Peer review history for:

Berg E, Hammond AS, Warrener AG, Mitchell MS, Tocheri MW, Baker SE, et al. Further assessment of a ~2-million-year-old hominin pelvis (DNH 43) from Drimolen Main Quarry. S Afr J Sci. 2025;121(3/4), Art. #17908. https://doi.org/10.17159/sajs.2025/17908

HOW TO CITE:

Further assessment of a ~2-million-year-old hominin pelvis (DNH 43) from Drimolen Main Quarry [peer review history]. S Afr J Sci. 2025;121(3/4), Art. #17908.
https://doi.org/10.17159/sajs.2025/17908/peerreview

The original manuscript for review is appended below.

Reviewer 1: Round 1
Date completed: 10 July 2024
Recommendation: Accept / **Revisions required** / Resubmit for review / Resubmit elsewhere / Decline / See comments
Conflicts of interest: None

Does the manuscript fall within the scope of SAJS?
Yes/No
Is the manuscript written in a style suitable for a non-specialist and is it of wider interest than to specialists alone?
Yes/No
Does the manuscript contain sufficient novel and significant information to justify publication?
Yes/No
Do the Title and Abstract clearly and accurately reflect the content of the manuscript?
Yes/No
Is the research problem significant and concisely stated?
Yes/No
Are the methods described comprehensively?
Yes/No
Is the statistical treatment appropriate?
Yes/No/Not applicable/Not qualified to judge
Are the interpretations and conclusions justified by the research results?
Yes/**Partly**/No
Please rate the manuscript on overall contribution to the field
Excellent/**Good**/Average/Below average/Poor
Please rate the manuscript on language, grammar and tone
Excellent/Good/Average/Below average/Poor
Is the manuscript succinct and free of repetition and redundancies?
Yes/No
Are the results and discussion confined to relevance to the objective(s)?
Yes/No
The number of tables in the manuscript is
Too few/**Adequate**/Too many/Not applicable
The number of figures in the manuscript is
Too few/**Adequate**/Too many/Not applicable

Is the supplementary material relevant and separated appropriately from the main document?

Yes/No/Not applicable

Please rate the manuscript on overall quality

Excellent/**Good**/Average/Below average/Poor

Is appropriate and adequate reference made to other work in the field?

Yes/No

Is it stated that ethical approval was granted by an institutional ethics committee for studies involving human subjects and non-human vertebrates?

Yes/**No**/Not applicable

If accepted, would you recommend that the article receives priority publication?

Yes/No

Are you willing to review a revision of this manuscript?

Yes/No

With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.

Yes/No

Comments to the Author:

This clearly written manuscript is the first quantitative study of the DNH 43 pelvis, and its results provide important context for the limitations of traditional methods for determining sex and species affiliations in fossils from this time period. It is written in a manner appropriate for a broader audience and delivers a nuanced take on pelvis evolution to a non-specialist audience. While I think this manuscript is well on its way to being ready for publication, I do have some concerns and suggestions.

First, I am unconvinced that the UPGMA analysis adds anything meaningful to this study and am concerned the measurement similarities it illustrates inappropriately reinforces phylogenetic interpretations in the discussion. UPGMA takes data and creates a tree based on similarities in that data. It may be an appropriate way to show similarities between DNH 43 and other individuals. However, Figure 3 shows that the differences between fossil taxa are similar if not less than the differences between individual humans. It is therefore very important that the authors clearly and carefully avoid using this analysis to draw taxonomic conclusions between fossils that might imply to a reader that the differences between human individuals are also taxonomic. I would like the authors to provide a stronger justification for the inclusion of this analysis and reframe the discussion of it to avoid any such misunderstandings.

Second, the interpretation of greater sciatic notch differences (Figure 4) needs improvement. Overall, I think the authors are trying to highlight that DNH 43 falls in the extreme end of the female range for humans, while also making the interesting point that except for two Neandertals, the fossils generally skew toward the female human range even when they are thought to be male (at least for SNA; SNP does not seem as useful for distinguishing sex). I think the discussion of these points would be clearer if the following issues were addressed:

- Sample: Please justify the inclusion of SK 50 and KNM-WT 15000 in this analysis. SK 50 has taphonomic deformation that may affect these measurements and KNM-WT 15000 does not preserve an os coxae that includes a complete greater sciatic notch for measurement (N and O just include the iliac portions and are lacking the ischial spine). For the latter, if a reconstruction is used that needs to be clarified since Supplement Table 2 suggests the measurements were taken on unreconstructed CT scans of the fragments.
- Interpreting Neandertals: The discussion states that all of the Neandertals have male-like notches. Yet, the analysis does not include the only Neandertal in the sample that is generally thought to be female (Tabun C1), presumably due to preservation issues. Nowhere is it clarified that Krapina 207, while more mature than KNM-WT 15000, is also not fully adult (has an unfused iliac crest). Please add these important contexts so that it is clear your sample cannot state whether all Neandertals (including females) would have male notch morphology. Krapina 207 may indicate that juvenile individuals are

closer to the female human range for these measurements, which supports the pattern of immature males appearing more female-form seen in WT 15000.
- Interpreting early Homo: Since two of these (Kabwe and KNM-ER 3228) fall between a male human point and the point representing Krapina 207 (Neandertal that is called male), the authors cannot claim that all early Homo individuals are in the female range. These two are borderline. Which still fits the model of the fossil range being closer to the human female range, with two Neandertal outliers.

Finally, when discussing pelvic incidence and Table 2, please include the context provided in Been et al. that SH Pelvis 1 has pathological anatomy of the sacrum that may affect the pelvic incidence measurement. With this context, it becomes true that all other fossils fall within the human range, which may change how you want to discuss these results.

Other than that, I have only some minor clarifying suggestions to improve the readability and interpretation of the manuscript:
- Measurement names & abbreviations: Introduce the abbreviations in the main text before using them to refer to specific indices (this would be under Methods). SNA and SNP are not defined anywhere, and seem to refer to both greater sciatic notch angle/proportion and scaphoid angle/proportion (in Figure 4); please use consistent names for these throughout. The abbreviations used in Table 1 should also appear in a footnote of that table so that the reader does not need to scroll to remember which abbreviation stands for what.
- Figure numbers: check all figure numbers; around Line 272 there are references to Figure 5 (doesn't exist) and parts of Figure 4 that I think are actually referencing Figure 2.
- Figure 4: Please label all of the fossils on this plot to aid the reader in interpreting this figure. It matters if the early Homo sp is OH 28 (wide notch) or KNM-ER 3228 (narrow notch).
- Table 2: In the footnotes, include information on the number of individuals for the two human samples used (one for the linear measurements, one for pelvic incidence); further, clarify that the PI data are also means (weighted?) with SD and range; if possible, you may consider including range for the other measurements as well.
- Supplemental Table 2: change "Homo sp" to "Early Homo sp" so that the categorization matches the ones in the main text and figures.

Author response to Reviewer 1: Round 1

Reviewer comments	**Author response**
Thank you for an interesting manuscript that provides several quantitative analyses of DNH 43 that assesses its morphological affinities to extinct hominins and living humans. My comments on the paper are mainly organizational but I also have suggestions to improve the methods section.	We are happy you enjoyed the manuscript and appreciate your constructive feedback.
Introduction: I thought that the majority of the introduction was quite sufficient, but I felt that the last section stating your objectives for the paper requires development. The specific objectives of the paper are clear in the abstract but are not as clear in the introduction of the manuscript. The paper could use more structure, specifically in directing the reader to the specific aims of the paper. The authors state in the end of the introduction that one of their main goals is to perform a broad quantitative assessment of the specimen, but does not present any hypotheses or more specific objectives, and is rather vague, making it feel like a shot in the dark rather than a purposeful research endeavor. The specific aims become clearer as the audience reads through the methods section, but this really should be outlined	Thank you. We have added a sentence to the Introduction that outlines the three primary aims of the study.

briefly in the introduction. For example, list that you will perform a (1) assess body size and obstetric affinities, and (2) hypothesize sex by comparing the greater sciatic notch to recent humans. Then, organize the methods/results paragraphs in that sequence (or in whatever sequence you choose to list these aims) may provide greater organization and clarity to the paper. This helps contextualize the chosen metrics that the audience reads about in the Methods and Results.	
Materials & Methods: I think the methods should include an error analysis on the measurements given that two different authors and two different kinds of software were used to collect landmark coordinates.	Due to space constraints we were more vague than we should have been about which author took which measurements. One author did all but one of the measurements using Stratovan Checkpoint and the other did only the proportions of the sciatic notch using Geomagic. However, we have now included text in the Methods indicating our error analysis of all sacrum and os coxae metrics.
Comparative sample - where are the H. sapiens samples from? Was an ethics review required/approved?	The humans came from the Maxwell Collection housed at the University of New Mexico, which is a fully documented skeletal collection and access followed all research and ethics review protocols of that institution. We have added a sentence to Comparative Sample section as well as a footnote in Supplemental Table 2 that provides the raw metrics for the sample.
I would also suggest providing an image in the manuscript showing all the linear measurements taken from the specimen, or at least the landmarks (maybe move Supplementary Fig 2 to main text).	We have now provided inset images in the plots on Figure 2 that show the measurements of interest for each plot. There are brief textual descriptions in the Methods section of the measurements and their relevance. We left the larger image with the specific landmarks and the table relating the metrics to the landmarks in the Supplemental Information to provide readers with more details should they need them (and keep within the SAJS page limit). Hopefully this will be sufficient.
Line 139: Are there no justifications for these sacral measurements? The os coxae measurements are contextualized by existing literature whereas the sacral measurements are not.	We have added a citation to Fornai et al in which sacral proportions and shape have been suggested to vary among early hominins.
Lines 148-155: Include abbreviations here in the text. For example, when writing acetabulosacral buttress thickness, include "(ASBT)" afterwards, to clarify the abbreviated measurements later in the paragraph. Some acronyms in the Methods section are not written out fully before being contracted into an acronym.	Thanks for catching this. We have now added these into the text.
Related to this, the tables could also use additional clarifying footnotes or descriptions regarding the acronyms used. Not all of the acronyms included in the tables are written out in	Thanks again. Agreed! We have added the acronym definitions to the footnote in Table 1 of the main text and to Supplemental

full where I expect them to be described, such as in the table with the landmarks or within the table descriptions or footnotes. This I believe clarity on the abbreviations used is especially critical since the journal is not specific to our field but has a broader readership.	Table 2.
Paragraph starting Line 157: Perhaps it is just me, but as a reader I would prefer the point of the paragraph to be stated in the beginning, rather than listing the explanation first. I would prefer the sentence structures to be "here's the point and here's the info describing why" as opposed to "here is the info to build up to the point". For example, in this paragraph, the authors state that the greater sciatic notch exhibits sexual dimorphism in humans therefore they measured the notch angle on the specimen. Instead, it makes more sense to me if these are reversed. For example: "We are measuring the notch angle on this specimen to estimate sex because the notch is shown to be sexually dimorphic." The reason why this is clearer is because it brings the focus of the paragraph on the fossil specimen, rather than the paragraph seemingly randomly talking about living humans, which may throw off the reader. Parts of the results section are also structured this way and the authors may want to reassess how they introduce the subject of the paragraphs.	Thanks. We have restructured this paragraph in line with your suggestion.
The results are interpreted appropriately in the discussion in my opinion.	Many thanks for this. We tried to err on the side of caution in our interpretations while providing as much data as we can on this interesting specimen to add to our understanding of early hominin pelvic variation. We hope readers of the SAJS will appreciate access to the 3D scans and build and improve on what we've done here.

