An Investigation into Reliability of Knee Extension Muscle Strength Measurements, and into the Relationship between Muscle Strength and Means of Independent Mobility in the Ward: Examinations of Patients Who Underwent Femoral Neck Fracture Surgery

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Abstract. [Purpose] The purpose of the present study was to investigate the reliability of isometric knee extension muscle strength measurement of patients who underwent femoral neck fracture surgery, as well as the relationship between independent mobility in the ward and knee muscle strength. [Subjects] The subjects were 75 patients who underwent femoral neck fracture surgery. [Methods] We used a hand-held dynamometer and a belt to measure isometric knee extension muscle strength three times, and used intraclass correlation coefficients (ICCs) to investigate the reliability of the measurements. We used a receiver operating characteristic curve to investigate the cutoff values for independent walking with walking sticks and non-independent mobility. [Results] ICCs (1, 1) were 0.9 or higher. The cutoff value for independent walking with walking sticks was 0.289 kgf/kg on the non-fractured side, 0.193 kgf/kg on the fractured side, and the average of both limbs was 0.238 kgf/kg. [Conclusion] We consider that the test-retest reliability of isometric knee extension muscle strength measurement of patients who have undergone femoral neck fracture surgery is high. We also consider that isometric knee extension muscle strength is useful for investigating means of independent mobility in the ward.

Key words: Muscle strength, Test-retest reliability, Independent walking

INTRODUCTION

Various researchers have reported that the lower limb muscle strength of patients who have suffered femoral neck fractures effects their mobility performance, such as in walking, and that adding high-load muscle strengthening training to existing physiotherapy interventions increases patients’ walking performance1–3).

Madsen et al.1) measured bone mineral density of the spine and hip, current physical activity (the Northwick Park activity index questionnaire specifically designed for hip fracture patients), isokinetic quadriceps strength of both the non-fractured and fractured legs, and walking and stair climbing speeds of in 47 elderly women (mean age 80 years), 3–36 months after hip fracture. They reported that the quadriceps strength of the fractured leg was the most robust predictor of walking speed, stair climbing speed, and the activity index.

Syllaas et al.2) compared outcome measures of before and after a 12-week (twice a week) intervention for 95 hip fracture patients. Their program comprised four exercises, performed at 80% of maximum capacity. Their outcome measures were the Berg Balance Scale (BBS), the sit-to-stand test, the timed up-and-go test, maximal gait speed, the 6-min walk test, the Nottingham Extended Activities of Daily Living scale, and the Short Form-12 questionnaire. They found no statistically significant post-intervention difference in the primary outcome BBS, presumably because of a ceiling effect. However, they did find significant improvements in strength, gait speed, gait distance, instrumental activities of daily living, and self-rated health.

Mitchell et al.3) compared a group of patients (40 patients) who only received standard physiotherapy and a group (40 patients) who received progressive high-intensity quadriceps training in addition to standard physiotherapy in a randomized controlled trial of patients who had a proximal femoral fracture. The training group exercised twice weekly, with six sets of 12 repetitions of knee extension (both legs), progressing up to 80% of their one-repetition maximum. Their results show that leg extensor strength in-

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creased significantly in the quadriceps training group (fractured leg mean improvement at six weeks 157% (SD=16%), nonfractured leg 80% (SD=12%) compared with the control group (63% (SD=1%), and 26% (SD=8%)). Moreover, the training group showed relatively more favorable outcomes than the control group in functional mobility (elderly mobility score), disability (Barthel Index) and quality of life (Nottingham Health Profile), and the gap in mobility function between the two groups continued until 16 weeks after the initial measurement.

If muscle strength is a factor which impacts performance, such as that of walking, and if such performance can be improved through muscle training, there is a possibility that guideline muscle values can be identified to select walking support tools, and to determine which patients will be able to independently walk. Additionally, with such muscle strength values, it would be easy to set muscle strength training target values and achievement periods; and we consider that such targets would be useful for motivating patients.

Various researchers have reported the muscle strength required for performance, such as walking. However, the subjects of those studies were elderly people with no restrictions on their mobility, elderly people in chronic care hospitals who had fallen, and cerebrovascular disease patients, but none of those studies enrolled patients who had undergone femoral neck fracture surgery as subjects. Therefore, the selection criteria for walking support tools and the decision criteria for independent walking in the process of physiotherapy following femoral neck fracture surgery have not been clarified.

There are a large number of methods for measuring muscle strength, such as manual muscle testing (MMT), and various types of isometric and isokinetic dynamometers. A hand-held dynamometer (HHD) is a type of isometric dynamometer, with which it is relatively easy to obtain quantitative values. However, the measurement values are low if it is not possible for the measurer to control the exercise performed by subjects. Katoh et al. developed an HHD method (HHD belt) which fixes the HHD with a belt, and investigated the validity and reliability of that method. Their measurements showed high validity and reliability in knee extension exercises. However, there have been no reports on the reliability of knee muscle strength measurements using a HHD belt for patients suffering from orthopedic conditions, such as those who have undergone femoral neck fracture surgery.

