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Supplementary Note 1: Description of skeletal elements

Because Lucy's epiphyses are fused, sutures of the cranium closed, and third molars erupted and in occlusion, it can be concluded that she had reached full skeletal and dental maturity at the time of her death. As with most fossil vertebrate remains, the majority of Lucy's skeletal elements show variable degrees of postmortem breakage and fracturing but are unusual in exhibiting only minor postmortem surface weathering and root markings and no certain carnivore damage. In many cases bone fragments can be refit perfectly to one another at break points but in others small to major portions of a particular element are damaged or were not recovered.

Humerus, right, head

The proximal portion of the right humerus (A.L. 288-1m) was described as "exploded by downward crushing of the head"[9:415]. Breakage of a skeletal element and the displacement of the fragments relative to one another ("exploded") is a common occurrence during fossilization. Once a bone is buried in sediment and becomes permineralized[35], if small fractures form, additional mineral growth (especially $CaCO_3$) can both propagate the fractures, thereby further separating the fragments and giving it an "exploded" appearance, with the mineral sometimes cementing the broken pieces together. However, in this case "exploded" is related to crushing by compression of the head into the shaft, and the condition seen in the right proximal humerus is identical to that produced by an impact following a fall[11-14,36-38]. When these head fragments were driven distally into the shaft with a slight posterior offset, the greater tuberosity was fractured into small fragments and displaced inferolaterally to rest at 45° to the shaft. With continued compression, a portion of the proximal shaft including the superior extent of the intertubercular groove and the lesser tuberosity along with the already shattered greater tuberosity were fractured away from the shaft and displaced inferolaterally, causing it to override the underlying shaft as a single fragment, thus creating an angled offset to the intertubercular groove (Fig. 1b, bottom; Extended Data Figs 1, 2 and Supplementary Video 1). High resolution CT scans show that the surface of the intact shaft immediately below this fragment experienced surface shear and was slightly ground down when it was overridden. Some of the bone fragments are tiny, and one sliver that was avulsed off of the surface of the articular head is less than 1 mm in breath and 5 mm in length; it was possible to accurately place it back on the head in the hollow from which it was fractured loose. A larger fragment was avulsed off of the posteroinferior aspect of the articular head and not recovered. This condition is sometimes seen in patients with severe trauma.

Humerus, right, midshaft

The right humerus was found as multiple segments with generally tight fits, and the two major segments conjoin near midshaft at a spiral fracture where a fragment of displaced cortical bone reveals how the shaft was fractured. This bone fragment is relatively large (~30x17 mm) and comprises 44% of shaft circumference (Fig. 1b, d) with its proximal apex ~111mm from the distal end. The fragment remains firmly cemented by matrix to the distal end of the proximal segment of the humerus and is anchored by a hinge fracture on the posterior surface of the shaft, with the fracture progressively opening along its posterior to anterior arc with 3 mm of vertical offset at its anteromedial margin. At first inspection this fragment appears to be simply displaced and rotated into its current position on the proximal segment, and this is how it was originally described[9]. However, when the entire proximal humeral shaft segment is refit to the distal humeral segment at this fragment's sharp distal fracture edge, it becomes clear that it is actually the entire proximal humeral segment, not the small shaft fragment, which was first broken along the hinge fracture and displaced and rotated posteromedially against the major distal humeral segment. As this hinge fracture formed, continued displacement of the proximal segment acted to create the spiral fracture at the base of the bone fragment around the entire circumference of the shaft that separates the two major segments; the more proximal hinge fracture is clearly the first step in the formation of the spiral fracture. When the shaft broke, small flakes of bone at the sharp anterior edge of the spiral fracture that separates the two major shaft segments were fractured outward away from the edge of the break to form a rough elevated rim around the edge of the break. The fact that these small fragments are preserved in place suggests that the periosteum was in place around the edge of the spiral fracture when the break occurred.

Humerus, left

The left humerus (A.L. 288-1r) is complete but slightly damaged across its head region. The proximal portion of the shaft is badly damaged, displays numerous fractures, and is missing some bone around some of the fractures; a major portion of the diaphysis was not recovered. The distal segment (A.L. 288-1s) is largely complete and is one of the few elements of the skeleton to show some flaking of the surface bone[9]. Close inspection reveals the extent of the damage at the proximal end, and we hypothesize that it also preserves evidence of a compressive impact fracture. Although the original curvature of the articular surface is largely complete, the head was driven into the shaft in an inferomedial direction, fracturing the greater and lesser tuberosities and causing the head to slightly override the anatomical neck[9]. Major fracture lines are clearly visible around the entire inferior circumference of the articular head (Fig. 1e), with these fractures running from a sharp break at the edge of the anterior surface just medial to the lesser tuberosity to continue under the head along its medial aspect to join a fracture that runs along the posterior margin of the head, with these fractures depressing the head with ~2 mm of maximum offset. Fractures radiate across the superior surface of the greater tuberosity and course along its posterolateral edge to intersect the intertubercular groove at the top of the shaft, following a trace similar to the much more extensive fracture preserved on the right humerus that dislocated a portion of the shaft and intertubercular groove; numerous smaller fractures are found across the entire proximal extent of the head. As noted for right humerus, because all of the fracture edges are sharp, and many tiny bone fragments remain in position, it appears that the periosteum and joint capsule were intact at the time of the fracture and that this was a perimortem injury.

Radii and ulnae

Both right (A.L. 288-1p, -1q) and left (A.L. 288-1v) radii and right (A.L. 288-1n, -1o) and left (A.L. 288-1t, -1u) ulnae preserve shaft breakage patterns consistent with a fall onto outstretched arms, argued here to be the most likely scenario responsible for the humeral fractures. In particular, the transverse break of the right radius (A.L. 288-1q) at ~25 mm from its distal end (Fig. 1f) is described as "quite jagged"[9:422] and is identical to distal radius fractures resulting from a fall onto an outstretched arm[39]; however, without the missing intervening fragment of the proximal shaft, it is difficult to conclusively determine if it is a Colles' (dorsal) or Smith's (ventral) fracture, but the sharp edges of this fracture and the attached small bone fragments are highly suggestive of a perimortem fracture. Fractures near the proximal end of the right radius, and two closed fractures through the proximal shaft and trochlear notch of the right ulna are also suggestive of an impact following a fall, with trochlear notch fractures also seen in *Australopithecus sediba* (MH2)[7].

Pelvis

The pelvis, represented by a complete sacrum and complete left innominate, is damaged by crushing and distortion. The original description states:

"During fossilization, pressure was clearly applied upon the sacrum and innominate while still in articulation as the two fit very closely together, but the sacroiliac region of each has been distorted. The bones were prevented from translating by some resisting force, so that the innominate has been bent and fragmented around the point of application of that force."[9:423]

This damage has long complicated efforts to reconstruct the pelvis[40-41]. Instead of the action of fossilization processes, the pelvis appears to have been fractured by a compressive impact force that operated in an approximate coronal direction that slightly angled from right-anterior to left-posterior across the pelvis. This force compressed the sacrum into the left innominate and fractured both elements.

Sacrum

Compressive superoinferiorly-oriented fractures of the sacrum (A.L. 288-1an) course across its anterior and posterior surfaces (Fig. 1g, h) and are similar to those seen in modern patients with a sacral fracture[42]. The body of the first sacral element reveals multiple superoinferiorly-oriented fractures, both within the body and along its lateral margins at the alae. The most obvious fracture is slightly left lateral of the median sacral crest, and together with the other fractures impart an overall asymmetry to the sacrum. Several compressive fractures on both the right and left sides that involve both alae and the auricular surfaces are seen at the approximate level of sacral elements 2-4. Hinge fractures near the center of anterior surfaces of both auricular surfaces are anchored superiorly and open inferiorly, with posteromedial displacement on the right side, and anteromedial displacement at the base on the left. These fractures attest to how the sacrum was twisted and rotated as it fractured, and are largely responsible for the sacrum's left lateral asymmetry.

