의학석사 학위논문

Knee extensor strength measurement in supine position for non-ambulatory patients using a portable dynamometer anchoring frame

휴대용 고정 동력계를 사용하여 누운 자세에서 거동이 어려운 환자의 무릎 신전 근력 측정

2020 년 7 월

서울대학교 대학원

의학과 재활의학

이 민 용

A thesis of the Master's degree

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July 2020

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이 논문을 의학석사 학위논문으로 제출함

2020 년 5 월

서울대학교 대학원

의학과 재활의학

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이민용의 석사학위논문을 인준함

2020 년 7 월

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Abstract

Knee extensor strength measurement in supine position for non-ambulatory patients using a portable dynamometer anchoring frame

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Introduction: Assessment of muscle strength is important to evaluate the outcomes of clinical interventions. The manual muscle test is the most common method of muscle strength measurement in busy clinical settings, but prone to error and poorly able to distinguish subtle differences. The isokinetic dynamometer (IKD) is considered the gold standard for muscle strength testing. However, it is physically large with limited portability Although a hand-held dynamometer (HHD) is suitable for bedside use, its inter-rater reliability is low because measurements can be influenced by tester strength. The aim of this study was to investigate the reliability of knee extensor strength measurement in supine position using a portable HHD anchoring frame in non-ambulatory patients.

Methods: Inpatients who were non-ambulatory in Seoul National University Hospital were enrolled. Using the portable dynamometer anchoring system which was consisted of an HHD attached to custom-designed portable mechanical frame, maximal knee extensor isometric strength was measured. During the measurement, the subject was in the supine position. Three trials of three maximal contractions were assessed by two raters.

Results: A total of 33 inpatients who were non-ambulatory due to acute illness participated in the study. The intraclass correlation coefficients were 0.974 (inter-rater) and 0.959 (intra-rater). The minimal detectable changes in intra- and inter-observer measurements were 29.46 N (24.10 %) and 36.73 N (29.26 %), respectively. The 95% limits of agreement ranged from -19.79% to 24.81% for intra-rater agreement and from -21.45% to 37.07% for inter-rater agreement.

Conclusion: The portable dynamometer anchoring system can measure the isometric strength of the knee extensor reliably in the supine position, and could be applied for patients who have difficulty visiting the laboratory and maintaining a seated posture to undergo measurements.

Keywords: Muscle strength, Dynamometer, Isometric contraction, Supine position, Reliability

Student Number: 2018-21934

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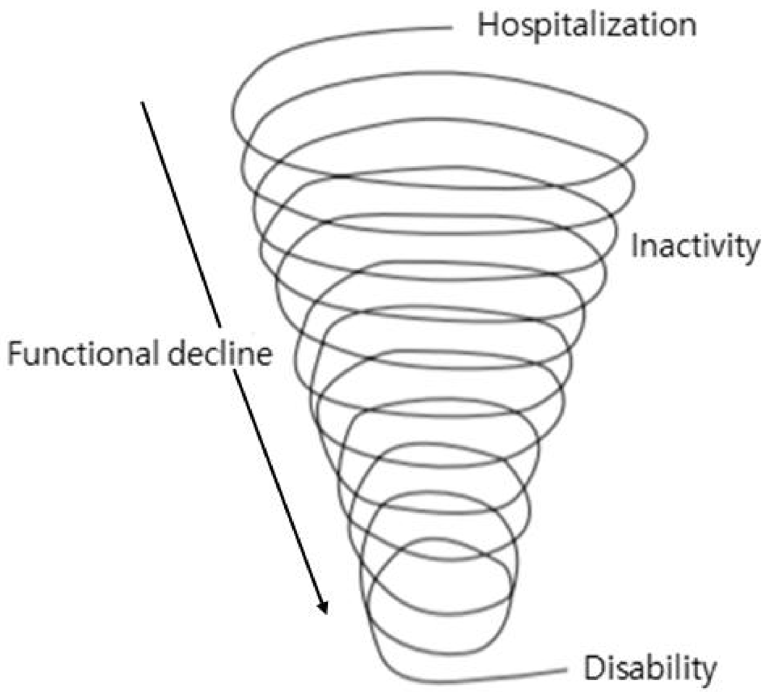
I. Introduction

Muscle weakness is an independent risk factor for morbidity and mortality [1, 2] and is an important contributor to long-term physical impairments [3]. It is well known that long-term hospitalization due to medical or surgical conditions can result in detrimental physiological effects on muscle strength and physical activity; this functional decline can lead to further inactivity, which enters a vicious cycle (Figure 1) [4].

Figure 1. Vicious cycle of deconditioning.



