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A Comparative Validity Assessment of the Grip Dynamometer K-Force

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The objective of this study is to compare and analyze the grip dynamometers developed by our research team with widely used devices in the research field and commercially available devices for grip strength assessment. Various studies on grip strength have been conducted, with a majority focusing on the correlation between grip strength and health. Prior to this, a study was conducted to verify the validity of the equipment. To achieve the study's objective, three dynamometers widely used commercially and in research were selected and compared with the grip dynamometer K-Force (Humanmecha Ltd., Korea). For the comparative analysis of the equipment, a customized jig was fabricated to hold the grip dynamometer in place and apply a consistent force. Analysis of variance (ANOVA) was used to examine significant differences in the forces measured by each device under various loads. Statistical analysis confirmed that K-Force showed no statistically significant differences from the applied loads, while other grip dynamometers exhibited statistically significant differences. In this study, we demonstrated that K-Force is suitable for measuring grip strength and the strength of each finger. On the basis of the results of this study, K-Force will be actively utilized in future research to explore the correlations between grip strength and various diseases.

1. Introduction

Grip strength, the force exerted when an object is grasped by the hand, is generated by the thenar muscle between the thumb and the middle finger and the forearm muscles that act on the four fingers: index, middle, ring, and little fingers.(1) Grip strength can be measured accurately and quantitatively using grip dynamometers, which are categorized into hydraulic, pneumatic, mechanical, and strain gauge types based on their measurement methods.(2,3) The hydraulic grip dynamometer is the most basic type, displaying measurements in lb and kg. The pneumatic type measures the pressure exerted by squeezing an air-filled pouch, but it is often deemed unsuitable for accurate grip strength measurement. The mechanical type uses the elasticity of springs, which can diminish with prolonged use. Lastly, the strain gauge type employs sensors such as

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load cells that detect deformations such as bending. Strain gauge grip dynamometers maintain their shape during measurement, making them preferable.(2) Strain gauge devices are commonly used for measuring grip strength. Typically, grip dynamometers measure only the peak value of the total grip strength, which is the sum of the strengths of all the fingers. Numerous studies have shown a correlation between the peak value of the total grip strength and various factors.

In previous studies, the commonly used grip dynamometers include the hydraulic hand dynamometer JAMAR (JAMAR Ltd., USA), EH101 (CAMRY Ltd., China), and TKK 5401 (Takei Ltd., Japan), all of which only measure the peak value. Among the studies using JAMAR, Kim *et al.*(4) performed grip strength measurements to observe the progress of pain relief methods for patients with wrist pain, whereas Yu(5) conducted a comparative analysis of grip strength in the paralyzed and nonparalyzed sides of stroke patients to determine if impedance values obtained through noninvasive bioimpedance analysis can be used to assess rehabilitation progress. Studies using EH101 include that by Chen *et al.*,(6) who performed grip strength measurements to monitor the progress of grip strength training in the elderly, and Podrihalo *et al.*,(7) who measured the grip strength of arm wrestling athletes with different skill levels to understand the differences in their techniques. Additionally, Pavlović *et al.*(8) examined the differences in grip strength by gender and dominant/nondominant hand in 22 students. In studies using TKK 5401, Jeong and Kim(9) investigated the relationship between physical function index and grip strength in community-dwelling elderly individuals, whereas Jo and Kim(10) observed changes in grip strength in patients wearing orthotic devices. Furthermore, Park and Kim(11) conducted grip strength measurements on field workers to study the impact of grip strength on musculoskeletal disorders, and An and Choi(12) analyzed the association between grip strength and periodontal disease in Korean adults aged 30 and above using previously obtained grip strength data.

Among the previous studies, there were also investigations aimed at verifying the validity of the equipment. Kim(13) tested the validity of a self-developed grip dynamometer (KGPM, Korec Grip Power Measurement) to determine if it could replace the TKK 5401 as a grip dynamometer for powered prosthetics. This study involved measuring grip strength and conducting usability surveys with test subjects using both the developed grip dynamometer and the TKK 5401. Huang *et al.*(14) compared and analyzed JAMAR and EH101 to evaluate the validity of EH101. In this study, the authors measured the grip strengths of both hands of the test subjects, alternating between hands and providing rest intervals between measurements to enhance the validity of the results. Statistical analyses for validity included correlation coefficients, consistency measurements, and validity coefficients.

