⁸⁸, and damage to articular cartilage or subchondral bone sustained at initial injury⁵¹.

Of greater importance to this review are risk factors that may be specific to particular patients, recognizable to the clinician, and perhaps even manageable or capable of being positively affected by appropriate physical therapy intervention. Risk factors of this nature, investigated by studies relating meniscectomy and OA, include:

- Condition of tibiofemoral cartilage at meniscectomy^{30-33,35,38-40,81}
- Age at meniscectomy^{30,32-34,37-40,81}
- Nature of the meniscal tear^{29,30,32,34,35,37-40,81}
- Quantity of meniscus resected^{29-32,36-38,40,81}
- BMI^{29,33,38,81}
- Gender^{29,30,33,37,38,40,81}
- Compartment of the knee joint that is affected^{30,31,33,38,81}
- Lower extremity alignment^{30,33,34,36}

TABLE 3. Retrospective Studies Assessing Relationship Between Meniscectomy and OA*

Small sample size, longer-range follow-up, active population			
Author/Title	Intervention	Outcome	Risk Factors
Rockborn & Gillquist. "Outcome of arthroscopic Meniscectomy". ³¹	<ul style="list-style-type: none"> • N=43 Athletic population • Age at surgery: ≤ 22 yrs • Follow-up: 11-15 years 	<ul style="list-style-type: none"> • Radiographic: 61% one or more Fairbanks changes; 18% Ahlback gr. 1 • Subjective: Lysholm mean 91.9; Tegner 77% ≥ level 5 • Clinical: No significant findings • Despite frequency of radiographic change, subjective outcome satisfactory. 	<ul style="list-style-type: none"> • Correlated to poor outcome: D • No correlation: A • Correlation not addressed: B, C, E, F, G, H
Rockborn & Gillquist. "Long-term results after meniscectomy: Role of preexisting cartilage fibrillation". ³²	<ul style="list-style-type: none"> • N=60 • Age at surgery: 20-40 yrs • Follow-up: 12-15 yrs 	<ul style="list-style-type: none"> • Radiographic: 62% one or more Fairbanks changes; 42% gr. 1-2 Ahlback change • Subjective: Lysholm 73% > 94, Tegner 71% ≥ level 5 • Clinical: No significant findings • Knee function minimally affected by meniscectomy 	<ul style="list-style-type: none"> • Correlated to poor outcome: B, D • No correlation: A, C • Correlation not addressed: E, F, G, H
Maletius et al. "Effect of partial meniscectomy on long-term prognosis with severe chondral damage". ³³	<ul style="list-style-type: none"> • N=42 • 20-40 yrs • Follow-up: 12-15 yrs 	<ul style="list-style-type: none"> • Radiographic: 81% ≥ gr. 2 combined Fairbank/Ahlback changes • Subjective: Lysholm 33% ≥ 94, Tegner mean level 4+/-2 • Clinical: No significant findings • Lack of correlation between radiographic and subjective findings 	<ul style="list-style-type: none"> • Correlated to poor outcome: B, H • No correlation: E, F • Correlation not addressed: A, C, D, G
Andersson-Molina et al. "Arthroscopic partial and total meniscectomy". ³⁶	<ul style="list-style-type: none"> • N=36 • Age at surgery: 16-38 yrs • Follow-up: 14 years 	<ul style="list-style-type: none"> • Radiographic: 28%-33% Fairbank changes; 39% gr. 1 Ahlback changes • Subjective: Lysholm median 95; Tegner median level 5 • Clinical: ROM in total meniscectomy 3° flexion loss 	<ul style="list-style-type: none"> • Correlated to poor outcome: D • No correlation: H • Correlation not addressed: A, B, C, E, F, G
Small sample size, short-term follow-up			
Author/Title	Intervention	Outcome	Risk Factors
Menetrey et al. "Medial meniscectomy in patients over age of 50". ³⁵	<ul style="list-style-type: none"> • N=32 • Age at surgery: 51-74 yrs • Follow-up: 3-7 yrs 	<ul style="list-style-type: none"> • Radiographic: 25% of nondegenerative tears and 74% degenerative tears had joint space narrowing, • Subjective: 92% nondegenerative tears and 15% degenerative tears rated "excellent/good" results • Clinical: Not reported 	<ul style="list-style-type: none"> • Correlated to poor outcome: A, C • No correlation: None • Correlation not addressed: B, E, F, G, H
Bonneux et al. "Partial lateral meniscectomy long term results in athletes". ²⁹	<ul style="list-style-type: none"> • N=31 • Age at surgery: 20-30 yrs • Follow-up: 6.5-9.5 yrs 	<ul style="list-style-type: none"> • Radiographic: 42.9% one Fairbank change; 50% two or more changes • Subjective: Lysholm 36% ≥ 94; Tegner 5.7 +/-1.9 • Clinical: No significant findings 	<ul style="list-style-type: none"> • Correlated to poor outcome: D, G • No Correlation: C, E, F • Correlation not addressed: A, B, H
Jaureguito et al. "Lateral meniscectomy outcome in normal knee". ³⁴	<ul style="list-style-type: none"> • N=21 • Age at surgery: 14-57 yrs • Follow-up: 5.5-11.25 yrs 	<ul style="list-style-type: none"> • Radiographic: 73% one Fairbank change, 19% two Fairbank changes • Subjective: Lysholm mean 84 • Clinical: No significant findings 	<ul style="list-style-type: none"> • No correlation between radiographic and functional • Correlated to poor outcome: None • No correlation: B, C, H • Correlation not addressed: A, D, E, F, G

