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Physical Activity Assessment in Adolescents with Limb Salvage

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Abstract

Objectives—To evaluate ambulatory activity differences between youth with limb salvage procedures and typically developing youth (TDY) and assess differences in self-reported activity levels in the 2 groups, to provide a basis for physical activity assessment in patients who had undergone limb salvage surgery and treatment planning that incorporates regaining normal physical and daily living activities.

Study design—In this cohort comparison study, we compared ambulatory and self-reported activity levels in 20 youth (aged 11.7–20.8 years) who had undergone limb salvage surgery and a sex- and age-matched comparison cohort of 20 TDY. StepWatch activity monitor and Activity Scale for Kids data were used to answer these questions.

Results—Significant differences were found between the youth who had undergone limb salvage surgery and the TDY in total time active each day (43% vs 48%; $P = .03$), median total strides per day (4487 vs 7671; $P = .001$), and amount of time per day at high activity levels (20 minutes vs 47 minutes; $P = .001$). Self-reported overall physical activity, locomotion, and standing Activity Scale for Kids subscale scores were significantly lower in the youth undergoing limb salvage surgery compared with the TDY (summary score, 88.3 vs 97.7; $P = .001$).

Conclusion—Patients undergoing limb salvage surgery exhibit reduced physical activity compared with normal age-matched controls.

Approximately 700 new cases of malignant pediatric bone tumors are diagnosed and treated each year in the United States. Of these, 78% are in the lower limbs (including 60% from osteosarcoma and 34% from Ewing sarcoma).¹ Treatment for these children used to be amputation²; however over the last 20 years, amputations have become less common as limb salvage techniques have improved.³ The objective of a limb salvage procedure is to resect the primary cancer and replace the resected bone with either an allograft or a prosthetic

implant while preserving maximal limb function. Limb salvage procedures have a similar overall survival rate as amputations, but carry a high rate of short-term and long-term complications.²

Youth who undergo limb salvage of the lower extremities experience limitations in ambulation and physical activity after surgery. This may be due to physician-imposed postoperative restrictions to allow implant or allograft healing and recovery of joint motion and strength. Other factors in activity limitations include residual pain, muscle weakness, and loss of muscular control after surgery. Previous bone tumor studies have used the Musculoskeletal Tumor Society's scoring system to assess function⁴⁻⁶; however, this system reflects the physician's interpretation of the patient's function, not a record of the patient's physical activity or his self-report of progress. Information regarding the postoperative level and quality of activity that patients who undergo limb salvage surgery can expect to experience would be of value in counseling patients before surgery and during postoperative rehabilitation.

The aims of this study were to document day-to-day ambulatory activity and self-reported physical activity in youth who had undergone limb salvage surgery, compared with a cohort of typically developing youth (TDY), measured using a 2-dimensional accelerometer (StepWatch) and the Activity Scale for Kids (ASKp-38).^{7,8} The study addressed differences in ambulatory activity and self-reported activity between the youth who underwent limb salvage surgery and the TDY cohort.

Methods

Patients provided signed informed consent on an institution-approved study protocol. A comparison cohort design for this preliminary study was used with a sample of pediatric patients who had undergone limb salvage surgery for osseous sarcoma at Seattle Children's Hospital between 1996 and 2006. Inclusion criteria included age 7-20 years, at least 1 year post-limb salvage procedure or major revision surgery, full recovery from any minor surgery, and previous chemotherapy. Patients who had undergone limb salvage surgery were matched by age and sex to a cohort of TDY who had been recruited for another large normative ambulatory activity project and/or by word-of-mouth community contacts by the study investigators. They were not selected for special characteristics, such as athletic participation. These comparison youth study participants were free of musculoskeletal impairment and major and chronic illnesses, such as severe asthma and diabetes.

