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Generalized Joint Hypermobility and Risk of Lower Limb Joint Injury During Sport



A Systematic Review With Meta-Analysis

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Background: Generalized joint hypermobility is a highly prevalent condition commonly associated with joint injuries. The current literature has conflicting reports of the risk of joint injury in hypermobile sporting participants compared with their nonhypermobile peers. Systematic reviews have not been conclusive and no meta-analysis has been performed.

Purpose: This review was undertaken to determine whether individuals with generalized joint hypermobility have an increased risk of lower limb joint injury when undertaking sporting activities.

Study Design: Systematic review with meta-analysis.

Methods: Studies were identified through a search without language restrictions of PubMed, CINAHL, Embase, and SportDiscus databases from the earliest date through February 2009 with subsequent handsearching of reference lists. Inclusion criteria for studies were determined before searching and all included studies underwent methodological quality assessment by 2 independent reviewers. Meta-analyses for joint injury of the lower limb, knee, and ankle were performed using a random effects model. The difference in injury proportions between hypermobility categories was tested with the z statistic.

Results: Of 4841 identified studies, 18 met all inclusion criteria with methodological quality ranging from 1 of 6 to 5 of 6. A variety of tests of hypermobility and varied cutoff points to define the presence of generalized joint hypermobility were used, so the authors determined a standardized cutoff to indicate generalized joint hypermobility. Using this criterion, a significantly increased risk of knee joint injury for hypermobile and extremely hypermobile participants compared with their nonhypermobile peers was demonstrated ($P < .001$), whereas no increased risk was found for ankle joint injury. For knee joint injury, a combined odds ratio of 4.69 (95% confidence interval, 1.33-16.52; $P = .02$) was calculated, indicating a significantly increased risk for hypermobile participants playing contact sports.

Conclusion: Sport participants with generalized joint hypermobility have an increased risk of knee joint injury during contact activities but have no altered risk of ankle joint injury.

Keywords: hypermobility; knee; ankle; joint; sports injury; meta-analysis

Generalized joint hypermobility (GJH) is a condition in which most of an individual's synovial joints move beyond the "normal" limits, with the age, gender, and ethnic

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background of the individual taken into account.¹⁴ Because of differing definitions and case identifications, the prevalence of GJH in published reports varies from 5% to 43% in adults^{7,20} and 2% to 55% in children.³⁰ Generalized joint hypermobility is also a recognized feature of many heritable disorders of connective tissue, such as Ehlers-Danlos syndrome, Osteogenesis Imperfecta, and Marfan syndrome.⁴⁵ Many of these disorders are associated with symptoms of chronic fatigue and widespread musculoskeletal pain, which may result from the GJH.⁴⁵

The increased connective tissue flexibility in GJH is considered to be of primarily genetic origin, given its common autosomal dominant presentation.¹⁵ Although many

of the genes responsible for the monogenetic disorders associated with GJH have been identified,⁴⁵ the cause of idiopathic GJH, including those with benign joint hypermobility syndrome, requires further investigation.

Dislocations, subluxations, and sprains are commonly reported in individuals with GJH¹ and it is assumed that the risk of such injuries is magnified during activities that are more physically challenging, particularly where the lower limbs are involved. However, reports in the current literature are inconclusive as to whether the risk of lower limb joint injury during sport is greater in hypermobile participants compared with their nonhypermobile peers. Conflicting evidence of the relationship between hypermobility and joint injuries has been reported among ballet dancers^{16,22} and gridiron players.^{21,32} To date, systematic reviews have also been unable to definitively determine any difference in the risk of lower limb joint injury sustained by hypermobile sporting participants^{18,29} and no meta-analysis has been performed.

This situation has led to varying recommendations from clinicians and researchers advising individuals with GJH on the risks incurred by sports participation. Advising caution when giving advice on sports participation for those with GJH, recommendations include participation in noncontact activities only, such as swimming, pilates, and tai chi⁴⁰; or greater caution so that “relatively lax individuals should avoid physical exertion at a higher than normal rhythm.”¹³ Others suggest that hypermobile participants can undertake sporting activities such as netball, stipulating that they should do so with the use of strapping and supports in order to limit injury.⁴¹ Conversely, Murray³⁰ recommends full involvement in sporting activities for pain-free hypermobile individuals.

Physical activity is routinely prescribed for patients with chronic conditions; however, patients with GJH need a statement of the best information available on the risks associated with such participation. Accordingly, the aim of the current study is to systematically review the literature to determine whether people with GJH are at significantly greater risk of lower limb joint injury if they participate in sporting activities.

METHODS

Identification of Studies

Eligible studies were identified through a search without language restrictions of PubMed, CINAHL, Embase, and SportDiscus databases from the earliest date through February 2009. The search strategy (Table 1) was formed by the authors in conjunction with an experienced medical librarian. Handsearching of reference lists of all included studies and relevant review papers was also performed.

