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# Trigger Finger Release With Stepwise Preservation of the A1 Pulley: A Functional Pulley-Preserving Technique

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**The first annular (A1) pulley is an important structure of the hand, providing a biomechanical support to the metacarpophalangeal joint and maintaining joint stability and flexor tendon alignment. Albeit uncommon, disruption of this pulley can result in dislocation or ulnar drift of the digit, particularly pronounced in patients with rheumatoid arthritis. Despite this, the A1 pulley is commonly divided without reconstruction in trigger finger. Several annular pulley reconstructive techniques have been developed to preserve its function. However, development of recurrent triggering has been observed due to fibrosis, largely due to inadequate release of the pulley. We have developed a technique to increase the volume within the flexor sheath while preserving the A1 pulley by way of stepwise lengthening. This has enabled an increase in the diameter of the pulley to 4 times its original size. A prospective study was performed comprising 10 trigger finger releases with stepwise lengthening of the A1 pulley. In all patients, there were no complications, and good hand function was achieved with no recurrence of triggering at 6 weeks of follow-up. This technique can thus safely achieve trigger release without sacrifice of the function of the A1 pulley.**

*Key words:* – Trigger finger release – A1 pulley reconstruction – Stepwise lengthening – Stenosing

The annular 1 (A1) or first annular pulley can become progressively stiff and thickened, and this may lead to the phenomenon of trigger finger.[1] It is one of the most common and debilitating conditions of the hand, with a prevalence of nearly 3% in the population.[2] Histologically this can be seen as a structural change from bilaminar to trilaminar, and the irregular change from normal deep layers of dense connective tissue to small collagen fibers with abundant extracellular matrix

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with fibrocartilage metaplasia.[3,4] This results in a diameter mismatch of the fibrous tendon sheath and the annular pulley, which restricts the ability for the flexor tendon to pass through. Injection of steroids with or without local anesthetic into the flexor sheath is often used in patients who experience a mild and early phase of the condition.[5] Complete resolution of symptoms can be observed in 64% to 71% of patients after 1 injection.[5] If conservative treatment fails, a surgical approach by way of percutaneous or open operation is offered. Traditionally, the A1 pulley is completely divided without reconstruction to allow the flexor tendon to glide through.

Although not as strong or functionally important as the fibro-osseous A2 and A4 pulleys, the A1 pulley still has an important role to play in the hand.[6,7] Loss of A1 pulley function, such as after A1 pulley release, can lead to metacarpophalangeal volar subluxation, bowstringing, and ulnar deviation, with subsequent effects on active range of motion. These effects are especially pronounced in A1 pulley releases for hands affected by rheumatoid arthritis (RA).[8] This theory has led to the concept of a functional release with preservation of A1 pulley. We present a prospective study of surgical release and reconstruction of the A1 pulley with stepwise lengthening.

## Patients and Methods

A prospective study of the A1 pulley step-lengthening technique was undertaken by a single hand surgeon in a single institution. A total of 10 consecutive trigger finger releases in 9 patients with preservation of the A1 pulley release were performed. All included patients were adults and were reviewed and consent obtained by the senior hand surgeon preoperatively. All patients had longstanding disease of longer than 6 months and had either had failed previous steroid therapy or experienced stage 3 or greater stenosing tenosynovitis, as shown in Table 1. Pediatric patients (younger than 15 years), patients with trigger finger involving the thumb or other pulleys, and patients who had prior operative A1 pulley release were planned exclusions from the study (although there were no actual exclusions).