Reviewer 2: Round 1
Date completed: 03 July 2024
Recommendation: Accept / **Revisions required** / Resubmit for review / Resubmit elsewhere / Decline / See comments
Conflicts of interest: None

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Yes/No
Are the methods described comprehensively?
Yes/**No**

Is the statistical treatment appropriate?
Yes/No/Not applicable/Not qualified to judge
Are the interpretations and conclusions justified by the research results?
Yes/Partly/No
Please rate the manuscript on overall contribution to the field
Excellent/**Good**/Average/Below average/Poor
Please rate the manuscript on language, grammar and tone
Excellent/Good/**Average**/Below average/Poor
Is the manuscript succinct and free of repetition and redundancies?
Yes/No
Are the results and discussion confined to relevance to the objective(s)?
Yes/No
The number of tables in the manuscript is
Too few/**Adequate**/Too many/Not applicable
The number of figures in the manuscript is
Too few/**Adequate**/Too many/Not applicable
Is the supplementary material relevant and separated appropriately from the main document?
Yes/No/Not applicable
Please rate the manuscript on overall quality
Excellent/**Good**/Average/Below average/Poor
Is appropriate and adequate reference made to other work in the field?
Yes/No
Is it stated that ethical approval was granted by an institutional ethics committee for studies involving human subjects and non-human vertebrates?
Yes/**No**/Not applicable
If accepted, would you recommend that the article receives priority publication?
Yes/**No**
Are you willing to review a revision of this manuscript?
Yes/No
With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.
Yes/No

Comments to the Author:

Thank you for an interesting manuscript that provides several quantitative analyses of DNH 43 that assesses its morphological affinities to extinct hominins and living humans. My comments on the paper are mainly organizational but I also have suggestions to improve the methods section.

Introduction:

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Materials & Methods: I think the methods should include an error analysis on the measurements given that two different authors and two different kinds of software were used to collect landmark coordinates. Comparative sample - where are the H. sapiens samples from? Was an ethics review required/approved? I would also suggest providing an image in the manuscript showing all the linear measurements taken from the specimen, or at least the landmarks (maybe move Supplementary Fig 2 to main text). Line 139: Are there no justifications for these sacral measurements? The os coxae measurements are contextualized by existing literature whereas the sacral measurements are not. Lines 148-155: Include abbreviations here in the text. For example, when writing acetabulosacral buttress thickness, include "(ASBT)" afterwards, to clarify the abbreviated measurements later in the paragraph. Some acronyms in the Methods section are not written out fully before being contracted into an acronym. Related to this, the tables could also use additional clarifying footnotes or descriptions regarding the acronyms used. Not all of the acronyms included in the tables are written out in full where I expect them to be described, such as in the table with the landmarks or within the table descriptions or footnotes. This I believe clarity on the abbreviations used is especially critical since the journal is not specific to our field but has a broader readership. Paragraph starting Line 157: Perhaps it is just me, but as a reader I would prefer the point of the paragraph to be stated in the beginning, rather than listing the explanation first. I would prefer the sentence structures to be "here's the point and here's the info describing why" as opposed to "here is the info to build up to the point". For example, in this paragraph, the authors state that the greater sciatic notch exhibits sexual dimorphism in humans therefore they measured the notch angle on the specimen. Instead, it makes more sense to me if these are reversed. For example: "We are measuring the notch angle on this specimen to estimate sex because the notch is shown to be sexually dimorphic." The reason why this is clearer is because it brings the focus of the paragraph on the fossil specimen, rather than the paragraph seemingly randomly talking about living humans, which may throw off the reader. Parts of the results section are also structured this way and the authors may want to reassess how they introduce the subject of the paragraphs. The results are interpreted appropriately in the discussion in my opinion.

Author response to Reviewer 2: Round 1

Reviewer comments	**Author response**
This clearly written manuscript is the first quantitative study of the DNH 43 pelvis, and its results provide important context for the limitations of traditional methods for determining sex and species affiliations in fossils from this time period. It is written in a manner appropriate for a broader audience and delivers a nuanced take on pelvis evolution to a non-specialist audience. While I think this manuscript is well on its way to being ready for publication, I do have some concerns and suggestions.	Thank you for your compliments and constructive feedback on the manuscript.
First, I am unconvinced that the UPGMA analysis adds anything meaningful to this study and am concerned the measurement similarities it illustrates inappropriately reinforces phylogenetic interpretations in the discussion. UPGMA takes data and creates a tree based on similarities in that data. It may be an appropriate way to show	Thanks for this discussion. We share the reviewers' reservations about the taxonomic implications. However, UPGMA is commonly used to assess overall morphological affinity without necessarily drawing strong phylogenetic/taxonomic conclusions and it

similarities between DNH 43 and other individuals. However, Figure 3 shows that the differences between fossil taxa are similar if not less than the differences between individual humans. It is therefore very important that the authors clearly and carefully avoid using this analysis to draw taxonomic conclusions between fossils that might imply to a reader that the differences between human individuals are also taxonomic. I would like the authors to provide a stronger justification for the inclusion of this analysis and reframe the discussion of it to avoid any such misunderstandings.	is in that vein that we have used the method. We find the three main clusters to be interesting and suggestive of some sort of "grade shift" in pelvic morphology (an "australopith" cluster to which DNH 43 belongs), a later Pleistocene Homo (or likely Homo) cluster (including Neanderthals and kin), and a recent human cluster. Arguably, these same points can be drawn from the bivariate plots in Figure 2 but the UPGMA clustering is a helpful way to draw it all together. We agree that no specific taxonomic distinctions can be made within those cluster given the pattern of variation within them. However, DNH 43's inclusion in the australopith cluster highlights the overall primitive pattern of its morphology that is consistent with the prior qualitative assessment by Gommery et al. The pairing with OH 28 required some unpacking and have now attempted to better clarify our consideration of that in the text including cautions. We have added some further cautionary language to the discussion to highlight the reviewers important observation that the cluster distances among recent humans exceed the distance within the fossil clusters. This suggests further that the pattern DNH 43 exhibits is simply an "early hominin" pattern but that it is difficult to resolve the taxonomic implications beyond that. However, if the reviewer and/or editor feel strongly about removing the UPGMA entirely, we would be willing to reconsider.
Second, the interpretation of greater sciatic notch differences (Figure 4) needs improvement. Overall, I think the authors are trying to highlight that DNH 43 falls in the extreme end of the female range for humans, while also making the interesting point that except for two Neandertals, the fossils generally skew toward the female human range even when they are thought to be male (at least for SNA; SNP does not seem as useful for distinguishing sex). I think the discussion of these points would be clearer if the following issues were addressed: • Sample: Please justify the inclusion of SK 50 and KNM-WT 15000 in this analysis. SK 50 has taphonomic deformation that may affect these measurements and KNM-WT 15000 does not preserve an os coxae that includes a complete greater sciatic notch for measurement (N and O just include the iliac portions and are lacking the ischial spine). For the latter, if a reconstruction is used that needs to be clarified since	Our assessment of the damage to SK 50 suggests that it does not preclude a reasonably accurate measurement of the sciatic notch proportions. The distortion of the posterior ilium at most would have the effect of opening the notch in a way that the angle becomes wider and push the apex position further anteriorly, in this way making the notch even more "female" in appearance. Thus, the conclusions don't change. However, we have now included some text to caution the reader and indicated that the raw measurements in Supplemental Table 2 for SK50 are estimates. Also, our apologies to the reviewers. We inadvertently included an auricular breadth

Supplement Table 2 suggests the measurements were taken on unreconstructed CT scans of the fragments.	measurement for SK50 in Supplemental Table 2. We had the questionable SK 50 measurement in an earlier version of the manuscript but failed to update the relevant cell in that table prior to submission. You will see that SK 50 was excluded from the UPGMA in both the original and currently revised versions submitted to SAJS (because the UPGMA would have required the AUR/AD index, which is lacking for SK 50). Our assessment of the SK 50 original fossil is that despite distortion of the iliac blade and a portion of the acetabulum, the acetabular diameter and tuberoacetabular sulcus measurements are accurate (given the landmarks we used to avoid damaged areas). Our KNM-WT 15000 measurements come from a surface scan of a cast of the Walker and Ruff reconstruction. Sorry, we introduced confusion because there was a typo in Supplemental Table 2 (the original manuscript indicated it was from a CT scan of the original). The Walker and Ruff reconstruction provides a reasonable estimate. We have provided language in the text to clarify and provide appropriate caution.
• Interpreting Neandertals: The discussion states that all of the Neandertals have male-like notches. Yet, the analysis does not include the only Neandertal in the sample that is generally thought to be female (Tabun C1), presumably due to preservation issues. Nowhere is it clarified that Krapina 207, while more mature than KNM-WT 15000, is also not fully adult (has an unfused iliac crest). Please add these important contexts so that it is clear your sample cannot state whether all Neandertals (including females) would have male notch morphology. Krapina 207 may indicate that juvenile individuals are closer to the female human range for these measurements, which supports the pattern of immature males appearing more female-form seen in WT 15000. • Interpreting early Homo: Since two of these (Kabwe and KNM-ER 3228) fall between a male human point and the point representing Krapina 207 (Neandertal that is called male), the authors cannot claim that all early Homo individuals are in the female range. These two are borderline. Which still fits the model of the fossil range being closer to the human female range, with two Neandertal outliers.	We have made revisions to the Discussion in an attempt to provide some clarifying language for these two points about the sciatic notch analysis.
Finally, when discussing pelvic incidence and Table 2, please include the context provided in Been et al. that SH Pelvis 1	Thank you for this suggestion. We have added the caution about pathology in SH

has pathological anatomy of the sacrum that may affect the pelvic incidence measurement. With this context, it becomes true that all other fossils fall within the human range, which may change how you want to discuss these results.	Pelvis 1. Even with this, the Neanderthal lineage specimens (Kebara 2 and SH Pelvis 2) may all fall within the human range but they still fall outside of two standard deviations from the mean reported by Been et al, which we think was an interesting finding by those workers. If early hominins were more "human like" in pelvic incidence, it begs the questions of what was going on with the Neanderthal pelvis. Very interesting and worthy of further investigation with an expanded Neanderthal-lineage sample.
Other than that, I have only some minor clarifying suggestions to improve the readability and interpretation of the manuscript: • Measurement names & abbreviations: Introduce the abbreviations in the main text before using them to refer to specific indices (this would be under Methods). SNA and SNP are not defined anywhere, and seem to refer to both greater sciatic notch angle/proportion and scaphoid angle/proportion (in Figure 4); please use consistent names for these throughout. The abbreviations used in Table 1 should also appear in a footnote of that table so that the reader does not need to scroll to remember which abbreviation stands for what.	Thank you for your careful reading. Reviewer 1 also caught this and we believe we have attended to these issues. "Scaphoid" should read "Sciatic" in that figure and we have now corrected this!
Figure numbers: check all figure numbers; around Line 272 there are references to Figure 5 (doesn't exist) and parts of Figure 4 that I think are actually referencing Figure 2.	Again, thanks for the careful reading. We have now corrected this.
Figure 4: Please label all of the fossils on this plot to aid the reader in interpreting this figure. It matters if the early Homo sp is OH 28 (wide notch) or KNM-ER 3228 (narrow notch).	We have now added the fossil specimen numbers to this plot.
Table 2: In the footnotes, include information on the number of individuals for the two human samples used (one for the linear measurements, one for pelvic incidence); further, clarify that the PI data are also means (weighted?) with SD and range; if possible, you may consider including range for the other measurements as well.	We have now provided this information in the footnote. Unfortunately, the human ranges are not available in the paper we referenced, so we have included only the standard deviations.
Supplemental Table 2: change "Homo sp" to "Early Homo sp" so that the categorization matches the ones in the main text and figures.	Done

Author response: Other additions
Many thanks to the editor and the reviewers for an opportunity to revise and resubmit our manuscript for the South African Journal of Science. All changes in the manuscript are highlighted using the Track Changes in the Word document. In addition to the edits made in response to the reviewers helpful comments (discussed below), we have made minor edits throughout for further clarity. We have also revised slightly the paragraph on the excavation context for DNH 43 and moved it to the Supplemental Information to save space in the main text. Supplemental Figure 1 has also been revised slightly so as to label the breccia pinnacles at the site.

