INTRODUCTION

“Musculoskeletal tumour” is a general term for bone tumours and soft tissue tumours. Such tumours can occur in various locations in the body, with sites of origin including bony tissues, fibrous connective tissues such as subcutaneous tissues and muscles, fibrous tissues such as tendons and ligaments, adipose tissues, striated muscle tissues, smooth muscle tissues, vascular and lymphatic tissues, tissues originating from the mesoderm such as synovial membranes, and tissues originating from the ectoderm such as peripheral nerve tissues. Among musculoskeletal tumours, the frequencies of benign tumours and malignant tumours are reported to be approximately 1:100.1) Both conservative treatment and various surgical treatments are performed, depending on the type of tissue, the tumour location, the diagnosis, the level of malignancy, and subjective symptoms involving the tumour.1–3) Although rehabilitation is implemented to ameliorate functional impairment after treatment, the efficacy of rehabilitation has been described mostly for malignant tumours.4–6) As part of the rehabilitation procedures, evaluation of the following items are recommended: functional impairment; deterioration in the performance of activities of daily living (ADL); and social disadvantages evaluated using...
scales such as the Performance Status, the Barthel Index, and the Functional Independence Measure.\textsuperscript{7,8)} Developed in 1965, the Barthel Index has a track record of being used in numerous studies and is still widely used today as a simple method to assess ADL for various diseases.\textsuperscript{9)} However, in musculoskeletal tumours, disease-specific methods for functional evaluation are widely used. These methods include the International Symposium on Limb Salvage/Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score; few reports have described the use of the Barthel Index for the assessment of ADL in patients with musculoskeletal tumours. Therefore, in this study, we used the Barthel Index to evaluate the postoperative ADL in patients treated for musculoskeletal tumours. We also examined the factors affecting the Barthel Index in these patients. Subsequently, we examined the relationship between the Barthel Index at the end of rehabilitation and the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score at final functional evaluation.

**METHODS**

This study was approved by the Institutional Review Board of our hospital, and all patients provided informed consent prior to their study enrolment. From 2013 to 2016, 464 patients with musculoskeletal tumours underwent orthopaedic surgery (amputation, wide resection, marginal resection, curettage, or corrective osteotomy) at our hospital. If the ADL performance was adversely affected after surgery, a therapist intervened with rehabilitation and made assessments using the Barthel Index. The patient was discharged from the hospital when able to perform daily life activities such as walking without assistance, climbing stairs, and bathing. Rehabilitation was considered complete at the time of hospital discharge, and the Barthel Index was subsequently evaluated by a physical therapist. If a patient exhibited no impairments in their postoperative ADL, rehabilitation procedures were not carried out. Patients who underwent rehabilitation and had malignant tumours that originated in the extremities were evaluated using the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score. When the functional improvement plateaued during follow-up observation, the final functional evaluation was conducted using the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score. Of the 464 patients with musculoskeletal tumours who underwent orthopaedic surgery, we excluded the 274 patients who did not undergo postoperative rehabilitation; this left a study population of 190 patients with musculoskeletal tumours who underwent rehabilitation. Based on information from medical records, we analysed the following factors: age at surgery, sex, histologic diagnosis and grade of the tumour, tumour location, tumour size, rehabilitation period, the Barthel Index at the end of rehabilitation, and the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score at final functional evaluation. In accordance with the United Nations report on population dynamics\textsuperscript{10)} and previous studies on musculoskeletal tumors,\textsuperscript{11)} patients were divided into two groups based on age: below age 60 years and age 60 years and above. Patients with mild to moderate disabilities reportedly can achieve a Barthel Index score of 100; this implies that the Barthel Index exhibits a ceiling effect.\textsuperscript{12,13)} Because we also anticipated that many patients in our study would exhibit a Barthel Index of 100, we conducted our analysis by separating the patients into two groups: those with a Barthel Index of 100 points and those with a Barthel Index <100 points. All histopathological specimens were classified by two or more pathologists from the Department of Laboratory Medicine. The tumour stage was calculated using the American Joint Committee on Cancer and International Union Against Cancer systems, 6th edition.\textsuperscript{14)} The follow-up period was defined as the time from surgery to the last follow-up.