Innominate

The left innominate (A.L. 288-1ao) is damaged at several places and is similar to fracture patterns seen in modern patients with a fractured pelvis[17,43]. The medial portion of the anterior surface of the iliac fossa is compressively fractured, with this plane buckled anteriorly to form a broken ridge along a jagged inferosuperiorly-oriented line that lies slightly lateral to the auricular surface and extends in an arc from the inferior demiface, through the apex, past the superior demiface, and across the iliac blade to end at the superior crest of the ilium (Fig. 1g). As noted in the original description[9], it is clear that this damage was caused when the sacrum and the ilium were forcefully impacted against each other at the sacroiliac joint. However, the damage is most severe in the auricular and retroauricular regions and is most obvious in posterior view (Fig. 1h). This surface is fractured and bent posteriorly so that it is elevated to sit at ~70° angle to the iliac blade; interestingly, the anteromedial surface of the retroauricular region is nearly identical to the imprint of the auricular surface of the sacrum. It appears that the same compressive force that drove the sacrum deeply into the auricular surface of the ilium and fractured and buckled the anterior plane was forceful enough to dislocate and rotate the sacrum in a posterolateral direction, further driving it into the postauricular region, and fracturing this region and bending it backwards into its 70° angle to the iliac blade. It is likely that the strong iliosacral ligments acted to keep these elements in contact with one another during this impact event.

The pubic rami are broken and fractured (Fig. 1g). The superior pubic ramus is broken close to its root near the acetabulum, while the inferior ramus is fractured into four fragments near the junction with the ischial ramus, with these fragments dislocated in a posterolateral direction; one of these fractured fragments remains firmly cemented to the lateral edge of the posterior extent of the inferior ramus. It appears that a compressive force fractured the pubic rami. This overall pattern is similar to that seen in a people who suffer a severe pelvic fracture. As noted for the humeri, because bone fragments of the sacrum and innominate have sharp fracture edges and display no sign of healing, and numerous small bone fragments remain in contact with one another across the numerous fractures and lines of displacement, the evidence suggests that the periosteum retained its integrity and that this was a perimortem injury.

The original description of Lucy's pelvis noted a small depression on the superior surface of the superior pubis ramus just posterior to the pubic symphysis that was described as a "puncture mark," and a second "oval puncture defect" on the inferior aspect of the ischial tuberosity, with both of these marks "possibly the result of carnivore activity"[9:424]. The mark on the pubis more closely resembles a puncture mark while the defect on the ischial tuberosity is less clearly due to a puncture. If the body was scavenged shortly after death, it is highly unusual that only two isolated puncture marks widely separated from one another would be found on a relatively complete skeleton and in this region in particular, especially given that the limbs and thorax were likely available for consumption. If the skeleton was trampled, more markings and bone weathering should be present. Instead of an isolated carnivore tooth mark, it is possible that the depression on the pubis represents an impact mark produced when the body contacted a sharp object on the ground that pierced the flesh and punctured the bone.

Femur

Only the left femur (A.L. 288-1ap) was recovered and although it is in generally good condition, the shaft is broken into five segments and some fragments of the cortical shaft are missing. While the femur is nearly perfectly preserved in its first proximal segment, there are two subparallel basicervical and transcervical fractures in the neck (Fig. 1i, described in the body of the article) in a roughly parasagittal orientation, Their more open superior aspect acts to slightly offset the head in an inferior direction and suggests that the neck was fractured when a compressive force drove the acetabulum and femoral head against one another. These neck fractures may be related to other fractures that course through the entire extent of the acetabulum, with one that continues across the ilium.

The femur is severely damaged in its distal portion. Although the damaged fifth segment of the shaft was illustrated and described in detail[9], the condition and morphology of distal epiphysis and condyles was not discussed or illustrated. However, the distal femur and condyles were illustrated in the initial description of the fossil [1]. The original photograph shows that the medial condyle with an attached portion of the medial epicondyle, and the lateral condyle along with the lateral epicondyle with a small portion of the shaft just superior to this epicondyle were attached to the fifth distal shaft segment. At some point after the 1976[1] publication, the femoral condyles were separated from the fifth distal shaft segment, and they along with the anterior surface of the distal shaft were reconstructed; this is their condition when they CT scanned by us and also the condition of the shaft as illustrated in the 1982 publication[9]. However, because this region was reconstructed, it is not possible to use the CT scans to assess their exact condition at the time of discovery. Fortunately, the distal fragments were molded in what appears to be close to their original discovery configurations, and study casts were made widely available. It is important to note that close inspection of these casts reveals that a small trapezoidal-shaped fragment of the anterosuperior portion of the medial condyle's articular surface along with the central posterior portion of the intercondylar fossa are duplicated in the casts of the left and right condyles, making a precise anatomical refit between these two casts impossible. Additionally, it appears that the fractured fragments of the articular surface of the medial condyle were separated and then refit to one another, thereby closing the wide cracks that existed in its discovery configuration. Still, it is possible to use these casts to illustrate the basic discovery condition of the distal femur.

A close-up photograph of a plaster cast of the distal fifth shaft segment and the medial condyle, attached lateral condyle, lateral epicondyle, and shaft fragment (Fig. 1j) that removes the duplicated fragments noted above clearly illustrates the severity of the compressive damage at this joint. The description that follows is based on these casts. The articular surface of the lateral condyle is fractured to create a step along its mediolateral profile, with the majority of its fractured medial portion positioned more superiorly than its lateral portion. The edge of the step is oriented anteroposteriorly and is formed by two fragments of the lateral extreme of the articular surface that comprises the inferior edge of the popliteus sulcus. The step is 2-3 mm in height and protrudes inferiorly, forming an edge ~24 mm in length along the lateral extent of the shattered articular surface. The medial condyle and attached epicondyle were also shattered, and the large open cracks on its articular surface seen in early photographs (subsequently closed in the reconstruction) were perhaps widened by later postmortem mineral growths.

The severe damage at the distal femur reflects the manner in which the entire epiphysis was fractured, dislocated, and compressively driven into the distal shaft. Along the medial side, the anterodistal surface of the shaft overrides by 4 mm the anterior and superior portion of the medial condyle in the region where the articular surface was driven into the trabecular bone of the distal shaft. The shaft override continues laterally to midline to the point where the medial articular surface joins the lateral articular surface to form the base of the patellar surface (with the semilunar area located posterior to this point) and decreases to ~1.5 mm in height; however, this is the region where the surface of the anterodistal shaft is depressed by almost 7 mm into the underlying trabeculae (see below) so the original override was clearly greater. Although the superior extent of the articular surface of the lateral condyle was also driven into the trabeculae, additional damage in this region involved the lateral condyle and epicondyle and a portion of the lateral shaft being fractured and compressively sheared superolaterally along the lateral edge of the shaft. The extent of the override and lateral shear are visible in Fig. 1j and especially in the left image of the stereo pair by the shadow cast by fractured edge around the anterodistal circumference of the shaft. The central portion of the anterodistal surface of the shaft preserves several small foramina just superior to its fractured edge but there is no evidence of the smooth superior central extent of patellar surface. A comparison with A.L. 129-1a, a right distal femur of approximately the same size, reveals multiple foramina just superior to the superior ridge of its central patellar surface, and their distribution and patterning suggests that ~11 mm of the superior extent of Lucy's patellar surface was driven under the shaft and into the trabeculae by compressive fracturing.

As noted in the original description, there is a "marked depression"[9:427] on the central portion of the anterodistal shaft that lies above the inferior edge of the fractured shaft (Fig. 1j). The shaft was fractured into multiple fragments and crushed into the underlying trabecular bone, and the original description states that the origin of the depression is "unknown" but occurred "prior to fossilization"[9:427]. As noted above, this region of the original fossil was reconstructed by separating these fragments and repositioning them to remove the depression and so the following description is based on the cast replica that was made prior to this reconstruction. The depression is asymmetrical in both its inferosuperior and mediolateral dimensions. The deepest portion of the depression is centrally located at the base of the fractured shaft and shallows superiorly, while the medial surface of the depression is less steeply inclined than the lateral surface, with the fractured edge of the lateral patellar lip found lateral to the edge of the depression. Although no patellae were recovered for Lucy, this asymmetrical contour is similar to that of the posterior articular surface of a modern human patella, with the less steeply inclined surface resembling the medial facet, the more steeply inclined surface the lateral facet, and the deep central depression the convexly rounded ridge that separates these two facets. The patella translates superiorly through the patellar surface as the leg extends, and it appears that the patella was located near the top of the patellar groove with the leg nearly fully extended or hyperextended when a second impact on the anterior surface occurred; this secondary impact appears to have driven the patella into the shaft, splintering and driving bone fragments into the underlying trabecular bone to form the depression. As noted above, it is likely that the superior portion of the patellar surface that is not visible was overridden by this portion of the shaft, and the anteroposteriorly-directed force of the patellar impact forced the shaft into this underlying surface to further follow its contour.