Reviewer 1: Round 2
Date completed: 13 November 2024
Recommendation: Accept / Revisions required / Resubmit for review / Resubmit elsewhere / Decline / See comments
Conflicts of interest: None

Does the manuscript fall within the scope of SAJS?
Yes/No
Is the manuscript written in a style suitable for a non-specialist and is it of wider interest than to specialists alone?
Yes/No
Does the manuscript contain sufficient novel and significant information to justify publication?
Yes/No
Do the Title and Abstract clearly and accurately reflect the content of the manuscript?
Yes/No
Is the research problem significant and concisely stated?
Yes/No
Are the methods described comprehensively?
Yes/No
Is the statistical treatment appropriate?
Yes/No/Not applicable/Not qualified to judge
Are the interpretations and conclusions justified by the research results?
Yes/Partly/No
Please rate the manuscript on overall contribution to the field
Excellent/Good/Average/Below average/Poor
Please rate the manuscript on language, grammar and tone
Excellent/Good/Average/Below average/Poor
Is the manuscript succinct and free of repetition and redundancies?
Yes/No
Are the results and discussion confined to relevance to the objective(s)?
Yes/No
The number of tables in the manuscript is
Too few/**Adequate**/Too many/Not applicable
The number of figures in the manuscript is
Too few/**Adequate**/Too many/Not applicable
Is the supplementary material relevant and separated appropriately from the main document?
Yes/No/Not applicable
Please rate the manuscript on overall quality
Excellent/Good/Average/Below average/Poor
Is appropriate and adequate reference made to other work in the field?
Yes/No
Is it stated that ethical approval was granted by an institutional ethics committee for studies involving human subjects and non-human vertebrates?
Yes/No/**Not applicable**
If accepted, would you recommend that the article receives priority publication?
Yes/**No**
Are you willing to review a revision of this manuscript?
Yes/No
With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.
Yes/No

Comments to the Author:
Thank you for making the changes I previously requested. The new version is much clearer and easy to follow. Your thoughtfully added context to the UPGMA section solves the problem I brought up previously and your changes greatly clarified the sciatic notch interpretation section. I think this submission is ready for publication. I include a few very minor suggestions below that will further improve the accuracy and readability of an already good paper. Minor suggestions: 1) You use "os coxae" throughout as both singular and plural. This is the singular form (translates to hip bone), the plural should be "ossa coxae" (hip bones). Check your usage and make changes where appropriate. 2) Consider introducing the literature-based chimpanzee and human samples used in Table 2 in the M&M section to make it clear that these are not the same humans you measured for the other analyses. 3) Page 8's new text has some readability issues: L247 - make individuals singular; L253: replace "it" with "these results" for clarity; L254: write out "early Homo species" to avoid having two periods in a row. 4) Skhul should be spelled Skhūl throughout, including in figures. In Fig. 3, it should refer to Skhūl IV not just the site. 5) Table 2: move Neanderthals to the row after H. heidelbergensis so that the fossils are all together with the extant species at the end. And just to make sure: the pelvic incidence data also came from Tague (1989), right? Asking because I don't recall him reporting range for that measurement, either, but that's how you currently have it cited in the footnote. 6) Consider reorganizing the last paragraph of the discussion (the one on the pelvic incidence results) to focus on what all the fossils except the pathological Pelvis 1 have in common (they fall within the human range, with some falling within 1 SD) and then what makes DNH 43 unique (it is the only fossil with an angle higher than the human mean). This will make the end of the discussion stronger, keeping the focus on the fossil that is the subject of the paper.

Author response to Reviewer 1: Round 2

Reviewer comments	Author response
1) You use "os coxae" throughout as both singular and plural. This is the singular form (translates to hip bone), the plural should be "ossa coxae" (hip bones). Check your usage and make changes where appropriate.	Done.
2) Consider introducing the literature-based chimpanzee and human samples used in Table 2 in the M&M section to make it clear that these are not the same humans you measured for the other analyses.	We have added text to clarify.
3) Page 8's new text has some readability issues: L247 - make individuals singular; L253: replace "it" with "these results" for clarity; L254: write out "early Homo species" to avoid having two periods in a row.	Thank you! Done.
4) Skhul should be spelled Skhūl throughout, including in figures. In Fig. 3, it should refer to Skhūl IV not just the site.	Done.
5) Table 2: move Neanderthals to the row after H. heidelbergensis so that the fossils are all together with the extant species at the end. And just to make sure: the pelvic incidence data also came from Tague (1989), right? Asking because I don't recall him reporting range for that measurement, either, but that's how you currently have it cited in the footnote.	We have moved the Neanderthals. The pelvic incidence data are from Been et al (2013), not Tague (1989). Only the breadth measurements are from Tague. We've attempted to revise the footnotes to the table to make it more clear.

6) Consider reorganizing the last paragraph of the discussion (the one on the pelvic incidence results) to focus on what all the fossils except the pathological Pelvis 1 have in common (they fall within the human range, with some falling within 1 SD) and then what makes DNH 43 unique (it is the only fossil with an angle higher than the human mean). This will make the end of the discussion stronger, keeping the focus on the fossil that is the subject of the paper.	Thank you—we have done as you suggested.

Appendix 1: Original manuscript for review

Further assessment of a ~2 million year old hominin pelvis (DNH 43) from Drimolen Main Quarry

Abstract

The palaeocave site of Drimolen Main Quarry (DMQ) in Gauteng Province, South Africa, has produced fossil hominin material dating to between 2.04 – 1.95 Ma including craniodental remains attributed to *Paranthropus robustus* and the earliest specimen of *Homo erectus sensu lato* along with numerous postcrania of uncertain taxonomic affiliation. Among this collection is a partial pelvis (DNH 43), which includes the sacrum and elements of the right os coxae. Though previously described as showing similarities to the pelvis of *Australopithecus* and *Paranthropus*, comparisons across the broader hominin fossil record have been limited and DNH 43 has never been analyzed quantitatively. Here we present a partial digital reconstruction of DNH 43 and compare it to an expanded dataset of fossil specimens to determine its closest morphological affinities. Overall, the quantitative analysis is congruent with qualitative results reflecting the primitive features of DNH 43, suggesting an *Australopithecus/Paranthropus*-like anatomy including small absolute size, relatively small sacroiliac articulation, moderately-wide tuberoacetabular sulcus, gracile acetabulosacral buttress, and obstetric dimensions that are relatively broad. A study of this rare articulated pelvis shows that the orientation of the sacrum (pelvic incidence) is similar that of recent *Homo sapiens*. Although DNH 43 shares some specific metric similarity with specimens MH2 (*Australopithecus sediba*) and OH 28 (cf. *Homo erectus*) the taxonomic relevance is unclear given poor understanding of *Paranthropus* and early *Homo* postcranial variation. Affiliation with *Paranthropus robustus* (which dominates the DMQ craniodental assemblage) cannot be ruled out and we consider assignment to that taxon to be a reasonable provisional attribution.

Significance:

- Associated pelvic elements (sacrum and os coxae) are rare in the hominin fossil record but provides information on overall body form, locomotion, and obstetrics.
- Anatomical assessment and partial reconstruction of specimen DNH 43 from the Drimolen Main Quarry in the Cradle of Humankind, South Africa thus provides additional insights into pelvic form in a ~2.0 million year old hominin.
- The fossil is best attributed *Paranthropus robustus* and displays an overall primitive, gracile morphology but presents with positioning of the sacrum similar to that of recent humans, which differs from prior interpretations of early hominin spinopelvic anatomy.

Introduction

Palaeontological work at the palaeocave site of Drimolen Main Quarry (DMQ; 25°58'08" S, 27°45'21"E) in Gauteng Province, South Africa has produced significant fossil hominin material since excavations began in the 1994[1]. The assemblage includes craniodental remains attributed to *Paranthropus robustus* and the earliest known specimen of *Homo erectus sensu lato* between, 2.04 – 1.95 Ma demonstrating that *Paranthropus* and *Homo* were effectively contemporaneous at the site and coeval with *Australopithecus* from nearby fossil localities in South Africa.[2] Numerous postcranial elements of uncertain taxonomic affiliation have also been recovered, but these have received little attention. Among these is a partial pelvis (DNH 43) with most of the sacrum (DNH 43A) and elements of the associated right os coxae (DNH 43B) preserved.

The context of DNH 43's recovery is shown in Supplemental Figure 1 A-C. The specimen was discovered by Andre Keyser's team working at DMQ, but the exact date of discovery is not noted in the excavation records from this period. DNH 44 was recovered in 1997 and DNH 40 in 1995 and so it is likely that it was recovered around this time. Photos from 1997 indicate sediments had already been removed from the area it was discovered (Supplemental Figure 1C), confirming this as an upper limit on its year of collection. It was discovered in a breccia block from a talus slope overlying what was then described as the Main Pinnacle (Northing 197.385, Easting 211.82, Depth 0.782; Supplemental Figure 1C). Later excavation revealed these were composed of several separate breccia pinnacles. If the breccia came from this height in the sequence, then DNH 43 would be the youngest fossil recovered from DMQ, coming from normal polarity deposits a little younger than 1.95 Ma.[2] However, no other hominin fossils have been recovered from such levels at the site (Supplemental Figure 1A). DNH 43 comes from directly above a series of breccia pinnacles that Keyser removed via drilling in the 1990s at some point after the discovery of the fossil pelvis (Supplemental Figure 1A-B). Because the specimen comes from a loose breccia block, its association to these removed pinnacles and the current in situ stratigraphy is difficult to ascertain.

The evolution of the pelvis bears on critical aspects of hominin biology including locomotion, obstetrics, and variation in body-size and shape related to climatic adaptation.[3-8] However, associated sacra and os coxae are especially rare in the early hominin fossil record[5], making DNH 43 of particular interest. Gommery and colleagues[9] described the specimen qualitatively, noted its similarities to the pelvis of other early South African hominins, and attributed it to *Paranthropus robustus*. However, comparisons across the broader hominin fossil record are lacking and the specimen has never been analyzed quantitatively to help determine its closest morphological affinities. The objective of the present paper is to make 3D polygon models of DNH 43 available online (including a partial virtual reconstruction) and to compare the specimen metrically to an expanded dataset of hominin pelvic material.

Materials and methods

Virtual reconstruction

More information on the preservation of DNH 43 and a detailed description of the specimen are provided by Gommery and colleagues.[9] For the current study, the DNH 43 pieces were surface scanned using an Artec Space Spider. Resulting surface scans of the individual pieces of DNH 43 as well as the partial reconstruction are provided in the University of the Witwatersrand Collection at https://human-fossil-record.org/index.php?/category/17879.