TABLE 3. (continued)

Medium to large sample size, longer-term follow-up			
Author/Title	Intervention	Outcome	Risk Factors
Chatain et al. “Natural history of the knee following medial meniscectomy”. ⁴⁰	<ul style="list-style-type: none"> • N=218 • Age at surgery: 11-67 yr • Follow-up: 10-15 yrs 	<ul style="list-style-type: none"> • Radiographic: 53% no IKDC changes; 16% one IKDC change • Subjective: 91% “normal” or “near normal”; 96% “very satisfied” or “satisfied” with outcome • Clinical: Not reported 	<ul style="list-style-type: none"> • Correlated to poor outcome: A, B, C, D, F, G • No correlation: E, H • Correlation not addressed: None
Chatain et al. “A comparative study of medial vs. lateral arthroscopic partial meniscectomy”. ³⁰	<ul style="list-style-type: none"> • N= 472 • Age at surgery: 26-50 yrs • Follow-up: 10 years 	<ul style="list-style-type: none"> • Radiographic: 22% medial and 38% lateral meniscectomy group had significant joint space narrowing • Subjective: ≥ 80% symptom-free • Clinical: No physical exam • Radiographic findings more sensitive to OA change than symptoms 	<ul style="list-style-type: none"> • Correlated to poor outcome: A, B, C, D, F, G • No correlation: H • Correlation not addressed: E
Englund et al. “Patient-relevant outcomes fourteen years after meniscectomy”. ³⁷	<ul style="list-style-type: none"> • N=205 • Age at surgery: 18-48 yrs • Follow-up: 12-15 yrs 	<ul style="list-style-type: none"> • Radiographic: not assessed • Subjective: addressed relative to univariate and multivariate only • Clinical: Not addressed 	<ul style="list-style-type: none"> • Correlated to poor outcome: B, C, D • No correlation: F • Correlation not addressed: A, E, G, H
Englund et al. “Impact of type of meniscal tear on radiographic and symptomatic knee OA”. ³⁸	<ul style="list-style-type: none"> • N=155 • Age at surgery: 42-64 yrs • Follow-up: 15-17 yrs 	<ul style="list-style-type: none"> • Radiographic: 43% ≥ gr. 2 Kellgren/Lawrence changes • Subjective: 49% symptomatic KOOS scale • Clinical: Not reported • 59% of knees with radiographic gr. 2 change also symptomatic 	<ul style="list-style-type: none"> • Correlated to poor outcome: A, B, C, D, E, F, G • No correlation: None • Correlation not addressed: H
Englund & Lohmander. “Risk factors for symptomatic knee OA fifteen to twenty-two years after meniscectomy”. ⁸¹	<ul style="list-style-type: none"> • N = 305 • Age at surgery: 43-66 yrs • Follow-up: 15-22 yrs 	<ul style="list-style-type: none"> • Radiographic: 48% gr. 2 Kellgen/Lawrence scale • Subjective: 27% symptomatic KOOS score • Clinical: Not assessed • Nearly half of patients with radiographic OA were asymptomatic 	<ul style="list-style-type: none"> • Correlated to poor outcome: A, B, C, D, E, F, G • No correlation: None • Correlation not addressed: H