Assessment of muscle strength is important to evaluate the outcomes of clinical interventions to break the vicious cycle. The manual muscle test (MMT), which uses the Medical Research Council (MRC)'s grading system, is the most common method of muscle strength measurement in busy clinical settings. However, MMT is prone to error and poorly able to distinguish subtle differences because it relies on an examiner's judgment [5]. In particular, the inter-rater reliability of MMT is not sufficient to distinguish between grades 4 and 5 muscle strength [6].

The isokinetic dynamometer (IKD) is considered the gold standard for muscle strength testing (Figure 2). However, it is physically large with limited portability [7]; therefore, patients are required to visit the laboratory to undergo measurements. As a result, it is impractical for use in patients who cannot ambulate independently or have several monitoring devices or drains.

Figure 2. Isokinetic dynamometer, Biodex system 4 pro (Biodex Medical Systems Inc., Shirley, New York).

The hand-held dynamometer (HHD) is a portable device that provides a quantified measurement of strength. Compared with an IKD, its convenience, small size, and low cost are more suitable for bedside use [7]. However, the inter-rater reliability is low because the measurements can vary depending on tester strength [8]. To increase reliability, recent studies have attempted to affix an HHD to frame rather than having it held by the examiner [9-12].

Kim et al. studied the reliability and validity of hand-held dynamometer (HHD) depending on its fixation in measuring knee extensor strength [9]. The measurements were conducted with the HHD fixed to distal tibia with a Velcro strap, and a hand-held method without a Velcro strap. They reported that fixation of HHD increased the reliability and validity in measuring knee extensor strength.

In the study measuring knee extensor and flexor strength, Lu et al. reported that increasing the examiner's resisting force improves the validity of muscle strength measurements [10]. They used the resistance-enhanced dynamometer system. The system is fixed to the ground, and the rater applied force to the subject's lower leg by pushing the handle of resistance-enhanced dynamometer system.

Koblbauer et al. modified the HHD with straps holding the HHD. Straps were fixated to the treatment table [11]. They reported good inter-rater reliability of knee extensor and flexor strength measurements, but intra-rater reliability was not appropriate for clinical use.

Gagnon et al. developed the chair-fixed dynamometer system measuring maximal isometric strength of knee flexors and extensors [12]. The HHD was mounted on a steel support and the rigid support can move along a shaft fixed to a chair.

In 2017, Jackson et al. developed a portable stabilization device for muscle strength of lower leg in an athletic population [13]. This device was constructed of polyvinyl chloride pipe. One end was used to accommodate the HHD and the other end was made to be fixed to the wall. However, reliability of knee extensor strength measurements was poor, although the reliabilities of hip muscles and ankle plantar flexors were good.

Sung et al. recently suggested the use of a portable dynamometer anchoring system that can measure knee extensor strength in the supine position, and confirmed its reliability and validity in 39 healthy people [14]. In this study, the validity of this system was proved through correlation analysis between torque values obtained using the portable anchoring system and IKD. This system could be appropriately applied to cases where it is difficult to move the patients to the laboratory or in patients who have difficulty maintaining a sitting position during the test because the system can measure the strength in the supine position.

The aim of the present study was to investigate the reliability of knee extensor strength measurement in supine position using a portable HHD anchoring frame for non-ambulatory patients.

II. Methods

1 .Subjects

Patients who were non-ambulatory due to long-term immobilization or neurologic conditions and older than 18 years were enrolled. Patients were excluded if they had a history of traumatic spinal or lower extremity injury within the past 6 months, an inserted femoral catheter, or inability to give consent and understand the procedures of the experiment (Table 1).

Table 1. Inclusion and exclusion criteria.

Inclusion criteria - Inpatinets - Non-ambulatory - > 18 years
Exclusion criteria - History of traumatic spinal or lower extremity injury within the past 6 months - Inserted femoral catheter - Inability to give consent and understand the procedures of the experiment

In this study, a patient was measured for knee extensor strength with the hip and knee flexed in a supine position. It can cause damage to the spine and leg, if the patient had history of traumatic spinal or lower extremity injury. In addition, if a femoral catheter was inserted, a catheter could be removed or broken during the measurement.

The local Institutional Review Board approved the study and informed consent forms. The participants were informed of the study purpose and procedures prior to enrollment.

2. Portable dynamometer anchoring system

The portable dynamometer anchoring system consisted of an HHD attached to custom-designed portable mechanical frame (Figure 3). The frame bar perpendicular to the tibia was designed to be moved up and down according to leg thickness. The other two frame bars, which were designed to be moved back and forth depending on leg length, were fixed by hand knob tightening screws.

Figure 3. Portable dynamometer anchoring system in a supine position.