All studies identified by the search were screened by the first author using the inclusion criteria and checked by a second author as required.

TABLE 1
PubMed Search Strategy^a

1. Causal*[tw]
2. Causation[tw]
3. Pred*[tw]
4. Risk*[tw]
5. Risk assessment[mh]
6. Risk factors[mh]
7. Odds ratio[mh]
8. Clinical trials[mh]
9. Prevalence[mh]
10. Prevalence studies[mh]
11. Incidence studies[mh]
12. Incidence[mh]
13. Epidemiological studies[mh]
14. Or/1-13
15. Hip injuries[mh]
16. Foot injuries[mh]
17. Knee injuries[mh]
18. Athletic injuries[mh]
19. Injur*[tw]
20. Sublux*[tw]
21. Disloc*[tw]
22. Sprain*[tw]
23. Sprains or strains[mh]
24. Dislocations[mh]
25. Ankle injuries[mh]
26. Or/15-25
27. Joint instability[mh]
28. Hypermob*[tw]
29. Hyper-mob*[tw]
30. Joint laxity[tw]
31. Joint instability*[tw]
32. Ligament* AND instability*[tw]
33. Ligament* AND laxity[tw]
34. Beighton[tw]
35. Hyperflex*[tw]
36. Hyperextens*[tw]
37. Or/27-36
38. 14 AND 26 AND 37

^aThis search strategy was modified for searches of other databases.

Database search terms: tw, textword; mh, MeSH term (biomedical term assigned to describe the subject of indexed articles); *wildcard (search for terms that begin with the letters preceding asterisk).

Inclusion Criteria

Studies were included if they used a prospective design with an objective scale to measure GJH and included participants who were undertaking any type of sports activity. To be included in the review, studies also had to be peer reviewed and have objective, quantitative injury data. Injury definition included injury diagnosis by a health professional, self-reported dysfunction, or time lost to athletic participation.

Methodological Quality Assessment

Methodological quality was assessed using the 6-point scale developed for prognostic studies by Pengel et al,³⁵

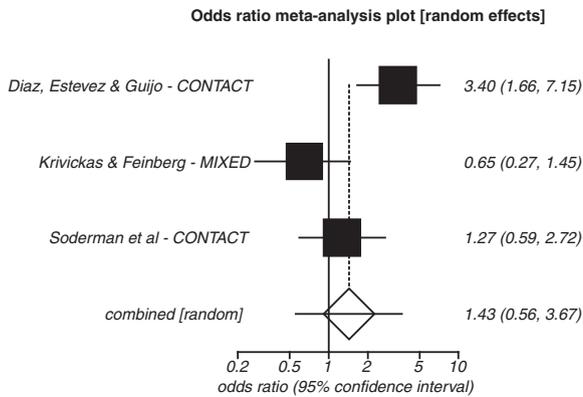


Figure 1. Meta-analysis of risk of lower limb joint injury to hypermobile sports participants utilizing the standardized generalized joint hypermobility definition.

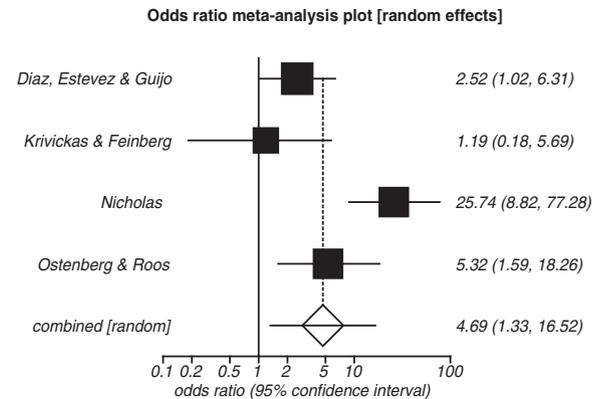


Figure 3. Meta-analysis of risk of knee joint injury to hypermobile participants of contact sports utilizing the standardized generalized joint hypermobility definition.

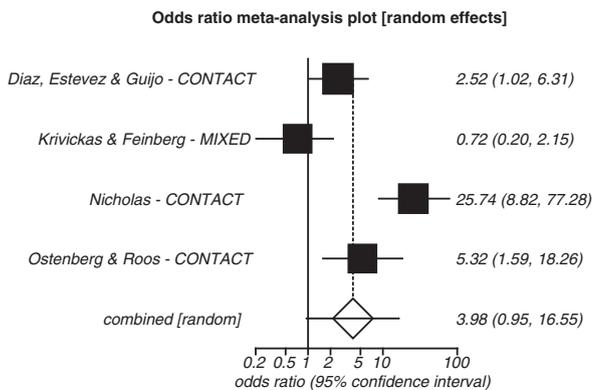


Figure 2. Meta-analysis of risk of knee joint injury to hypermobile sports participants utilizing the standardized generalized joint hypermobility definition.

