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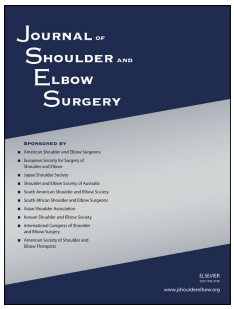

Kinetic chain revisited: Consensus expert opinion on terminology, clinical reasoning, examination and treatment in people with shoulder pain

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Abstract

Objectives: To determine the most appropriate terminology and issues related to clinical reasoning, examination and treatment of the kinetic chain (KC) in people with shoulder pain by an international experts panel.

Design: Delphi study

Methods: A three-round Delphi study that involved an international panel of experts with extensive clinical, teaching and research experience in the study topic was conducted. A search equation of terms related to KC in Web of Science and a manual search were used to find the experts. Participants were asked to rate items across five different domains (terminology, clinical reasoning, subjective examination, physical examination and treatment) using a 5-point Likert-type scale. An Aiken's Validity Index ≥ 0.7 was considered indicative of group consensus.

Results: Participation rate was 30.2% (n=16) while retention rate was high throughout the 3 rounds (100%, 93.8%, 100%). A total of 15 experts from different fields and countries completed the study. After the three rounds, consensus was reached on 102 items: 3 items were included in the "terminology" domain, 17 items in the "rationale and clinical reasoning" domain, 11 items in the "subjective examination" domain, 44 items in the "physical examination" domain and 27 items in the "treatment" domain. "Terminology" was the domain with the highest level of ~~more~~ agreement with two items achieving an Aiken's V of 0.93, whereas "physical examination" and "treatment" of the KC where the two areas with less consensus. Together with "terminology" items, one item from the "treatment" and two items from the "rationale and clinical reasoning" domains reached the highest level of agreement (v=0.93 and 0.92, respectively).

Conclusion: This study defined a list of 102 items across five different domains (terminology, rationale and clinical reasoning, subjective examination, physical examination and treatment) regarding to KC in people with shoulder pain. The term KC was preferred and a definition for this concept agreed. Dysfunction of a segment in the chain (i.e., weak link) was agreed to result in altered performance or injury to distal segments. Experts considered important to assess and treat the KC in particular in throwing/overhead athletes and agreed that no one size fits all approach exist when implementing shoulder KC exercises within the rehabilitation process. Further research is now required to determine the validity of the identified items.

Level of evidence: Consensus Development Study; Delphi Method

Keywords: kinetic chain; shoulder pain; terminology; clinical reasoning; examination; Delphi study

Human movement patterns in dynamic upper extremity dominant tasks are produced through series of interrelated links or segments.[22,60] This form of integrated motion is known as the kinetic chain (KC), which refers to the complex task-specific interaction of different body segments or links sequentially activated to produce a functional movement pattern.[26,54] An efficient KC allows an appropriate sequential energy transfer from more proximal (i.e., trunk, lower limbs) to distal body segments (i.e., shoulder, elbow) with minimal energy consumption, reduced joint loads, optimal velocity and optimal force production during movement.[55] Breakdown or dysfunction at any "link" within the KC may negatively influence force transfer

to other segments and possibly increase the mechanical stress and consequently the risk of injury and pain in more distal segments.[19,54]

The shoulder complex does not work in isolation when performing upper extremity tasks but is integrated manner within the whole musculoskeletal system. In this sense, the KC has been studied with regard to its role in normal shoulder function and its impact on shoulder injury.[9,19,26,33,38,54,55] Additionally, the KC principle provides the rationale for assessing and treating musculoskeletal regions remote from the shoulder (i.e., trunk, lower limbs), despite the shoulder joint being injured. Although the relevance of the KC in the management of people with shoulder pain is well recognized in the literature,[19,54] there are still some gaps in relation to this topic. For instance, different terms such as "kinetic chain",[7,26] "kinetic link",[22] "proximal-to-distal sequencing",[45] or "summation of speed principle"[48] have been used to refer to the same concept so a lack of consensus in terminology seems evident. While the overall concept of connected segments and energy transfer may be underlying the use of all these apparently diverse terms by clinicians and thus be considered synonyms, how this varied terminology might impact evaluation and treatment of people with shoulder pain is currently unknown. In addition, both research and expert opinion encourage clinicians to integrate the KC principle in the assessment and management of people with shoulder pain.[11,63] Indeed, incorporating the KC into shoulder exercise regimes seems to positively influence shoulder muscle recruitment patterns (e.g., if the goal of an exercise intervention is to reduce the demands on the rotator cuff).[6,50] However, compelling evidence to support the additional clinical benefit of treating the KC over a more local shoulder approach is still scarce.[12]

No consensus exists yet on which battery of tests are the most appropriate to conduct a comprehensive evaluation of the KC in an individual patient with shoulder pain. Clinical criteria to determine that a KC dysfunction or deficit exists in a specific body area and that it is clinically relevant for the patient with shoulder pain are neither well established. Finally, no

agreement exists about how to adapt or modify traditional shoulder treatments to involve the KC when a KC dysfunction is considered clinically relevant.