REVIEWERS: for evaluation, please use these temporary log-in credentials to access the scans, which will be made public upon publication. Username = DNH43_reviewers Password = m7RUmSJa

The sacrum (DNH 43A) includes a nearly complete plateau and most of the right side of the vertebrae, though the anterior aspect of the right-side ala is mostly missing. The left side of the sacral vertebral bodies and left-side ala are absent. The plateau exhibits plastic deformation such that the left half is shifted cranially; however, the right side is complete and undistorted (Figure 1A). On the right side, the cranial-most one third of the sacral ala and auricular surface is absent, but the caudal two-thirds of the surface is reasonably well-preserved and only minimally distorted. To partially reconstruct the sacrum, the virtual model of DNH 43A was sectioned at the midline and the more-complete right side was reflected to the left (Figure 1B) using Geomagic Control.

The partial right os coxae (DNH 43B) is preserved in two pieces that refit cleanly at a postmortem break approximately midway along the acetabulosacral buttress, which is the bony strut connecting the sacroiliac joint and the hip (Figure 1C). The anterior portion includes most of the lunate surface of the acetabulum (missing the superomedial and inferomedial horns) allowing for measurement of the superoinferior diameter. A small anterior portion of the iliac blade (which is mostly missing otherwise) projects superolaterally from the anterior inferior iliac spine, which is present but weathered. The superior portion of the ischium is preserved including a somewhat polished ischial spine and approximately 1 cm of bone inferior to it. The ischial tuberosity is almost entirely absent, but a lip of bone representing the superior edge of what would be the roughened tuberosity is discernable, allowing assessment of tuberoacetabular sulcus width. The posterior portion of DNH 43B includes a complete auricular surface and much of the iliac tuberosity. The iliac tuberosity is damaged posterolaterally such that the posterior-superior and posterior-inferior iliac spines are absent.

The two pieces of the os coxae were fit together virtually and reflected to generate a left side for articulation with the reconstructed sacrum (Figure 1D-F). Each piece of DNH 43A and B were 3D printed using a Lulzbot Taz 6 printer (an "extrusion" printer using fused-deposition modeling with a polylactic acid printing filament) at a layer height of 0.1 mm. The 3D prints were manipulated physically to evaluate the fit and ground-truth the virtual articulation.

Comparative sample

To evaluate the closest morphological affinity of DNH 43 it was compared to a sample of recent *H. sapiens* (12 males and 13 females) and several fossil hominin specimens. Fossil pelvic remains included specimens typically attributed to *Australopithecus afarensis* (AL 288-1), *A. africanus* (Sts 14 and Stw 431), *A. sediba* (MH1 and MH2), *Paranthropus robustus* (SK 50, SK 3155b, TM 1605), *Homo* sp. (likely representing various taxa including *Homo erectus* and its probable immediate descendants[10,11]: Arago XLIV, Kabwe E. 719, KNM-ER 1808, KNM-ER 3228, KNM-ER 5881, KNM-WT 15000, and OH 28), *H. floresiensis* (LB1), Neanderthals (Amud 1, Kebara 2, Krapina 207, Neandertal 1, and Tabun C1), and early *H. sapiens* (Omo-Kibish 1 and Skhul IV). Comparative metric assessment of the articulated pelvis included data available from the literature allowing the consideration of additional material attributed to either *Homo* sp. or Neanderthals (Sima de los Huesos Pelvis 1 and Pelvis 2[12]), *H. erectus* (BSN49/P26[13] though some have argued this could represent *P. bosei*[14]), and a late Pleistocene *Homo sapiens* specimen (Ohalo II[15]), as well as data on modern *Pan troglodytes*[15,16].

Measurements and analysis

Measurements were taken on 3D scans of the individual DNH 43A and DNH 43B specimens and compared with data from the fossil and recent *H. sapiens* sample. Measurements were taken by the authors (EB and CMO) on the 3D scans (using landmarks placed with Geomagic Control or Stratovan Checkpoint) or taken from the literature where indicated. Differential preservation precluded measurement of certain variables on individual fossils, so analyses included subsamples of these specimens as available. Measurement definitions and relevant landmarks are provided in Supplemental Table 1 and Supplemental Figure 2.

Sacrum measurements captured total craniocaudal length and maximum mediolateral and anteroposterior dimensions of the plateau.

Analysis of the os coxae focused on measurements available on as broad a sample of fossil specimens as possible following metrics from Churchill et al[17]. The width of the tuberoacetabular sulcus (the "gap" between the superior-most aspect of the ischial tuberosity and the inferior margin of the acetabulum) and auricular surface were evaluated relative to the superoinferior acetabular diameter. Recent humans and fossils attributed to *Homo* tend to have relatively narrow tuberoacetabular sulci compared to earlier hominins including *Australopithecus* and *Paranthropus.*[17-19] The index of the acetabulosacral buttress thickness (mediolateral breadth superior to the greater sciatic notch) to the acetabulosacral buttress load arm (anteroposterior length from acetabulum to the auricular surface) captures the relative robusticity of the lower ilium. Members of the genus *Homo* tend to exhibit thicker acetabulosacral buttresses.[10,17] In addition to bivariate plots to examine the scaling of specific metrics, a cluster analysis of the indices TAS:AD x 100, AUR:AD x 100, and ASBT:ASLA x 100 was conducted using the unweighted pair group method with arithmetic mean (UPGMA) to assess the closest overall metric affinities of the DNH 43B os coxae.

The greater sciatic notch shows sexual dimorphism in recent *H. sapiens*, with females typically exhibiting a notch that opens more widely and is relatively symmetric with the apex of the notch shifted anteriorly such that the anterior and posterior arcs are closer in length than in males.[13,20] A sciatic notch angle was used to quantify the "openness" of the notch while the relative position of the notch's apex quantified the proportions following the method from reference[13].

Mediolateral (transverse) dimensions with locomotor and obstetric implications were measured on the virtually articulated pelvis. These included the mediolateral diameter of the pelvic inlet (between most lateral points on the right and left arcuate lines), the bispinous breadth (between right and left ischial spines quantifying the mediolateral dimension of the obstetric midplane), and biacetabular breadth (between the centers of the right and left acetabulae). Without a pubis, reconstruction of the anterior enclosure of the inlet is impossible and anteroposterior dimensions are unmeasurable. Sacral orientation, which is related to the degree of lumbar lordosis, varies among nonhominins, *Australopithecus*, and later members of the genus *Homo*[15]. Relative to extant apes, *H. sapiens* exhibit a high degree of anterior sacral tilt, which corresponds to an increased lumbar lordosis to position the superincumbent body weight over the hips[15]. Sacral orientation (Supplemental Figure 3) was assesed in DNH 43 by quantifying pelvic incidence using a method following reference[21] and comparing it to data from Been and colleagues[15].

Results

The DNH 43A sacrum has a minimum craniocaudal length of ~72 mm. This is probably an underestimate as only a portion of the fifth sacral vertebra is intact, but it closely matches the length of specimen AL 288-1 (73.5 mm) attributed to *A. afarensis*. The reconstructed sacral plateau measures 16.6 mm anteroposteriorly by 29.3 mm mediolaterally. An index of sacral plateau proportions is compared among hominins in Figure 2A. DNH 43A shows its closest affinities with sacra attributed to *A. afarensis* and *A. africanus* though one human male matches DNH 43A in having a similarly anteroposteriorly compressed plateau.

Measurements of the DNH 43B os coxae are shown in Table 1 along with a comparative sample of fossils and recent *H. sapiens.* Fossils are grouped in Table 1 for brevity and the most useful overall comparisons, but individual specimen data are provided in Supplemental Table 2. Bivariate plots of tuberoacetabular sulcus width versus acetabular diameter, auricular breadth (AUR) versus acetabular diameter, and acetabulosacral buttress thickness versus acetabulosacral load arm are shown in Figure 2B-D.

Results of the UPGMA cluster analysis are shown in Figure 3. The dendrogram exhibits two primary clusters: the recent *H. sapiens* sample plus the LB1 *H. floresiensis* specimen and a fully fossil hominin cluster. Within the fossil cluster, there are two further main divisions: 1) a cluster that includes DNH 43B along with os coxae assigned to *Australopithecus* or *Paranthropus* plus the OH 28 specimen (cf. *Homo erectus*); and 2) a cluster including os coxae referred to various Pleistocene members of the genus *Homo* (including early taxa such as *H. erectus* and later groups such as Neanderthals and “early *H. sapiens*”). Within the first cluster DNH 43B shows its closest linkages to OH 28 and MH2 (*Australopithecus sediba*) (Figure 3).

Greater sciatic notch measurements (sciatic notch angle and sciatic notch proportion) are shown in Table 1 and Figure 4. Mean sciatic notch angle for *H. sapiens* females (81.9°; standard deviation = 5.7; range: 75.0° – 93.9°) is significantly different from that for the males (67.7°;

standard deviation = 4.0; range: 59.4° – 72.6°) (t = 7.14, p < 0.001). The sciatic notch proportions also differ significantly (t = 3.8, p < 0.001) between recent human females (mean = 0.38; standard deviation = 0.08; range: 0.31 – 0 .52) and males (mean = 0.24; standard deviation = 0.10; range: 0.12 – 0.45). For both variables, DNH 43B falls at the high end of the range for *H. sapiens* females.

Measurements from the articulated DNH 43 pelvis are provided in Table 2. DNH 43 has a pelvic inlet and bispinous breadth that are somewhat narrow mediolaterally but a biacetabular breadth similar to other individuals including recent *H. sapiens* (which are absolutely broad when compared to *P. troglodytes*). The pelvic incidence angle of 56° (Supplemental Figure 3) falls close to the *H. sapiens* mean (54° ± 10° standard deviation) and higher than all other fossil hominins and 4.5 standard deviations above the *P. troglodytes* mean (29° ± 6° standard deviation).

Discussion

In absolute measurements, DNH 43 is small and similar to specimens attributed to *Paranthropus* and *Australopithecus* (Tables 1 and 2; Figure 2). The close correlations among acetabulum size, femoral head size, and body mass[14] suggests that the individual represented by DNH 43 would have been of a similar overall body size to these early hominin taxa.

The DNH 43A sacral plateau is relatively narrow in the anteroposterior dimension compared with the mediolateral dimension, linking it with early hominins including *A. afarensis* and *A. africanus* versus the recent *H. sapiens* sample (Figure 2A). The Kebara 2 sacrum is also anteroposteriorly compressed though it overlaps the low end of the human sample (as does the Sts 14 specimen attributed to *A. africanus*). However, although the sacral plateau is not well preserved in the Sts 431 sacrum (attributed to *A. africanus*) or for that of MH2 (*A. sediba*), the sacral body in these is somewhat thicker anteroposteriorly than those of DNH 43A, AL 288-1, and Sts 14[22], suggesting some variation in sacral robusticity within *Australopithecus* that might have taxonomic implications including heterogeneity in the Sterkfontein sample[23]. Unfortunately, there are no sacral specimens attributed to *Paranthropus* against which DNH 43A can be compared.

The DNH 43B os coxae exhibits an auricular surface that is small relative to the size of acetabulum (Figure 2B) and a transverse acetabular sulcus that is only moderately wide relative to the size of the acetabulum (Figure 2C). As with most of *Australopithecus* and *Paranthropus* specimens sampled here, DNH 43B has a gracile communication between the sacroiliac joint and hip joint with an acetabulosacral buttress that is slender relative to its length (Figure 2D) as reflected in its low ASBT/ASLA x 100 index (Table 1).