Univariate analyses were performed, comparing patient-, tumour-, and treatment-related factors according to the two age categories using the Mann–Whitney U test for continuous variables and the chi-squared test for categorical variables. Factors that were found to be associated with a low Barthel Index were analysed using multivariate logistic regression analysis. Spearman correlation analyses were performed to evaluate associations between the Barthel Index and the Musculoskeletal Tumour Society Score and between the Barthel Index and the Toronto Extremity Salvage Score. Statistical analyses were performed using statistical analysis software (IBM Corp.; IBM SPSS Statistics for Windows, Version 25.0). In all analyses, $P <0.05$ indicated statistical significance.

**RESULTS**

The median age at surgery was 56 years (range, 6–91). One hundred and two patients were under 60 years old, and 88 patients were over 60 years old. There were 97 male and 93 female patients. One hundred and eighteen cases of soft tissue tumour and 72 cases of bone tumour were included in the study. The locations of the tumours were 23 in the upper extremities, 137 in the lower extremities, and 30 in the...
In 131 patients, the tumour was smaller than 10 cm and in 59 patients the tumour was larger than 10 cm. Benign tumours (including the intermediary group) were present in 88 patients, and malignant tumours were present in 102 patients. In order of frequency, the benign tumours included 12 atypical lipomatous tumours, 10 osteochondromas, and 10 lipomas. Likewise, malignant tumours included 16 undifferentiated pleomorphic sarcomas, 16 liposarcomas, and 15 myxofibrosarcomas. In total, 47 of 102 patients with malignant tumours were less than 60 years old, whereas 55 such patients were more than 60 years old. Sixty-four malignant tumours were smaller than 10 cm and 38 were larger than 10 cm. Further details on patient characteristics in relation to Barthel Index are given in Table 1.

The median duration of postoperative rehabilitation was 16 days (range, 3–389). The duration was significantly longer in patients aged 60 years or more (P <0.001). There was no significant difference in rehabilitation duration in terms of gender (P=0.074). For patients with tumours that originated in the soft tissues, the rehabilitation duration was significantly longer (P=0.014). There was no significant difference between sites of occurrence (P=0.093). Patients with a tumour size greater than 10 cm exhibited a significantly longer rehabilitation period (P <0.001). Moreover, malignant tumours resulted in a significantly longer duration (P <0.001). The duration of rehabilitation and the Barthel Index at the end of rehabilitation were significantly negatively correlated (Fig. 1a). In patients with a Barthel Index below 95 points,
Fig. 1. (A) Relationship between the rehabilitation period and the post-rehabilitation Barthel Index. The Barthel Index and the duration of rehabilitation showed significant correlation (P < 0.001). (B) Comparison of the rehabilitation period when the Barthel Index is divided into two groups (below 95 points or 100 points) at the end of rehabilitation. Patients with scores less than 95 points had a significantly longer rehabilitation period (P < 0.001). (C) Relationship between the post-rehabilitation Barthel Index and the Musculoskeletal Tumour Society Score at final functional evaluation. The Barthel Index and Musculoskeletal Tumour Society Score showed significant correlation (P < 0.001). (D) Comparison of the Musculoskeletal Tumour Society Score at final functional evaluation when the Barthel Index is divided into two groups (below 95 points or 100 points) at the end of rehabilitation. In patients with a Barthel Index of 95 or below, the Musculoskeletal Tumour Society Score was significantly lower (P < 0.001). (E) Relationship between the post-rehabilitation Barthel Index and the Toronto Extremity Salvage Score at final functional evaluation. The Barthel Index and the Toronto Extremity Salvage Score were significantly correlated (P = 0.004). (F) Comparison of the Toronto Extremity Salvage Score at final functional evaluation when the Barthel Index is divided into two groups (below 95 points or 100 points) at the end of rehabilitation. The Toronto Extremity Salvage Score was significantly lower in patients with a Barthel Index of 95 points or below (P = 0.004).
the rehabilitation period was significantly longer (Fig. 1b).