The Delphi method is a consensus-based, survey approach, designed to distil and obtain consensus from a group of experts (Delphi respondents) when incomplete or contradictory evidence exists about a topic.[24,40] It includes several rounds of structured questionnaires where experts anonymously reply in a timely fashion and subsequently receive feedback of the "group response".[10,21,65] The anonymity avoids domination of the consensus by one or a few experts and the influence of group pressure and status, thus achieving more sincere and real opinion.[10,21]

The purpose of this study was to use a Delphi method to reach consensus among multi-disciplinary, international shoulder experts on the most appropriate terminology, rationale and clinical reasoning, subjective examination, physical examination and treatment of the KC in people with shoulder pain.

METHODS

Study design

A three-round online Delphi survey that incorporated a working and a respondent group was conducted between November 2020 and May 2021. This study was conducted in accordance with CREDES recommendations[25] and was approved by the University of Valencia Research Ethics Committee (register number: 164154).

Working group

In the Delphi method, the working group has an important role in establishing the research problem and rationale after a previous literature review, guiding the study, analyzing

the data and interpreting the results of each round.[61] Additionally, the working group makes an important task assembling the expert panel, creating and administering multiple survey rounds, synthetizing experts' feedback, making decisions about similarities and redundancy of variables and guiding the group toward consensus.[10,61]

In this study, the working group was composed of six individuals (ELL, NRS, RFM, ER, ME and AC), including the first and last author of this publication. No eligibility criteria were used to be part of the working group. Members of the working group had clinical and/or research background on the use of KC in people with shoulder pain including its evaluation or screening tools. All six were physical therapists and two of them (ELL and AC) are experienced researchers having published multiple papers on the topic of shoulder pain including the KC.

Expert panel

The expert panel provides an opportunity to achieve a consensus of a geographically scattered group of experts.[21] In this study, the expert panel was composed of clinicians and researchers from an array of specialties (physical therapists, athletic trainers, sport medicine physicians, coaches) purposely selected based on: (1) their expertise in treating shoulder problems, (2) their knowledge about the concept of KC related to the shoulder and (3) their scientific publications on this latter topic.

To guarantee a representative group of experts, they were identified via a Web of Science search using relevant terms related to the study topic (Supplementary Table 1). The following inclusion criteria were considered in this study: (1) to have at least 1 scientific publication about the KC related to shoulder; (2) to have at least 10 years of clinical experience treating and diagnosing shoulder pain; and (3) to have experience as a teacher at graduate or postgraduate levels. Additionally, a manual search was performed to ensure that additional

experts proposed by the working group, which might not be recruited by the search strategy but met the inclusion criteria, were not missed. The process of selecting panel members was done by two investigators (NRS, RFM) and verified by the principal (ELL) and senior (AC) authors of this study. The expert panel selection process is depicted in Figure 1.

Procedure

Electronic surveys were created using Google Forms, a web-based survey app from Google Tools. Once a list of potential Delphi respondents was generated, the expert panel received three documents via email: (1) an invitation letter informing of the length and number of survey rounds, the purpose and importance of the Delphi study and instructions for participation, (2) an informed consent document, and (3) a link to the round I questionnaire in case they accepted the invitation to participate. Invitations to round II and III were automatically distributed through e-mail to all respondents from round I, providing the respondents with the link to the corresponding survey together with feedback in the form of a statistical representation of the previous round results.

The experts were given 4-6 weeks to complete each questionnaire and weekly reminders (up to three) as per the Dillman method[17] were sent to non-respondents on consecutive weeks in order to encourage participation.

Round I

The round I survey included demographic questions, professional questions related to academic specialization and a list of items related to the topic of KC in people with shoulder pain which was developed by the working group and presented in closed- and open-ended formats. Research questions, domains of interest and individual survey items comprising round I were developed from current evidence after a non-systematic search of the literature as well

from opinion of the working group. Successive face-to-face and online group meetings allowed the working team to develop 19 survey items related to the topic of KC in people with shoulder pain. They were organized into five domains: (1) terminology (3 items), (2) rationale and clinical reasoning (4 items), (3) subjective examination (1 item), (4) physical examination (6 items) and (5) treatment (5 items).

Participants were asked to rate closed-ended items using a 5-point Likert-type scale (*strongly disagree, disagree, neutral, agree and strongly agree*). Experts had space for free-text answers in the open-ended items. In addition, free text options were embedded into the survey to enrich data collected where experts were allowed to provide comments and suggest additional items that had not been included by the research team when developing round I.

Survey questions and items comprising round I are detailed in Supplementary Table 2.

Round II

After respondents completed round I, response data were exported from Google Forms to an Excel spreadsheet for working group analysis. A quantitative and qualitative analysis of responses from round I was performed whereby responses from close-ended questions reaching agreement passed to round II and each single data provided in open-ended questions and free-text options was analyzed in a qualitative fashion. In particular, similar words or phrases provided by experts were coded and joined into specific items based on similar meanings and contexts (known as "literal coding"). New item categories were thus created using descriptor statements that represented and joined the (similar) responses provided by experts. This coding process was conducted for the data entries received for the five domains.

In round II, participants received the list of items produced at the end of round I and they were asked to rate their degree of agreement with each proposed item using the same

Likert scale as round I. Only closed-ended Likert style responses were used in this round.

