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ORIGINAL ARTICLE

Kinesiophobia modulates lumbar movements in people with chronic low back pain: a kinematic analysis of lumbar bending and returning movement

Michihiro Osumi[1] · Masahiko Sumitani[2] · Yuko Otake[2] · Tomohiko Nishigami[3] · Akira Mibu[3] · Yuki Nishi[1] · Ryota Imai[1] · Gosuke Sato[1] · Yusuke Nagakura[1] · Shu Morioka[1]

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Abstract

Purpose We aimed to kinematically analyze lumbar bending and returning movements and clarify the relationship between fear of movement and kinematic output.

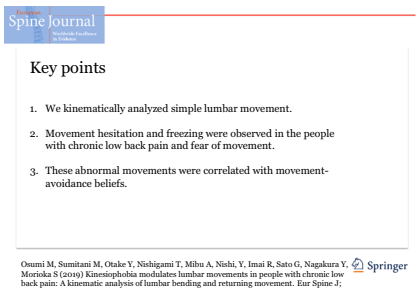
Methods We recruited 45 participants with CLBP (i.e., > 6 months) and 20 healthy control (HC) participants with no history of CLBP. We used the numerical rating pain scale (NRS), Tampa Scale for Kinesiophobia (TSK-11), and Pain Self-Efficacy Questionnaire (PSEQ-2) as qualitative outcome measurements. CLBP participants were divided into two subgroups (high- and low-fear groups) based on the median split of the total TSK-11 score. In the kinematic recording session, a starting-cue beep signaled participants to bend forward using the lumbar region of their spine and then return to an upright posture, and we used a flexible twin-axis electrogoniometer to record the lumbar movements. The time series of lumbar movements was divided into four phases according to lumbar movement velocity, and we calculated the length (sec) of each phase.

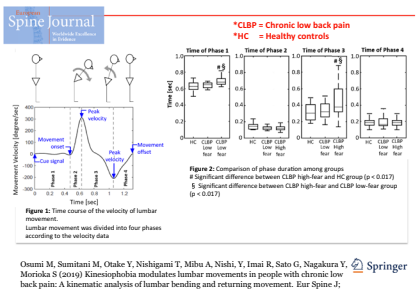
Results Phase 1 (duration prior to cue-induced movement initiation) and phase 3 (switch in the direction of lumbar movement from forward to backward) were significantly longer in the CLBP high-fear group compared with those in the CLBP low-fear group and HC group ($p < 0.05$). The increased lengths of these two phases were positively correlated with not only pain intensity but also TSK-11 scores ($p < 0.05$).

Conclusions These results represent evidence of a particular lumbar movement pattern associated with kinesiophobia. These results might help to identify psychological factors that impact lumbar movement patterns in individuals with CLBP.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.





Keywords Low back pain · Kinematic analysis · Fear of movement · Kinesiophobia

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Extended author information available on the last page of the article

Introduction

Musculoskeletal disorders such as chronic low back pain (CLBP) can limit ability in daily activities [1], subsequently resulting in a lower quality of life [2]. Among musculoskeletal disorders, CLBP is a highly prevalent condition in adults [3] and has been one of the most common physical complaints since the 1990s [1]. Patients with CLBP frequently present with impaired lumber movements, for example, limited movement range and velocity, atypical lumbar movement variability, and abnormal trunk muscle contraction [4]. A systematic review reported that slower lumbar movements are robustly observed in CLBP patients [5]. Disturbance of the sensorimotor system (e.g., impaired somatosensory input, musculoskeletal impairment) has been proposed as a possible factor affecting these abnormal movement patterns [6]. Several studies have examined the utility of physical therapy based on lumbar movement assessment as a treatment for abnormal movement patterns observed in CLBP patients [7]. For example, motor control exercises, which retrain optimal movement patterns based on lumbar movement assessments, have been found to improve pain and disability associated with CLBP [8]. Therefore, quantitative kinematic analyses of movement patterns can directly facilitate objective assessments of CLBP disability as well as the selection of CLBP management plans [9]. CLBP disability is influenced by several biopsychosocial factors [10]. Among these, fear of movements (termed "kinesiophobia") is a particularly robust predictor of CLBP disability [11, 12]. Management of biopsychosocial factors via therapeutic education has reportedly improved CLBP disability [13]. However, few reports have concretely revealed how kinesiophobia influences movement patterns in individuals with CLBP. Analyzing the kinematic features associated with kinesiophobia could be important for the comprehensive management of movement disorders in CLBP patients. Thus, in the present study, we aimed to examine the relationship between kinesiophobia and lumbar kinematic output in individuals with CLBP.

