Original article

Prediction of muscle strength and postoperative function after knee flexor muscle resection for soft tissue sarcoma of the lower limbs

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\section*{A B S T R A C T}

\textbf{Introduction:} Oncological margins and prognosis are the most important factors for operative planning of soft tissue sarcomas, but prediction of postoperative function is also necessary. The purpose of this study was to predict the knee flexion strength and postoperative function after knee flexor muscle resection for soft tissue sarcoma of the lower limbs.

\textbf{Materials and methods:} Seventeen patients underwent knee flexor muscle resection for soft tissue sarcoma of the lower limbs between 1991 and 2015. The type of resected muscles was surveyed, knee flexion strength (ratio of affected to unaffected side) was evaluated using the Bodied System isokinetic dynamometer, and differences between the type of resected muscles were examined. The Musculoskeletal Tumor Society (MSTS) score, Toronto Extremity Salvage Score (TESS), European Quality of Life-5 Dimensions (EQ-5D), and Short Form 8 (SF-8) were used to assess postoperative function and examine correlations with flexion strength. The cutoff value for flexion strength to predict good postoperative results was calculated by a receiver operating characteristic (ROC) curve and Fisher’s exact test.

\textbf{Results:} Median flexion strength decreased in the resection of sartorius (97.8\%), gracilis (95.4\%), gastrocnemius (85.2\%); interquartile range (IQR): 85.0–86.2\%), medial hamstrings (semimembranosus and semitendinosus, 76.2\%; IQR: 73.3–78.0\%), lateral hamstrings (long and short head of biceps femoris, 66.1\%; IQR: 65.9–70.4\%), and bilateral hamstrings (27.3\%; IQR: 26.6–31.5\%). A significant difference was observed between lateral and bilateral hamstrings resection \((P=0.049).\) Flexion strength was associated with lower functional scales (MSTS score, \(P=0.021;\) TESS, \(P=0.008;\) EQ-5D, \(P=0.034).\) Satisfactory function was obtained at a flexion strength cutoff value of 65.7\%, and strength remained above the cutoff value up to unilateral hamstrings resection.

\textbf{Discussion:} Greater knee flexor muscles resection can result in functional deficits that are associated with decreased flexion strength. If continuity of unilateral hamstrings is maintained, good postoperative results can be expected.

\textbf{Level of evidence:} IV, retrospective study.

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1. Introduction

Soft tissue sarcomas frequently occur in the lower limbs and often require wide resection. Consequently, knee flexor muscle resection for soft tissue sarcoma in the posterior compartment of the thigh can reduce knee flexion strength. Although there have been several reports describing postoperative results after the resection of the posterior compartment of the thigh [1–3], most of these reports have been comparative studies with anterior and medial compartments. Moreover, these reports have not referred to resected muscles and muscle strength specific to each case. Thus, the influence of the extent of resection on postoperative results remains unclear. Wide resections which involve multiple muscles may possibly decrease knee flexion strength and postoperative function than expected.

In this study, we classified each soft tissue sarcoma of the lower limb after knee flexor muscle resection by their resected muscles and focused on muscle strength. Accordingly, we aimed to evaluate the postoperative function in greater detail and investigate the extent of resection for good postoperative results.
2. Patients and methods

Fifty-one patients with soft tissue sarcoma in the lower limbs underwent knee flexor muscle resection at our institution from 1991 to 2015. Of these patients, cases arising from the posterior compartment of the thigh or lower leg, sartorius, gracilis, and gastrocnemius were examined. In addition, the purpose of this study was to evaluate the decrease in muscle strength as a result of muscle resection; therefore, we excluded cases that could clearly affect postoperative muscle strength and function, including sciatic nerve resection cases, advanced-stage cases, and cases undergoing chemotherapy at the time of the survey. Furthermore, patients who had died or had subcutaneous tumors were also excluded, leaving 17 cases for examination.

Medical records were reviewed for age at final follow-up, follow-up period, maximum tumor size, tumor site, adjuvant therapy, and type and number of resected knee flexor muscles. Median age at final follow-up of the 17 patients (8 men, 9 women) was 54.0 years (interquartile range: IQR: 42–70 years). Median follow-up period was 38.0 months (IQR: 18.9–71.5 months). Postoperative chemotherapy and radiation therapy were performed in 7 and 2 patients, respectively, and median time from final adjuvant therapy to measurement of muscle strength was 28.0 months (IQR: 21–120 months). The demographic and clinical characteristics of the 17 eligible patients are presented in Table 1.

