

CORRIGENDUM

In the February 2020 issue of the *JOSPT*, the article “Young Athletes Who Return to Sport Before 9 Months After Anterior Cruciate Ligament Reconstruction Have a Rate of New Injury 7 Times That of Those Who

Delay Return” erroneously reported that females were 64% of the total sample. When the data were extracted again, the authors found that 22 participants (total sample, $n = 159$) had been misclassified as females, making

the actual percentage of females 50%. The text, **TABLES 4** and **6**, and the **APPENDIX** have been corrected to reflect this finding. The updated article is available at www.jospt.org.●

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FIGURE 1. Lateral radiograph of the left ankle, non-weight bearing, with deformity of the inferior talus and lucency at the talar neck. Small ossific fragments are visible adjacent to the distal anterior tibia within the tibiotalar joint, which may represent a small avulsion fracture and an apparent ossicle at the calcaneocuboid junction.



FIGURE 2. Lateral radiograph of the right ankle, non-weight bearing, with intra-articular deformity of the inferior talus (with lucency) and Hawkins type 2 gapping at the talar neck.

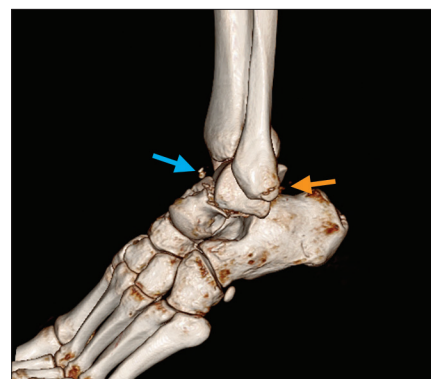


FIGURE 3. A 3-D reconstruction computed tomography image of the left ankle without contrast, demonstrating a comminuted impacted fracture of the left talus, with rotary subluxation of the tibiotalar joint, extensive fragmentation, and impaction through the talus (blue arrow), as well as a nondisplaced fracture of the lateral malleolus (orange arrow).

Simultaneous Bilateral Fractures of the Tali

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A 22-YEAR-OLD MALE US MILITARY Academy cadet fell while sidestepping across the 8-ft-high bar portion of the indoor obstacle course. The cadet described landing on cushioned mats with his ankles inverted and feet supinated. The cadet, in immense pain, was unable to bear weight immediately after the fall. Direct-access, sports fellowship-trained physical therapists working within the cadet fitness center were summoned to provide care.

Significant bilateral ankle bony deformities were observed. The cadet was unable to evert or dorsiflex either ankle due to mechanical blocks. Initially neurovas-

cularly intact, palpable cooling was noted in his right foot after a few minutes. Physical exam confirmed bilateral mechanical blocks, raising concern for intra-articular fractures and/or dislocations. Emergency medical service personnel transported the cadet to the emergency department for definitive care.

Radiographs demonstrated impaction fractures of the tali, and correlation with computed tomography or magnetic resonance imaging was recommended (FIGURES 1 and 2). To improve diagnostic imaging accuracy and surgical planning, bilateral ankle computed tomography scans were ordered by the orthopaedist to assess the

talar neck fractures.¹ Computed tomography imaging of his ankles demonstrated Hawkins type 2 fractures bilaterally, indicating talar neck displacement and dislocation of the subtalar joints (FIGURE 3).^{1,3}

The cadet underwent bilateral open reduction and internal fixation of the tali. Due to the severity of injury and the prognosis and length of recovery, the cadet did not return to military service. Talus fractures account for approximately 0.1% of all fractures. Initially observed in Royal Air Force pilots, talus fractures were first termed “aviator’s astragalus.”² *J Orthop Sports Phys Ther* 2020;50(7):409. doi:10.2519/jospt.2020.9098

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2. Coltart WD. Aviator’s astragalus. *J Bone Joint Surg Br*. 1952;34-B:545-566.
3. Gérard R, Kerfant N, Dubois de Mont Marin G, Stern R, Assal M. Hawkins’ type-II talar fracture with subtalar dislocation: a very unusual combination. *Orthop Traumatol Surg Res*. 2017;103:403-406. <https://doi.org/10.1016/j.otsr.2016.12.009>

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the US Army or Department of Defense.

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Patient Education for Patellofemoral Pain: A Systematic Review

Patellofemoral pain (PFP), characterized by diffuse anterior knee pain,¹⁵ is one of the most common knee conditions. The prevalence of PFP ranges from 7% to 35%, with the highest prevalence in sporting populations.^{18,46} Exercise therapy, with or without additional interventions (manual therapy, taping, or foot orthoses), is supported by level 1 evidence for managing PFP.^{2,12,30}



expectations), which is considered essential by clinicians and researchers.^{1,2,12} Patient education is frequently included in PFP trials as part of a combined treatment approach or used as a comparator.

However, the efficacy of patient education for PFP is not known.

We aimed to evaluate the effect of education interventions (combined with other treatments or in isolation) in people with PFP compared to any other comparator.

METHODS

REPORTING FOLLOWED THE Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.³¹ The protocol was registered in the PROSPERO database in February 2018 (registration number CRD42018088671).³⁸ Patients or public partners were not involved in the design, conduct, or interpretation of this systematic review.

Deviations From Study Registration and the Study Protocol

In our preregistered protocol, we planned a mixed-methods study, including a cross-sectional analysis of general web content. Following suggestions from the peer-review process, we decided to separate the cross-sectional analysis from this systematic review. We preplanned to determine the quality of evidence by using a modified

One in 3 people continue to experience symptoms 12 months following treatment,¹³ and 1 in 4 people report persistent symptoms 20 years after diagnosis.³⁷ Persistent PFP is associated with higher body mass index,²⁴ pain-related fear,⁴⁰ impaired quality of life,⁹ reduced physical activity levels,²³ increased risk of ceasing sports participation,⁴² and manifestations of pain sensitization.¹⁷ The high

prevalence of poor long-term outcomes highlights the need to identify additional treatment targets and resources for improved self-management.

One potential solution to improve long-term outcomes (longer than 12 months) is to provide high-quality patient education (eg, patient-specific advice and information on the condition, empowering patients to manage their

• **OBJECTIVE:** To evaluate the effect of education interventions compared with any type of comparator on managing patellofemoral pain (PFP).

• **DESIGN:** Intervention systematic review. PROSPERO identifier: CRD42018088671.

• **LITERATURE SEARCH:** MEDLINE, Embase, CINAHL, and Web of Science were searched for studies evaluating the effect of education on clinical and functional outcomes in people with PFP.

• **STUDY SELECTION CRITERIA:** Two reviewers independently assessed studies for inclusion and quality. We included randomized controlled trials on PFP where at least 1 group received an education intervention (in isolation or in combination with other interventions).

• **DATA SYNTHESIS:** Available data were synthesized via meta-analysis where possible; data that were not appropriate for pooling were synthesized qualitatively. Interpretation was guided by the Grad-

ing of Recommendations Assessment, Development and Evaluation approach.

• **RESULTS:** Nine trials were identified. Low-credibility evidence indicated that health education material alone was inferior to exercise therapy for pain and function outcomes. Low- and very low-credibility evidence indicated that health professional-delivered education alone produced outcomes similar to those of exercise therapy combined with health professional-delivered education for pain and function, respectively.

• **CONCLUSION:** Health professional-delivered education may produce similar outcomes in pain and function compared to exercise therapy plus health professional-delivered education in people with PFP. *J Orthop Sports Phys Ther* 2020;50(7):388-396. Epub 29 Apr 2020. doi:10.2519/jospt.2020.9400

• **KEY WORDS:** anterior knee pain, health, knee, rehabilitation

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version of van Tulder's criteria. However, following suggestions from the peer-review process, we decided to use the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Search Strategy and Screening Process

We searched the MEDLINE, Embase, CINAHL, and Web of Science databases from inception to February 2019. The electronic search was complemented by searching the reference lists of the retrieved articles. The full search strategy is available in **APPENDIX A** (available at www.jospt.org). A review author (D.O.S.) exported all studies identified by the search to EndNote Version X7.5 (Clarivate Analytics, Philadelphia, PA), then cross-referenced the results and deleted duplicates. Two review authors (D.O.S. and M.P.) independently screened all titles and abstracts. Full-text articles were obtained for those eligible for full-text screening, based on the inclusion and exclusion criteria (outlined below). All full-text articles were screened in duplicate, any discrepancies were resolved during a consensus meeting, and a third reviewer was available (C.B.) if needed.

Inclusion and Exclusion Criteria

We included randomized controlled trials on PFP in which at least 1 group received an education intervention (in isolation or in combination with other interventions). We defined education as providing information, advice, and/or behavior modification techniques, aimed at influencing a person's knowledge, health behavior, and/or coping strategies.^{20,39} The comparison group could be any other intervention, "wait and see," or a combined intervention (eg, education and exercise compared to exercise alone, or education and exercise compared to education alone). Abstracts, posters, unpublished trials, nonrandomized controlled trials, articles unrelated to PFP, and trials without at least 1 education intervention group were excluded.

Participants must have been diagnosed with PFP in line with current rec-

ommendations for PFP diagnosis.¹⁵ There were no restrictions for sex, age, year, or language of publication. In the event of unreported data, missing data, or data that could not be extracted, the study's authors were contacted via e-mail. If the authors could not provide the missing data or did not reply to the request after 3 attempts, the study was excluded from further statistical analysis.

Outcomes

The primary outcome was self-reported pain. Secondary outcomes were self-reported function, objective function, quality of life, lower-limb strength, and psychological factors (ie, depression, anxiety).

Quality Assessment

Two review authors (M.P. and E.B.) used the Physiotherapy Evidence Database scale to independently evaluate the quality of the trials.³⁴ This is a validated and reliable appraisal tool designed to assess methodological quality in clinical trials and consists of 11 items.³⁴ We rated trials as high quality (7/10 or greater), moderate quality (4-6/10), and low quality (3/10 or less). When available, the score was cross-checked with the Physiotherapy Evidence Database. Any discrepancies were resolved during a consensus meeting, and a third reviewer was available (D.O.S.) when disagreements could not be resolved.

Assessment of Risk of Bias

Two review authors (D.O.S. and M.P.) independently assessed the risk of bias using the Cochrane risk-of-bias tool. Any discrepancies were resolved in a consensus meeting, and a third reviewer was available (C.B.). We assessed random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Other sources of bias were lack of comparability in clinicians' experience with the interventions under testing and compliance with the intervention. As these potential sources of bias were not covered

by those previously mentioned items, we included them. The domains were classified as low risk of bias, high risk of bias, or unclear risk of bias ("unclear" referring to a lack of information or uncertainty over the potential for bias).

Data Extraction

Two review authors (D.O.S. and M.P.) independently extracted data using a standardized data-extraction sheet and compared the extracted data. Inconsistencies were discussed between the reviewers. The following data were extracted: trial characteristics (publication details, author, and year), participant characteristics (population, age, sex, body mass index, and number of participants in each group), education resource development process (description, expert and/or end-user consultation), intervention description (extracted using the Template for Intervention Description and Replication [TIDieR] checklist as a guide), and education delivery method (website, advice, leaflet with no time dedicated to education, leaflet with time dedicated to education).

Data Synthesis and Statistical Analysis

We pooled data (using Review Manager Version 5.3; The Nordic Cochrane Centre, Copenhagen, Denmark) if trials investigated similar interventions (eg, health education material or education delivered by a health professional) using comparable outcome measures (eg, self-reported pain using a visual analog scale) at comparable time points. We considered short term to be less than 12 weeks, medium term to be 6 months to less than 12 months, and long term to be 12 months or longer from treatment commencement.

Data that were not appropriate for pooling were summarized in a table. We calculated the standardized mean differences (SMDs) with 95% confidence intervals (CIs) for both pooled and unpooled continuous data from the end of treatment and subsequent follow-ups. The end-of-treatment time point was based on the intervention duration of each trial.

[LITERATURE REVIEW]

For quantitative synthesis, we used random-effects models and calculated pooled point estimates and 95% CIs. We quantified heterogeneity with the I^2 statistic. Individual or pooled SMDs were categorized as small (0.59 or less), medium (0.60–1.19), or large (1.20 or greater).^{7,27}

Quality of evidence for each outcome was assessed according to the Grading of Recommendations Assessment, Development and Evaluation approach, per section 12.2 of the *Cochrane Handbook for Systematic Reviews of Interventions*.²⁵ We assessed the quality of the evidence for the following comparisons: health education material compared to supervised exercise therapy plus education material, and health professional–delivered education compared to exercise therapy plus health professional–delivered education. We presented knee pain, knee self-reported function, and knee extensor isometric strength at the end of treatment (short term) and in the medium and/or long term (3 months or longer). We did not assess quality of evidence for outcomes present in 1 study (see **APPENDIX B**, available at www.jospt.org, for a detailed description).

For trials with 2 or more comparator groups,^{36,47} we combined groups to prevent a unit-of-analysis error due to the unaddressed correlation between the estimated intervention effects from multiple comparisons.²⁵ To perform the combination of 2 or more comparator groups, we used the formulae described in section 7.7.3.8 of the *Cochrane Handbook*.²⁵

RESULTS

SIX THOUSAND NINE HUNDRED eighty-two records were identified for screening, prior to removal of duplicates (**FIGURE 1**). Nine trials were eligible based on full-text screening; we excluded 1 trial due to inability to retrieve data (after 3 attempts to contact the authors).²⁸ Three trials delivered education via leaflets or booklets^{36,47,48} and 5 trials delivered education via a health professional.^{8,21,35,43,44} Comparators were exercise therapy (stretching, strengthening),^{21,35,36,43,44,48} taping,^{8,35} and gait retraining.²¹ The content of all interventions is described in **APPENDIX C** (available at www.jospt.org).

Participant Characteristics of Included Studies

Trial characteristics are outlined in **APPENDIX D** (available at www.jospt.org). There were 731 participants with PFP (467 women, 63.8%). The mean age ranged from 13 to 82 years and the mean body mass index ranged from 21 to 25.2 kg/m². Of the 731 participants, 279 (38%) were included in the education intervention group and 452 (62%) were included in the comparator groups. The trial populations included adolescents,^{43,44} young adults,^{8,47,48} older adults,^{35,36} and runners²¹ with PFP.

Methodological Quality Assessment and Risk of Bias

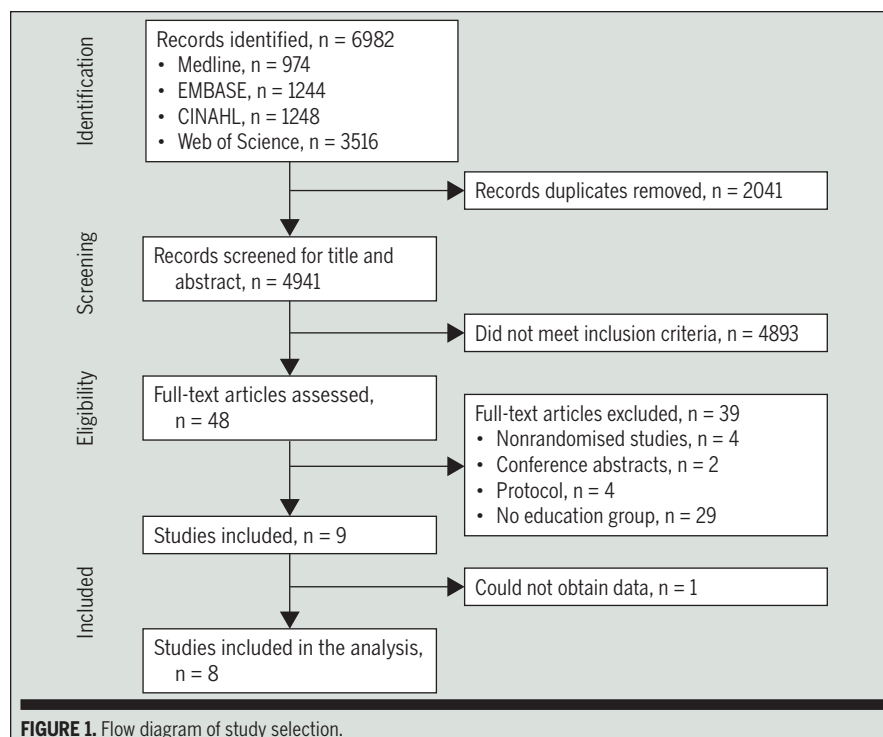
Three trials were rated as high quality^{8,21,47} and 6 trials were rated as moderate quality^{28,35,36,43,44,48} (**APPENDIX E**, available at www.jospt.org). Domains with the highest risk of bias were blinding of participants (89%) and allocation concealment (44%) (**FIGURE 2**). Descriptions of educational interventions lacked many of the specific items from the TIDieR checklist, particularly details such as location of the intervention (50%), adherence to the intervention (100%), and the content of the intervention (85%). No included manuscripts fulfilled all criteria proposed by the TIDieR checklist.

Number of Sessions of Each Intervention

Trials offered an average of 2 education sessions to participants with PFP. When education was offered as health education material, an average of 1 session was reported. When education was delivered via a health professional, there was an average of 3 sessions. An average of 20.5 exercise therapy sessions were offered for participants with PFP in exercise groups. For taping and gait retraining interventions, an average of 3.5 and 5 sessions were offered, respectively (**APPENDIX C**).

Effect of Education Intervention Versus Exercise Therapy on Knee Pain

Data were available for pooling to compare (1) education material versus exer-



cise therapy for pain (visual analog scale and/or numeric rating scale of worst pain), and (2) education delivered verbally by a health professional versus exercise therapy plus education delivered by a health professional for pain (as above).

There was low-credibility evidence from 3 trials^{36,47,48} (314 participants) of greater short-term reduction in knee pain with supervised exercise therapy plus health education material compared with health education material alone (SMD, 1.12; 95% CI: 0.07, 2.17) (FIGURE 3). There was low-credibility evidence from 1 trial⁴⁸ (131 participants) of no difference between health education material and supervised exercise therapy plus health education material for knee pain in the long term (SMD, 0.31; 95% CI: -0.04, 0.65). There was low-credibility evidence from 3 trials^{8,21,43} (209 participants) of no difference between health education material verbally delivered by a health professional and exercise therapy plus health professional-delivered education for knee pain in the short term (SMD, 0.14; 95% CI: -0.56, 0.85) (FIGURE 3) and medium term (SMD, 0.30; 95% CI: -0.30, 0.89) (FIGURE 3).

Effect of Education Intervention Versus Exercise Therapy on Secondary Outcomes

Regarding the secondary analyses, data were available for pooling on (1) the effect of health education material versus exercise therapy on self-reported function, and (2) the effect of health professional-delivered education versus exercise therapy plus health professional-delivered education on self-reported function and knee extensor isometric strength (FIGURE 4). The results that could not be pooled were synthesized qualitatively and are summarized in APPENDIX F (available at www.jospt.org).

There was low-credibility evidence from 3 trials^{36,47,48} (314 participants) indicating greater self-reported function in the short term after exercise therapy compared to health education material (SMD, -1.28; 95% CI: -2.28, -0.27) (FIGURE 4). There was very low-credibility evidence

from 2 trials^{8,43} (163 participants) of no difference between health professional-delivered education and exercise therapy plus health professional-delivered education for self-reported function in the short term (SMD, -0.73; 95% CI: -1.57, 0.11) (FIGURE 4). There was low-credibility evidence from 3 trials^{8,21,43} (145 participants) of no difference between health

professional-delivered education and exercise therapy for knee extensor isometric strength in people with PFP in the short term (SMD, -0.29; 95% CI: -0.62, 0.04) (FIGURE 4).

Findings from one trial indicated that knee range of motion,³⁶ and another that vastus medialis cross-sectional area and volume,⁴⁷ increased more in the short

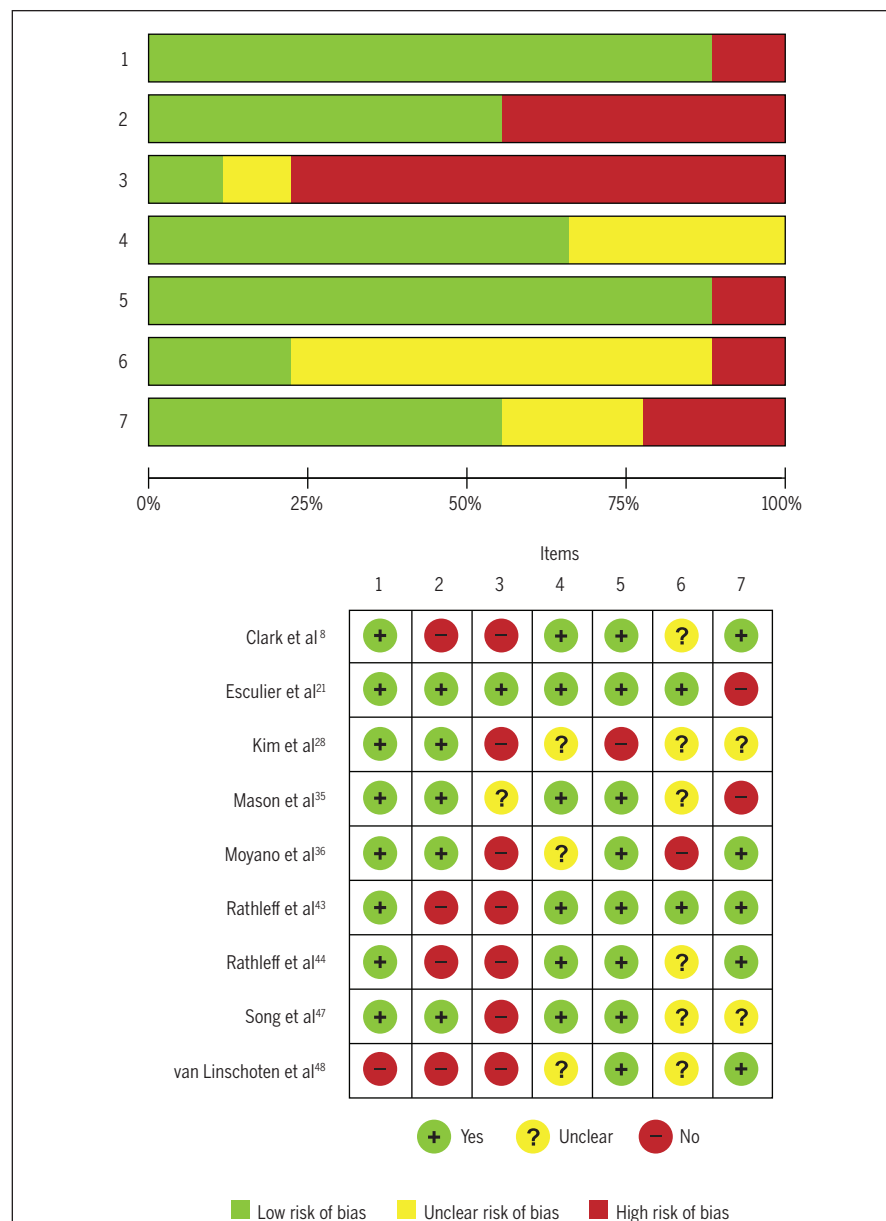


FIGURE 2. Risk-of-bias assessment in answer to the following items: 1, Random sequence generation (selection bias); 2, Allocation concealment (selection bias); 3, Blinding of participants and personnel (performance bias); 4, Blinding of outcome assessment (detection bias); 5, Incomplete outcome data (attrition bias); 6, Selective reporting (reporting bias); 7, Baseline characteristics (other bias).

[LITERATURE REVIEW]

term with supervised exercise therapy compared to health education material (APPENDIX F). Findings from individual studies indicated no difference between health professional-delivered education and exercise therapy plus health professional-delivered education for knee-related quality of life,⁴³ anxiety,⁸ depression,⁸ and weekly running distance²¹ in people with PFP in the short term (APPENDIX F).

Effect of Education Intervention Versus Other Interventions

There was no difference between health education delivered by a health profes-

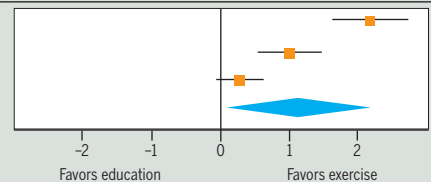
sional and taping plus health professional-delivered education on worst knee pain (SMD, -0.54; 95% CI: -1.16, 0.09), knee pain ascending or descending stairs, self-reported function, anxiety, depression, and knee extensor isometric strength^{8,35} (APPENDIX F). There was no difference between health professional-delivered education and gait retraining plus health professional-delivered education on worst knee pain (SMD, -0.28; 95% CI: -0.86, 0.30) and weekly running distance for runners with PFP in the short term (APPENDIX F).²¹

DISCUSSION

WE IDENTIFIED 9 TRIALS EVALUATING education interventions in people with PFP. Low-credibility evidence suggested that patient education delivered by a health care professional produced similar improvements in pain and function as those seen after exercise therapy combined with health professional-delivered education. There was low-credibility evidence that health education material was inferior to exercise therapy for improvements in self-reported pain and function.

Health Education Material Versus Exercise Therapy: Short Term

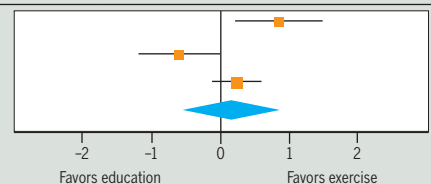
Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Moyano et al ³⁶	6.57 ± 1.39	26	2.30 ± 2.14	68	32.4%	2.16 (1.60, 2.71)
Song et al ⁴⁷	4.81 ± 2.55	30	2.34 ± 2.44	59	33.3%	0.99 (0.52, 1.45)
van Linschoten et al ⁴⁸	4.60 ± 3.00	66	3.81 ± 2.90	65	34.3%	0.27 (-0.08, 0.61)
Total ^a		122		192	100.0%	1.12 (0.07, 2.17)



^aHeterogeneity: $\tau^2 = 0.80$, $\chi^2 = 32.99$, $df = 2$ ($P < .0001$), $I^2 = 94\%$. Test for overall effect: $z = 2.09$ ($P = .04$).
Abbreviations: IV, inverse variance; SMD, standardized mean difference.

Health Professional-Delivered Education Versus Exercise Therapy: Short Term

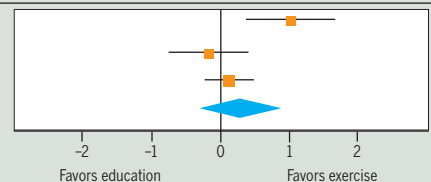
Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Clark et al ⁸	4.2 ± 1.4	22	3.0 ± 1.39	20	30.9%	0.83 (0.20, 1.46)
Esculier et al ²¹	3.1 ± 1.6	23	4.4 ± 2.5	23	31.9%	-0.61 (-1.20, -0.02)
Rathleff et al ⁴³	5.1 ± 2.7	59	4.0 ± 6.4	62	37.3%	0.22 (-0.14, 0.58)
Total ^a		104		105	100.0%	0.14 (-0.56, 0.85)



^aHeterogeneity: $\tau^2 = 0.31$, $\chi^2 = 10.87$, $df = 2$ ($P = .004$), $I^2 = 82\%$. Test for overall effect: $z = 0.40$ ($P = .69$).
Abbreviations: IV, inverse variance; SMD, standardized mean difference.