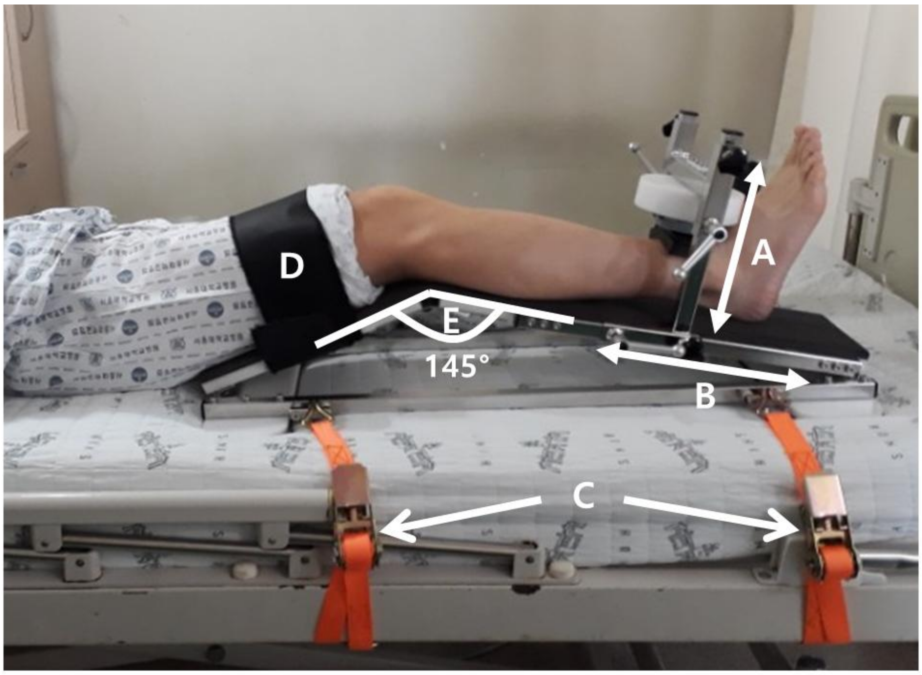
A: The frame can be moved to adjust the HHD depending on leg thickness

B: The frame can be moved to adjust the HHD depending on leg length

C: Belts that fix the frames to the bed

D: Velcro strap to fix the patient's thigh to minimize hip flexion movement

E: The frame was designed at an angle of 145° to flex the knee to 35°



The frame was designed at an angle of 145° to flex the knee at 35°. The angle of 35° was chosen considering the previous study results, which reported that high-level surface electromyography activity was observed when the knee joint was flexed by 35° [15]. The studies that measured knee extensor strength with the knee joint flexed by 35º in the HHD test showed good reliability [9, 14, 15].

In clinical settings, most of the bed-ridden patients had air mattresses on the bed to prevent pressure ulcer. Therefore, a shaking problem could occur when measuring muscle strength. To reduce it, the four U-shaped rings were placed on the corners of the frame to connect the belts to fix the device to the bed. These rings and belts are usually devices used to secure cargo, and excellent for fixing something. In addition, the thigh of the participants can be fixed using a Velcro strap to minimize hip flexion movement [14].

Isometric knee extension strength was assessed with a microFET IITM (Hoggan Health Industries, Draper, UT, USA), a battery-operated, load cell system with a digital reading of peak force ranging from 12.1 N to 1334.5 N in 0.4 N increments (Figure 4). The HHD was located 5 cm above the upper margin of the lateral malleolus [14].

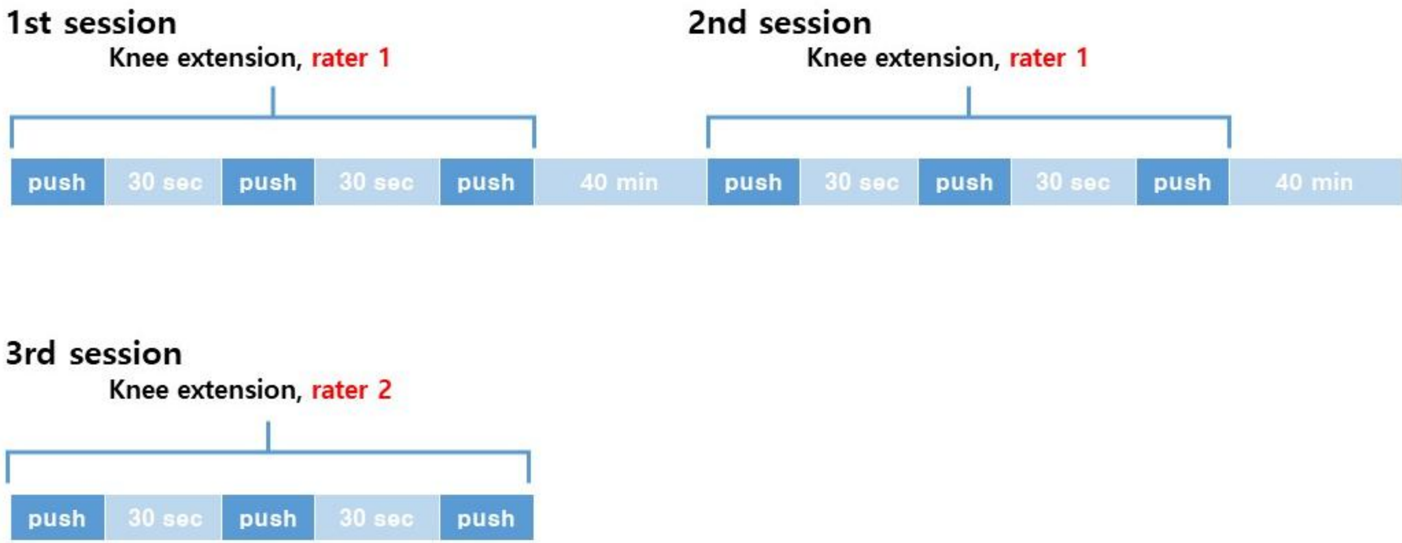
Figure 4. A hand-held dynamometer, microFET IITM (Hoggan Health Industries, Draper, UT, USA).