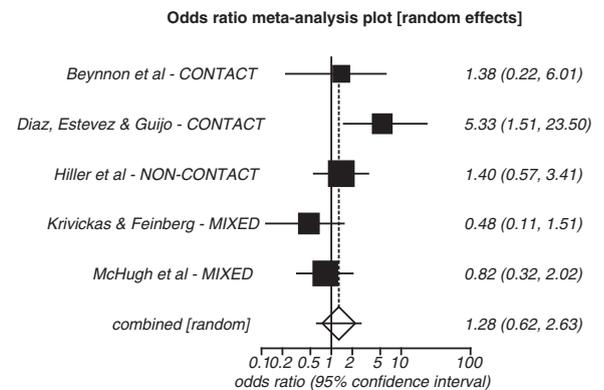


Figure 4. Meta-analysis of risk of ankle joint injury to hypermobile sports participants utilizing the standardized generalized joint hypermobility definition.

used previously in reviews of prognosis of musculoskeletal conditions.^{10,28} Two reviewers independently assessed the quality of each study. Ambiguities were resolved through discussion, with a third reviewer consulted when agreement could not be reached.

Data Extraction and Analysis

Data extracted from each included study by 2 authors included participant age, gender, and sporting activity; number of participants; length of follow-up; measure and definition of GJH; definition of injury used; injuries studied; and reported injury data. In line with the American Academy of Pediatrics system, sporting activities were classified into 3 groups—collision or contact sports, limited contact sports, and noncontact sports.³⁸ Four studies²³⁻²⁶ included sporting activities in more than 1 of these groups and were therefore classified into a fourth group referred to as mixed sports. Where studies reported insufficient data to be included in a meta-analysis, an attempt was

made to contact the authors by e-mail. From this, 4 sets of more detailed data were obtained.^{16,23,26,33}

Odds ratios and 95% confidence intervals (CIs) were generated using StatsDirect software (version 2.7.2, StatsDirect Ltd, Altrincham, Cheshire, United Kingdom). Because an odds ratio of 1 demonstrates that an injury is equally as likely to occur in the hypermobile group as the nonhypermobile group, where the odds ratio is greater than 1, and the 95% CI does not include 1,³⁹ then statistical significance was accepted as $P < .05$. Forest plots were generated (Figures 1-4) and the area of each square symbol (odds ratio) is proportional to the study's weight in the meta-analysis, reflecting the weighting of each study's results in the random effects analysis model. The open diamond symbol represents the combined odds ratio.

Because of differences among the included studies in the participants, sports, and measures used, the DerSimonian and Laird random effects method¹² was used for the meta-analysis and I^2 was calculated to determine the level of heterogeneity, with an I^2 value of 100% representing

TABLE 2
Included Studies^a

Author(s) (Year)	Participants' Gender and Age	Participants' Sporting Activity	Length of Follow-up	Injuries Studied	Injury Definition	Author(s)' Conclusion: Does GJH Affect the Risk of Injury?
Baumhauer et al ⁵ (1995)	73 males, 72 females aged 18- 23 years	Lacrosse, soccer, field hockey (college)	Not stated	Lateral ankle sprains	Trainer review	Ankle: No significant difference
Beynon et al ⁶ (2001)	50 males, 68 females aged 18-23 years	Lacrosse, soccer, field hockey (college)	Not stated	Lateral ankle sprains	Medical review	Ankle: No significant difference
Davies and Gibson ⁹ (1978)	185 males aged 23 ± 5 years	Rugby union (1st class—British, Welsh, and English)	1 season	Any injury, any body part	Self-report: Temporary interruption to game OR impaired ability to train or play	Overall: No significant difference
Decoster et al ¹¹ (1999)	147 males, 163 females aged 20 ± 4 years	Lacrosse (college)	1 season	Any injury, any body part	Trainer report: Injury resulting in missing at least 1 practice or game	Overall: No significant difference Ankle: Increased risk
Diaz et al ¹³ (1993)	675 males aged 17 years	Soldier recruits	2 months	Any injury, any body part	Medical review: Lesions or alterations to the locomotor system requiring treatment	Overall: Increased risk
Hiller et al ¹⁶ (2008)	21 males, 94 females aged 12-16 years	Ballet and dance (high school)	Up to 13 months (until 1st lateral ankle sprain)	Lateral ankle sprains	Self-report: Swelling or bruising from inversion injury and limping for >1 day	Ankle: No significant difference
Hopper et al ¹⁷ (1995)	72 females aged 15- 36 years	Netball (A grade)	14 weeks	Any injury, any body part	Medical review	Overall: No significant difference
Kalenak and Morehouse ²¹ (1975)	72 males	American football (college)	1-4 seasons	Knee ligaments	Medical review: Medial, lateral, or anterior cruciate ligament	Knee: No increased risk
Krivickas and Feinberg ²³ (1996)	131 males, 70 females aged 17-21 years	Football, baseball, basketball, soccer, cross-country, golf, diving, and others (college)	1 year	Any type of back or lower extremity injury	Trainer or medical review: Injury that limited activity or prevented play in practice or game	Overall: Decreased risk
Lompa et al ²⁴ (1998)	71 males, 34 females aged 9-24 years	Amateur gymnastics, volleyball and basketball	12 months	Any injury, any body part	Medical review	Overall: Increased risk
Lysens et al ²⁵ (1989)	118 males, 67 females aged 17-19 years	Physical education (college)	1 year	Any injury, any body part	Medical review: Injury during sport session resulting in ≥3 days absence from sport	Overuse: Increase risk
McHugh et al ²⁶ (2006)	101 males, 68 females, aged 14-18 years	Athletes (high school)	2 years	Lateral ankle sprains	Trainer review: Ankle injury with inversion mechanism resulting in missing ≥1 game or practice	Ankle: No significant difference
Nicholas ³² (1970)	139 males	American football (professional)	At least 1 season	Knee ligaments	Medical review: 3° ligament rupture requiring surgery within 2 weeks due to instability	Knee: Increased risk
Ostenberg and Roos ³³ (2000)	123 females aged 14-39 years	Soccer (all levels)	1 season (7 months)	Any injury, any body part	Medical review: Absence from at least 1 practice or game	Overall: Increased risk Knee: Increased risk