Health Professional-Delivered Education Versus Exercise Therapy: Medium Term

Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Clark et al ⁸	5.1 ± 1.3	22	3.7 ± 1.4	20	29.5%	1.02 (0.37, 1.67)
Esculier et al ²¹	2.3 ± 1.8	23	2.7 ± 2.7	23	31.7%	-0.17 (-0.75, 0.41)
Rathleff et al ⁴³	5.1 ± 7.6	59	4.1 ± 7.8	62	38.9%	0.13 (-0.23, 0.49)
Total ^a		104		105	100.0%	0.30 (-0.30, 0.89)



^aHeterogeneity: $\tau^2 = 0.20$, $\chi^2 = 7.85$, $df = 2$ ($P = .02$), $I^2 = 75\%$. Test for overall effect: $z = 0.97$ ($P = .33$).
Abbreviations: IV, inverse variance; SMD, standardized mean difference.

FIGURE 3. Meta-analyses for knee pain.

Implications for Practice

If a health professional delivers patient education alone, it may be as effective for improving pain and function as combining education with exercise therapy, gait retraining, or taping interventions. This is despite requiring a much smaller number of visits (one sixth on average). The most consistent education content delivered by health professionals in the included trials was (1) advice on load management, (2) advice on self-management of pain, and (3) explanation of the nature and possible causes of PFP.

Health education material may be less effective compared with exercise therapy

for improving pain, function, and physical outcomes such as knee range of motion, quadriceps cross-sectional area, and muscle volume in people with PFP.³⁶ Key differences between health education material and health professional–delivered education include shorter consultation time or fewer sessions and reduced specific guidance on PFP management. Most of the educational material used in the trials is not available for public use, which limits implementation and translation of findings into clinical practice.

Implications for Research

Patient education is not mentioned as

a recommended intervention in recent international consensus statements on managing PFP.^{12,16} We suggest that future clinical practice guidelines and consensus statements consider addressing the role of patient education. However, trials on education are needed, because the current evidence is of low credibility at best.

Education content and mode of delivery may play an important role in the potential for education to assist a patient's recovery. We did not identify any trials evaluating online education for people with PFP. Previous research has reported benefits of online education and exercise interventions for other musculoskeletal

Health Education Material Versus Exercise Therapy—Knee Function: Short Term

Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Moyano et al ³⁶	29.95 ± 10.6	26	61.14 ± 13.99	68	32.2%	-2.35 (-2.92, -1.78)
Song et al ⁴⁷	75.7 ± 10.9	30	86.11 ± 9.44	59	33.3%	-1.04 (-1.50, -0.57)
van Linschoten et al ⁴⁸	74.9 ± 17.6	66	83.2 ± 14.8	65	34.4%	-0.51 (-0.86, -0.16)
Total ^a		122		192	100.0%	-1.28 (-2.28, -0.27)

^aHeterogeneity: $\tau^2 = 0.73$, $\chi^2 = 29.48$, $df = 2$ ($P < .0001$), $I^2 = 93\%$. Test for overall effect: $z = 2.49$ ($P = .01$).

Abbreviations: IV, inverse variance; SMD, standardized mean difference.

Health Professional–Delivered Education Versus Exercise Therapy—Knee Function: Short Term

Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Clark et al ⁸	86.2 ± 15.8	22	90 ± 11.8	20	46.1%	-0.27 (-0.87, 0.34)
Rathleff et al ⁴³	81 ± 5.88	59	89 ± 8.03	62	53.9%	-1.13 (-1.51, -0.74)
Total ^a		81		82	100.0%	-0.73 (-1.57, 0.11)

^aHeterogeneity: $\tau^2 = 0.30$, $\chi^2 = 5.48$, $df = 1$ ($P = .02$), $I^2 = 82\%$. Test for overall effect: $z = 1.70$ ($P = .09$).

Abbreviations: IV, inverse variance; SMD, standardized mean difference.

Health Professional–Delivered Education Versus Exercise Therapy—Knee Extensor Strength: Short Term

Study	Education		Exercise		Weight	SMD IV, Random (95% Confidence Interval)
	Mean ± SD	Total, n	Mean ± SD	Total, n		
Clark et al ⁸	279.9 ± 155.1	22	307.9 ± 193.6	20	29.3%	-0.16 (-0.76, 0.45)
Esculier et al ²¹	70.9 ± 15.2	23	72.7 ± 17	23	32.2%	-0.11 (-0.69, 0.47)
Rathleff et al ⁴³	2.17 ± 0.59	29	2.54 ± 0.74	28	38.5%	-0.55 (-1.08, -0.02)
Total ^a		74		71	100.0%	-0.29 (-0.62, 0.04)

^aHeterogeneity: $\tau^2 = 0.00$, $\chi^2 = 1.46$, $df = 2$ ($P = .48$), $I^2 = 0\%$. Test for overall effect: $z = 1.74$ ($P = .08$).

Abbreviations: IV, inverse variance; SMD, standardized mean difference.

FIGURE 4. Self-reported knee function and strength meta-analyses.

conditions, including improvements in pain.⁴⁻⁶ Recent digital and social media innovations provide opportunities for enhanced knowledge translation,³ and an increasing number of people use the internet to seek health information.^{10,45} Further research and development of online education for people with PFP is needed. Such an approach could yield an effective and highly scalable management strategy at low cost.

There are currently no published trials evaluating patient education compared to a no-treatment control in people with PFP. A trial has reported improvements of large effect in pain and function in people with knee osteoarthritis in favor of education compared to no treatment.¹¹ Testing efficacy of education should be a priority for PFP research. Considering recent reports of psychological factors associated with PFP, including kinesiophobia,^{33,40} pain catastrophizing,^{32,40} depression,³² and anxiety,^{32,33} development and evaluation of educational interventions that incorporate psychological support should also be a future research priority.

Limitations

Our findings from very low- to low-credibility evidence that health professional-delivered education produces outcomes similar to those of exercise therapy, taping, or gait retraining are based on high heterogeneity in some meta-analyses. Variable outcomes are possibly the result of the different education and exercise therapy interventions evaluated. These findings indicate that any recommendation on patient education remains challenging, and further research is warranted to determine whether patient education is effective in improving clinical outcomes. In addition, 44% of the studies included in our systematic review did not conceal participant allocation, which may be an important source of bias. Overall, the description of educational interventions was poor (eg, 85% did not clearly describe the content of the intervention). Only 1 trial provided the educational content used,⁴³ and previous reviews have

highlighted limited²⁶ and sometimes inaccurate²⁹ reporting related to exercise therapy. This is a barrier to implementing current education interventions in clinical practice. We recommend that future studies adopt the TIDieR guidelines to design their education interventions.

Education interventions appear to have been developed with limited code-sign elements, including partnership with patients and other stakeholders in the development of interventions.^{14,49} Development of education strategies may also benefit from inclusion of cognitive, behavioral, or learning theories, which, when used, are associated with moderate to large effects on patient self-efficacy in people with other chronic musculoskeletal conditions.^{19,22} Such an approach has also been reported to result in large improvements in pain and function in a large (n = 151) adolescent PFP cohort.⁴¹ Further evaluation of similar interventions in people of all ages with PFP via high-quality trials is warranted.

CONCLUSION

HEALTH PROFESSIONAL-DELIVERED education produced similar outcomes in pain and function compared to exercise therapy plus health professional-delivered education in people with PFP at 3 and 6 months post intervention. Health education material alone was inferior to exercise therapy for improving pain and function at 3 months post intervention. ●

KEY POINTS

FINDINGS: Health professional-delivered education produced similar outcomes in pain and function compared to exercise therapy plus health professional-delivered education at 3 and 6 months post intervention. Health education material alone was inferior to exercise therapy for improving pain and function at 3 months post intervention.

IMPLICATIONS: Health professional-delivered education provided similar outcomes to those of exercise therapy

in fewer sessions. Advice about load management, self-management of pain, and explanation of the nature and possible causes of patellofemoral pain were the most consistent types of education used. Health education material alone should be prescribed with caution, as it was inferior to exercise therapy for most outcomes in people with patellofemoral pain.

CAUTION: Low-credibility evidence and high heterogeneity in the meta-analyses suggest that the results may change in the presence of future evidence.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors were fully involved in the study and preparation of the manuscript. Each of the authors has read and concurs with the content in the final manuscript.

DATA SHARING: All data relevant to the study are included in the article or are available as online appendices.

PATIENT AND PUBLIC INVOLVEMENT: Patients or public partners were not involved in the design, conduct, or interpretation of this systematic review.

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[LITERATURE REVIEW]

APPENDIX A

SEARCH HISTORY

1. anterior knee pain.ab,kf,ti,tw.
2. (patella or patellofemoral).ab,kf,ti,tw.
3. (pain or syndrome or dysfunction).ab,kf,ti,tw.
4. 2 and 3
5. 1 or 4
6. Clinical trials as topic/
7. Randomized Controlled Trial/
8. Controlled Clinical Trials as Topic/
9. Randomized controlled trial.pt.
10. Controlled clinical trial.pt.
11. randomized.ab.
12. placebo.ab.
13. randomly.ab.
14. trial.ti.
15. ((clinical or controlled or comparative or placebo or prospective* or randomi#ed) adj3 (trial or study)).tw.
16. (random* adj7 (allocar or allot* or assign* or basis* or divid* or order*).tw.
17. ((allocar or allot* or assign* or divid*) adj3 (condition* or experiment* or intervention* or treatment* or therap* or control* or group*)).tw.
18. 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19. 5 and 18

APPENDIX B

GRADE RATINGS

Health Education Material Compared to Supervised Exercise Therapy Plus Education Material

	Study Limitations (Risk of Bias)	Indirectness	Inconsistency	Imprecision	Publication Bias	GRADE Conclusion ^a
Knee pain: short term	No	No	Yes	Yes	No	Low credibility
Knee pain: long term	No	No	Yes	Yes	Yes	Very low credibility
Self-reported function: short term	No	No	Yes	Yes	No	Low credibility

Abbreviation: GRADE, Grading of Recommendations Assessment, Development and Evaluation.

^aGRADE Working Group grades of evidence: high credibility, further research is very unlikely to change our confidence in the estimate of effect; moderate credibility, further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; low credibility, further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; very low credibility, we are very uncertain about the estimate.

Health Professional-Delivered Education Compared to Exercise Therapy Plus Health Professional-Delivered Education

	Study Limitations (Risk of Bias)	Indirectness	Inconsistency	Imprecision	Publication Bias	GRADE Conclusion ^a
Knee pain: short term	No	No	Yes	No	Yes	Low credibility
Knee pain: medium term	No	No	Yes	No	Yes	Low credibility
Self-reported function: short term	No	No	Yes	Yes	Yes	Very low credibility
Knee extensor isometric strength: short term	No	No	Yes	Yes	No	Low credibility

Abbreviation: GRADE, Grading of Recommendations Assessment, Development and Evaluation.

^aGRADE Working Group grades of evidence: high credibility, further research is very unlikely to change our confidence in the estimate of effect; moderate credibility, further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; low credibility, further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; very low credibility, we are very uncertain about the estimate.

APPENDIX C

DESCRIPTION OF INTERVENTIONS DELIVERED BY STUDIES, BASED ON THE TEMPLATE FOR INTERVENTION DESCRIPTION AND REPLICATION GUIDELINE

Education Intervention

Study	Provider	How	Where	When and How Much	Tailoring	How Well	What
Clark et al ¹⁸	Physical therapist	Face-to-face sessions	NR	6 face-to-face sessions over 3 mo	Standardized	NR	Nature and possible causes of PFP, anatomy, footwear, appropriate sporting activities, pain-controlling drugs, stress relaxation techniques, ice, massage, diet, weight advice, prognosis, and self-help
Esculier et al ²¹	Physical therapist	Face-to-face sessions	Clinic	5 face-to-face sessions over 8 wk	Individualized weekly running programs	NR	Education on load management and instruction to self-modify running training according to symptoms. Education on pain management
Mason et al ³⁵	Physical therapist	NR	NR	1 session	Standardized	NR	Advice and overview of knee anatomy and function, especially in relation to the loading of the patellofemoral joint and the importance of the quadriceps muscle
Moyano et al ³⁶	Physical therapist	Health education material	Clinic	1 session	Standardized	NR	NR
Rathleff et al ⁴³	Physical therapist	Face-to-face session and leaflet	School	1 face-to-face session, 30 min in duration	Standardized	NR	Reasons for pain, pain management, how to modify physical activity using pacing and load management strategies, and information on optimal knee alignment during daily tasks
Rathleff et al ⁴⁴	Physical therapist	Face-to-face session and leaflet	School	1 face-to-face session, 30 min in duration	Standardized	NR	Reasons for pain, pain management, how to modify physical activity, how to return slowly to sports, how to cope with knee pain, and information on optimal knee alignment during sit-to-stand, standing, walking, stair walking, and cycling
Song et al ⁴⁷	Physical therapist	Health education material	NR	1 session	Standardized	NR	Health education material regarding PFP
van Linschoten et al ⁴⁸	GP or sport physician	Health education material (leaflet)	NR	1 session	Standardized	NR	Information about PFP and advice to refrain from all sports activities that provoke pain. Instructions for daily isometric quadriceps contractions

Abbreviations: GP, general practitioner; NR, not reported; PFP, patellofemoral pain.

[LITERATURE REVIEW]

APPENDIX C

Exercise Intervention

Study	Provider	How	Where	When and How Much	Tailoring	How Well	What
Clark et al ⁸	Physical therapist	Face-to-face sessions	NR	6 face-to-face sessions over 3 mo	NR	Adherence in diary sheet	Hamstring, iliotibial band, quadriceps, and gastrocnemius stretches Quadriceps and hip strengthening Functional isotonic exercises
Esculier et al ²¹	Physical therapist	Face-to-face sessions	Clinic	5 face-to-face sessions over 8 wk	Standardized home exercise program and personalized program	NR	Standardized home exercise program aimed at improving strength, capacity to sustain mechanical load, and dynamic control of the lower limbs
Mason et al ³⁵	Physical therapist	Home sessions	Patients' homes	3 face-to-face sessions over 1 wk	Standardized with personalized dosage adjustments	A weekly exercise diary indicating the number of sessions completed each day	Quadriceps strengthening and stretching exercises
Moyano et al ³⁶	Physical therapist	Face-to-face sessions	Clinic	3 face-to-face sessions of 20-60 min in duration per week over 16 wk	Standardized with personalized stretching adjustments	NR	Hip and knee stretching exercises
Rathleff et al ⁴³	Physical therapist	A combination of supervised group training sessions and unsupervised (5-page leaflet) home-based exercises	School	3 face-to-face group sessions plus 4 home sessions of 15 min in duration per week over 3 mo	Standardized with personalized dosage adjustments	Adherence was recorded as attendance. Adherence to home exercises was monitored by weekly follow-ups using SMS	A combination of supervised group training sessions and unsupervised home-based exercises Supervised group training sessions consisted of neuromuscular training of the muscles around the foot, knee, and hip and strength and stretch training for the knee and hip
Rathleff et al ⁴⁴	Physical therapist	Face-to-face group and home sessions	School	3 face-to-face group sessions plus 4 home sessions of 15 min in duration per week over 3 mo	Standardized with personalized dosage adjustments	Adherence was recorded as attendance. Adherence to home exercises was monitored by weekly follow-ups using SMS	A combination of supervised group training sessions and unsupervised home-based exercises Supervised group training sessions consisted of neuromuscular training of the muscles around the foot, knee, and hip and strength and stretch training for the knee and hip
Song et al ⁴⁷	Physical therapist	Exercise sessions	NR	3 weekly exercise sessions over 8 wk	Standardized with personalized dosage adjustments	NR	Simple leg-press exercise, performed unilaterally, starting from 45° of knee flexion to full extension. Or, a 50-N hip adduction force was applied to the distal one third of the thigh; this force was achieved by tying a blue Thera-Band to an arm of the leg-press machine
van Linschoten et al ⁴⁸	Physical therapist	Face-to-face and home sessions	NR	9 face-to-face sessions over 6 wk plus exercises daily for 25 min over 3 mo	Standardized with personalized dosage adjustments	Patients received a diary to register their amount of exercise	Static and dynamic muscular exercises for the quadriceps, adductor, and gluteal muscles The intervention also included balance exercises and flexibility exercises for major thigh muscles

Abbreviations: NR, not reported; SMS, short message service.

APPENDIX C

Taping Intervention

Study	Provider	How	Where	When and How Much	Tailoring	How Well	What
Clark et al ⁸	Physical therapist	Face-to-face sessions	NR	6 face-to-face sessions over 3 mo	During the fourth and fifth visits, taping was only applied during painful activities	Adherence in diary sheet	Tape was applied from the lateral border of the patella, pulling medially and upward over the medial femoral condyle
Mason et al ³⁵	Physical therapist	Face-to-face and home sessions	Patients' homes	1 session	Taping was specifically applied and targeted to the patient's requirements	Tape was replaced by the treating physical therapist if it came off during the week	Patients had infrapatellar taping applied for 1 wk

Abbreviation: NR, not reported.

Gait Retraining

Study	Provider	How	Where	When and How Much	Tailoring	How Well	What
Esculier et al ²¹	Physical therapist	Face-to-face sessions	Clinic	5 face-to-face sessions over 8 wk	Individualized weekly programs	NR	Runners were asked to increase step rate by 7.5% to 10%. Runners were also asked to run softer and to adopt a non-rearfoot-strike pattern

Abbreviation: NR, not reported.

APPENDIX D

STUDY CHARACTERISTICS

Study	Population	Education	Participants ^a	Comparator Intervention (plus education)	Participants ^a
Clark et al ⁸	Young adults	Health professional-delivered education (n = 22)	Men, n = 13 (59%); women, n = 9 (41%) Age, 27 ± 7 y BMI, 25.2 ± 4.2 kg/m ²	Taping, n = 19	Men, n = 10 (53%); women, n = 9 (47%) Age, 29 ± 6 y BMI, 25.0 ± 3.9 kg/m ²
				Exercise, n = 20	Men, n = 12 (60%); women, n = 8 (40%) Age, 29 ± 6 y BMI, 24.9 ± 4.2 kg/m ²
				Taping plus exercise, n = 20	Men, n = 10 (50%); women, n = 10 (50%) Age, 29 ± 6 y BMI, 24.8 ± 5.7 kg/m ²
Esculier et al ²¹	Runners	Health professional-delivered education (n = 23)	Men, n = 8 (35%); women, n = 15 (65%) Age, 30 ± 5 y BMI NR	Exercise, n = 23	Men, n = 9 (39%); women, n = 14 (61%) Age, 33 ± 6 y BMI NR
				Gait retraining, n = 23	Men, n = 9 (39%); women, n = 14 (61%) Age, 28 ± 6 y BMI NR
Kim et al ²⁸	Adolescents, adults, and elderly persons	Online health education material (n = 286)	Men, n = 111 (39%); women, n = 175 (61%) Age, 52 y BMI, 28 kg/m ²	Simple exercise therapy, n = 290	Men, n = 104 (36%); women, n = 186 (64%) Age, 51 y BMI, 29.2 kg/m ²
				Progressive exercise therapy, n = 284	Men, n = 111 (39%); women, n = 173 (61%) Age, 51 y BMI, 29.1 kg/m ²
Mason et al ^{35b}	Adolescents, adults, and elderly persons	Health professional-delivered education (n = 15)	NR	Taping, n = 15	NR
				Strengthening, n = 15 Stretching, n = 15	NR NR
Moyano et al ³⁶	Young and older adults	Health education material (n = 26)	Men, n = 21 (81%); women, n = 5 (19%) Age, 39 ± 3 y BMI, 24.5 ± 6.2 kg/m ²	Stretching, n = 35	Men, n = 22 (63%); women, n = 13 (37%) Age, 40 ± 3 y BMI, 24.8 ± 5.1 kg/m ²
				PNF stretching, n = 33	Men, n = 19 (57%); women, 14 (43%) Age, 40 ± 2 y BMI, 25.2 ± 6.5 kg/m ²
Rathleff et al ⁴⁴	Female adolescents	Health professional-delivered education (n = 29)	Women, n = 29 (100%) Age, 17 (16-18) y ^c BMI, 21.0 ± 2.0 kg/m ²	Exercise therapy, n = 28	Women, n = 28 (100%) Age, 17 (16-18) y ^c BMI, 20.2 ± 1.7 kg/m ²
Rathleff et al ⁴³	Adolescents	Health professional-delivered education (n = 59)	Men, n = 9 (15%); women, n = 50 (85%) Age, 17 ± 1 y BMI, 22.4 ± 3.1 kg/m ²	Exercise therapy, n = 62	Men, n = 16 (26%); women, n = 46 (74%) Age, 17 ± 1 y BMI, 21.1 ± 2.5 kg/m ²
Song et al ⁴⁷	Young adults	Health education material (n = 30)	Men, n = 4 (13%); women, n = 26 (87%) Age, 43 ± 9 y BMI, 22.5 ± 2.1 kg/m ²	Simple leg-press exercise, n = 30	Men, n = 8 (27%); women, n = 22 (73%) Age, 40 ± 9 y BMI, 23.0 ± 3.0 kg/m ²
				Leg press plus 50 N of hip adduction force, n = 29	Men, n = 8 (28%); women, n = 21 (72%) Age, 38 ± 10 y BMI, 22.2 ± 3.2 kg/m ²

Table continues on page D7

APPENDIX D

Study	Population	Education	Participants ^a	Comparator Intervention (plus education)	Participants ^a
van Linschoten et al ⁴⁸	Adolescents and adults	Health education material (n = 66)	Men, n = 24 (36%); women, n = 42 (64%) Age, 23 ± 7 y BMI, 23.0 ± 3.4 kg/m ²	Exercise therapy, n = 65	Men, n = 23 (35%); women, n = 42 (65%) Age, 24 ± 8 y BMI, 23.2 ± 3.9 kg/m ²

Abbreviations: BMI, body mass index; NR, not reported; PNF, proprioceptive neuromuscular facilitation.

^a*Values are mean or mean ± SD unless otherwise indicated.*

^b*Authors reported anthropometric data of the entire sample before randomization (mean age, 45 years; BMI, 27 kg/m²).*

^c*Authors reported data as median (interquartile range).*

APPENDIX E

PEDRO APPRAISAL TOOL RESULTS

Study	Criterion ^a											Score
	1 ^b	2	3	4	5	6	7	8	9	10	11	
Clark et al ⁸	1	1	0	1	0	0	1	1	1	1	1	7
Esculier et al ²¹	1	1	1	1	0	0	1	1	1	1	1	8
Kim et al ²⁸	0	1	0	0	0	0	0	0	1	1	1	4
Mason et al ³⁵	1	1	1	1	0	0	1	0	0	1	1	6
Moyano et al ³⁶	1	1	1	1	0	0	0	1	0	1	1	6
Rathleff et al ⁴⁴	1	1	0	1	0	0	1	0	0	1	1	5
Rathleff et al ⁴³	1	1	0	1	0	0	1	0	1	1	1	6
Song et al ⁴⁷	1	1	1	1	0	0	1	1	1	1	1	8
van Linschoten et al ⁴⁸	1	1	0	1	0	0	0	1	1	1	1	6

Abbreviation: PEDro, Physiotherapy Evidence Database.

^aCriteria: 1, Eligibility criteria were specified; 2, Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received); 3, Allocation was concealed; 4, The groups were similar at baseline regarding the most important prognostic indicators; 5, There was blinding of all subjects; 6, There was blinding of all therapists who administered the therapy; 7, There was blinding of all assessors who measured at least 1 key outcome; 8, Measures of at least 1 key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9, All subjects for whom outcome measures were available received the treatment or control condition as allocated, or, where this was not the case, data for at least 1 key outcome were analyzed by "intention to treat"; 10, The results of between-group statistical comparisons were reported for at least 1 key outcome; 11, The study provided both point measures and measures of variability for at least 1 key outcome.

^bThis eligibility criterion does not contribute to the total score.

APPENDIX F

STANDARDIZED MEAN DIFFERENCES OF INDIVIDUAL STUDIES

Health Education Material Versus Exercise Therapy—Other Outcomes: Short Term

Study/Outcome	SMD ^a
Moyano et al ³⁶	
Knee range of motion	-1.86 (-2.39, -1.34)
Song et al ⁴⁷	
Vastus medialis volume	-0.69 (-1.14, -0.24)
Vastus medialis CSA	-0.59 (-1.04, -0.14)

Abbreviations: CSA, cross-sectional area; SMD, standardized mean difference.

^aValues in parentheses are 95% confidence interval.

Health Professional–Delivered Education Versus Exercise Therapy Plus Health Professional–Delivered Education—Other Outcomes: Short Term

Study/Outcome	SMD ^a
Clark et al ⁸	
Anxiety (HADS)	-0.52 (-1.10, 0.07)
Depression (HADS)	-0.31 (-0.67, 0.05)
Esculier et al ²¹	
Weekly running distance	-0.01 (-0.62, 0.59)
Rathleff et al ⁴³	
Knee-related quality of life	-0.31 (-0.92, 0.30)

Abbreviations: HADS, Hospital Anxiety and Depression Scale; SMD, standardized mean difference.

^aValues in parentheses are 95% confidence interval.

Health Professional–Delivered Education Versus Taping Plus Health Professional–Delivered Education—Other Outcomes: Short Term

Study/Outcome	SMD ^a
Clark et al ⁸	
Worst knee pain	-0.54 (-1.16, 0.09)
Self-reported function	-0.44 (-1.07, 0.18)
Anxiety (HADS)	-0.05 (-0.66, 0.56)
Depression (HADS)	0.06 (-0.55, 0.68)
Knee extensor isometric strength	-0.23 (-0.85, 0.38)
Mason et al ³⁵	
Pain ascending stairs	-0.29 (-1.01, 0.43)
Pain descending stairs	-0.24 (-0.96, 0.48)

Abbreviations: HADS, Hospital Anxiety and Depression Scale; SMD, standardized mean difference.

^aValues in parentheses are 95% confidence interval.

Health Professional–Delivered Education Versus Gait Retraining Plus Health Professional–Delivered Education—Other Outcomes: Short Term

Study/Outcome	SMD ^a
Esculier et al ^{21,b}	
Worst knee pain	-0.28 (-0.86, 0.30)
Usual knee pain	-0.42 (-1.01, 0.16)
Weekly running distance	-0.07 (-0.65, 0.51)

Abbreviation: SMD, standardized mean difference.

^aValues in parentheses are 95% confidence interval.

^bParticipants who were randomized to receive exercise therapy also received the education intervention.

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Internal and External Workload in Youth Basketball Players Who Are Symptomatic and Asymptomatic for Patellar Tendinopathy

Basketball is the most popular youth sport in North America, with over 11 million participants in the United States. Among Canadian youth, it is the third most popular team sport, with over 354 000 youth participants.^{38,41} Basketball is a high-intensity sport, involving frequent change-of-direction movements, sprinting, and repetitive vertical jumping/landing,³ and knee overuse injuries occur frequently. Patellar tendinopathy is an overuse condition

characterized by patellar tendon pain at the inferior pole of the patella.³⁷ It is common in basketball players, with a prevalence as high as 32% in elite adult populations.²⁷ In youth basketball players, a prevalence of 7% has been previously reported.¹⁰ However, this value, obtained from a study conducted 2 decades ago, may not reflect the true prevalence of patellar tendinopathy in this population.^{2,33} Current evidence suggests that player self-reporting and consistent monitoring of tendinopathy (weekly or biweekly, using prevalence instead of incidence) are imperative for a robust understanding of the true burden of tendinopathy.² Overuse injuries of this nature may not affect player participation and are therefore likely to be underreported or underestimated, and may be exacerbated by continued play, inadequate rest, or an imbalance between the workload and recovery potential of the athlete.^{2,21}

Research examining the association between workload and tendon health in youth athletes participating in jumping sports is important, given the occurrence of jumping-related injuries such as

● **OBJECTIVE:** To examine the differences in external and internal workload in players with and without patellar tendinopathy.