3. Measurement procedure

During the measurement, the subject was in the supine position with their arms lightly positioned on their chest. The examiner adjusted the position of the HHD depending on leg length and thickness. Before the measurement, the subjects repeated the knee extension of the dominant legs several times to become familiar with the device. The measurement consisted of three total sessions consisting of three 5-seconds maximal isometric contractions of the dominant knee extensors in each trial [14].

The measurements were evaluated by two examiners who were physiotherapists. The first and second sessions were evaluated by one rater, while the third was evaluated by the other rater. The order of the raters was randomized. The interval between sessions was 40 minutes, and the interval between the test repetitions was 30 seconds (Figure 5). To minimize fatigue in patients, the rest interval was longer than the 10 min used in the previous study with normal subjects [14].

Figure 5. Procedure of measuring the strength of the knee extensor.



The measurement began with a recorded sound ('kick'). When a subject extended a knee, the examiner pressed on both anterior superior iliac spine regions of the pelvis to prevent pelvic rotation to prevent the pelvis from shaking (Figure 6). Among the knee extensors, rectus femoris is a two-joint muscle that also function as hip flexion. Therefore, if the pelvis is not fixed, knee extension can rotate the pelvis, which affects the knee extensor strength measurement.

The participants were instructed to inform the examiner of any pain or discomfort during a test, and the test was allowed to be stopped at any time on request [14]. The participants were not provided encouragement during the test or given knowledge of their results between trials.

After the measurements were taken, one investigator assessed the MRC sum score and de Morton Mobility Index to evaluate the functional status of a subject.

Figure 6. An examiner is pressing the pelvis to prevent pelvic rotation of a subject.

4. Statistical analyses

The normality of the data was checked using the Kolmogorov-Smirnov test. To evaluate relative reliability, a two-way random effect model of the intraclass correlation coefficient (ICC) was used for the estimation of intra- and inter-rater reliabilities [17]. The ICCs were interpreted according to the following guidelines: Based on the 95% confidence interval of the ICC, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.9 were indicative of poor, moderate, good, and excellent reliability, respectively [18].

To ensure absolute reliability, several parameters were calculated according to COnsensus-based Standards for the selection of health Measurement Instruments quality assessment[19]. The standard error of mean (SEM) was calculated using the following formula: $SEM=SD\sqrt{(1-ICC)}$, where SD represents the standard deviation [20]. The minimal detectable change (MDC) was calculated using the following formula $MDC=z\times SEM\times\sqrt{2}$, where $z=1.96$ (based on 95% confidence) [21]. The SEM and MDC were expressed in absolute strength units (in N) and relative (in percent) to the mean strength values measured by the two raters.

The 95% limits of agreement (LoA) were calculated as the difference against the mean plot, mean $\pm(t_{(0.5,d.f.n-1)})(s_{diff})\sqrt{(1+1/n)}$ as proposed by Bland and Altman [22]. In the Bland-Altman plot system, the differences were also expressed as percentages of the values on the axis [(method A - method B)/mean %)] [22]. The

Bland-Altman plots graphically display between measurement differences, thereby allowing direct insight into the variability of the measurement under study [23].

A repeated measures ANOVA was conducted to test for learning and fatigue effects with the three maximal isometric knee extension strength measurements of each session [24]. All statistical analyses were performed using SPSS 23 for Windows (SPSS, Inc.).