There were 83 patients with a post-rehabilitation Barthel Index of 95 or less and 107 patients with a Barthel Index of 100. The median score was 100 (range, 5–100) and the mean score was 93.84 ± 0.896. The Barthel Index was significantly lower in patients over 60 years of age compared to those under 60 years of age (P <0.001), with a larger proportion of patients with a Barthel Index below 95 points (under 60 years old, 35 cases; over 60 years old, 48 cases; P=0.004). There was no significant difference in the Barthel Index between male and female patients (P=0.683), or for the type of tissue (P=0.476), or site of occurrence (P=0.353). In patients with tumours larger than 10 cm, the post-rehabilitation Barthel Index was significantly lower than for those with a tumour smaller than 10 cm (P=0.005). A larger proportion of patients with tumours larger than 10 cm had a Barthel Index below 95 points (smaller than 10 cm, 48 cases; larger than 10 cm, 35 cases; P=0.003). In patients with tumours larger than 10 cm, the post-rehabilitation Barthel Index was significantly lower than for those with a tumour smaller than 10 cm (P=0.005). Compared to patients with benign tumours, a larger proportion of patients with malignant tumours had a Barthel Index below 95 points (benign, 17; malignant, 66; P <0.001). Patients with malignant tumours also had a significantly lower Barthel Index (P <0.001). Multivariate analysis revealed that malignancy and tumour size were risk factors for a lower post-rehabilitation Barthel Index, as described in Table 2. In order of frequency, the Barthel Index items for which points were deducted included STAIRS (58 cases), BATHING (54 cases), and MOBILITY (24 cases).

The rehabilitation period was significantly longer (Fig. 1b).

Although soft tissue tumours required a longer rehabilitation period than bone tumours, there was no reduction in the Barthel Index at the end of rehabilitation. One reason for this result may be complications, such as the necessity for functional reconstruction during surgery, failure of sutures, or infection. Risk factors for a low post-rehabilitation Barthel Index were malignant tumours and tumours larger than 10 cm; these findings were also consistent with past reports on other types of cancers.21,22

In the current study, we also examined the relationship between the post-rehabilitation Barthel Index and the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score at final evaluation (Fig. 1e), and the Toronto Extremity Salvage Score was significantly lower in patients with a Barthel Index below 95 points (Fig. 1f).

**DISCUSSION**

In this study, by using the Barthel Index, we evaluated the postoperative ADL of patients who had undergone surgery for musculoskeletal tumours. We also investigated factors affecting the post-rehabilitation Barthel Index score. The Barthel Index is applied to evaluate 10 items of ADL in two to four stages; its efficacy is widely accepted.15–17 The Barthel Index is used to assess functional impairment resulting from stroke, neurological disorders, and many other diseases.18,19 Rehabilitation for cancer patients is known to improve the Barthel Index and Performance Status, and the efficacy of the Barthel Index for estimating the survival rate of cancer patients has been reported in the literature.6,20,21 However, there are few reports that have evaluated postoperative impairment resulting from musculoskeletal tumours using the Barthel Index. In the current study, we found that the impairment of ADL after musculoskeletal tumour surgery is related to the need for long-term rehabilitation, which implies an extension of the hospitalization period. Moreover, patients aged 60 years or older, patients with tumours larger than 10 cm, and patients with malignant tumours required a longer rehabilitation period; these results were consistent with past reports on cancers other than musculoskeletal tumours.21,22

