

Title: Load sharing between the palm and knuckles with cradle-style push-up handles

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Load sharing between the palm and knuckles with cradle-style push-up handles

Abstract

Push-up handles that distribute load between the palm and dorsal metacarpophalangeal region have been developed in an effort to increase comfort and reduce risk of injury for some users compared with floor push-ups (whether on palms or knuckles) and push-ups with handles currently on the market. A broad, flat, angled palm support places the wrist at a more neutral angle than palms-on-floor push-ups, and at a more consistent angle than a tubular handle would. The angle also allows a shifting of weight so the dorsal metacarpophalangeal region effectively engages a strap, providing the load sharing. The strap also functions as a safety device, to help prevent hand slippage. Using the measurement and form protocols described in this paper, wrist extension in the up position was 42° with the cradle handles and 60° with palms-on-floor push-ups. Across four tested hand-engagement/body-position conditions, the dorsal hand bore 8.2%–21.3% of the total load on the subject's hand.

Design and function

The palm support

The palm support is made of 7-in.-long, 2 × 4 lumber (1½ in. × 3 ½ in. actual size) with ½-in. radii at the two gripped corners. A 15° angle causes the fingers to be lower than the palm. The thenar and hypothenar eminences contact a cushioned pad made of smooth, ⅛-in. thick, food-grade silicone with a hardness of 40 Shore A, providing adequate slip resistance with dry hands. The pad material was chosen for its known physical characteristics, skin-contact safety, and ease of cleaning, but grip tape with greater slip resistance and moisture absorption should be considered.

Use of the handles was most comfortable when the distal palm made little or no contact with the top surface of the palm support, likely factors being palm support thickness and palm support-to-strap spacing.

The joints between the palm supports and side supports were engineered for strength, part availability, and ease of inspection. Structural brackets and structural screws are the primary joinery hardware, with pocket screws used to create a tighter joint for appearance and to resist forces that wouldn't normally be applied to the handles (Figure 1).

A palm-support strength test assembly was built (Figure 2). A foot support was clamped to the palm support of a strapless cradle handle, overhanging the gripping edge by 8 ½ in. so applied load would simulate the front-loaded condition that exists during normal use. This assembly was clamped to a base that prevented tipping when load was applied. The foot support of the assembly held the 188 lb subject as he was holding a 30 lb dumbbell for 10 seconds. The 218 lb load on one support caused no noticeable damage.



Figure 1. Underside of cradle handle showing joinery

The strap

The strap bears on the metacarpophalangeal region concurrently with part of the proximal phalanges region. It's made of 25-mm-wide, PVC-coated polyester webbing with ends spliced together using a 4 in. long overlapping strap that's fastened with four Chicago screws, two at each end. It becomes a narrow obround shape when mounted. From a face-up orientation, the strap is rotated 50° toward the palm support and attached to the side supports using welded rectangular rings and brackets.



Figure 2. Palm-support strength test assembly

Adding or removing padding from the obround strap adjusts distance from the palm support, as does utilizing the extra strap bracket holes pre-drilled into the side supports. Adding or removing palm support padding adjusts vertical hand position. If additional palm support padding doesn't extend over the radiused edge, the wrist angle becomes more neutral.

Even with padding in the obround strap, it's taut when mounted. Silicone strips with notched ends slip into the already mounted rectangular rings holding the strap, providing a softer hand contact surface.

Strength testing of the strap was limited to disassembly and inspection after fairly light use. The four Chicago screws in the strap were unscrewed. No hole elongation was found.

Sewing, as an alternative to or in addition to use of rivets or Chicago screws, would be expected to increase the strength of the splice and is the recommended way to construct a commercial or future experimental version of the cradle handles. The welded steel rings and brackets appear comparatively robust and unlikely to be the weak link in the strap assembly.

Prior art

Though not optimized for push-up handle use, the Hand Based Weight Distribution System¹ functions similarly. Its patent protection expired in 2013.²

Load-sharing measurement

Load on the right palm was measured using a two-piece version of a cradle handle that isolated a palm support assembly from a strap assembly (Figure 3). The strap assembly was clamped to a riser to prevent it from contacting an OHAUS Courier 3000 scale, model I-C31M75R (OHAUS Corporation, Parsippany, NJ, USA). The riser contacted a wall for stabilization while providing safe spacing from the wall. The scale was tared to exclude the weight of the palm support before measuring right palm load. Hands were at equal height during weighing. Feet were raised to reproduce the body angle of regular cradle handle use.

