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RESEARCH ARTICLE

Analysis of Grip Strength of Women Workers Using IoT Digital Devices

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ABSTRACT

The purpose of this study was to determine the grip strength of female workers in the beauty industry and to examine differences between various grip strength measuring devices. The specific research objectives are to determine the differences in grip strength according to the age and work area of female workers, as well as to assess the accuracy of IoT grip strength measuring devices compared to existing devices. This revision clarifies the objectives and improves sentence flow. The study included 121 beauty industry workers, comprising 19 skin care workers, 18 nail care workers, 66 hair designers, and 18 makeup artists. Three types of grip strength measuring devices were used: a Japanese digital grip dynamometer (Takai TKK-5401, Takei Scientific Instruments Co., Ltd., Tokyo, Japan), a Chinese digital grip dynamometer (Camry EH101, China), and a Korean wireless digital grip dynamometer (Soundbody-grip, Korea). Each device was used to measure grip strength twice, with the average value used for analysis. The results showed no significant differences in grip strength across different beauty industry fields, but grip strength varied by age. Additionally, there was a trend of decreasing grip strength with increasing work experience. This study underscores the potential of a new IoT grip strength measuring device and provides insights into the unique grip strength characteristics of female workers in the beauty industry.

INTRODUCTION

In medical and rehabilitation settings, handgrip strength assessment is important as a surrogate marker for overall muscle strength and functional status (Rose et al, 2002). Muscle function is utilized as a significant health indicator not only in healthy populations but also in individuals with various diseases (Yasumoto et al., 2014). Specifically, handgrip strength is widely used because it allows for the assessment of an individual's muscle function in a non-invasive and economical manner (Li et al., 2014). Grip strength is also related to osteoporosis risk and socioeconomic status (Kim et al., 2018). It is also used to diagnose possible sarcopenia in the elderly (Miller et al, 2014). With the advent of digital healthcare technologies, there is a demand for more accurate and integrated measurement tools. The measurement of hand and finger movements and strength plays a crucial role in medical diagnosis, rehabilitation, and even in virtual reality (VR) applications (Becerra et al, 2021; Khaleel et al., 2024). The development of accurate and reliable tools can improve the quality of user experience and contribute to the enhancement of the medical rehabilitation process.

Therefore, this study introduces a wireless IoT handgrip strength measurement device designed to meet the requirements of precision, ease of use, and digital integration in the era of the Fourth

Industrial Revolution. This device's performance is compared with two traditional types of dynamometers to assess its efficacy and usability. Traditional devices widely used in Korea, such as the JAMAR® and Takei dynamometers, provide reliability and accuracy but are limited in their integration with modern digital healthcare systems (Cronin et al., 2017; Helaudho et al., 2024) The researchers aimed to overcome these limitations by developing an enhanced wireless IoT handgrip device.

In the era of the Fourth Industrial Revolution, working or operational environments may involve prolonged use of computers, mice, etc., or entail rapid and continuous tasks, often requiring repetitive use of fingers, wrists, and shoulders. In the era of the 4th Industrial Revolution, work or operating environments often involve using computers, mice, etc. for long periods of time or performing fast and continuous tasks, often requiring repetitive use of fingers, wrists, and shoulders. In addition, hair designers, who are considered traditionally female occupations, also require repetitive use of fingers, wrists, and shoulders. Hair designers are occupations that require constant use of the upper extremities during the work process. They have occupational musculoskeletal disorders of the upper extremities, including the shoulders and neck (Song & Han, 2006). Age and gender are variables that should be considered in changes in grip strength (Miller et al, 2014). This initiative seeks to measure and compare upper extremity strength (handgrip) of female workers in manual industries using IoT digital device.

Therefore, the purpose of this study is to assess the grip strength of female workers in the beauty industry and evaluate the reliability of various grip strength measurement devices. The specific objectives are as follows: First, to determine whether there are differences in grip strength based on the age and work area of female workers. Second, to assess the accuracy of IoT grip strength measurement devices in comparison to existing devices.