We identified the type of resected knee flexor muscle, including the sartorius, gracilis, gastrocnemius, medial hamstrings (semimembranosus and semitendinosus), and lateral hamstrings (long and short head of biceps femoris). Complete excision of a muscle’s continuity was counted as 1 muscle, and resection with continuity was counted as 0.5 muscles. For knee flexion strength, the peak torque was measured using the Biodex System 4 isokinetic dynamometer (Biodex Medical System Inc., Shirley, NY, USA) by following several previously reported methods [4–6], mobilizing the knee from 90° flexion to 0° extension at 60°/second. Hip muscle strength was also measured isometrically using a hand-held dynamometer (ANIMA Corp., Chofu, Tokyo, Japan). Muscle torque was measured twice, and the maximum value was used to calculate the ratio of the affected side to the unaffected side (%), which was defined as muscle strength. The same physical therapist who was blinded to treatment status performed all measurements under the same conditions.

In the functional evaluation of patients, we used the Musculoskeletal Tumor Society (MSTS) score [7] to evaluate postoperative limb function, Toronto Extremity Salvage Score (TESS) to assess ADL [8,9], and European Quality of Life-5 Dimensions (EQ-5D) [10,11] and Short Form 8 (SF-8) [12] to estimate QOL. Good results were defined as ≥80% for MSTS score and TESS, and ≥0.800 for EQ-5D [13]. The cutoff value for flexion strength was the point at which good results could be expected. In SF-8, the national standard of Japan is 50 points and were compared to each parameter [12].

Knee flexion strength and postoperative function were evaluated at final follow-up. Factors affecting postoperative knee flexion strength, and correlations between flexion strength and postoperative functional evaluations were examined. The cutoff value for flexion strength to predict good postoperative results was also calculated.

For statistical analysis, we used the Mann-Whitney U test to compare median values, Spearman’s rank correlation coefficients to estimate correlations between 2 variables and a receiver operating characteristic (ROC) curve, and Fisher’s exact test to determine cutoff values. The threshold for significance was P < 0.05. Data were analyzed using IBM SPSS Statistics version 21 (IBM Corp., Armonk, NY, USA).

<table>
<thead>
<tr>
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<th>Gender</th>
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<th>Follow-up period (mths)</th>
<th>Tumor size (mm)</th>
<th>Tumor site</th>
<th>Resected muscles</th>
<th>Knee flexor muscle resections (n)</th>
<th>Flexion strength (%)</th>
<th>MSTS score (%)</th>
<th>TESS (%)</th>
<th>EQ-5D (pts)</th>
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<tr>
<td>15</td>
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<td>86</td>
<td>18</td>
<td>63</td>
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<tr>
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<td>25.8</td>
<td>73.3</td>
<td>80.3</td>
<td>0.725</td>
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</tbody>
</table>
NY, USA). This study had ethical approval and all patients provided informed consent.

3. Results

The resected muscles (median knee flexion strength) were classified as follows: sartorius (97.8%), one; gracilis (95.4%), one; sartorius and gracilis (86.1%), one; gastrocnemius (85.2%; IQR: 85.0–86.2); three; semimembranosus, semitendinosus, and gracilis (76.2%; IQR: 73.3–78.0), three; long head and half of short head of biceps femoris (76.1%), one; long and short head of biceps femoris and half of gastrocnemius (70.2%), one; long and short head of biceps femoris (66.1%; IQR: 65.9–70.4), three; long and short head of the biceps femoris, semimembranosus, semitendinosus, and gracilis (27.3%; IQR: 26.6–31.5), three. A significant difference was observed between lateral and bilateral hamstrings resection (Mann-Whitney test, P = 0.049; Fig. 1). Reduced flexion strength correlated with increased number of resected muscles (Spearman’s test, r = −0.79, P = 0.002; Table 2).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Correlation between flexion strength and various parameters.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>P-value</td>
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<tr>
<td>Resection (n)</td>
<td>−0.79</td>
</tr>
<tr>
<td>Age</td>
<td>−0.08</td>
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<td>Follow-up period</td>
<td>0.36</td>
</tr>
<tr>
<td>Tumor size</td>
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<td>0.57</td>
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<td>TESS</td>
<td>0.66</td>
</tr>
<tr>
<td>EQ-5D</td>
<td>0.53</td>
</tr>
</tbody>
</table>

* Statistically significant difference.