The grip dynamometer K-Force (Humanmecha Ltd., Korea) is an improved and advanced version of the multi-finger force measurement system developed by Kim and Kong.(15) K-Force incorporates four small load cells (DYHW-110, CALTSensoR, China) positioned at each finger (index, middle, ring, and little fingers) to measure the force exerted by each finger. On the basis of the findings from previous studies, the grip span can be adjusted to 50 and 60 mm, which have been shown to provide the highest grip strength and preference when using hand tools.(15) For data storage and analysis, specialized software was developed using LabVIEW (National Instruments Ltd., USA). This software not only displays the peak values of the measured data but also graphs all segments of the measurement process. To enhance data variety, the software includes fields for recording anthropometric data, military service status, gender, and the hand used for measurement. The K-Force system also enables the measurement of targeting and tracking forces using the collected grip strength data. The measured data can be stored on a computer and a dedicated K-Force server through the software.

In this study, the validity of K-Force was verified through two experiments using a total of four grip dynamometers, including three other commonly used devices. First, a customized jig was employed to assess the accuracy and repeatability of the devices. Second, grip strength measurements and a subjective usability survey were conducted with test subjects using all four grip dynamometers to confirm the validity of K-Force.

2. Data, Materials, and Methods

2.1 Experimental Equipment

The experimental equipment includes four grip dynamometers: JAMAR (JAMAR Ltd., USA), a hydraulic grip dynamometer widely used in many studies; the TKK 5401 (Takei Ltd., Japan), a strain gauge-type grip dynamometer used in exercise performance measurements and many physical examinations; EH101 (CAMRY Ltd., China), also a strain gauge-type device used by various organizations at a low cost; and K-Force (Humanmecha Ltd., Korea), which can measure both total grip strength and individual finger strength (Table 1). All grip dynamometers can measure grip strength by grasping the grip, but except for K-Force, the other grip dynamometers can only measure total grip strength and provide peak values.

2.2 Subjects

The participants were 11 healthy male college students from Dongseo University, aged 20–29 years (average: 24.0 ± 1.20 years), with no history of musculoskeletal disorders in the upper limbs, including the hands and arms. The average hand length, hand width, hand thickness, wrist circumference, and body mass index (BMI) of the participants were measured. Hand length was defined as the distance from the wrist crease to the tip of the middle finger with the

Table 1
(Color online) Four grip dynamometers (JAMAR: hydraulic hand dynamometer JAMAR; Takei: TKK 5401; CAMRY: EH101; Humanmecha: K-Force).

Category	Manufacturer			
	JAMAR	Takei	CAMRY	Humanmecha
Grip dynamometer				

hand fully extended. Hand width was defined as the straight-line distance from the inside to the outside edge of the hand. Hand thickness was defined as the maximum thickness between the back of the hand and the palm. Finally, wrist circumference was measured around the wrist at the lateral point. The average measurements of the 11 participants are presented in Table 2 below.

2.3 Experimental Procedure

2.3.1 Experiment 1

A customized jig was fabricated and used to compare and analyze the measurements of the four grip dynamometers, including K-Force, when weights of 10 kg were applied from 0 to 60 kg in 10 kg increments (Fig. 1). The experiment was conducted in the order of JAMAR, TKK, EH101, and K-Force, with three trials performed for each grip dynamometer, resulting in a total of 12 load trials. Given that the jig weighs 3.4 kg, each grip dynamometer was measured eight times, starting from 0 kg (without any load) and adding increments of 10 kg up to 63.4 kg (jig weight plus load). The average value of the three repeated measurements for each weight was used for comparison and analysis.

Table 2
Characteristics of participants.