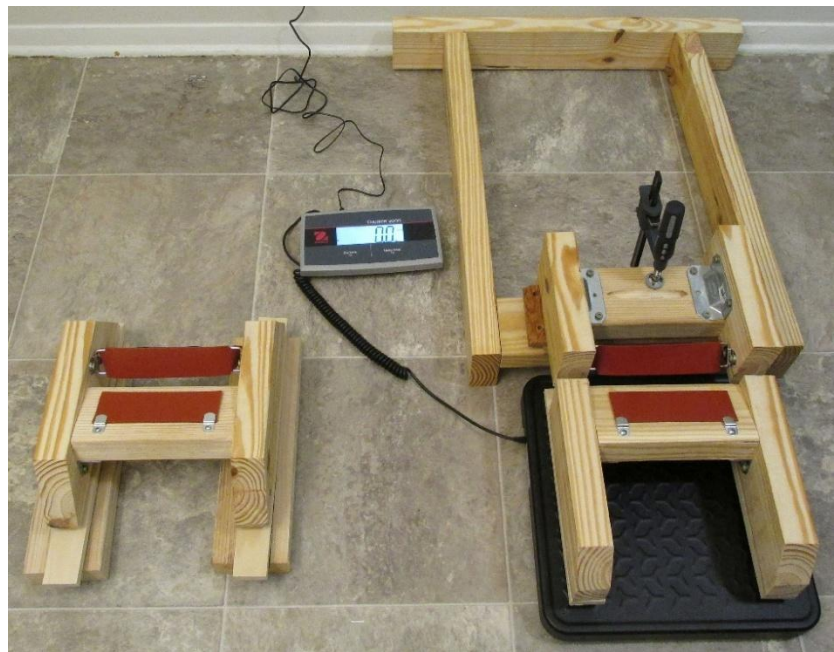


Figure 3. Load-sharing test setup

Right dorsal-hand load was calculated as full right-hand load without strap use minus right palm load with strap use for the corresponding body position. The full right-hand loads were 73 lb in the up position and 75 lb in the down position.

Total body weight of the subject was 188 lb and his right hand was his dominant hand.

Table 1. Palm and dorsal hand loads

Hand engagement ^a	Body position	Right palm load	Right dorsal-hand load ^b
Natural grip	Up	67 lb (91.8%)	6 lb (8.2%)
Natural grip	Down	68 lb (90.7%)	7 lb (9.3%)
Increased strap load	Up	63 lb (86.3%)	10 lb (13.7%)
Increased strap load	Down	59 lb (78.7%)	16 lb (21.3%)

a) The subject adjusted grip to approximate each hand-engagement condition.

b) Calculated as full right-hand load for corresponding body position minus palm load.

Wrist extension measurement

An established protocol for measuring wrist extension, described by Norkin and White³ and used by recent investigators,⁴ cannot be used with a subject in push-up position, but the push-up-specific protocol below uses the same anatomical structures as reference locations for goniometer alignment as Norkin and White. The push-up protocol causes the proximal arm of the goniometer to appear less parallel to the long axis of the forearm than it would with the Norkin and White protocol, causing lower wrist extension measurements than may be expected for both floor and cradle handle push-ups. While wrist angles are not directly comparable between the two protocols, the angles obtained with the push-up protocol can quantify the difference in wrist extension between floor and cradle handle push-ups.

Push-up form

- Thenar and hypothenar eminences in contact with the slip-resistant pad on the palm support (for measurements with cradle handles)
- Knuckle area, specifically the metacarpophalangeal region and part of proximal phalanges region, pressed against strap (for measurements with cradle handles)
- Hands flat on floor, fingers separated and facing forward (for measurements during palms-on-floor push-ups)
- Centers of palms placed slightly forward of shoulders
- Centers of palms placed slightly wider than shoulder-width apart

- Feet separated 3–6 in.
- Body straight
- Arms straight (up position)
- Arms bent 90° at elbow (down position)

Measurement in the up position

Two small squares of tape, each with a centered dot, marked the olecranon and ulnar styloid process on the arm that would face the camera during a video of a push-up. The subject assumed the up position. A video recorded the profile of the subject's upper body as he did one push-up. A screenshot of the up position was taken from the video, marked with a line between the two dots, and a second line over the estimated location of the lateral midline of, preferably, the 5th metacarpal (Figure 4). The 3rd or 4th metacarpal can be used if better visualized, for example, in the event the side support of the cradle handle obstructs the view. The angle formed by the lines, as measured with a physical goniometer against a monitor, was the angle of wrist extension: approximately 60° in the up position with palms on floor; approximately 42° in the up position with cradle handles.

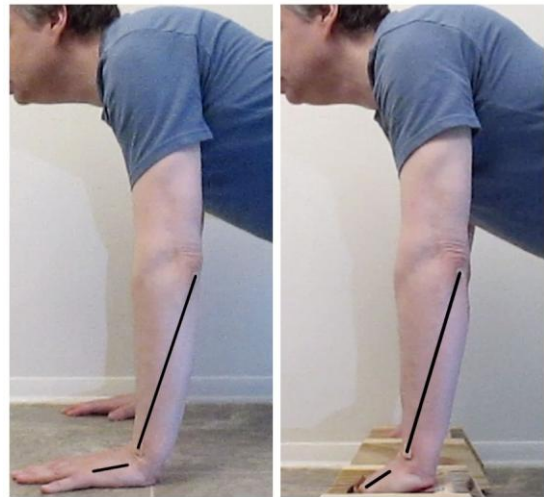


Figure 4. Palms on floor (left) vs. palms on cradle handles (right), up position

Measurement in the down position

Elbows flared due to ulnar deviation as the body was lowered, bringing the olecranon of the arm being videoed closer to the camera. This requires a more complex measurement procedure than used for the up position to achieve comparable accuracy. A composite photo could be used, comprising the hand from the up-position screenshot and a separate photo of the ulna region taken with the camera positioned so the lens-to-olecranon and lens-to-ulnar styloid process distances match those in the up-position photo. This technique was not used and no down-position wrist angle was estimated.



Figure 5. Palms on floor (left) vs. palms on cradle handles (right), down position

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Statements and Declarations

Consent to participate: The subject in the photos is the author who consents to participate.

Declaration of conflicting interests: The author is not involved with any entity that has an interest in the subject matter or products discussed in this manuscript. The author neither holds nor filed any patents. The author is unaware of any patent or patent application whose value may be affected by publication of this manuscript. The general public, including the author, has the nonexclusive right to profit from the sale of a product in the public domain and this right may be exercised in the future regarding a product described in this manuscript. As of the date of submission, the author has neither sold nor offered for sale any product described in this manuscript.

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