SUPPLEMENTARY FILE 6

Qualitative analysis of individual panellists' feedback

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Definitions – Delphi domain 1

Table SF6-1 Qualitative feedback themes for the definitions domain

	Themes	Quotations, comments and recommendations
1	Cam morphology of unknown origin (statement 6)	**Quotations** *'Disagree as the origin is not entirely 'unknown' - likely due to variable loading demands.'* *'We have good knowledge about pathogenesis at this stage but may be not enough'* *'If it's unknown I find it hard to know if primary or secondary'* *'Agree, at an individual level not all PCM has clear cause. Parents want to know if their children will get it.'* **Comments and recommendations** ➢ A primary condition/disease, per definition, includes idiopathic conditions/diseases of unknown aetiology. ➢ The aetiology of primary cam morphology in non-athletes without any known existing or pre-existing hip disease is unknown. ➢ A better-worded statement might be: "Primary cam morphology also includes idiopathic cam morphology (of unknown origin)" ➢ More research is needed in ethnic diverse groups
2	All cam morphology in young and active adults without any symptoms or history of previous hip disease is primary cam morphology until proven otherwise (statement 7)	**Quotations** *'Could the statement possibly be modified to add "known" before history? If there is no history of disease it cannot be proven otherwise, correct? So the statement would be: "Cam morphology that develops in young and active individuals without any symptoms (e.g. hip-related pain; stiffness) or known history of previous/existing hip disease, is primary cam morphology until proven otherwise.'* **Comments and recommendations** ➢ Individuals with primary cam morphology might develop symptoms (including pain; stiffness) secondary to the morphology ➢ Any cam morphology, according to the agreed definition, that develops in young and active adults without any (known) hip disease, should be referred to as primary cam morphology ➢ Secondary cam morphology develops secondary to previous or existing hip disease (e.g., Perthes; SCFE)
3	Prevalence in asymptomatic males and females	**Quotations** *'I don't think we know enough about females to make it categorical that it more frequently occurs in males and therefore would make this differentiation a lower priority i.e. not critical'* *'Is this because more males are playing sports with higher loading?'* *'Is it proportionally just as prevalent in female?'*

		'This statement suggests PCM occurs only/mostly in males but I am not sure if that is the case. I thought it occurs in both sexes.' *'It is common in males; but I would argue that it's mainly because we've looked at historically male sports (American football; ice hockey; wrestling)'* *'We know the prevalence in males and bilateral appearance. The only reason I cannot score this is I am not sure if I can comment on demographics and population as we do know that most of the studies include mainly male participants.'* *'Females often left out of research; From my understanding there is a paucity of research in females.'* *'I'm reacting to the suggestion that this is for "male athletes". Female athletes also have cam (and when they do have worse outcomes).'* *'I would hesitate to include gender in the definition to avoid people thinking that it is a male-only problem'* *'Use current rather than common as the number of females and specifically athletes are less known.'* *'Can we suggest based on the (limited) available literature, that the prevalence might be lower but must be explored in upcoming studies?'* **Comments and recommendations** ➢ Limited evidence in females (consider possible selection bias) ➢ Current evidence suggests that primary cam morphology is less prevalent in females. ➢ More research needed in female cohorts/women's sports
4	Unilateral vs bilateral	**Quotations** *'Isn't it 50-50? 50% bilateral and 50% unilateral. At least that mostly comes out of our studies; not sure by hard if other studies show differently?'* *'We know the prevalence in males and bilateral appearance [of primary cam morphology]'* **Comments and recommendations** ➢ Current best evidence supports the statement that primary cam morphology is usually (but not always) bilateral while secondary cam morphology is usually (but not always unilateral). Some athletes might have unilateral primary cam morphology (refer to study in golfers: trail leg more affected)
5	Primary cam morphology as a concept	**Quotation** *'I do not agree that the concept of Primary and secondary CAM is commonly agreed and established'* **Comments and recommendations** ➢ The majority Delphi panel members agreed that primary cam morphology as a concept is critical and has utility in research (e.g., prognosis), treatment, and important for classification in research. ➢ Work is needed to convince a small but important group of stakeholders
6	Primary cam morphology develops as a normal	**Quotations** *'I think the statement should remove the word 'normal'. It seems that specific types of loading influence the development of a cam morphology. As we do not know details of which loads are key in this regard; the use of normal response to load may not be accurate. I would agree with the statement: "Primary cam morphology develops during skeletal maturation as a*