As described in the body of the article, we hypothesize that the compressive fractures seen at both the femoral neck and distal femur are related and were produced when the foot impacted the ground following a fall. The compressive force acted along the long axis of the leg and impacted the proximal tibial condyles against distal femoral condyles. This impact shattered the articular surfaces of the femoral condyles and was so forceful that it dislocated, separated, and drove the entire femoral epiphysis into the distal shaft in a superoposterior direction with the anterodistal shaft overriding the epiphysis by greater than 11 mm. This orientation suggests that the leg was hyperextended at the knee during impact. The knee's bicondylar angle perhaps served to concentrate greater force on the lateral side so that the lateral condyle and epicondyle and a fragment of the lateral shaft were sheared and dislocated superolaterally in a slightly posterior direction along the lateral edge of the shaft. The slightly angled offset between the distal fifth and more proximal fourth shaft segments might also reflect this compressive fracturing; these segments were also separated from one another during the reconstruction and the shaft straightened. It is interesting to note that the rounded contour at the contact between the anterior margin of the medial condyle's articular surface and the shaft overhang offers a close match to the rounded profile of the anterior portion of the tibia's medial condyle. Furthermore, the edge of the tibia's lateral condyle resembles the indentation between this contour and the edge of the lateral femoral condyle's fracture surface demarcated by the "step" described above. The tibial plateau appears to have acted as a "punch" in a manner similar to how the glenoid acted as an anvil at the humeral head[12]: as the proximal surface of the tibia was compressed into the femoral epiphysis, it drove the medial condyle, patellar surface, and lateral condyle into the trabeculae of the distal shaft, and sheared and dislocated the lateral condyle superoposteriorly, leaving an imprint of its surface on the distal femoral epiphysis. We tested this fit by printing out the right proximal tibia (A.L. 288-1aq) mirrored as a left, and its 3D shape matches the contour and dimensions of the indentation on the femoral epiphysis and further shows that the femur twisted to the right during the impact. The impact also apparently produced basicervical and transcervical fractures in the femoral neck when the femoral head and acetabulum impacted one another. Finally, the contrast between the superiorly-directed force hypothesized to have produced the epiphyseal dislocation and compressive fracture versus the anteroposteriorly-directed force hypothesized to have produced the depression on the central anterodistal surface of the shaft just superior to the patellar surface suggests that these fractures represent separate events. The geometry of the depression leads us to hypothesize that it was produced by the patella being impacted into the shaft in an anteroposterior direction when the leg was nearly fully extended or hyperextended and the patella was at the superior-most extent of its excursion, probably as the result of a secondary impact when the knee later impacted the ground. Together this evidence strongly suggests that the pelvis, femur, patella, and tibia were articulated at the time of impact and that this compressive damage occurred perimortem, not postmortem. As noted for the other skeletal elements described here, the femoral shaft segments preserve tiny fragments of bone in their original fractured positions which suggest that the periosteum and joint capsules were intact when the injury occurred; the fact that these fragments retain sharp fracture edges points to an absence of healing and thus offers additional support to the idea that this was a perimortem injury. The damage to the right tibia described below is similar to what we would predict to find in the left tibia if it is ever discovered.

Tibia

The right tibia is represented by proximal (A.L. 288-1aq) and distal (A.L. 288-1ar) segments but is missing its diaphysis. At first inspection the proximal tibia segment appears relatively complete but it displays several fractures that were described in detail and assumed to result from fossilization processes[9]. However, these fractures appear to have been caused by compressive fracturing along the long axis of the shaft produced by an impact following a fall and match clinical descriptions of a tibial plateau fracture[44,45]. Given the fractured state of the left distal femur, the state of the right tibia is what we would hypothesize to be the approximate condition of the left proximal tibia if it is ever discovered. Both tibial condyles are fractured, and a prominent fracture runs across the superior surface of the medial condyle anteromedially to end just lateral to the posterior intercondylar area near a superoinferiorly-oriented fracture on the medioposterior surface (Fig. 1k). The fracture on the superior surface of the medial condyle serves to depress its lateral surface inferiorly ~1 mm relative to its medial surface. This fracture communicates with a nearly horizontal transverse fracture on the anterior aspect of the tibia that lies just superior to the tibial tuberosity; on its anterolateral margin it joins an inferosuperiorly-oriented fracture that lies just lateral to the tibial tuberosity (Fig. 1l). The transverse fracture appears to follow the growth plate of the proximal tibia; in spite of the fact that the epiphysis was completely fused to the shaft, this may have been a naturally weak plane. Another fracture is present along the superior surface of the medial condyle at its medial anteroposterior edge. This fracture communicates with a roughly superoinferiorly-oriented fracture on the posterolateral surface. Together these fractures point to the fact that the majority of the tibial plateau was depressed inferolaterally, a point also made in the original description[9], to produce an unnatural angle and distinct valgus set to the shaft that adds ~5° to the average 15° bicondylar angle for *Australopithecus afarensis*[46]. The distinct compressively-induced valgus set of A.L. 288-1 is in sharp contrast to the similarly-sized but undamaged A.L.129-1b proximal tibia that does not have this shaft offset. It appears that the knee's bicondylar angle appears to have concentrated greater force on the lateral side, creating a fracture pattern that depressed the tibial plateau on its lateral edge.

The distal segment of the right tibia is estimated to represent one fourth of the shaft and preserves the entire articular surface for the talus along with the medial malleolus[9]. The superior end of this shaft segment preserves evidence of a compressive spiral fracture (Fig. 1m) that in many respects is similar to the midshaft spiral fracture on the right humerus described above. Preserved within this spiral fracture on its posterior aspect is one large flake ~16x11 mm and several smaller flakes that show sharp fractures around their perimeters (Fig. 1m). The shaft was compressively fractured at this point, with the large flake dislodged and driven distally into the shaft, elevating its medial edge and depressing its lateral edge, and fracturing and dislodging several smaller flakes along its inferior edge. Just medial to this large flake is another bone flake that was also dislodged from the shaft and driven into the medullary canal. Together the orientations of these flakes indicate that as the shaft was compressively fractured along its long axis, a torque caused it to buckle and rotate, and it was this combined action that drove the small bone fragments into the medullary canal as the shaft was spirally fractured. Many of these bone fragments are tiny, with some only a few mms in size, and they are preserved at the site of the fracture. As with the other fractures described above, it again appears that the periosteum was in place when this fracture occurred; if the fracture occurred after the periosteum had decomposed, it is likely that these fragment would have been lost. Additional evidence for a perimortem fracture is found in the fact that there is no evidence of healing along any of the sharp fracture edges.