When considering indices TAS:AD x 100, AUR:AD x 100, and ASBT:ASLA x 100 together in the UPGMA cluster analysis (Figure 3), DNH 43B has its closest linkage with specimen OH 28 (*Homo* cf. *erectus*) while its next closest linkage is to specimen MH2 (*Australopithecus sediba*). DNH 43B, OH 28, and MH2 all form a direct 'sister' group with the branch that includes the *Australopithecus* and *Paranthropus* specimens to the exclusion of most of the individual fossils typically attributed to the various *Homo* taxa suggesting a general 'early hominin-grade' morphology. Linkage with OH 28 might may reflect some "early *Homo*" characteristics in DNH 43B and the MH2 os coxae. Indeed, the MH2 pelvis has been argued to display some *Homo*-like features[17,22] and craniodental characters tentatively suggest a close common ancestor[24]. However, it may also reflect greater variability in the measured characters for both *Australopithecus*/*Paranthropus* and early *Homo* sp. than previously recognized. Indeed, the exact UPGMA link with OH 28 should be considered cautiously based solely on the three included indices. OH 28 is much larger in absolute dimensions (Figure 2B-D) and exhibits an exceptionally robust acetabulocristal buttress (Supplemental Figure 4)—characters expressed strongly in other os coxae attributed to early *Homo* sp.[25] but not evident in either DNH 43B or MH2. Indeed, Rose[25] noted a close overall similarities among specimens such as OH 28, KNM-ER 3228, and recent *H. sapiens* vis-à-vis *Australopithecus* and *Paranthropus* in terms of iliac features. MH2 represents *A. sediba* from Malapa in South Africa and is thus geographically closer to DMQ and is dated to around the same period as DNH 43.

Unfortunately, specimens SK 50 and TM 1605 usually considered to represent *P. robustus* from the sites of Swartkrans and Kromdraai, respectively[5], could not be included in the cluster analysis because damage precludes accurate measurement of the auricle breadth in both specimens and acetabular diameter in TM 1605. However, in preserved anatomy, these specimens exhibit apparently plesiomorphic characteristics of the lower os coxae. SK 50 has the widest tuberoacetabular sulcus relative to the acetabular diameter of any specimen in the sample and the acetabulosacral buttress is gracile relative to the acetabulosacral load arm in both SK 50 and TM 1605. It should be cautioned that even for these specimens from Swartkrans (whose craniodental sample is overwhelmingly attributed to *P. robustus*), the association with *Paranthropus* is circumstantial, lacking direct association with taxonomically identifiable jaws and teeth, and early *Homo* also occurs at the site.

P. robustus is the most frequently sampled hominin at DMQ[1,26,27], which has produced remarkably complete cranial remains of the species[28,29]. The morphology preserved in DNH 43 cannot rule out an affiliation with that taxon corresponding with the initial description[9]. However, early *Homo* (including *Homo erectus sensu lato*) has been documented at DMQ[2], so caution is warranted. Associated craniodental and pelvic remains of definitive early *Homo* are scarce generally[10,11] and unknown from the South African record, although *H. naledi* may represent a relatively plesiomorphic member of the genus[10]. Much of the postcranial skeleton is variable among fossil samples thought to represent taxa of truly early *Homo*[11]. *Homo naledi* pelvic remains from the Rising Star Cave system preserve fragmented os coxae that evince an *Australopithecus*/*Paranthropus*-like lateral iliac flare with an anteriorly placed and lightly-expressed acetabulocristal buttress and an absolutely narrow acetabulosacral buttress but short *"Homo*-like" load arm[18] and a narrow tuberoacetabular sulcus. Notably, the LB1 *H. floresiensis* pelvis also exhibits a laterally-flared ilium similar to *Australopithecus* and *Paranthropus*.[30] Although LB1 clusters with a single recent male *H. sapiens* individual in the UPGMA analysis (Fig. 5) due primarily to its relatively large auricular surface (Fig. 4B), it shows a relatively wide tuberoacetabular sulcus (Fig. 4C) and gracile acetabulosacral buttress relative to load arm (Fig. 4D) considered to be plesiomorphic (see also reference[30]). The small body size of both *H. floresiensis* and *H. naledi* and their somewhat different morphologies of the lower os coxae suggest variation in these traits may not be the result of allometric effects (i.e, *"Homo*-like" features do not necessarily covary with differences in overall body size). Uncertainty concerning the magnitude of variation in these features among early diverging members of the genus *Homo* makes it difficult to evaluate their taxonomic utility vis-à-vis DNH 43.

Sex attribution of the DNH 43 pelvis remains uncertain. The specimen has an "open" greater sciatic notch and the apex of the notch is situated anteriorly, giving it a semicircular appearance similar to what is observed commonly in pelvises of recent *H. sapiens* females. However, whether sexually dimorphic aspects of the modern human pelvis also characterize fossil taxa is not established.[13] Furthermore, the acetabular diameter of DNH 43 is somewhat larger than all *Australopithecus* and *Paranthropus* specimens sampled (Table 1); thus, an appeal to overall size does not further clarify whether DNH 43 is male or female. The rest of the fossils span the distribution of males and females for both greater sciatic notch variables (Table 1 and Figure 4) though there is some clustering by group. If the sexually-dimorphic features of recent *H. sapiens* characterize the fossil populations, then these clusters probably represent sampling error (i.e., mostly males or females sampled in a fossil group). Neanderthal specimens all exhibit a more "male-like" sciatic notch, while the "early *Homo* sp." group all fall within the female distribution. Interestingly, all specimens typically assigned to *Paranthropus* fall at the high end of the female distribution of the two variables along with DNH 43. In contrast, pelvises attributed to *A. afarensis* (AL 288-1), *A. africanus* (Sts 14), and the subadult *H. erectus* (KNM-WT 15000) show an unusual combination of a wide sciatic notch angle ("female-like") coupled with a more posterior notch apex ("male-like") (Figure 4). Based on a broader evaluation of pelvic morphology, AL 288-1 and Sts 14 are generally considered to represent the females of their respective taxa due to small size[31] (but see reference[32]) and KNM-WT 15000 is considered to represent a young male[33]. Determining whether these individuals are outliers or that the unusual combination of these greater sciatic notch features has phylogenetic valence would require an expanded fossil sample.

A mediolaterally broad pelvis is often considered a plesiomorphic trait associated with *Australopithecus* though it is retained in the few available pelvises of early *Homo.*[4,13] Compared with available comparative material (Table 2), the DNH 43 pelvis is wide mediolaterally when considering a reasonable proxy of overall body size (superioinferior acetabular diameter). This is especially pronounced when considering the width between the hip joints (biacetabular breadth) and the narrowest point in a hominin birth canal (bispinous breadth). Indexed against the acetabular diameter, the biacetabular breadth of DNH 43 is 301% and bispinous breadth is 257% that of the acetabulum size. These relative dimensions are exceeded only in *A. afarensis* specimen AL288-1 (335% and 274%) and the BSN49/P27 pelvis (possibly a female *H. erectus*) at 320% and 280% of the superoinferior acetabular diameter[12]. The *A. sediba* specimen MH2 is similar to DNH43 in biacetabular breadth relative to the acetabular diameter (300%). Among other absolutely-wide fossil pelvises, the biacetabular diameter of Kebara 2 is 228% that of the acetabular diameter (no bispinous diameter is available), though Kebara 2 is probably a male. The Sima de los Huesos Pelvis 1 biacetabular and bispinous breadths are respectively 235% and 198% of the reported[12] superoinferior diameter of the acetabulum (58.8 mm). In contrast to the early hominin fossil sample, in *H. sapiens* females, the mean biacetabular and bispinous breadths (Table 3) are 230% and 225% that of the mean acetabular diameter while the same male dimensions are 196% and 172% respectively. The exceptionally wide bispinous and biacetabular breadths of DNH 43 suggest a capacious pelvic outlet that might indicate a nonrotational birth mechanism as sometimes inferred for *Australopithecus*[34,35]. A pelvis that is mediolaterally broad from hip-joint to hip-joint may also influence lower limb kinematics by maintaining stride length in individuals with relatively shorter hindlimbs via the recruitment of greater pelvic rotation.[36-38]

However, such an arrangement does not appear to increase locomotor cost.[39] A better sample of articulated fossil pelvises will shed further light on our understanding the evolution of hominin encephalization and its evolutionary interplay with locomotor biomechanics, though much of the theoretical and empirical basis of this relationship remains controversial[3,7,40-44].

The pelvic incidence of DNH 43 (Table 2; Supplemental Figure 3) indicates an anterior tilt to the sacrum and concomitant lumbosacral alignment that would facilitate a humanlike lumbar lordosis[15]. Although the 56° pelvic incidence measured for DNH 43 is higher than the values measured for *A. afarensis* (42°) and *A. africanus* (45°), the *Australopithecus* specimens also fall comfortably within the variation documented for recent *H. sapiens* sacral orientation[15]. Sts 14 is within one standard deviation of the human pelvic incidence mean of 54° and AL 288-1 is well within the range (32° - 84°) (Table 2). These data suggest that spinopelvic mechanics in *Australopithecus* (and likely other early hominin taxa including *Paranthropus* if DNH 43 indeed represents the genus) were similar to recent *H. sapiens* in how they positioned the torso and head over the hip joint during bipedal posture and locomotion. However, DNH 43 and the *Australopithecus* specimens highlight the peculiarly low pelvic incidence demonstrated for members of the Neanderthal lineage including the Sima de los Huesos pelvises and the Kebara 2, which all fall outside of two standard deviations from the human mean[15].

Conclusion

Overall, the quantitative analysis presented here is congruent with prior qualitative results reflecting the primitive features of DNH 43. *Paranthropus robustus* is a reasonable taxonomic assignment given the overall plesiomorphic morphology and that *P. robustus* remains dominate the DMQ hominin assemblage. However, caution is warranted as *H. erectus sensu lato* is documented at DMQ[2] and well-associated cranial and postcranial remains are scarce for both *Paranthropus* and early *Homo*. Because phylogenetic analyses based primarily on craniodental character sets indicate that *Paranthropus* and *Homo* may represent sister groups[24] these taxa would be expected to share some postcranial features based on that common ancestry. Consequently, basal members of *Homo* might be difficult to identify based solely on the pelvic traits visible in DNH 43. Thus, taxonomic assignment of postcranial remains such as DNH 43 may be subject to revision with a better understanding of the postcranial anatomy of *Paranthropus* and early *Homo,* which overlapped chronologically in both southern [2] and eastern Africa[51].

Table 1: Summary metric data for the os coxae measurements[1].