METHODS

Subjects

The study subjects had not undergone surgical operation on the shoulder or upper limb within the past year and were currently working in their respective occupations. The exclusion criteria were those with cognitive function problems, neurological diseases, or diabetes. All study subjects were explained the experimental methods and procedures and were informed that they could refuse participation and terminate their participation at any time during the experiment. The subjects were asked to participate voluntarily if they agreed to the experimental process and procedures. This study received approval from the Sehan University Institutional Review Board (SH-IRBB 2024-007). The subjects of this study are 121 people, all of whom are women. In G*Power, when setting the effect size using Cohen's f for ANOVA at 0.4, the significance level at 0.05, and the power at 0.95, the required minimum sample size per group for a one-way ANOVA is approximately 16 individuals. This indicates that the study has met the sufficient sample size based on these parameters. The subjects of this study were 121 women. They were all working in the beauty industry, including skin care, nail care, hair designers, and makeup artists.

Methods

In this study, the maximum grip strength of the right and left hands was measured twice each using three types of grip strength measuring devices: a Japanese digital grip dynamometer (Takai TKK-5401, Takei Scientific Instruments Co., Ltd., Tokyo, Japan), a Chinese digital grip dynamometer (Camry EH101, China), and a Korean digital grip dynamometer (Soundbody-grip, Korea). To minimize the impact of device-specific results, the assignment method was randomized, and all subjects were measured twice after sufficient explanation and practice, taking into account hand size and grip strength. After the first measurement, the second measurement was performed after a 1-minute rest. Before measuring the grip strength, an explanation and demonstration were provided, and the subjects were asked to practice once so that they could measure naturally before the measurement was performed.

When measuring with the Takai grip dynamometers (A device) and Camry grip dynamometers (C device), the measurements were made in the same posture, as shown in Figure 1. When measuring with the Takai grip strength meter and the Camry grip strength meter, lower the arm naturally and adjust the handle so that the second joint of the measurement subject's finger can be bent at 90°, then stand up with both feet shoulder-width apart, elbows, The number displayed on the instrument panel was recorded by holding the handle with maximum force for 3 seconds without bending the wrist (Richard et al, 2014). The Soundbody-grip strength measuring device (B device) is a product that is linked to a smartphone app (Soundbody-grip), and the degree of grip strength and heart rate can be checked visually and numerically in the app. This equipment provides visual feedback on the device's signals by tracking user upper limb movement and connecting real-time data wirelessly (via Bluetooth) to an application. The Soundbody-grip strength meter is a device in which the subject sits with the elbows slightly bent at 20 to 30 degrees, wraps the entire grip strength meter with the hand, and grips the grip strength meter with maximum force for 3 seconds. The developed wireless IoT handgrip device (Soundbody) is multifunctional, using a combination of inertial sensors and force sensors to measure user grip strength, pulse, and motion simultaneously. It utilizes an integrated Micro-Electro-Mechanical System (MEMS) to evaluate various sensors. The numbers displayed on the app were checked and recorded.

Data Analysis

The measured data were analyzed using the statistical program statistical program SPSS 26.0. Grip strength was measured twice and analyzed using the average value. Data on general characteristics, grip strength were subjected to descriptive statistics using average values. The intraclass correlation coefficient was used to measure the reliability between the three types of grip strength meters. To identify the differences in grip strength between the three types of devices and the differences in grip strength by job field and age, one-way ANOVA and post hoc analysis were performed using Scheffe, and the significance level was set at $p < .05$.