### *Surgical technique*

After consent was obtained from the patient, the procedure was performed under local anesthesia with infiltration of 5 mL of 1% lignocaine. An arm tourniquet was used to allow for better visualization of the structures during the procedure. A standard transverse palmar crease skin incision over the metacarpophalangeal joint was made to expose the flexor sheath. The neurovascular bundles on either side of the tendon sheath were then identified and protected. The A1 pulley was then delineated in its entire extent. The fibrous sheath was incised transversely in its proximodistal midline. Two further incisions were made on either side of the A1 pulley—one over the entire border of the radial proximal half and one over the entire border of the ulnar distal half. The resultant released pulley formed 2 flaps, which were approximated at their tips. The 2 flap edges were sutured together with simple interrupted 5/0 synthetic nonabsorbable monofilament [either Prolene (polypropylene) or nylon], shown in Figs. 1 and 2. Patients were asked to mobilize the digit to check for any restriction. A further release was thus able be performed if needed. Skin was then closed in a standard manner. Light dressings were applied with instructions for the patient to mobilize the digit from postoperative day 1.

*Table 1 Stages of stenosing tenosynovitis*

| Stage | Symptoms |
|---|---|
| 1 | Normal |
| 2 | A painful, palpable nodule |
| 3 | Triggering |
| 4 | The PIP joint locks into flexion and is unlocked with active PIP joint extension |
| 5 | The PIP joint locks and is unlocked with passive PIP joint extension |
| 6 | The PIP joint remains locked in a flexed position |

PIP, proximal interphalangeal.

### *Postoperative care and follow-up*

All patients were reviewed in the outpatient department at 1 and 6 weeks postoperatively to assess for pain, strength, triggering, locking, range of movement, and disabilities of the arm, shoulder, and hand (DASH) score,[9] with a midrange 3-month review of any complications. None of the patients required any supervised hand therapy postoperatively.

### *Statistical analysis*

Statistical analysis was performed on all of the collected data. A comparison of outcomes was

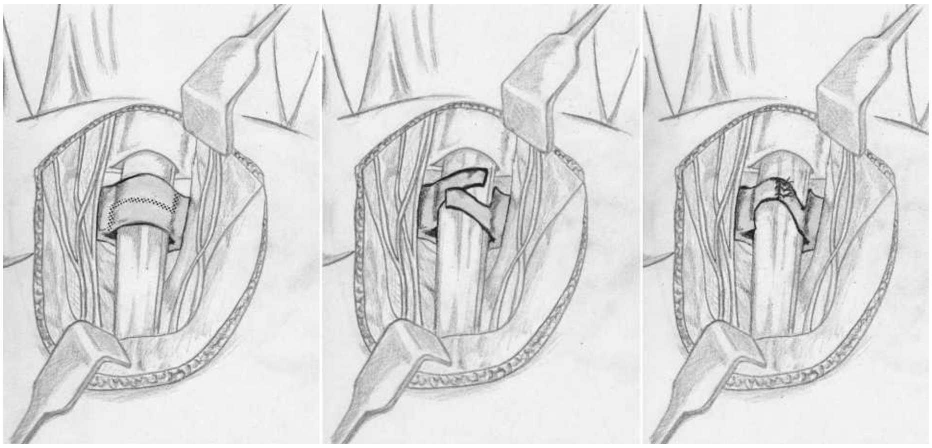

**Fig. 1** Schematic representation of "stepwise lengthening of A1 pulley reconstruction."

calculated between preoperative and postoperative assessment. Chi-square test and Fisher exact test were used to analyze the group rates for statistically significant differences.

## Results

We performed a total of 10 A1 pulley release and reconstructions on 9 patients. One patient had bilateral operations. In our group there were 6 female and 3 male patients, with the mean age of 58 years (range, 44–69 years). There were 2 patients with left-hand dominance and 7 with right-hand dominance. A total of 5 trigger fingers were released on the dominant hand and 5 on the nondominant hand. A total of 6 middle fingers and 4 ring fingers were operated on. A total of 2 of 9 patients had diabetes, with 1 patient on insulin. All 9 patients experienced locking and pain of the affected fingers for at least 6 months. A total of 1 of the 9 patients presented with a firm, palpable nodule in the line of the flexor tendons (Notta node). All 9 patients (10 trigger fingers) experienced stage 4 (20%) or 5 (80%) of the disease (stages of stenosing tenosynovitis shown in Table 1). None of the patients had undergone a trial of conservative management due to their delay in presentation, with chronic disease. Only 1 of 9 patients had been previously treated with steroid injections but had shown no improvement of symptoms. Because of advancement of their chronic disease, all 9 patients were then offered a surgical treatment. A total of 2 of 7 patients had previous carpal tunnel syndrome. Both had previously been treated by carpal tunnel release. No patients in our study had previously experienced De Quervain tenosynovitis, RA, gout, or Dupuytren