Methods

Participants and assessment

We recruited participants from the geographic region around our laboratory via local flyers that stated the inclusion and exclusion criteria. Inclusion criteria were as follows: males and females aged 30–80 years; LBP duration of > 6 months; a score of 1 or more on an 11-point numeric rating scale (NRS, 0–10) for pain intensity; sufficient walking ability to travel to our laboratory without assistance; at least one previous visit to an orthopedic clinic due to LBP, and received a diagnosis and recommendation of the conservation treatment from attending physician. Exclusion criteria were as follows: previous spinal surgery (fusion, instrumentation, or discectomy), serious spinal pathology (cancer, inflammatory arthropathy, or acute vertebral fracture), or a diagnosis of neurological disease. Forty-five participants with CLBP (mean age 56.2 [30–78] years), diagnosed with lumbar disk herniation ($n = 9$), lumbar spondylolisthesis ($n = 6$), lumbar osteoarthritis ($n = 4$), and nonspecific CLBP ($n = 26$) fulfilled these criteria and participated in the study.

We also recruited 20 age-matched healthy participants (mean age 54.3 years, [31–75 years]) with no history of CLBP and no other diagnosed illnesses as healthy controls (**HC group**). The HC participants were recruited through a temporary employment agency and received about 8 Euros as compensation for their involvement. We obtained ethical approval from the institutional ethics committee of Kio University. We explained the purpose and protocol of the study to all participants who gave their informed consent before participation. The study was conducted in compliance with the Declaration of Helsinki.

Pain intensity was assessed on an 11-point numerical rating scale (NRS: 0 = no pain and 10 = highest possible degree of pain). Kinesiophobia was assessed using the 11-item version of the Tampa Scale for Kinesiophobia (TSK-11) [14]. We used the two-item short-form version of the Pain Self-Efficacy Questionnaire (PSEQ-2) [15] to assess self-efficacy. To investigate the influence of kinesiophobia on lumbar movements, participants with CLBP ($n = 45$) were evenly divided into **CLBP low-fear** and **CLBP high-fear groups** based on a median split of TSK-11 scores.

Lumbar movement task

Participants were asked to conduct a lumbar movement task as follows: Participants stood upright with their natural posture and then bent forward at the start cue, which was a beep. They were asked to initiate lumbar bending as quickly as possible upon hearing the cue. They were instructed to bend their lumbar spine forward until they had reached the maximum range of lumbar motion, as if trying to reach their hands to the floor. Then, they were instructed to extend their lumbar spine backward and finally to return to an upright posture. Participants were instructed to repeatedly conduct this lumbar movement sequence as fast as possible without any discomfort. Following several practice trials, participants performed the lumbar movement task three times (Fig. 1).

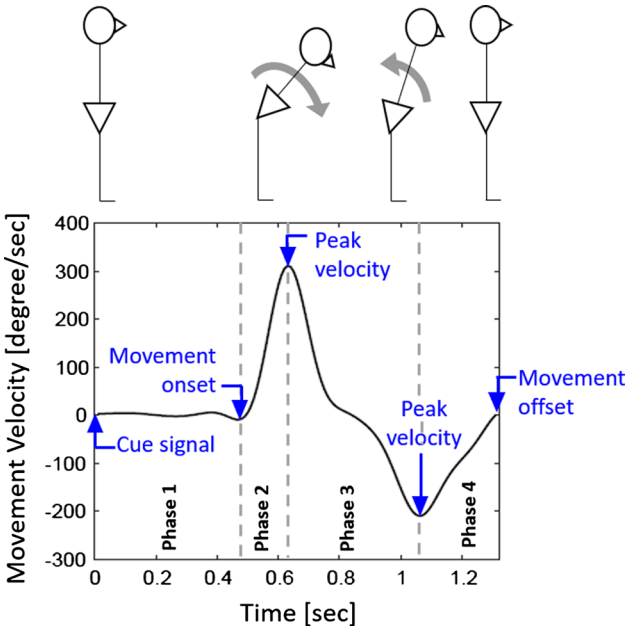

Fig. 1 Time course of the velocity of lumbar movement. Lumbar movement was divided into four phases according to the velocity data

Kinematic data collection and processing

As per a previous validation study [16], we recorded lumbar angles during the lumbar movement task using a flexible twin-axis electrogoniometer with two endblocks (SG150, Biometrics Ltd., UK). In reference to the previous study [16], the two endblocks of the electrogoniometer were, respectively, attached to the spinous processes (T12–L2) and sacral spine (S1–S3). The endblocks were connected by a composite wire with a series of strain gauges to measure lumbar angles in the sagittal plane. The electrogoniometer data were wirelessly transmitted to a receiver (Trigno™ Wireless System, DELSYS Inc., Natick, Massachusetts, USA). The motion recording system was synchronized with the start-cue beep stimulator using the LabVIEW system (National Instruments, Austin, Texas, USA) at a sampling frequency of 1000 Hz. The angular signals from the electrogoniometer were filtered using a fourth-order Butterworth low-pass filter at 6 Hz. The time series of lumbar movement was divided into the following four phases according to lumbar movement velocity (Fig. 1), and the length (sec) of each phase was calculated.

Phase 1 **Response phase**, which started with the start-cue beep and ended when the movement velocity of lumbar bending exceeded 15 °/s (i.e., movement onset).

Phase 2 **Lumbar bending phase**, which started immediately at the end of phase 1 and ended when the velocity of lumbar bending reached the peak value.