The distal segment of the tibia preserves numerous fractures, and three major features along with a fracture in the talus offer additional information about how the lower limb was fractured (Fig. 1n). A fracture is oriented anteroposteriorly on the lateral edge of the talar joint surface and begins inferiorly at its posterior edge and runs along the trochlear ridge for the talus; it widens as it passes superiorly onto the anterior surface of the shaft, narrows as it curves anterolaterally around and above the fibular notch, and again expands into a wide inferosuperiorly-oriented fracture on the lateral side of the shaft as it continues to the superior end of the segment. A medial fracture is found along the junction between the medial edge of the talar articular surface and the medial malleolus and is oriented subparallel to the lateral fracture; it continues superiorly onto the posterior surface of the tibia to pass through the malleolar groove and then narrows and ends; as the fracture passes onto the anterior surface, it, like the lateral fracture, widens as it passes superiorly on the lateral side of the medial malleolus, jags slightly posteriorly, and then again widens as it follows a superior course along the medial side of the tibia to continue to the end of the segment. These two fractures are intersected at their distal extent by a mediolaterally-oriented fracture on the anterior surface that lies superior to the articular surface and within a shallow depression that receives the talus when the foot is fully dorsiflexed. A third large inferosuperiorly-oriented fracture is found on the anterior surface of the distal shaft and is slightly lateral to midline. It begins slightly superior to the lateral fracture described above but widens and deepens along its superior length; the narrow anterior portion of the shaft between it and the inferosuperiorly-oriented fracture on the medial surface is fractured and depressed into the medullary canal. As noted for the other elements, nearly all of the small bone fragments are present with sharp edges and no sign of healing which again suggests that periosteum and joint capsule were intact and that the damage was perimortem and not due to postmortem fossilization processes.

Talus
The right talus (A.L. 288-1as) offers additional information for understanding the damage to the lower limb. At first glance it appears that the talus (Fig. 1o) has not suffered any damage but close inspection reveals that a hairline fracture runs through nearly the entire circumference of the neck, and this feature was noted in the original description[9]. The fracture begins near the superomedial edge of the neck and continues laterally across and around the neck to the inferior surface to end at the medial edge of the sulcus tali.

Fibula
A segment of the distal right fibula (A.L. 288-1at), 44 mm in length, is in perfect condition but shows a sharp transverse break at its superior end. This breakage pattern is frequently seen in many modern pilon fractures of the type described here for the distal tibia and talus and is consistent with the hypothesis that the fracture to the lower right limb was caused by an impact following a fall.

The fracture patterns preserved in the right tibia, talus, and fibula described above strongly suggest that the lower limb experienced a severe impact following a fall from considerable height[44,45,47,48]. At the time of impact, fracture patterns at the ankle suggest that the foot was dorsiflexed, thus bringing the talar neck into close contact with the anterodistal edge of the tibia, fracturing both the distal tibia and the neck of the talus[47,48] along with the fibula. This force apparently torqued the distal portion of the limb in an anteromedial direction as the body fell forward, probably toward the right side, and buckled and fractured the shaft thus creating a spiral fracture. The inferosuperiorly-oriented fractures on the distal shaft fragment were likely caused by some combination of the spiral shaft fracture and ankle fracture. This pilon facture pattern is witnessed in people who experience high-energy trauma to the lower limb that under natural conditions involves a fall from considerable height. Impact forces apparently drove the tibia into the distal femur, fracturing the tibial plateau, with greater forces operating on the lateral than medial side, similar to what it hypothesized for the left distal femur, with this greater lateral force likely a consequence of the high bicondylar angle seen in *Australopithecus afarensis*. The fracture of the tibial plateau matches that of patients who suffer a fall from height[44,45].

Cranium
The cranium is represented by nine fragments, several of which demonstrate fits across sharp fractures, with all but one showing sharp fracture edges around their entire perimeter. For example, three fragments connect to one another to form a portion of a biparieto-occipital vault fragment (A.L. 288-1a). A major longitudinal fracture runs approximately along midline and

branches anteriorly. These fractures generally have a gap of 1.0-1.5 mm along their external surface, while the endocranial edges demonstrate a somewhat tighter connection. The external gap was described as due to "erosion of opposing edges"[9:403] but it is possible that this gap formed when the posterior portion of the cranium fractured open along the longitudinal fracture, with these fragments bending outward along the fracture line and forming the gap when the external edges of the fractures impacted against one another. There is a small fragment of bone above inion on the right side of the fracture line that is slightly elevated above the surface by a hinge fracture on its lateral edge.

The second specimen (A.L. 288-1c/g) consists of two fragments that represent a portion of the biparietal fused to a portion of the frontal squama. These two segments join posteriorly and again show a tight fit along the fracture line on the endocranial surface but one wedge-shaped flake of bone is missing on the lateral margin of the fracture. The external contact is generally tight but somewhat more open along its central extent. The posterior segment preserves a hinge fracture at its posterolateral corner that elevates a still connected 20x11 mm fragment of bone 1.4 mm above the rest of the external surface and includes two tiny bone fragments several mm on edge at its lateral extent. This damage is described as "prefossilization" [9:406] without further comment. This fragment lies anterior to the biparieto-occipital vault fragment (A.L. 288-1a) described above and the outward bending fracture pattern hypothesized here is similar in both of these fragments. A third parietal fragment (A.L. 288-1b) has sharp edges around its perimeter and connects to A.L. 288-1c/g at a sharp break posteriorly at midline. A fourth parietal fragment (A.L. 288-1e) also shows sharp edges around its perimeter but does not join the other fragments.

The other two cranial specimens represent fragments of the frontal and zygomatic bones. The right frontal fragment (A.L. 288-1h) preserves a 20 mm long parasagittally-oriented fracture on its endocranial surface with 2 mm of vertical relief along its entire linear extent. This relief demonstrates that the central portion of the frontal immediately medial to the lateral edge of the orbit was fractured and displaced inferiorly. The vertical relief of the fracture line is sharp along its entire endocranial trace; however, the external surface of this bone is weathered and abraded, exposing a small window into the diploë above the orbit, and the abrasion removed evidence of the vertical offset even though the trace of the fracture remains visible.

The zygomatic bone (A.L. 288-1d) preserves a portion of the zygomaticotemporal suture; this suture is visible on its inferior surface but fracturing and weathering on its superior and medial surface makes it difficult to assess any potential fracture patterns. It seems likely that most of these cranial fractures described above, as is the case with the other fractured skeletal elements, occurred perimortem because small fragments of bone remain in place along the fracture lines, suggesting that the pericranium was intact, and there is no evidence of any healing along the shape fracture edges. These fractured cranial fragments offer evidence that is consistent with an impact[49].

Mandible

The mandible (A.L. 288-1i, -1j, -1k) is represented by "about ten fragments" [9:410]. The fits between fractured edges appear to be generally tight where preserved but because the mandible has been reconstructed, some of these conjoins are difficult to see since they are obscured by repair and binding materials. Still, most of the visible breaks are sharp and in spite of extensive fracturing, the mandible displays minimal distortion. Major fractures are found at the symphysis and parasymphysis, body, angle, ramus, and subcondylar region, and these fractures are clearly visible in the CT scans (Extended Data Figs 3, 4, and Supplementary Videos 2, 3).

On the right side, the angle, coronoid process, and a portion of the ramus are missing, and the subcondyle with condyle was found as a separate fragment (A.L. 288-1k) but shares a contact with the ramus; the left subcondyle with condyle was also found as a separate fragment (A.L. 288-1j), and the left coronoid, while largely absent, is represented by a small portion of its base. The angle and ramus are badly fractured on the left side but share a contact with the subcondyle. The body is relatively more complete on the right than left and includes rooted and complete p3-m3. The left body is more severely damaged overall, especially around m2-m3 where only portions of their alveoli are present; this damage is somewhat less severe mesially with the roots of p4-m1 present but the p4 is missing its crown. The left p3 and left m3 are isolated and there are two fragments of the left m1. Fractures are especially obvious in the region around the symphysis. The central incisors are broken near crown level and only their roots remain; the root of the left i2 is fractured along its vertical axis and is also missing its crown, and the right i2 is missing entirely. Both canines are missing. Two major fractures run through the entire mandible in the parasymphyseal region, with one fracture located at the mesial edge of the right canine alveolus, and the second at the mesial edge of the left p3 alveolus. These two major fractures converge on the lingual surface of the symphysis near the transverse torus; the region around the inferior portion of the torus presents multiple accessory fractures and this portion of the torus is broken and was not recovered. A large plate of bone on the buccal surface of the left canine/p3 is missing and the alveoli are completely exposed nearly all of the way to the bottom of their sockets. Immediately distal to this area is a fragment of bone on the buccal surface superior to the left mental foramen that also forms the alveolar wall of the p3/p4. This fragment remains largely in place but displays a small hinge fracture that opens superiorly along its buccodistal edge, with ~1 mm offset across the fracture line with the plate of bone that forms the buccal alveolar wall of the m1. The alveolus of the right canine is also exposed. It appears that when parasymphyseal region was fractured, the plates of bone that form the buccal walls of the alveoli of the right canine and right i2, and left i2, left canine, and left p3, were broken loose, perhaps taking these all of these teeth with them, and breaking loose the crowns of the right i1 and left i1-i2; when the large buccal plate of bone on the left was broken loose, it dislodged the small p4 buccal fragment and created the hinge fracture.