	physiological response to high-load sporting activity	*physiological response to load" or "Primary cam morphology develops during skeletal maturation as a physiological response to specific types of load'* *'I would debate the term 'normal'; it's a physiological reaction but normal is questionable.'* *'While I agree that CAM appears to occur during maturation as a response to load, whether this can be considered a normal response to load is more unclear.'* *'Primary cam morphology is not caused by previous disease, injury or an acute event. I would agree with this.'* *'I don't agree with a normal physiological response to 'load'. Isn't it overload? And can we then still call it a physiological response?'* *'The same. I would debate the term 'normal'; it's a physiological reaction but normal is questionable.'* *'Again the use of 'normal' response to load reduces my agreement'* **Comments and recommendations** ➢ The majority Delphi panel members agreed that primary cam morphology in athletes likely develops secondary to a <u>normal</u> physiological response of the femoral capital growth plate to high-load sporting activity. ➢ This might constitute an 'abnormal' load for the individual/maturing skeleton but the cellular response is not
7	Genetics as a risk factor/cause	**Quotations** *'Would include a statement on genetic influences'* **Comments and recommendations** ➢ Important to do further research on the genetic background to primary cam morphology development
8	Varying size and shape	**Quotations** *'Varying size and probably varying shape'* **Comment and recommendation** ➢ Primary cam morphology has varying size and shape
9	Any location vs anterosuperior / more common antero-superior	**Quotations** *'"Any location" suggests equal occurrence in all locations but I understood it predominantly occurs at superior/anterior.'* *'Primary cam morphology mainly occurs in the antero-superior quadrant, followed by anteroinferior and no morphologies in the posterosuperior or posteroinferior'* *'Agree but see caveats above about "any location" and "males".'* **Comment and recommendation** ➢ Primary cam morphology can develop in any location around the femoral head-neck junction but is more common in the antero-superior quadrant.
10	Bump	**Quotations** *'Consider removing 'bump' from the definition'* **Comment and recommendation** ➢ Although not perfect, 'bump' is a more patient-friendly term
11		**Quotations**

	Alpha angle; Combining the conceptual and operational definition	*'Methodological issues with treating alpha angle as both dichotomised and continuous'* *'I wouldn't have the text that says 'CT scans or MR imaging, reported per hip, per person or both.' I think it distracts the reader and we know that we need to measure the alpha angle - how we achieve that I am not sure needs to be in the overall definition.'* *'I think the most common outcome measure part is better to be mentioned in taxonomy.'* *'Instead of "the most common outcome measure...", might consider something such as 'It is often diagnosed using a cartilage or bone alpha angle on radiographs, CT scans.....' Incorporation of 'outcome measure' and 'dichotomised or continuous variable' is really an operationalization of the definition.'* **Comment and recommendation** ➢ Refer to imaging outcome agreements – Statement 41: "In primary cam morphology epidemiological research (e.g.; when regression is being used in aetiology or prognosis research), continuous imaging outcome measures (variables), like the alpha angle, should be kept continuous" ➢ The panel reached agreement on a definition that combines primary cam morphology's 5 conceptual attributes and how the morphology is operationalised
12	Existing hip disease vs pre-existing- vs known- vs previous hip disease as it relates to secondary cam morphology (Statement 3).	**Quotations** *'I think the word 'existing' should be changed to 'pre-existing'. I do not think a healed proximal femoral fracture, as in the example, classify as an existing disease; rather a disease existing prior to the cam development therefore 'pre-existing' or 'prior' or 'preceding''* **Comment and recommendation** Although strong consensus, the Delphi steering committee agreed that a reworded statement might be more accurate: "Secondary cam morphology develops due to <u>existing and/or pre-existing</u> hip disease…".