No correlation with flexion strength was observed between tumor size, age, and follow-up period (Spearman’s test, tumor size, r = −0.29, P = 0.24; age, r = −0.08, P = 0.734; follow-up period, r = 0.36, P = 0.146; Table 2). Fourteen tumors occurred from the thigh and three from the lower leg. No significant difference in flexion strength was observed between thigh and lower leg cases (Mann-Whitney test, P = 0.101).

Functional scale median values were 90.0% (IQR: 80.0–96.7%) for MSTS score, 97.7% (IQR: 90.0–100%) for TESS, and 0.814 (IQR: 0.796–0.850) for EQ-5D. All functional scales showed significant differences when compared to flexion strength, with decreased flexion strength associated with lower scores (Spearman’s test, MSTS score, r = 0.57, P = 0.021; TESS, r = 0.66, P = 0.008; EQ-5D, r = 0.53, P = 0.034; Table 2). Reduced flexion strength and reduced function correlated in 16/30 TESS items (Spearman’s test).

In the 8 subscales and summary scores of SF-8, median values of the physical scales, including physical functioning (PF), role physical (RP), bodily pain (BP), and physical component summary (PCS) were below the Japanese national standard. Reduced flexion strength were associated with lower scores in BP and PCS (Spearman’s test, BP, r = 0.67, P = 0.007; PCS, r = 0.50, P = 0.046). In contrast, median values of the mental scales, including social functioning (SF), role emotional (RE), mental health (MH), and mental component summary (MCS) were above the national standard. No correlations with flexion strength were observed in mental scales (Table 3).

For hip muscle strength, hip flexion strength of sartorius resection (case 1; 95.8%) and hip adductor strength of gracilis resection (case 5; 90.6%) were slightly reduced. In hamstrings resection (case 7–17), hip extension strength was decreased (median value 78.0%; IQR: 75.2–87.1%), but no significant difference in hip extension strength was observed between hamstrings resection of medial, lateral, and bilateral cases. Furthermore, there was no correlation between hip extension strength and functional scores (Spearman’s test, MSTS score, P = 0.416; TESS, P = 0.410; EQ-5D, P = 0.063).

We calculated the flexion strength cutoff value of MSTS score, TESS, and EQ-5D to predict good results (ROC curve, Fisher’s exact test; Table 4). A cutoff value of 65.7% was obtained for all scales (sensitivity, specificity, area under the curve, and p-values were 100%, 75.0%, 0.87, and 0.006 for MSTS score, respectively; 93.3%, 100%, 0.93, and 0.024 for TESS; and 100%, 60.0%, 0.78, and 0.015 for EQ-5D). Patients with bilateral hamstrings resection had median flexion strength scores below the cutoff value, but other resected muscles had scores above the threshold (Fig. 1).

4. Discussion

This study investigated the knee flexion strength and postoperative function after knee flexor muscle resection for soft tissue sarcoma of the lower limbs. The main finding of this study was that flexion strength clearly decreased in the bilateral hamstrings resection, and their postoperative function also declined. Previous studies have shown that hamstrings are used for the reconstruction of knee extensor mechanism after quadriceps femoris resection [14] and anterior cruciate ligament (ACL) reconstruction [4] which result in their partial defect, but the decrease in knee flexion strength is considered mild. Additionally, the function including ADL, QOL, and patient satisfaction are maintained despite decreased flexion strength [14,15]. However, wide resections of soft tissue sarcoma include cases that require the resection of many muscles, possibly decreasing muscle strength and postoperative function further.

We have previously reported the postoperative muscle strength and function after quadriceps resection [13]. Of the lower limb muscles, the knee extension strength of the quadriceps is closely associated with activities of daily living (ADL), and a decrease in extension strength is known to cause limitations in ADL for healthy middle-aged and elderly adults [16]. However, in cases such as soft tissue sarcoma surgeries where knee flexor muscles are actually resected, the postoperative function may be lower than expected as a result of a decrease in flexor muscle strength. Moreover, the relationship between the extent of resection, postoperative muscle strength, and function are difficult to assess in previously described comparisons between different compartment resections [1,2]; we selected and reported cases that underwent resections of the knee flexor muscles.