The aim of the present study was to investigate the reliability of isometric knee extension muscle strength measurements using a HHD belt for patients who had undergone femoral neck fracture, and to investigate the relationship between means of independent mobility in the ward of patients who had undergone femoral neck fracture surgery (walking with walking sticks, walking with walking frames, and moving with wheelchairs) and isometric knee extension muscle strength.

**SUBJECTS AND METHODS**

From the initially-selected 80 patients who underwent bipolar hip arthroplasty or osteosynthesis for femoral neck fracture due to falling over between April 2011 and October 2012 at Sado General Hospital, 75 patients (60 women and 15 men) with an average age of 81.7 years (SD= 8.1 years; range: 62–97) were enrolled in this study, after excluding those younger than 60 years old, those with dementia, and those who had restrictions on the application of load at the time of the measurements due to other conditions.

The average number of days post-surgery of the subjects was 26.4 (SD = 8.4 days). Subjects were able to walk indoors prior to fracture. Means of independent mobility in the ward at the time of the measurements were: walking with walking sticks for 30 patients, walking with walking frames for 39 patients, and moving by wheelchair for six patients. This research was done after applying to and receiving consent from the Sado General Hospital. We explained the aims of the study to the subjects and obtained their consent prior to carrying out the study.

A HHDμTas F-1 (Anima Corp., Tokyo) was used for isometric knee extension muscle strength measurement.

The subjects sat on a mat table, and the position of their buttocks was adjusted so that the leg on the mat table was positioned behind the lower limb to be measured. The mat table had a height such that, when the subjects sat on it, both their feet were off the floor. The subjects kept their trunks vertical and put both their hands on the top of the mat table at the sides of their trunks. The examiners laid out bath towels that had been folded under the subjects’ popliteal fossa, and set up the subjects so that their thighs were kept horizontal and their lower legs were hanging down, with the knee joint at a flexion angle of 90 degrees. The HHD was placed on the distal anterior surface of the lower thigh, and the lower edge of the HHD was fixed with a hook-and-loop fastener at the height of the upper edge of the malleolus medialis. Then the limb being measured, to which the HHD had been attached, and the leg on the mat table, were linked with a belt. Isometric movement, exerting maximum effort in knee joint extension, for about five seconds was conducted three times, with an interval of 30 seconds or more between measurements. During the measurements, the examiner held both sides of the sensor, to maintain the direction of the sensor, so that the surface of the sensor stayed relative to the direction of the movement. After explaining the method, the measurements were conducted three times without practice. The examiner was well-experienced in the measurement method employed in this research.

The researchers neither informed subjects of the number of times that measurements would be carried out, nor of the values obtained in each measurement, until the end of the series of measurements.

Intraclass correlation coefficients [ICCs (1, 1)] and a one-way analysis of variance (repeated-measures) were used to analyze the measurement values of each gender in the investigation of reliability. We also calculated the difference between the maximum value from within three measurements (Max3) and the initial value (1st) [Δ1st= Max3-1st], as well as the values normalized for bodyweight (Δ1st/BW).

In investigating the knee extension muscle strength and the means of mobility in the ward, we examined the cutoff values for independent walking with walking sticks of...
the 30 subjects who were able to walk independently with walking sticks at wards, and of the 45 subjects who were not able to independently walk with walking sticks (using walking frames or in wheelchairs). To determine the cutoff values, we employed a Receiver Operating Characteristic (ROC) curve. Additionally, we obtained a muscle value distribution range for each group by categorizing subjects into a walking stick walking group of 30 subjects (Walking stick group), a walking frames walking group of 39 subjects (Walking frame group), and a wheelchair moving group of six patients (Wheelchair group). Furthermore, we calculated the percentages of the walking stick walking in-dependence subjects in muscle strength increments of 0.100 kgf/kg.

We used SPSS ver.15.0 J for Windows (SPSS Japan Inc., Tokyo) for the statistical analyses with a significance level of 5%.

RESULTS

The average value obtained in the first measurement of isometric knee extension muscle strength was 7.6 kgf for the fractured leg, and 12.4 kgf for the non-fractured leg, a 10.0 kgf average for both lower limbs. The values obtained the second measurement were 8.2 kgf for the fractured leg, and 13.5 kgf for the non-fractured leg, a 10.9 kgf average for both lower limbs. The values obtained the third measurement were 8.5 kgf for the fractured leg, and 13.6 kgf for the non-fractured leg, a 11.0 kgf average for both lower limbs. The one-way analysis of variance did not find any major effects in any subject. The major effects were not found in the one-way analysis of variance. Moreover, the one-way analysis of variance found major effects for neither males nor females. The ICCs (1, 1) for all subjects was 0.948 (0.926–0.965) for the fractured leg, 0.953 (0.932–0.968) for the non-fractured leg, and 0.961 (0.944–0.974) for both lower limbs. Moreover, when women and men were analyzed separately, all ICCs were 0.9 or more (Table 1).