	Age (y)	Height (cm)	Weigh (kg)	Hand length (mm)
	24.0 ± 1.20	170.0 ± 9.6	78.0 ± 21.4	180.1 ± 10.0
Mean	Hand width (mm)	Hand thickness (mm)	Circumference (mm)	BMI
	79.0 ± 24.0	28.0 ± 2.0	149.0 ± 45.1	26.7 ± 5.3

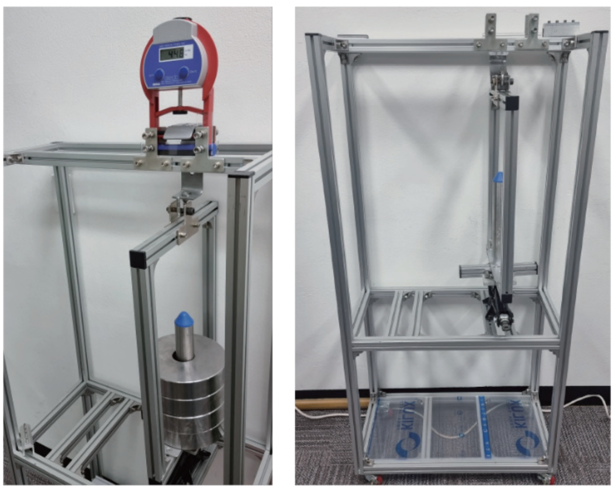

Fig. 1. (Color online) Self-made measuring jig.

2.3.2 Experiment 2

Before the experiment, participants were briefed on the measurement of anthropometric data, the experimental procedure, and the experimental equipment. The grip strength measurement posture followed the standards established by the American Society of Hand Therapists. The correct posture involves sitting in a chair with the shoulder adducted and in a neutral position, the elbow flexed at 90°, the forearm in a neutral position, and the wrist maintaining 0–30° extension and 0–15° ulnar deviation. Grip strength measurements were conducted by having participants hold the posture and exert maximum grip strength for approximately 5 s. Each participant's right-hand grip strength was measured three times for a total of 12 measurements, with a 3 min rest between measurements to minimize fatigue-related errors. The order of the grip dynamometers was randomized for each participant to minimize errors due to learning effects. After all the measurements were completed, a subjective usability survey was conducted on the four grip dynamometers used in the experiment, based on the ergonomic PUI evaluation scale.

2.4 Experimental design

All statistical analyses in the experiment were conducted using analysis of variance (ANOVA) through IBM Statistical Package for the Social Sciences (SPSS) Statistics (IBM Corp., USA), with post-hoc analysis performed using the Duncan test. The independent variables were set as the four grip dynamometers (JAMAR, EH101, TKK 5401, and K-Force) and the load range from 0 to 60 kg in 10 kg increments. The dependent variables included the total grip strength measured by the four devices, the individual finger strength measured by K-Force, and the results of the subjective rating. Anthropometric data (hand length, hand thickness, hand width, wrist circumference, height, weight, and BMI) were set as extraneous variables.

3. Results

3.1 Experiment 1

The statistical analysis of Experiment 1, as shown in Table 3, revealed that there were statistically significant differences ($\alpha < 0.01$) between K-Force and the other dynamometers for the given loads (10–60 kg, in 10 kg intervals) (Fig. 2). The Duncan test results indicated that TKK 5401, EH101, and K-Force showed significant differences compared with JAMAR.

Table 3
Grip dynamometer measurement results according to load force.

		Load force						
		0 kg	10 kg	20 kg	30 kg	40 kg	50 kg	60 kg
Estimated load force	JAMAR	0	6.1	16.5	26.2	35.4	46.8	54.5
	TKK5401	0	14.2	24.6	35.4	46.8	54.5	65.5
	K-Force	3.3	13.3	23.3	33.3	42.9	53.4	63.4
	EH101	3.8	12.7	26.1	34.7	43.0	54.2	63.5