Mandibular fractures of the symphyseal or parasymphyseal region often result from falls that impact the chin[50,51]. This fracture is referred to as a guardsman (parade ground) fracture and commonly occurs as a fall from standing height. It often presents concomitant fractures at one or both condyles as well as other parts of the mandible. For example, if the impact against the chin is severe enough, the force drives the mandible posteriorly, fracturing the condyle, and bilateral condylar or subcondylar fractures are common, with this type known as a tripartite guardsman fracture. In Lucy's case, the fact that the parasymphyseal region is fractured across the right canine to left canine/p3, and left body is more severely damaged than the right, suggests that the fracture was caused by an impact with the major point of contact slightly left of center; it is hypothesized that the impact was sufficiently strong to produce bilateral subcondylar fractures, and both the left and right condyles were found as separate fragments. Small closed fractures are seen in the right condyle (Extended Data Figs 3, 4, and Supplementary Videos 2, 3). It is important to point out that both of Lucy's coronoid processes are missing, and in a severe guardsman fracture the temporalis muscles often retracts the fractured coronoid processes when the condyle or subcondyle is fractured. It is common for the body of the mandible to also be fractured during a severe impact, and the hypothesized impact slightly to the left of center appears to be responsible for the more severe damage to the left body. Given the fresh and sharp nature of the breaks, with some of these being hinge fractures, and the fact that small fragments of bone were preserved in place with no sign of healing, it appears that this was a perimortem injury. This fracture pattern is consistent with an injury resulting from a fall. See Extended Data Figs 3, 4, and Supplementary Videos 2, 3.

Thorax

Lucy is one of the few early hominins that preserves a complete first rib, rib fragments, a portion of the clavicle, and several vertebrae and vertebral fragments. Nearly all of these fragments present sharp breaks on their fractured edges and some preserve partial or hinge fractures.

First rib

The first rib (A.L. 288-1ax) displays a transverse hinge fracture that opens superiorly and lies just medial to the tubercle to form an inferiorly-oriented angle of nearly 60° between the neck and the body, along with a second set of closed fractures across the middle portion of the body. Because this element is so well protected, a fracture of the first rib ranks as the most uncommon rib fracture. Considerable force is required to fracture the first rib, and its fracture is "a hallmark of severe trauma"[52] that portends critical clinical challenges because it is often associated with massive abdominal, chest, and cardiac injuries accompanied by high mortality rates[52,53]. The closed fractures of the midbody of the first rib are positioned below the point where contact with the shaft of the clavicle would occur when the scapula is retracted and depressed. We hypothesize that when the scapula was retracted and depressed by the impact between the arm and the ground, the clavicle was depressed into the first rib, fracturing the rarely fractured first rib including the closed midbody fractures and the hinge fracture with its inferiorly-oriented angle near the neck. This impact likely also fractured the clavicle (A.L. 288-1bz, see below).

The remaining ribs all display sharp, fresh fracture edges, and some (*e.g.*, A.L. 288-1bf, -1bd, -1bb, -1au, -1be, -1bq, -1bt, -1bh, -1bl, -1bt, -1bo, -1bm) show hinge fractures. Richardson *et al.*[52] found that 78% of the patients with a first rib fracture also suffered fractures of other ribs, and 75% had a fracture of a non-rib element, often represented by multiple fractures of the upper and lower extremities, with 18% having a fractured pelvis. Chest wall damage as represented by fractured ribs is commonly associated with a severe impact following a fall from height, and these fractures are consistent with a vertical deceleration event.

Clavicle

The fragment of the right clavicle (A.L. 288-1bz) is ~25 mm in length and represents about one-third of the lateral shaft with has sharp breaks on both ends[9]. Fractures of the clavicle are commonly caused by direct blunt trauma blows, and in one study falls are the second most common cause after vehicular accidents[54]. This fracture pattern is consistent with an impact following a fall and appears to have been caused when the clavicle was impacted against and fractured the first rib (see above).

Vertebrae

Several relatively complete and partial vertebrae are preserved. Many of vertebrae display fractures in their bodies and neural arches and were found as separate fragments with refits (*e.g.*, A.L. 288-1ae and -1ah; A.L. 288-1ag and -1aj; and A.L. 288-1aa, -1ak, and -1al) and there is also an isolated body (A.L. 288-1af), spinous process (A.L. 288-1ab), and neural arch A.L. 288-1ai), with a second neural arch (A.L. 288-1am, shown in Fig. 1a) now believed to belong to a baboon[55]. A probable third lumbar vertebra comprised of three fragments, the body, arch, and spine (A.L. 288-1aa, -1ak, -1al), show tight fits to one another with only minor fragments of missing bone. The body of this vertebra displays multiple fractures of the body that are oriented in the parasagittal plane and demonstrate a fracture pattern that is consistent with an impact following a fall[56].

Supplementary Note 2: 3D reconstruction and video of compressive and spiral fractures of right humerus

Lucy's right humerus offers a textbook example of a valgus impacted head-splitting four-part proximal fracture[11-14,36-38]. In order to reconstruct the injury, we completed hires CT scans to image the humerus and scapula (see Methods and Extended Data Table 1). A small portion of the inferior aspect of the articular head and neck on the medial side of the right humerus escaped damage, and this portion of the head along with a the less damaged left proximal humerus (see above) mirrored as a right were aligned to one another at these points to effect the reconstruction. The CT scan of the shattered proximal right humerus (Figs. 1b, c) was first digitally segmented into nearly 30 distinct fragments (Extended Data Figs 1, 2), and the fragments were then moved back into their original positions; most of the fragments were simply fractured apart from one another with sharp breaks that demonstrate tight refits in the reconstruction. The diaphyseal shaft fragment was repositioned from its hinge fracture across its elevated displacement from the proximal shaft fragment, and the proximal and distal shaft fragments were then repositioned relative to one another along the circumference of the spiral fracture.

Given that the largest fragment of the articular head retained ~62% of its original curvature, it is probable that the head remained articulated with the undamaged glenoid during the majority of the compressive impact event. In order to digitally recreate the injury, the glenoid of the scapula was positioned on the reconstructed articular surface, and the fractured fragments along with the spiral midshaft fracture were animated with keyframing to return them to their post-injury positions in order to illustrate the progression, relative timing, and extent of the compressive impact. It appears that the same impact force that operated on the outstretched arm and compressively fractured the proximal end of the right humerus also broke the shaft at the midshaft hinge and spiral fractures, causing the proximal segment to bend and rotate posteromedially.

As seen in the 3D reconstruction (Extended Data Figs 1, 2 and Supplementary Video 1), a small portion of the articular surface at its posteromedial margin was likely avulsed from the head and dislocated, just as witnessed in some modern cases[57]. This fragment was not recovered. Lucy had robustly built limb bones[58] so the severity of this fracture was not due to weakened humeral shaft cortical bone. Under natural conditions, the majority of these sorts of injuries are due to severe impact trauma following a fall from considerable height. Unconscious or inebriated persons do generally suffer this sort of fracture from a fall because the arms are limp when the body impacts the ground. Of course, unnatural conditions such as vehicular or industrial accidents can also produce high compressive forces that fracture the proximal humerus in a manner similar to that of an impact following a fall from considerable height.

