REVIEW ARTICLE

2007 IFSSH Committee Report of Wrist Biomechanics Committee: Biomechanics of the So-Called Dart-Throwing Motion of the Wrist

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The dart-throwing motion (DTM) plane can be defined as a plane in which wrist functional oblique motion occurs, specifically from radial extension to ulnar flexion. Most activities of daily living are performed using a DTM. The DTM utilizes the midcarpal joint to a great extent. Scaphotrapezio-trapezoidal anatomy and kinematics may be important factors that cause a DTM to be a more stable and controlled motion. During a DTM, there is less scaphoid and lunate motion than during pure flexion-extension or radioulnar deviation. Clinically, a DTM at the plane approximately 30° to 45° from the sagittal plane allows continued functional wrist motion while minimizing radiocarpal motion when needed for rehabilitation. (J Hand Surg 2007;32A:1447–1453. Copyright © 2007 by the American Society for Surgery of the Hand.)

Key words: Anatomy, biomechanics, dart-throwing motion, midcarpal joint, wrist.

Our vision of carpal kinematics may be obscured by a relatively rigid adherence to the orthogonal sagittal and coronal planes of wrist motion, when in fact most activities of daily life rarely use these planes of motion. It has been historically well known that most activities are performed using an oblique wrist motion from radial deviation-extension to ulnar deviation-flexion, which has often been called the *dart thrower's motion* or the *dart-throwing motion* (DTM). There have been relatively few studies that comprehensively examined DTM, however, and even the definition and terminology of this functional oblique motion is still obscure. Therefore, the purpose of this report is to comprehensively discuss DTM from the viewpoint of anatomy, anthropology, and biomechanics in order to emphasize the importance of DTM.

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Terminology

One of the aims of the International Federation of Societies for Surgery of the Hand is to establish and recommend the adoption of certain standards of nomenclature in surgery of the hand. We should use clear and appropriate descriptions and terminology when describing biomechanical methods and results, as well as in the clinical setting. Regarding the description of the extreme positions of DTM, we would like to advocate the usage of *radial extension* instead of *radial deviation-extension* and *ulnar flexion* instead of *ulnar deviation-flexion*. The DTM plane can be defined as a plane in which wrist functional oblique motion occurs, specifically from radial extension to ulnar flexion.

History

Several centuries elapsed from the first formal anatomical description of the carpal by Vesalius[1] in 1543 to the first comprehensive physiological study by Henke in 1859,[2] just before the 1895 discovery of the x-ray by Roentgen. Henke, quoted by Linscheid[3] in his review of wrist history, was the first to systematically study carpal motion in cadaver wrists. He noted independent motions at the radiocarpal and midcarpal joints, and he considered motion in the wrist to occur through mutually perpendicular axes passing through the capitate. On the other hand, he noted also that there was no "pure" motion in the joint, and this may be the first suggestion of an oblique axis of wrist joint motion. Roentgen's discovery of the x-ray at the end of 1895 had a deep impact on wrist biomechanics comprehension. During the early years following 1895, many authors tried to understand carpal biomechanics through dynamic radiographs. Destot and Cousin[4–6] focused on the adaptability of the first carpal row (especially the scapholunate unit) during wrist motion and noted that functional wrist motion results from combinations of flexion, extension, abduction, and adduction. Corson[7] concluded in 1897 that the axes of motion of the radiocarpal and midcarpal joints were oblique and confirmed Henke's view that pure flexion-extension and abduction-adduction of the wrist were questionable. He noted that extension aided abduction, whereas flexion aided adduction, and this may be the first formal suggestion of what will later be called DTM. Fick[8] in 1901 constructed a 3-dimensional model of the wrist, which led him to also propose oblique axes for each carpal row that intersected in the capitate.

Almost 50 years elapsed before Bunnell's classic 1944 book was published; Bunnell[9] explains in the chapter about normal wrist motion that "the wrist moves well in the anteroposterior plane but in lateral movements the motion is freer in a plane running slightly dorso-radial and volar-ulnar." In Boyes' 4th edition of Bunnell's book, this assessment is further emphasized: "in normal use, the axis of motion in the wrist is not in a true dorsal volar direction but more from dorso-radial to ulnar volar." Capener[10] published in 1956 his landmark paper about functional wrist motion. Capener quoted Bunnell's description that lateral deviation movements of the wrist are most easily carried out radialward with extension and ulnarward with flexion. Capener noted that in these 2 directions lies the plane of physiological movement and that it corresponds respectively with the action of the radial carpal extensors and the flexor carpi ulnaris. He noted that this oblique movement was well seen in the use of a mallet. He pointed out that in wrist radial deviation-extension (radial extension), there is slight pronation of the forearm; conversely, in wrist ulnar deviation-flexion (ulnar flexion), there is slight supination. He considered that this motion is important in all manual occupations involving a swinging action of the forearm with extension of the elbow joint and strong action of the wrist in an ulnar direction. It is thus seen in the use of most tools of percussion as by sculptors, carpenters, stonemasons, motor mechanics, fly fishermen, tennis players, and orthopedic surgeons.

Fisk[11] described in 1981 that this action is seen in holding a fishing rod to cast a fly, throwing a dart, or conducting an orchestra using a baton. He noted this is the true physiological axis of extension and flexion of the carpus.

Sturzenegger et al[12] reported in 1991 that the results of radioscapholunate arthrodesis showed that the residual plane of motion was restricted to an oblique plane extending from radiodorsal to ulnopalmar. This finding implies that the motion plane of the midcarpal joint is almost identical to the DTM plane. Saffar and Seumaan[13] described in 1994 that there is more mobility and more agility in this oblique plane, as this oblique plane utilizes the midcarpal joint to a great extent. They suggested that more attention should be paid to this plane of motion because the center of rotation of the carpal and of the wrist, the different angles between these bones, and the relative motions of those bones could be more easily understood if studied in this plane.

Contributing Anatomical Factors to DTM

The so-called DTM is the most commonly used plane of wrist rotation in activities of daily living. Furthermore, it is one of the most natural rotations of the wrist that can be done with minimal muscle force. If, in the cadaver, equal amounts of tension are applied to all wrist motor tendons with the forearm horizontal in pronation while the hand is allowed to flex by gravity, there is always an associated ulnar deviation vector added to the obvious flexion tendency. Similarly, when in supination, if the muscle-balanced wrist is allowed to extend by gravity, the natural extension moment generated is always coupled by a variable degree of radial deviation. This oblique plane of physiologic DTM is unique to each individual and depends on a number of anatomical factors.

Joint Geometry Factors

The distal scaphoid surface contains an obliquely oriented ridge, the orientation of which guides scaphotrapezio-trapezoidal (STT) joint motion in a semiconstrained fashion.[14,15] Any motion at the STT