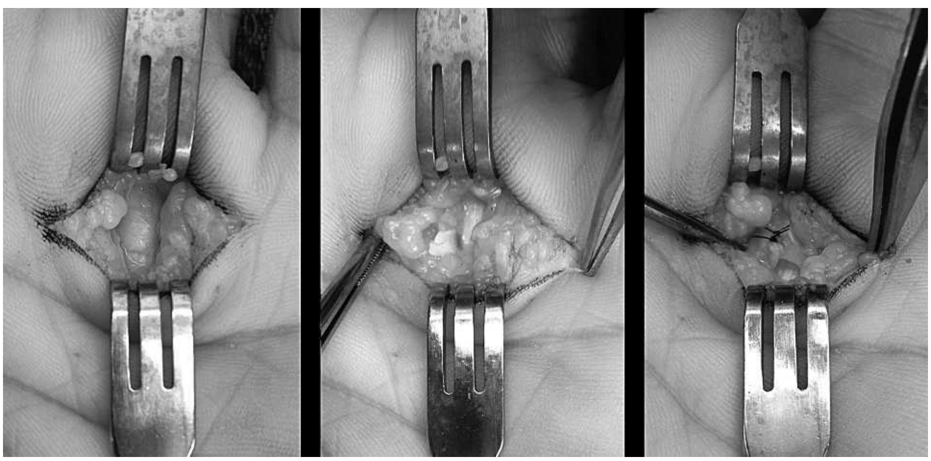

**Fig. 2** Operative images of "stepwise lengthening of A1 pulley reconstruction."

disease. Patients' demographic details are shown in Table 2.

Our operating times ranged from 9 to 21 minutes; however, the initial learning curve resulted in longer times for the first 2 operations (19 and 21 minutes). Subsequent operations were more efficient, with a median operation time of 11 minutes.

Good functional outcome was observed in all patients. No patients had recurrent triggering. Good range of motion was recorded in all patients at the 6-week postoperative clinic review. A total of 7 of 9 patients completed the preoperative and postoperative DASH questionnaire shown in the Appendix. The patients had significant improvement in their function and symptoms, with an improvement in their DASH score from 26.9 $\pm$ 9.9 preoperatively to 5.8 $\pm$ 9.5 postoperatively ($P < 0.001$), as shown in Table 3. At a minimum of 3 months of follow-up, there had been no further complications or recurrent triggering.

## Discussion

The fibro-osseous sheath of the flexor tendon in the hand is composed of thickened areas of arcing fibers, known as the annular pulleys, that alternate with crisscrossing fibers described as cruciate pulleys. There are 5 annular and 3 cruciate pulleys. The function of the annular pulleys is to enhance effective flexor tendon functions by holding the tendons close to the phalanges, thereby preventing the "bow-stringing" effect across the small joints when the digits are in flexion. Although the absence of the pulley allows for a higher angled approach, a given angular motion would require greater tendon excursion, and thus reduce the strength of the digit. Peterson *et al*[6] examined the flexion biomechanical effect in the absence of the A1 pulley and found an increase in the requirement for work of flexion by 10% ($\pm$8.16%). Although the effect of the absence of the A1 pulley was minor and less likely to influence the hand function, the effect became more pronounced when the palmar aponeurosis or the A2 pulley was divided. The A1 pulley also provides stability of the metacarpophalangeal joint by preventing progression of subluxation and ulnar drift of the joint, particularly in RA patients. The joint stability is primarily maintained by the presence of the collateral ligaments and the volar plate. However, rheumatoid synovitis can stretch these ligaments, resulting in laxity of the joint that can lead to subluxation. It is believed that the A1 pulley provides the additional support that can slow down this process.[8] Furthermore, a division of the A1 pulley increases the ulnar-directed forces on the proximal phalanx during active finger flexion.[10] The weakened radial proper collateral ligament stretches, allowing for ulnar drift, which is more pronounced in the RA joint.[11] Furthermore, development of bow stringing after a trigger finger release, although uncommon, has certainly been reported in the literature. Heithoff *et al*[12] found the development of bowstringing after an accidental release of the A1 and A2 pulley of a patient with no associated comorbidity. Although it has been demonstrated that up to 25% of either end of the A2 pulley can be divided without a mechanical effect on digital flexion, anatomic studies have demonstrated a variant by which a continuity exists between the A1 and A2 pulleys in up to 40% to 60% of digits.[13,14] This makes an iatrogenic cause of bowstringing a potential complication that could be prevented with the technique of pulley reconstruction.