● **DESIGN:** Nested case-control study.

● **METHODS:** Workload was monitored in 152 players (aged 13-18 years) for a 1-week period, including all practices, games, and conditioning sessions. Players were prescreened into patellar tendinopathy cases and controls without patellar tendinopathy, using the previously validated Oslo Sports Trauma Research Center-patellar tendinopathy questionnaire. Simple linear regression analysis, with adjustment for clustering by team and Bonferroni correction, was used to examine mean differences in measures of external workload (cumulative jump counts and sessions completed) and internal workload (session rating of perceived exertion in arbitrary units) between cases and controls.

● **RESULTS:** A total of 144 players (19 cases, 125 controls) met the inclusion criteria for final

analysis. No significant differences were found between players with patellar tendinopathy and those without patellar tendinopathy in the 3 outcomes: jump count (mean difference, 45 jumps; 98.3% confidence interval [CI]: -41, 130; $P = .177$), basketball sessions completed (mean difference, 0.9; 98.3% CI: -0.3, 2.2; $P = .067$), and session rating of perceived exertion (mean difference, 346 arbitrary units; 98.3% CI: -459, 1151; $P = .260$).

● **CONCLUSION:** In the current study, a significant difference in workload was not detected between youth basketball players with patellar tendinopathy and players without patellar tendinopathy. Efforts toward identifying players at early stages of patellar tendinopathy and applying relevant interventions are warranted. *J Orthop Sports Phys Ther* 2020;50(7):402-408. Epub 6 Sep 2019. doi:10.2519/jospt.2020.9094

● **KEY WORDS:** adolescent, injury prevention, jumper's knee, load, overuse injury, recovery

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patellar tendinopathy (often referred to as “jumper’s knee”).^{14,36} Considering that patellar tendinopathy is an overuse injury with an insidious onset, participation in the aggravating activity may persist at the initial stages,⁴ leading to an exacerbation of the injury consequent to unmodified sport participation. However, it is currently unknown whether youth basketball players who are symptomatic for patellar tendinopathy adjust their workload consequent to tendon injury during the competitive season compared to players without patellar tendinopathy.

Monitoring workload has been proposed to identify athletes who may be at risk for overuse injuries.^{6,24,40} Workload includes the physiological response to exercise (internal workload) and the external work performed by the player (external workload).^{1,24,40} However, to date there are no accepted methods for evaluating workload in youth basketball, and limited scientific research exists evaluating the relationship between workload and overuse knee injuries. The session rating of perceived exertion (sRPE) developed by Foster et al¹⁸ (TABLE 1) is a simple and inexpensive method for quantifying internal workload in athletes, including youth sport.^{18,24,28,30} The sRPE and sport-specific measures of external workload, such as participation exposure, have also been used successfully to quantify workload in youth sport.^{6,24,35,39}

The use of wearable devices such as global positioning systems, accelerometers, and commercial activity monitors is becoming more commonplace in field sports to quantify external workload.^{7,13,34} However, limited scientific research exists on the use of wearable devices to monitor workload in youth sports like basketball. Recently, a validation study demonstrated the efficacy of a wearable accelerometer device to quantify vertical jump count (vertical jump workload) in youth volleyball and basketball compared to 3-D motion analysis, which is considered to be the gold standard, even though it does not allow for data collection on the field.^{8,20,29}

The primary objective of this study was to examine the differences in workload in youth basketball players with and without patellar tendinopathy. Workload measures included game/practice session exposure, vertical jump count, and sRPE. It was hypothesized that symptomatic players would present with lower measures of workload compared to asymptomatic players.

METHODS

Study Design

A NESTED CASE-CONTROL STUDY DESIGN within a larger prospective cohort study (the Patellar and Achilles Tendinopathy [PAT] Prevention

Study) was conducted. The PAT Prevention Study was a prospective cohort study in youth basketball players (n = 518) during the high school (December 2016 to March 2017) and subsequent club (March to June 2017) basketball seasons. The club basketball season started after the school basketball season, in which most players participated. In the present study, participants were assessed for patellar tendinopathy, and workload during practices, games, and conditioning sessions was monitored over a 1-week period. The data-collection period was chosen based on balancing study feasibility and data quality. To obtain the highest probability of recruiting players with patellar tendinopathy, the study was conducted within the latter third of the season.

Participants

In total, a convenience sample of 160 youth club basketball players (aged 13-18 years) from 15 teams were recruited from the PAT Prevention Study to participate in this substudy. Prior to enrollment, approval for recruitment was obtained through each club. Informed consent was provided by players who were at least 15 years of age, with parental consent and accompanying player assent provided by players younger than 15 years of age. Ethics approval was received from the Conjoint Health Research Ethics Board at the University of Calgary (ethics approval number REB16-0864).

Baseline and Preparticipation Patellar Tendinopathy Screening

As per the PAT Prevention Study, participants completed a baseline questionnaire at the time of enrollment (ie, club basketball participants who enrolled in March 2017); this included questions regarding acute and overuse injury history, medical history, health care utilization, sport participation in the preceding 6 weeks, sport participation in the preceding year, and physical education class exposure. Inclusion criteria comprised all actively participating players in the PAT Prevention Study cohort, within the selected teams

TABLE 1

THE MODIFIED RATING OF PERCEIVED EXERTION SCALE^a

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	...
7	Very hard
8	...
9	...
10	Maximal

^aReprinted with permission from Foster et al.¹⁸ ©2001 National Strength and Conditioning Association.

who consented to be part of the study. Exclusion criteria, specific to the current study, included participants reporting any musculoskeletal injury resulting in time loss in the previous 6 weeks and any ongoing acute injuries precluding basketball participation. A research staff member assigned to each team at the start of the 1-week study screened each athlete for the exclusion criteria through a one-on-one player interview.

At the beginning of the 1-week study period, all participants completed a self-report measure of patellar tendinopathy, the Oslo Sports Trauma Research Center-patellar tendinopathy (OSTRC-P) questionnaire.³³ The OSTRC-P questionnaire is a valid assessment tool with a sensitivity of 79% and specificity of 98% when compared to clinical evaluation.³³ The OSTRC-P questionnaire was specifically designed to capture patellar tendinopathy in surveillance studies involving a large number of adolescent athletes, in situations where physician/physical therapist evaluation is not feasible. Briefly, the OSTRC-P questionnaire adds 6 new questions to the original Oslo Sports Trauma Research Center Overuse Injury Questionnaire (4 questions)⁹ relating to self-reported knee problems in the previous week. These new questions probe ongoing knee pain in a sequence that leads up to a final question on whether a player's anterior knee pain is specifically located on "the bottom tip of the knee cap." Players without an ongoing knee problem or potential for patellar tendinopathy do not get to complete all 10 questions. Players were subsequently categorized into 2 groups, based on the outcomes of the OSTRC-P questionnaire: patellar tendinopathy cases and non-patellar tendinopathy controls. Study participants were followed for 1 week during their regular basketball season to measure workload.

Workload Monitoring

External Workload Cumulative external load was measured prospectively using jump workload (ie, jump count) and the

number of basketball sessions completed (ie, sum of the number of practice/training, game, and conditioning sessions attended by each player during the week). Jump workload was obtained using an inertial measurement unit, the VERT Classic accelerometer (Version 2.0; Mayfonk Athletic, Fort Lauderdale, FL). The VERT provides vertical jump height data (to the nearest 0.01 cm) in real time to an Apple iPad (Apple Inc, Cupertino, CA) via WiFi and Bluetooth 4.0 technology, and has been found to provide reliable information on jump height and count in youth volleyball and basketball.^{5,8,20,29} A senior research staff member with expertise in the VERT application for research and field use (3 years) trained junior research staff in both the lab and field settings for a combined 10 hours. Data-collection personnel received training in naming, grouping, syncing, and assigning the VERT devices for data collection prior to data collection. One or both of these researchers attended each practice/game during the data-collection period, where the VERT devices and study iPads were handled only by study staff. Support and supervision were provided to the junior staff throughout data collection. The device was secured to participants using an elastic waistband or clip, positioned anteriorly below the navel near the midline of the body. Data were stored on the iPad until the end of the study week and subsequently uploaded to an encrypted server.

Internal Workload Overall rating of perceived exertion was collected from individual players after each session. As a subjective measure, rating of perceived exertion has shown more sensitivity and consistency in reflecting acute and chronic loads than objective measures like blood markers, heart rate, oxygen consumption, and heart rate response, and has been previously validated in youth basketball players.^{19,28} As per Foster et al,¹⁸ the Borg sRPE scale (TABLE 1) was administered to players by research staff after every practice, conditioning session, or game. Player sRPE and session dura-

tion were manually recorded by research staff on a weekly exposure sheet. Internal training load was defined as sRPE multiplied by total participation time (minutes, derived from scheduled session time) in arbitrary units.¹⁷ Weeklong cumulative internal workload was calculated for individual players by summing all sRPE scores recorded for the week.

Data Analysis

Data analysis was conducted using Stata (Version 14.1; StataCorp LLC, Collage Station, TX). Descriptive statistics were calculated for player characteristics using means and standard deviations or medians and ranges (for data not normally distributed) for numerical data, and frequencies (proportions) for categorical data. We examined mean differences between patellar tendinopathy cases and controls for all 3 measures of workload (jump count, sessions completed, and sRPE) using simple linear regression analysis. Due to the greater likelihood that players on the same team would be more similar to each other than to individuals on different teams, adjustment for clustering by team was conducted for a more robust and reliable analysis.¹⁶ Significance level was set with Bonferroni correction of the 3 primary study outcomes ($\alpha = .05/3 = .017$) and a 98.3% confidence interval (CI) was employed. Finally, we compared cases and controls graphically (box plots), separately for male and female players, for all 3 measures of workload. This was an exploratory analysis based on the evidence that male players are more likely to suffer from patellar tendinopathy compared to female players.^{10,32}

RESULTS

IN TOTAL, 144 OF 152 CONSENTING PLAYERS (94.7%) ON 15 TEAMS (males, $n = 79$; 54.9%) met the inclusion criteria and were included in final analyses. Eight players were excluded due to acute lower extremity injuries that precluded full participation in basketball during the study

period. In this cohort, 19 cases of patellar tendinopathy (13.2%) were identified. Player characteristics were comparable in cases, controls, and excluded players (TABLE 2).

Assumptions for each of the regression analyses were met. There was no significant difference in workload measures between players with and without patellar tendinopathy (jump count: mean difference, 45 jumps; 98.3% CI: -41, 130; $P = .177$; basketball sessions completed: mean difference, 0.9; 98.3% CI: -0.3, 2.2; $P = .067$; sRPE: mean difference, 346 arbitrary units; 98.3% CI: -459, 1151; $P = .260$) (TABLE 3).

In the stratified descriptive analysis, the median workload values for all 3 measures were higher in patellar tendinopathy cases than in controls in both male and female players (sample sizes: female cases, $n = 5$; female controls, $n = 60$; male cases, $n = 14$; male controls, $n = 65$). This was most remarkable for internal workload in female players with tendinopathy (median, 2880 arbitrary units; interquartile range, 2340-3060) versus controls (median, 1215 arbitrary units; interquartile range, 810-3060) (FIGURE).

DISCUSSION

THE PRESENT STUDY EVALUATED 3 measures of workload in youth basketball players, including vertical jump workload using a novel wearable device. Contrary to the study's hypothesis, mean workload measures were not found to be lower in basketball players with patellar tendinopathy compared to those without patellar tendinopathy. Patellar tendinopathy is a progressive chronic injury that is related to an imbalance between workload and the regenerative capacity of the patellar tendon.¹¹ Treatment of patellar tendinopathy aims in part to restore this balance by reducing workload to promote patellar tendon healing.¹¹ As patellar tendinopathy is related to an excessive external mechanical workload, objective sport- and structure-specific measures of workload

may be important in this setting to identify basketball players who present with a workload-recovery imbalance during the season. To this end and to our best knowledge, this was also the first study to address this problem by using a wearable sensor to monitor vertical jump workload in youth basketball players with and without patellar tendinopathy.

Consistent with this perspective, a study by Lian et al²⁶ found that volleyball players with patellar tendinopathy demonstrated higher vertical jump load compared to noninjured controls. In the present study, the relatively small sample size may have limited our ability to detect a statistical difference in vertical jump workload between basketball players with and without patellar tendinopathy. Alternatively, vertical jump workload in basketball may not be directly comparable to volleyball, due

to an increased involvement of multidirection running and change-of-direction movements in basketball. Thus, vertical jump workload may not accurately reflect the external workload in the present group of basketball players. Nevertheless, objective assessments of workload using wearable devices such as inertial measurement units may be important for detecting problematic workloads in youth basketball players who may be at risk for developing patellar tendinopathy or exacerbating their injury consequent to an imbalance between workload and recovery. The VERT jump device (Mayfonk Athletic) used in the current study may provide a feasible external-load measurement tool in court sports with high jump volumes and high overuse injury occurrence.

Consistent with the jump count findings, a statistical difference was not ob-

TABLE 2

PLAYER CHARACTERISTICS^a

	Controls (n = 125)	Cases (n = 19)	Excluded (n = 8)
Sex (male), n (%)	65 (52.0)	14 (73.7)	1 (12.5)
Age, y	16 (13-18)	16 (14-17)	16.5 (13-17)
Years played	6 (1-14)	5 (1-11)	5 (2-9)
Body mass index, kg/m ²			
Male	21.6 (20.0-23.6)	21.3 (19.7-23.3)	21.7 ^b
Female	20.8 (18.6-22.5)	20.6 (20.0-23.2)	20.0 (18.2-23.0)

^aValues are median (range) unless otherwise indicated.

^bNo range because there was only 1 participant in this category.

TABLE 3

WORKLOAD IN BASKETBALL PLAYERS WITH AND WITHOUT PATELLAR TENDINOPATHY

	Controls (n = 125) ^a	Cases (n = 19) ^a	Difference ^{ab}	P Value ^b
External workload				
Jump count	163 (142, 183)	208 (139, 276)	45 (-41, 130)	.177
Sessions completed ^c	3.14 (2.84, 3.43)	4.05 (3.17, 4.94)	0.92 (-0.33, 2.17)	.067
Internal workload				
sRPE, AU ^d	1926 (1694, 2159)	2273 (1681, 2864)	346 (-459, 1151)	.260

Abbreviations: AU, arbitrary unit; sRPE, session rating of perceived exertion.

^aValues are mean (98.3% confidence interval).

^bBased on simple linear regression, adjusted for clustering by team.

^cTotal number of all basketball sessions (games, practices, and conditioning) completed within the 1-week study period.

^dsRPE = RPE × duration for each session.

served in game/practice exposure over the study period in players with and without patellar tendinopathy. This suggests that basketball players with symptoms of patellar tendinopathy could potentially incur similar intrasession external workloads (jump count) and intersession external workloads (game/practice exposure) compared to basketball players without patellar tendinopathy. For this reason, an objective assessment of external workload may be of benefit in youth athletes at risk for patellar tendinopathy.²⁵ In fact, a divergence between exposure to the aggravating activity and

the corresponding symptoms of patellar tendinopathy in the early clinical stages is common, as symptoms typically appear several hours after physical activity and often do not limit sport participation.²⁵ However, the progressive nature of patellar tendinopathy suggests that in the latter stages, sports participation and performance may be compromised.^{4,12} This may explain why young competitive athletes diagnosed with patellar tendinopathy continue to exhibit increased workload compared to athletes without patellar tendinopathy.²⁶ The findings in the current study are important because

the persistent imbalance between workload and the regenerative capacity of the strained patellar tendon consequent to continued participation in the aggravating activity may lead to grave long-term health consequences, such as potentially irreversible tendon damage.³¹

It is recommended that both internal and external measures of workload be used in athlete monitoring systems in order to identify potentially problematic workloads that may contribute to injuries such as patellar tendinopathy.²³ Internal workload measures may include physiological measures such as the heart rate response to exercise or, as used in the present study, subjective measures obtained from the athlete such as the sRPE. Subjective measures such as the sRPE are advantageous, as they are inexpensive, pragmatic, and account for psychoemotional factors that may influence the physiological response to a given external workload.²³ In agreement with the findings on external workload measures, no statistical difference was found in sRPE between the 2 groups. The relationship between internal workload assessed with sRPE and patellar tendinopathy is unclear. There are reports suggesting that internal workload may have a higher association with injuries compared to external workload in other athlete populations.²² Thus, the inclusion of internal workload measures alongside external workload seems warranted in future studies aimed at evaluating the relationship between workload and patellar tendinopathy in youth basketball players.¹⁵

Limitations and Future Research

There are limitations of this study that need to be considered when interpreting the results. First, the present study was limited by a relatively small sample size. Thus, the ability to detect statistically significant group differences in workload might have been affected. Also, a limitation of the OSTRC-P questionnaire is characterized by the inability to differentiate Sinding-Larsen-Johansson

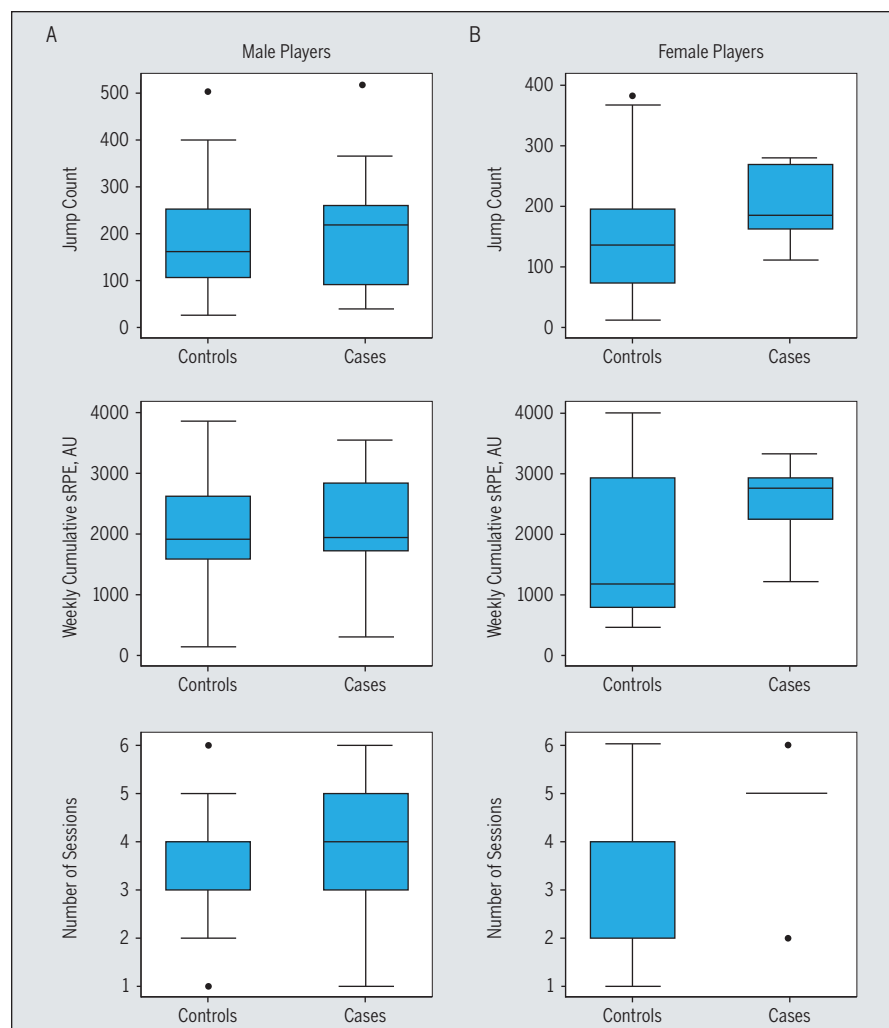


FIGURE. Sex-stratified workload comparison in players with and without patellar tendinopathy for (A) male players ($n = 79$; 65 controls and 14 cases) and (B) female players ($n = 65$; 60 controls and 5 cases). Each plot represents the median, first and third quartiles, range, and outliers (indicated by dots). Abbreviations: AU, arbitrary unit; sRPE, session rating of perceived exertion.

syndrome from patellar tendinopathy, relevant for the age group in question, without diagnostic imaging. Basketball is a complex sport involving multidirectional running and change-of-direction movements. Therefore, it is possible that the measures of internal workload and external workload (ie, vertical jump count) employed may not have accurately accounted for all aspects of workload incurred by the study participants. To attenuate this limitation, the VERT device (Mayfonk Athletic) was fitted on players using an elastic waistband anteriorly, below the navel near the midline of the body, as it has been shown that the device has its highest accuracy for measuring jump height when worn in this position, independent of other directions of motion. Thus, we do not expect the reliability and validity of the VERT to have been significantly impacted when jumps were not purely vertical. The present study, conducted over only 1 week, may not have been sufficiently long to provide an accurate representation of the difference in workload between basketball players with and without patellar tendinopathy, or of the changes in workload before and after the study period. The data-collection period was chosen based on balancing study feasibility and data quality. Thus, a limitation is that the data-collection period did not occur during the same week for all study participants.

To improve data quality, the data-collection period was consistently obtained from the latter third to the end of the season, and a study assumption was that the workload would be relatively constant between these 2 time points. A high degree of consistency was observed in terms of the weekly training/competition schedule employed by the teams in the study, providing support for a cross-sectional assessment of player workload. The investigation was limited by the use of a simple linear regression model that excluded other covariates and potential confounders due to a limited sample size and few patellar tendinopathy cases. The

convenience sampling technique employed in this study presents the potential for selection bias.

Using a measure of external workload that is directly focused on joints with the highest predisposition to acute and overuse injuries in basketball (ie, the knee and ankle joints) provides a suitable approach to effective basketball-specific workload and athlete recovery monitoring. From a public health perspective, it is imperative to monitor individual player workload and implement prevention strategies to mitigate persistent patellar tendon pain and potential long-term consequences of tendon degeneration and future tendon rupture. Despite the limitations, the current study provides directions for future research on how best to apply jump workload measures (count and, with further analysis, height) and sRPE in the monitoring and prevention of patellar tendinopathy and other common overuse injuries that occur in basketball.

CONCLUSION

WE DID NOT FIND SIGNIFICANT DIFFERENCES in workload between youth basketball players with patellar tendinopathy and players without patellar tendinopathy, suggesting that players with symptoms of patellar tendinopathy may load their tendons at the same level as their asymptomatic counterparts. Secondary prevention efforts toward identifying symptomatic players in the early stages of patellar tendinopathy and applying relevant interventions such as workload modification and tendon-strengthening protocols are warranted. ●

KEY POINTS

FINDINGS: There were no significant differences in measures of internal and external workload between youth basketball players who were symptomatic and those who were asymptomatic for patellar tendinopathy. Point estimates suggest a clinically important difference in the loading of symptomatic versus asymptomatic tendons.

IMPLICATIONS: Youth basketball players do not appear to be modifying their workload in response to their tendinopathy symptoms, which may have health implications as they continue to increase their workload and develop as basketball players.

CAUTION: The cross-sectional nature of this study does not allow for comments on temporality of the relationship between workload and tendinopathy. More longitudinal research is needed to understand this association.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors contributed to the development of the study proposal and to data collection, entry, and cleaning. All authors contributed to data analysis and interpretation of study results. Drs Emery and Owøye contributed to the acquisition of funding and to study design, and led all aspects of the study. All authors critically reviewed and edited the manuscript before submission.

DATA SHARING: There are no data available.

PATIENT AND PUBLIC INVOLVEMENT: Basketball Alberta, Calgary Basketball clubs, and schools from the Calgary Board of Education and Calgary Catholic School Board were involved as community partners in contributing to study recruitment, injury surveillance methods, and dissemination of research findings within the basketball and school communities. The Sport Medicine Centre at the University of Calgary supported clinical follow-up for players with tendinopathy.

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Knee Injuries in Normal-Weight, Overweight, and Obese Runners: Does Body Mass Index Matter?

Running is one of the most popular forms of exercise¹⁴ and affords a range of health benefits.⁶ However, running-related injuries are a major reason why runners quit running.⁵ The knee is one of the anatomical locations most frequently affected by running-related injuries.⁷ Running-related knee injuries include patellofemoral pain, runner's knee, jumper's knee, and meniscal injury.^{8,11,16} These injuries may require long periods of rehabilitation before the runner can return to running. The median time to recovery ranges from 49 to 89 days, depending on the knee injury diagnosis.^{8,11}

Higher body mass index (BMI) may be associated with increased risk of running-related injury.^{2,9} However, to our knowledge, no studies have investigated whether the anatomical location of a running-related injury differs between obese (BMI, 30 kg/m² or greater), overweight

(BMI, 25 kg/m² to less than 30 kg/m²), and normal-weight runners (BMI, less than 25 kg/m²). Running-related knee injuries could be more common in obese and overweight runners for at least 2 reasons.

First, obese and overweight runners run more slowly than normal-weight runners.¹ This difference may be important, as a running session can be broken down

into a series of loading cycles (strides) that each apply a unique load to body structures.³ Slower-speed running seems to distribute a larger proportion of the total load per stride to the knee region.¹² The sum of the loads from each stride (cumulative load) may also be higher during slow-speed running compared with fast-speed running when the distance is fixed. This relationship is explained by a shorter stride length when running at a slower speed, resulting in more strides completed (ie, 600 strides per 1000 m at 8 km/h versus 400 strides per 1000 m at 12 km/h).¹³ Consequently, overweight and obese runners may accumulate more knee load.

Second, obesity and overweight are known risk factors for knee osteoarthritis.^{3,17} This could indicate that obese and overweight runners might have a lower knee load capacity than normal-weight runners due to prevalent or developing knee osteoarthritis. Therefore, less cumulative load could result in a running-related knee injury compared with normal-weight runners.

We aimed to investigate whether there was a difference in the proportion of running-related knee injuries among normal-weight, overweight, and obese runners. We hypothesized that the proportion of running-related knee injuries would be 10% higher among overweight

● **OBJECTIVE:** To investigate whether the proportion of running-related knee injuries differed in normal-weight, overweight, and obese runners.

● **DESIGN:** Comparative study.

● **METHODS:** Data from 4 independent prospective studies were merged (2612 participants). The proportion of running-related knee injuries out of the total number of running-related injuries was calculated for normal-weight, overweight, and obese runners, respectively. The measure of association was absolute difference in proportion of running-related knee injuries with normal-weight runners as the reference group.

● **RESULTS:** A total of 571 runners sustained a running-related injury (181 running-related

knee injuries and 390 running-related injuries in other anatomical locations). The proportion of running-related knee injuries was 13% lower (95% confidence interval: -22%, -5%; $P = .001$) among overweight runners compared with normal-weight runners. Similarly, the proportion of running-related knee injuries was 12% lower (95% confidence interval: -23%, -1%; $P = .042$) among obese runners compared with normal-weight runners.

