EDITOR'S CHOICE

Forces in the Distal Radius During a Pushup or Active Wrist Motions

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Purpose To determine the 6 degrees of freedom forces and moments in the distal radius that occur during a pushup or other active wrist motions.

Methods Eight fresh-frozen cadaveric wrists were moved through 6 physiological motions and held at 1 static pushup position while the force through the distal radius was measured with a 6 degrees of freedom load cell. Three levels of compressive force were applied at the pushup position.

Results Active wrist motions caused axial forces up to 283 N and moments up to 0.7 N-m. Those motions with a smaller range had significantly smaller axial forces than the larger flexion-extension or dart-thrower's motions. With an 89-N pushup force applied, the average maximum axial force was 69 N, the radially directed force was 12 N, and the moment about the radioulnar axis was 2.3 N-m. Linear extrapolation of the forces to 100% body weight indicate that the axial force going through the distal radius would be 663 N, the radial force would be 147 N, and the moment about the radioulnar axis would be 18.6 N-m.

Conclusions Large distal radius forces and moments can occur during pushup and active wrist motions. There are not only large axial compressive forces but also nontrivial radially directed forces.

Clinical relevance This study may help surgeons and therapists better treat complicated distal radius fractures as well as provide for better comparisons of existing or new distal radius plates and constructs that are designed to treat these complicated loading patterns. *(J Hand Surg Am. 2018;■(■):■−■. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words distal radius forces, wrist pushup, active wrist motions, 6 degrees of freedom.

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THE TREATMENT OF DISTAL RADIUS fractures has changed rapidly over the past 15 years with the introduction of new plate designs[1] and other constructs, such as intramedullary cage devices,[2] to treat simple and complicated fractures. To evaluate new plate designs and constructs, researchers have typically applied moments in the sagittal plane or axial forces to constructs having a plate secured to cadaver radii or sawbones models. They suggest that one design is better if it has the greatest force to failure or stiffness. Frequently, only axial forces were applied, such as in the study by Gesensway et al[3] who tested plates under axial load and found the strongest plates failed at 825 N. Others, such as Levin et al,[4] included cyclic axial loading before loading radii to failure. Martineau et al[5] applied both axial forces and sagittal plane bending moments and compared the stiffness value of the constructs. Liu et al[6] applied subfailure axial loads

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and bending moments before testing the constructs to failure under axial loading.

Slutsky and Herman[7] summarized 4 stages of fracture healing that occur and commented on the corresponding activity levels that are safe for patients with a healing fracture. Rehabilitation that allows gentle wrist motion may be allowed early on, depending upon the type of fracture and treatment. They note that, with time, active wrist motions are allowed and finally strengthening exercises are permitted. Little is known about the forces that occur in the distal radius during activities of daily living that a fracture fixation plate or construct might need to support during rehabilitation, an unexpected fall, or pushing up from a lying position. Greenburg et al[8] measured the *in vitro* radial and ulnar force during physiological motions but only reported them as percent force distributions between the 2 bones. Osada et al[9] compared the deformation and strength of different distal radius plating constructs with 100 N, 250 N, or failure forces applied. The 100-N force was selected based on theoretical calculations of the loading during active wrist motion. The 250-N force was chosen to represent physiological loading with active finger flexion.

One goal of this study was to determine the magnitude of forces that occur in the distal radius during simple wrist motions. These data can directly be used to confirm the validity of these previous estimates. These results may also clarify whether certain motions cause smaller distal radius forces and, therefore, may be preferable early on during rehabilitation. Another goal of this study was to determine the direction (eg, proximal, dorsal, radial) of the forces and moments in the distal radius during unrestricted wrist motions and during a pushup. In this study, we use the term pushup to reflect the loading when a person's wrist is maximally extended and forces are applied during various activities during the day, such as when someone lifts themselves out of a chair, moves furniture to vacuum beneath it, or even reaches up to put a heavy box onto a high shelf. For some patients seeking to return to competitive sports, physical exercise pushups may be included toward the end of a rehabilitation protocol.[10] The activities examined in this study represent a range from lightly loaded passive activities to higher load activities with the wrist extended that might occur during the healing process. The direction of loading during these activities may have an impact on the timing of when they are allowed for different types of fractures because a plate or construct may have to continue to support these forces while the healing process is completed. A third goal of this study was to aid in the evaluation of new plate designs. Simply designing a stronger plate may not be beneficial. To reduce soft tissue impingement, a thinner plate may be desirable if it can support the forces during healing of a fracture. Therefore, information on these forces may help determine ideal loading profiles to apply when testing plates and constructs and in the treatment of complicated fractures.

The purpose of this study was to determine the 6 degrees of freedom forces and moments in the distal radius that occur during a pushup or other active wrist motions.

METHODS

Eight fresh-frozen cadaveric wrists (average age, 79 years [range, 54–92 years], 6 men) were tested in a computer-controlled, servohydraulic simulator.[11,12] The sample size of 8 wrists was based on previous studies using similar methods but for different clinical applications. In 1 study, 7 wrists were used,[8] and in another, a total of 9 wrists were tested.[13]

Using the simulator, each wrist was dynamically moved through simulated active arcs of 2 flexion-extension, 1 radioulnar deviation, and 3 dart-thrower's motions. The small flexion-extension motion was from 30° extension to 30° of flexion. The large flexion-extension motion was from 30° extension to 50° flexion. The radioulnar deviation motion was from 20° of ulnar deviation to 10° of radial deviation. The small dart-thrower's motion had a range from 30° of flexion and 10° of ulnar deviation to 30° of extension and 10° of radial deviation. The larger dart-thrower's motion had the same extension and radial deviation but had an increase to 50° of flexion at 10° of ulnar deviation. The third dart-thrower's motion was similar to the larger dart-thrower's motion, but all of its motion was offset ulnarly 5° to better represent the dart-thrower's motion seen in many daily activities, based on a study by Garg et al.[14] In that study, they reported that a number of activities of daily living occur with a dart-thrower's motion with the path of motion ulnarly offset from neutral. These 6 motions were chosen to reflect what is considered to be a functional wrist range of motion and to include several dart-thrower's motions, the importance of which has been described by Moritomo et al.[15] The tested motions exceed the suggested functional wrist range of motion suggested by Nelson,[16] slightly exceed the range of motion suggested by Palmer et al,[17] and are slightly less than that suggested by Ryu et al.[18]