Supplementary Note 3: Postmortem burial

Whether or not the discovery site is also the general area where Lucy died has not been conclusively established and, because the sandstone unit was fully processed and screened for bone fragments[1,59], it might no longer be possible to evaluate this point. However, given the relative completeness of the skeleton and representation of portions of each limb, the fact that there is little sign of bone weathering or carnivore damage, no rodent gnawing, and the observation that bone fragments are often tiny, are cemented in place near their fractures sites, and preserve sharp fracture edges with no sign of healing, it appears that the body experienced minimal transport or disturbance and was rapidly buried in the crevasse splay channel (see below), perhaps close to the death site, before the periosteum and joint capsules had decayed. The thickness of 0.5 m for this crevasse splay sandstone unit[24] suggests that it was deposited by a shallow channel with insufficient vertical relief to have caused the severe compressive fractures seen in Lucy's skeleton if she had tumbled down its cut bank. Fine plant root etchings appear to be present on the right humerus (Fig. 1b, c) which suggests that the channel ceased to be active and was vegetated shortly after the body was buried but while the bone was still relatively fresh. These root etchings appear to postdate the fractures.

Supplementary Note 4: Alternative scenarios for the compressive impact fractures

Postmortem damage

It is important to consider whether the compressive impact event apparently responsible for the damage to the humeri and other elements could have occurred postmortem. Given the fact that the largest fragment of the right humeral articular surface retains ~62% of its curved profile (Fig. 1b, c, Extended Data Figs 1, 2, and Supplementary Video 1), and the left head is largely complete (Fig. 1e), it seems highly unlikely that these heads were impacted by a hard object, for example, an animal hoof, rock, or branch, when isolated and exposed on the surface of the ground, or after burial in the sediments, because anything other than an exact match to the convex curvature of the head would have likely flattened, scarred, or destroyed the articular surfaces. Even if the damage was caused postmortem, its recreation as modeled above in the 3D video strongly suggests that the impact fracture was caused by contact between the concave surface of the glenoid and the convex surface of the head, with the glenoid operating as an anvil[12]. If so, the humerus and scapula must have remained articulated with an intact joint capsule when they were compressively driven against one another, with the distal end of one of the two elements resting against or coming to rest against an immovable surface. Given the substantial cortical bone strength present in Lucy's humerus[58], a high force would be required to fracture the head, tuberosities, and shaft, and drive the fractured elements into the shaft. It seems highly unlikely that this event could have happened while the elements were simply lying on the surface of the ground. It also seems unlikely that this compressive fracture could have occurred when the elements were articulated and buried horizontally within the channel sediments because no soil process is known to operate so powerfully in this manner; if positioned vertically so that the process was driven by compaction, the two elements would again have to have retained their exact anatomical positions relative to one another with the joint capsule intact, but it seems highly unlikely that soil compaction could have created the high force necessary to produce such severe compression.

The fact that evidence of a compressive fracture is also present on the left proximal humerus serves to make this unlikely scenario of postmortem damage even more improbable. If this damage occurred postmortem as a result of either of an impact while the element was laying on the ground or by soil compaction, both described above in hypothetical scenarios for the right humerus, the even more completely preserved curved surface of the left head would also have likely been flattened, scarred, or destroyed if it was not articulated with the scapula. If the humerus and scapula remained articulated as would seem necessary in order to retain the nearly complete curvature of the left humeral articular surface, the left side would have had to have remained in the same orientation as the right side; it seems highly improbable for this event to have happened to both proximal humeri in exactly the same manner albeit at lower force on the left if they were both isolated from the body. It seems highly improbable that a postmortem process would so exactly mimic the damage preserved in the humerus to match that seen in a person who suffers a fall on outstretched arms, especially with this facture pattern so extensively documented in the clinical literature. We hypothesize that a fall from considerable height with an impact on outstretched arms is the most probable explanation for these fractures.

Given that compressive fractures oriented along the long axis of the bones are also seen in many other skeletal elements (*e.g.*, right ankle, right knee, left knee, and left hip) and appear to have occurred when they too were articulated with the joint capsules, periosteum, and ligaments all apparently intact (*e.g.*, left sacroiliac joint), alternative postmortem scenarios similar to the ones outlined above for the upper extremity would have to be constructed in order to account for these multiple fracture occurring on isolated bones. Again, given the consistency between these fracture patterns and those witnessed in the clinical literature for victims who experienced a vertical deceleration event, postmortem non-fall impact scenarios (discussed below), while possible, appear to be highly improbable.

Seizure-generated fractures

There are documented instances of antemortem and perimortem injuries resulting from electrocution, electroconvulsive therapy, and epileptic or other seizures as a consequence of violent tetanic muscle contractions producing joint dislocations and even fractures[60-63]. These fractures usually occur at a single site, are rarely bilateral, and even more rarely include several different joints[64]; in the case of epileptics, the patient may be predisposed to fractures because of osteomalacia produced by anticovulsants[65]. Unlike the compressive fractures seen in Lucy's proximal humeri, humeral head fractures are usually produced by posterior and more rarely anterior dislocation[60,61]. In addition, in many instances it appears that it is the impact from a fall precipitated by the event that is responsible for the facture rather than the violent contraction itself [66,67]. For example, Barass *et al.* report two cases from Papua New Guinea of epileptics falling out of a tree after a seizure, with the adult dying, and the child suffering a fractured femur[68]. Although electrocution via a lightning strike, or even an epileptic or hypocalcemic seizure might possibly account for a single or small subset of the fractures preserved in Lucy's skeleton, it seems unlikely that they would create the compressive fractures seen in her skeleton, and highly improbable that violent tetanic muscle contractions could be the proximate cause accounting for the multiple fractures preserved at Lucy's numerous limb joints.

Body transport and blunt force trauma during floods

As noted above, Lucy's skeleton was recovered from a 0.5 m thick crevasse splay sandstone deposited by a small stream which suggested the possibility that the body "may have been transported as a floater"[69:380]. The movement of human bodies in water is complex and involves initial sinking and variable movement near or along the bottom of the channel followed by a general increase in buoyancy due to gas production as the body decomposes, and then potentially continued movement depending upon current flows and obstacles in the channel[70]. With additional time in the water, the body usually undergoes natural disarticulation beginning with the separation of the mandible, cranium, and hands, followed by the arms, neck, feet, and legs, with the torso, pelvis, and thighs usually remaining together[71]. The fact that Lucy's skeleton is represented by the skull (cranial fragments and mandible), portions of upper and lower limb elements including some small bones (a proximal hand phalanx, a capitate, talus, and intermediate and proximal foot phalanges), torso (vertebrae and ribs), and pelvis (left innominate and sacrum) strongly suggests that the body was not in the water long enough for skull and limb disarticulation to occur because even weak currents probably would have dispersed the elements once they were disarticulated. Similar cases are seen with the nearly complete Nariokotome skeleton[6] and the partial Woranso-Mille skeleton[5]. Given that Lucy's skeleton was initially recovered as a surface find that had eroded out of a sandstone bed, it is possible that the missing portions of the skeleton had eroded out in the years or decades before the discovery and were destroyed by trampling and surface weathering[59].

The suggestion that Lucy's body was not in the water long enough for skull and limb disarticulation and dispersal to have occurred also suggests that the body was unlikely to have experienced long distant transport, and we hypothesis that it is likely that the place of death was in proximity to the discovery site. However, it remains possible that Lucy's body entered the watershed in an upstream portion of the main river channel and was transported into the much smaller distributary channel to rest at its discovery site. There are cases of rivers transporting human bodies great distances, with one body moved 64-80 km from its point of entry to its discovery site eight months later, but such long distance transport usually results in natural disarticulation, and in this case the skull was separated from the body by about 3 m[72].