The number (%) of subjects in which the maximum of three measurements values was greater than the initial value in all subjects was 66 for the fractured leg (88.0%) and 61 for the non-fractured leg (81.3%), and 61 for the average of both lower limbs (81.3%). The greatest difference between the maximum value of three measurements and the initial value ($\Delta_1$st) was 0.041 (4.1%), less than 0.05 (5.0%) for each subject (Table 2).

Table 1. Isometric knee extension strength values and their test-retest reliability for patients following femoral neck fracture surgery

| Gender | n   | Age mean (SD) | Leg           | 1st : kgf mean (SD) | 2nd : kgf mean (SD) | 3rd : kgf mean (SD) | ICCs (1,1) (95%CI) |
|--------|-----|---------------|---------------|---------------------|---------------------|---------------------|-------------------|
| Women and men | 75  | 81.7 (8.1)    | fractured     | 7.6 (4.3)           | 8.2 (4.3)           | 8.5 (4.5)           | 0.948 (0.926–0.965) |
|          |     |               | non-fractured | 12.4 (7.6)          | 13.5 (7.8)          | 13.6 (7.4)          | 0.953 (0.932–0.968) |
|          |     |               | both lower limbs | 10.0 (5.5)         | 10.9 (5.7)         | 11.0 (5.6)         | 0.961 (0.944–0.974) |
| Women   | 60  | 81.3 (8.2)    | fractured     | 7.2 (3.6)           | 7.7 (3.6)           | 8.0 (3.8)           | 0.927 (0.892–0.953) |
|          |     |               | non-fractured | 11.3 (6.4)          | 12.4 (6.3)          | 12.5 (5.9)          | 0.932 (0.889–0.956) |
|          |     |               | both lower limbs | 9.2 (4.6)         | 10.1 (4.5)         | 10.3 (4.5)         | 0.940 (0.910–0.961) |
|          |     |               | fractured     | 9.3 (6.5)           | 10.1 (6.4)          | 10.3 (6.4)          | 0.966 (0.922–0.987) |
| Men     | 15  | 83.0 (8.0)    | non-fractured | 16.8 (10.2)         | 17.8 (11.2)         | 17.7 (11.0)         | 0.973 (0.939–0.990) |
|          |     |               | both lower limbs | 13.0 (7.6)        | 14.0 (8.3)          | 14.0 (8.4)          | 0.982 (0.958–0.993) |

1st: 1st value, 2nd: 2nd value, 3rd: 3rd value, ICCs (1,1): intraclass correlation coefficients (1,1), 95%CI: 95% confidence interval

Table 2. A comparison of the maximum of three measurement values and the first measurement value in isometric knee extension strength measurements of femoral neck fracture surgery patients

| Gender | n   | Age mean (SD) | Leg           | A: 1st 1)(kgf/kg) mean (SD) | Max 3 2)(kgf/kg) mean (SD) | A=B 3) B-A 4)(kgf/kg) |
|--------|-----|---------------|---------------|----------------------------|-----------------------------|------------------------|
| Women and men | 75  | 81.7 8.1      | fractured     | 0.162 0.083                | 0.186 0.082                 | 66 0.025               |
|          |     |               | non-fractured | 0.261 0.135                | 0.301 0.136                 | 61 0.041               |
|          |     |               | both lower limbs | 0.211 0.098            | 0.24 0.1                     | 61 0.029               |
|          |     |               | fractured     | 0.156 0.067                | 0.181 0.068                 | 52 0.025               |
| Women   | 60  | 81.3 8.2      | non-fractured | 0.244 0.117                | 0.284 0.109                 | 49 0.040               |
|          |     |               | both lower limbs | 0.203 0.1                | 0.233 0.079                | 48 0.029               |
|          |     |               | fractured     | 0.185 0.129                | 0.209 0.124                 | 14 0.023               |
| Men     | 15  | 83 8          | non-fractured | 0.327 0.182                | 0.368 0.203                 | 12 0.041               |
|          |     |               | both lower limbs | 0.258 0.201            | 0.288 0.155                | 13 0.028               |

1) The initial value; 2) The maximum of three values; 3) The number of people in whom the maximum of three measurement values was greater than the initial value; and 4) The maximum value of B-A for all subjects
The average muscle strength value of both lower limbs in relation to the means of independent mobility in the ward was in the range (minimum value – maximum value) of 0.066–0.233 kgf/kg for the Wheelchair group, 0.077–0.363 kgf/kg for the Walking frame group, and 0.162–0.656 kgf/kg for the Walking stick group (Table 3). Also, 16 out of 19 (84.2%) of the subjects with muscle strength of 0.280 kgf/kg or higher and 15 out of 16 subjects (93.8%) with muscle strengths of 0.310 kgf/kg or higher were in the Walking stick group (Table 3).