	AD	TAS	ASBT	ASLA	SNA	SNP	AUR	TAS/ AD x 100	ASBT/ ASLA x 100	AUR/ AD x 100
DNH 43	41.1	13.2	16.6	46.8	87.3	0.48	31.2	32.1	35.5	75.9
Australopithecus										
N	3	3	5	5	2	2	4	3	5	4
Mean	38.2	17.5	16.3	41.8	90.8	0.27	28.6	45.9	35.0	75.2
Std Dev	1.8	4.7	1.7	3.8	-	-	2.6	13.8	5.6	6.5
Min	36.8	9.5	14.4	37.0	85.9	0.25	27.3	23.3	32.8	69.1
Max	40.7	18.6	18.6	45.3	95.6	0.28	33.7	50.5	46.5	82.8
H. floresiensis	36.0	15.9	18.5	39.1	81.0	0.44	41.0	44.2	47.4	113.8
***H. sapiens* fossil**										
N	2	2	1	2	2	2	2	2	2	2
Mean	59.3	11.1	24.0	54.7	81.1	0.41	45.7	18.7	53.6	77.3
Min	58.3	10.1	24.0	44.8	80.4	0.34	39.4	17.4	53.6	65.4
Max	60.3	12.1	24.0	64.6	81.8	0.48	52.0	20.0	53.6	89.1
***H. sapiens* recent**										
N	25	25	25	25	25	25	25	25	25	25
Mean	54.5	16.3	23.0	51.6	75.1	0.31	56.3	29.7	45.4	103.1
Std Dev	4.5	3.5	3.2	5.4	8.7	0.11	6.0	5.2	9.6	5.4
Min	48.3	11.2	17.5	41.3	59.4	0.12	46.4	20.8	28.0	93.7
Max	65.0	22.1	30.6	64.2	93.9	0.52	71.4	40.0	74.0	112.7
***Homo* sp.**										
N	5	5	6	7	5	4	5	5	6	5
Mean	58.1	12.2	20.7	50.2	79.3	0.30	37.6	20.9	40.5	65.0
Std Dev	3.3	2.6	2.5	7.4	6.8	0.07	3.7	4.3	5.6	8.8
Min	54.9	9.3	17.8	41.7	73.4	0.22	35.2	16.2	34.2	57.2
Max	62.0	15.5	24.1	63.0	86.3	0.36	43.9	26.0	48.1	80.1
Neanderthals										
N	4	4	4	4	3	3	3	3	4	3
Mean	57.8	9.7	22.3	53.1	64.7	0.16	36.5	19.5	41.9	63.6
Std Dev	3.4	3.0	3.9	6.7	7.7	0.07	7.0	2.2	4.7	7.7
Min	53.6	5.3	17.6	45.2	59.8	0.08	31.1	17.8	37.3	58.1
Max	61.3	11.8	26.6	61.0	73.6	0.22	44.4	22.0	47.6	72.4
P. robustus										
N	2	2	3	3	2	2	2	2	3	2
Mean	38.4	20.2	16.2	47.9	82.6	0.50	39.0	52.7	33.2	101.7
Std Dev	-	-	1.7	5.6	-	-	-	-	2.2	-
Min	38.0	16.1	14.6	41.9	80.7	0.49	31.8	41.5	30.8	82.0
Max	38.8	24.2	18.0	52.9	84.5	0.51	46.1	63.8	34.9	121.3

[1] All measurements included were taken for the current study with the exception of ASBT and ALSA for MH2 taken from reference[17]. Data for individual specimens are provided in the Supplemental Information.

Table 2: Measurements of the articulated pelvis.

Taxon/Group & Specimen(s)	Mediolateral breadth of pelvic inlet (mm)	Biacetabular breadth (mm)	Bispinous breadth (mm)	Pelvic Incidence (degrees)Ŧ
DNH 43[a]	108.9	123.6	106.3	56
Australopithecus afarensis				
AL 288-1[b]	132	118	101	42
Australopithecus africanus				
Sts 14[c]	116.8	107.5	89.0 - 93.1	45
Sts 65[d]	101.5 (109)	-		-
Australopithecus sediba				-
MH 2[e]	117.6	122.3	-	
Homo erectus				-
KNM-WT 15000 (subadult)[f]	100	102	-	
Homo* cf. *erectus				
BSN49/P27[g]	124.5	131.0	114.5	-
Homo heidelbergensis				
Sima de los Huesos pelvis 1[h]	139.3	138	116.4	28
Sima de los Huesos pelvis 2	-	-	-	33
***Homo sapiens* (fossil)**				
(Ohalo)	-	-	-	52
***Homo sapiens* (recent)**[i]	132.5 ± 7.5 (female) 127.4 ± 7.4 (male)	121.1 ± 8.1 (female) 111.2 ± 6.7 (male)	117.2 ± 1.0 (female) 97.3 ± 9.2 (male)	54 ± 10 (32 – 84)
Neanderthal				
Kebara 2[j]	138	129	-	34
Tabun C1[k]	131	133.8	-	
Pan troglodytes[l]	100 ± 12.6 n = 29	105.8 ± 35.6 n = 29	-	29 ± 6 n = 8

Ŧ Except for DNH 43, all pelvic incidence data are from [15];
[a] DNH 43: measurements from current study.
[b] AL 288-1 pelvic inlet and bispinous breadth from [34]; biacetabular breadth from [16] based on [45].
[c] Sts 14: all data except pelvic incidence are from [16].
[d] Sts 65: data from [46].
[e] MH2: data from [22].
[f] KNM-WT 15000: data from [33].
[g] BSN49/P27: data from [13].
[h] Sima de los Huesos Pelvis 1: data from [12].
[I] Recent *Homo sapiens* obstetric data represent the weighted mean of six populations from [47].
[j] Kebara 2 biacetabular breadth is the mean of two reconstructions from [48] and bispinous breadth is from [49].
[k] Tabun C1: pelvic inlet breadth from [50] and biacetabular breadth measured on the 3D reconstruction from [50].
[l] *Pan troglodytes* pelvic inlet and biacetabular breadth data from [16]

Figure Legends

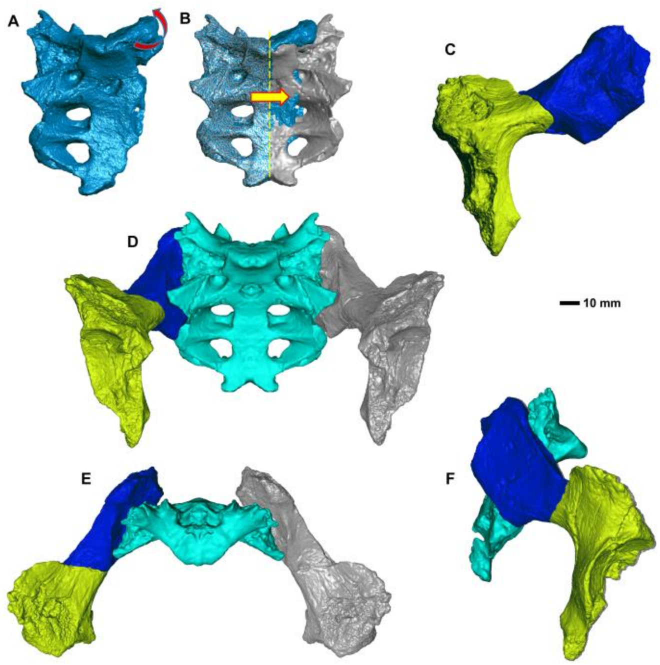

Figure 1: Three-dimensional polygon models derived from surface scanning of DNH 43. A) sacrum (DNH 43A) with arrow indicating cranially-directed deformation of the left side of the sacral plateau; B) bisection and reflection of the relatively undistorted right side to reconstruct the left side; C) medial view of the two refit pieces of the os coxae (DNH 43B); D) anterior view of the articulated pelvis with the reconstructed sacrum and the right os coxae reflected to reproduce the left side; E) superior view of the articulated pelvis; F) lateral view of the articulated pelvis.

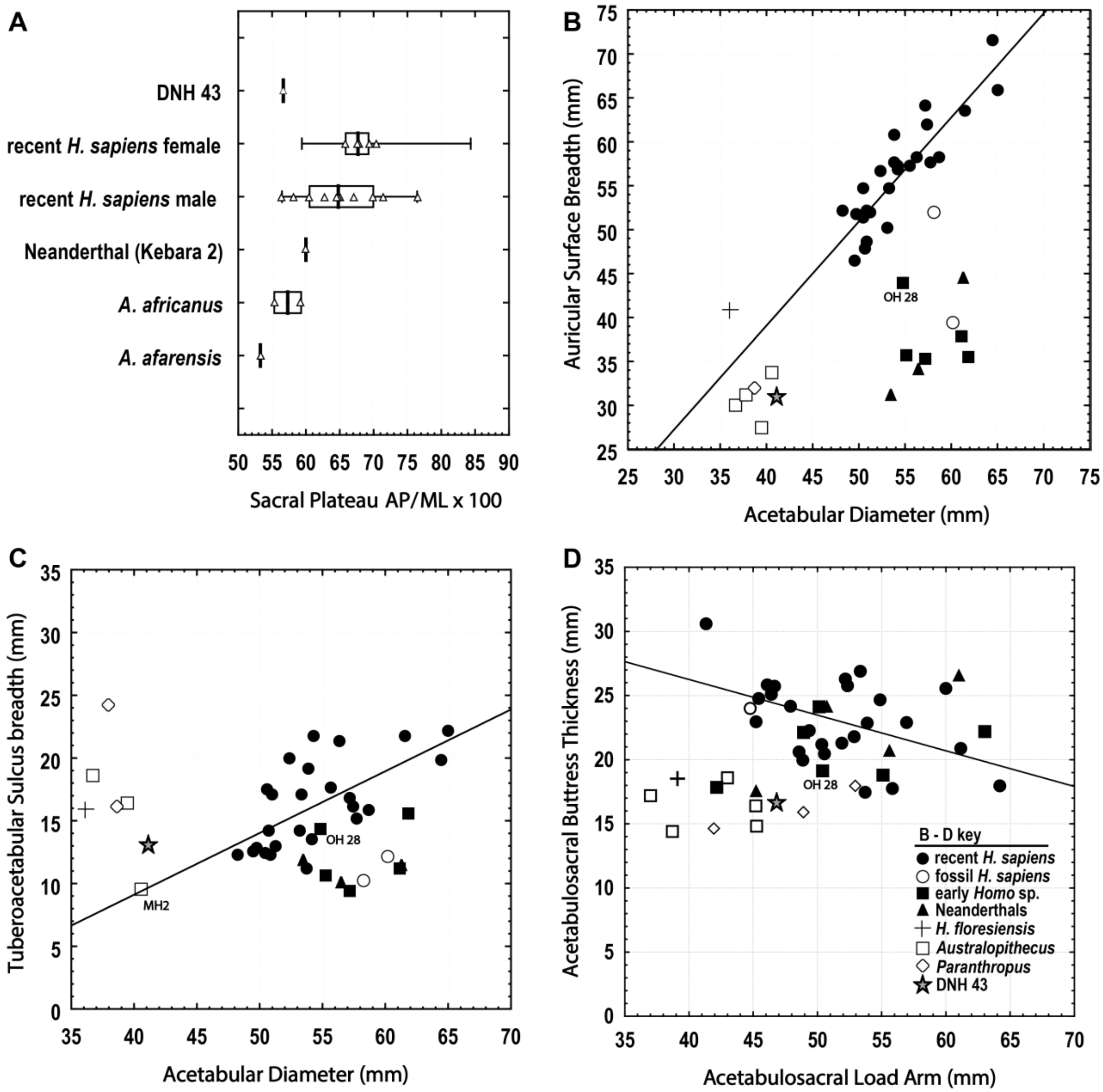

Figure 2: Anteroposterior versus mediolateral proportions of the sacrum (A) and bivariate plots of three features of the os coxae demonstrating scaling relationships between the auricular surface breadth and the superoinferior acetabular diameter (B), tuberoacetabular sulcus breadth and superoinferior acetabular diameter (C), and the acetabulosacral buttress thickness versus the acetabulosacral load arm (D). In all cases, the plotted least-squares regression lines are fit solely to the recent *Homo sapiens* sample.