Body movement is both facilitated and hindered by flood waters, and especially a flash flood, because the higher volume and greater velocity of water create more potential for long distance transport, but the amount of debris and sediment washed into the channel often form choke points that can entangle or bury the body. In areas of highly seasonal rainfall in northwestern Ethiopia, river and stream channels often accumulate large amounts of plant debris including branches and tree trunks during the dry season that, during flood transport, form log and debris jams and dams[73]. When a body in a river or stream encounters moving or fixed obstacles, blunt force trauma can occur. For example, in 1976 the Big Thompson River located along the front range of the Rocky Mountains in Colorado flooded and killed 139 people[74]. This flash flood was a highly unusual and extreme event, and its magnitude was clearly related to both the intense rain storm over river's large catchment area and the river's steep, narrow canyon[75] with the peak flow estimated at 4-8X greater than the river's all-time record maximum[76]. Flood victims were whole or partly dismembered and fragmented, and injuries included "…multiple fractures, bodies ripped apart, [and] extremities torn from torsos…"[74:140]. The recovery of bodies and body parts was complicated by the fact that in some places the deposited silt was nearly 2 m in depth. A large amount and variety of debris including automobiles, trailers, campers, and man-made structures in addition to the river's usual bed load of cobbles and boulders were incorporated into and transported by the flood waters. The extreme degree of blunt force trauma was clearly due to collisions with and perhaps crushing by these moving and stationary objects. Collisions between bodies with objects that were also in transport would be less forceful than those with stationary objects, but in both cases it is likely that multiple impacts occurred before a body ceased movement. Maximum mean stream flow velocity during the height of the Big Thompson flood was estimated at about 7 m/sec [77], the equivalent of the speed reached when a body falls from a height of ~2.5 m (slightly less than a 1 story building; see Table 2 for the calculation method). After impacting a stationary object, a body in this particular flood could theoretically be reaccelerated to a maximum speed of 7 m/sec, so multiple impacts with stationary objects could mirror successive falls from a maximum height of 2.5 m. Even though natural ancient floods would not include man-made debris, and most floods do not reach the same high speed of the Big Thompson flood, blunt force trauma and dismemberment from collisions with and crushing by tree trunks or large boulders remains possible but the resulting dismemberment of body parts would likely result in their wide dispersal and impede their recovery. However, simple drowning is responsible for the majority of flash floods deaths, with one study reporting 93% from drownings and only 1% from trauma[78] so the probability of this scenario appears to be very low under normal circumstances.

Our interpretation of the compressive fractures in Lucy's limbs (see above) suggest that the arms were abducted and outstretched at the time of impact in order to create both the right humeral four-part proximal and spiral shaft fractures and the left humeral head fracture, and that the legs were extended in order to create the right ankle pilon fracture, the spiral fracture of the right tibial shaft, the right tibial plateau fracture, the left distal femoral epiphyseal fracture, and the fractures of the left femoral neck (see Table 1). Although the degree of high energy blunt force trauma required to produce injuries of this extent is certainly possible in an extreme flash flood, if this had happened to Lucy, it is likely that the injury pattern would have required successive high energy impacts but also likely that such high energies would have ripped the body apart and disarticulated, dismembered, and dispersed at least the head and limbs, just as seen with many of the victims of the Big Thompson flood. Given that a large proportion of Lucy's skeleton was found together at the discovery site, this scenario seems unlikely.

Injuries and fractures caused by animals

Humans are sometimes injured or killed by animals. Injuries are more common than death, and in the case of encounters with Yellowstone bison, blunt trauma occurs when the victim is shoved or butted by the animal's head or when the victim hits the ground after being tossed into the air, with some tosses about 3 m in height[79]. Fractures are dependent upon how the victim lands and have included wrist (Colles'), arm, ribs, pelvis, scapula, orbital rim, and transverse processes of lumbar vertebrae but are generally few in number for any given victim. It is interesting to note that fractures and dislocations in intercollegiate rodeo athletes represent only 5% of total injuries and are again generally few in number[80]. Fatal injuries among farm workers who handle large animals include broken ribs and blunt force chest trauma caused by butting or charging, and broken bones and crushing injures caused by kicking and trampling[81,82]. The incidence of rodeo and farm injuries is certainly due in large part to the high frequency of large animal contact by human handlers, usually in close-quarters, and at a presumably much higher level than would have been the case for an ancient Pliocene hominin, so these injury and fatality statistics are of limited applicability. The fracture types and patterns do offer some utility, but we found no evidence of the range and extent of compressive injuries seen in Lucy's skeleton in any cases of human encounters with large animals.

Death and injury statistics

It is challenging to know the most appropriate way to use death and injury statistics to assess the likelihood of the potential mechanisms of skeletal damage discussed above. These statistics are generally gathered for industrialized societies rather than human hunter-gatherer groups living under conditions that might be more comparable to those of a fossil hominin, and, as detailed above, not every event produces the sorts of fractures witnessed in Lucy's skeleton.

The US Center for Disease Control provides a database of Injury Prevention & Control: Data & Statistics WISQARS™ (Web-based Injury Statistics Query and Reporting System: *Leading Causes of Death 1999-2014, National or Regional* (http://webappa.cdc.gov/sasweb/ncipc/leadcaus10_us.html). For the 15 years from 2000-2014 (US; 2000-2014; Race = all races, Hispanic Origin = All; Sex = Both Sexes; Output Options = Standard Output; Number of Cases = 20; Categories of Causes = All; Deaths = with drill-down to ICD codes; Age Group Formatting = 1-14 in 5-year groups; 15-85+ in 10-year groups), the category "unintentional injury" ranks fifth among the top 20 causes of death, with falls and natural environment coded within this category, and falls from trees (W14) a subcategory of falls, and lightning (X33) and floods (X38) subcategories of natural environment. Within unintentional injury (1,772,204 deaths), motor vehicle traffic accidents (587,051 deaths), poisonings (415,197 deaths), and falls (336,961 deaths) rank 1st-3rd, respectively, and natural environment (24,023 deaths) ranks 8th. Subtracting out these four subcategories from the unintentional injury total so that they can stand as separate entities, and then re-ranking them with the top 20 categories places motor vehicle traffic accidents at #9, poisonings at #13, falls at #16, and natural environment at #24. Deaths by falls from trees (1341 cases) were more than twice as likely as deaths by lightning strikes (584 cases), and death by lightning strikes more than twice as likely as deaths by flood (282 cases).

The World Health Organization global rankings are somewhat similar to those of the US, with road traffic injuries ranked at #9 and falls at #21; falls rank at #13 overall for the cause of death for the both sexes in 5-14 year age group in 2012, behind malaria (#11) and epilepsy (#12), and ahead of measles (#14) and homicide (#15)[83]. With regard to US emergency room visits in 2004-2005, falls accounted for 26% of the visits and were the leading cause of visits for children under 15 years of age and among adults 45 years of age and older, and "…falls were the leading mechanism of nonfatal injury but were the fourth leading mechanism for mortality"[84:63]. Falls ranked first (30%) among the leading causes of nonfatal unintentional injuries in the US among all ages from 2001-2014 (WISQARS™ *Leading Causes of Nonfatal Injury 20001-2014* http://webappa.cdc.gov/sasweb/ncipc/nfilead2001.html : Sex = Both Sexes; Disposition = All Cases; Intent of Injury = Unintentional Only; Number of Cases = Top 20; Age Group Formatting = 1-14 in 5-year groups; 15-85+ in 10-year groups).

With regard to the various alternative scenarios discussed above, the statistics can be summarized by stating that dying from a fall out of a tree is more than twice as likely as dying from a lightning strike and five times more likely than dying from a flood, with the overwhelming number of flood deaths apparently due to drowning and not trauma[78]. Furthermore, lightning strikes and seizures only rarely produce tetanic muscle contractions that in some cases produce fractures, whereas a fall from a tree is much more likely to cause fractures. And, as noted above, because available animal-injury and fatality statistics are based in large part on circumstances of frequent and close-quarter handling unique to agricultural settings that would not be expected in the Pliocene, this scenario appears to be highly unlikely.

Supplementary Note 5: Hadar paleohabitats

Reconstructions of the paleohabitats at Hadar based on fossil mammals reveal a landscape that fluctuated between more open and closed environments. During the interval of the KH-1 Submember that includes the Lucy discovery site A.L. 288, the vegetation was open woodland with some edaphic grassland[21]. Pollen recovered from multiple strata through the Hadar sequence documents a total of 51 tree and shrub taxa that fluctuated from 1-30% of the total sample[22], with some of these taxa representing tree species that reach heights of 20 m or more. Unfortunately, no pollen is known from the exact interval of the A.L. 288. The geology of Hadar has been the focus of detailed studies for decades. Aronson *et al.*[23] present their work on paleopedology and $\delta^{18}O$ and $\delta^{13}C$ paleosol carbonates and conclude that the paleohabitat of Hadar was a grassy woodland with sizable trees. The remains of fossilized tree branches are common in sandstones, and tree trunks up to 1 m in diameter are known from the lower part of the section[23,24].