Round III

In round III, participants received feedback on round II results (group consensus measured with Aiken's V coefficient of validity) in the form of descriptive statistics thus enabling reflection before providing their final opinion. Four weeks lapsed between round II and III.

The respondents were asked to re-score their level of agreement with each item using the same Likert-type scale after viewing the distribution of group opinion from round II.

Data analysis

The survey instrument was built on Google Forms software which was managed by two researchers (ER, MVM) to ensure the privacy of participants was maintained. After each round, the data were downloaded from Google Forms into an Excel spreadsheet (Microsoft Corp, Redmon, WA, USA) for analysis. All the analyses were performed with statistical software R version 4.1.0 (R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/).

Descriptive statistics including mean and standard deviation (SD) and absolute and relative frequencies were used to present sociodemographic characteristics of the expert panel and the experts' response rate per round. Semantically equivalent responses from open-ended questions and free-text options were grouped and categorized under one heading where appropriate by using a content analysis approach.[44] Data entries were independently coded and categorized by three investigators (ELL, NRS, RFM) through a process of discussion in order to reduce categorization bias.[44]

The level of agreement among the experts was analyzed by means of the Aiken's V

coefficient of validity (V). This coefficient is used to quantify the content validity or relevance of an item with respect to a content domain evaluated by several experts' judgement. Aiken's V is calculated as the ratio of the sum of agreement score obtained from all authors for a given item, with respect to the maximum possible punctuation (i.e., maximum value of the Likert scale * number of experts rating that item). The value of Aiken's V ranges from 0 to 1, the latter representing perfect agreement. An Aiken's $V \geq 0.7$ was considered reflective of group consensus, as recommended for Delphi studies.[42]

RESULTS

Expert panel

Fifty-three experts were initially identified as potential candidates and were invited to participate in the overall Delphi process. All of them responded to the initial email, but 37 were excluded. A total of 16 experts completed the consent form and responded to round I, thus participation rate was limited to 30.2% (n=16). One expert withdrew from round II after agreeing to participate due to personal reasons. A total of 15 experts from diverse fields (research, clinical practice, education or mixed) and six different countries finally completed all three rounds of the survey (Figure 1).

Ten respondents were female (66.7%) and five were male (33.3%). Most of the cohort were physiotherapist-researchers with the United States of America being the country with the largest representation (40%). The group had an average of 18.4 (SD, 7.8) years of clinical experience treating patients with shoulder pain and 19.4 (SD, 8.9) years using the KC concept when assessing and treating patients with shoulder pain. The response rate across the three rounds was16/16 (100%), 15/16 (93.8%) and 15/15 (100%), respectively.

Further demographic information of the expert panel members is provided in Table 1.

Delphi survey

At the end of the three rounds, a total of 102 items reached consensus among experts (Aiken's Validity Index ≥ 0.7). They were distributed amongst the five domains as follows: terminology (n = 3), rationale and clinical reasoning (n = 17), subjective examination (n=11), physical examination (n=44) and treatment (n=27) (Table 2). "Terminology" was the domain where more agreement was achieved. Two items from this domain ("definition" and "preferred term when referring to the concept of kinetic chain") achieved the highest Aiken's V value (v=0.93), together with an item from the "treatment" domain, in particular "when should KC exercises be implemented within the rehabilitation process of a patient with shoulder pain" where experts agreed on: "*There is no one size fits all approach. It is necessary to consider subjective history and led clinical reasoning to dictate where you hone your objective assessment, as this will vary from patient to patient, to finally decide when to implement kinetic chain exercises within the rehabilitation process*"). Two items from the "rationale and clinical reasoning" domain also reached a very high level of agreement (v=0.92): "*Dysfunction of a particular segment in the chain (i.e. weak link) can result in either altered performance or injury to a more distal segment*" and "*It is important to assess and treat the KC in Throwing/overhead athletes (e.g., baseball players)*". Physical examination and treatment of the KC where the two areas where less consensus was reached as, proportionally, a high number of items obtained an Aiken's V close to 0.7.

After round I, 11 out of 20 (55%) items proposed by the working group and required to be responded with the 5-point Likert-type scale met consensus (Supplementary Table 3). Additional 314 items were proposed by the experts in the free-text answers in this round I (Supplementary Table 4). "Physical examination" domain was the one where a higher number

of items was proposed (n=120).

The working group prepared a survey with 288 items for round II after synthesizing experts' feedback which included the 11 items that reached consensus in round I (Supplementary Table 5). In round II, 149 items out of 288 (51.7%) reached consensus (Supplementary Table 6). Before round III, 31 items of these 149 were removed despite reaching consensus because the working group considered them to be highly similar to each other. A total of 118 items comprised round III from whom a total of 102 (86.4%) finally reached consensus (Supplementary Table 7).

Overall, 7 out of 20 (35%) of the items initially proposed by the working group remained at the end of round III and 102 out of 149 (68.5%) of the items that reached consensus in round II remained at round III. The complete item selection process is represented in Figure 2.