When we examined the incidence of walking stick walking independence in muscle strength increments of 0.100 kgf/kg, we found that as muscle strength increased, the independence rate became higher, and walking stick walking independence was 100% at muscle strengths of 0.500 kgf/kg or more on the non-fractured side, 0.400 kgf/kg or more on the fracture side, and an average of both limbs of 0.400 kgf/kg or more (Table 4).

We categorized subjects into an in-ward independent walking with walking stick group and a non-independent group (the Walking frame group and the Wheelchair group). Based on the ROC curve, the cutoff value for the group of subjects independently walking with walking sticks was 0.238 kgf/kg (sensitivity 0.833, specificity 0.756) for the average of both lower limbs, 0.289 kgf/kg for the non-fractured leg (sensitivity 0.733, specificity 0.711), and 0.193 kgf/kg for the fractured leg (sensitivity 0.677, specificity 0.804).

**DISCUSSION**

The results of isometric knee muscle strength measurement of inpatients at an average 26.4 days following femoral neck fracture surgery show that all ICCs of three measurements were 0.9 or higher. Therefore, it was considered that its test-retest reliability is high. Katoh et al. investigated the test-retest reliability of this measurement method with healthy young people, healthy elderly people, and hemiplegic patients as subjects. For healthy young subjects, ICCs (1, 1) of two measurements were investigated in three segments (morning, afternoon, and one week later), and the results were values of 0.94, 0.96, 0.96. In healthy elderly people, ICCs (1, 1) of two measurements were 0.91 for males and 0.88 for females, and in hemiplegic subjects, ICCs (1, 1) of three measurements were 0.98 in Session 1 and 0.99 in Session 2 on the paralyzed side, and 0.98 in Session 1 and 0.99 in Session 2 on the non-paralyzed side. We consider that ICCs values obtained in the present study are similar to those obtained in previous studies. Therefore, the test-retest reliability of isometric knee muscle strength measurement using HHD with a belt for patients approximately 4 weeks after femoral neck fracture surgery is high.

We compared the maximum value of the three measurements against the initial value. The maximum value of the three measurements was found to be higher in 80% or more of subjects, however, it was less than 5% as a bodyweight ratio for all subjects. Therefore, we consider that if it is necessary to minimize the number of measurements, e.g. when there is limited time available, there would be no impact on the reliability even if only one measurement were carried out. Additionally, we suggest that if the maximum value of three measurements is adopted in interpreting the value obtained in a single measurement, the possibility should be considered that the value may be higher by a maximum of 5%.

When the average value of the muscle strength of both lower limbs was used to examine independent mobility in the ward, the lowest value in the Walking frame group was 0.077 kgf/kg. However, 4 out of 5 in the Wheelchair group showed a higher muscle strength value. Moreover, the muscle strength of 27 out of 39 (69.2%) in the Walking frame group was 0.233 kgf/kg in the Wheelchair group. Therefore, we consider that whether or not it is possible to walk with a walking frame is affected by factors other than muscle strength, and the possibility that subjects might be able to walk with a walking frame, even if they have low muscle strength, was also considered.

The lowest value for walking with a walking stick was 0.162 kgf/kg. The value at which all subjects could walk with walking frames or a walking stick was 0.234 kgf/kg, and the value at which all subjects could independently walk with a walking stick was 0.364 kgf/kg. In the range of muscle strength from 0.162 to 0.233 kgf/kg, there was...
a mixture of walking with a walking stick, walking with walking frames, and moving in a wheelchair. In the range of muscle strength from 0.234 to 0.363 kgf/kg, there was a mixture of walking with a walking stick and walking with walking frames. Moreover, muscle strength and walking stick walking independence were related. The probability of walking with a walking stick became higher as muscle strength increased, and a threshold value existed.

The present results suggest that it is possible to determine the means of movement in the ward based on measurements of muscle strength. Additionally, we considered it necessary to investigate factors other than muscle strength, when there is a possibility of multiple means of mobility. Moreover, we consider further investigation is warranted of cut-off values for walking with walking sticks.

The present study employed a cross-sectional method of investigation at approximately 4 weeks post-surgery, and it will be necessary to investigate changes in muscle strength and changes in means of mobility using a longitudinal method. Additionally, we consider it necessary to investigate the determining factors of means of mobility by including factors other than muscle strength.

This research adopted the muscle strength of the quadriceps femoris as a representative value of the muscle strength of the leg. Therefore, when other muscle strengths are declining, it may not be a suitable parameter.

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