Medium to large sample size, short-range follow-up

Author/Title	Intervention	Outcome	Risk Factors
Rangger et al. “OA after partial meniscectomy”. ³⁹	<ul style="list-style-type: none"> • N=284 • Age at surgery: 15-74 yrs • Follow-up: 3.5-6.6 yrs 	<ul style="list-style-type: none"> • Radiographic: 18%-39% one or more Fairbank changes • Subjective: 86%-91% rated outcome excellent/good • Clinical: Not reported 	<ul style="list-style-type: none"> • No correlation between radiographic and subjective outcome • Correlated to poor outcome: A, B • No correlation: C • Correlation not addressed: D, E, F, G, H

*Risk factors: A-Condition of tibio-femoral cartilage, B-Age at meniscectomy, C-Nature of meniscal tear, D-Quantity of meniscus resected, E-Body Mass Index, F-female, G-Lateral compartment, H-Lower extremity alignment

IKDC-International Knee Documentation Committee Subjective Knee Form; KOOS-Knee Injury and Osteoarthritis Outcome Tool

Post-meniscectomy studies reviewed for this paper have used three different parameters to assess outcome: subjective^{29-38,40,81}, radiographic^{29-36,38-40,81}, and clinical parameters^{29,31-36}. Subjective outcome is most commonly determined by way of the Lysholm Scale^{29,31-34,36,89}, the Tegner Activity Scale^{29,31-33,36,90}, the International Knee Documentation Committee (IKDC) Subjective Knee Form^{29,30,40}, and the Knee Injury and Osteoarthritis Outcome tool (KOOS)^{37,38,81,91} (Table 4). Studies have also incorporated questionnaires and/or visual analog scales^{30-32,35,37,40}, which may be unique to that particular study. Radiographic outcome has been reported using the diagnostic criteria sets described in Table 1. As previously discussed, there are a number of generally recognized interpretive scales for radiographic outcome but no single radiographic measurement or descriptor is indicated as the gold standard in the literature. Additionally, several studies reviewed for this article used radiographic protocols unique to that individual study.

Clinical outcome post-meniscectomy has been measured in varied ways as described previously. No standardized method for determining clinical outcome is in common use in the literature. Arthroscopic findings at initial surgery are generally reported using the classification systems described in Table 2. While some studies have attempted to correlate arthroscopic findings at initial surgery with outcome measures, it is, of course, not practical or ethical to use arthroscopy as a measurement tool at follow-up.

Two risk factors, i.e., the quantity of meniscus removed (Table 5) and the nature of the meniscal tear (Table 6), were assessed by most studies reviewed and these warrant defini-

tion. An understanding of the definitions in Tables 5 and 6 is important for the subsequent discussion of risk factors following meniscectomy. “Partial,” “subtotal,” and “total” are the three common descriptors found in the literature for quantity or size of meniscal resection. Table 5 details the parameters, well accepted in current literature, of these descriptors. Two broad categories with regard to the nature of a meniscal tear are identified in the literature, “traumatic” and “degenerative.” Table 6 contains a description of traumatic and degenerative tears, based on an amalgamation of descriptors found most often in the literature. Determination of etiology or nature may be by way of history or description of the tear as identified on arthroscopy or relevant imaging. However, there is no universally agreed-upon method for determining the nature of the tear. Chatain et al³⁰ did not classify tears as necessarily traumatic or degenerative. Instead they used descriptors common to the literature such as “complex” or “parrot beak” without specifying the nature or etiology. In two necropsy studies, Noble and Hamblen⁵⁴ and Noble⁵⁵ conducted both gross and histological post-mortem analysis of more than 100 and 280 menisci, respectively. They determined that a horizontal cleavage tear, past the age of 45 years, is “so common that to regard it as a clinicopathological entity is questionable.” Noble regarded these tears as a normal part of the degenerative aging process. Most of the literature has agreed with Noble in regarding the nature of horizontal tears as degenerative.

Thirteen studies that investigated the relationship between meniscectomy and post-surgical OA were reviewed for this paper. Six studies^{30,32,36,38,40,81} (Table 7) calculated relative

TABLE 4. Subjective Outcome Measures for Patient Satisfaction and Activity Level

Name	Description	Rating
Lysholm Knee Scale ⁸⁹	<ul style="list-style-type: none"> • Graded from 0 – 100. • Assesses function and symptoms such as locking, swelling, instability, pain, squatting, and stair-climbing 	<ul style="list-style-type: none"> • 95 –100 Excellent result • 84 – 94 Good result • 66–83 Fair result • <66 Poor result
Tegner Activity Scale ⁹⁰	<ul style="list-style-type: none"> • Graded from 0 – 10; • Assesses activities in daily life, recreational and competitive sports 	<ul style="list-style-type: none"> • Levels 8-10 for participants in competitive sports • Level 5-7 are only achieved by participants in recreational or competitive sports; jogging at least 5x/week @ level 6 • Levels 0-4 address full disability through moderately heavy labor. Jogging is addressed at level 4
Knee Injury and Osteoarthritis Outcome Score (KOOS) ⁹¹	42-item questionnaire with 5 subscales: pain, other symptoms, activities of daily living (ADL), function in sport and recreation, and knee-related quality of life	<ul style="list-style-type: none"> • 0–100 for each category