(continued)

TABLE 2 (continued)

Author(s) (Year)	Participants' Gender and Age	Participants' Sporting Activity	Length of Follow-up	Injuries Studied	Injury Definition	Author(s)' Conclusion: Does GJH Affect the Risk of Injury?
Pasque and Hewett ³⁴ (2000)	418 males aged 14- 19 years	Wrestling (high school)	1 season (3 months)	Any injury, any body part	Medical review: Any condition reducing function resulting in seeking medical care OR Self-report: Loss of practice or match and loss of ≥ 1 day from athletic participation	Overall: No significant difference
Soderman et al ⁴² (2001)	146 females aged 20.6 \pm 4.7 years	Soccer (2nd and 3rd division)	1 season (7 months)	Leg injuries	Self- or coach report: Absence from 1 practice or game	Traumatic : Increased risk
Stewart and Burden ⁴³ (2004)	51 males aged 23.6 \pm 3.3 years	Rugby union (1st class New Zealand)	1 season	Shoulder, hip, knee, ankle, wrist, and hand injuries	Medical review: Any condition reducing function requiring treatment	Overall: Increased risk
Uhorchak et al ⁴⁶ (2003)	1021 males, 177 females aged 17- 23 years	Cadets	4 years	ACL rupture	Medical review: ACL rupture on arthroscopy	Overall: Increased risk

^aGJH, generalized joint hypermobility; ACL, anterior cruciate ligament.

complete heterogeneity. Potential publication bias was not tested because of the substantial heterogeneity and low number of studies included within the meta-analysis.^{19, 44}

Although differing definitions of GJH were identified between studies, obtaining the original raw data sets allowed us to use a standardized criterion of ≥ 4 of 9 on the Beighton scale to indicate GJH, as recommended by the British Society of Rheumatology.³⁷ Where the scale used to determine the extent of hypermobility was not a 9-point scale, the point closest in percentage to 4 of 9 (44.44%) was used (eg, 2 of 5, 3 of 6).

Therefore, odds ratios for all lower limb, knee, and ankle joint injuries related to GJH are reported in 2 ways: first, by the original authors' definition; and second, by the standardized definition using the British Society of Rheumatology criterion for defining GJH (≥ 4 of 9 or equivalent). Thus the odds ratios for each area (ankle, knee, overall lower limb) and for each definition (authors' and standardized) are pooled from differing numbers of studies and individual data sets, depending on the data that could be extracted.

Participants in the 6 studies that provided hypermobility scores as continuous data^{13,16,23,26,32,42} were then classified on the basis of extent of hypermobility into 1 of 3 categories—not hypermobile (0 of 9 to 3 of 9 or equivalent), hypermobile (4 of 9 to 6 of 9 or equivalent), or extremely hypermobile (7 of 9 to 9 of 9 or equivalent)—with a method used previously.^{13,23,43} The 95% CIs for the injury rates of participants in each of these 3 categories were calculated, and the difference in injury proportions between categories was tested with the z statistic.³

The number of individual data sets able to be used in each calculation differs from the odds ratio calculations depending on the number of data sets able to be categorized into these 3 groups.