Lucy's remains were discovered as surface finds but were shown to have eroded out of a medium-grained sandstone near the base of the Kada Hadar Member[1]; subsequent processing and screening of this unit produced numerous skeletal elements[59] that demonstrated Lucy's exact stratigraphic provenience and also produced crocodile and turtle eggs and crab claws[1]. The discovery unit, KH-1s, is 0.5 m thick at the Lucy site[24] but varies considerably in thickness across the landscape. In those areas where the unit is thicker, the sandstone is interbedded with a thin poorly laminated siltstone which shows that at these locations the unit represents multiple depositional episodes; the Lucy discovery site sandstone is the youngest depositional event of KH-1s and is followed by a mudstone facies[24]. The sandstone at the Lucy site is interpreted as a distributary crevasse-splay channel that was deposited over a low-relief area of the floodplain during a flood episode[24]. This facies is likely associated with one of the larger channel systems in the lower Kada Hadar Member[25], perhaps the time-transgressive DD-3, with some of these containing large root casts and tree trunks[24]. Most channels and crevasse-splays are heavily vegetated because these areas represent places with abundant surface and subsurface water. Together this evidence suggests that trees were a part of the landscape at Hadar.

Supplementary Note 6: Chimpanzee and human tree climbing and falls

Chimpanzees are adept tree climbers but they do experience skeletal trauma, presumably produced by impacts from falls[85-87], and sometimes these falls are from considerable heights.

Goodall[88] recorded 51 falls with ground impacts over a two year period. For those falls when height was noted, 21 were falls from over 5 m, and 13 were from over 10 m. These falls occurred when adult chimpanzees were engaged in fights or chases, or during locomotion when feeding, with two occurring while males were hunting monkeys, and 16 occurring after a branch broke. Two falls are known to have resulted in deaths: an adult male who, after becoming excited when two parties reunited, fell out of a tree from a height of at least 10 to 15 m, perhaps because a branch broke[88,89]; and a juvenile who was blown out of a 14 m palm tree in a strong wind[88].

Modern human hunter-gatherers often engage in tree climbing, primarily when foraging for honey[90], with Efe men in the Ituri Forest spending one-third of their foraging time at considerable height (mean = 19.1 m, max = 51.8 m)[91]. The incidence of accidental falls resulting in death while tree-climbing in these populations varies from ~1% in the Agta of the Phillipines[92] to 4.3% for adolescent and young adult, adult, and middle aged adult male Aka pygmies of the Central African Republic who are actively engaged in hunting and gathering[93]. Tree-climbing injuries in Papua New Guinea include simple and compound fractures of the arm (radius and ulna, elbow, humerus, with some bilateral), thorax (clavicle, vertebra, ribs), leg (tibia and femur), and skull, with these injuries representing 27% of the trauma cases admitted over a four year period at the Provincial Hospital at Alotau, Milne Bay Province, and 28 fatalities reported via questionnaire[68]. Given the rural setting of most of these accidents and the difficulty faced in transporting these victims to the hospital, it is likely that this injury rate is underreported. Injuries in tree-climbers in Nigeria were described as moderate to severe and included fractured ribs, pelvis, upper limb, and lower limb, with 35% of the patients sustaining multiple injuries (two to five in total)[94].

Supplementary Note 7: Free fall impacts

A full consideration of the physics of a free fall impact includes the height of the fall, impact force, impact energy, duration of impact (a measure of impact surface compliance), distribution of forces on the body, and additional factors including a bounce(s) and following impact[29]. Several of these variables are difficult to impossible to ascertain in Lucy's case. We here limit our estimates to unimpeded free fall velocity, estimated body mass, and assume zero drag. Lucy's mass is estimated as 26 kg[31].

Weilemann *et al.*[30] report on twenty human fatalities produced by falls from considerable heights (5-70 m) and provide calculations of potential energies (PE) that range from 2.26 kJ (5 m) to 44.64 kJ (70 m). The values for fatal falls from 5-22 m (mean = 12.35 m, n=8), close to the minimum/maximum range of chimpanzee mean nest heights (see Table 2), range from 2.26-16.87 kJ. We used the estimated body mass for Lucy[31] and chimpanzee nest heights as fall heights to calculate her PEs, and found that these values are within the lower range of the human values, with Lucy's lower values resulting from her lower body mass (see Table 2).

Supplementary Note 8: Other hominin fossils

Close inspection of other fossil specimens from the interval of time when hominins possessed a suite of adaptations for both terrestrial and arboreal locomotion may reveal other individuals who also suffered injuries that could prove to be consistent with fractures suffered from vertical deceleration events because the adaptations for bipedal terrestrial locomotion might have compromised their ability to move safely and efficiently in the trees. L'Abbe *et al.*[7] have suggested that an impact following a fall is responsible for some of the fractures in the Malapa hominins but they propose that this was a fall into an open pit depression rather than out of a tree.

Specimen A.L. 333-107 from Hadar is a right proximal partial humerus of *Australopithecus afarensis* that, although exfoliated, chipped, and abraded[95], appears to preserve evidence of proximal humerus fracture. The greater tuberosity is complete but the lesser tuberosity is damaged, and the articular head was crushed inferiorly into the shaft so that the head overhangs the neck in the medial direction, presenting a pattern similar to that preserved on Lucy's left proximal humerus (A.L. 288-1r).

The relatively complete skeleton from Woranso-Mille[5,96] that dates to ~3.6 Ma includes a left tibial shaft (KSD-VP-1/1e) that preserves evidence described as an antemortem preadult injury thought to represent an ununited fracture of the fibula. The medial malleolus of the tibia is missing but it is not noted whether or not this fracture is related to the antemortem injury or occurred postmortem. This injury is consistent with pilon fractures reported in the clinical literature that are produced by a high energy impact from a vertical deceleration event. This specimen also preserves a right os coxa (KSD-VP-1/1d), and the damage to its retroauricular region that might be somewhat similar to that witnessed in Lucy's pelvis (A.L. 288-1an, -1ao), potentially also produced by a vertical deceleration event.

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Supplementary Methods

Supplementary Video 4: Video of Lucy's fall and vertical deceleration event

The stop motion video depicts a hypothetical scenario for Lucy's fall out of a tall tree and the subsequent vertical deceleration event and impact as based on the severity and patterning of the fractures. The tree is *Pterocarpus tinctorius*, one of the preferred species used by chimpanzees for nesting[27]. The velocity of a fall from a chimpanzee's savanna mean nest height of 13.71 m is calculated as 16.40 m/sec (Table 2). The first video clip depicts about the last half of the fall over 7.4 m, and the second video clip shows a close-up of the last 2.2 m of the fall. The third video is a close-up of the last 1.7 m of the fall in slow-motion that shows the hypothesized feet-first impact, followed by a twist of the body to the right that impacts the left knee, right hip, outstretched arms (the right arm more severely impacted than the left), and finally the pubis, thorax, and skull. Replica casts of the individual elements were positioned and digitally photographed against a black velvet background to match their orientation in the body at each point of impact. Adobe Photoshop C5.1 Extended was used to isolate each element with the lasso tool, and then it was cut and scaled to match the size of the figure and the other elements. Individual frames of the stop motion video were constructed in Adobe Photoshop C5.1 Extended as layers and saved as jpgs. The video was composed in Windows Movie Maker ver. 2012. See Figure 2 for a full description of the progression of the fractures; Supplementary Note 4 for a discussion of alternative scenarios that might have caused the compressive fractures; Supplementary Note 6 for data about chimpanzee and human falls, impacts, and skeletal damage; and Supplementary Note 7 for the physics of free fall impacts. Background photograph is by J.

Mellenthin from The Flora of Mozambique and is used by permission of M. Bingham. The photograph is reversed and slightly altered with “filter/stylize/diffuse” in Adobe Photoshop C5.1 Extended in order to blur the background and emphasize Lucy.