TABLE 5. Types of Meniscectomy

Quantity of Meniscus Removed	Definition
Partial Meniscectomy	Resection of less than or equal to one-third of the meniscal surface ³⁸ Less than half of meniscal length ³⁶
Subtotal Meniscectomy	Resection of greater than one-third of the meniscal surface ³⁸
Total Meniscectomy	Resection of the posterior, middle, and anterior menisci preserving small peripheral rim ³² Resection of posterior, middle, and anterior menisci leaving small peripheral rim ³⁶

TABLE 6. Nature of Meniscal Tears

Nature of Meniscus Tear	Description
Traumatic	Longitudinal tear ³⁷ Longitudinal or bucket handle ³²
Degenerative	Flap, horizontal, complex tears, tears in the presence of degenerative cartilage ³⁷ Flap, horizontal, and radial tears ³² Horizontal tear ^{54,55} Horizontal or complex tears ³⁵ Complex tear with cartilage change ³⁰

risk or odds ratios for poor subjective and/or radiographic outcome post-meniscectomy based on the risk factors identified above. Seven studies^{29,31,33-35,37,39} (Table 8) determined whether risk factors were statistically significant (using $P < 0.05$ for the risk factors in question), but they did not report on relative risk or odds ratios.

In the six studies that calculated odds and relative risk ratios, quantity of meniscus resected^{30,32,36,40,81} was cited as a risk factor in five studies, age at surgery in four^{30,32,40,81}, nature of the tear in three^{38,40,81}, and condition or articular cartilage also in three of the six studies^{30,40,81}. Because these studies used two different statistical measures, odds ratio and relative risk, and in the absence of raw data that would allow for conversion, it is difficult to draw relevant quantitative clinical conclusions. It is, however, possible to identify trends or similarities between the studies. The five studies^{30,32,36,40,81} that calculated relative risk based on size of resection found an RR of 2.0–3.5 for partial meniscectomy as compared to controls and up to 7 times greater risk for subtotal meniscectomy as compared to controls. Age >30 at the time of surgery was found to increase risk for subsequent OA by 1.5 to nearly 3 times in two studies^{32,81}. Two studies^{30,40} calculated an OR of 1.12–5 with age >35. Three studies^{38,40,81} determined that degenerative tears resulted in an OR of 2.9–5.3 for developing OA. Englund et al³⁸ calculated an RR of 2.7 for a traumatic tear and an RR of 7.0 with a degenerative tear. Being female as compared to male resulted in an OR of 1.6–2.9 for developing OA following meniscectomy^{38,40,81}.

In the seven studies that did not calculate odds or relative risk ratios (Table 8), quantity of resection was cited as “significant” three times^{29,31,39}, age >30 years in two studies, and age >40 in a third study. Pre-existing damage to the ar-

ticular cartilage was reported to have a “significant” effect on outcome in two studies.

Discussion

This review asked the question, “Is there evidence to demonstrate that runners, post-meniscectomy, incur great enough risk for early degenerative OA to cease all running?” If the answer to this question is a “qualified ‘yes,’” then a second question is raised, “Does the literature reveal consistent risk factors, post-meniscectomy, that would guide a physical therapist in advice to the patient contemplating a return to recreational running?”

In a clinical commentary on evidence-based practice, Cormack⁹² suggested the following hierarchy of evidence: 1) meta-analysis, 2) systematic reviews, 3) clinical practice guidelines, 4) randomized control trials, 5) cohort studies, 6) case control studies, 7) case studies, 8) opinion from respected authorities, and 9) basic science research. At the completion of this review in April 2006, this author identified a paucity of higher-level evidence to directly address the questions identified above. A limited number of retrospective cohort studies examined running and OA or incidence and prevalence of OA post-meniscectomy, but these data were insufficient due to limitations in sample size and methodological rigor to answer the questions posed above. Five of the reviewed studies^{29,31-33,36} reported on patient post-meniscectomy activity level using Tegner scores. In our attempt to extrapolate outcomes with regard to running, it is relevant that the Tegner scale level 7 includes cross-country running whereas level 6 includes jogging five times per week. However, run-