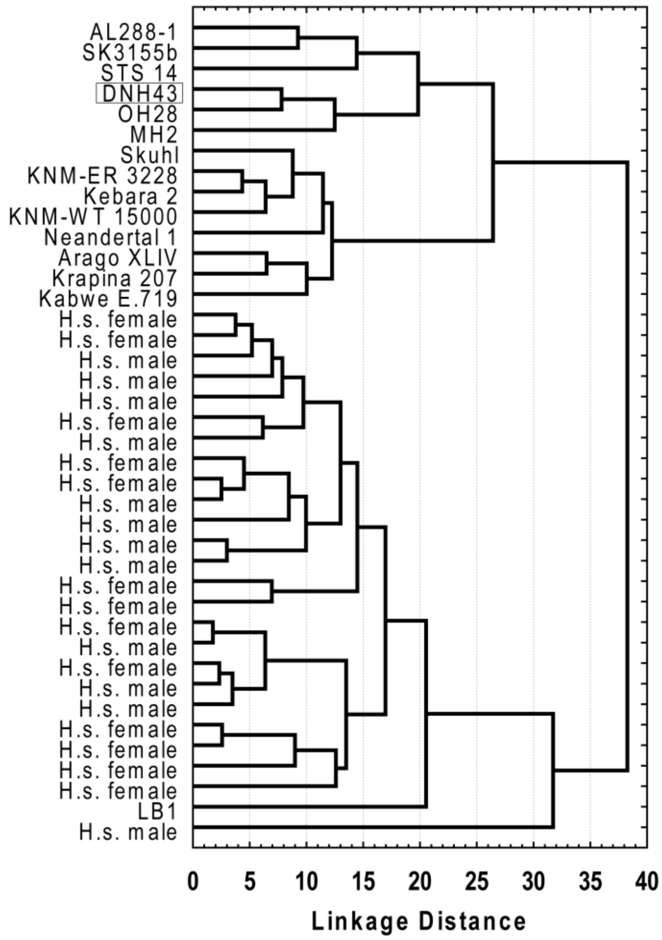

Figure 3: Dendrogram from the UPGMA cluster analysis.

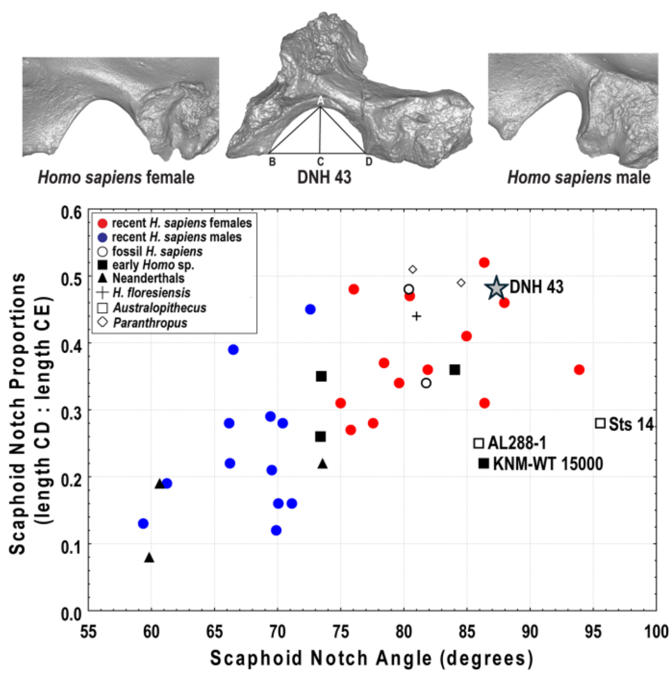

Figure 4: Examples of greater sciatic notch morphology (top: oriented in medial view with sacroiliac joint to the right) in DNH 43 versus a recent *H. sapiens* female and male and a bivariate plot (bottom) of the sciatic notch proportions versus the sciatic notch angle in DNH 43 and the comparative sample.

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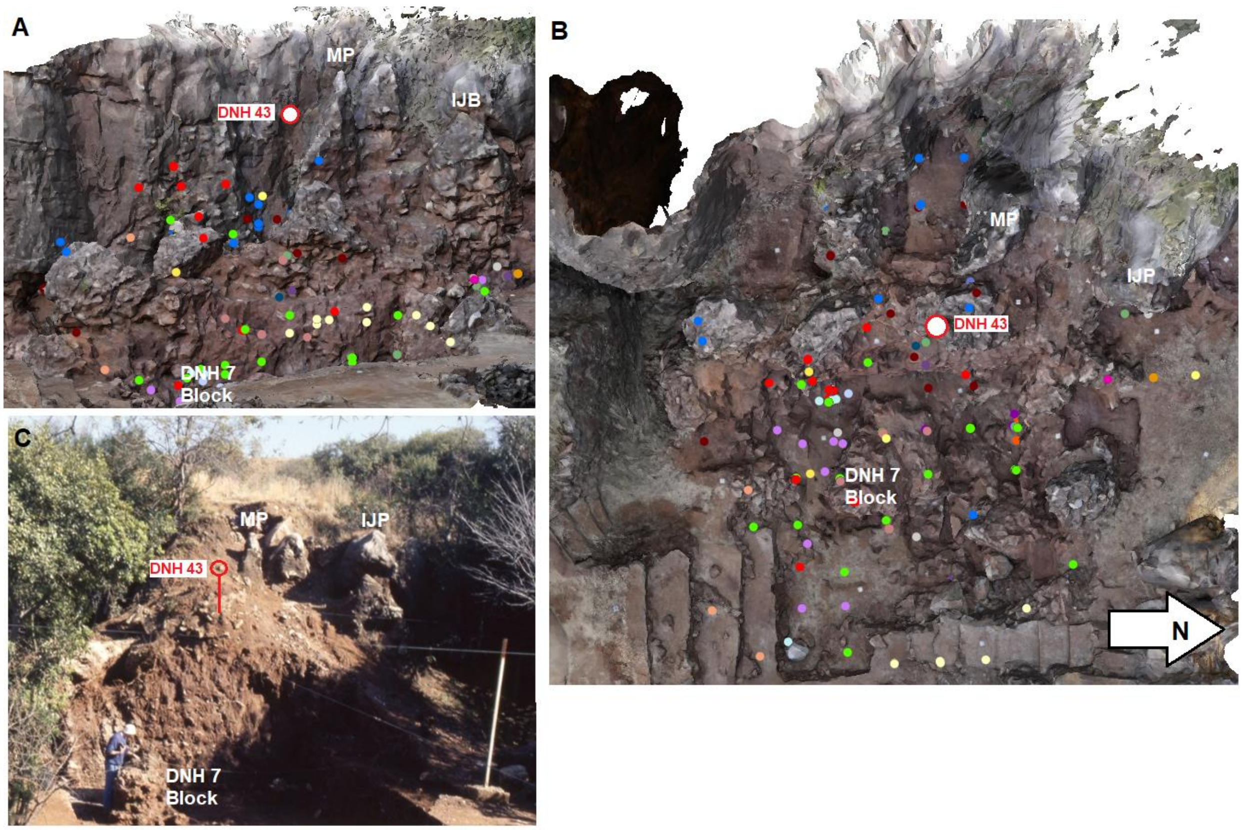
SUPPLEMENTAL INFORMATION

Further assessment of a ~2 million year old hominin pelvis (DNH 43) from Drimolen Main Quarry.

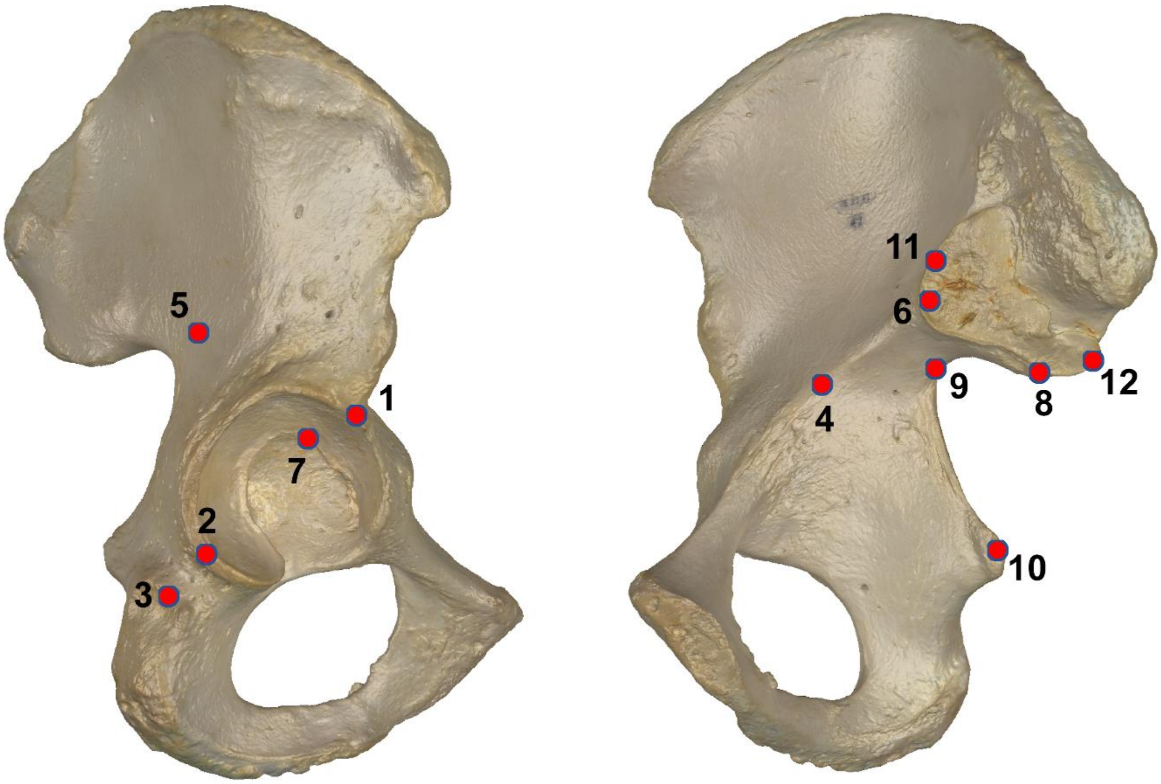


Supplemental Figure 1: Location of the DNH 43 fossil block: A.) GIS data overlain on photogrammetry model looking west; B) plan view; and C). Projected location (circle) based on a 1997 photo from DMQ looking west. The location of major pinnacles described by Supplemental Reference[1] are shown: Marcel Pinnacle (MP), Italian Job Pinnacle (IJP), & DNH 7 Block.

Supplemental Table 1: Measurements definitions

Measurement	Element	Description/Landmarks[1]
Anteroposterior dimension of sacral plateau	Sacrum	Maximum anteroposterior dimension
Mediolateral dimension of sacral plateau	Sacrum	Maximum mediolateral dimension
Superoinferior Acetabular Diameter (AD)	Os coxae	Landmarks 1 → 2
Tuberoacetabular Sulcus Width (TAS)	Os coxae	Landmarks 2 → 3
Acetabulosacral Buttress Thickness (ASBT)	Os coxae	Landmarks 4 → 5
Acetabulosacral Load Arm (ASLA)	Os coxae	Landmarks 6 → 7
Greater Sciatic Notch Angle	Os coxae	Landmarks 8 → 9 → 10
Greater Sciatic Notch Proportions	Os coxae	Relative posterior-positioning of the notch apex quantified as the length of segment defined by landmark 8 and the projection of landmark 9 onto segment 8 → 10 and divided by length of 8 → 10
Auricular Surface Breadth (AUR)	Os coxae	Landmarks 11 → 12
Pelvic inlet mediolateral breadth	Articulated reconstruction	Maximum mediolateral distance across the pelvic inlet taken on the arcuate line
Biacetabular breadth	Articulated reconstruction	Mediolateral distance between the centers of the left and right acetabula
Bispinous breadth	Articulated reconstruction	Mediolateral distance between the left and right ischial spines (midplane obstetric dimension)
Pelvic Incidence (PI)	Articulated reconstruction	Verticality of the sacrum following Ref. (21)

[1] Landmark numbers refer to those shown in Supplemental Figure 2



Supplemental Figure 2: *Homo sapiens* os coxae demonstrating the landmarks used for measurements (see Table 1 for definitions of the measurements).