DISCUSSION

This Delphi study aimed to achieve an international and multi-disciplinary expert consensus on terminology, rationale and clinical reasoning, subjective examination, physical examination and treatment relating to the KC in people with shoulder pain. A list of 102 (34.3%) items across the aforementioned five domains from a total of 297 items reached consensus. "Terminology" was the domain where more between experts' agreement was achieved which may suggest that understanding and thinking about the term KC may be similar amongst clinicians and researchers, despite the apparently diverse terms used in the literature. "Physical examination" and "treatment" of the KC were the two areas with less consensus. The high number of consented items reflects the complexity of the topic of this study. Although our results are supported by the opinion of 15 highly qualified and experienced individuals,

obtaining a consensus does not mean that the correct answer has been found.[5,21] Future research aiming to establish an evidence-based decision-making framework related to the topic of the KC in people with shoulder pain is needed.

Respondent group characteristics

The sample size of Delphi surveys does not depend on statistical power, but on the dynamics of the expert group arriving at consensus.[42] There is currently no consensus about the ideal sample for an experts' panel with some authors recommending a minimum of 15,[32] 10[15] or even 7 members.[31] Additionally, the quality of an experts' panel seems to be more important than the quantity [47] and the criteria for defining an expert are not clearly established.[3] Our study recruited 15 participants which is in the range of previous Delphi studies where 10-50 participants have been reported.[16,34,51,57,64,68] Importantly, based on the characteristics of our panel members including their clinical experience number of years using the KC concept and their highest professional degree (Table 1), its quality is considered high. This gives robustness and credibility to the results of the current study.

Terminology

The lack of standard terminology in research is considered one important barrier when interpreting and comparing results between studies.[18,52,59] One of the goals of this Delphi study was to reach consensus on taxonomy related to the concept of KC. The preferred term by experts when referring to the concept of KC was "*kinetic chain*". Additionally, two very similar definitions which emphasized the concept of KC as the coordination between multiple body segments or links to produce a movement pattern such as throwing met consensus (Supplementary Table 7). Our results are in line with previous consensus studies on terminology within the field of sport medicine.[20,41,56,62] We hope that the proposed KC

terminology serves as a first step towards improving inter-professional communication and between-study comparisons.

Rationale and clinical reasoning

In this section, several reasons were argued why integrating the assessment and management of the KC in people with shoulder pain is important. For instance, it was proposed that shoulder function normally occurs in an integrated but not isolated manner. Additionally, experts agreed that taking the KC into consideration reduces load in the shoulder, opens a window for exercise prescription, increases exercise compliance, is more functional than isolated shoulder assessment and training, and prevents reinjury once patient is symptom free. Interestingly, the item with highest level of agreement was "*Dysfunction of a particular segment in the chain (i.e., weak link) can result in either altered performance or injury to a more distal segment*". This is in accordance with previous research which has demonstrated that breakdown at proximal "links" of the KC (i.e., trunk, lower limb) may negatively influence force transmission to the shoulder thus increasing mechanical stress and the risk of shoulder injury and pain.[8,30,35,43,53]

Experts did not consider it important to assess and treat the KC in "*all the patients with shoulder pain*", but to assess and treat the KC only in specific shoulder pain populations, with "*throwing/overhead athletes*" being the most agreed group. This finding might be explained by the fact that most of the available research related to the concept of KC has been performed in that group.[9,19]

To the authors' knowledge little evidence is currently available about the role of KC in other shoulder pain populations proposed by experts, such as rugby and hockey players or gymnasts.

Subjective examination

Different features emerged as helpful for indicating a potential involvement of the KC based on experts' opinion. In particular, a history of previous injury or pain in any body part other than the shoulder (e.g., lower limb), recurrent episodes of shoulder pain despite repeated treatments, intermittent shoulder pain with an insidious onset associated with problems in other body regions or suboptimal performance and pain during functional and sporting tasks involving global movements were agreed by the experts. The mere participation in overhead sports, performing arts or occupation and a history of wrist/elbow pain in tennis players also met consensus. Based on these results, we recommend incorporating all these features in the clinical history to ascertain a potential contribution of the KC to the patient problem. However, further research aiming to determine their diagnostic accuracy is needed.

Physical examination

When experts were asked about body regions that should be evaluated to determine the involvement of the KC in people with shoulder pain, they agreed on all the spinal regions, scapula, pelvis, and hip. Interestingly, neither the knee nor the ankle met consensus which is in accordance with the current literature, as studies showing a clinical association between these two joints and the shoulder are scarce.[29,58] Physical examination of the scapula was the item achieving the highest level of agreement. Indeed, the scapula is considered a vital segment within the KC and scapular dyskinesis and its relation to shoulder pain is a widely discussed topic in the literature.[13,27,28]

An extensive list of factors to be evaluated to determine the involvement of the KC met experts' consensus. The role of some of them (e.g., thoracic posture) in shoulder pain has been questioned.[4] The item "*core stability (neuromuscular control)*" achieved the highest level of consensus. Importantly, although core stability is widely incorporated in rehabilitation of

people with shoulder pain, many patients may not present with impairments in core neuromuscular control so an individualized assessment is warranted.[46] The item "*lumbopelvic-hip complex stability*" which also met consensus has been shown to be correlated with improved overhead performance and reduced number of shoulder injuries.[14]

One of the major gaps in the shoulder literature is the lack of a universal battery of tests to identify the presence of a KC dysfunction in patients with shoulder pain. The Delphi expert panel suggested a list of specific assessment tests which can be grouped into four categories: (1) a functional or sport movement pattern relevant to the patient, (2) symptom modification tests (e.g., repeating the relevant shoulder movement during a squat), (3) scapular tests (e.g. scapular dyskinesis test) and (4) lower extremity physical performance tests (e.g., single leg balance). Some controversy exists regarding the use of symptom modification tests[39] and scapular dyskinesis tests[67]. Additionally, the star excursion balance test, which did not meet consensus, appears to be the only lower extremity physical performance test correlated with shoulder injury risk.[23] Reliability and validity of the agreed KC tests as well as the establishment of their cut-off scores for determining the existence of a KC dysfunction may be the subject of further research.