Terminology – Delphi domain 2

Table SF6-2 Qualitative feedback themes for the terminology domain

	Themes	Quotations, comments and recommendations
1	Morphology – not deformity, lesion or abnormality	**Quotations** *'We've agreed it is a 'normal physiological response' and therefore shouldn't be called a lesion/deformity with their connotations of abnormality'* *'Abnormality is not a very optimistic term'* **Comments and recommendations** ➢ Morphology is better (less threatening) language for patients but still too scientific. Perhaps important to consider tailoring terms to different stakeholder groups ➢ Avoid deformity, lesion, abnormality and 'pistol grip deformity'
2	"Bump"	**Quotations** *'Consider replacing bump with prominence. Not every cam morphology has a 'bump'. It might has only decreased offset and that certainly does not constitute a bump'* **Comments and recommendations** ➢ Alternative to bump or prominence, consider 'thickening', 'egg-shape' - important to involve patients [in future research on this]
3	Femoroacetabular impingement syndrome	**Quotations** Regarding statement 26: *Femoroacetabular impingement (FAI) Syndrome with cam morphology is the preferred term to use for hip-related pain due to a bony bump at any location around the femoral head-neck junction – 'I do not agree that you can say it is the preferred term for hip-related pain, but this is one type of pathology that may occur in the hip'* **Comments and recommendations** ➢ 'Syndrome', whilst agreed at Warwick and in this Delphi and much preferred scientifically, may require further patient-orientated research to assess whether it has negative consequences and whether femoroacetabular impingement (FAI) used in isolation may be a better term when communicating with patients."
4	Any location vs anterosuperior / more common antero-superior	**Quotations** *'More confident that 'any location' is a bad element'* **Comment and recommendation** ➢ Primary cam morphology can develop in any location around the femoral head-neck junction but is more common in the antero-superior quadrant.

Taxonomy – Delphi domain 3

Table SF6-3 Qualitative feedback themes for the taxonomy domain

	Themes	Example quotations; Online mixed stakeholder group discussions; Comments and recommendations
1	Assumption that we can distinguish / difficult to distinguish in clinical practice	**Quotations** *'this assumes the distinction can be made!'* **Comments and recommendations** ➢ Easier to find relevant literature when distinguishing between PCM and SCM ➢ PCM vs SCM can be a grey area - subclinical SCFE
2	Important for diagnosis	**Quotations** *'I agree mainly for the diagnosis'* **Comments and recommendations** ➢ Distinguishing between primary and secondary cam morphology has diagnostic utility
3	Important for treatment	**Quotations** *'from what I understand treatment is different between the two...so yes'* **Comments and recommendations** ➢ Distinguishing between primary and secondary cam morphology important for treatment as it is different
4	Important for prognosis	**Quotations** *'This 100% depends on prognosis - given the presence of previous injury; it would suggest secondary CAM morphology has a poorer prognosis and therefore should be distinguished to improve treatment planning'* **Comment and recommendations** ➢ Prognosis for primary and secondary cam morphology is different – therefore important to distinguish
5	Depends on age	**Quotations** *'Depends a bit on age – if someone is 30 years old – less relevant'* **Comments and recommendations** ➢ Might be more important and easier to make the distinction between primary and secondary cam morphology at a young age
6	Mix of both types	**Quotation** *'Agree but I wonder if there may be cases where a patient has a mix of both types. This note applies to all my answers in this section'* **Comment and recommendation** ➢ Primary and secondary cam morphology might co-occur in the same patient/hip