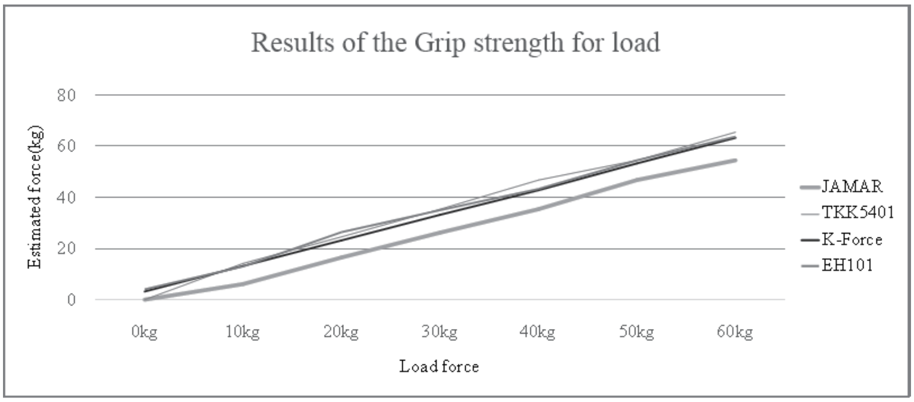

Fig. 2. Results of grip strength for load.

TKK 5401, EH101, and K-Force all accurately measured the load considering the weight of the jig. In contrast, JAMAR measured 6.6 to 8.9 kg less than the other dynamometers. This resulted in JAMAR recording only half of the actual load, including the weight of the jig and the applied load.

Additionally, while JAMAR and TKK 5401 failed to recognize the weight of the jig (3.4 kg) in the initial state without any applied load, displaying 0 kg, EH101 and K-Force correctly identified and displayed the initial weight of the jig.

3.2 Experiment 2

The statistical analysis of Experiment 2 revealed a statistically significant difference (α = 0.022). The results of post-hoc analysis using the Duncan test revealed no statistically significant difference between K-Force, TKK 5401, and EH101, and the measured grip strengths were as follows: TKK 5401 (39.7 ± 1.65 kg), K-Force (40.3 ± 1.65 kg), and EH101 (42.5 ± 1.65 kg). On the other hand, JAMAR measured the grip strength at 35.4 kg, which was about 4 kg lower than those measured by the other dynamometers, indicating a statistically significant difference when JAMAR is compared with TKK 5401, K-Force, and EH101 (Fig. 3).

Furthermore, subjective survey results show that TKK 5401, K-Force, and EH101 all showed similarly high preference in terms of light weight, easy-to-grab shape, and easy usability, while JAMAR showed low preference due to its heavy weight and inconvenience due to its rigid material.

K-Force distinguishes itself from other devices by being able to measure the strength of each individual finger. The measurements from this experiment showed that the middle finger had the highest strength, averaging 15.5 ± 5.2 kg. The ring finger measured 10.3 ± 4.5 kg, the index finger 8.3 ± 1.9 kg, and the little finger 6.2 ± 2.5 kg (Fig. 4).

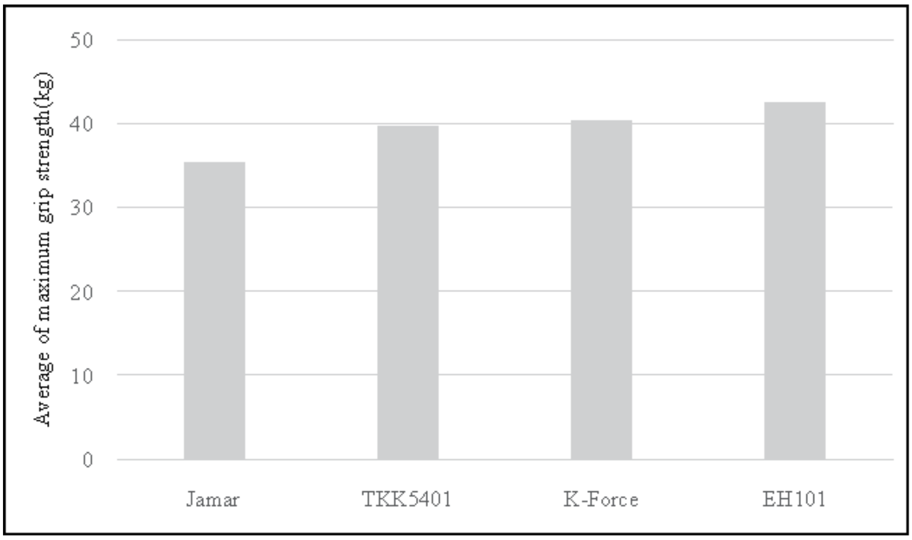

Fig. 3. Maximum grip strengths measured by grip dynamometers.