RESULTS

The search identified 4841 studies, of which 18 met all inclusion criteria (Table 2). Of the 18 studies, 4 considered only ankle injuries,^{5,6,16,26} 3 considered only knee injuries,^{21,32,46} 1 study pooled all leg injuries,⁴² and all others considered both lower limb and injuries to other areas of the body.[¶] Attempts were made to contact authors of all studies by e-mail with a request to provide de-identified data of sufficient detail to be included in the meta-analyses. Authors were not contacted if the complete data were available within the publication, as was the case for 2 studies. Three of the 10 authors who responded were able to provide the required data. No specific injury data relating to GJH could be obtained for 8 of the 18 articles and consequently these studies are not included in the meta-analyses. Hip joint injury data were only available from 1 study²³ that reported 3 hip joint injuries, generating an odds ratio of 1.33 (95% CI, 0.12-14.94; $P = .82$) utilizing the standardized definition of GJH.

¶References 9, 13, 17, 23-25, 33, 34, 43, 46.

TABLE 3
Methodological Rating

Author(s) (Year)	Defined Sample ^a	Representative Sample ^b	Complete Follow-up ^c	Prognosis ^d	Blinded Outcome ^e	Statistical Adjustment ^f	Methodological Score
Baumhauer et al ⁵ (1995)	Yes	Yes	No	Yes	No	No	3
Beynon et al ⁶ (2001)	Yes	No	Yes	Yes	No	Yes	4
Davies and Gibson ⁹ (1978)	No	No	Yes	Yes	No	No	2
Decoster et al ¹¹ (1999)	No	Yes	No	Yes	No	No	2
Diaz et al ¹³ (1993)	Yes	No	No	Yes	No	N/A	2
Hiller et al ¹⁶ (2008)	Yes	Yes	Yes	Yes	No	Yes	5
Hopper et al ¹⁷ (1995)	No	No	Yes	Yes	No	Yes	3
Kalenak and Morehouse ²¹ (1975)	No	No	No	Yes	No	No	1
Krivickas and Feinberg ²³ (1996)	Yes	No	Yes	Yes	No	Yes	4
Lompa et al ²⁴ (1998)	Yes	No	Yes	Yes	No	No	3
Lysens et al ²⁵ (1989)	No	No	Yes	Yes	No	Yes	3
McHugh et al ²⁶ (2006)	No	No	Yes	Yes	No	Yes	3
Nicholas ³² (1970)	Yes	Yes	No	Yes	No	No	3
Ostenberg and Roos ³³ (2000)	No	No	Yes	Yes	No	Yes	3
Pasque and Hewett ³⁴ (2000)	No	No	Yes	Yes	No	No	2
Soderman et al ⁴² (2001)	Yes	No	No	Yes	No	Yes	3
Stewart and Burden ⁴³ (2004)	No	No	No	Yes	No	No	1
Uhorchak et al ⁴⁶ (2003)	Yes	Yes	No	Yes	No	Yes	4

^aDescription of source of participants with defined inclusion and exclusion criteria.

^bParticipants randomly selected or consecutive cases.

^cAt least 1 prognostic factor available from 80% of study population at 3-month follow-up or later.

^dStudies must provide raw data, percentages, survival rates, or continuous outcomes.

^eAssessor unaware of at least 1 prognostic factor, used to predict prognostic outcome, at time prognostic outcome was measured.

^fFor at least 2 prognostic factors with adjustment factor reported.

Methodological Quality

The 2 reviewers scored 108 quality criteria and initially agreed on 94 (87%) of these ($\kappa = 0.74$; 95% CI, 0.62-0.87). Further discussion led to agreement on 107 (99%) ($\kappa = 0.98$; 95% CI, 0.95-1.0), requiring only 1 quality criterion to be decided by a third reviewer. Nine studies (50%) defined the population from which the sample was drawn, 5 (28%) clearly described methods for assembling a representative sample, and 10 (56%) reported follow-up of at least 80%. All studies (100%) quantified prognosis, no study reported blinded assessment of outcome measures, and 9 studies (53%) reported statistical adjustments. Final methodological quality scores for these studies ranged from 1 of 6 to 5 of 6 (Table 3).

Objective Measures Used

Seven different measures of GJH were used by the 18 studies, incorporating varying cutoff points to indicate the presence of hypermobility (Table 4). Of the 8 studies that reported using the modified 9-point Beighton scale, 4 described different criteria for positive identification.

Joint Injury

All Lower Limb Joint Injuries. Original authors' definition: Odds ratios and confidence intervals for all lower limb joint injuries were calculated from 3 studies using the original

authors' definition of GJH (Table 5) giving a combined odds ratio of 1.71 (95% CI, 0.60-4.85; $P = .31$; $I^2 = 80.9\%$).