● **CONCLUSION:** Overweight and obese runners had a lower proportion of running-related knee injuries than normal-weight runners. *J Orthop Sports Phys Ther* 2020;50(7):397-401. doi:10.2519/jospt.2020.9233

● **KEY WORDS:** BMI, knee injury, running, running-related injury

¹Department of Public Health, Aarhus University, Aarhus, Denmark. All 4 parent studies from which this study was conducted conformed to Danish law regarding data protection and ethics approval. Michael Bertelsen is funded by Aarhus University (the Graduate School of Health). Dr Nielsen is funded by the Aarhus University Research Fund. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article. Address correspondence to Michael Lejbach Bertelsen, Department of Public Health, Aarhus University, Bartholins Allé 2, DK-8000 Aarhus C, Denmark. E-mail: michael.bertelsen@cesu.au.dk • Copyright ©2020 *Journal of Orthopaedic & Sports Physical Therapy*

and obese runners than among normal-weight runners.

METHODS

Study Design

THIS COMPARATIVE STUDY IS BASED on demographic and injury data collected in 4 independent, prospective running-related injury studies undertaken from 2011 to 2016 at Aarhus University in Denmark.^{2,4,10,15} All 4 studies conformed to Danish law regarding data protection and ethics approval. All participants in the 4 studies provided written informed consent prior to inclusion.

Participants

Runners who sustained an injury during 1 of the 4 studies (DANO-RUN, ProjectRun21, Run Clever, and Start-to-run) were included in the present study. Only the first running-related injury was included if a runner had multiple running-related injuries during follow-up. In the DANO-RUN, Run Clever, and ProjectRun21 studies, a running-related injury was defined as “a musculoskeletal complaint of the lower extremity or back caused by running, which restricted the amount of running (distance, speed, duration, or training) for at least 7 days or 3 running sessions.”^{2,4,10,15} In the Start-to-run study, a running-related injury was defined by the same criteria, except only 1 day of restricted running was needed to fulfill the injury definition.² Runners were excluded if data on running-related injury location were missing or unclear (eg, symptoms from 2 or more locations were reported for an injury).

An overview of the specific inclusion/exclusion criteria for each of the 4 studies is provided in the **APPENDIX** (available at www.jospt.org). The 4 studies had different inclusion criteria regarding running experience. The DANO-RUN and Start-to-run studies included novice runners, defined as runners with no more than 10 km of total running completed during the past year. ProjectRun21 included runners training for a half-marathon. Run Clever

included runners who had consistently been training 1 to 3 sessions per week for 6 months prior to inclusion. In addition, the DANO-RUN and Start-to-run studies had an exclusion criterion regarding the maximum amount of other sports activity allowed (4 h/wk and 1 h/wk, respectively). The eligibility criteria of the 4 studies were similar: aged 18 to 65 years, no previous injury in a specified time period preceding inclusion, no absolute contraindication to vigorous physical activities, and no pregnancy. During follow-up, runners who were included in the Run Clever, Start-to-run, and ProjectRun21 studies were instructed to follow study-specific running programs. Runners who participated in the DANO-RUN study could choose their running exposure.

Exposure

The exposure of interest was BMI, categorized according to the cutoffs used by the World Health Organization: normal weight (BMI, less than 25 kg/m²), overweight (BMI, 25 kg/m² to less than 30 kg/m²), and obese (BMI, 30 kg/m² or greater).¹ The BMI was calculated based on the baseline measurements of weight and height. In the ProjectRun21 and Run Clever studies, baseline weight and height were self-reported through an online questionnaire. In the DANO-RUN and Start-to-run studies, height was measured with a ruler and weight with a calibrated personal scale (SC-330; Tanita Corporation, Tokyo, Japan).

Outcome

The primary outcome of interest was running-related injury location (dichotomized: knee/other injury location). In the ProjectRun21 and Start-to-run studies, participants reported running-related injury through an online questionnaire. Participants reported symptoms and the anatomical location of the running-related injury, but no clinical diagnosis was made.^{2,4} In the DANO-RUN and Run Clever studies, runners with a running-related injury attended a clinical examination, performed by a physical therapist

according to a standardized examination procedure. If the physical therapist was unable to diagnose the running-related injury, an additional examination including diagnostic imaging (most often magnetic resonance imaging) was performed.^{10,15}

Based on the running-related injury diagnosis, running-related injuries from the DANO-RUN and Run Clever studies were classified according to anatomical location: knee, ankle/foot, lower leg, thigh, hip, and other. Two groups of 2 physical therapy students performed the categorization independently. The results were then compared, and an authorized physical therapist resolved any discrepancies. The assessors who classified the diagnoses were blinded to BMI. If a participant had multiple injuries during the follow-up, we included the first injury for analysis.

Statistics

The proportion of running-related knee injuries was calculated for each BMI group (running-related knee injuries/running-related injuries). In the primary analysis, the absolute difference in running-related knee injury proportions and a corresponding 95% confidence interval (CI) were calculated between the obese and normal-weight runners and between the overweight and normal-weight runners. We conducted 2 sensitivity analyses. The first sensitivity analysis only included runners with a clinically diagnosed running-related injury, because the validity of self-reported injuries may be questionable. The second sensitivity analysis stratified by sex, because sex was unequally distributed in the BMI groups. All analyses were performed using Stata/IC Version 15.0 (StataCorp LLC, College Station, TX).

RESULTS

FIVE HUNDRED SEVENTY-SEVEN OF the 2612 runners (22%) sustained a running-related injury. We excluded 6 injured runners from the analysis be-

cause data on running-related injury location were missing or unclear. Finally, 571 runners with a running-related injury were included in the analyses (APPENDIX). Of the 571 runners with a running-related injury (TABLE 1), 302 were normal-weight runners (73% female; mean $\pm$ SD age, 37 $\pm$ 11 years), 189 were overweight runners (46% female; mean $\pm$ SD age, 40 $\pm$ 10 years), and 80 were obese runners (55% female; mean $\pm$ SD age, 40 $\pm$ 9 years).

The running-related knee injury proportion of running-related injuries among overweight runners was 13% lower than among normal-weight runners (95% CI: -22%, -5%) (TABLE 2). Among obese runners, the running-related knee injury proportion of running-related injuries was 12% lower than among normal-weight runners (95% CI: -23%, -1%) (TABLE 2). In the total sample, the knee (32%) and the lower leg (32%) were the most common injury locations (TABLE 3).

The absolute running-related knee injury proportion differences for clinically diagnosed and self-reported running-related injuries are reported in the APPENDIX. Stratification by sex did not change the results.

DISCUSSION

THE PROPORTION OF RUNNING-RELATED knee injuries was lower among overweight and obese runners than among normal-weight runners. The proportion of running-related injuries to the lower leg was higher among overweight and obese runners compared to normal-weight runners. We cannot determine whether the observed higher proportion of lower-leg running-related injuries is a consequence of a lower proportion of running-related knee injuries or whether the lower running-related knee injury proportion is the consequence of a higher proportion of lower-leg running-related injuries. Nevertheless, our findings suggest that runners with different BMIs sustain injuries to different body regions in different proportions.

Limitations

There are 4 important limitations to our study.

Limitation 1 Body mass index could have changed between the baseline measurement and injury occurrence. Therefore, it is possible that some BMI exposures

were misclassified. However, we believe that any misclassification of BMI was independent of the injury location. In this case, the misclassification would not result in information bias.

Limitation 2 Two in every 3 obese runners and half of the overweight runners

TABLE 1

DEMOGRAPHIC CHARACTERISTICS BY BODY MASS INDEX^a

	Normal Weight (<25 kg/m ²)	Overweight (25 – <30 kg/m ²)	Obese (≥ 30 kg/m ²)
Total, n	302	189	80
Mean $\pm$ SD age, y	37 $\pm$ 11	40 $\pm$ 10	40 $\pm$ 9
Sex			
Male	83 (27)	102 (54)	36 (45)
Female	219 (73)	87 (46)	44 (55)
Proportion from each study			
DANO-RUN	97 (32)	97 (51)	54 (68)
ProjectRun21	117 (39)	49 (26)	12 (15)
Run Clever	88 (29)	42 (22)	9 (11)
Start-to-run	0 (0)	1 (1)	5 (6)

^aValues are n (percent) unless otherwise indicated.

TABLE 2

PROPORTION OF INJURIES THAT WERE KNEE INJURIES BY BODY MASS INDEX

Knee Injuries	Normal Weight ^a	Overweight ^a	Obese ^a	APD, % ^b	P Value
Normal weight versus overweight	38%	24%		-13% (-22%, -5%)	.001
Normal weight versus obese	38%		26%	-12% (-23%, -1%)	.042

Abbreviation: APD, absolute proportion difference.
^aValues are prevalence proportion.
^bValues in parentheses are 95% confidence interval.

TABLE 3

ANATOMICAL LOCATION OF INJURY BY BODY MASS INDEX^a

	Normal Weight (<25 kg/m ²)	Overweight (25 – <30 kg/m ²)	Obese (≥ 30 kg/m ²)	Total
Knee	114 (38)	46 (24)	21 (26)	181 (32)
Ankle/foot	56 (19)	32 (17)	13 (16)	101 (18)
Lower leg	74 (25)	74 (39)	36 (45)	184 (32)
Thigh	13 (4)	10 (5)	1 (1)	24 (4)
Hip	40 (13)	24 (13)	6 (8)	70 (12)
Other	5 (2)	3 (2)	3 (4)	11 (2)
Total	302 (100)	189 (100)	80 (100)	571 (100)

^aValues are n (percent). The chi-square test revealed a P value of .004.

participated in the DANO-RUN study, which only included novice runners. Among the normal-weight runners, only 1 in every 3 participated in the DANO-RUN study. The differences in the proportions of novice runners between BMI groups may have influenced our results. We did not have enough experienced overweight and obese runners in our population to conduct an experience-stratified analysis. However, inexperienced and experienced runners may have a similar distribution of injuries to anatomical locations.⁷ Sex was also unequally distributed in the BMI groups. We conducted a sex-stratified analysis, but our findings were the same as those of the main analysis.

Limitation 3 When injuries are self-reported, the validity of the injury could be questioned. However, the analysis stratified by injury location indicated a lower proportion of running-related knee injuries among the overweight and obese runners than among the normal-weight runners, regardless of whether the injuries were clinically diagnosed or self-reported.

Limitation 4 Running exposure was not self-determined. Runners who participated in the Run Clever, Start-to-run, and ProjectRun21 studies were provided with running programs. Body mass index may influence the runner's choice of running exposure, and a difference in running exposure may influence the amount of load applied to the knee while running. Consequently, our results may have been different had the running exposure been self-determined by all runners in our study. We recommend that future studies investigating the association between runner characteristics and injury location allow the running exposure of the runners to be self-determined. This approach would increase the results' generalizability to the general running population.

Perspectives

We studied novice and recreational runners, and the results should primarily be applied in that context. The results may have been different if a similar study

had been conducted in other subgroups of runners (eg, elite, track, or trail runners). Clinicians may use the results of the present study to inform normal-weight, overweight, and obese runners about where (in which anatomical location) most running-related injuries occur. In further studies, it may be interesting to investigate whether overweight and obese runners have a higher proportion of specific knee injuries (eg, a higher proportion of bone/meniscus injuries than normal-weight runners do). In addition, the substantially higher lower-leg running-related injury proportions among overweight and obese runners than in normal-weight runners may be an interesting target for further investigation.

CONCLUSION

RUNNERS WITH DIFFERENT BMIs HAD different injury location distributions. The running-related knee injury proportion of running-related injuries in overweight and obese runners was lower than that in normal-weight runners. Overweight and obese runners had a higher proportion of lower-leg running-related injuries than normal-weight runners. ●

KEY POINTS

FINDINGS: The proportion of running-related injuries in the knee was lower in overweight and obese runners than in normal-weight runners. In contrast, overweight and obese runners had a higher proportion of lower-leg running-related injuries than normal-weight runners.

IMPLICATIONS: Clinicians may inform normal-weight, overweight, and obese runners that they are likely to sustain an injury in certain anatomical locations.

CAUTION: The results from the present descriptive study are unable to justify a causal relationship between body mass index and injury location distributions. Therefore, it remains open to speculation why different runners are more likely to sustain an injury in certain parts of their bodies.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors formulated the research question. Cecilie Juhler and Karen Bredahl Andersen wrote the first draft of the manuscript. Michael Lejbach Bertelsen merged the data from the 4 studies (DANO-RUN, ProjectRun21, Run Clever, and Start-to-run) and performed the statistical analyses. Michael Lejbach Bertelsen and Dr Nielsen made important intellectual contributions to the content of the manuscript. All authors reviewed the final manuscript.

DATA SHARING: There are no data available.

PATIENT AND PUBLIC INVOLVEMENT: There was no patient and/or public involvement in the design, conduct, interpretation, and/or translation of the research.

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APPENDIX

Table 1. Overview of the Specific Inclusion and Exclusion Criteria for the 4 Studies

Study	Inclusion	Exclusion
DANO-RUN	• Healthy • 18-65 y of age • Had no injury to the lower extremity for at least 3 mo prior to the start of the study • Had access to the internet • Had an e-mail address • Did not run on a regular basis (<10 km over the previous 12 mo)	• Participated in other sports for more than 4 h/wk • Used insoles during training • Pregnant • Reported a history of stroke, heart disease, or pain in the chest during training • Unwilling to use the neutral running shoe or the GPS watch to upload their training sessions
Run Clever	• Healthy recreational runners, with an average of 1-3 weekly running sessions over the past 6 mo • 18-65 y of age • Owned an iOS- or Android-based phone	• Injury to the lower extremity in the 6 mo preceding baseline • Any of the following contraindication to vigorous physical activity, in accordance with the ACSM - Former heart or chest surgery - Symptoms of chest pain, dizziness, or discomfort when physically active - Pregnant - Taking prescribed medication related to cardiovascular problems
ProjectRun21	• ≥18 y of age • Agreed to follow one of the available running schedules • Agreed to use a GPS watch or an application for an Android- or iOS-based smartphone to quantify their running • Agreed to report running data, if any, via daily e-mails • Agreed to fill out e-mail-based weekly questionnaires covering injury status, health status, use of the health care system, changes in weight, participation in other sports, and other supplemental questions • All participants had to sign an informed-consent form before inclusion in the project	• Had a running-related injury in the lower extremity or lower back in the 6 mo preceding baseline • Had any other injury limiting their intended running activity in the past 6 mo • Any contraindication to vigorous physical activity - Symptoms of heart or chest pain - Previous heart or chest surgery - Lung diseases - Dizziness or discomfort when physically active - Pregnancy - Nonregulated diabetes
Start-to-run	• Individuals with a BMI of 30-35 kg/m² • 18-65 y of age • No previous running experience (<10 km in the last year) and less than 1 h of other sports activity per week within the last year	• Absolute contraindication to vigorous physical activities • A new injury or symptoms from an older injury in the lower extremities within the last 2 y • Unwilling to monitor their running training using a GPS watch or a smartphone application

Abbreviations: ACSM, American College of Sports Medicine; BMI, body mass index; GPS, global positioning system.

Table 2. Proportion of Clinically Diagnosed Injuries That Were Knee Injuries by Body Mass Index

Knee Injuries	Normal Weight ^a	Overweight ^a	Obese ^a	APD, % ^b	P Value
Normal weight versus overweight	36%	26%		-10% (-20%, -0.3%)	.044
Normal weight versus obese	36%		29%	-7% (-21%, 5%)	.254

Abbreviation: APD, absolute proportion difference.

^aValues are prevalence proportion.

^bValues in parentheses are 95% confidence interval.

Table 3. Proportion of Self-reported Injuries That Were Knee Injuries by Body Mass Index

Knee Injuries	Normal Weight ^a	Overweight ^a	Obese ^a	APD, % ^b	P Value
Normal weight versus overweight	40%	20%		-20% (-34%, -6%)	.005
Normal weight versus obese	40%		18%	-23% (-43%, -2%)	.029

Abbreviation: APD, absolute proportion difference.

^aValues are prevalence proportion.

^bValues in parentheses are 95% confidence interval.

APPENDIX

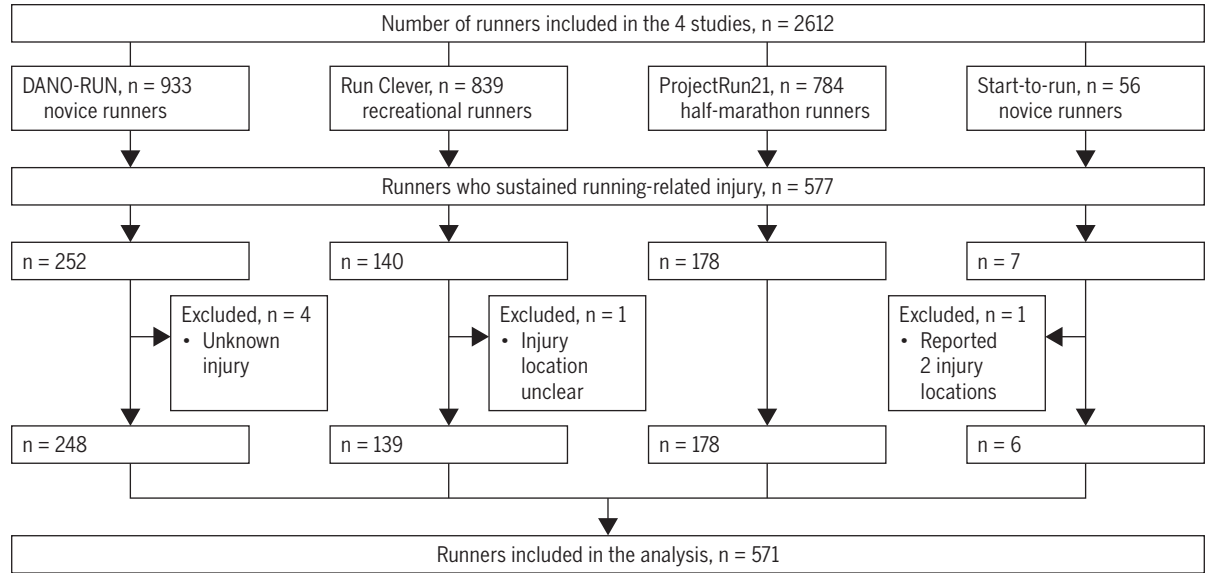


FIGURE. Flow chart.

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Shoulder Rotation Strength Changes From Preseason to Midseason: A Cohort Study of 292 Youth Elite Handball Players Without Shoulder Problems

Frequent high-velocity throwing in handball predisposes the player's shoulder to injury. Of youth handball players, 26% to 44% report shoulder problems during the season, 23% report shoulder problems of substantial severity, and 1 in 4 report shoulder problems in a given week.^{1,6} Handball players with shoulder problems during their career may have muscle imbalances, joint instability, and chronic rotator cuff pathologies, which may impair daily

activities, sport participation, and quality of life.^{11,24,27}

One important step toward preventing injury is to establish the cause of injury.^{34,36} It has been suggested that shoulder strength impairments affecting the balance between shoulder internal rotator muscles and external rotator muscles may be a risk factor for shoulder injury in overhead athletes, though there is conflicting evidence.^{5,12} In handball, the association between external rotation (ER) weakness and shoulder injury risk has been reported in studies of youth French female elite players¹⁶ and youth German female and male elite players,¹ while ER weakness in youth Swedish elite players was only associated with shoulder injury development in female players.⁷ In adults, internal rotation (IR) weakness¹⁹ and ER weakness¹¹ have also been identified as risk factors in male elite players, but the latter could not be confirmed in male elite players¹⁹ or in a mixed-sex elite cohort.²

Previous longitudinal studies have measured shoulder rotation strength only

• **OBJECTIVE:** To investigate change in shoulder rotation strength from preseason to midseason during a competitive season in youth elite handball players without shoulder problems.

• **DESIGN:** Prospective cohort study.

• **METHODS:** Players (n = 292, 45% female, 14-18 years of age) without shoulder problems from Danish youth elite handball clubs were assessed in the preseason and midseason. We measured isometric shoulder strength using handheld dynamometry in internal rotation (IR) and external rotation (ER) in supine, with the shoulder abducted 90° in neutral rotation and in 30° of IR. The primary outcome was the change in corresponding ER/IR ratio.

• **RESULTS:** The mean ER/IR ratios increased from preseason to midseason in neutral rotation (male player difference, 0.02; 95% confidence

interval [CI]: -0.01, 0.06; female player difference, 0.05; 95% CI: 0.01, 0.09) and in 30° of IR (male player difference, 0.15; 95% CI: 0.11, 0.20; female player difference, 0.12; 95% CI: 0.07, 0.17). The change in ER/IR ratio may be explained by an increase in ER strength in female players and a decrease in IR strength in male players. The amount of change in ER/IR ratio over the season was greater than individual measurement error metrics for 45% to 66% of the players.

• **CONCLUSION:** Shoulder rotation strength ratios changed during a competitive season in Danish youth elite handball players. *J Orthop Sports Phys Ther* 2020;50(7):381-387. doi:10.2519/jospt.2020.9183

• **KEY WORDS:** adolescent, handball, handheld dynamometry, normative reference values, shoulder strength

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once during the preseason, which may explain the conflicting results. During a competitive season, elite handball players face changes in physical demands and cumulative training exposure, which may contribute to a change in strength measures from preseason to midseason. These changes may make the players more or less susceptible to injury. In youth soccer, 40% of in-season injury risk alerts were related to changes in muscle strength.³⁷ Assuming this is the case in handball, evaluating shoulder strength during a competitive season to better understand strength changes in response to training load is necessary. As part of this evaluation, sport-, sex-, and position-specific normative reference values can be obtained to guide return-to-training, return-to-play, and return-to-performance decision making.^{10,12}

Our primary objective was to investigate changes in isometric shoulder IR strength, ER strength, and the accompanying ER/IR ratio, using handheld dynamometry, from preseason to midseason in youth elite handball players without shoulder problems. Our secondary objective was to report normative preseason reference values for shoulder rotation strength.

METHODS

IN THIS PROSPECTIVE COHORT STUDY, we followed youth elite handball players ($n = 292$, 45% female, 14–18 years of age) without shoulder pain or other shoulder problems for a full competitive handball season (October 13, 2013 to May 11, 2014; 31 weeks). As part of a larger testing protocol lasting 1.5 to 2.0 hours, we tested IR and ER strength of the throwing shoulder in the preseason (August–October 2013) and retested at midseason (January–March 2014). There was no participant and/or public involvement in the study design.

Participants

We recruited players from teams enrolled in the Danish First Division U-18 (range,

16–18 years of age) and First Division U-16 (range, 14–16 years of age) from all regions of Denmark. Participants and their parent/guardian provided assent and written informed consent according to the Helsinki Declaration,³⁸ and the rights of the participants were protected. A detailed description of the recruitment procedure and study flow has previously been presented.²⁵ All players without shoulder problems in the preseason and midseason were included. Players were excluded if they reported a history of shoulder surgery, glenohumeral dislocation, glenoid labral tear, rotator cuff tear, or fracture in the shoulder region within the previous 6 months.

Procedures

Players were tested in the evenings during their normal handball training, both in preseason and midseason. The strength measurements were completed in the same order for all players as part of the larger testing battery, which also included measures of shoulder range of motion, scapular dyskinesis, shoulder abduction strength, and the drop-jump test. We did not control for physical activity or recovery in the 24 hours prior to testing. However, all testing procedures were performed before, or instead of, normal handball practice.

The same physical therapist performed the shoulder strength measurements in the preseason and midseason. The physical therapist was blinded to the players' injury and exposure reports, preseason strength results, and any hypothesis concerning the analyses conducted in this study. Before study start, the physical therapist completed thorough training in the testing procedures. An investigation of how shoulder strength, range of motion, and scapular dyskinesis modify the association between training load and shoulder injuries in this cohort has previously been reported and showed that reduced shoulder ER strength (ER/IR ratio less than 0.75) exacerbated the effect of handball load on shoulder injury rate.²⁵ In the present study, we report data from the isometric shoulder IR and ER strength measurements.

Outcome Measurement Maximum isometric shoulder IR and ER strength was measured with a handheld dynamometer (HHD) (Commander 158 Muscle Tester; JTECH Medical, Midvale, UT) externally affixed with suction cups, according to a protocol previously described.²⁵ Participants were positioned supine on an examination table against a door or wall, with the shoulder abducted to 90° and the elbow flexed to 90° of neutral rotation with the olecranon at the table side. The tests were performed with the shoulder first in neutral rotation and then in 30° of IR, using a goniometer (**FIGURE**). We added the 30° IR position to the neutral rotation position traditionally used in studies,^{2,11,13} because we wanted a position closer to the end range (eg, following ball release) of the handball throw,³⁵ when the ER muscles are under the greater physiological and biomechanical stress of braking IR after ball release.

The physical therapist stabilized the HHD with one hand and the player's upper body with the other hand. The players were given standardized verbal instruction to press against the HHD with maximal effort and hold this pressure for 5 seconds in 3 trials. The players received verbal encouragement.

The shoulder rotation strength measures have excellent²² test-retest reliability (absolute agreement: intraclass correlation coefficient model 3,1 of 0.99 for all measures).²⁵ The individual standard error of measurement agreement ranged between 4.8 and 6.4 N (neutral rotation: IR, 6.4 N; ER, 6.3 N; ER/IR ratio = 0.047, and 30° of IR: IR, 4.8 N; ER, 5.3 N; ER/IR ratio = 0.039) (unpublished data from Møller et al²⁵). The individual 95% minimal detectable change (MDC_{95}) values ranged between 13.4 and 17.8 N (neutral rotation: IR, 17.8 N; ER, 17.5 N; 30° of IR: IR, 13.4 N; ER, 14.6 N). These were used to calculate MDC_{95} values for group means of 1.1 to 1.4 N for male players and 1.2 to 1.6 N for female players, using the equation: individual $MDC_{95}/\sqrt{n}$,³⁰ which can be used to evaluate our data on changes during

the season. The individual MDC_{95} values for ER/IR ratios were 0.13 and 0.11 for neutral rotation and 30° IR positions, respectively. These were used to calculate MDC_{95} group values of 0.01 for both positions.

Data Analysis

Maximum strength was defined as the mean of 3 strength measurements and presented as absolute values (Newtons) and relative values normalized to body weight (Newtons per kilogram).²¹ We used a linear regression model with robust standard error (considering the cluster nature of the study) to estimate the increase in shoulder rotation strength measures with age, and to assess differences in strength measures between player positions. The models were checked by diagnostic plots of the residuals. Based on these results, we analyzed changes in strength measures and ER/IR ratios from the preseason to midseason using a mixed-level regression, independent of age and player position, and stratified by sex. Club was included as a random variable to account for possible clustering. Results are reported as estimates and 95% confidence intervals (CIs). We performed all statistical analyses using Stata/SE Version 15 (StataCorp LLC, College Station, TX).

RESULTS

OF 679 YOUTH ELITE HANDBALL PLAYERS available for testing at preseason, 471 were included in the preseason analysis of normative reference values. Reasons for exclusion were missing age data (n = 13), shoulder injury at preseason, defined as having shoulder symptoms for more than 2 weeks (n = 86), previous shoulder injury during the last year (n = 37), new shoulder injury before midseason testing (n = 27), and not tested at preseason for various reasons (n = 45).²⁵ In total, 292 players were tested at both preseason and midseason, because not all players participated in the midseason testing²⁵ (TABLE 1).