III. Results

A total of 40 patients were initially included in the study. Of them, six refused to undergo the test due to fatigue, and one patient dropped out due to knee pain during the test. A total of 33 patients were analyzed, 18 men and 15 women (median age, 75.0 years; interquartile range, 60.5 to 89.5). The demographics and characteristics of the patients are presented in Table 2. All subjects were non-ambulatory, 15 of whom were unable to sit unsupported in a chair.

Table 2. Demographics and characteristics of patients.

Characteristic	
Age (years)	75.0 (60.5 to 89.5)
Male sex	18 (54.55%)
Height (cm)	162.87 ± 7.65
Weight (kg)	55.62 ± 10.34
ICU survivors	15 (45.45%)
Days of stay in hospital	17.0 (0.5 to 33.5)
MRC sum score	37.82 ± 5.54
MRC grade of the dominant knee extensor	3.0 (2.0 to 4.0)
DEMMI	20.94 ± 10.67
Main causes of hospitalization	
Cardiovascular disease	9 (27.27%)
Respiratory disease	8 (24.24%)
Neurologic disease	8 (24.24%)
Gastrointestinal disease	3 (9.09%)
Malignancy	2 (6.06%)
Connective tissue disease	2 (6.06%)
Immunologic disease	1 (3.03%)

Data presented as median(interquartile range), n(%) or mean ± standard deviation.

ICU: intensive care unit, MRC: Medical Research Council, DEMMI: de Morton mobility index.

Table 3 shows the maximal isometric knee extension strength values. The relative reliability of the anchoring system using an HHD, including the ICCs and 95% CIs, was excellent for the intra-observer and inter-observer measurement sessions. The MDCs of the intra- and inter-observer measurements were 29.46 N (24.10%) and 36.73 N (29.26%), respectively (Table 4).

The average difference between the two sessions performed by the first rater for intra-observer measurements was 3.31 N (2.51%), and the LoA ranged from −26.15 to 32.77 N (−19.79% to 24.81%). The average difference between the first and second raters for inter-observer measurements was 9.84 N (7.81%), and the LoA ranged from −26.89 to 46.57 N (−21.45% to 37.07%). The distributions are represented in the Bland-Altman plot (Figure 7).

The ANOVA test for repeated measures yielded no significant changes ($p = 0.924$) among the three sessions, indicating that there were no learning effects from the first to the third measurements in a session.

Table 3. Maximal isometric knee extension strength values using a portable dynamometer anchoring system (n = 33).

Measurement	Mean ± SD (Range) (N)
1st session – rater 1	120.61±65.24 (15.5 - 325.6)
2nd session – rater 1	123.91±67.55 (21.8 - 328.7)
3rd session – rater 2	130.45±66.29 (14.6 - 339.0)

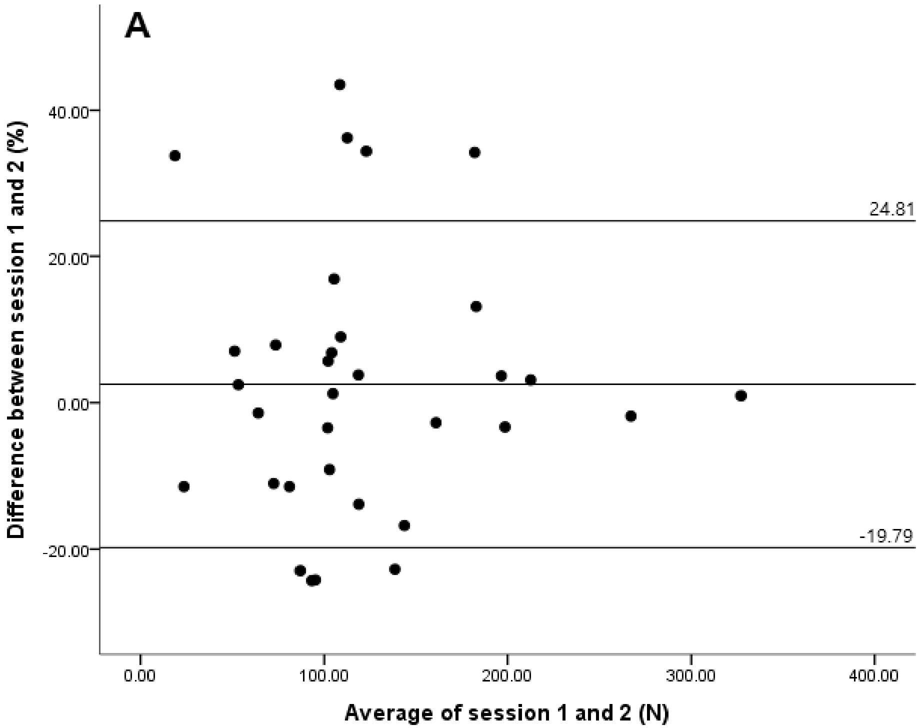
N: Newtons, SD: standard deviation.