The goal of treating restrictive flexor tenosynovitis (trigger finger) is to increase the diametric ratio of the flexor tendon sheath and annular pulley to allow for gliding. This can be achieved by either reducing the swelling and thickening of the synovial covering the tendon, or increasing the diameter of the annular pulley. Most patients who experience an early phase of the disease with mild symptoms (*i.e.*, stages 1 and 2) can be treated successfully with extension splintage, anti-inflammatory medication, and/or steroid injection into the flexor sheath. Salim *et al*[15] reported an improvement or resolution of symptoms in 60% to 97% with conservative management in this group of patients. However, patients with advanced disease, prolonged disease, or failed conservative management usually indicate a secondary process of thickening and hypertrophy within the flexor tendon that requires a release of the A1 pulley.[16–18] In our study, all of the patients were informed of the risk, benefits, and course of resolution of symptoms between conservative and surgical approaches. All 9 recruited patients chose to undergo trigger finger release and pulley reconstruction.

The standard operative approach for treating moderate to severe trigger finger is a complete release of the A1 pulley without reconstruction of the annular pulley. This can be achieved by either an open operation or via a percutaneous insertion of a hypodermic needle. Both of these techniques completely divided the A1 pulley, thus allowing the tendon sheath to move freely without impingement.

*Table 2 Demographics*

| | Trigger finger release (n = 10) |
|---|---|
| Age, y (range) | 58 (44–69) |
| Sex, No. | |
| Female | 6 |
| Male | 3 |
| Dominance, No. | |
| Right | 7 |
| Left | 2 |
| Finger, No. | |
| Middle | 6 |
| Ring | 4 |
| Operation time, mins (range) | 11 (9–21) |
| Comorbidity, No. | |
| Diabetes | 2 |
| Carpal tunnel syndrome | 2 |
| De Quervian tenosynovitis | 0 |
| RA | 0 |
| Gout | 0 |
| Previous steroid injections, No. | 1 |
| Stages of stenosing tenosynovitis, No. | |
| Stage 1 | 0 |
| Stage 2 | 0 |
| Stage 3 | 0 |
| Stage 4 | 2 |
| Stage 5 | 8 |
| Stage 6 | 0 |

This may result in bow stringing of the tendons and destabilize the joint, especially in patients who experience RA. A desirable operative approach should accomplish complete A1 pulley release without sacrificing its function. To address this issue, rather than dividing the annular pulley, a more conservative approach is applied. The pulley can be enlarged and preserved by different designs. Kapandji[19] performed an "enlargement plasty" by making a diagonal incision over the pulley; the incision was then resutured with the use of Z-plasty, thereby lengthening the width of the annular pulley. Mehrotra[20] described the use of N-plasty by making 2 opposing vertical incisions of the fibrous sheath to accomplish release without removing tissue from the A1 pulley. Pabari undertook this method and found early recurrences, and upon reexploration he found that the incised limbs of the "N" had reformed with fibrosis. He then further modified this technique by excising the 2 limbs to prevent fibrosis.[21] However, we believe that these techniques provide only a small increase in the pulley cross-sectional area, and therefore there is still a risk of fibrosis, stenosis, and recurrence.