The StepWatch is a 2-dimensional accelerometer used to evaluate the walking patterns and intensity of patients with and without motor impairment.⁹ The device measures the movement of one leg (stride). It has a high level of accuracy for detecting strides across walking speeds, and individualized calibration makes the device suitable for pretesting and posttesting of interventions expected to affect walking activity levels and intensity. High activity levels can be achieved by normal activity, such as walking quickly for distance, and not necessarily sports-related activity; however, StepWatch data do not discriminate between these sources of input.^{10,11}

The StepWatch device was calibrated using a manual count of 100 strides for each patient. Participants were instructed to wear the monitor for at least 7 consecutive days during all waking hours except when swimming or bathing. Five full days of StepWatch data were analyzed for the study sample. Inadequate monitoring was defined as wearing the monitor upside down, incorrect positioning of the device, or not wearing the monitor for more than 3 hours in any 1 day.

Comparisons of patients who had undergone limb salvage surgery with the age- and sex-matched TDY cohort were performed using the independent t-test or χ^2 test for age, sex, race, calibration accuracy, body mass index, leg discrepancy, and socioeconomic status (SES). The consenting parent's education level served as a proxy measure of SES. Each participant self-reported physical activity for the week spent wearing the monitor with the ASKp-38 by completing the questionnaire on the final day of monitoring. The Mann-Whitney U test was used to determine group differences for the ASKp-38 and StepWatch variables. The relationship of step activity to ASKp-38 score and subscale scores was tested using the Spearman rho correlation. Statistical significance was set at $P < .05$, and all analyses were performed with SPSS version 13.0 (SPSS, Chicago, Illinois).

Results

A total of 22 patients who had undergone limb salvage surgery and 20 matched TDY were studied in this cohort comparison. Two patients who had undergone limb salvage surgery were eliminated from study owing to loss of the monitor. Characteristics of the limb salvage and TDY groups are displayed in Table I. The average age of the participants was 15.8 years (range, 11.7-20.8 years). There were no significant differences between the groups in terms of age, sex, race, or body mass index. Leg length discrepancy was significantly greater in the limb salvage group, averaging 1.8 cm ($P = .001$). SES/parental education was higher in the TDY group ($P = .05$). Thirteen patients had osteosarcoma, 5 had Ewing sarcoma, and 2 had other types of cancer involving bone. Implants were the rotating hinge type, and 2 intercalary allografts were used. None of the patients who received an implant required surgical revision. The patients who received an allograft underwent major revision for graft fracture and hardware replacement (Table I). The average interval since a major revision or initial limb salvage operation was 2.46 years (range, 1.01-10.09 years), and the average interval since any operative procedure was 1.79 years (range, 0.39-3.82 years). The mean time since the last chemotherapy was 4.31 years (range, 0-14.80 years). All but 1 patient had completed a prescribed chemotherapy regimen at least 1 year before the start of the study. One patient who was very active was placed on activity restrictions by the surgeon. Clinical data were not assessed for evidence of chemotherapy complications that would specifically limit physical activity, such as cardiomyopathy; however, these types of complications are rare in the pediatric population.

The StepWatch ambulatory activity data are displayed in Table II. The limb salvage surgery group had significantly fewer strides per day compared with the TDY group (median, 4487 [range, 1777-12 056] versus 7671 [range, 4763-11 437]). However, the single participant averaging the most strides per day was a patient in the limb salvage group, walking approximately 12 000 strides/day. The median active time while wearing the monitor was

significantly lower in the limb salvage group compared with the TDY group (370 minutes vs 438 minutes; $P = .05$). When active, youth in the limb salvage group spent a significantly greater percentage of the day at lower levels of activity, spent less time at high levels of activity, and had fewer strides/minute for 60-, 30-, 20-, 5-, and 1-minute epochs of sustained activity ($P < .001$).

Self-reported physical activities as measured by the ASKp-38 summary and subscale scores are documented in Table III. Self-reported physical activity was lower in the limb salvage group than in the TDY group on the summary, locomotion, and standing subscales, and the transfer and personal care subscales were similar in the 2 groups. There was moderate correlation between walking activity (average strides/day and % time active) and self-reported physical activity in the limb salvage group (Table IV).