RESULTS

General character of subjects

The general characteristics of the study subjects are shown in Table 1. The study comprised 19 skin care professionals (15.7%), 66 hair designers (54.5%), 18 makeup professionals (14.9%), and 18 nail professionals (14.9%), totaling 121 subjects (100%). The mean ages were 40.53 ± 12.44 years for skin care professionals, 47.48 ± 14.29 years for hair designers, 31.00 ± 12.14 years for makeup professionals, 41.06 ± 6.06 years for nail professionals, and 42.98 ± 13.93 years for the total subjects. Their careers were 7.79±7.67 years in skin care, 21.52±14.59 years in hair design, 6.89±8.89 years in makeup, 9.12±5.84 years in nail care, and the total subjects had 15.35±13.67 years.

Reliability Analysis

The reliability between three types of grip strength measuring devices was measured, and the results are shown in Table 2. The correlation coefficient was .910, indicating high reliability between grip strength measuring instruments. Therefore, reliability between grip strength measuring devices was secured.

Comparison of grip strength and work fields

In this study, the grip strength of female workers in the beauty work field was measured using an IoT grip strength meter and an existing grip strength meter, and the analysis results of the type of grip strength devices are shown in Table 3.

In A device the degree of right-hand grip strength was the highest in the nail care field at 24.93±3.97 kg and the lowest in the makeup field at 21.40±4.02 kg. However, there was no statistical difference. In the left-hand grip strength, the degree of skin care was the highest at 23.49±6.34 kg and the lowest in the makeup field at 20.66±4.19 kg. However, there was no statistical difference. In the C device, the degree of right-hand grip strength was the highest in the skin care field at 26.16±3.25 kg and the lowest in the makeup field at 24.03±3.60 kg. However, there was no statistical difference. In the left-hand grip strength, the degree of nail care was the highest at 25.47±1.66 and the skin care field at 25.45±3.70 kg, and the lowest in the makeup field at 23.31±4.03 kg. However, there was no statistical difference. The right-hand grip strength in B device was the highest in the nail care field at 24.48±4.04 kg, and the lowest in the makeup field at 21.13±4.06 kg. However, there was no statistical difference. The left-hand grip strength was the lowest in the nail care field at 22.42±3.38 kg, and the makeup field at 19.17±4.26 kg. However, there was no statistical difference. Therefore, there was no difference in the grip strength according to the job characteristics of women working in the beauty work area.

Comparison of grip strength and age

The grip strength by age group was examined, and the results are presented in Table 4. For Device A, right-hand grip strength was highest in the 30s, measuring 26.49±4.79 kg, and lowest in those aged 60 and older, at 19.71±3.88 kg. There was a statistically significant difference in grip strength by age group ($p<.01$). The left-hand grip strength followed a similar pattern, being highest in the 30s at 25.36±4.97 kg and lowest in the 60s and older at 18.69±3.91 kg, with a statistically significant difference observed ($p<.01$). In Device B, right-hand grip strength peaked in the 30s at 26.88±2.08 kg and was lowest in the 60s and older at 23.67±3.23 kg, showing a statistically significant difference by age group ($p<.05$). Although left-hand grip strength was highest in the 30s at 26.65±2.14 kg and lowest in the 60s and older at 23.57±2.87 kg, no statistically significant difference was found. For Device C, the highest right-hand grip strength was recorded in the 30s at 26.88±3.78 kg, with the lowest in the 60s and older at 19.53±4.54 kg. A statistically significant difference by age group was observed ($p<.01$). The left-hand grip strength also peaked in the 30s at 24.28±5.16 kg and was lowest in the 60s and older at 18.31±3.80 kg, with a statistically significant difference ($p<.01$). Across all three devices, grip strength was highest in the 30s and lowest in those aged 60 and older.

Correlation between the career experience and grip strength

In order to find out the correlation between the subjects' career experiences and grip strength, the average of the grip strength measured by three types of grip strength measuring devices was used. The results are shown in Table 5. There was a negative correlation between career experiences and the degree of grip strength of the right hand ($r=-.220$, $p<.05$). There was no correlation between career and grip strength of the left hand. Therefore, it seems that the higher the career, the lower the grip strength of the right hand.