Standardized definition: Calculation of odds ratios using the standardized definition of GJH was possible for the same 3 studies, enabling pooling of 1047 individual data sets (Figure 1) and demonstrating that 14% of the sporting participants suffered all lower limb joint injuries. Odds ratios ranged from 0.65 to 3.40 with a combined odds ratio of 1.43 (95% CI, 0.56-3.67; $P = .46$; $I^2 = 81\%$). Figure 5 reveals that overlap between the 95% CIs of each mobility status group and the difference in the proportion of participants with lower limb joint injuries between nonhypermobility participants and the combined hypermobility and extremely hypermobility participants was not significant ($z = 1.69$; $P = .09$).

Knee Joint Injuries. Original authors' definition: From the 5 studies that reported knee injury data, a significant relationship between hypermobility status and risk of knee joint injury was found with a combined odds ratio of 2.62 (95% CI, 1.04-6.58; $P = .04$; $I^2 = 74.1$) (Table 5).

Standardized definition: Four studies assessed injury risk in male army recruits, female soccer players, professional male American football players, and athletes engaged in mixed college level sports allowed pooling of 1167 individual data sets (Figure 2) and calculation of odds ratios using the standardized definition of GJH. The overall knee injury rate in these studies was 8.65%, with odds ratios for knee joint injury in those with GJH ranging from 0.72 to 25.74, giving a combined odds ratio of 3.98 (95% CI, 0.95-16.55; $P = .06$; $I^2 = 88.4\%$).

TABLE 4
Objective Measures Used^a

Objective Measure of Hypermobility	Description of Measure (Including Variations)	Cutoff Point Indicating Hypermobility
Modified 9-point Beighton ^{5,6,11,16,17,23,33,43}	5th finger MCP dorsiflexion >90°	≥3 ¹⁷
	(passively extend fingers parallel to forearm ¹¹)	≥4 ^{5,6,16,23,33,43}
	Passive thumb to forearm	≥5 ¹¹
	Hyperextension of elbows >10°	
	Hyperextension of knees >10° (>15° ⁴³)	
6-point Beighton and Horan ³⁴	Palms flat on the floor	
	Passive 5th finger MCP joint extension >90°	Cutoff not used, treated as continuous scale
	Thumb to forearm passively	
	Elbow hyperextension >10°	
	Knee hyperextension >10°	
Modified 5-point Carter and Wilkinson ^{13,24}	Ankle hyperextension >45°	
	Palms to floor with knees straight	
	Passive dorsiflexion of 5th finger >90°	≥2 ¹³
	(passive hyperextension of the fingers parallel to the forearm ²⁴)	≥3 ²⁴
	Thumb to forearm	
Modified 10-point Carter and Wilkinson ⁴²	Hyperextension of elbow (>5° ¹³)	
	Hyperextension of knee (>5° ¹³)	
	Palms on floor (femoral anteversion ²⁴)	
	Passive hyperextension of fingers to parallel with forearm	≥5 ⁴²
	Passive thumb to forearm flexor aspect	
5-point Nicholas ^{21,26,32}	Elbow hyperextension >10°	
	Knee hyperextension >10°	
	Dorsiflexion of ankle >30°	
	Upper extremity laxity—hypothenar eminence inclines cephalad in vertical plane with elbows extended and forearms supinated (hyperextension of the elbow with the wrist in supination and the shoulder flexed to 90° ²⁶)	≥1 ^{21,32}
	Hyperextension of the knee ≥20° (>10° ²⁶)	≥3 ²⁶
	Over pivot ability—feet >180° degrees heel to heel and toes out (hip, knee, and ankle max external rotation with knees flexed 15°-30°)	
	Knees or ankles parallel to floor when lying or sitting in either external rotation (lotus position) or internal rotation (thumb to forearm with wrist flexed ²⁶)	
	Flex spine so palms touch floor with knees fully extended	
8-point Wynne and Davies ⁴⁶	Thumb to volar aspect of forearm	≥5 ⁴⁶
	5th MCP hyperextension >90°	
	Elbow hyperextension	
	Knee hyperextension	

^aOriginal references cited within text with no description of test provided for 5-point Beighton and Horan⁹ or combination of joint laxity, looseness, and mobility test.²⁵

MCP, metacarpophalangeal joint.

Data were extracted from 4 studies comprising 1043 participants in the contact activities of soccer, gridiron, basketball, diving,³⁸ and Army recruit training (Figure 3). Army recruit training was included as a contact activity because of the nature of combatant activities and the high-impact body contact with the ground likely to be involved. Using the standardized definition of GJH, a combined odds ratio of 4.69 (95% CI, 1.33-16.52; $P = .02$; $I^2 = 82.81\%$) was calculated, indicating a significant increased risk of knee joint injury for hypermobile participants playing contact sports.