Imaging outcomes – Delphi domain 4

Table SF6-4 Qualitative feedback themes for the imaging outcomes domain

	Themes	Quotations, comments and recommendations
1	How often should MR imaging be repeated in research on how primary cam morphology develops (Statement 40)	**Quotations** *'Really depends on research question; statement is too general'* *'Do we know how quickly cam morphology develops/progresses?'* *'Depends on phase of growth'* *'This will depend on the research question. Timeline could for instance be required to be shorter"* *'Evidence for 18-24 months?'* *'What about more often? I know it will be difficult but if there is a critical window that we want to identify 2 year intervals would not be frequent enough'* **Comments and recommendations** ➢ Radiologist felt that more is better. Radial vs block imaging ➢ More frequent MR imaging in development studies - 11-16y (boys) and 9-14y (girls) – MR imaging at least every year ➢ Aetiology: Serial imaging more frequent (every 3/12 to capture periods of faster growth. Value of serial radiographs is questionable. To reduce research waste we should not use serial radiographs in aetiological research. "If you cannot do serial MRI in aetiology, don't do the study"
2	Quantifying epiphyseal morphology (epiphyseal extension / epiphyseal tilt) for research on how primary cam morphology develops (Statements 43 & 44)	**Quotations** *'What is nice about this is that it can be quantified with minimal measurement error'* *'Probably critical but insufficient data'* **Comments and recommendations** ➢ Epiphyseal morphology has been quantified (epiphyseal extension and epiphyseal tilt) and correlated with alpha angles in prospective MR imaging research on primary cam morphology development (Palmer *et al*; Fernquest *et al*; Hancke *et al*)

3	Main imaging modality for primary cam morphology prognosis research and time interval (Statement 45)	**Quotations** *'Would suggest frog-leg lateral or Dunn'* *'Any lateral head-neck views; also dependent where the particular centre is familiar with'* *'Tough with sweeping statement - advantage of x-ray is cheap and little time costs; but radiation and less detail - so depends on exact question'* *'Prefer MRI with all clock positions'* *'Standardizing the imaging and radiographs across research seems important'* *'If after closure of growth plate; long term study -> X-Ray. Otherwise for research MRI'* *'I think the evidence is already beyond such approach'* *'Evidence for 5years?'* *'Prefer MRI with all clock positions'* *'AP too imprecise'* **Comments and recommendations** ➢ Important to consider nuance of choice. MR scan refers to ideal world; many have no access, it is expensive and therefore not always feasible. Important to consider radiation exposure ➢ Dissemination of findings: Important consideration in imaging - do athletes want to know the results? How/what do we communicate to participants/parents; Consider positive/negative response by athletes/parents ➢ MRI vs radiographs. Ethics benefits (easier); radiographs are more practical but issue with radiation; consider economics (MR imaging expensive); logistical issues; motion artifact with young individuals; ➢ In prognosis - degenerative; every 5 years for as long as possible; statistical issues with too high frequency - see: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC280679/
4	Alpha angle (continuous vs dichotomous; threshold) (Statement 46)	**Quotations** *'In the end to relate back to daily practice some dichotomous reporting can also help'* *'There is no consensus on optimum threshold for dichotomizing this variable. It makes comparing across studies very difficult when different thresholds are used'* *'From an epidemiology standpoint, yes; you don't lose information. However, I have clinicians ask to identify cut points frequently'* **Comment and recommendation** ➢ The Delphi panel agreed on the continuous alpha angle as preferred primary cam morphology imaging outcome measure in aetiology or prognosis studies (statements 42 and 47). However, they failed to agree that, for prognosis studies, radiographs (AP pelvis and Dunn 45° views) should be used to calculate the alpha angle. ➢ Panellists reminded that, to date, '*there is no consensus on optimum threshold for dichotomizing this [alpha angle] variable. It makes comparing across studies very difficult when different thresholds are used'*. Despite this, a diagnostic threshold is important for clinicians—they frequently ask '*to identify [alpha angle] cut points'*.
5	Cost of MRI	**Quotations**