The expert panel agreed that there is no predetermined order for assessing the KC within the physical examination (e.g., first shoulder, then KC), but the order depends on the clinical history. It might be argued that in case several clinical features agreed by experts in the subjective examination section are present, physical examination may initially be focused in the KC. In order to determine the relevance of a KC dysfunction experts agreed on the use of symptom modification tests whose usefulness, as mentioned above, has been criticized.[39]

Treatment

Based on the experts' opinion, the KC should be integrated in patients with shoulder pain when there is a KC dysfunction and depending on the cause, when the goal is to activate other structures as much as possible or to work on more functional activities and as a prevention strategy. This latter contrasts with current evidence for prevention of shoulder injuries which is limited.[2,66]

Regarding the temporal sequence (before, during or after local shoulder treatment) for integrating the KC during treatment, the panel agreed that there is no-one-size-fits-all approach. They should be used across the continuum of the rehabilitation process, including return to play, varying their intensity in a tailored way according to the stage of rehabilitation and patient progression. This is an important finding as KC exercises are often used only at the very end of the rehabilitation process. Indeed, one reason argued by experts to integrate the KC in treatment was to avoid re-injury once the patient is symptom free, which would indicate a preferential use of KC exercises in later rehabilitation stages.

A wide range of strategies for treating a KC dysfunction met consensus. Experts considered the dynamic integration of KC exercises during shoulder exercises important while focusing on sports-specific skills and functional movement patterns and avoiding "negative stress" on the shoulder. Both active (e.g., exercise) and passive (e.g., mobilizations) interventions were included. Different exercise modalities were recommended such as isolated core strengthening exercises or in combination with shoulder exercises, balance and speed exercises, proper posture exercises, motor control exercises, lower limb stability exercises, hip and thorax mobility exercises or stability exercises for scapular and glenohumeral muscles. However, this list of interventions only represent a general guideline for treatment. Assessment tests for identifying specific KC dysfunctions (see physical examination section) may be used to individualize exercise interventions.

Research strengths and limitations

A great challenge when conducting a Delphi study is to identify appropriate experts.[47] There are currently no universal objective criteria for one to be considered an expert.[3] Our study involved a highly experienced and multi-disciplinary panel of experts who were chosen using a systematic search strategy. This ensured a wide spectrum of opinion was provided and diminished selection bias. We decided to assess the knowledge on KC by means of three criteria: publications, clinical experience and academic background. In this manner, we anticipated to include "experts" with a "more complete" expertise profile in the researched topic. The terms used to identify experts were quite broad for pathology and assessment/treatment but narrower for KC terms, whereas other KC synonyms (e.g. kinetic link) were not included in the search strategy. This may have influenced the results of the search. The low participation rate after the initial invitation (30.2%) might represent a limitation of this study and limit its external validity. However, it has been demonstrated that if experts have considerable training and knowledge, small sample sizes are acceptable.[1] Retention rate throughout the different rounds remained high (94% to 100%) in contrast to what is common in Delphi studies. The regrouping and categorization of similar items through the study may have introduced bias although all data entries were independently coded by three investigators and subsequently discussed until consensus. A priori consensus threshold of 70% was used in order to be more sensible and avoid missing possible items that might be of interest but it is lower than other similar Delphi studies.[56,57] There is currently no agreement in the literature about which is the "best" threshold (if any) to be used in Delphi studies. Importantly, different thresholds can produce different number of items retained at the end of the Delphi study. Round I survey items were created after a non-systematic literature research and working team expertise which may have also introduced bias. Unfortunately, it is unknown how the results of this study compare to current clinical practice as no data on the latter is available.

Finally, the expert panel was a very targeted and unique population authoring a large part of the published research on the topic of KC. This fact may have introduced bias when considering the relevance of the KC as they may not represent general practice.[5]

CONCLUSIONS

This Delphi study shows the expert consensus on terminology, rationale and clinical reasoning, subjective examination, physical examination, and treatment of the KC in people with shoulder pain. A total of 102 items were obtained and further research is now required to determine their validity. The term KC was preferred and a definition for this concept agreed. Dysfunction of a segment in the chain (i.e., weak link) was agreed to result in altered performance or injury to distal segments. Experts considered important to assess and treat the KC in particular in throwing/overhead athletes and agreed that no one size fits all approach exist when implementing shoulder KC exercises within the rehabilitation process. We hope that the results of this study serve as a first step to develop an evidence-based framework that helps guide decisions regarding the concept of KC in people with shoulder pain.

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FIGURES AND TABLES LEGEND

Figure 1. Expert panel selection process.