Changes Over the Season

The ER/IR mean ratios increased from preseason to midseason in neutral rotation (male player difference, 0.02; 95% CI: -0.01, 0.06; female player difference, 0.05; 95% CI: 0.01, 0.09) and in 30° of

IR (male player difference, 0.15; 95% CI: 0.11, 0.20; female player difference, 0.12; 95% CI: 0.07, 0.17) (TABLE 2). For female players, the change in ER/IR ratio may be due to an increase in ER strength, while in male players it may be explained



FIGURE. Testing position for isometric shoulder rotation strength measurements, using a handheld dynamometer with external fixation. (A) Internal rotation with the shoulder in the neutral rotation position, (B) internal rotation with the shoulder in 30° of internal rotation, (C) external rotation with the shoulder in the neutral rotation position, and (D) external rotation with the shoulder in 30° of internal rotation.

TABLE 1	DEMOGRAPHICS OF THE STUDY POPULATION ^a	
	Male Players (n = 162)	Female Players (n = 130)
Age group, n (%) ^b		
U-16	62 (38)	64 (49)
U-18	100 (62)	66 (51)
Age, y	17.0 ± 1.1	16.8 ± 1.2
Player position, n (%)		
Back	62 (38)	49 (38)
Wing	46 (28)	32 (25)
Line	26 (16)	28 (22)
Goalkeeper	28 (17)	21 (16)
Height, cm	184.1 ± 6.6	171.4 ± 6.2
Weight, kg	79.9 ± 11.5	67.0 ± 9.0
Weekly handball training, h	6.7 ± 4.8	6.1 ± 2.0
^a Values are mean ± SD unless otherwise indicated.		
^b The U-16 group included participants aged 14 to 16 years, and the U-18 group included participants aged 16 to 18 years.		

by a decrease in IR strength. All changes were above the group MDC_{95} values. The proportions of players who had a change in ER/IR ratio greater than the individual MDC_{95} value were 45% in neutral rotation and 66% in 30° of IR for both sexes. For changes in absolute shoulder rotation strength, a larger proportion of male players (53%-72%) to female players (40%-52%) had changes above the individual MDC_{95} values.

Normative Reference Values for Strength

Preseason normative reference values for youth elite handball players and a regres-

sion equation to obtain the normative reference values by sex and age are provided in the **APPENDIX** (available at www.jospt.org). In general, male players were stronger than female players. Age-related strength differences were limited to the absolute strength of male players, who were stronger with higher age. Differences in strength between player positions (back players were the reference group and were compared to wings, line players, and goalkeepers) showed reduced strength for goalkeepers in relative values (Newtons per kilogram) and for wings in absolute values (Newtons).

DISCUSSION

THE ER/IR RATIO ON A GROUP LEVEL increased from the preseason to midseason during a competitive season. The amount of change in ER/IR ratio over the season was greater than individual measurement error metrics for 45% to 66% of the players, and changes in ER/IR ratios were larger in the 30° IR position than in neutral rotation. Male players were stronger than female players, irrespective of age. We used standardized testing procedures performed by the same tester, with external fixation of the dynamometer to improve reliability of the measurements. The large sample size improves the external validity of the results.

Strength Changes During the Season: What Do They Mean, and What Are the Implications?

The mean ER/IR ratios for players without shoulder problems at both time points were above 0.75, which has been reported as the cut point for exacerbated risk of sustaining shoulder injury in this population.²⁵ At the individual level, fewer players had ER/IR ratios below 0.75 at midseason compared to the preseason in neutral rotation (preseason, 42% of male players and 27% of female players; midseason, 30% of male players and 20% of female players) and in 30° of IR (preseason, 27% of male players and 26% of female players; midseason, 5% of male players and 5% of female players), indicating a positive change in muscle balance in players without shoulder problems.

Strength changes during the season were generally above the measurement error metrics (group MDC_{95} values ranging from 1.1 to 1.6 N for both sexes).^{25,30} On an individual level, the ER/IR ratio in neutral rotation was greater than individual MDC_{95} values in 45% of players, and in 66% of players in 30° of IR. It is debatable whether the observed strength changes in absolute values are large, relevant changes. Because the ER/IR ratio is typically used as a risk parameter in studies and in clinical settings, even small absolute changes

TABLE 2

COMPARISON BETWEEN PRESEASON AND MIDSEASON SHOULDER STRENGTH FOR MALE (N = 162) AND FEMALE (N = 130) PLAYERS, AND CHANGES DURING THE COMPETITIVE SEASON^a

	Preseason	Midseason	Difference ^b
Neutral rotation			
Male players			
IR, N	175 ± 48 (168, 183)	162 ± 40 (156, 168)	-12.4 (-23.5, -1.3)
ER, N	140 ± 40 (134, 146)	135 ± 39 (129, 141)	-4.8 (-13.7, 4.1)
IR, N/kg	2.2 ± 0.5 (2.1, 2.3)	2.1 ± 0.9 (2.0, 2.2)	-0.1 (-0.3, 0.1)
ER, N/kg	1.8 ± 0.5 (1.7, 1.8)	1.7 ± 0.4 (1.6, 1.8)	-0.1 (-0.2, 0.0)
ER/IR ratio	0.81 ± 0.15 (0.78, 0.83)	0.83 ± 0.14 (0.81, 0.85)	0.02 (-0.01, 0.06)
Female players			
IR, N	119 ± 26 (114, 123)	113 ± 24 (108, 117)	-4.2 (-12.1, 3.8)
ER, N	100 ± 30 (95, 105)	100 ± 25 (96, 104)	0.3 (-5.1, 5.6)
IR, N/kg	1.8 ± 0.4 (1.7, 1.9)	1.7 ± 0.4 (1.6, 1.8)	-0.1 (-0.2, 0.1)
ER, N/kg	1.5 ± 0.5 (1.4, 1.6)	1.5 ± 0.3 (1.4, 1.6)	0.0 (-0.1, 0.1)
ER/IR ratio	0.84 ± 0.19 (0.81, 0.88)	0.89 ± 0.15 (0.87, 0.91)	0.05 (0.01, 0.09)
30° of IR			
Male players			
IR, N	163 ± 50 (156, 171)	140 ± 39 (134, 146)	-20.8 (-33.2, 8.5)
ER, N	136 ± 39 (130, 142)	140 ± 45 (134, 148)	4.6 (-3.3, 12.5)
IR, N/kg	2.0 ± 0.6 (1.9, 2.1)	1.8 ± 0.4 (1.7, 1.8)	-0.3 (-0.4, -0.1)
ER, N/kg	1.7 ± 0.5 (1.6, 1.8)	1.8 ± 0.5 (1.7, 1.8)	0.05 (-0.1, 0.2)
ER/IR ratio	0.86 ± 0.19 (0.83, 0.89)	1.01 ± 0.21 (0.98, 1.04)	0.15 (0.11, 0.20)
Female players			
IR, N	110 ± 26 (106, 114)	103 ± 25 (99, 107)	-5.5 (-12.8, 1.8)
ER, N	93 ± 24 (89, 97)	101 ± 26 (96, 105)	8.1 (3.2, 12.9)
IR, N/kg	1.7 ± 0.4 (1.6, 1.7)	1.6 ± 0.4 (1.5, 1.6)	-0.1 (-0.2, 0.0)
ER, N/kg	1.4 ± 0.4 (1.3, 1.5)	1.5 ± 0.4 (1.4, 1.6)	0.1 (0.0, 0.2)
ER/IR ratio	0.85 ± 0.16 (0.82, 0.88)	0.98 ± 0.15 (0.96, 1.00)	0.12 (0.07, 0.17)

Abbreviations: ER, external rotation; IR, internal rotation.

^aValues are mean or mean ± SD (95% confidence interval).

^bValues in bold represent a statistically significant difference between the preseason and midseason ($P \leq 0.05$).

may have important clinical implications.¹ Whether the strength changes between the 2 time points are within the normal individual daily fluctuations in strength, negative adaptations, or positive adaptations to training load during a competitive season is open for speculation.

Most risk factor studies solely include preseason strength as a covariate in the analysis, without considering that strength adaptations may occur due to changes in training load and periodization in strength training. Further, limited evidence suggests that a competitive season results in muscle imbalances (eg, reduced ER/IR ratios in the shoulder at different time periods of the season).^{8,17,18,29} Therefore, studies investigating the importance of rotation strength ratios in shoulder injury etiology should consider including the strength-related variable as a time-varying covariate.^{25,28} Although more research is needed to fully understand the clinical implications of these data, shoulder rotation strength deficits have been associated with lower tolerance of handball load.²⁵ Therefore, clinicians who use strength measures to evaluate players before and after injury should consider regular monitoring to account for potential strength changes. Researchers and clinicians should account for the individual fluctuations in strength that can be observed in strength measurements at different time points.

The Importance of Different Shoulder Strength Testing Positions

There was a larger increase in ER/IR ratios in 30° of IR than in neutral rotation. This might be because the external rotators of the shoulder are in a better length-tension relationship in this position, which is closer to post ball release in handball throwing. Only ER strength deficits in 30° of IR exacerbated an effect between a large weekly increase in handball shoulder injury rate,²⁵ which supports the 30° IR position as being more relevant for the handball throw compared to neutral rotation position. Other studies primarily test in a single shoulder position.^{1,7}

However, our data suggest that one may miss important information about injury risk by doing so.

Sex Differences

Female players had significant increases in ER strength; male players had significant reductions in IR strength. The exact mechanisms for these differences are not explained by our data, but are likely due to factors such as an adaptive response¹⁷ or work-induced fatigue^{15,26} from repetitive overhead throwing. In our normative reference values, sex differences were present: male players were stronger than female players, both in terms of absolute strength values (Newtons) and when strength values were normalized to body weight (Newtons per kilogram), which can be explained by large sex differences in body composition during adolescence. These findings support the majority of previous studies,^{1,2,4,7,9,32} while some studies have not found sex differences in normalized strength data.^{14,20,32} Sex differences in shoulder strength and the different patterns of changes throughout the season could explain why prospective cohort studies identify sex-dependent risk factors for shoulder injuries.^{1,6,7}

Normative Values: Relevance and Similarities

Few studies have reported normative data for the handball population. Absolute values (Newtons) for German elite handball players at a mean age of 14 years were slightly higher than the normative reference values reported here, even though players on average were younger and had lower body weight.¹ Normative data from a large cohort of Swedish elite handball players with a mean age of 16.3 to 16.4 ± 0.8 years were consistent with our data.⁷ Different testing positions (eg, supine and seated, with the arm in different positions), equipment (eg, brands of HHD), the use of external fixation, and using the average of 3 tests in contrast to using the best score of 2 tests¹ or the average of 2 tests⁷ might explain differences in strength. Because differences

between ages and player positions were not consistent in our data, we decided to examine differences between the sexes in strength changes from preseason to mid-season. However, future studies should consider using player position as a potentially relevant factor.⁵

Methodological Issues That Could Influence the Interpretation of the Results

We measured strength twice during the season. More frequent measurements could give a better indication of potential changes. Strength has a normal individual fluctuation throughout the day due to many factors, such as level of recovery from previous load,³³ muscle fatigue,³ and timing of the testing during the day.²³ For practical reasons, we did not control for these factors in our study. Using averages from the large sample size in this cohort counterbalances the individual reasons for normal day-to-day fluctuation in strength.

We report the ER/IR ratio based on isometric strength measures, while other studies have suggested novel procedures to assess eccentric ER strength with HHDs, which will provide a functional shoulder ER/IR strength ratio in handball players.¹³ Eccentric measurement requires more advanced procedures and may cause more fatigue in the shoulder muscles and likely less reliability, which was the reason for not using this method in our youth population. Our data represent a sample from Danish youth elite handball players aged 14 to 18 years, with a mean age of 17 years, which should be considered when generalizing data to other populations.

CONCLUSION

THE SHOULDER ER/IR STRENGTH RATIO increases at the group level from preseason to midseason in youth elite handball players. The change in ER/IR ratio may be explained by an increase in ER strength in female players and by a decrease in IR strength in male play-

ers. The amount of change in ER/IR ratio over the season was greater than individual measurement error metrics for 45% to 66% of the players. Male players were stronger than female players across all ages in absolute strength values and relative values normalized to body weight. ●

KEY POINTS

FINDINGS: During a competitive season in youth elite handball, shoulder strength balance changes between 2 different time points. Shoulder external rotation-internal rotation strength ratios increased from the preseason to midseason.

IMPLICATIONS: Clinicians and researchers should be aware that strength in youth elite handball players may have a normal variation over the course of the season. This warrants ongoing monitoring and should be considered when normative reference values are compared, and when measuring the effect of targeted exercise programs. Studies investigating whether shoulder strength causes shoulder injuries should consider including the strength variable as a time-varying covariate.

CAUTION: Shoulder strength changes in this study are based on only 2 time points. Further research is needed to answer the questions of how strength in youth elite handball players changes at several time points over the whole season and the clinical importance of those changes. The amount of change in external rotation-internal rotation ratio over the season was greater than individual measurement error metrics for 45% to 66% of the players. When measuring changes in shoulder strength during the season, one should ascertain that the observed changes are above the test-retest measurement error at group and individual levels.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors contributed to the conception or design of the study. Merete Møller was responsible for the data collection. Behnam Liaghat and Merete Møller performed

the analyses and drafted the first version of the manuscript. All authors contributed to the interpretation of the results, revised and approved the final manuscript, and take responsibility for the integrity of the work from inception to the finished article.

DATA SHARING: Data are available on request from Merete Møller (memoller@health.sdu.dk) for inclusion in future meta-analyses on related research topics. All personally identifiable information will be deleted or anonymized before data transfer. Sharing of individual data is not available because this was not included in the participant consent.

PATIENT AND PUBLIC INVOLVEMENT: There was no participant or public involvement in the study design.

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APPENDIX

NORMATIVE VALUES, REGRESSION EQUATIONS, AND STRENGTH DIFFERENCES

Normative Values

Below are normative values for 471 youth elite handball players attending preseason testing. Maximum strength was defined as the mean of 3 strength measures and presented as absolute values (Newtons) and normalized to body weight (Newtons per kilogram). Normative values were defined using the cutoff points employed previously by Redmond et al,³¹ namely: normal range was mean $\pm$ 1 SD, providing a 68% prediction interval. Low strength included values from -1 to -2 SD, very low strength included values outside -2 SD, high strength included values from $+1$ to $+2$ SD, and very high strength included values outside $+2$ SD.

Regression equations to obtain the preseason normative values by sex and age are shown below (TABLE 1) and illustrated in FIGURES 1 and 2.

Table 1. Regression Equations to Obtain Normative Values for Youth Elite Handball Players by Sex and Age

Assessment Parameter	Male Players	Female Players
30° of IR		
IR, N/kg	$[1.08 + (\text{age} \times 0.05) \pm 1 \text{ or } \pm 2 \times 0.56]$	$[2.72 + (\text{age} \times -0.06) \pm 1 \text{ or } \pm 2 \times 0.40]$
ER, N/kg	$[1.08 + (\text{age} \times 0.04) \pm 1 \text{ or } \pm 2 \times 0.46]$	$[1.98 + (\text{age} \times 0.03) \pm 1 \text{ or } \pm 2 \times 0.36]$
ER/IR ratio ^a	$[0.89 + (\text{age} \times 0.000002) \pm 1 \text{ or } \pm 2 \times 0.20]$	$[0.70 + (\text{age} \times 0.01) \pm 1 \text{ or } \pm 2 \times 0.18]$
Neutral rotation		
IR, N/kg	$[1.39 + (\text{age} \times 0.05) \pm 1 \text{ or } \pm 2 \times 0.56]$	$[2.94 + (\text{age} \times -0.07) \pm 1 \text{ or } \pm 2 \times 0.40]$
ER, N/kg	$[0.53 + (\text{age} \times 0.07) \pm 1 \text{ or } \pm 2 \times 0.45]$	$[2.45 + (\text{age} \times -0.06) \pm 1 \text{ or } \pm 2 \times 0.42]$
ER/IR ratio ^a	$[0.45 + (\text{age} \times 0.02) \pm 1 \text{ or } \pm 2 \times 0.16]$	$[0.86 + (\text{age} \times -0.001) \pm 1 \text{ or } \pm 2 \times 0.18]$

Abbreviations: ER, external rotation; IR, internal rotation.

^aThe ER/IR ratio denotes the muscle balance of the shoulder rotators.

Strength differences between male and female players (TABLE 2) and between player positions (TABLES 3 and 4) are shown below.

Table 2. Differences in Strength Between Male and Female Players at Preseason^a

	Male Players	Female Players	Sex Difference ^b
Relative strength, N/kg			
IR, 30° of IR	2.0 $\pm$ 0.6	1.7 $\pm$ 0.4	0.3 (0.2, 0.4)
IR, neutral rotation	2.2 $\pm$ 0.6	1.8 $\pm$ 0.4	0.4 (0.3, 0.5)
ER, 30° of IR	1.7 $\pm$ 0.5	1.4 $\pm$ 0.4	0.3 (0.2, 0.4)
ER, neutral rotation	1.8 $\pm$ 0.5	1.5 $\pm$ 0.4	0.3 (0.2, 0.4)
Absolute strength, N			
IR, 30° of IR	161 $\pm$ 48	112 $\pm$ 27	48 (41, 55)
IR, neutral rotation	174 $\pm$ 49	121 $\pm$ 28	53 (46, 60)
ER, 30° of IR	139 $\pm$ 39	95 $\pm$ 24	43 (37, 49)
ER, neutral rotation	142 $\pm$ 40	100 $\pm$ 29	42 (35, 48)
ER/IR ratio			
30° of IR	0.89 $\pm$ 0.20	0.86 $\pm$ 0.18	0.03 (-0.01 , 0.06)
Neutral rotation	0.83 $\pm$ 0.16	0.84 $\pm$ 0.18	-0.01 (-0.02 , 0.04)

Abbreviations: ER, external rotation; IR, internal rotation.

^aValues are mean $\pm$ SD unless otherwise indicated.

^bValues in parentheses are 95% confidence interval. Values in bold represent a statistically significant difference between male and female players ($P \leq 0.05$).

APPENDIX

Table 3. Differences in Strength Normalized to Body Weight (N/kg) Between Player Positions^a

	Back (reference)	Wing	Line	Goalkeeper
IR, 30° of IR				
Male	2.1 ± 0.6	2.0 ± 0.6	2.0 ± 0.6	1.9 ± 0.5
Difference ^b		-0.1 (-0.3, 0.2)	-0.1 (0.0, 1.4)	-0.2 (-0.4, 0.0)
Female	1.7 ± 0.4	1.7 ± 0.4	1.6 ± 0.4	1.6 ± 0.4
Difference ^b		0.0 (-0.1, 0.2)	-0.1 (-0.3, 0.1)	-0.2 (-0.3, 0.0)
IR, neutral rotation				
Male	2.2 ± 0.5	2.2 ± 0.7	2.2 ± 0.5	2.1 ± 0.5
Difference ^b		-0.1 (-0.3, 0.2)	0.1 (-0.3, 0.1)	-0.1 (-0.3, 0.2)
Female	1.9 ± 0.4	1.9 ± 0.4	1.7 ± 0.4	1.7 ± 0.4
Difference ^b		0.0 (-0.1, 0.1)	-0.15 (-0.30, -0.02)	-0.2 (-0.3, -0.1)
ER, 30° of IR				
Male	1.8 ± 0.5	1.7 ± 0.5	1.7 ± 0.5	1.6 ± 0.5
Difference ^b		-0.1 (-0.3, 0.1)	-0.1 (-0.4, 0.1)	-0.2 (-0.3, 0.0)
Female	1.5 ± 0.4	1.5 ± 0.4	1.3 ± 0.3	1.3 ± 0.3
Difference ^b		0.0 (-0.2, 0.2)	-0.1 (-0.3, 0.0)	-0.1 (-0.3, 0.0)
ER, neutral rotation				
Male	1.8 ± 0.5	1.8 ± 0.5	1.7 ± 0.4	1.7 ± 0.5
Difference ^b		-0.1 (-0.2, 0.1)	-0.1 (-0.3, 0.0)	-0.2 (-0.4, 0.0)
Female	1.5 ± 0.4	1.6 ± 0.4	1.4 ± 0.6	1.4 ± 0.3
Difference ^b		0.0 (0.0, 0.2)	0.0 (-0.3, 0.2)	-0.1 (-0.2, 0.0)
ER/IR ratio, 30° of IR				
Male	0.89 ± 0.21	0.91 ± 0.21	0.86 ± 0.17	0.87 ± 0.19
Difference ^b		0.02 (-0.05, 0.09)	-0.03 (-0.12, 0.06)	-0.01 (-0.06, 0.03)
Female	0.85 ± 0.16	0.86 ± 0.17	0.86 ± 0.19	0.89 ± 0.22
Difference ^b		0.01 (-0.05, 0.07)	0.01 (-0.07, 0.08)	0.04 (-0.04, 0.13)
ER/IR ratio, neutral rotation				
Male	0.84 ± 0.15	0.84 ± 0.18	0.81 ± 0.14	0.80 ± 0.15
Difference ^b		0.01 (-0.06, 0.07)	-0.03 (-0.09, 0.03)	-0.03 (-0.09, 0.02)
Female	0.82 ± 0.14	0.84 ± 0.13	0.85 ± 0.31	0.85 ± 0.15
Difference ^b		0.02 (-0.03, 0.02)	0.03 (-0.07, 0.12)	0.02 (-0.02, 0.06)

Abbreviations: ER, external rotation; IR, internal rotation.

^aValues are mean ± SD Newtons per kilogram unless otherwise indicated.^bValues in parentheses are 95% confidence interval. Values in bold represent a statistically significant difference between player positions, with back players set as the reference group ($P \leq 0.05$).

APPENDIX

Table 4. Differences in Absolute Strength (N) Between Player Positions^a

	Back (reference)	Wing	Line	Goalkeeper
IR, 30° of IR				
Male	167 ± 49	143 ± 43	178 ± 51	157 ± 41
Difference		-23 (-36, -11)	11 (-11, 33)	-10 (-22, 33)
Female	118 ± 26	105 ± 26	115 ± 29	107 ± 28
Difference		-12 (-23, -2)	-3 (-11, 6)	-11 (-21, -1)
IR, neutral rotation				
Male	177 ± 44	160 ± 52	193 ± 52	173 ± 46
Difference		-17 (-35, 1)	16 (0, 32)	-4 (-17, 9)
Female	127 ± 28	113 ± 26	121 ± 29	116 ± 28
Difference		-14 (-24, -4)	-6 (-15, 2)	-11 (-21, -2)
ER, 30° of IR				
Male	144 ± 36	127 ± 36	151 ± 44	136 ± 41
Difference		-17 (-30, -3)	7 (-13, 27)	-8 (-17, 2)
Female	99 ± 25	89 ± 24	95 ± 22	93 ± 25
Difference		-10 (-21, 1)	-4 (-12, 4)	-6 (-17, 5)
ER, neutral rotation				
Male	146 ± 38	131 ± 39	154 ± 44	138 ± 39
Difference		-15 (-27, -2)	8 (-10, 26)	-9 (-24, 6)
Female	104 ± 25	96 ± 27	102 ± 40	96 ± 22
Difference		-8 (-17, 1)	-3 (-17, 12)	-8 (-17, 2)
ER/IR ratio, 30° of IR				
Male	0.89 ± 0.21	0.91 ± 0.21	0.86 ± 0.17	0.88 ± 0.19
Difference		0.02 (-0.05, 0.09)	-0.03 (-0.12, 0.06)	-0.01 (-0.06, 0.03)
Female	0.85 ± 0.16	0.86 ± 0.17	0.86 ± 0.20	0.89 ± 0.22
Difference		0.01 (-0.05, 0.07)	0.01 (-0.07, 0.08)	0.04 (-0.04, 0.13)
ER/IR ratio, neutral rotation				
Male	0.84 ± 0.15	0.84 ± 0.18	0.81 ± 0.14	0.80 ± 0.15
Difference		0.01 (-0.06, 0.07)	-0.03 (-0.09, 0.03)	-0.03 (-0.09, 0.02)
Female	0.83 ± 0.14	0.84 ± 0.13	0.85 ± 0.31	0.85 ± 0.15
Difference		0.02 (-0.03, 0.02)	-0.03 (-0.07, 0.12)	0.02 (-0.02, 0.06)

Abbreviations: ER, external rotation; IR, internal rotation.

^aValues are mean ± SD Newtons unless otherwise indicated. Values in parentheses are 95% confidence interval. Values in bold represent a statistically significant difference between player positions, with back players set as the reference group ($P \leq 0.05$).

APPENDIX

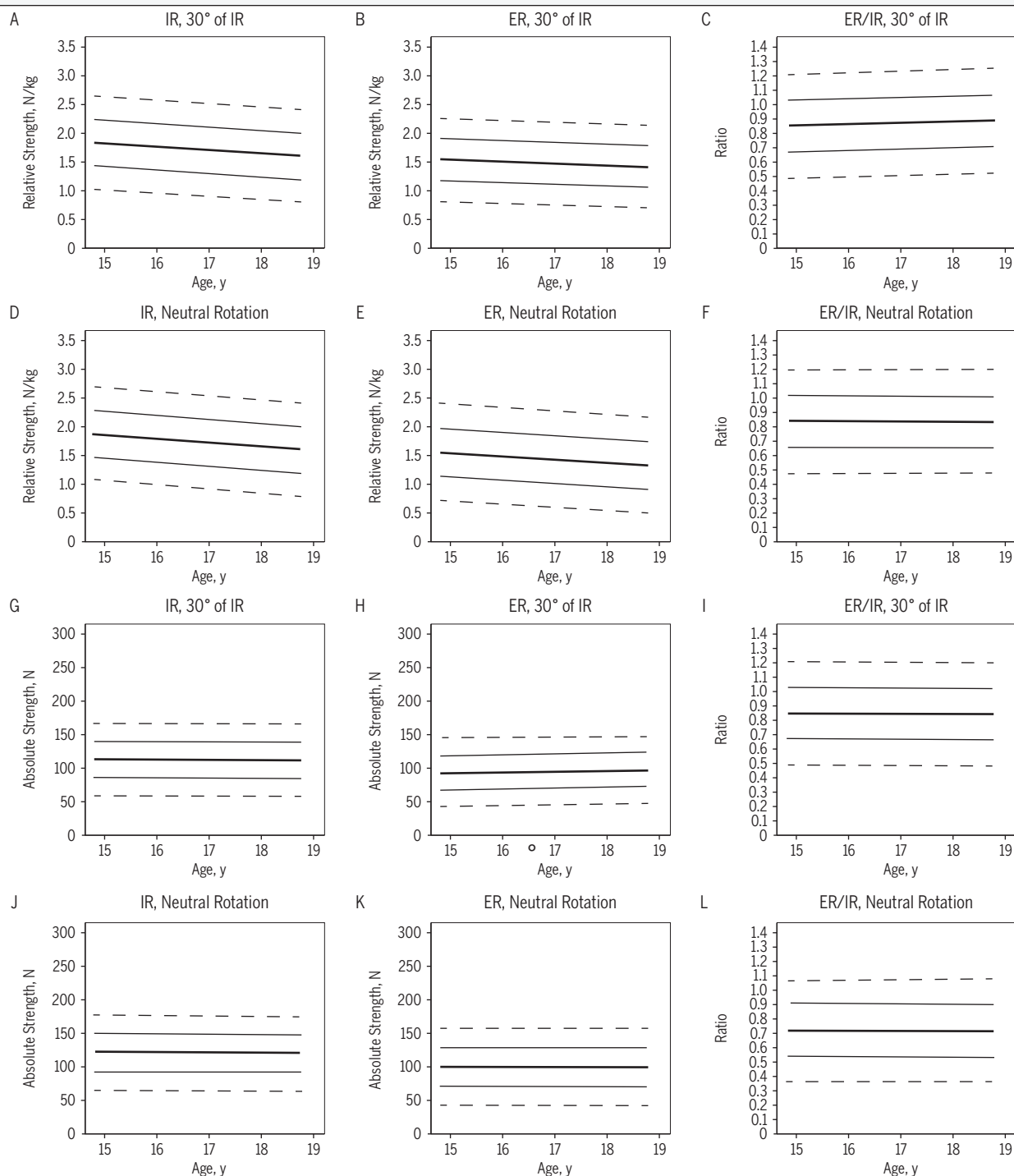


FIGURE 1. Preseason strength measures for female players: normative values in shoulder rotation strength for IR and ER. The ER/IR ratio denotes the muscular balance of the shoulder rotators. To display values between a very low strength and low strength or very high strength and high strength, the ± 1 and ± 2 root-mean-square errors were added. Abbreviations: ER, external rotation; IR, internal rotation.