TABLE 7. Relative Risks and Odds Ratios for Identified Risk Factors

Author	Condition of Articular Cartilage	Age at Surgery	Nature of Meniscal Tear	Quantity Resected	BMI	Gender	Compartment	Alignment
Chatain	OR 2.8	> 35 yrs OR 5.0		Total OR 2.2 partial OR 2.3				
Rockborn & Gillquist ³²		> 30 yrs RR 2.75		Part vs. control RR 3.62 Subtotal vs. control RR 7.09 Subtotal vs. partial RR 2.16				Ruled out as relevant RR
Andersson-Molina et al ³⁶				Total vs. partial OR 8.0 Total vs. control OR 11				
Englund et al ³⁸			Traumatic RR 2.7 Degenerative RR 7.0		≥ 30 RR 4.0	Female OR 2.9		
Chatain et al ⁴⁰	OR 2.3	> 35 yrs OR LM 1.12 OR MM1.03	Degenerative OR 5.3	Total vs. subtotal LM OR 6.5		Female OR 1.9 (for pain only)		Ruled out as relevant RR
Englund & Lohmander ⁸¹	OR 2.6	> 30 yrs OR 1.6	Degenerative OR 2.9	Subtotal OR 2.2 Total OR 3.6	≥ 30 RR 2.5	Female OR 1.6	LM OR 2.4	

OR-Odds ratio; RR-Relative risk; LM-Lateral meniscus; MM-Medial meniscus; BMI-Body mass index.

TABLE 8. Risk Factors (Identified but statistical analysis not reported in detail)

Author	Condition of Articular Cartilage	Age at Surgery	Nature of Meniscal Tear	Quantity Resected	BMI	Gender	Compartment	Alignment
Rockborn & Gillquist ³¹	RO			RI				
Maletius et al ³³		RI (age > 30 yrs)			RO	RO		RI
Menetrey et al ³⁵	RI		RI				(lateral compartment)	
Bonneux et al ²⁹				RI				
Jaureguito et al ³⁴		RO	RO					RO
Englund et al ³⁷		RI (age > 30 yrs)	RI	RI				
Rangger et al ³⁹	RI	RI (age > 40yrs)	RO					

RI-Ruled in as significant risk factor; RO-Ruled out as significant risk factor

TABLE 9. Scale for Predicting Successful Return to Running Following Meniscectomy

Predictors	Present/Absent
Quantity of meniscus removed • $\geq 1/3$ of total	_____
Age • ≥ 40 years	_____
Pre-existing evidence of OA • Radiographic or • Arthroscopic	_____
Method of injury • Degenerative	_____
Gender • Female	_____
Body Mass Index • ≥ 30	_____
Compartment • Lateral	_____
Lower extremity alignment • Genu valgum with lateral meniscectomy • Genu varum with medial meniscectomy	_____
Total	_____

ning is not the sole component of these levels nor do any of the studies reviewed report on runners as a separate cohort. No rigorous longitudinal studies were identified that examined OA post-meniscectomy on a cohort of long-distance recreational runners compared to matched controls.

Keeping in mind the absence of high-level research evidence related to the question as to the possibly greater incidence of tibiofemoral OA in runners post-meniscectomy, the survey of the literature concerning the etiology of OA, running and OA, and meniscectomy and OA did yield potentially useful information on risk factors for, or predictors of, early degenerative OA following meniscectomy with a return to recreational running. Table 9 summarizes the predictors identified in the studies reviewed in this paper. These risk factors are ranked from *most frequently* to *least frequently* identified as significant predictors of OA.

Quantity of meniscus resected was identified in eight studies^{29-32,36,37,40,81}. Odds or relative risk ratios were consistently increased, in the order of 2-11, with the increased size of resection. However, only two studies^{30,32} reported odds or relative risk ratios for partial meniscectomy compared to controls. It is in precisely this population that the advisability of a return to running is most open to debate. Chatain et al³⁰ calculated an OR of 2.3 and Rockborn and Gillquist³² determined a RR of 3.2 for developing OA after partial meniscectomy when compared to non-operated controls.