### *Annular pulley geometry*

The annular pulley has a semielliptical shape. The aim of an annular pulley preservation technique is to increase the cross-sectional area of the annular pulley, which allows for the flexor tendon to glide through without restriction. In order to increase the cross-sectional area of an ellipse, either the width ($r_1$) or the perimeter ($P$) of the pulley needs to be increased, as shown in Fig. 3. However, it is not possible to increase the pulley width, because the floor of the annular pulley comprises the metacarpal bone. Therefore, all pulley preservation techniques rely on an increase in the perimeter length. The cross-sectional area of a pulley is then proportional to the perimeter length (*i.e.*, an increase in the length of the perimeter after reconstruction will result in an increase of the cross-sectional area). This relationship can be demonstrated by calculating the cross-sectional area when the perimeter is increased by 50% (1.5 times) compared with 100% (double the length). The cross-sectional area ($A$) and perimeter ($P$) can be calculated by using the following formula:

$$A = \frac{\pi r_1 r_2}{2} \qquad P = \frac{\sqrt{r_1^2 + r_2^2}}{2}$$

Using this formula, when the width of pulley is 1 cm (*i.e.*, $r_1 = 0.5$ cm) and the height is 1 cm, the cross-sectional area equals 0.79 cm$^2$ with a perimeter length of 0.56 cm, as shown below.

$$A = \frac{\pi 0.5 \times 1}{2} \qquad P = \frac{\sqrt{0.5^2 + 1^2}}{2}$$

$$A = 0.79 \text{ cm}^2 \qquad P = 0.61 \text{ cm}.$$

*Table 3 Surgical outcome (Fisher exact test)*

| | Preoperative (n = 10) | Postoperative (n = 10) | *P* value |
|---|---|---|---|
| ROM | | | |
| Poor | 0 | 0 | 1.00 |
| Full ROM | 10 | 10 | 1.00 |
| Triggering | 10 | 0 | <0.001 |
| DASH score | 28.8 (± 10.6; range, 15–42.6) | 5.8 (± 8.8; range, 0–26.9) | <0.001 |

ROM, range of movement.

If the same pulley were to undergo a reconstruction that resulted in an increase of the pulley length by 50% or 1.5 times, the height of the ellipse ($r_2$) would increase as the width ($r_1$) remained constant, as shown below.

$$1.5P = \frac{\sqrt{r_1^2 + r_2^2}}{2}$$

$$1.5 \times 0.61 = \frac{\sqrt{0.5^2 + r_2^2}}{2}$$

$$1.5 \times 0.61 \times 2 = \sqrt{0.25 + r_2^2}$$

$$(1.5 \times 0.61 \times 2)^2 - 0.25 = r_2^2$$

$$\sqrt{(1.5 \times 0.61 \times 2)^2 - 0.25} = r_2$$

$$1.76 \text{ cm} = r_2.$$

The cross-section area can then be calculated from a known $r_1$ (0.5 cm) and $r_2$ (1.76 cm), with the resultant area of 1.38 $\text{cm}^2$, as shown below.

$$A = \frac{\pi 0.5 \times 1.76}{2}$$

$$A = 1.38 \text{ cm}^2.$$

Using the same formula, the cross-section area is found to be 1.88 $\text{cm}^2$ when the perimeter is doubled in length ($2 \times P$) or 1.2 cm, as shown below.