APPENDIX

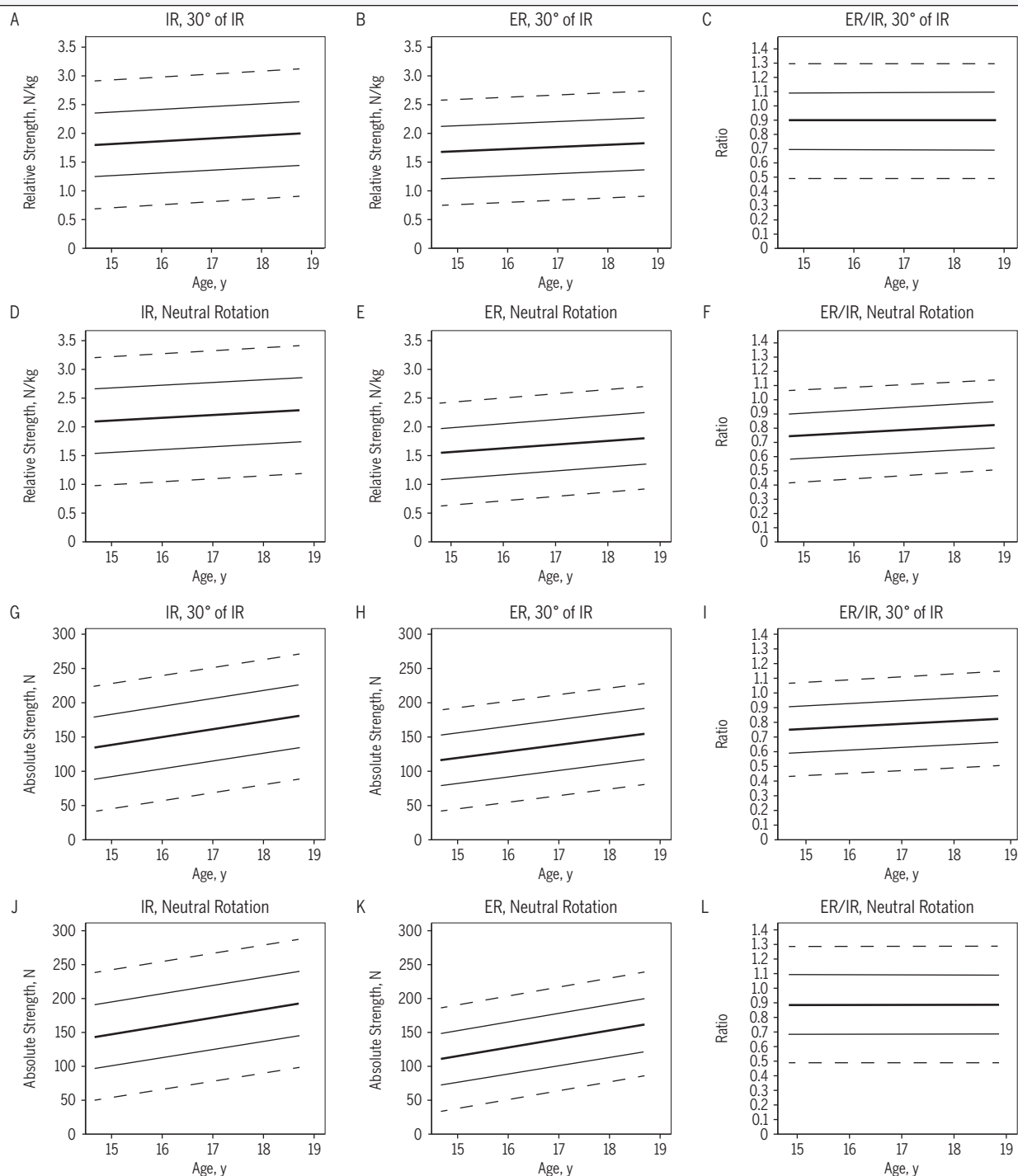


FIGURE 2. Preseason strength measures for male players: normative values in shoulder rotation strength for IR and ER. The ER/IR ratio denotes the muscular balance of the shoulder rotators. To display values between a very low strength and low strength or very high strength and high strength, the ± 1 and ± 2 root-mean-square errors were added. Abbreviations: ER, external rotation; IR, internal rotation.



FIGURE 1. Anteroposterior oblique (mortise view) radiograph of the left ankle identifying a trans-syndesmotic fracture of the fibula.



FIGURE 2. Lateral radiograph of the left ankle demonstrating minimal posterior displacement of the trans-syndesmotic fibular fracture (blue arrow). An incidental finding of os trigonum is noted (orange arrow).

Isolated Trans-syndesmotic Fibular Fracture in a Skateboarder

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A 20-YEAR-OLD MALE MILITARY technician reported to a direct-access physical therapy clinic 1 week after falling off a skateboard. His primary complaint was left lateral ankle pain that began immediately after his injury and persisted with weight-bearing activity. He reported being able to walk with the pain since the injury. Rest, ice, and elevation eased the pain.

On physical exam, moderate ecchymosis was observed over the left distal fibula, with slight ecchymosis over the medial hindfoot and the lateral planar aspect of the midfoot. Left lateral ankle swelling was present, with a 2.5-

cm girth differential on figure-of-eight measurement. Gait was antalgic, with an ipsilateral toe-out pattern and accelerated heel-off. Left ankle passive range of motion was grossly hypomobile in all planes, though the patient only experienced distal fibular pain at end-range dorsiflexion with overpressure. Anterior drawer testing was noncontributory. The patient experienced sharp and severe pain with palpation on the posterior lateral malleolus, indicating a positive finding by the Ottawa ankle rules.¹ The physical therapist ordered ankle radiographs, which revealed a minimally displaced oblique trans-

syndesmotic fibular fracture (**FIGURES 1 and 2**).

The patient was provided crutches and referred to orthopaedics for same-day evaluation. The orthopaedic surgeon evaluated the ankle under fluoroscopy and found no signs of medial instability. The patient was issued a walking boot and advised to weight bear as tolerated.² The patient was transitioned out of the walking boot after 6 weeks and was able to return to full activities 3 months after his injury. This case illustrates the utility of the Ottawa ankle rules in nonemergency settings. ● *J Orthop Sports Phys Ther* 2020;50(7):410. doi:10.2519/jospt.2020.9355

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Patients as Partners in Research: A Practical Example of How Researchers Are Contributing to the Patient-Partnership Revolution

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Every musculoskeletal pain condition and rehabilitation experience is different. That is why listening to, and truly collaborating with, people who experience pain is imperative in research and, ultimately, clinical management of musculoskeletal pain. Patient-centered care and shared decision making are core principles when working with people with musculoskeletal pain conditions, including low back pain (LBP).⁶ These principles should include research as a part of developing care.

In practice, people with LBP often do not feel listened to or that treatment is tailored to their needs.^{1,9} Part of this problem is a lack of engagement in research, one of the ways in which care is developed. Despite widespread adoption of shared decision-making principles as a concept, clinical care is almost always clinician driven.⁴ In order to address these ongoing concerns, we need a large shift in practices to place people at the center of their health care and to better share power between health practitioners and patients (and researchers).

Patient partnership in research is a key avenue for facilitating change so that patients are a core part of creating health care knowledge and understanding.³

The necessity to partner with patients in research has been recently discussed in *JOSPT*.² The editorial emphasized that patient partnership in musculoskeletal research is still relatively rare, and because there is little discussion on how to best achieve this partnership, there is a need to provide concrete examples of the work being done along these lines.

In this editorial, we provide one example of how we are partnering with patients (and clinicians) in our current research. We aim to encourage researchers to foster patient partnership in musculoskeletal research and share with potential patient partners how patients were engaged in our research.

An Overview of Our Research

In our work, we aim to enhance, and propose an extension of, the biopsychosocial

model of health care to include ethical, moral, and interpersonal aspects of LBP care (**FIGURE 1**). We call these the “human aspects of care,” which include, for example, the stigma associated with having a chronic musculoskeletal condition and power imbalances in patient-health professional interactions. We engage and collaborate with clinicians and patients to codevelop and locally implement recommendations to change practice toward enhancing these human aspects of care. This engagement and collaboration is not directly underpinned by any specific framework. However, we can consider it to be in line with frameworks such as the International Association for Public Participation⁵ because the advice of patients and clinicians is frequently and consistently incorporated into our research. We used sociological concepts to drive our research methodology design.

Our collaborative design is an adapted approach used in an earlier project with a different clinical group, young people with muscular dystrophy and their families.⁸ We employ the same key data-collection method of ethnographic

observations⁷ in order to observe the interaction between clinicians and patients with LBP across 2 sites: a private physical therapy practice and a publicly funded pain clinic.⁷ Data from these observations are collaboratively and iteratively analyzed on multiple occasions by 3 different groups: (1) researchers, (2) clinicians from the practices, and (3) patients with lived experience of LBP and its clinical management. Therefore, our study engages not only researchers, but also clinicians and patients, to co-develop changes in health care practice. In this editorial, we focus on how patients participate in the research.

How We Engage Patients in Our Research

The patient advisor group contributing to our research project includes 5 people with LBP, with different health care and other life experiences. We meet with them in the form of a patient advisor panel ap-

proximately every 2 months in 2-hour face-to-face meetings during the 3-year project. After an introductory meeting that provides a chance for input into study design, each meeting has a similar structure to that shown in **FIGURE 2**. The meeting starts with a brief overview of our study progress (eg, number of observations and meetings with researchers). We then ask the panel specific questions that are relevant to our emerging findings. The questions take into consideration the patients' previous or present experience with health care professionals and are focused on the human aspects of care. For example, we have discussed the interpersonal interaction between patients and therapists, what their expected roles are, and how power dynamics are negotiated in practice.

Toward the end of each meeting, in group exercises borrowed from the design industry, we summarize or brain-

storm the main ideas that emerged in the discussion in ways that were meaningful to patients using sticky notes, cards, and butcher paper. The patient advisors then share, group, and prioritize these ideas into recommendations to change practice toward enhancing the human dimensions of LBP care. These activities enable patients to contribute to complex qualitative analysis without specialized training.

Although we actively engaged patients and incorporated their advice and expertise into our study, they were neither part of the core research team nor engaged in the development of research questions. In this respect, patient participation in our research had limits. Future studies could expand participation by, for example, engaging patients in the development of research questions, research meetings, and greater contributions to research outputs (eg, papers, infographics).

Summary: Ushering in the Patient-Partnership Revolution

It is not easy to prioritize and implement collaborative patient partnership in musculoskeletal research, because established systems and practices have not traditionally created appropriate spaces for patients to engage and share their important expertise and insights to improve research. However, with some thought, there are appropriate and meaningful ways to include patient expertise and insight in any type of research. Beyond a shift in how we think about conducting research, including patients is usually not very difficult, and it is very often rewarding and even fun. With our research, we hope to add to this necessary patient-partnership revolution and share how researchers can actively (and joyfully) engage patients in research. ●

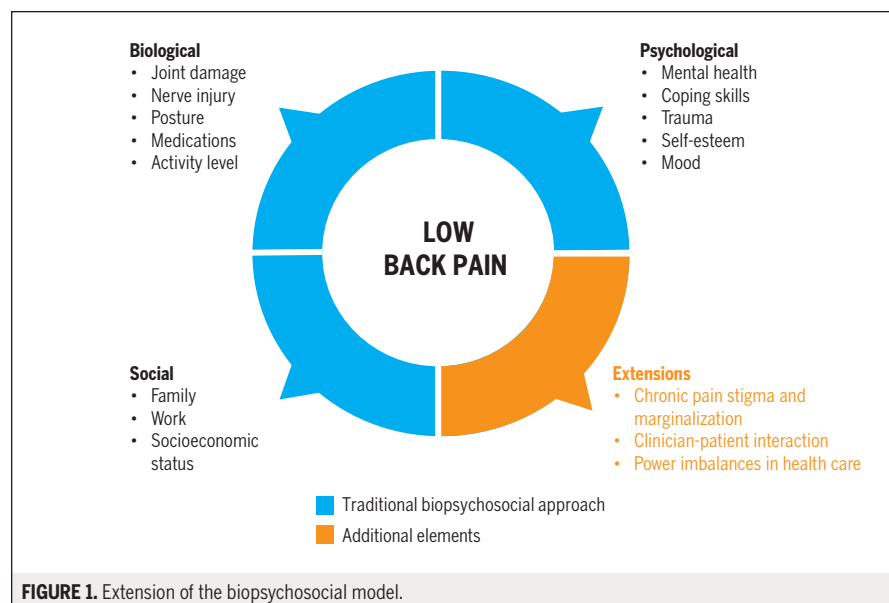


FIGURE 1. Extension of the biopsychosocial model.

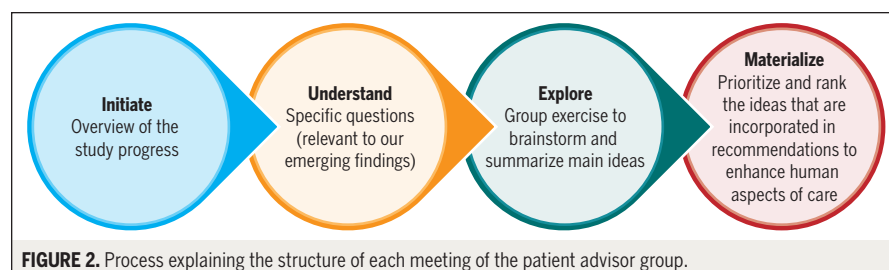


FIGURE 2. Process explaining the structure of each meeting of the patient advisor group.

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Posterior Shoulder Instability Classification, Assessment, and Management: An International Delphi Study

Posterior shoulder instability (PSI) is challenging to diagnose, and prioritizing management options can be difficult.^{8,29,30} Prior literature reported that the incidence of PSI ranges from 1.0% to 3.8% of all dislocations,^{4,23,36} and PSI currently constitutes approximately 10% of all instability events.^{25,26} Up to 1 in 4 surgically

managed shoulder instabilities have a component of posterior instability.^{1,2,21,39}

There is weak evidence to guide the clinician on what to include in the clinical assessment of PSI.¹⁰ A patient may describe pain in the posterior glenohumeral joint,³ a sensation of joint looseness,¹⁴ or provocation of symptoms during sport^{7,8,37,45} and

activities of daily living.^{20,37,46} Recurrent, position-specific symptoms occur in patients without a specific injury event or mechanism.³² Patients may have a history of repetitive movement into the symptom-provoking position of flexion, adduction, and internal rotation (eg, in volleyball, baseball, and football).^{3,30,31}

Direction of instability (unidirectional, bidirectional, and/or multidirectional),^{1,3,14} mechanism of injury (traumatic, microtraumatic, and/or atraumatic),^{3,29,30} and degree of injury (subluxation, reduced dislocation, and/or nonreduced dislocation)^{3,31,33} may help the clinician diagnose PSI. The terms *microtraumatic* and *atraumatic* have been suggested as subgroups of PSI but are not well differentiated.⁴⁰ Subgrouping may assist with prognostic outcomes for both nonsurgical and surgical management of PSI.

Nonsurgical management of atraumatic PSI is promoted as the appropriate initial treatment, despite little supporting evidence.^{19,34,41} Appropriate nonsurgical care has yet to be well defined and supported in traumatic PSI.^{22,42} Surgery is often recommended for traumatic dislocations.^{13,15,35}

Given the lack of empirical evidence to guide classification, assessment, and management of PSI, expert consensus may enhance a pathway of care for PSI and define areas for future clinical research. One strategy to achieve consensus is the Delphi method.^{9,11,38}

The purpose of this study was to reach consensus among international shoulder experts on the most appropriate clinical assessment and management strategies for PSI.

• **OBJECTIVE:** To reach consensus among international shoulder experts on the most appropriate assessment and management strategies for posterior shoulder instability (PSI).

• **DESIGN:** Delphi.

• **METHODS:** In phase 1 of the study, we reviewed the literature, generated the Delphi items, created the survey, and identified clinical experts. In phase 2 of the study, clinical shoulder experts (physical therapists, orthopaedic surgeons, sports medicine physicians, and researchers) participated in a 3-round e-Delphi survey. For consensus, we required a minimum of 70% agreement per round. Descriptive statistics were used to present the characteristics of the respondents, the response rate of the experts in each round, and the consensus for PSI classification, assessment, and management.

• **RESULTS:** Round 3 was completed by 47 individuals from 5 different countries. The response rate ranged from 57/70 (81%) to 47/50 (94%) per round. Respondents agreed on 3 subgroups to define PSI: traumatic (100% agreement), microtraumatic (98% agreement), and atraumatic (98% agreement).

• **CONCLUSION:** International shoulder experts agreed that the clinical presentation, management strategy, and outcome expectations differ for traumatic, microtraumatic, and atraumatic PSI. Their recommendations provide a framework for managing these subgroups, with additional consideration of sport and work participation and subsequent risks. *J Orthop Sports Phys Ther* 2020;50(7):373-380. Epub 29 Apr 2020. doi:10.2519/jospt.2020.9225

• **KEY WORDS:** classifications, Delphi, PSI, subgroups

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METHODS

Study Design

DELPHI STUDY COLLECTS INFORMATION through a series of successive surveys, completed by experts over a large geographical region, with a feedback loop to allow the authors to revise responses to the panel.^{17,24,47} A 3-round e-Delphi study¹¹ was conducted from June 2017 to January 2018. This survey design allowed for respondent anonymity while providing the experts with synthesized results from each round. This study received approval through the Western University Health Science Research Ethics Board.

Phase 1

Literature Review Prior to commencing the Delphi study, 2 systematic reviews were completed.^{10,22} An up-to-date search of the prior databases and gray literature (Google Scholar, Physiopedia) occurred from November 2014 to November 2016.

Generation of the Delphi Items and Survey Questions The prior systematic reviews, an updated literature search, and the expertise of the research team informed the Delphi items and survey questions. The research team comprised 4 shoulder experts (1 orthopaedic surgeon, 2 physical therapists, and 1 upper extremity clinical researcher) and 4 experienced physical therapists, who reviewed the literature to help extract items to support the purpose of our study. Upon completion of the literature review, the research team extracted and organized information into 7 categories: (1) classification of PSI, (2) subjective examination, (3) objective examination, (4) prognosis and risk, (5) clinical outcome measures, (6) therapeutic interventions and strategies in nonsurgical PSI, and (7) medical management in traumatic PSI.

A series of group meetings, discussions, and multiple revisions within the research team allowed for the development of questions within the 7 cat-

egories. These questions were reviewed, refined, and eventually narrowed down to a 50-item survey (**APPENDIX A**, available at www.jospt.org). Nine clinicians provided feedback on survey construction, question clarity, redundancy, the importance of the items selected, and barriers to survey completion (**APPENDIX B**, available at www.jospt.org).

Revised questions were subsequently programmed into internet-based survey design software (SurveyMonkey, San Mateo, CA). We used 2- to 4-point Likert scales and free-text response options.

Expert Recruitment We identified potential participants (physical therapists, sport medicine physicians, orthopaedic surgeons, and clinical researchers with expertise in treating shoulder problems) through our research and clinical networks in North America, Europe, and Australia, and through snowball recruitment.¹⁷ We contacted 70 experts and invited them to participate in 3 rounds of Delphi consensus development. The **FIGURE** outlines the phases of our Delphi methods.

We identified experts as clinicians who had specialty training in surgery or physical therapy of the shoulder, experience in treating shoulder conditions as a major component of their practice, and at least 5 years of experience in managing shoulder instability. Expert clinical researchers had previous clinical experi-

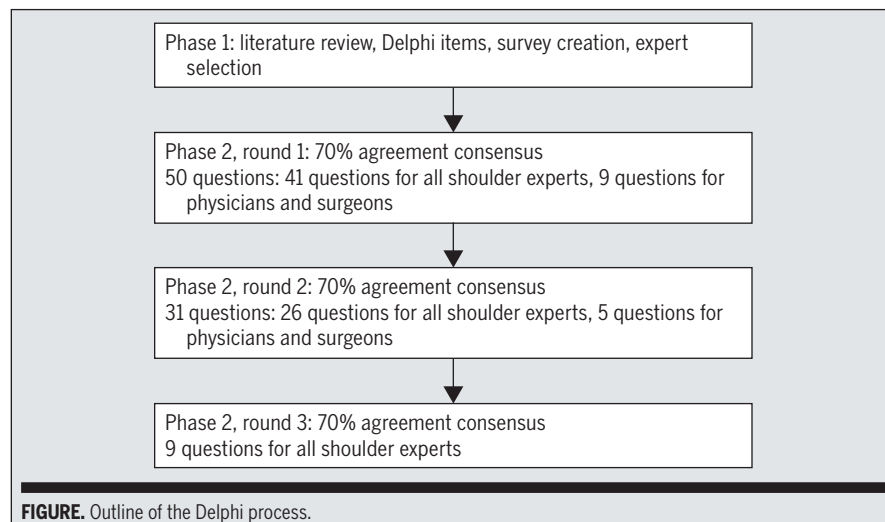
ence managing shoulder instability and had published on this topic.

The validity and reliability of observations obtained using the Delphi method improve when a panel includes at least 10 individuals.^{16,38} To reduce nonresponse and respondent dropout, a letter of participation and consent was submitted to expert participants and included expected survey completion time and a schedule of subsequent survey rounds.¹²

Phase 2

In round 1, we sent an online survey of 50 questions by e-mail to the 70 shoulder experts, including an explanation of the objectives of the study and specific instructions for participation. All experts were asked to complete the first 41 questions, and physicians and surgeons completed an additional 9 questions. Each expert was asked to respond using the assigned Likert scales and was given an opportunity to provide comments and suggest additional items that might not have been included in the development of the initial statement list. Agreement of 70% on individual items was our predefined threshold for consensus.¹⁸ Statements not meeting 70% agreement were amended according to feedback and redistributed to the experts for Delphi rounds 2 and 3.

Round 2 was delivered 4 to 6 weeks following completion of round 1, pro-



viding time for the research team to analyze and revise the questionnaire for round 2. Statements that did not meet our threshold for consensus were either modified or removed, based on feedback. Experts were provided with summarized group results of round 1. Round 2 had 41 questions, and all experts were asked to complete the first 36 questions. The final 5 questions were completed by physicians and surgeons only. The protocol of round 3 was similar to that of round 2 and incorporated results from the previous round. Round 3 had 9 questions completed by all experts. Anonymity of respondents was maintained through this phase for both experts and the research team.

Statistical Analysis

Descriptive statistics were used to present the characteristics of the respondents, the response rate of the experts for each round, and the consensus on PSI classification, assessment, and management.

RESULTS

IN ROUND 1, THE DELPHI PANEL INCLUDED 70 shoulder experts, and 47 respondents completed the final round. Respondents in the final round were from 5 different countries, with Canada having the largest representation at 24/47 (51%). The response rate ranged from 57/70 (81%) respondents in round 1 to 47/50 (94%) in round 3. The majority of the shoulder experts were physical therapists (38%), orthopaedic surgeons (34%), and shoulder clinical researchers (15%). Most respondents (96%) had more than 10 years of clinical experience treating patients with PSI (TABLE 1).

After round 1, respondents reached consensus on 34 of the 50 questions. The 16 questions that respondents did not reach consensus on were related to clinical orthopaedic tests, self-report outcome measures, rehabilitation management, immobilization timelines, indications for surgery, and return-to-sport timelines. We created 41 questions for round

2. There was consensus on 33 of 41 questions. The round 3 survey contained 9 questions. All questions within round 3 achieved consensus.

We identified 3 PSI subgroups based on mechanism, direction, and type of injury:

- 1. *Traumatic*: acute injury that provides an immediate and/or forceful impact that causes posterior or posteroinferior dislocation of the humerus on the glenoid (100% agreement)
- 2. *Microtraumatic*: posterior or posteroinferior subluxation more than dislocation of the humerus on the glenoid, with or without degenerative changes, and associated with gradual or acute overload of the musculature (98% agreement)
- 3. *Atraumatic*: subluxation of the glenohumeral joint in a posteroinferior

direction or multidirection due to congenital and/or systemic laxity of the ligamentous, labral, or capsular glenohumeral structures and/or congenital anomalies of the bony glenoid or humerus (98% agreement)

Clinical history questions related to age of the patient (84% agreement) and goals of treatment (96% agreement) should be explored, and clinical symptoms reported may not be specifically related to instability, but rather to weakness or diminished performance (98% agreement) (APPENDIX C, available at www.jospt.org). The predominant functional limitations for all 3 subgroups were similar and had a range of agreement between 78% and 96% (TABLE 2). APPENDIX C summarizes the clinical assessment agreement for all patients with PSI prior to subgrouping. TABLE 2 and

TABLE 1		RESPONSE RATE AND CHARACTERISTICS OF ROUND 3 INTERNATIONAL SHOULDER EXPERTS ^a	
		Value	
Response rate			
Round 1 (n = 70)		57 (81)	
Round 2 (n = 57)		50 (88)	
Round 3 (n = 50)		47 (94)	
Round 3 (n = 47)			
Country			
Australia		12 (26)	
Belgium		2 (4)	
Canada		24 (51)	
England		1 (2)	
United States		8 (17)	
Specialties			
Clinical researchers (physical therapists/physicians)		7 (15)	
Orthopaedic surgeons		16 (34)	
Physical therapists		18 (38)	
Radiologists		1 (2)	
Sports medicine physicians		5 (11)	
Time in practice >10 y		45 (96)	
Patients with PSI treated per year			
1-9		10 (21)	
10-19		17 (36)	
20-49		12 (26)	
>50		8 (17)	
Abbreviation: PSI, posterior shoulder instability.			
^a Values are n (percent).			

APPENDIX D (available at www.jospt.org) summarize clinical assessment agreement based on the 3 PSI subgroups.

TABLE 3 and **APPENDIX D** summarize management and recovery timelines for PSI subgroups.