DISCUSSION

This study aims to assess the grip strength of female workers and examine the accuracy of different grip strength measuring devices. First, the study investigated whether there is a difference in grip strength according to the age of female workers. The results showed that women in their 30s had the highest grip strength, while those aged 60 and above had the lowest. Grip strength peaks in the 30s (Bohannon, 2008) and gradually declines, with a sharp decrease after the 50s (Richard et al., 2014). Therefore, the results of this study are consistent with previous findings. William et al. (1991) reported significant differences in grip strength between the right and left hands and across age groups for both men and women, with significant declines observed in men aged 50–54 and 55–59 and in women aged 50–54 and 60–64. According to Lee et al. (2023), longer hand length is associated with stronger grip strength. Additionally, since grip strength can vary depending on the posture during measurement (Seo et al., 2020), it is essential to measure grip strength in a consistent posture. Hands are essential tools in daily life and have broad applications, such as assessing children's developmental stages, facilitating return to work after occupational hand injuries, and assisting in career choices. Hand strength is an important independent parameter for assessing morbidity, mortality risk, and general disability in old age, and predicting future outcomes (Angst et al., 2010; Al-Aarajy., 2024).

In this study, although there was no difference in grip strength according to the work area, it was found that the grip strength of the right hand decreased as work experience increased, whereas no correlation was observed between work experience and left-hand grip strength. In studies comparing the grip and pinch strength of the dominant and non-dominant hands, the dominant hand has been reported to have stronger grip strength (Incel et al., 2002). This finding indirectly relates to the results of this study, which showed a correlation between career length and right-hand grip strength. Most Koreans use their right hand as the dominant hand, and over 90% of older adults also use their right hand as the dominant hand. Therefore, the significant correlation between right-hand grip strength and work experience in this study is likely due to the dominance of the right hand.

This study also aimed to evaluate the accuracy of a newly developed wireless IoT grip strength measurement device compared to existing measuring tools. The comparative analysis showed that the developed wireless device had a range similar to that of existing dynamometers, providing some evidence of its reliability and accuracy. The ease of use of the wireless IoT handgrip device, its application in VR programs, and its dynamic simulation in handling virtual objects during rehabilitation exercises have been shown to enhance user experience. The comparison further demonstrated that the developed wireless device could serve as an efficient alternative to traditional measuring tools. The device offers a novel approach beneficial for assessing physical health status, medical rehabilitation, and performing interactive tasks in virtual reality environments. It is considered that further studies can investigate grip strength measurements, comparisons, and understanding of characteristics across various sectors among industry workers, as well as the relationships between different occupations, career lengths, and grip strength. These results suggest that the device could be useful for physical health assessments, medical rehabilitation, and virtual reality applications. Continued collection of age-related data could contribute to the development of health improvement programs for workers in various industries.

This study has limitations, as it only targeted female workers, making it impossible to compare with male workers, and the number of participants was not equal across age groups and occupations. Future research is needed to compare male workers in the same field.

CONCLUSION

In this study, we investigated the grip strength of female workers and compared an IoT grip strength measuring device with existing devices. The study found no difference in grip strength among female workers based on their work area; however, grip strength varied with age. Additionally, it was confirmed that grip strength tended to decrease as work experience increased.

AUTHORS' CONTRIBUTION

Kim conceived the idea and statistical analysis.

Lee performed designed the project and wrote the manuscript.

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APPENDIX

Figure 1: Grip Strength devices for Takai, Camry, Soundbody

Table 1: General character of subjects

Work fields	N (%)	Age years (Mean±SD)	Carrer year (Mean±SD)
Skin care	19(15.70%)	40.53 ±12.44	7.79±7.67
Hair designer	66(54.50%)	47.48 ±14.29	21.52± 14.59
Makeup artist	18(14.90%)	31.00 ± 12.14	6.89 ±8.89
Nail care	18(14.90%)	41.06 ±6.06	9.12± 5.84
Total	121(100%)	42.98 ±13.93	15.35± 13.67