Three studies of participants in contact sports^{13,23,32} provided knee injury data that could be categorized into the 3 mobility-status groups (not hypermobile, hypermobile, and extremely hypermobile, using the standardized definition of GJH). When the proportion of nonhypermobile participants who sustained knee injuries was compared with those who were hypermobile or extremely hypermobile (combined), the difference was statistically significant ($z = 4.08$; $P < .001$), with the hypermobile groups injured more often (Figure 5).

TABLE 5
Odds Ratios and 95% Confidence Intervals for Studies Using the Authors' Definition of GJH^a

Author(s) (Year)	Type of Sport	Area of Injury	Odds Ratio	95% Confidence Interval
Beynon et al ⁶ (2001)	Contact	Ankle	1.38	0.22-6.01
Diaz et al ¹³ (1993)	Contact	Lower limb	3.40	1.66-7.15
		Knee	2.52	1.02-6.31
		Ankle	5.33	1.51-23.50
Decoster et al ¹¹ (1999)	Contact	Ankle	1.99	0.57-6.30
Hiller et al ¹⁶ (2008)	Noncontact	Ankle	1.40	0.57-3.41
Kalenak and Morehouse ²¹ (1975)	Contact	Knee	1.08	0.36-3.24
Krivickas and Feinberg ²³ (1996)	Mixed	Lower limb	0.65	0.27-1.45
		Knee	0.72	0.20-2.15
		Ankle	0.48	0.11-1.51
McHugh et al ²⁶ (2006)	Mixed	Ankle	0.61	0.15-1.93
Nicholas ³² (1970)	Contact	Knee	15.56	3.61-138.32
Ostenberg and Roos ³³ (2000)	Contact	Knee	5.32	1.59-18.26
Soderman et al ⁴² (2001)	Contact	Lower limb	2.24	0.79-6.71

^aGJH, generalized joint hypermobility.

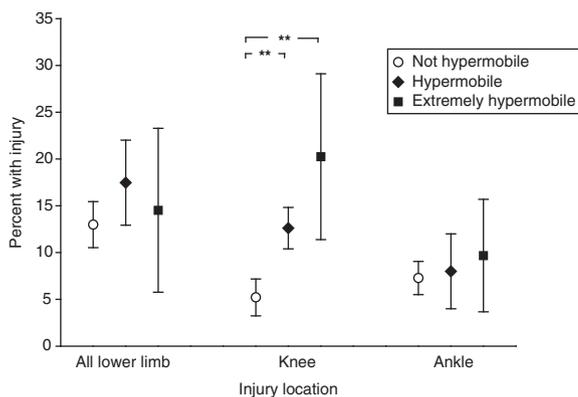


Figure 5. Proportion of injuries by hypermobility status. Bars represent 95% confidence intervals. **Difference in proportions of injuries significant at $P < .001$ level.

Ankle Joint Injuries. Original authors' definition: Odds ratios and CIs for ankle joint injury were calculated from 6 studies using the original authors' definition of GJH (Table 5). The combined odds ratio was 1.34 (95% CI, 0.69-2.60; $P = .39$; $I^2 = 55.2\%$).

Standardized definition: Pooling 1361 individual data sets from the studies providing data able to use the standardized definition of GJH, 8.74% of participants suffered ankle joint injuries. The combined odds ratio of 1.28 (95% CI, 0.62-2.63; $P = .51$; $I^2 = 59.4\%$) was not significantly different from 1 (Figure 4). Combined data from 4 studies^{13,16,23,26} providing the continuous scores from 1244 sports participants demonstrated the 95% CIs between the nonhypermobile, hypermobile, and extremely hypermobile groups all overlapping (Figure 5). There was, therefore, no significant difference in ankle injury rates between these groups or the nonhypermobile and combined hypermobile and extremely hypermobile group ($z = 1.22$; $P = .22$).

Joint Injuries Incurred During Participation in Different Sports: Contact, Limited Contact, Noncontact, or Mixed

Relating lower limb, knee, and ankle joint injuries to the type of sporting activity undertaken (contact, limited contact, noncontact, or mixed), differences became apparent. Studies involving mixed sporting activities had lower odds ratios compared with those obtained for the contact or collision sports, with no odds ratio equal to or above 1.00 for any of the mixed sporting activity studies, whereas all collision or contact sporting activity studies generated odds ratios greater than 1 when using the standardized definition of GJH (Figures 1, 2, and 4).

DISCUSSION

The findings of this review and meta-analyses indicate that for those people who have GJH, there is a significantly increased risk of injury to the knee joint during participation in contact sports; however, the ankle joint is not at an increased risk of injury during any sporting participation.

Much of the current literature is consistent with the findings of the present review. Several prospective studies of ankle injuries incurred during a range of sporting activities have been undertaken, with most finding no significantly increased risk of injury associated with GJH.^{5,6,16,23,26} A recent systematic review of the predictors of ankle injury reported that it was reduced ankle dorsiflexion range of motion (hypomobility at the ankle) that was a strong predictor of ankle sprains.¹⁰ With respect to the knee joint, our findings support studies suggesting that individuals with increased knee hyperextension are at increased risk of anterior cruciate ligament injury,^{31,36} one of the most common knee joint injuries.