DISCUSSION

THIS STUDY REPORTS AN INTERNATIONAL agreement on the classification of PSI by subgrouping based on mechanism of injury, clinical

assessment, management, recovery timelines, risk factors, and outcome measures. Assessment, management, and clinical outcome measurement of PSI lack consensus and gold standard care.^{8,10,22}

TABLE 2

CLINICAL ASSESSMENT OF POSTERIOR SHOULDER INSTABILITY SUBGROUPS^a

Clinical Assessment	Traumatic	Microtraumatic	Atraumatic
Mechanism of injury	Fall or unexpected WB into shoulder horizontal adduction/IR between 60° and 140° of flexion (85%)	Tasks that involve repetitive or increased load with pushing or WB through straight arm or reaching across body or overhead tasks (94%)	- Tasks that involve pushing or WB through straight arm, reaching across body (92%) - Repetitive activities overhead or in flexion/adduction/IR (79%)
Type of injury (acute or functional) and direction of dislocation or subluxation	- Acute injury (98%) - Posterior (98%) or posteroinferior dislocation (96%)	- Functional subluxations (85%) - Episodic: <3 subluxations per year (86%) - Chronic: >3 subluxations per year (84%) - Posterior (77%) and posteroinferior subluxation more than dislocation (76%)	- Functional subluxation (94%) - Chronic: >3 subluxations per year (94%) - Posteroinferior subluxations (84%) - Multidirectional subluxations (96%)
Questions to ask	- Do you remember your shoulder position at time of injury? (100%) - When was your initial injury? (96%)	Did this problem begin due to a single event or over time? (96%)	- Do you have other joints in your body that you can dislocate or subluxate? (100%) - Do you have a family history of connective tissue disorders (eg, Ehlers-Danlos, Marfan, general hypermobility syndrome) (100%)
Sports/occupations at risk	- Contact sports: football (American and Australian), rugby, ice hockey (98%) - Occupations: military, police, firefighter (98%) - Fall-risk sports: cheerleading, skateboarding, figure skating (94%) - Combat sports: karate, judo, wrestling, jujitsu (85%) - Performing artists: acrobat, martial artist, stunt performer (81%)	- Highly repetitive demands into horizontal flexion/adduction/IR of the shoulder (100%) - Overhead activity: baseball pitcher, tennis player, swimmer, laborer (94%) - Performing artists: acrobat, dancer, martial artist, stunt performer (90%) - Overhead activity with heavy load: weightlifter (89%)	- Highly repetitive demands into horizontal flexion/adduction/IR of the shoulder (92%) - Performing artist: acrobat, dancer, martial artist, stunt performer (73%) - Weightlifter (73%)
Symptoms/signs	- Acute pain with loss of shoulder ROM in all directions (94%) - Shoulder feels unstable (94%) - Posterior greater than anterior GH pain (82%)	- Catch/click with shoulder motion (96%) - Arm fatigues easily (94%) - Night pain/disturbed sleep (92%) - Functional instability: self-subluxation (84%)	- Arm fatigues easily (92%) - Functional instability: self-subluxation (90%) - Night pain/disturbed sleep (90%) - Catch/clunk with shoulder motion (86%) - Nerve-like pain in arm (84%) - Intolerance to lying on affected side (79%)
Active motion	- Initially, all shoulder ROM will be limited - Limited range: ER and/or HBB (85%) - Horizontal flexion/adduction/IR pain or apprehension (85%)	- Aberrant active shoulder and scapular motion (90%) - Apprehension with horizontal flexion/adduction/IR (87%) - Decreased or locked ER (87%)	- Aberrant active shoulder and scapular motion (96%) - Decreased or locked external rotation (91%) - Apprehension with horizontal flexion/adduction/IR (91%)
Tests or cluster of tests	- Posterior apprehension, jerk, and Kim tests (92%) - Posterior load and shift (85%) - Posterior drawer (80%)	- Posterior apprehension or jerk test (100%) or - Subjective history and posterior apprehension, and scapular and/or humeral head repositioning with symptom or strength improvement (80%)	Subjective history and Beighton score >4/9, positive sulcus test, and scapular and/or humeral head repositioning with symptom or strength improvement (93%)
Strength deficits	Acute dislocation: all strength tests would be painful and weak (79%)	Weak scapular upward rotators (ie, upper/lower trapezius, serratus anterior) (74%)	Weak scapular upward rotators and outer ranges of overhead GH ROM (78%)
Functional limitations	- Intolerance in WB or pushing through their arms (eg, plank push-up, bench press, pushing open a door) (88%-96%) - Reaching across the body (eg, putting on a seatbelt, brushing teeth, pulling off a shirt/bra) (78%-94%)		
Outcome measures	- Self-report outcome measure: frequency of subluxations/dislocations over a year (96%), WOSI (96%), NPRS (91%), SANE (89%) - Functional outcome measure: any clinically relevant form of testing for sport, occupation, or ADL (eg, lifting overhead, reaching across body with/without resistance, swimming, pushing out of a chair) (94%)		

Abbreviations: ADL, activities of daily living; ER, external rotation; GH, glenohumeral; HBB, hand behind back; IR, internal rotation; NPRS, numeric pain-rating scale; ROM, range of motion; SANE, Single Assessment Numeric Evaluation; WB, weight bearing; WOSI, Western Ontario Shoulder Instability Index.

^aValues in parentheses are percent agreement. See APPENDICES C and D for additional assessment agreement details.

PSI Subgroups

Many authors support^{14,30,32} the need for classification of PSI based on 3 broad etiological categories: acute traumatic, microtraumatic, and atraumatic. However, few clinical studies report results according to these different groups, making it difficult to define how presentation or management differs across these theoretically informed subgroups. Subgroup classification may assist with early diagnosis of PSI and management. Accurate directional diagnosis of PSI, based on mechanism and clinical evaluation, may help reduce the high rates of recurrence that have been attributed to misdiagnosis of bidirectional and multidirectional instability.^{8,27} Through all rounds of our

Delphi process, there was extremely high agreement (98%-100%) on the definitions associated with traumatic, microtraumatic, and atraumatic etiologies for PSI. Experts typically associated the term *dislocation* with acute traumatic injury and *subluxation* with microtraumatic and atraumatic mechanisms.⁴⁵

Clinical Assessment

There was consensus about the clinical assessment for type of injury, clinical questions to ask, and sports/occupations at risk. These history-taking items are essential to help identify PSI and its appropriate subgrouping. Clinical history alone may be sufficient for diagnosing injuries 76% of the time.²⁸

The type of injury and dislocation and/or subluxation varied between subgroups. Traumatic PSI was considered to involve an acute posterior (98% agreement) or posteroinferior dislocation (96% agreement). Microtraumatic was considered more likely to be characterized by episodic subluxations (fewer than 3 subluxations per year; 86% agreement), and atraumatic PSI was considered to have a more chronic subluxation history (greater than 3 subluxations per year; 94% agreement). Shoulder experts agreed (98% agreement) that participation in contact sports (football, rugby) had a higher risk of acute traumatic PSI, which correlates well with recent studies.^{5,21} There was 73% agreement

TABLE 3

MANAGEMENT AND TIMELINES FOR POSTERIOR SHOULDER INSTABILITY SUBGROUPS^a

	Traumatic (acute trauma)	Microtraumatic	Atraumatic
Medical management ^b	• X-ray prior to reduction (97%) • Closed reduction in ED (86%) • Immobilization^c (74%) • Nonopioid-based medication (86%) • NSAIDs (75%) • Refer to physical therapy (77%) • Recommend elbow and wrist ROM exercises (84%)	• Refer to physical therapy (96%) • Modify or limit horizontal adduction, flexion, and internal rotation initially (92%) • NSAIDs only during acute phase (75%) • Immobilization^c post reduction only (74%)	• Refer to physical therapy (96%) • Modify or limit horizontal adduction, flexion, and internal rotation initially (92%) • NSAIDs only during acute phase (75%) • Immobilization^c post reduction only (74%)
Surgical management ^d	• Large bony structural lesion (89%) • Fragment fixation >25% (79%) • Labral repair (76%) • After 3 mo if unsuccessful nonsurgical management (86%)	• Referral for surgery should be considered after 6 mo of unsuccessful nonsurgical management (73%)	• Referral for surgery should be considered after 6 mo of unsuccessful nonsurgical management (77%)
Physical therapy management	• Limit arm-across-body activities during acute/irritable phase (92%) • Scapular, rotator cuff, and sport/occupation-specific strength training as needed (92%) • Minimum of 12 wk of individualized exercise progression (87%)	• Assess and manage scapular and/or humeral head position (100%) • Scapular, rotator cuff, and sport/occupation-specific strength training (98%) • Exercise progression should encompass local and global muscles (72%)	• Assess and manage scapular and/or humeral head position (100%) • Scapular, rotator cuff, and sport/occupation-specific strength training (98%) • Exercise progression should encompass local and global muscles (72%)
Management	• Education: rehabilitating shoulder for optimal motor control and strength (81%), anatomy/pathomechanics (78%), pain coping strategies (72%). Patients are knowledgeable about their condition and understand the value of rehabilitation (98%) • Home-based exercise program: motivation and knowledge to perform at home (100%), high expectations of success (94%) • Clinician-supervised exercise program: low efficacy (83%), requires verbal and tactile feedback (100%), poor support at home (81%), lacks insight into exercises (90%), and sedentary lifestyle (75%)		
Timelines	• Pain, ADL recovery: 6-12 wk (77%) • Immobilization^c: 1-3 wk (81%) • Return to high-risk sport/work post immobilization and 3-6 mo of physical therapy (70%) based on individualized discussion with patient • Return to high-risk sport/work post surgery and 6-12 mo of physical therapy (96%) based on individualized discussion with patient		

Abbreviations: ADL, activities of daily living; ED, emergency department; NSAID, nonsteroidal anti-inflammatory drug; ROM, range of motion.

^aValues in parentheses are percent agreement. See APPENDICES C and D for further management agreement details.

^bPhysician and surgeon agreement values only.

^cImmobilization in 30° of external rotation/neutral abduction.

^dSurgeon agreement values only.

for increased risk of atraumatic PSI in performance-based sports and weightlifting, which concurs with elevated rates reported in the literature.⁴⁴

A physical examination complements a patient's history and is useful to assist with diagnosis. The PSI clinical tests reported in the literature are the jerk test and Kim test.¹⁰ There was consensus that the jerk test, Kim test, and posterior apprehension test (92%-100% agreement) were useful. All 3 were similar in perceived clinical value, thus clinician preference and experience should be considered when selecting between tests.¹⁰ Despite consensus on these physical tests and/or a cluster of tests (74%-100% agreement), the reported diagnostic accuracy values of these tests are low when interpreted independently, and the tests have never been studied in a cluster.^{10,28,43} The combination of clinical history and physical examination may improve diagnostic accuracy²⁸ (TABLE 2 summarizes the 10 consensus recommendations for clinical assessment).

Management

Classifying PSI based on mechanism of injury and standardizing clinical assessment could enhance decision making for nonoperative prognosis, treatment, and return-to-activity guidelines. Management of acute traumatic posterior dislocation has been the most consistently reported.^{21,39} Male intercollegiate athletes participating in wrestling, rugby, and football had an 8-times higher risk of PSI and were more likely to require surgical treatment.²¹ Other studies have shown only a 19% success rate with nonsurgical management of traumatic PSI.^{6,14}

There was consensus among the orthopaedic surgeons and physicians on immediate surgical referral following acute trauma if there was a large structural bony lesion visible on X-ray (89% agreement) or after 3 months of unsuccessful nonsurgical management (86% agreement). Referral for surgical management within the microtraumatic and atraumatic subgroups is controversial, and nonsurgical management should

be considered first.^{22,29} Specific surgical management was beyond the scope of our study, and indications for orthopaedic referral have not been standardized.^{15,20}

Nonsurgical management for microtraumatic and atraumatic PSI has a success rate of 70% to 89%.^{6,14,21} We found high agreement for management of microtraumatic and atraumatic PSI with the following physical therapy treatments: improving scapular position and humeral head position (100% agreement), rotator cuff and sport/occupation-specific training (98% agreement), and exercise progressions that encompass local and global muscles (72% agreement). This rehabilitation approach is supported by a recent randomized controlled trial⁴⁴ for patients with multidirectional instability. There is a dearth of well-designed nonoperative management options for PSI. This may be due to the weak identification of various subgroups within PSI (TABLE 3 summarizes the 5 consensus recommendations for management).

Outcome Evaluation and Return to Activity

Reaching consensus on standardized outcome measures and timelines to return to high-risk sport and work was challenging. All 3 rounds were required to achieve threshold consensus, and results for the outcome measures are likely related to regional preferences of the experts. For example, the Western Ontario Shoulder Instability Index (WOSI) had 96% agreement; however, half the experts were from Canada, where this measure was developed. The lack of standardized PSI outcome measures is reflected within the DeLong et al⁸ systematic review, which listed 29 functional outcome measures in 29 PSI studies. Our Delphi study supports the need to develop specific PSI outcome measures based on an understanding of the subgroups and their clinical patterns. By round 2, consensus on immobilization time (81% agreement) and on recovery time for pain and activities of daily living (77% agreement) was consistent in all 3 subgroups. Three Delphi rounds were

required to achieve consensus thresholds for the return to high-risk sports and occupations for both nonoperative management (3-6 months) and/or surgery (6-12 months). There is limited evidence to support these timelines.⁴⁴

Strengths and Limitations

Our study reflects the expertise of experienced international clinicians and researchers from 5 different countries with case loads that include PSI. We had a high response rate from the shoulder experts for each round. Although there was a gradual attrition to 47 experts, the final round represented a substantial and adequate sample.

Some limitations should be considered when interpreting our consensus. Item generation and formulation for the Delphi rounds involved systematic reviews and a literature search that incorporated "English only" as an inclusion criterion. This search might have missed relevant papers, although, given our pool of international experts, the likelihood and potential impact were minimized. Half of the shoulder experts were from Canada, the region that led the project. This might have influenced perceptions and experiences with regard to prognostic factors, such as common sport activities. Further, the management of injury might have been affected by the infrastructure associated with a publicly funded health care system. The results of this survey are geographically limited to the 5 countries represented by the shoulder experts. The consensus reached may be biased by the type of experts included, with physical therapists (38%) and orthopaedic surgeons (34%) comprising the majority of the shoulder experts. Future studies should examine the validity of our findings across different clinical settings or professions.

CONCLUSION

CLINICAL PRESENTATION, MANAGEMENT strategy, and outcome expectations differ for traumatic,

microtraumatic, and atraumatic PSI. The recommendations achieved provide a framework for managing these subgroups, with additional consideration of sport and work participation and subsequent risks. This may provide a framework for future research, including randomized controlled trials or prospective cohort studies that control for the different subgroups. ●

KEY POINTS

FINDINGS: Traumatic, microtraumatic, and atraumatic posterior shoulder instability (PSI) comprise different subgroups that are recognized and managed differently by expert clinicians.

IMPLICATIONS: Using the consensus for assessment and management defined by shoulder experts, a more consistent approach to managing PSI may be achieved by clinicians, with expectations for better outcomes.

CAUTION: Consensus may not reveal important prognostic indicators or the best management interventions.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: All authors contributed to the conception and design of the study. Jackie Sadi, Erik Torchia, and Drs MacDermid and Faber were responsible for analysis and interpretation of the data. Jackie Sadi and Erik Torchia were responsible for drafting the manuscript. All authors revised the manuscript and approved the final version for publication.

DATA SHARING: Data are available on request. Data include round 2 and 3 Delphi questions and further demographic data.

PATIENT AND PUBLIC INVOLVEMENT: There was no patient or public involvement in this study.

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[RESEARCH REPORT]

APPENDIX A

DELPHI POSTERIOR SHOULDER INSTABILITY

Participant Information

- In which country do you currently practice?
 - ☐ Australia
 - ☐ Belgium
 - ☐ Canada
 - ☐ England
 - ☐ Scotland
 - ☐ United States
 - ☐ Other (specify)
- Which type of professional are you?
 - ☐ Physical therapist: clinician
 - ☐ Physical therapist: researcher
 - ☐ Physician (orthopaedic surgeon)
 - ☐ Other (specify)
- How many years of experience do you have treating musculoskeletal patients?
 - ☐ 1-5
 - ☐ 6-9
 - ☐ 10-20
 - ☐ >20
- How many clients with suspected posterior shoulder instability do you see per year?
 - ☐ 0
 - ☐ 1-9
 - ☐ 10-19
 - ☐ 20-49
 - ☐ ≥50

Classification of Posterior Shoulder Instability

- Do you believe that posterior shoulder instability should be classified according to the following criteria?

	Always	Sometimes	Never
Direction			
Unidirectional	☐	☐	☐
Bidirectional	☐	☐	☐
Multidirectional	☐	☐	☐
Stage			
Acute	☐	☐	☐
Chronic	☐	☐	☐
Mechanism			
Traumatic	☐	☐	☐
Microtraumatic	☐	☐	☐
Atraumatic	☐	☐	☐
Degree			
Dislocation	☐	☐	☐
Subluxation	☐	☐	☐

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Do you have any additional suggestions about how posterior shoulder instability should be classified?

Subjective Examination

6. How important are the following questions concerning the history of present injury?

	Very Important	Somewhat Important	Not Important
When was your initial injury?	☐	☐	☐
Did the problem begin due to a single event, or did it develop over a longer period of time?	☐	☐	☐
Do you remember the position your shoulder was in at the time of injury?	☐	☐	☐
Has your shoulder been getting worse (ie, getting more painful, able to use your shoulder less, more catching/clicking)?	☐	☐	☐

7. How important are the following questions concerning the patient's symptoms?

	Very Important	Somewhat Important	Not Important
Does your arm get fatigued easily with activity?	☐	☐	☐
Where is your pain located?	☐	☐	☐
What is your pain intensity?	☐	☐	☐
Is your injury on your dominant side?	☐	☐	☐
Can you make your shoulder pop in/out (subluxate/dislocate) on demand?	☐	☐	☐
Does your shoulder ever feel unstable or have the feeling that it may give way?	☐	☐	☐
Are there particular positions that make your arm worse, or that you avoid moving into?	☐	☐	☐
Do you get nerve-like pain in the arm (eg, pins and needles, numbness, shooting, buzzing sensations)?	☐	☐	☐
Do you get clicking or catching in the arm when moving it?	☐	☐	☐

Are there any other questions related to symptoms you believe should be asked?

8. How important are the following questions concerning the patient's basic function?

	Very Important	Somewhat Important	Not Important
Do you have trouble pushing objects away from you (eg, push-up, bench press, etc)?	☐	☐	☐
Are you limited with any of your activities at home (eg, washing your hair, brushing your teeth, eating, etc)?	☐	☐	☐

Are there other questions you believe should be asked concerning basic function?

APPENDIX A

9. How important are the following questions concerning the patient's occupation?

	Very Important	Somewhat Important	Not Important
Do you work in a job that places high demands on your arm?	☐	☐	☐
Do you work in a job that requires overhead use of the arm?	☐	☐	☐

Are there other questions you believe should be asked concerning patient occupation?

10. Do you believe that there are particular occupations that place more risk on the shoulder for acquiring posterior shoulder instability? (please state)

11. How important are the following questions concerning sport and activity?

	Very Important	Somewhat Important	Not Important
Do you participate in a sport that requires repetitive arm motion?	☐	☐	☐
Do you participate in a contact sport?	☐	☐	☐
Do you participate in a sport that has a high risk of falling?	☐	☐	☐
At this moment, are you able to continue to play your sport?	☐	☐	☐

Are there any other questions that you believe should be asked concerning sport and activity?

12. Do you believe that there are particular sports that place more risk on the shoulder for acquiring posterior shoulder instability? (please state)

13. How important are the following questions to be used in addition to those already stated above?

	Very Important	Somewhat Important	Not Important
What is your current age?	☐	☐	☐
Does any other member of your family have a history of loose joints (eg, dislocations, hypermobility, etc)?	☐	☐	☐
What is your main reason for seeking care?	☐	☐	☐
What are your goals of treatment?	☐	☐	☐

Are there any other questions you believe should be asked of your client with suspected posterior shoulder instability?

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Objective Examination

14. How important are the following components to your patient observation?

	Very Important	Somewhat Important	Not Important
Resting position of the humerus in relation to the acromion	☐	☐	☐
Dynamic motion of the shoulder blade through active range of motion	☐	☐	☐
Active range of motion of the shoulder, looking for aberrant motion	☐	☐	☐
Active range of motion of the shoulder, looking for blocked motion of external rotation	☐	☐	☐
Patient's ability to voluntarily subluxate or reduce the shoulder	☐	☐	☐
Identification of localized muscle hypertrophy	☐	☐	☐
Identification of localized muscle atrophy	☐	☐	☐
Identification of localized swelling	☐	☐	☐
Identification of bruising	☐	☐	☐
Identification to changes of bony contours	☐	☐	☐
Identification of skin dimpling	☐	☐	☐
Pain behaviors (including but not limited to wincing, hesitation to move the shoulder, holding the arm by the side)	☐	☐	☐

15. How important are the following components of tissue palpation?

	Very Important	Somewhat Important	Not Important
Palpation of the posterior joint line of the glenohumeral joint	☐	☐	☐
Palpation of distal pulses	☐	☐	☐
Palpation of the humeral head in relation with the acromion	☐	☐	☐
Palpation for increased muscle tone	☐	☐	☐

Any other important areas to palpate?

16. How important are the following tests within your orthopaedic examination?

	Very Important	Somewhat Important	Not Important
Use of the posterior, inferior, and anterior passive translation of the humeral head	☐	☐	☐
Use of the posterior load and shift test	☐	☐	☐
Use of the posterior drawer test	☐	☐	☐
Use of the hand squeeze test	☐	☐	☐
Use of the Kim test	☐	☐	☐
Use of the jerk test	☐	☐	☐
Use of the sulcus sign	☐	☐	☐
Use of the Beighton exam for generalized hypermobility	☐	☐	☐
Use of the O'Brien test	☐	☐	☐
Use of the posterior apprehension test in arm flexion, adduction, and internal rotation with/without axial load	☐	☐	☐
Use of scapular repositioning for symptom modification	☐	☐	☐
Use of humeral head repositioning for symptom modification	☐	☐	☐
Assessment of shoulder strength with manual muscle testing or dynamometry	☐	☐	☐

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17. If you believe the sulcus sign is important, do you use it in combination with external rotation and/or internal rotation of the humerus?

	Yes	No
In combination with internal rotation	☐	☐
In combination with external rotation	☐	☐
With both internal rotation and external rotation	☐	☐

18. Do you believe the clustering of tests is important in the orthopaedic clinical exam?

☐ Yes

☐ No

If yes, what clusters do you feel are important to use?

19. Are there any other components or tests you believe should be used in the objective examination of a patient with potential posterior shoulder instability?

20. Are there any specific movement patterns or muscle strength deficits that you believe are common in patients with posterior shoulder instability?

Outcome Measures

21. How important are the following patient-reported outcome measures for clinical decision making with patients of posterior shoulder instability?

	Very Important	Somewhat Important	Not Important
Pain and function visual analog scale	☐	☐	☐
Subjective shoulder value or rating system	☐	☐	☐
Patient-Specific Functional Scale	☐	☐	☐
Rowe score for instability (or modified)	☐	☐	☐
University of California, Los Angeles activity rating scale	☐	☐	☐
Modified ASES score	☐	☐	☐
Western Ontario Shoulder Instability Index	☐	☐	☐
Disabilities of the Arm, Shoulder and Hand Questionnaire	☐	☐	☐
SF-36	☐	☐	☐
Oxford Shoulder Instability Score	☐	☐	☐
Shoulder Pain and Disability Index	☐	☐	☐
Melbourne Instability Shoulder Scale	☐	☐	☐
Quantification of past episodes of instability	☐	☐	☐
Patient satisfaction	☐	☐	☐

Abbreviations: ASES, American Shoulder and Elbow Surgeons; SF-36, Medical Outcomes Study 36-Item Short-Form Health Survey.

Are there any other self-reported measures you believe should be used with patients presenting with posterior shoulder instability?

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22. How important are the following physical outcome measures for clinical decision making with patients with posterior shoulder instability?

	Very Important	Somewhat Important	Not Important
Range of motion	☐	☐	☐
Strength/muscle testing (with or without dynamometry)	☐	☐	☐
Functional testing	☐	☐	☐
Test load-transfer tasks with humeral head control	☐	☐	☐

Which outcome measures do you feel are more relevant to measure in this population? Are there outcomes outside of those reviewed that you believe should be used? (please state)

23. Are there any other physical outcome measures you believe should be used with patients presenting with posterior shoulder instability? (please state)

Risk/Prognosis

24. How important are the following risk factors for development of posterior shoulder instability?

	Very Important	Somewhat Important	Not Important
Family history of shoulder instability	☐	☐	☐
Younger than 40 years of age	☐	☐	☐
General joint laxity (high Beighton score)	☐	☐	☐
Voluntary self-subluxation	☐	☐	☐
Participation in sport/occupation with repetitive demands on the shoulder	☐	☐	☐
Participation in overhead sport/occupation	☐	☐	☐
Participation in contact sport	☐	☐	☐
Participation in sport that requires repetitive acceleration/deceleration of the arm (throwing/swinging)	☐	☐	☐

25. How important are the following characteristics in determining the prognosis of conservative management?

	Very Important	Somewhat Important	Not Important
Suspected microtraumatic posterior shoulder instability	☐	☐	☐
Suspected traumatic posterior shoulder instability	☐	☐	☐
Positive jerk test on initial assessment	☐	☐	☐
Retroversion of the humeral head	☐	☐	☐
Retroversion of chondrolabral portions of the glenoid	☐	☐	☐
Thinner posterior band of the inferior glenohumeral ligament	☐	☐	☐
Congenital anomalies of the humeral head, glenoid, or posterior ligaments	☐	☐	☐

26. Are there other factors that you believe may influence a positive outcome in patients with posterior shoulder instability?

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27. Are there other factors that you believe may influence a negative outcome in patients with posterior shoulder instability?

Timeline

28. Do you agree with the following timeline in regard to conservative care before a surgical consultation?

	Agree	Disagree
Immediate surgical consultation for those with a traumatic history of PSI and younger than 40 years of age	☐	☐
Immediate surgical consultation those with a traumatic history of PSI and older than 40 years of age	☐	☐
Immediate surgical consultation for those with a painful positive jerk test on initial assessment	☐	☐
3 months of conservative care for those with a traumatic history of PSI and older than 40 years of age	☐	☐
3 months of conservative care for those with a microtraumatic history of PSI	☐	☐
3 months of conservative care for those with a negative jerk test and a positive hand squeeze test on initial assessment	☐	☐
6 months of conservative care for those with a microtraumatic history of PSI	☐	☐

Abbreviation: PSI, posterior shoulder instability.

Are there other timelines that you consider in the care of a patient with posterior shoulder instability?

Management of Microtraumatic and Atraumatic Posterior Shoulder Instability

Strategy 1: Education

29. How important do you consider the following positions/movements/activities to be modified, limited, or avoided?

	Very Important	Somewhat Important	Not Important
Pushing horizontally	☐	☐	☐
Positions of combined movement of horizontal adduction, flexion, and internal rotation (arm across body)	☐	☐	☐
Sleeping positions	☐	☐	☐
Overhead activities	☐	☐	☐
Weight-bearing activities	☐	☐	☐
Activities with risk of sudden jarring to the shoulder	☐	☐	☐
Throwing and swinging activities	☐	☐	☐

Are there any other positions/movements/activities you would like to additionally mention?