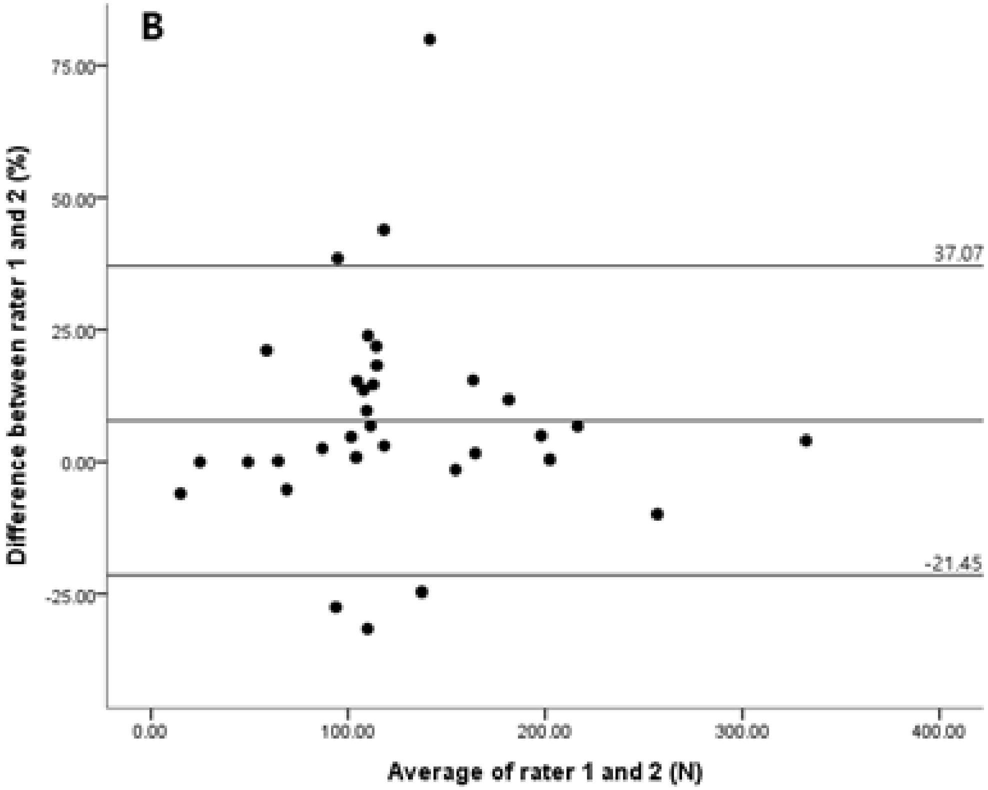
Table 4. Reliability of the portable dynamometer anchoring system.

	ICC (95% CI)	SEM (N) (%)	MDC (N) (%)
Intra-rater	0.974 (0.948 - 0.987)	10.63 (8.69)	29.46 (24.10)
Inter-rater	0.959 (0.917 - 0.980)	13.25 (10.56)	36.73 (29.26)

ICC: intraclass correlation coefficient, SEM: standard error of measurement, MDC: minimal detectable change, CI: confidence interval, N: Newtons.

Figure 7. Distribution from Bland and Altman plots for the mean difference and limits of agreement (LOA) of A. Intra-rater measurements and B. Inter-rater measurements.




B
75.00
50.00
25.00
0.00
-25.00
37.07
-21.45
Difference between rater 1 and 2 (%)
0.00
100.00
200.00
300.00
400.00
Average of rater 1 and 2 (N)

IV. Discussion

The present study evaluated the reliability of the portable dynamometer anchoring system in non-ambulatory patients in supine position. This system showed excellent intra- and inter-rater reliabilities for maximal isometric knee extensor strength measurements, and the relative reliability calculated by ICC was excellent (intra-rater: 0.974, inter-rater: 0.959). These results are similar to those of previous HHD studies. Lu et al. reported excellent ICCs for the intra- and inter-rater reliabilities of knee extensor strength measurements (0.91 - 0.94 and 0.98) using a fixation structure in the sitting position [10]. In the study of Jackson et al. that used a portable stabilization device in the sitting position, the ICC for intra-rater reliability of knee extensor strength measurements was 0.93 [25]. However, these studies measured the knee extensor strength in healthy adults in a sitting position, which is difficult to replicate in severely deconditioned patients who are unable to balance and kick in the position. In addition, relative reliability is relevant for assessing the instrument that is to be used for discriminative purpose, not evaluative purpose. Henrica et al. suggested that absolute reliability including SEM, MDC and LoA is preferable in situations that the instrument will be used for evaluation, which is often the case in medical research [26].