Table 2. Risk factors for a low post-rehabilitation Barthel Index

<table>
<thead>
<tr>
<th>Factors</th>
<th>Hazard ratio</th>
<th>95% Confidence interval</th>
<th>P value</th>
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<tbody>
<tr>
<td>Age ≥60 years</td>
<td>0.536</td>
<td>0.277 – 1.037</td>
<td>0.064</td>
</tr>
<tr>
<td>Malignancy</td>
<td>0.143</td>
<td>0.072 – 0.283</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>Tumour size ≥10 cm</td>
<td>0.472</td>
<td>0.234 – 0.949</td>
<td>0.035*</td>
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Of the patients with malignant tumours present in the extremities, 58 were evaluated using the Musculoskeletal Tumour Society Score and 28 were evaluated using the Toronto Extremity Salvage Score. The median follow-up period was 24.4 months (range, 4.7–60.1). The Barthel Index at the end of rehabilitation correlated significantly with the Musculoskeletal Tumour Society Score (Fig. 1c), and patients with a Barthel Index below 95 had a significantly lower Musculoskeletal Tumour Society Score (Fig. 1d). The Barthel Index at the end of rehabilitation also significantly correlated with the Toronto Extremity Salvage Score.
The Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score were developed as disease-specific postoperative functional evaluation scales for musculoskeletal tumours.23,24) The Musculoskeletal Tumour Society Score is an easily applied, highly reproducible, and versatile scale that is aimed at evaluating functional impairment and decreased functional ability after treatment of musculoskeletal tumours. Although it was originally developed for the functional evaluation of patients undergoing limb-sparing surgery, the scale can also be used for the functional evaluation of patients after amputation. The scoring system of the Musculoskeletal Tumour Society Score is the most standard method of evaluation in assessing the function of the affected limb. It has also been reported that a moderate correlation was found between physical role functioning, social role functioning, and physical functioning in SF-36, a comprehensive health-related quality of life health survey. Although the Toronto Extremity Salvage Score is a patient-reported measure to assess physical function of patients after limb-salvage surgery for musculoskeletal tumours, the measure can also be used for evaluating physical function after amputation. It is the sole patient-reported measure that can be used for musculoskeletal tumours. The only methods generally used for evaluating health-related quality of life that are specific to musculoskeletal tumours are the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score, and the combined use of the two scoring systems is recommended to evaluate disease-specific health-related quality of life, including the physical functioning of the patient. Although their efficacy has been reported,25–29) these methods of evaluation are limited to musculoskeletal tumours of the extremities, underscoring a flaw in that they can neither be adapted for tumours of the head, neck, and trunk, nor used for comparison with other diseases. In addition to the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score, several new evaluation scales have been developed in recent years, and some have also been used for musculoskeletal tumours.30–34) However, these methods of evaluation are disease-specific, and a generalized evaluation method remains to be developed for future evaluations. Davis et al. reported that the Musculoskeletal Tumour Society Score and the Toronto Extremity Salvage Score demonstrate a significant correlation.24) However, there are few reports that evaluate the relationship between the Barthel Index and the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score. We found that the Barthel Index, which is a widely used and simple method for assessing ADL, shows a significant correlation with the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score at final functional evaluation and can potentially be used to predict health-related quality of life following the treatment of musculoskeletal tumours.

There are several limitations to this study. First, there is the potential for bias because some patients, often those with small benign tumours, suffered no postoperative impairment. For these patients, we neither intervened with postoperative rehabilitation nor evaluated ADL using the Barthel Index (although a Barthel Index score of 100 could be assumed). Second, multiple evaluators, including surgeons and therapists, assessed the Barthel Index and the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score, and we did not evaluate their reproducibility. Third, because this was a retrospective study, there were variations in the time at which the Musculoskeletal Tumour Society score and the Toronto Extremity Salvage Score were evaluated at the final follow-up observation. Furthermore, because this was a one-time-point assessment, we were unable to evaluate changes over time. Finally, this research was conducted at a single institution only.

The postoperative and post-rehabilitation ADL for patients with musculoskeletal tumours were evaluated using the Barthel Index. Multivariate analysis revealed that a tumour larger than 10 cm and malignant tumours were risk factors for a low Barthel Index at the end of rehabilitation. The Barthel Index at the end of rehabilitation and the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score at final functional evaluation were significantly correlated. We believe that the Barthel Index at the end of rehabilitation could potentially predict the disease-specific health-related quality of life at the final functional evaluation. Patients with musculoskeletal tumours comprise a highly heterogeneous population, and we believe that higher sensitivity and better outcomes may be achieved in evaluating the validity and effectiveness of treatments through the combined use of the Musculoskeletal Tumour Society Score/Toronto Extremity Salvage Score with a much simpler ADL assessment, such as the Barthel Index.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.
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