Figure 2. Flow diagram of the Delphi study.

Table 1. Characteristics of the Delphi participants.

Table 2. Final items reaching consensus in the Delphi study.

Table 1. Characteristics of the Delphi participants.

Sex (female: male)	10:5
Age* (years)	43.7 (8.4)
Clinical experience treating patients with shoulder pain (years)*	18.5 (7.7)
Number of patients with shoulder pain treated per month*	28.7 (26)
Years using the KC* concept when assessing/treating patients with shoulder pain*	14.7 (7.1)
Country	
Turkey	1
USA	6
United Kingdom	4
Sweden	1
Belgium	2
Brazil	1
Type of professional	
Physiotherapist-Clinician	7
Physiotherapist-Researcher	12
Physiotherapist-Professor	3
Certified Athletic Trainer/Researcher/Professor	1
Athletic Trainer-Biomechanics Sports Medicine Researcher	1
Current professional area	
Clinical practice	9
Research	11
Education	6
Highest academic degree	
Bachelor	1
Master	3
PhD	11

*Mean (Standard Deviation); KC, Kinetic Chain.

Table 2. Final items reaching consensus in the Delphi study.

TERMINOLOGY
Kinetic chain definition
Coordinated sequencing of activation, mobilization, and stabilization of body segments to produce a dynamic activity. (V = 0.82) Complex interaction and coordination of multiple body segments or links sequentially activated for force generation and transfer to produce a functional movement pattern (i.e. throwing). (V = 0.93)
Preferred term when referring to the concept of kinetic chain
Kinetic chain. (V = 0.93)
RATIONALE AND CLINICAL REASONING AROUND KINETIC CHAIN
Why it is important to integrate the assessment and management of the kinetic chain in patients with shoulder pain
Dysfunction of a particular segment in the chain (i.e. weak link) can result in either altered performance or injury to a more distal segment. (V = 0.92) Shoulder function occurs in an integrated but not isolated manner. (V = 0.80) Kinetic chain reduces the proximal load on the shoulder muscles and provides economy of effort. (V = 0.72) Gives a window into exercise prescription, especially in those with atraumatic shoulder pain presentations. (V = 0.72) Evaluating the "kinetic chain" increases the understanding of the demands which may be placed on the shoulder during relevant movements/tasks/activities. (V = 0.78) The kinetic chain helps to build a picture of the person's capabilities as a whole not just as an isolated joint. (V = 0.75) The kinetic chain can increase a patient's understanding of their pain and increase exercise compliance when symptom modification is possible when integrating the kinetic chain. (V = 0.77) Because we need the kinetic chain to avoid reinjury once the athlete is free for pain and returns to play and/or performance. (V = 0.70)

Kinetic chain assessment and training might be more functional than isolated shoulder assessment and training which might better prepare the patient for return to activity and/or return to sport. (V = 0.82)

Shoulder evaluation without proximal scapulothoracic evaluation would be incomplete because proximal scapular stabilization and strength has been found to be critically important in shoulder (glenohumeral joint) function. (V = 0.78)

It is important to assess and treat the kinetic chain in the following shoulder pain populations

Workplace and occupational injuries. (V = 0.72)

Rotator cuff tendinopathy. (V = 0.72)

Rugby players. (V = 0.87)

Throwing/overhead athletes (e.g., baseball players). (V = 0.92)

Gymnasts. (V = 0.88)

Hockey players (field and ice). (V = 0.83)

Swimmers. (V = 0.90)

SUBJECTIVE EXAMINATION

Subjective descriptors from the clinical history indicating a potential involvement of the kinetic chain in a patient with shoulder pain

Report of previous shoulder injury. (V = 0.78)

Report of previous injury or pain in any segments other than the shoulder (e.g., lower limb, hip, spine…). (V = 0.88)

Prior injury to all major upper extremity joints. (V = 0.77)

Prior injury to all major lower extremity joints. (V = 0.73)

Previous history of hip or lumbar spine pain/injury in the subjective evaluation of the thrower. (V = 0.80)

History of wrist/elbow pain in tennis players. (V = 0.75)

Recurrence of similar injury despite repeated treatment. (V = 0.88)

History of suboptimal performance during specific functional or sporting tasks that involve global movements despite passing shoulder tests. (V = 0.85)

Intermittent shoulder pain that has appeared slowly with gradual onset, which is

associated with problems in other regions (e.g., back, elbow, wrist…). (V = 0.77)

Shoulder pain is present during specific functional tasks, daily life activities or sports movements. (V = 0.75)

Participating in overhead sports, arts, or occupation. (V = 0.87)

PHYSICAL EXAMINATION

Body regions that should be evaluated to determine the potential involvement of the kinetic chain in a patient with shoulder pain

Cervical spine. (V = 0.83)

Scapula. (V = 0.90)

Thoracic spine. (V = 0.88)

Lumbar spine. (V = 0.73)

Pelvis. (V = 0.77)

Hip. (V = 0.82)

Factors that should be evaluated to determine the potential involvement of the kinetic chain in a patient with shoulder pain

General posture. (V = 0.77)

Fluidity of movement across relevant body segments. (V = 0.78)

Cervical mobility. (V = 0.72)