A few studies that used fixation devices have reported the absolute reliability of HHD for measuring knee extensor strength in a clinical population. In the study by Koblbauer et al., patients awaiting total knee arthroplasty were assessed in the sitting position; in this study, the HHD was modified with straps to support HHD. The

MDCs for intra-rater reliability and inter-rater reliability were 19.0% - 31.4% and 21.7%, respectively [11]. In a study by Gagnon et al., the MDC for inter-rater reliability was 23.84% - 36.50% in patients who underwent knee arthroplasty [12]; in this study a chair-fixed dynamometer system was developed and used. The HHD was mounted on a rigid support, which was able to move along a shaft fixed to a chair.

Several studies have reported the reliability of an IKD for measuring knee extensor strength in a clinical population. In the study by Kean et al., the MDC for inter-rater reliability using IKD in patients with knee osteoarthritis was 17.81% [27]. Another IKD study in post-stroke patients reported an intra-rater MDC of 25.34% [28]. In a study of COPD patients, Machado et al. found the MDC to be 22.05% in IKD measurements [29]. Using Biodex IKD, Adsuar et al. reported that an MDC was 21.50% in patients with fibromyalgia [30]. Franbjer et al. reported an MDC of 24.90% for intra-rater reliability using IKD in 30 patients with late effects of polio [31] (Table 4).

Table 5. Previous reports regarding the absolute reliability for measuring knee extensor strength in clinical populations.

Article	Populations	Type of dynamometer	MDC%
Kean et al., 2010 [27]	knee OA (n=20)	Biodex, IKD	inter-rater: 17.81
Dehkordi et al., 2008 [28]	post-stroke (n=30)	Biodex, IKD	intra-rater: 25.34
Machado et al., 2017 [29]	COPD (n=46)	Biodex, IKD	intra-rater: 22.05
Adsuar et al., 2011 [30]	fibromyalgia (n=37)	Biodex, IKD	intra-rater: 21.50
Flansbjer et al., 2010 [31]	late effects of polio (n=30)	Biodex, IKD	intra-rater: 24.90
Koblbauer et al., 2011 [11]	awaiting TKA (n=32)	HHD	intra-rater: 19.00, 31.40 inter-rater: 21.70
Gagnon et al., 2005 [12]	TKA (n=25)	HHD	inter-rater: 11.75 inter-rater: 23.84
Knols et al., 2009 [24]	hematological malignancy (n=24)	HHD	intra-rater: 11.04 inter-rater: 16.77

MDC: minimal detectable change, OA: osteoarthritis, IKD: isokinetic dynamometer, COPD: chronic obstructive pulmonary disease, TKA: total knee arthroplasty

Few studies have examined knee extensor strength using an HHD in intensive care unit (ICU) patients, who should undergo measurements while in bed. Baldwin et al. reported an MDC of 47.3% for intra-rater reliability using an HHD in ICU patients without the use of a fixation device [32]. Rousseau et al. designed a highly standardized dynamometer for measuring knee extensor strength in ICU patients in the supine position. The MDC in that study was 17.13 - 27.33% [33]. Rousseau et al. reported that, although the MDC was comparable, the highly standardized dynamometry developed therein was difficult to install, making it less convenient to use.

The MDC is a decision limit from a change in variability or measurement error. In this study, the MDCs were 29.46 N (24.10%) for intra-rater reliability and 36.73 N (29.26%) for the inter-rater reliability. The MDC% values reported in the current study were lower than those reported in previous studies using the HHD anchoring frame, and comparable to those using an IKD. These values may be clinically meaningful to detect the deterioration of muscle strength. It was known that muscle strength at complete rest loses 10% to 15% each week. Within 3 to 5 weeks of bed rest, about half of normal strength is lost [34]. The MDC% of this study was about 30%, so it can be possible to detect muscle weakness in acute settings in hospital.

We infer that the reasons for comparable reliabilities of the present study are as follows: First, the supine position could be related to the results. The supine measurement technique was found to be stable for the subjects because it was easier for them to maintain the testing position compared to sitting posture [16]. Second, when the patients were kicking the dynamometer, the examiner pressed both sides of the anterior superior iliac spine to prevent compensatory rotation of the pelvis. This stabilization technique could not be performed in a sitting position. Third, the frame was fixed to the patient's bed using non-elastic belts. The belts were inserted into the four U-shaped rings on the frame and pulled toward the bed to fix the frame, minimizing shaking during kicking (Figure 1).

The system developed in this study can only measure knee extensor strength. In deconditioned patients, lower limb weakness is more severe than trunk weakness [35]. In particular because muscle atrophy is pronounced in knee extensor muscles, the knee extensor strength has been evaluated as an indicator of deconditioning in bed rest patients [36]. In addition, knee extensors are essential for walking and reflect functional states well [37]. Therefore, knee extensor strength assessment can be considered as a parameter for surveilling muscle weakness and functional outcome in severely deconditioned patients due to acute illness.