In this study, flexion strength was found to decrease as more muscles were resected, but the cross-sectional area and length of knee flexor muscles can vary, and the strength of muscles greatly differ by muscle type. Flexion strength decreased in the resection of sartorius, gracilis, gastrocnemius, medial hamstrings, lateral hamstrings, and bilateral hamstrings in said order, and there was minimal decrease in muscle strength in the sartorius and gracilis resection. Therefore, the type of resected muscle may more significantly affect strength deficit than the number of resected muscles. According to a report on the residual strength after partial hamstrings resection for soft tissue sarcoma [17], residual isometric strength was 76% for semitendinosus, 72% for biceps femoris, and 33% for bilateral hamstrings. Additionally, the average flexion strength after quadriceps femoris reconstruction using either the biceps femoris alone or biceps femoris and semitendinosus graft was 74% [15]. According to Ardern et al. [4], when the semitendinosus or gracilis are grafted for ACL reconstruction, the flexion strength deficit ranges from 3–27%. Although a different measurement method was used, their results are similar to this study, and the type of resected muscle could be a good preoperative indicator for postoperative muscle strength.
The effect of reduced flexion strength on postoperative function using 4 functional evaluation scores were investigated. In this study, postoperative function based on MSTS score and ADL evaluations based on TESS both decreased with flexion strength. When individual TESS items were examined, functional decline was unexpectedly observed in many movements along with reduced flexion strength. In the partial deficit of hamstrings for ACL reconstruction, special attention should be paid for athletes that require a stable posture in deep flexion [5,6]. However, soft tissue sarcomas that require greater knee flexor muscles resection can result in functional deficits in general activities that are associated with decreased flexion strength. Yonemoto et al. [18] suggest that function of the affected limb associated with physical but not mental QOL in osteosarcoma patients and good function of the affected limb were not always necessary for good QOL. In this study, decreased flexion strength was correlated with reduced EQ-5D (one dimensional evaluation). Physical scales of SF-8 (multidimensional evaluation) declined with decreased flexion strength, but mental scales were maintained.

We also calculated a cutoff value for flexion strength to predict good postoperative results, and we estimated that the extent of resection predicted good postoperative function. Satisfactory function was obtained at a flexion strength cutoff value of 65.7%. Flexion strength remained above the cutoff value for unilateral hamstrings resection. In contrast, strength was significantly below the cutoff value for bilateral hamstrings resection. Therefore, if 65.7% of flexion strength is retained, postoperative function without significant hindrance to activities can be expected. Thus, good results can be estimated if, at minimum, the continuity of unilateral hamstrings is maintained.
The limitation of this study includes the small sample size and retrospective study. Additionally, the fact that most knee flexor muscles are bi-articular is also a limitation. It is probable that the muscle strength deficit other than knee flexion may have affected functional assessment, because knee flexor muscles are associated with hip motion and ankle motion. However, correlation between hip extension strength and functional scores were not observed in the hamstrings resection of this study. The primary motion of hamstrings is knee flexion and hip extension, but hip extension is compensated by the gluteus maximus that serves as a main muscle. Thus, we believe that knee flexion may be more reflective of the loss of muscle strength and function from hamstrings resection. Because multiple muscles are surgically resected for the treatment of soft tissue sarcoma, it is possible to evaluate muscle strength under a unique circumstance in which muscles are actually resected. For this reason, the results of this study can also be used for the functional prediction of trauma and reconstructive surgery, in addition to bone and soft tissue sarcoma.

5. Conclusion

We predict the knee flexion strength and postoperative function after knee flexor muscle resection for soft tissue sarcoma of the lower limbs. Knee flexion strength correlated with postoperative function, including ADL and QOL (particularly in physical scales). Bilateral hamstrings resection can particularly result in functional deficits that are associated with decreased flexion strength. At minimum, if continuity of unilateral hamstring is maintained, a function without significant difficulties in activities can be expected.

Disclosure of interest

The authors declare that they have no competing interest.

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References