Cervical muscles stiffness (e.g., upper trapezius, levator scapulae…). (V = 0.70)

Shoulder endurance. (V = 0.78)

Shoulder strength. (V = 0.80)

Shoulder stability. (V = 0.82)

Shoulder internal rotation range of motion. (V = 0.78)

Shoulder external rotation range of motion. (V = 0.82)

Scapulohumeral rhythm. (V = 0.72)

Scapular muscle strength. (V = 0.78)

Thoracic posture. (V = 0.77)

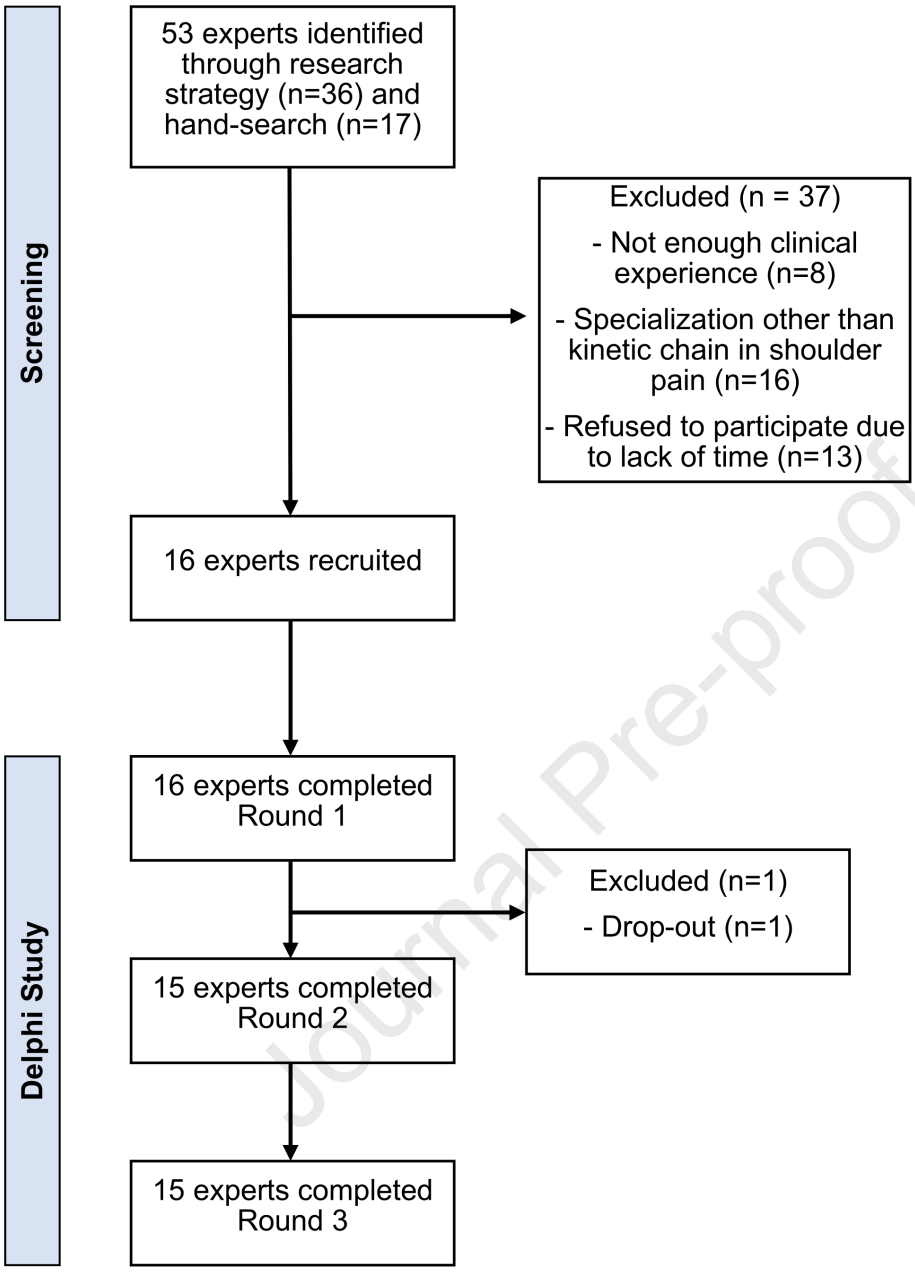
Thoracic spine extension mobility. (V = 0.77)

Thoracic spine rotation mobility. (V = 0.77)
Thoracolumbar flexibility, especially latissimus dorsi. (V = 0.70)
Core stability (neuromuscular control). (V = 0.83)
Core strength. (V = 0.73)
Lumbopelvic-hip complex stability. (V = 0.78)
Overall lower limb strength. (V = 0.70)
Lower limb dynamic stability. (V = 0.75)
Hip mobility. (V = 0.75)
Hip stability. (V = 0.75)
Hip muscle strength. (V = 0.73)
Specific assessment tests, including criteria of cut-off values (if indicated) used to identify a kinetic chain dysfunction
A functional or sporting movement pattern relevant to the patient (e.g., functional recorded demo of a serve, an Olympic lift, etc.). (V = 0.88)
Symptom modification tests that impose changes in movement patterns to assess if this changes pain (e.g. increase thoracic rotation, repeating the shoulder movement during a squat…). (V = 0.87)
Scapular Dyskinesis Test (criteria, yes/no). (V = 0.75)
Scapular Assistance Test (SAT). (V = 0.78)
Scapular Reposition Test (SRT). (V = 0.77)
Scapular Retraction Test. (V = 0.72)
Passive range of motion in standing and supine positions for shoulders and hips. (V = 0.80)
Active shoulder range of motion in standing. (V = 0.80)
General upper limb range of motion assessment. (V = 0.70)
Shoulder internal/external rotation range of motion assessment in supine position at 90 degrees of abduction in the frontal plane. (V = 0.78)
Trendelenburg sign for hip stability. (V = 0.75)
Single leg balance. (V = 0.73)
Single leg squat visual analysis. (V = 0.73)