Seymour et al. reported that the quadriceps cross-sectional area estimated by ultrasonography was related to strength in COPD patients [38], while Grimm et al. suggested that muscle ultrasound could be useful for screening of critical illness neuromyopathy[36]. However, it has been reported that estimating muscle volume is not useful for predicting functional outcome [39]. Direct muscle strength measurement, as in this study, might be more likely to predict a functional outcome than evaluation of muscle function indirectly through imaging studies. For example, the knee extensor strength measurement method presented in this study could be used for rehabilitation in the ICU. This system can be simply installed on a bed using only four ropes in about 10 min, and the test can be completed in less than 5 min. This HHD anchoring system is suitable for the bedside measurement of knee extensor strength. In future studies, it may be possible to investigate how muscle strength directly measured in deconditioned patients is associated with functional recovery after the treatment for acute illness.

The current study has several limitations. First, although the participants of this study had similar limitations in physical function such as walking and maintaining sitting posture, they were from diverse disease groups. The reliability of measuring muscle strength using the supine HHD anchoring frame may differ according to the specific disease group. Second, the participants in this study were using air mattresses to prevent pressure ulcer formation related to their limited mobility. In this study, the frame was placed on the mattress and the muscle strength was measured; thus, the measurement could have been affected. However, it would be difficult to remove the air mattresses to measure leg strength in actual clinical situations. Third, unlike other studies, the measurements were not compared with that of the IKD. This is because patients in this study were unable to move to the laboratory. However, we can assume that the measurements in this study are validated because the portable dynamometer anchoring system was validated in healthy subjects [14]. Finally, bias from the two examiners could not be completely eliminated because the examiners were not blinded to the test results. However, since the examiner could not control the dynamometer, which was attached to the portable dynamometer anchoring system, and only pressed on the anterior superior iliac spine regions of the pelvis to prevent pelvic rotation during the measurement, we believe that there was little chance of bias.

V. Conclusion

The portable dynamometer anchoring system designed in this study can measure the isometric strength of the knee extensor reliably in the supine position; therefore, it can measure the strength in non-ambulatory patients who have difficulties in moving to the laboratory and maintaining a sitting posture for the measurement.

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초 록

서론: 근력 측정은 임상 중재의 결과를 평가하는 데 있어서 중요하다. 도수 근력 검사는 바쁜 임상의 상황들에서 가장 많이 쓰이는 근력 측정 방법이지만, 오류가 쉽게 발생하고 작은 차이를 구별하기는 어렵다. 등속성 동력계는 근력 측정에 있어서 최적 표준이지만, 크기가 커서 휴대성이 떨어진다. 휴대용 동력계는 침상에서 사용하기 적합하지만, 측정값이 검사자의 힘에 의해 영향을 받기 때문에 검사자간 신뢰도가 낮다. 본 연구에서는 신체 활동이 제한된 환자를 대상으로 누운 자세에서 휴대용 동력계를 이용한 무릎관절 신전 근력 측정 프레임의 신뢰도를 확인하고자 한다.

방법: 서울대학교 병원에 입원한 거동이 어려운 환자들을 모집하였다. 맞춤형 휴대용 프레임에 부착된 HHD로 구성된 휴대용 동력계 고정 시스템을 사용하여 최대 등척성 무릎 신전 근력을 측정하였다. 측정은 누운 자세에서 시행하였다. 한 세션 당 총 3회 근력 측정을 시행하며, 두 명의 측정자가 총 3 세션을 통해 근력을 측정한다.

결과: 혼자서 거동이 어려운 입원 환자 33명이 연구에 참여하였다. 급내 상관 계수는 검사자 내 0.974, 검사자 간 0.959 로 계산되었다. 최소 감지 변화는 검사자 내 29.46 N (24.10 %), 검사자 간 36.73 N (29.26 %) 로 계산되었다. 95% 일치 한계값들은 검사자 내에서는 -19.79% to 24.81%, 검사자 간에서는 -21.45% to 37.07% 로 계산되었다.

결론: 휴대용 동력계를 이용한 무릎관절 신전 근력 측정 프레임은 혼

자서 거동이 어려운 환자를 대상으로 누운 자세에서 무릎관절의 등척성 신전 근력을 신뢰성 있게 측정할 수 있다. 따라서, 근력 측정을 위해 검사실로 이동하거나 앉은 자세를 유지하기 어려운 환자들을 대상으로 휴대용 동력계를 이용한 무릎관절 신전 근력 측정 프레임을 적용할 수 있다.

주요어: 근력, 동력계, 등척성 수축, 앙와위, 신뢰도

학번: 2018-21934