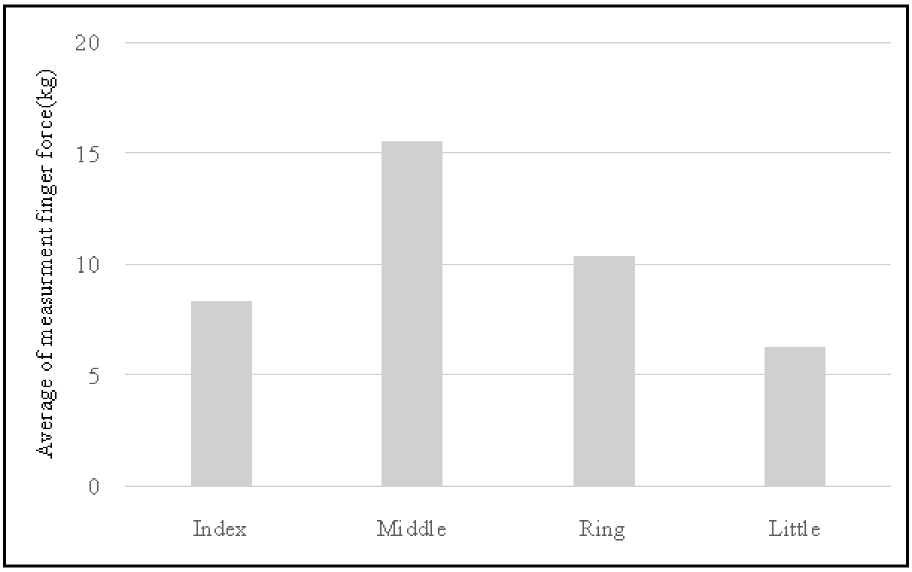

Fig. 4. Individual finger forces measured by K-Force.

4. Discussion

To establish the validity of the grip dynamometer (K-Force) developed by our research team, we verified whether each dynamometer could accurately measure force when a consistent load was applied using a jig developed in-house. Additionally, we examined the differences in grip strength among different dynamometers when maximum grip strength was exerted by 11 male university students in their 20s.

First, when measuring the same load with each dynamometer, JAMAR recorded a lower force compared with the same load, resulting in a statistically significant difference from other grip dynamometers. The grip strength measured by JAMAR in this study was consistent with previous studies by Andrade *et al.*[16] and Tai and Wan,[17] which reported that JAMAR measured lower forces than EH101. The main reason for the lower measurements by JAMAR is presumed to be attributable to its handle shape and material. The curved shape of the JAMAR handle may alter the direction of force application, making it difficult to measure the full force accurately.

The grip strengths measured from the participants, including the strength of each finger, also showed that JAMAR measured lower forces than the other dynamometers. Subjective rating evaluations of grip dynamometer preferences conducted after the experiment indicated that JAMAR was less preferred owing to discomfort caused by its handle shape and slippery material.

K-Force, which can measure the strength of each finger, showed that the middle finger exerted the greatest force, followed by the ring, index, and little fingers. Generally, the strengths of the ring and index fingers vary among individuals, similar to the findings of Kim and Kong.[15]

The results of this study validate the validity of K-Force, suggesting that it can be used for various applied research studies. Numerous studies have shown statistically significant correlations between maximum grip strength and the prevalence of diseases. K-Force not only measures the overall hand strength but also the individual strength of each finger, tracks changes in strength over time, and measures the accuracy and reaction time in exerting target forces. These features can be utilized to explore the relationship between detailed grip strength measurements and various health conditions, offering new research directions. This research can contribute to developing hand strength indicators and predictive models for health outcomes.

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