		'Huge cost aspect here - depends on the research question in case' *'Tough with sweeping statement - advantage of x-ray is cheap and little time costs; but radiation and less detail - so depends on exact question'* **Comments and recommendations** ➢ The *'huge cost aspect'* of MR imaging deprives minoritised and marginalised populations from participating in research. While radiographs are '*cheap and [have] little time costs'*, the concerns are '*radiation and less detail'*
6	Primary cam morphology as a concept (refer to Definitions table)	**Quotation** *'I do not agree that the concept of Primary and secondary CAM is commonly agreed and established'* **Comments and recommendations** ➢ The majority Delphi panel members agreed that primary cam morphology as a concept is critical and has utility in research (e.g., prognosis), treatment, and important for classification in research. ➢ Work is needed to convince a small but important group of stakeholders
7	Radial MR Imaging / Prefer MR vs radiographs	**Quotations** *'But qualify type of radial imaging'* *'Number of slices is not that important if you can do 3d imaging with MPR'* *'All o'clock locations seem not necessary'* *'Prefer MRI with all clock positions'* *'AP too imprecise'* **Comments and recommendations** ➢ Research should qualify the type of radial MR imaging
8	Remove fluid sensitive images of pelvis (for research on primary cam morphology formation)	**Quotations** *'Consider removing the iii) portion because the rationale for this is to find pathological processes elsewhere besides the hip. If we want to study primary cam morphology development this might be excluded data on the role of screening for oedema elsewhere'* **Comments and recommendations** ➢ Fluid sensitive pelvis images, when studying primary cam morphology development are unnecessary because '*the rationale for this is to find pathological processes elsewhere'*
9	Research question dependent	**Quotations** *'Really depends on research question; statement is too general. all o'clock locations seem not necessary' – Statement 42 'This will depend on the research question. Timeline could for instance be required to be shorter'* (Quotation relevant to statement 40: The magnetic resonance (MR) imaging for prospective research on how primary cam morphology develops should be repeated every 18 to 24 months) *'Really depends on research question and audience/readers; statement is too general* (Quotation relevant to statement 41: In primary cam morphology epidemiological research (e.g. when regression is being used in aetiology or prognosis research), continuous imaging outcome measures (variables), like the alpha angle, should be kept continuous)

		Comment and recommendation ➢ Although a continuous alpha angle should always be measured and reported, additional outcome measures (including a dichotomous alpha angle), are research question dependant
10	Alternative outcome measures / can create confusion	**Quotations** *'Although this appear to be relevant currently new technologies - including for instance 3D reconstructions may provide outcome variables that are more relevant than the alpha angle'* *'I would take care in allowing too many additional measurement options that may introduce confusion to the definition/taxonomy. By all means discuss them but I wonder if this needs to be tightened further to avoid potential confusion over what is/is not suggested for future research studies'* *'Relevant to statement 47: I would change AND to OR. Please be aware that the statements imply a lot of multiple testing with each type of measurement and each location of measurement having their uncertainty. I would advocate not using too much different measures and not too much locations'* *'I would suggest that section 2 [of statement47] is not critical since it's not a reliable tool for assessing CAM morphology'* *'Very confusing as it is'* **Comment and recommendation** ➢ Although a continuous alpha angle should always be measured and reported, additional outcome measures (including a dichotomous alpha angle), are research question dependant. Researchers should be guard against *'too many additional measurement options that may introduce confusion to the definition/taxonomy'*
11	Important to standardise imaging across research	**Quotations** *'Standardizing the imaging and radiographs across research seems important'* **Comment and recommendation** ➢ Standardising imaging across research improves rigour and provides a solid basis for meaningful collaboration and data sharing
12	Radiation	**Quotations** *'Tough with sweeping statement [statement 45] - advantage of x-ray is cheap and little time costs; but radiation and less detail - so depends on exact question'* *'If after closure of growth plate; long term study -> X-Ray. Otherwise for research MRI'* **Comment and recommendation** ➢ Researchers should consider the benefits (they are cheap) and limitations (radiation and less detail) of radiographs in long-term prospective research
13	Lack of knowledge to score statement	**Quotations** *'As a non-clinician I don't have a strong understanding of MRI sequences and feel unqualified to answer these questions'* *'It sounds reasonable; but I do not feel qualified to provide an answer with certainty. It for instance be influenced by the specific research question'* *'Again, I don't feel qualified to answer these statements because I don't know how MRIs are conducted'*

Comment and recommendation

- The steering committee members acknowledge the technical imaging and subject-specific knowledge needed to score some of the domain 4 statements. All panellists had access to the Oxford-Aspetar-La Trobe Young Athlete's Hip Webinar Series (specifically Webinars 1 and 2 provided all the necessary background knowledge). Panellists had the option to choose "Unable to score"

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