Supplemental Table 2. Measurements for individual specimens

Taxon/Group	Specimen	Sacral Plateau AP	Sacral Plateau ML	AD	TAS	ASBT	ASLA	SNA	SNP	AUR	Source[a]
DNH 43	DNH43	16.6	29.3	41.1	13.2	16.6	46.8	87.3	0.48	31.2	1
Australopithecus afarensis	AL288-1	16.6	31.1	36.8	18.6	14.8	45.3	85.9	0.25	29.9	2
Australopithecus africanus	STS 14	14.6	24.6	39.5	16.4	14.4	38.7	95.6	0.28	27.3	3
Australopithecus africanus	STW 431	18.0	32.5								1
Australopithecus africanus	STS 65					16.4	45.2			23.2	4
Australopithecus sediba	MH1			37.8		18.6	43.0			31.1	5
Australopithecus sediba	MH2			40.7	9.5	17.2	37.0			33.7	5
Early Homo *sapiens*	Omo-Kibish 1			58.3	10.1		64.6	81.8	0.34	52.0	4
Early *Homo sapiens*	Skuhl IV			60.3	12.1	24.0	44.8	80.4	0.48	39.4	2
Recent *H. sapiens* Female	Maxwell Museum 127	24.2	40.7	50.6	12.3	23.0	45.2	76.0	0.48	54.6	1
Recent *H. sapiens* Female	Maxwell Museum 216	27.5	40.6	51.4	12.9	21.2	50.3	88.0	0.46	51.9	1
Recent *H. sapiens* Female	Maxwell Museum 220			51.0	17.0	17.5	53.7	85.0	0.41	52.0	1
Recent *H. sapiens* Female	Maxwell Museum 223			55.7	17.6	24.8	45.4	75.8	0.27	57.1	1
Recent *H. sapiens* Female	Maxwell Museum 224	38.3	45.4	57.5	16.1	26.9	53.3	77.6	0.28	61.9	1
Recent *H. sapiens* Female	Maxwell Museum 230	26.8	40.6	48.3	12.3	20.6	48.6	81.9	0.36	52.0	1
Recent *H. sapiens* Female	Maxwell Museum 242	34.0	50.3	61.7	21.7	20.9	61.2	78.4	0.37	63.5	1
Recent *H. sapiens* Female	Maxwell Museum 257	32.6	48.2	50.6	17.5	21.3	51.9	86.4	0.31	51.3	1
Recent *H. sapiens* Female	Maxwell Museum 259	30.4	43.1	53.4	17.0	22.3	49.4	75.0	0.31	54.7	1
Recent *H. sapiens* Female	Maxwell Museum 261	29.8	43.0	53.8	11.2	21.8	52.9	80.5	0.47	60.7	1
Recent *H. sapiens* Female	Maxwell Museum 267			49.9	12.7	17.8	55.8	79.6	0.34	51.6	1
Recent *H. sapiens* Female	Maxwell Museum 269	27.6	41.9	50.8	14.1	22.9	53.9	93.9	0.36	47.8	1
Recent *H. sapiens* Female	Maxwell Museum 272			49.6	12.6	18.0	64.2	86.4	0.52	46.4	1
Recent *H. sapiens* Male	Maxwell Museum 42	29.4	45.1	50.9	12.2	20.0	48.9	70.1	0.16	48.5	1
Recent *H. sapiens* Male	Maxwell Museum 227	33.4	49.7	58.8	15.7	25.7	46.7	61.2	0.19	58.1	1
Recent *H. sapiens* Male	Maxwell Museum 228	34.3	44.8	54.3	21.7	22.9	56.9	69.9	0.12	57.1	1
Recent *H. sapiens* Male	Maxwell Museum 232	32.5	53.7	54.0	19.1	26.3	52.2	66.5	0.39	57.5	1
Recent *H. sapiens* Male	Maxwell Museum 234	32.6	50.3	56.4	21.2	30.6	41.3	71.1	0.16	58.2	1
Recent *H. sapiens* Male	Maxwell Museum 238	29.5	47.1	54.2	13.5	25.1	46.4	70.4	0.28	56.7	1
Recent *H. sapiens* Male	Maxwell Museum 240	31.4	44.8	53.3	14.1	20.5	50.5	69.4	0.29	50.1	1

Recent *H. sapiens* Male	Maxwell Museum 245	30.2	53.4	57.8	15.1	25.6	60.0	72.6	0.45	57.6	1
Recent *H. sapiens* Male	Maxwell Museum 252			57.3	16.8	25.8	52.3	66.2	0.22	64.1	1
Recent *H. sapiens* Male	Maxwell Museum 256	34.4	59.1	65.0	22.1	24.7	54.9	59.4	0.13	65.8	1
Recent *H. sapiens* Male	Maxwell Museum 265	36.8	57.0	64.5	19.8	25.8	46.1	66.2	0.28	71.4	1
Recent *H. sapiens* Male	Maxwell Museum 268	34.1	47.7	52.4	19.9	24.2	47.9	69.5	0.21	56.6	1
Homo sp.	Arago XLIV			61.2	11.1	22.2	63.0			37.8	2
Homo sp.	Kabwe E.719			62.0	15.5	22.1	48.9	73.4	0.26	35.4	2
Homo sp.	KNM-ER 3228			55.3	10.6	24.1	50.1	73.5	0.35	35.6	6
Homo sp.	KNM-ER 5881						41.7				2
Homo sp.	KNM-WT 15000			57.3	9.3	17.8	42.2	86.3	0.22	35.2	7
Homo sp.	OH28			54.9	14.3	19.1	50.4	84.0	0.36	43.9	7
Homo sp.	KNM-ER 1808					18.8	55.1				2
Neanderthal	Amud 1			59.7		20.7	55.6				2
Neanderthal	Kebara 2			56.5	10.0	24.2	50.7	60.7	0.19	34.0	2
Neanderthal	Krapina 207			53.6	11.8	17.6	45.2	73.6	0.22	31.1	6
Neanderthal	Neandertal 1			61.3	11.5	26.6	61.0	59.8	0.08	44.4	6
Neanderthal	Tabun				5.3						6
Homo floresiensis	LB1			36.0	15.9	18.5	39.1	81.0	0.44	41.0	7
Paranthropus robustus	SK3155b			38.8	16.1	14.6	41.9	84.5	0.49	31.8	1
Paranthropus robustus	SK50			38.0	24.2	18.0	52.9	80.7	0.51	46.1	1
Paranthropus robustus	TM1605					15.9	48.9				4

[a] Data sources (measured by authors on 3D polygon models generated using the following scanning methods unless literature citation provided) :

1 Artec Space Spider scan of original specimen

2 NextEngine scan of research-quality cast

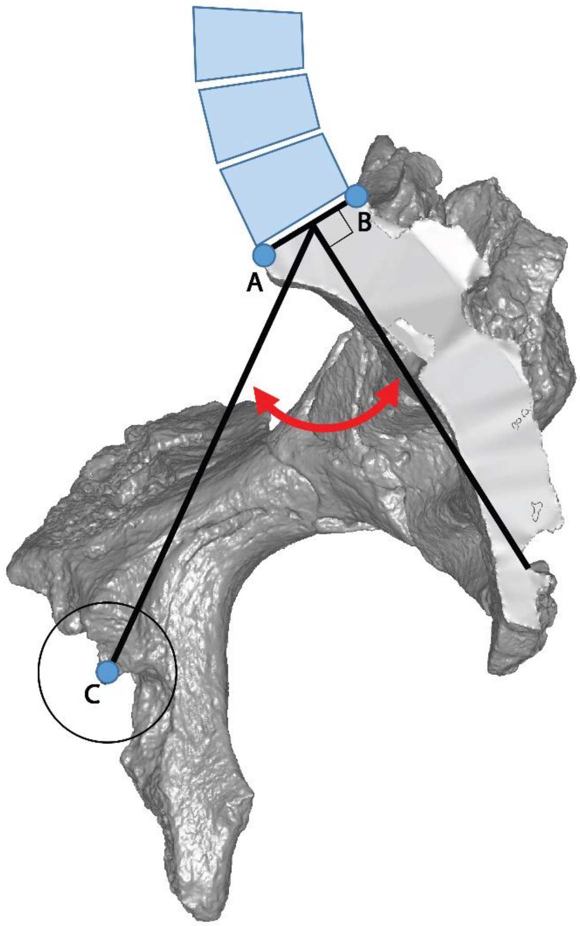
3 Konika-Minolta scan of original specimens

4 NextEngine scan of original specimen

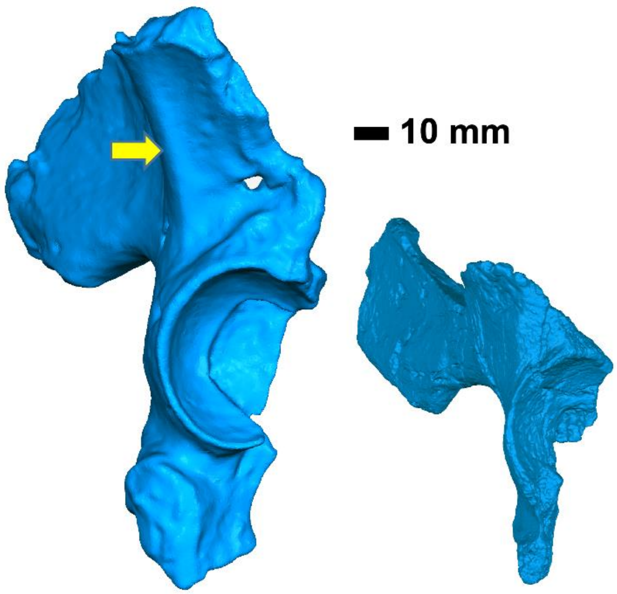
5 Measurements from Supplemental Reference[2]

6 Geomagic Capture scan of research-quality cast

7 Computed -tomography scan of original specimen



Supplemental Figure 3: Pelvic incidence (56°) measured in the partially-reconstructed and articulated DNH 43. The pelvis has been bisected sagitally for demonstration. The angle was measured following the 3D method from Supplemental Reference[3]. Landmarks A and B represent the anterior- and posterior-most points on the sacral plateau's sagittal midline. Landmark C represents the midpoint of a line segment that connects the centers of the right and left acetabular fossae. The pelvic incidence angle (red arrow) was then calculated as the angel between the orthogonal to line segment AB (which approximates the orientation of the sacrum) and line segment AC. The blue boxes represent an approximate reconstruction of the inferred positioning of the caudal three lumbar vertebrae in lordosis.



Supplemental Figure 4: Comparison of 3D polygon models of specimen OH 28 (left) versus DNH 43B (right). Note the much larger overall size and prominent acetabulocristal buttress (yellow arrow) in OH 28.

Supplemental References

1. Anonymised
2. Churchill SE, Kibii JM, Schmid P, Reed ND, Berger LR. The pelvis of *Australopithecus sediba*. PaleoAnthropology. 2018;2018:334-356. https://doi.org/10.4207/PA.2018.ART116
3. Peleg S, Dar G, Medlej B, Steinberg N, Masharawi Y, Latimer B, et al. Orientation of the human sacrum: anthropological perspectives and methodological approaches. Am J Phys Anthropol. 2007;133(3):967-77. https://doi.org/10.1002/ajpa.20599