Discussion

In this preliminary study, we assessed disabilities in physical activity and function in activities of daily living in youth who had undergone limb salvage surgery compared with TDY, using the StepWatch to track steps over time in the community setting and the ASKp-38 self-reported questionnaire. Patients in the limb salvage surgery group spent less time at higher activity levels (either normal or sports-related activity) and showed less variability in walking speed over various time intervals (as reflected in endurance, peak, and burst scores), suggesting that patients who undergo limb salvage surgery also have difficulty adapting to higher activity levels, or “flexing up.” The inability to “flex up” to high levels of activity may have a more significant impact on self-reported perceptions of disability than total physical activity. On the ASKp-38, self-reported overall, locomotion, and standing physical activities were significantly lower in the limb salvage group compared with the TDY group. Lower activity levels recorded by StepWatch were moderately correlated with the summary and locomotion subscales of the ASKp-38.

Patients who have undergone limb salvage surgery are advised to be careful when engaging in physical activity because of the fragility of their implants and bone grafts. Only one patient in the group was instructed to reduce activity level by the surgeon. Our data may reflect good patient adherence to these instructions. Others have reported similar findings. In 2001, Sugiura et al¹¹ used an Omron pedometer to document walking ability in 56 patients aged 14-85 years who had undergone limb salvage surgery. That study evaluated different tumor types and different reconstructions, and focused primarily on middle-aged adults. A major limitation of the study was the inaccuracy of the pedometer, which was found to undercount steps by approximately 40%. Van Dam et al¹² used a 3-dimensional accelerometer to document total physical activity and walking over a 24-hour period in 20 patients who had undergone limb salvage surgery and found that their patients spent approximately 5.6% of the 24 hours walking versus standing or sitting.

Based on their review of 7 psychometric criteria, Pakulis et al⁵ recommended using the ASKp-38 for studies of the pediatric bone tumor population. However, the ASKp-38 may lack some content validity, because it does not contain items specific to the pediatric bone

tumor population, such as participation in competitive sports. Our study overcame many of the problems in previous studies.

Our preliminary study has several limitations that suggest areas for further exploration. We evaluated a limited number of youth who had undergone limb salvage procedures, and did not segregate the results based on the level or extent of surgery. Patients who had undergone limb salvage surgery have widely varying outcomes, complication rates, and recovery time, depending on tumor location. It is possible that, like children who have undergone amputation, children with limb salvage will demonstrate varying levels of energy consumption and function based on tumor size and location.¹³ Our study inclusion criteria included completion of chemotherapy and at least a 1-year interval from primary surgery, but did not control for different chemotherapy regimens and their toxicities, surgical complications, age at diagnosis, differences in physical function, or duration of follow-up. Appropriate control groups for future activity studies in this population should include increased numbers of age-matched controls and assessment of extremity function. Patients with limb amputations for similar diagnoses were not studied as a comparison cohort in this study, because we see few of these patients in our practice; such a group should be included in a larger multi-institutional comparison prospective study.

In this study, we found that children who undergo limb salvage procedures for bone tumors demonstrate significantly less daily activity and lower activity levels than age-matched TDY controls. This decline in activity correlates with self-reported ASKp-38 subscale scores for locomotion and standing and summary scores. Future studies using the StepWatch device that focus on surgical and nonsurgical variables in age-specific comparisons with an improved outcome tool for adolescents and adults should yield highly significant results that will provide data for tumor treatment plans that specifically include attention to regaining more normal physical activity levels (physical therapy integrated plans) and improving activities of daily living task levels (occupational therapy integrated plans) as well.

Patients who undergo limb salvage surgery exhibit reduced physical activity compared with normal age-matched controls. The clinical relevance of our findings is that quantitative objective and subjective assessments of patient activity can be made in patients who had undergone limb salvage surgery. This information can be used in postoperative treatment planning that includes specific plans to help these patients return to normal physical activity function for their age group. ■

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Glossary

ASKp-38	Activities Scale for Kids
SES	Socioeconomic status

TDY Typically developing youth

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Table I

Characteristics of the sample (n = 40)