$$2P = \frac{\sqrt{r_1^2 + r_2^2}}{2}$$

$$2 \times 0.61 = \frac{\sqrt{0.5^2 + r_2^2}}{2}$$

$$2 \times 0.61 \times 2 = \sqrt{0.25 + r_2^2}$$

$$(2 \times 0.61 \times 2)^2 - 0.25 = r_2^2$$

$$\sqrt{(2 \times 0.61 \times 2)^2 - 0.25} = r_2$$

$$2.39 \text{ cm} = r_2$$

$$A = \frac{\pi 0.5 \times 2.39}{2}$$

$$A = 1.88 \text{ cm}^2.$$

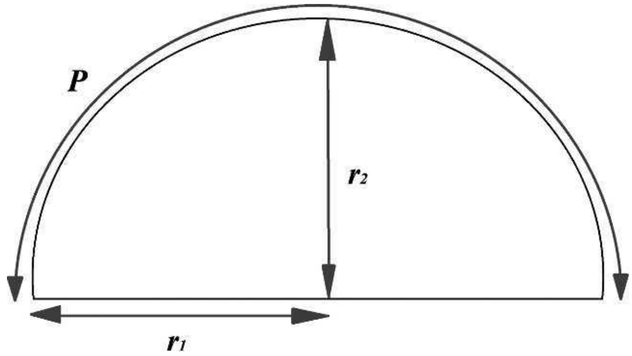


**Fig. 3** A1 pulley geometry: $A$, cross-sectional area of the A1 pulley; $P$, perimeter of the A1 pulley; $r_1$, width of the A1 pulley; and $r_2$, height of the A1 pulley.

*Annular pulley geometry change outcome*

These calculations demonstrate that the longer the length of the pulley, the greater the cross-sectional area. Pulley release techniques by Kapandji, Pabari, Mehrotra, and their coworkers use only part of the pulley to increase the cross-sectional surface area. All of these techniques rely on the change in geometer of the pulley from a rectangular to an oblique shape.[19–21] Therefore, only a minimal increase in pulley perimeter length can be achieved. In order to achieve an improved perimeter lengthening of the A1 pulley, we have used stepwise lengthening, which incorporates the entire perimeter ($P_0$) of the annular pulley to reconstitute an end–to-end reconstruction, resulting in a doubling of the length of the perimeter ($P_1$) to increase the cross-sectional surface area ($A_1$), as demonstrated in Fig. 4. This appropriately broad increase can facilitate restriction-free tendon glide while maintaining the function of the A1 pulley.

All of the patients in our series had a complete resolution of symptoms with no recurrence at 6-week postoperative review. There were no complications found to date. All patients were able to return to their normal active daily living without issue. The preservation of the annular pulley is postulated to preserve joint stability and prevent ulnar drift. This technique is essential in patients with or at risk of developing RA. In RA patients, steroid injection is contraindicated in these patients because of an increased risk of tendon rupture. The surgical treatment of rheumatoid flexor tenosynovitis is tenosynovectomy and preservation of the A1 pulleys, with selected cases requiring ulnar superficialis slip resection or excision of rheumatoid nodules from the tendon.[22] However, this treatment

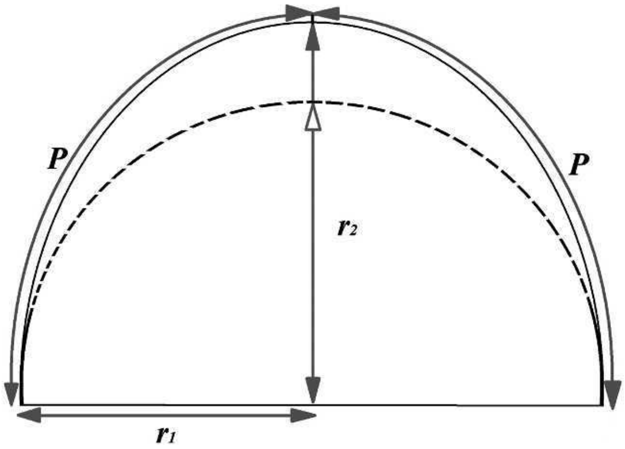


**Fig. 4** Stepwise lengthening of the A1 pulley reconstruction geometry: *A*, cross-sectional area of the A1 pulley; *P*, perimeter of the A1 pulley; $r_1$, width of the A1 pulley; and $r_2$, height of the A1 pulley.

is invasive, with risk of recurrence, tendon adhesion, and tendon and nerve injury. The stepwise preservation of the first annular pulley should therefore be performed in this group of patients.