The increased risk of knee injury but not ankle injury in sports participants with GJH has not been reported previously; however, it is consistent with ankle and knee joint anatomy and biomechanics. Ankle stability relies on both active (musculotendinous) and passive (ligamentous) restraints to prevent injury, whereas the knee relies to a greater extent on passive restraints. The most common ankle injury, lateral ankle sprain, occurs as a result of unrestrained inversion and plantar flexion.⁸ Along with the passive restraints to inversion provided by the lateral ligament complex, the peroneus longus and brevis also provide active restraint. Both active and passive tissues, in conjunction with the bony congruency of the talocrural joint, provide restraint to all planes of the movement at the ankle joint.² However, the knee has less bony congruency and the alignment and action of surrounding musculature offer little active joint restraint. Most knee joint injuries occur either at the end of extension range, or involve unrestrained rotation, varus, or valgus force.⁸ While the large hamstring muscle group, sartorius and gracilis, provide some active restraint to the end range of knee extension, their moment arms are small, rendering them unlikely to be able to provide sufficient torque to restrain extension. During rotatory, valgus, and varus motion, passive restraint is provided by tension in the cruciate, medial, and lateral collateral ligaments, respectively. There is minimal active control of rotation and no active control of varus or valgus movement at the knee joint,²⁷ which relies almost completely on the passive ligamentous and capsular restraints to prevent injury. When the foot remains in contact with the ground as forces are applied to the joints (such as in the contact sport of football, where the player wears studded or cleated shoes), greater internal torques are created at the knee joint than at the ankle joint because of the increased distance from the ground, again further predisposing the knee joint to injury. The sporting participant with GJH may rely more on their dynamic muscular control to maintain joint stability of their lax lower limb joints than their nonhypermobile peers, placing them at greater risk of musculotendinous as well as capsuloligamentous injury.

The intention of the current study was to combine the results from many available studies. However, of the 18 included studies, the results from 10 studies were ineligible for meta-analysis because of the method of reporting data. Meta-analysis performed with access to individual patient data sets is highly desirable as it allows consistency of data analysis.⁴

Variation in the definition and assessment of GJH is evident within this review. Seven different objective measures of GJH, involving 10 differing measurement methods, were used in the 18 studies. These methods of determining GJH vary in terms of the particular joints assessed, the range considered hypermobile, and the application of an injury allowance point (Table 4). While all the tests aim to be measures of GJH, upper limb mobility measures are highly represented in the Beighton scale, while lower limb measures dominate the Nicholas scale, raising questions about the face validity of either scale in relation to generalized or whole body mobility.

Several differing cutoff points to indicate the presence of GJH were used for the same tests of GJH reported within this review. Every effort was made to establish the risk of injury related to GJH utilizing all available data across the 18 studies by using the standardized criterion; however, conversion of the 5-point scale to a 9-point scale may be somewhat ambitious. The odds ratios calculated using the authors' original definition of GJH differed from those calculated using the standardized definition of GJH, yet the overall results were similar.

Definitional inconsistencies encountered during this review were not limited to those concerning GJH. Different definitions of "injury" were also used among the studies reviewed. These varied from diagnostic definitions, for example ligament rupture confirmed under arthroscopy,³² to functional definitions such as absence from training or a game because of injury.³³ Increased uniformity in the reporting of injury incidence in prospective cohort trials is recommended.

One of the confounders to determining the risk of lower limb joint injury for those with GJH is that the studies available cover a wide range of sports (from ballet to gridiron) as well as a range of levels of participation (from recreational to occupational and elite). A previous review was inconclusive as to whether professional competition or amateur participation resulted in a greater risk of injury.²⁹ Sporting activities included in the present systematic review varied extensively in both the demands of the sporting tasks undertaken and the level at which participation occurred (Table 2). The injury rate varied within the included studies, which is likely to be attributable to multiple factors, including not only sporting activity undertaken but also the definition of "injury" used. Investigating risk of injury related to type of sport by categorizing those sports according to the American Academy of Pediatrics classification³⁸ revealed a marked difference between contact and other sporting activities. Generalized joint hypermobility may indeed be protective against injury in some limited contact and noncontact sports; however, the results of this study indicate that there is an increased risk of injury, particularly to the knee, for participants with GJH during contact activities.

In conclusion, the risk of ankle injury while participating in sporting activities is not altered by the presence of GJH, yet individuals with GJH do have an increased risk of knee injury during sporting activities, particularly during contact sporting activities. Improved consistency in the measurement of GJH and definitions of injury used within research studies may assist in providing further evidence as to which sports are associated with the least risk to hypermobile individuals.

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