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30. When limiting activity or exposure to a particular position, how do you monitor their use of the shoulder?

31. How important are the following aspects to enable patient understanding regarding musculoskeletal education?

	Very Important	Somewhat Important	Not Important
Particular anatomy and pathomechanics	☐	☐	☐
Understanding of pain and coping strategies	☐	☐	☐
Optimal upper-quadrant posture and positions	☐	☐	☐
Optimal mechanics and motor control	☐	☐	☐

Are there any other aspects of musculoskeletal education you believe should be addressed with these patients?

32. How important is it to discuss the following aspects of prognosis with your patient?

	Very Important	Somewhat Important	Not Important
The patient's potential prognosis	☐	☐	☐
The patient's expectation of outcome	☐	☐	☐
The patient's specific goals	☐	☐	☐
Importance of using exercises as prevention in a long run	☐	☐	☐
Rehabilitation plan from acute to return to work/sport (including potential timeline)	☐	☐	☐

Are there any other aspects of prognosis education you believe should be included with these patients?

Strategy 2: Exercises

33. List 3 patient characteristics you think would make someone successful with an independent home exercise program.

1.

2.

3.

34. List 3 patient characteristics you think would make someone successful with supervision in a clinic.

1.

2.

3.

35. How important do you think the following positional/postural corrections need to be addressed with exercises?

	Very Important	Somewhat Important	Not Important
Humeral head correction	☐	☐	☐
Scapular correction	☐	☐	☐
Cranial/cervical correction	☐	☐	☐
Thoracic correction	☐	☐	☐

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36. How important is it to address the strength of the following muscle groups?

	Very Important	Somewhat Important	Not Important
Scapular muscles			
Upward rotators	☐	☐	☐
Retractors	☐	☐	☐
Posterior tilters	☐	☐	☐
Protractors	☐	☐	☐
Rotator cuff muscles			
External rotators	☐	☐	☐
Internal rotators	☐	☐	☐
Posterior deltoid	☐	☐	☐
Sport/occupation-specific training	☐	☐	☐
Other areas to consider			
Lower trunk	☐	☐	☐
Cervical	☐	☐	☐
Lower limb	☐	☐	☐

Are there any other aspects or categories of resistance training that you believe are valuable in the rehabilitation of a patient with posterior shoulder instability?

37. Do you believe that a specific mode of training is more effective than others? (this may include differentiation between types of contraction, endurance versus strength, motor control, plyometrics, tempo, open versus closed kinetic chain, specific versus global shoulder training, etc)

- ☐ Yes
☐ No

38. Are there specific milestones that are reviewed to advance patients through their rehabilitation progression?

- ☐ Yes
☐ No

39. Is there a specific time frame that you believe should be used through the progression of exercise?

- ☐ Yes
☐ No

40. How important are the following tools/strategies in the rehabilitation of patients with posterior shoulder instability?

	Very Important	Somewhat Important	Not Important
Visual feedback (video, mirrors)	☐	☐	☐
Tactile feedback (manual correction)	☐	☐	☐
Neurofacilitation (proprioceptive neuromuscular facilitation, vibration techniques, etc)	☐	☐	☐
Electronic biofeedback	☐	☐	☐
Taping	☐	☐	☐
Use of external cuing	☐	☐	☐
Use of internal cuing	☐	☐	☐
Other (please specify): _____			

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Strategy 3: Manual Therapy

41. Do you believe manual therapy interventions are an effective form of management for patients with posterior shoulder instability?

☐ Yes

☐ No

If yes, please state which forms of manual therapy you believe can/should be used:

Management of Traumatic (Dislocation) Posterior Shoulder Instability**Acute Phase (physicians and surgeons only)**

42. How important are the following aspects of joint reduction in the care of the traumatically dislocated shoulder?

	Very Important	Somewhat Important	Not Important
Closed reduction within a few hours (less than 24 hours)	☐	☐	☐
Closed reduction under intravenous sedation (opioid)	☐	☐	☐
Closed reduction using in-line longitudinal traction	☐	☐	☐
Closed reduction using gentle manipulation and external rotation	☐	☐	☐
Closed reduction under general anesthesia	☐	☐	☐

Are there other modes of joint reduction you believe are important in the care of the traumatically dislocated shoulder?

43. Which of the following positions do you believe is best for immobilizing the traumatically dislocated shoulder post reduction?

☐ Arm by side with forearm resting on abdomen in a sling

☐ Abduction to 30°, with arm in internal rotation

☐ Arm by side in 30° of external rotation

☐ Other (please specify): _____

44. Which is the ideal length of time for immobilization post reduction?

☐ 1 week

☐ 3 weeks

☐ 6 weeks

☐ Other (please specify): _____

Subacute Phase (physicians and surgeons only)

45. During the immobilization phase, do you recommend the following:

	Always	Sometimes	Never
Shoulder pendulum/circumduction exercises	☐	☐	☐
Elbow active range of motion	☐	☐	☐
Wrist active range of motion	☐	☐	☐

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46. After immobilization, do you recommend the following:

	Always	Sometimes	Never
Referral to physical therapy	☐	☐	☐
Home exercise program	☐	☐	☐
No further follow-up	☐	☐	☐
Avoid pushing movements	☐	☐	☐
No contact sports for 6 weeks	☐	☐	☐
No contact sports for 16 weeks	☐	☐	☐
Other (please specify): _____			

47. After immobilization, do you prescribe the following:

	Yes	No
X-ray	☐	☐
Magnetic resonance imaging	☐	☐
Computed tomography scan	☐	☐
Ultrasound	☐	☐
Pain medications (nonopioids)	☐	☐
Pain medications (opioids)	☐	☐
Nonsteroidal anti-inflammatory medications	☐	☐
Other (please specify): _____		

Surgical Options (surgeons only)

48. Based on your knowledge/experience, which of the following is an indication that surgery is required?

	Very Important	Somewhat Important	Not Important
Initial traumatic episode	☐	☐	☐
Failed conservative approach	☐	☐	☐
Presence of an associated fracture with posterior dislocation	☐	☐	☐
Presence of a glenoid fracture greater than 20%	☐	☐	☐
Presence of a glenoid fracture less than or equal to 20%	☐	☐	☐
Presence of static subluxation	☐	☐	☐
Presence of dynamic subluxation	☐	☐	☐
Presence of a detached labrum	☐	☐	☐
Presence of an associated soft tissue injury (rotator cuff tear)	☐	☐	☐
Presence of a retroverted glenoid on X-ray greater than 15°	☐	☐	☐
Presence of a retroverted glenoid on X-ray less than or equal to 15°	☐	☐	☐

Are there other situations where a surgical approach would be considered?

- ☐ Yes
☐ No

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49. Based on your knowledge/experience, to what extent should the following surgeries be considered for posterior instability?

	Always	Occasionally	Never
Labral repair	☐	☐	☐
Capsule plication	☐	☐	☐
Fragment fixation greater than 25%	☐	☐	☐
Fragment fixation less than or equal to 25%	☐	☐	☐
Retroversion: humeral osteotomy	☐	☐	☐
Retroversion: glenoid osteotomy	☐	☐	☐
Other (please specify): _____			

50. Post surgery, how important is physical therapy/physiotherapy?

- ☐ Very important
- ☐ Somewhat important
- ☐ Not important

APPENDIX B

PILOT SURVEY FEEDBACK

Feedback

	Result
1. Please complete the entire survey and state how long it took to complete	Mean $\pm$ SD survey completion time, 44 $\pm$ 14 minutes
2. Please list which questions or items within each question require further information or additional items, removal, or rewording	Refer to table below
3. Which questions do you feel the physical therapists should complete, and which questions should the physicians and orthopaedic surgeons complete?	The majority of panelists agreed on the proposed division of questions among professions
4. What barriers do you feel may prevent a participant from completing all 3 rounds of this e-Delphi study?	Identified barriers included time (n = 6), limited to online access (n = 2), and survey language being limited to English (n = 1)
5. Do you feel the "open boxes" within the survey are helpful?	Unanimous acceptance of open comment boxes to be used in conjunction with Likert selection

Answers to Question 2

Questionnaire Category	Questions per Category, n	Participants With Feedback, n	Feedback
Participant information	4	0	Not available
Classification	1	5	Confusing question
		2	Add a question on percentage of PSI patients classified in each category
Subjective examination	8	1	Add descriptors of patient symptoms (eg, feeling of nervousness)
		2	Clarify or add examples of patient's function and/or occupation restrictions (eg, reaching for seatbelt)
Objective examination	7	4	Unfamiliar with clinical exam techniques or test designed for particular settings (eg, under anesthesia)
		1	Add components of patient's observation (eg, hand behind back)
Outcome measures	3	7	Unfamiliar with the measures, specific relevance of measures to PSI, and usefulness in clinical practice
Risk/prognosis	4	2	Clarification requested
Timeline	1	0	Not available
Nonsurgical management of PSI	13	2	Add specific PSI questions in the educational component of care, and in the exercise implementation strategies
		3	Unfamiliar with internal and external cuing
		2	Clarify or add components of patient's activity limitations and add proprioception as a specific mode of training
Management of traumatic dislocation	9	2	Add "avoidance of contact sport for a minimum of 6 months"

Abbreviation: PSI, posterior shoulder instability.

APPENDIX C

OVERALL POSTERIOR SHOULDER INSTABILITY AGREEMENT

Subjective/Clinical History Questions for All Subgroups

1. What is your age? (84% agreement)
2. Did the problem begin due to a single event, or did it develop over a longer period of time? (96% agreement)
3. What is your main reason for seeking care? (90% agreement)
4. What are your goals of treatment? (96% agreement)

Symptom Questions for All Subgroups

1. Is weakness or decreased performance a major concern? (98% agreement)
2. Does your shoulder feel unstable or have the feeling that it may give way? (96% agreement)
3. Are there particular positions that you avoid due to a "giving out" sensation? (92% agreement)
4. Do you have other joints that feel unstable, subluxate, or dislocate? (96% agreement)
5. Are there particular positions that specifically bring on pain location? (78%-90% agreement)
6. Do you get clicking, clunk, or catching with your shoulder motion? (96% agreement)

Risk/Prognosis Questions for All Subgroups

1. Do you participate in contact sports? (98% agreement)
2. Do you participate in a sport/occupation with repetitive demands on the shoulder? (98% agreement)?
3. Do you have a family history of shoulder subluxation/dislocation? (71% agreement)
4. How many times has your shoulder subluxated or dislocated? (86% agreement)

Assessment for All Subgroups

- Range of motion, manual muscle testing, and motor control testing should be done at the discretion of the clinician, based on mechanism of injury (87% agreement)

Functional Limitations for All Subgroups

- Intolerance for weight bearing or pushing through the arms (eg, plank position, push-up, bench press, pushing a door open, etc) (88%-96% agreement)
- Intolerance for reaching across the body (eg, putting on a seatbelt, brushing teeth, pulling off a tight shirt/bra, etc) (78%-94% agreement)

Outcome Measures for All Subgroups

- Self-report
 - Number of episodes/times per year the shoulder is subluxated or dislocated (96% agreement)
 - Western Ontario Shoulder Instability Index (96% agreement)
 - Numeric pain-rating scale (91% agreement)
 - Single Assessment Numeric Evaluation (89% agreement)
- Physical outcome measures
 - Some form of functional testing for sport, occupation, or activities of daily living (eg, pushing out of chair, lifting overhead, reaching across body with resistance, etc) (94% agreement)

Recommendations for High-Risk Sport/Work

- Recommendations for activity limitations: during acute or irritable phase, patients should modify, limit, or avoid positions of combined horizontal flexion, adduction, and internal rotation (ie, arm across body) with/without axial load (92% agreement)
- Return to high-risk work/sport: post immobilization and after receiving 3 to 6 months of physical therapy (no surgery) (70% agreement)
- Return to high-risk work/sport: post immobilization and after receiving 6 to 12 months of physical therapy (post surgery) (96% agreement)

Overall Management

- Education regarding injury and prognosis that all patients with posterior shoulder instability should learn about:
 - Rehabilitating shoulder for optimal motor control and strength (81% rated very important)
 - Anatomy/pathomechanics (78% rated very important)
 - Pain coping strategies (72% rated very important)
- Factors for successful nonsurgical management of posterior shoulder instability
 - Willingness of patient to adhere/participate in rehabilitation (100% agreement)

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- Positive expectations for rehabilitation and exercise (98% agreement)
- Patients are provided with staged exercise program, with motor control and increased load (90% agreement)
- Patients are knowledgeable about their condition and the value of rehabilitation (98% agreement)
- Therapist is familiar with care of posterior shoulder instability (90% agreement)
- Improvement of symptoms with scapular and/or humeral head modifications (90% agreement)
- Factors for unsuccessful nonsurgical management of posterior shoulder instability
 - Negative beliefs or expectations about nonsurgical management (94% agreement)
 - Large traumatic structural lesions to glenoid or humeral head (89% agreement)
 - Belief that only surgery will correct the posterior shoulder instability (75% agreement)
- Considerations for home-based exercise programs
 - Motivation to perform at home (100% agreement)
 - Understanding and knowledge of home exercises (100% agreement)
 - High expectations that home exercises will be successful (94% agreement)
- Considerations for clinician-supervised exercise program
 - Low efficacy (83% agreement)
 - Poor support at home (81% agreement)
 - Sedentary lifestyle (75% agreement)
 - Requires verbal and tactile feedback (100% agreement)
 - Patient reports low motivation for home exercises (91% agreement)
 - Lower level of education or lacks insight into exercises (90% agreement)

Timelines for

- Referral to surgery: see recommendations for each of the 3 posterior shoulder instability subgroups in **TABLE 3**
- Return to high-risk sport/work: see recommendations for each of the 3 posterior shoulder instability subgroups in **TABLE 3**

APPENDIX D

TRAUMATIC, MICROTRAUMATIC, AND ATRAUMATIC POSTERIOR SHOULDER INSTABILITY POST ROUND 1, 2, AND 3 CONSENSUS

Traumatic

An injury that requires an immediate and/or forceful impact to cause a posterior or posteroinferior subluxation/dislocation of the humerus on the glenoid (100% agreement)

Clinical History

Mechanism of injury: fall or unexpected weight bearing/pushing into horizontal flexion/internal rotation or flexion (60°-140°) with adduction and internal rotation (85% agreement)

Occupations at risk: tactical (eg, firefighter, military, police officer, etc) (98% agreement), performing artist (eg, acrobat, martial artist, stunt performer, etc) (81% agreement)

Sports at risk: contact sports (eg, American football, rugby, ice hockey) (98% agreement), sports with increased fall risk (eg, cheerleading, figure skating, skateboarding, gymnastics) (94% agreement), combat sports (eg, karate, judo, wrestling, jiu-jitsu) (85% agreement)

Occupation- or sport-related shoulder demands: pushing, falling, or weight bearing with shoulder elevated between 60° and 140° of flexion, with or without adduction with internal rotation (79% agreement)

Questions to ask:

- Do you remember the position your shoulder was in at the time of injury? (100% agreement)
- When was your initial injury? (96% agreement)

Type: acute (98% agreement), dislocation (96% agreement), posterior dislocation direction (98% agreement), posteroinferior dislocation direction (96% agreement after round 3)

Symptoms: acute pain with loss of shoulder mobility in all directions, shoulder feels unstable or may give way (94% agreement after round 3), pain location: posterior more than anterior (82% agreement after round 3)

Functional limitations: intolerance for weight bearing or pushing through the arms (eg, plank, push-up, bench press, pushing a door open) (88% agreement)

Clinical Examination

Observation: pain behaviors: wincing, hesitation to move the shoulder, holding arm by side (75% agreement)

Active motion: horizontal flexion, adduction, internal rotation: limited secondary to pain or apprehension, external rotation, and/or hand behind back (limited range) (85% agreement)

Tests: posterior apprehension/jerk/Kim test (92% agreement), posterior load and shift (85% agreement), and/or posterior drawer test (80% agreement)

Strength deficits: acute dislocation: all strength tests would be painful and weak (79% agreement)

Outcome Measures

These outcome measures were common in all subgroups of posterior shoulder instability:

- Self-report
 - Episodes/times per year the shoulder is subluxated or dislocated (96% agreement)
 - Numeric pain-rating scale (91% agreement)
 - Single Assessment Numeric Evaluation (89% agreement)
 - Western Ontario Shoulder Instability Index (96% agreement after round 3)
- Physical outcome measures
 - Some form of functional testing for sport, occupation, or activities of daily living (ie, pushing out of chair, lifting overhead, reaching across body with/without resistance, etc) (94% agreement)

Management

- Medical: acute trauma
 - X-ray prior to reduction (97% rated very important)
 - Closed reduction in the emergency department (86% agreement), with consideration for duration of dislocation, evidence of locked humeral head, or deep reverse Hill-Sachs lesion on radiographs
 - Closed reduction in the operating room if presence of fracture, degree of reverse Hill-Sachs lesion, or locked humeral head
 - Immobilization in 30° of external rotation with neutral abduction (74% agreement) for 1 to 3 weeks (81% agreement)
 - Nonopioid pain medication (86% rated always) and nonsteroidal anti-inflammatory drugs (75% rated always)
 - Refer to physical therapy (77% rated always)

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- Recommend elbow and wrist range-of-motion exercises (84% rated always)
- Physical therapy
 - Minimum of 12 weeks of individualized exercise progression (87% agree to strongly agree)
 - Limit arm-across-body activities during acute/irritable phase (92% agreement)
 - Scapular, rotator cuff, and sport/occupation-specific strength training as needed (92% agreement)
- Surgery
 - Large bony structural lesion (89% agreement)
 - Fragment fixation greater than 25% (79% rated very important)
 - Labral repair (76% rated very important)
 - Failed nonsurgical management after 3 months (86% agreement)

Timelines for

- General recovery: pain/activities of daily living—6 to 12 weeks (77% agreement)
- Immobilization in 30° of external rotation with neutral abduction (74% agreement) for 1 to 3 weeks (81% agreement)
- Referral for surgery: immediately if there are large structural bony lesions to the glenoid or humeral head (89% agreement) or after 3 months if not responding to physical therapy or nonsurgical management (86% agreement)
- Return to high-risk work/sport: post immobilization and after receiving 3 to 6 months of physical therapy (no surgery) (70% agreement)
- Return to high-risk work/sport: post surgery and after receiving 6 to 12 months of physical therapy, based on individualized discussion with patient (96% agreement after round 3)

Microtraumatic

A posterior or posteroinferior subluxation/dislocation of the humerus on the glenoid, with or without degenerative changes, and associated with gradual or acute overload of the musculature (98% agreement)

Clinical History

Mechanism of injury: tasks that involve repetitive or increased load with pushing or weight bearing through the straight arm, or reaching across body, or overhead tasks (94% agreement after round 3)

Occupations/sports at risk: highly repetitive overhead activity (eg, swimmer, baseball pitcher, tennis player, manufacturing laborer) (94% agreement), sports with overhead activity with heavy load (eg, weightlifter) (89% agreement), performing artist (eg, acrobat, dancer, martial artist, stunt performer) (90% agreement)

Occupation- or sport-related shoulder demands: repetitive—overhead (92% agreement); horizontal flexion (96% agreement); horizontal flexion, adduction, and internal rotation (100% agreement); pushing, falling, or weight bearing through the arms between 60° and 140° of flexion (77% agreement)

Question to ask:

- Did the problem begin due to a single event or over a period of time? (96% agreement)

Type: functional subluxations (85% agreement), episodic (fewer than 3 subluxations/dislocations per year) (86% agreement), chronic (more than 3 subluxations/dislocations per year) (84% agreement), unidirectional (posterior, 77% agreement), bidirectional dislocations/subluxations (more than 1) (posteroinferior, 76% agreement)

Symptoms: functional instability—self-subluxation (84% agreement), night pain/disturbed sleep (92% agreement), catching/clicking with shoulder motion (96% agreement), nerve-like pain in arm (77% agreement), arm fatigues easily (94% agreement)

Functional limitations: intolerance for weight bearing or pushing through the arms (eg, plank position, push-up, bench press, pushing open a door, etc) (96% agreement)

Clinical Examination

Observation: patients may be able to voluntarily subluxate or reduce the glenohumeral joint (100% agreement)

Active motion: aberrant active shoulder and scapular motion (90% agreement), apprehension with horizontal flexion/adduction/internal rotation, decreased or locked external rotation (87% agreement)

Tests or cluster of tests: posterior apprehension/jerk test (100% agreement), posterior drawer test (84% agreement), or subjective history plus posterior apprehension plus scapular and/or humeral head repositioning tests with symptom or strength improvement (80% agreement)

Strength deficits: weak scapular upward rotators (upper and lower trapezius, serratus anterior) (74% agreement)

Outcome Measures

- Self-report
 - Episodes/times per year the shoulder is subluxated or dislocated (96% agreement)
 - Numeric pain-rating scale (91% agreement)
 - Single Assessment Numeric Evaluation (89% agreement)

APPENDIX D

- Western Ontario Shoulder Instability Index (96% agreement after round 3)
- Physical outcome measures: some form of functional testing for sport, occupation, or activities of daily living (ie, pushing out of chair, lifting overhead, reaching across body with/without resistance, etc) (94% agreement)

Management

- Recommendations for activity limitations: during acute or irritable phase, patients should modify, limit, or avoid positions of combined horizontal flexion, adduction, and internal rotation (ie, arm across body) with/without axial load (92% agreement)
- Physical therapy
 - Assess and manage scapular and/or humeral head position (100% agreement)
 - Scapular upward rotators, rotator cuff muscles, and sport/occupation-specific strength training should be addressed (98% agreement)
 - Exercise progression should encompass local and global muscles, with progression through motor control to endurance to strength to functional retraining (72% agreement)
 - Emphasis is on exercise progression, but manual therapies are considered acceptable (96% agreement) if defined as active feedback using various forms of tactile touch, mobilization with movement, or manual repositioning of the scapula or humerus
- Medical
 - Refer for physical therapy (96% agreement)
 - Nonsteroidal anti-inflammatory drugs only during acute phase (75% agreement)
 - Immobilization post reduction only in 30° of external rotation with neutral abduction (74% agreement) for 1 to 3 weeks (81% agreement)
 - Modify or limit horizontal adduction, flexion, and internal rotation initially (92%)
- Surgery
 - Referral for surgery should be considered after 6 months if physical therapy or nonsurgical management is unsuccessful (73% agreement)

Timelines for

- General recovery: pain/activities of daily living—6 to 12 weeks (77% agreement)
- Immobilization post reduction: 1 to 3 weeks (81% agreement)
- Return to high-risk work/sport: no surgery and after receiving physical therapy for 3 to 6 months (70% agreement)
- Return to high-risk work/sport: post surgery and after receiving physical therapy for 6 to 12 months, based on individualized discussion with patient (96% agreement after round 3)

Atraumatic

A subluxation/dislocation of the humerus on the glenoid in a posterior or posteroinferior direction due to congenital and/or systemic laxity of the ligamentous, labral, or capsular glenohumeral structures, or congenital anomalies of the bony glenoid or humerus (98% agreement)

Clinical History

Mechanism of injury: tasks that involve pushing or weight bearing through the straight arm or reaching across body (92% agreement), repetitive activities that include overhead or horizontal flexion, adduction, or internal rotation activities (79% agreement)

Occupations/sports at risk: athletic-based performing artist (acrobat, dancer, martial artist, stunt performer, etc), weightlifter (73% agreement)

Occupation- or sport-related shoulder demands: repetitive—overhead (79% agreement); horizontal flexion (89% agreement); horizontal flexion, adduction, and internal rotation (92% agreement)

Questions to ask:

- Do you have other joints in your body that you can dislocate or subluxate? (100% agreement)
- Do you have a family history of connective tissue disorders? (eg, Ehlers-Danlos, Marfan syndrome, general hypermobility syndrome) (100% agreement)

Type: functional subluxations (94% agreement), chronic (more than 3 subluxations/dislocations per year) (94% agreement), multidirectional (96% agreement), bidirectional posterior/inferior subluxations (84% agreement)

Symptoms: arm fatigues easily (92% agreement), functional instability—self-subluxation (90% agreement), night pain/disturbed sleep (90% agreement), catching/clicking with shoulder motion (86% agreement), nerve-like pain in arm (84% agreement), intolerance for lying on affected side (79% agreement)

Signs: can make shoulder pop in/out or demonstrate generalized shoulder laxity (98% agreement)

Functional limitations: functional instability is primary limiting complaint (90% agreement), intolerance for lying on affected shoulder (79% agreement)

Clinical Examination

Observation: patients able to voluntarily subluxate or reduce the glenohumeral joint (100% agreement)

Active motion: aberrant active shoulder and scapular motion (96% agreement), apprehension with horizontal flexion/adduction/internal rotation, decreased or locked external rotation (91% agree)

APPENDIX D

Cluster of tests: subjective history plus Beighton score greater than 4/9, positive sulcus test (internal rotation or external rotation), scapular and/or humeral head repositioning with/without improvement in muscle strength or symptoms (93% agreement)

Strength deficits: weak scapular upward rotators and outer ranges of overhead glenohumeral range of motion (78% agreement)

Outcome Measures

- Self-report
 - Episodes/times per year the shoulder is subluxated or dislocated (96% agreement)
 - Numeric pain-rating scale (91% agreement)
 - Single Assessment Numeric Evaluation (89% agreement)
 - Western Ontario Shoulder Instability Index (96% agreement after round 3)
- Physical outcome measures
 - Some form of functional testing for sport, occupation, or activities of daily living (ie, pushing out of chair, lifting overhead, reaching across body with/without resistance, etc) (94% agreement)

Management

- Recommendations for activity limitations: during acute or irritable phase, patients should modify, limit, or avoid positions of combined horizontal flexion, adduction, and internal rotation (ie, arm across body) with/without axial load (92% agreement)
- Physical therapy: based on physician, physical therapist, and orthopaedic surgeon agreement
 - Assess and manage scapular and/or humeral head position (100% agreement)
 - Scapular upward rotators, rotator cuff muscles, and sport/occupation-specific strength training should be addressed (98% agreement)
 - Exercise progression should encompass local and global muscles, with progression through motor control to endurance to strength to functional retraining (72% agreement)
 - Emphasis is on exercise progression, but manual therapies are considered acceptable (96% agreement) if defined as active feedback using various forms of tactile touch, mobilization with movement, or manual repositioning of the scapula or humerus
- Medical: based on physician agreement only
 - Refer for physical therapy (96% agreement)
 - Nonsteroidal anti-inflammatory drugs only during acute phase (75% agreement)
 - Immobilization post reduction only in 30° of external rotation with neutral abduction (74% agreement) for 1 to 3 weeks (81% agreement)
 - Modify or limit horizontal adduction, flexion, and internal rotation initially (92% agreement)
- Surgery: based on orthopaedic surgeon agreement only
 - Referral for surgery should be considered after 6 months if physical therapy or nonsurgical management is unsuccessful (77% agreement)

Timelines for

- General recovery: pain/activities of daily living—6 to 12 weeks (77% agreement)
- Immobilization post reduction: 1 to 3 weeks (81% agreement)
- Return to high-risk work/sport: no surgery and after receiving 3 to 6 months of physical therapy (70% agreement)
- Return to high-risk work/sport: post surgery and after receiving 6 to 12 months of physical therapy (post surgery) (96% agreement after round 3)