Characteristic	Limb salvage	TDY	P value *
Number	20	20	
Age, years, mean (SD)	15.8 (2.8)	15.8 (2.9)	.82
Female sex, n (%)	12 (60)	12 (60)	1.0
Race, n (%)			
Caucasian	14 (70)	13 (65)	.37
Hispanic	2 (10)	0	
Asian	0	2 (10)	
Black	2 (10)	1 (5)	
Other	2 (10)	4 (20)	
BMI, mean (SD)	21.9 (5.8)	21.1 (3.8)	.14
Limb length discrepancy, cm, mean (SD)	1.80 (4.11)	0.18 (.05)	.001
Calibration accuracy, %, mean (SD)	99.6 (6.2)	98 (5.1)	.39
Type of limb salvage, n (%)			
Implants	12 (60)	NA	NA
Proximal femur	2		
Distal femur	6		
Proximal tibia	4		
Allografts	8 (40)	NA	NA
Distal femur	3		
Proximal tibia	4		
Distal tibia	1		
Type of tumor, n (%)			
Osteosarcoma	13 (65)	NA	NA
Ewing sarcoma	5 (25)	NA	NA
Other malignancy	2 (10)	NA	NA
Location of tumor, n (%)			
Distal tibia	1 (5)	NA	NA
Proximal tibia	8 (40)	NA	NA
Distal femur	9 (45)	NA	NA
Proximal femur	2 (10)	NA	NA
SES, % parent education level			.05
Some high school	10	2.5	
High school/GED	5	2.5	
Vocational school	8	10	
College degree	22	15	
Professional/graduate school	5	20	

BMI, body mass index; NA, not available; GED, General Educational Development Test.

* Level of significance was determined by one-way ANOVA for continuous variables and the χ^2 test for categorical variables.

Table II

Step activity variables for limb salvage and TDY groups

StepWatch variable	Limb salvage	TDY	<i>P</i> value *
Average daily total strides	4487 (1777-12 056)	7671 (4763-11 437)	.001
% all time active	43 (25-61)	48 (36-66)	.03
% time in low activity when active [†]	64 (53-83)	56 (40-70)	.03
% time in medium activity when active [†]	28 (16-39)	30 (24-45)	.45
% time in high activity when active [†]	6 (6-.2)	11 (4-22)	.001
Endurance [‡]	18 (8-33)	28 (18-47)	<.001
Accumulated peak effort [‡]	22 (13-39)	33 (25-54)	<.001
Cardiovascular score [‡]	27 (16-44)	39 (28-57)	<.001
Burst score [‡]	41 (25-61)	54 (42-66)	<.001
Peak score [‡]	55 (39-69)	66 (60-75)	<.001
Average minutes/day StepWatch worn	814 (701-1100)	840 (725-1032)	.53
Average minutes/day active (walking)	370 (211-587)	438 (275-518)	.05
Average minutes/day low activity	226 (166-370)	233 (148-340)	.86
Average minutes/day medium activity	106 (39-250)	127 (77-232)	.22
Average minutes/day high activity	20 (.6-71)	47 (21-114)	.001

Data are reported as median (range).

* Mann-Whitney *U* test.[†] Low activity, <15 strides/minute; medium activity, 15-42 strides/minute; high activity, >42 strides/minute.[‡] Endurance: peak step count for a continuous 60-minute effort; accumulated peak effort, best step count for 30 minutes noncontinuous; cardiovascular score, peak step count for a continuous 20-minute effort; burst score, peak step count for a continuous 5-minute burst; peak score, peak step count for 1 minute.

Table III

ASKp-38 scores for the limb salvage surgery and TDY groups

ASKp-38 subscale	Limb salvage	TDY	<i>P</i> value *
ASKp-38 summary score	88.3 (69-98)	97.7 (88-100)	.001
ASKp-38 personal care	100 (92-100)	100 (100)	.15
ASKp-38 locomotion	89.3 (50-100)	100 (71-100)	<.001
ASKp-38 standing	100 (75-100)	100 (95-100)	.005
ASKp-38 transfers	100 (70-100)	100 (90-100)	.98

Data are reported as median (range). ASKp-38 scores range from 0 to 100.

* Mann-Whitney *U* test.

Table IV

Spearman rho correlation of StepWatch (walking activity) variables and self-reported physical activity (ASKp-38) for youth who underwent limb salvage surgery (n = 20)

ASKp-38	StepWatch Average strides/day	StepWatch % all time active
ASKp-38 summary score	0.50 *	0.44
ASKp-38 personal care	0.16	-0.002
ASKp-38 locomotion	0.63 †	0.56 *
ASKp-38 standing	0.32	0.17
ASKp-38 transfers	0.07	-0.15

* $P < .05$.

† $P < .01$.