## Conclusion

The natural history of flexor tendon entrapment is characterized by inflammation and hypertrophy of the retinacular sheath, which progressively restricts the motion of the flexor tendon. The symptoms of trigger digit are a mechanical problem caused by a mismatch between the relative sizes of the flexor tendon and its sheath. Treatment aims to restore the full range of motion and to prevent snapping and pain of the digit. In severe disease, release of the A1 pulley has been the traditional method, but this technique requires sacrifice of the pulley. We have developed a technique to increase the length of the pulley twofold, thereby allowing the flexor tendon to glide through and preserve the pulley in order to prevent bowstringing, maintain flexion strength, and provide joint stability, which are particularly useful for the rheumatoid arthritic hand.

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*Appendix DASH score outcome measure ($\chi^2$)*

| | DASH score | | | | | |
|---|---|---|---|---|---|---|
| Question | Preoperative mean | SD | Postoperative mean | SD | Difference | $P$ value ($\chi^2$) |
| 1 | 3.29 | 0.95 | 1.57 | 0.79 | –1.71 | 0.172 |
| 2 | 2.57 | 1.40 | 1.14 | 0.38 | –1.43 | 0.349 |
| 3 | 1.71 | 1.11 | 1.14 | 0.38 | –0.57 | 0.920 |
| 4 | 2.14 | 0.69 | 1.14 | 0.38 | –1.00 | 0.654 |
| 5 | 2.14 | 1.07 | 1.14 | 0.38 | –1.00 | 0.598 |
| 6 | 1.86 | 0.90 | 1.29 | 0.76 | –0.57 | 0.887 |
| 7 | 2.14 | 0.69 | 1.14 | 0.38 | –1.00 | 0.654 |
| 8 | 2.14 | 1.07 | 1.00 | 0.00 | –1.14 | 0.533 |
| 9 | 1.71 | 0.49 | 1.14 | 0.38 | –0.57 | 0.920 |
| 10 | 2.43 | 0.79 | 1.29 | 0.76 | –1.14 | 0.665 |
| 11 | 2.86 | 0.90 | 1.43 | 0.79 | –1.43 | 0.414 |
| 12 | 2.00 | 0.82 | 1.50 | 1.00 | –0.50 | 0.986 |
| 13 | 1.71 | 0.95 | 1.29 | 0.76 | –0.43 | 0.934 |
| 14 | 1.43 | 0.79 | 1.29 | 0.76 | –0.14 | 0.998 |
| 15 | 1.43 | 0.79 | 1.14 | 0.38 | –0.29 | 0.991 |
| 16 | 2.71 | 1.25 | 1.29 | 0.76 | –1.43 | 0.396 |
| 17 | 2.14 | 1.21 | 1.00 | 0.00 | –1.14 | 0.492 |
| 18 | 2.33 | 1.53 | 1.33 | 0.58 | –1.00 | 0.959 |
| 19 | 2.00 | 1.41 | 1.00 | 0.00 | –1.00 | 0.970 |
| 20 | 1.43 | 0.79 | 1.00 | 0.00 | –0.43 | 0.934 |
| 21 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.000 |
| 22 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.000 |
| 23 | 1.57 | 0.79 | 1.14 | 0.38 | –0.43 | 0.934 |
| 24 | 2.86 | 0.90 | 1.86 | 0.69 | –1.00 | 0.766 |
| 25 | 3.29 | 1.25 | 2.00 | 1.00 | –1.29 | 0.548 |
| 26 | 1.43 | 0.79 | 1.14 | 0.38 | –0.29 | 0.991 |
| 27 | 1.43 | 0.53 | 1.14 | 0.38 | –0.29 | 0.868 |
| 28 | 3.14 | 1.07 | 1.14 | 0.38 | –2.00 | 0.147 |
| 29 | 1.57 | 0.53 | 1.00 | 0.00 | –0.57 | 0.920 |
| 30 | 2.00 | 1.15 | 1.00 | 0.00 | –1.00 | 0.598 |
| Total | 57.29 | 9.55 | 34.00 | 9.83 | –23.29 | <0.001 |
| DASH score | 26.88 | 9.70 | 5.81 | 9.48 | –21.07 | <0.001 |