SCIENTIFIC ARTICLE

Influence of Maximal or Submaximal Effort on the Load Distribution of the Hand Analyzed by Manugraphy

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Purpose This study aims to investigate if the hands' load-distribution pattern differs during maximal and submaximal grip.

Methods Fifty-four healthy subjects used the 200-mm Manugraphy cylinder to assess the load-distribution pattern of both hands. On 2 testing days, the subjects performed grip-force testing: 1 hand with maximal effort and the other with submaximal effort. Sides changed for the second testing day. The whole contact area of the hand was sectioned into 7 anatomical areas, and the percent contribution of each area, in relation to the total load applied, was calculated. Maximal and submaximal efforts were compared across the 7 areas in terms of load contributions.

Results Comparing maximum effort of the left and right hand, the load distribution was very similar without statistically significant differences between the corresponding areas. Comparing the maximal and the submaximal effort for each hand, 4 (left) and 5 (right) of the 7 corresponding areas showed statistically significant differences. Comparing the right hand, performing with maximal effort, with the left hand, performing with submaximal effort, 5 areas varied significantly. With the right hand performing submaximal effort, all 7 anatomical areas were significantly different.

Conclusions The load distribution of a healthy hand is different when performing with submaximal effort compared with maximal effort. To analyze a hand's load-distribution pattern, the opposite hand can be used as a reference.

Clinical relevance The hand's load-distribution pattern may be a useful indication of submaximal effort during grip-force testing. *(J Hand Surg Am. 2018;■(■):1.e1-e9.*

Key words Insincere effort, grip force, load distribution, malingering, manugraphy.

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GRIP FORCE IS AN ESSENTIAL aspect of hand function and an important criterion with which to rate manual dysfunction. Grip-force measurement depends on the patient's cooperation to exert a maximal effort. Patients may have various motives and reasons for submaximal effort during grip-force testing. Pain, depressive mood, medication, or avoidance behavior may result in an unconsciously low effort.[1–6] There may be also intentionally feigned grip testing, motivated by any

secondary gain like prolonged work incapacitation, avoiding military duties, or claiming financial compensation through worker's compensation.[7,8] In particular, patients with a wide discrepancy between the severity of their complaints and demonstrated limitations and no objective findings to account for their symptoms may pose a problem for the physicians and therapists. Clinical tools to prove the sincerity of grip-force testing may be helpful.[9–11]

At present, there is no commonly accepted test or method to reliably detect sincerity of grip-force testing. The 5-rung test (5R),[10,12] the rapid exchange grip test (REG),[13–16] the SD and coefficient of variation (VC) among several measurement trials,[17–21] or a combination of several tests (5R, REG, VC)[22] may give only a subtle hint of submaximal effort in grip-force testing. Digital instruments develop a force-over-time curve during isometric grip-force testing and the subsequent analysis of this curve may provide some indications of submaximal effort.[23,24] However, none of these methods allows for reliable prediction of the sincerity of grip-force testing.[2,11,25–28]

Another approach to detect submaximal effort is to analyze the load distribution of the hand. Mitterhauser et al[29] stated that, during sincere testing, the force exerted by the index and middle fingers is higher than those of the ring and little fingers. The authors reasoned from a large series of patients that a stronger ulnar grasp force, in combination with a variance in grip strength of either hand higher than 15.1% and a difference of more than 5.1% between left and right, is a predictor of exerting less than maximum effort. Because the validity of the method remains unclear, that guide may not be generally applicable.

Following the idea of analyzing the hand's load distribution to detect sincerity of effort, we considered the Manugraphy system (Novel, Munich, Germany) an adequate instrument for further research. The Manugraphy system measures the load applied on the contact area between the hand and a cylinder surface during isometric grip, resulting in a high-resolution map of the hand's load distribution.

This study aimed to investigate if the load-distribution pattern of the hand differs with maximal and submaximal grip when testing healthy subjects.

MATERIALS AND METHODS

Subjects and testing sequence

Fifty-four healthy subjects participated in this study, which the institutional review board approved. The study subjects were students or hospital employees, none received any compensation. All subjects gave informed consent prior to their inclusion in the study. The number of individuals included was determined by a sample size estimate ($P < .05$; power $\beta = .8$). The effect size and SD was estimated by a previous study investigating normative values of Manugraphy.[30] The sample size calculation was reassessed and confirmed using data from the first 15 subjects of this study tested. Exclusion criteria included subjects with disorders or previous injuries of the upper extremities, congenital malformations, myofascial pain syndrome, rheumatoid diseases, neurological disorders, or diabetes. Twenty-five subjects were men and 29 were women with a mean age of 34 years (range, 19–53 years). Fifty-two subjects were right handed.

Grip force and load distribution were measured using the Manugraphy system, as shown in Figure 1. For this study, a cylinder with 200-mm circumference covered with a pressure sensor matrix was analyzed. The subjects performed the testing in a standardized position as recommended by the American Society of Hand Therapists.[31] During testing, the individuals sat on a stool without a backrest, with the shoulder in neutral rotation, the arm adducted, and the elbow flexed at 90°. The subjects could not see the pressure and grip-force values on the screen during testing to rule out any influence caused by visual cues.[32] The testing started with the left hand, followed by the right hand. To ensure a standardized time sequence of gripping and releasing the cylinder for the study testing, the Manugraphy system replayed prerecorded audio instructions for all subjects ("Grip! ... Release!"). The subjects gripped the cylinders for 3 intervals of 5 seconds (trials, 1–3), each of which was followed by a 10-second break. The subjects kept the measurement devices in the tested hand during the 3 trials. Owing to the short relaxation phases between the trials, a fatigue effect occurred. A previous study showed that this was within a negligible range and did not compromise the validity of the testing method.[33] This sequence was chosen because it was practical in terms of time and effort in the clinical setting.

Grip-force testing included 2 visits over the course of 1 week with an interval of at least 24 hour between the visits. The subjects were instructed to perform grip-force measurements using 1 hand with maximal force and the opposite hand with one-half to three-quarters of the maximal force to feign weakness. The side that had to perform submaximal effort at the first session was randomized; sides changed at the second visit. Hence, both hands performed 1 test each with maximal and with submaximal effort.