Table 2. Reliability Analysis

Cronbach 's α	.910

Table 3. Work fields and grip strength

		Work area	**N**	**Mean**	**SD**	**F**	**p**
A device	Rt	Skin care	19	24.47	6.80	1.806	0.15
		Hair designer	66	23.98	4.94		
		Makeup artist	18	21.40	4.02		
		Nail care	18	24.93	3.97		
		Total	121	23.82	5.08		
	Lt	Skin care	19	23.49	6.34	1.495	0.22
		Hair designer	66	21.77	5.09		
		Makeup artist	18	20.66	4.19		
		Nail care	18	23.41	3.57		
		Total	121	22.12	5.03		

B device	Rt	Skin care	19	26.16	3.25	2.59	0.056
		Hair designer	66	25.98	2.64		
		Makeup artist	18	24.03	3.60		
		Nail care	18	25.94	1.64		
		Total	121	25.71	2.84		
	Lt	Skin care	19	25.45	3.70	2.147	0.098
		Hair designer	66	25.14	2.86		
		Makeup artist	18	23.31	4.03		
		Nail care	18	25.47	1.66		
		Total	121	24.96	3.11		
C device	Rt	Skin care	19	24.03	6.46	1.58	0.198
		Hair designer	66	23.81	5.39		
		Makeup	18	21.13	4.06		
		Nail care	18	24.48	4.04		
		Total	121	23.54	5.27		
	Lt	Skin care	19	21.83	6.39	1.64	0.184
		Hair designer	66	21.21	4.55		
		Makeup artist	18	19.17	4.26		
		Nail care	18	22.42	3.38		
		Total	121	21.18	4.73		

Table 4. Age and grip strength

		Age	N	Mean	SD	F	p	post hoc
A device	Rt	20s [a]	27	23.42	3.89	4.21	0.003	e,a,d>a,d,c,b
		30s [b]	17	26.49	4.78			
		40s [c]	35	24.44	5.95			
		50s [d]	27	24.00	4.52			
		60s≥ [e]	15	19.71	3.88			
		Total	121	23.82	5.08			
	Lt	20s [a]	27	21.34	3.06	4.099	0.004	e,a,c, d>a,d,c,b
		30s [b]	17	25.36	4.97			

		40s [c]	35	22.35	6.13			
		50s [d]	27	22.44	4.52			
		60s≥ [e]	15	18.69	3.91			
		Total	121	22.12	5.03			
B device	Rt	20s [a]	27	25.76	2.69	2.873	0.026	e,a,c, d>a,d,c,b
		30s [b]	17	26.88	2.08			
		40s [c]	35	25.86	3.12			
		50s [d]	27	25.87	2.40			
		60s≥ [e]	15	23.67	3.23			
		Total	121	25.71	2.84			
	Lt	20s [a]	27	24.72	3.14	2.136	0.081	e,a,c, d>a,d,c,b
		30s [b]	17	26.65	2.14			
		40s [c]	35	25.03	3.47			
		50s [d]	27	24.83	2.95			
		60s≥ [e]	15	23.57	2.87			
		Total	121	24.96	3.11			
C device	Rt	20s [a]	27	22.09	3.84	5.431	0.00	e,a,d>b, d,e>d,e,b
		30s [b]	17	26.88	3.78			
		40s [c]	35	24.54	5.77			
		50s [d]	27	23.84	5.43			
		60s≥ [e]	15	19.53	4.54			
		Total	121	23.54	5.27			
	Lt	20s [a]	27	19.70	3.40	4.517	0.002	e,a,c d>c,d,b
		30s [b]	17	24.28	5.16			
		40s [c]	35	21.55	5.40			
		50s [d]	27	21.84	3.95			
		60s≥ [e]	15	18.31	3.80			
		Total	121	21.18	4.73			

Table 5. Correlation between career experience and grip strength

	Rt hand	**Lt hand**

Career experience	-.220*	-0.135

* p<.05