Order when assessing the kinetic chain in a patient with shoulder pain
The order of assessment of the shoulder and kinetic chain depends on the subjective history of the patient. (V = 0.80)
How to determine the clinical relevance of a kinetic chain dysfunction in a patient with shoulder pain
I apply the kinetic chain concept more as a “symptom modification test/procedure” in my physical examination: i.e. if a particular shoulder movement/test is symptomatic I repeat that movement/test changing/altering some component of the kinetic chain and evaluate the influence on patient signs and symptoms. (V = 0.77)
TREATMENT
Situations when the kinetic chain should be integrated in treatment in patients with shoulder pain.
It is necessary to determine if kinetic chain dysfunction is present in order to prevent those possible future events. (V = 0.78) When the goal is to activate other structures as much as possible. (V = 0.70) When we want to work on more functional activities. (V = 0.85) When there is a kinetic chain dysfunction. (V = 0.83) It depends on the cause of the kinetic chain dysfunction, because for example, in subjects with neurological disorders, it might not be possible to incorporate some areas of the kinetic chain. (V = 0.77)
Temporal sequence for integrating the kinetic chain (before, during, or after local shoulder treatment) when treating people with shoulder pain
Subjective history taking and clinical reasoning will dictate the order of treatment, and this will vary from patient to patient. (V = 0.82)
When should kinetic chain exercises be implemented within the rehabilitation process of a patient with shoulder pain?
Kinetic chain exercises should be used across all the rehabilitation process, from the start to the very end including return to play, not at selected time points. (V = 0.70) There is no one size fits all approach. It is necessary to consider subjective history and led clinical reasoning to dictate where you hone your objective assessment, as this will

vary from patient to patient, to finally decide when to implement kinetic chain exercises within the rehabilitation process. (V = 0.93)
The implementation of kinetic chain exercises on the beginning of the rehabilitation depends on the pathology and patients' characteristics. (V = 0.75)
Kinetic chain exercises should be implemented in all the rehabilitation process varying their intensity according to the stage of rehabilitation and the patient progression. (V = 0.70)
Specific treatment strategies used when a patient with shoulder pain presents a kinetic chain dysfunction.
Complex/integrated exercises which focus on sport-specific skills and movement patterns. (V = 0.87)
Dynamic integration/initiation during shoulder exercises. (V = 0.87)
It is important that specific treatment strategies addressing the whole kinetic chain don't negatively stress the shoulder being treated. (V = 0.85)
Exercises for improving the sports' biomechanics/technique together with the sports-coach. (V = 0.82)
Functional exercises. (V = 0.87)
Motor control exercises. (V = 0.78)
Balance exercises. (V = 0.72)
Speed exercises. (V = 0.70)
Proper posture exercises. (V = 0.72)
Strengthening exercises. (V = 0.82)
Mobilizations for shoulder and thoracic spine range of motion. (V = 0.77)
Stability exercises for scapular and glenohumeral muscles (e.g., low row, wall slide...).
Shoulder strengthening exercises. (V = 0.83)
Core strengthening exercises (e.g., swiss ball). (V = 0.75)
Work on the core muscles while performing shoulder exercises (e.g., shoulder exercises while squatting). (V = 0.82)
Lower limb stability exercises. (V = 0.70)
Hip mobility exercises. (V = 0.70)

V = Aiken's Validity Index.



Round 1

Data obtained from 16 experts:

- 11 items proposed by the working group accepted
- 9 items proposed by the working group rejected
- 277 new items proposed

Round 2

Data obtained from 15 experts:

- 4 items previously accepted from Round 1 rejected
- 7 items maintaining acceptance from Round 1
- 135 new items proposed rejected
- 142 new items proposed accepted

31 items removed by the working group because of similitudes

Round 3

Data obtained from 15 experts:

- 0 items previously accepted from Round 1 rejected
- 7 items maintaining acceptance from Round 1
- 95 items maintaining acceptance from Round 2

Breakdown by domain from Round 1 to Round 3

Terminology: 3/5 (60%).
Rational and clinical reasoning: 17/51 (33.3%).
Subjective examination: 11/20 (55%).
Physical examination: 44/123 (35.8%).
Treatment: 27/62 (43.5%).

***Footnote:** Numbers refer to the items reaching consensus at the end of the round 3 on each domain, as a percentage from the overall number of items included in that domain through rounds 1 and 2 (without considering the items removed because of similitudes).