Age at surgery as a risk factor was identified in seven

studies^{30,32,33,37,39,40,81} with 30 years as the threshold in four studies^{32,33,37,81}, 35 years in two^{30,40}, and 40³⁹ years in one study. Chatain et al⁴⁰ calculated the OR with age>35 as 1.03 and 1.12 for medial meniscus and lateral meniscus, respectively. Englund and Lohmander⁸¹ found the OR for age>30 to be 1.6.

A finding of pre-existing damage to the articular cartilage at the time of surgery was also identified as a significant risk factor in five studies^{30,35,39,40,81}. The three studies^{30,40,81} that calculated an OR found that the odds were two to three times greater in the presence of pre-existing OA change.

A degenerative tear was identified as a significant risk factor in five studies^{35,37,38,40,81} of 13. Englund et al³⁸ calculated the RR in cases with a traumatic tear as 2.7; the RR was calculated as 7.0 with a degenerative tear. The authors speculated that a degenerative tear might in fact be an indicator of early osteoarthritic change even in the presence of apparently undamaged articular cartilage.

While the relative significance of risk factors identified in the aforementioned studies varies in magnitude, trends in the literature do emerge. Table 9 identifies key predictors for a successful return to running following meniscectomy. The clinician can use this table to provide a mainly qualitative assessment of the various risk factors present in the patient's history. This qualitative risk assessment may then be used to guide patient education and discussion regarding prognosis for a safe return to recreational running. This author believes that when the clinician is performing this risk assessment, the quantity of meniscus resected, age at surgery, condition of articular cartilage, and presence of a degenerative tear should be given the greatest weight based on the frequency in which they appear in the literature. Admittedly, it is difficult to draw conclusions from the odds and relative risk ratios calculated because only one risk factor (condition of articular cartilage) had consistent odds ratios reported across the studies.

The conclusions drawn from studies researching OA post-meniscectomy might further be informed by the results from studies on the relationship between running and OA. These studies found that pre-existing OA, high BMI, and female gender were correlated with a higher risk for degenerative changes^{2,61,79,80,84}. These studies add further weight to the evidence that pre-existing OA should likely be considered a higher-order risk factor. The reader must recognize the limitations in the studies that have been used here to develop Table 9. As of yet, conclusive evidence is not available upon which to base clinical decisions.

Conclusion

While the probability for early degenerative OA in the post-meniscectomy population is substantial, it is a probability and not a certainty. In 7 of the 12 studies^{29,30,35,36,38,39,81} that

used radiographic diagnostic measures, the frequency of significant radiographic change was less than 50%. If patients with pre-existing degenerative articular cartilage changes^{30,35,38,40,39,81} or subtotal and total meniscectomy are factored out^{29,32,36-38,81}, the frequency of radiographic change is less, seemingly to a clinically relevant degree. Many patients with radiographic OA were symptom-free^{30-32,35,36,39,81} or had few enough symptoms to report an excellent post-surgical outcome^{30-32,35,36,39,40,81}. It may be fair to speculate that runners are a self-selecting group. As evidence builds for a strong genetic link to OA, it may be fair to speculate that runners with a predisposition for OA would have developed self-limiting pain and quit the sport. Runners who have been at the sport for a number of years and present with a traumatic versus degenerative tear may fall into a lower risk category. Chatain et al³⁰ actually found an OR of 0.3 for preoperative participation in sport indicating that it may in fact be protective against OA.

This review points to a number of limitations in the current literature. Basic definitions of OA, consistent methods for measuring and reporting OA progression, and a comprehensive understanding of tibiofemoral OA etiology are clearly lacking. No longitudinal studies comparing meniscectomized runners to non-meniscectomized runners as controls have been reported. Lacking in the literature are also studies that assess and report on the construct validity of the components of a thorough clinical physical therapy assessment. We are, therefore, unsure how certain measurements, e.g., tibiofemoral or patellofemoral joint mobility tests, integrated

lower extremity strength tests, proprioception tests, balance reactions, and running gait analysis, relate to the outcome measures used in the various studies described to assess presence and stage of tibiofemoral OA.

Despite the absence of high-level research evidence, specifically relevant studies comparing the incidence and prevalence of OA in meniscectomized as compared to non-meniscectomized runners and the lack of consistent and comparable outcome measures or even the definition of OA across studies, trends do seem to emerge as identified in Table 9. When a patient approaches the clinician to seek advice on whether to return to running after meniscectomy, the clinician may wish to use information from Table 9 in a very qualitative manner to advise patients with a high cumulative total of risk factors to refrain from returning to running in order to minimize the risk for early degenerative OA. Patients with a lower cumulative total of risk factors may deem the probability for early OA change to be an acceptable risk.

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