Phase 3 **Switching movement direction phase**, which started at the peak velocity of lumbar bending and ended when the lumbar extension velocity reached the peak value.

Phase 4 **Lumbar extension phase**, which started at the peak velocity of lumbar extension and ended when the participant had resumed an upright posture.

In addition to the time data for each phase, we extracted the maximum range of motion (ROM) for lumbar bending [°] and the peak velocity of lumbar bending/extension [°/s]. For these kinematic data (i.e., maximum lumbar ROM, peak velocity of lumbar bending/extension, length of each phase), we used the average value from the three trials for subsequent statistical processing.

Statistical analysis

We compared age, LBP duration, pain intensity, PSEQ-2 score, and TSK-11 score among the groups (**HC** vs. **CLBP low-fear** vs. **CLBP high-fear**) using the Kruskal–Wallis test (significance level, $p < 0.05$) and the Mann–Whitney U test as a post hoc test for multiplicity (significance level, $p < 0.017$). We compared the cause of CLBP in the CLBP low-fear versus CLBP high-fear groups using a Chi-squared test. Kinematic data such as the maximum ROM of lumbar bending, peak velocity of lumbar bending/extension in the lumbar movement task, and length of each movement phase were also compared among groups using the Kruskal–Wallis test (significance level, $p < 0.05$) and the Mann–Whitney U test as a post hoc test for multiplicity (significance level, $p < 0.017$). This dichotomization technique is thought to be useful for reporting results to non-statistical communities [17].

Additionally, we divided the TSK-11 score into subordinate items such as "TSK somatic focus" and "TSK activity avoidance" in reference to a previous study [18]. We used Spearman's correlation test to investigate the relationships between total TSK-11 item scores or subordinate item scores and the kinematic data for all participants (significance level, $p < 0.05$). We used correlation coefficients to indicate the strength and direction of the relationship between kinesiophobia and the kinematic data [19]. We used SPSS version 17.0 (SPSS, Chicago, IL) for statistical analyses.

Results

Participant characteristics and clinical assessments

Table 1 summarizes the participant characteristics and results of the clinical assessments. Participants with CLBP were divided into CLBP low-fear ($n = 24$) and CLBP high-fear groups ($n = 21$) based on a median split of the TSK-11 score (median value = 25). The mean and standard deviation

Table 1 Participant characteristics and clinical information

	Healthy control (HC) ($n=20$)	LBP low-fear ($n=24$)	LBP high-fear ($n=21$)
Age (year)	54.3 (±12.2)	56.0 (±11.5)	56.5 (±9.5)
Duration (months)[#,¶]	0.0 (±0.0)	127.9 (±136.6)	147.9 (±140.1)
Pain NRS (0–10)[#,¶]	0.0 (±0.0)	3.9 (±2.5)	4.6 (±2.4)
TSK-11 (11–44)[#,§]	21.0 (±4.1)	22.5 (±2.3)	27.7 (±2.4)
PSEQ-2 (0–12)	8.2 (±3.1)	8.1 (±2.2)	7.9 (±2.0)
Cause of LBP (*n*)			
Lumbar disk herniation	0	4	5
Lumbar spondylolisthesis	0	2	4
Lumbar osteoarthritis	0	2	2
Nonspecific	0	16	10

NRS numerical rating scale, *TSK-11* Tampa Scale for Kinesiophobia-11, *PSEQ-2* Pain Self-Efficacy Questionnaire-2

[§]Significant difference between LBP high TSK and LBP low TSK group ($p<0.001$)

[#]Significant difference between LBP high TSK and healthy control group ($p<0.001$)

[¶]Significant difference between LBP low TSK and healthy control group ($p<0.001$)

values of TSK-11 scores were 22.5 ± 2.3 and 27.7 ± 2.4 for the low- and high-fear groups, respectively. Based on previous reports in which the mean TSK-11 scores of CLBP patients were 23–25 [20–23], we labeled the two groups "high fear" and "low fear." We found no significant differences in the cause of LBP between the CLBP high- and low-fear groups ($p>0.05$).

We conducted the Kruskal–Wallis test for data from the three groups (HC, CLBP low-fear, CLBP high-fear group) and found significant main effects of total TSK-11 score ($K=37.71$, $p<0.001$), pain intensity (NRS: $K=42.86$, $p<0.001$), and duration ($K=42.46$, $p<0.001$), but no main effects of age ($K=1.29$, $p=0.52$) or PSEQ-2 data ($K=0.47$, $p=0.79$). A post hoc test showed that TSK-11 scores in the CLBP high-fear group were significantly higher than those in the CLBP low-fear ($U<0.001$, $p<0.001$) and HC groups ($U=29.0$, $p<0.001$). We found no significant differences in TSK-11 scores between the CLBP low-fear and HC groups ($U=179.5$, $p=0.15$). The pain intensity and duration in the CLBP high-fear group were higher than those in the HC group (NRS: $U<0.001$, $p<0.001$, duration: $U<0.001$, $p<0.001$), and those in the CLBP low-fear group were higher than those in the HC group (NRS: $U<0.001$, $p<0.001$, duration: $U<0.001$, $p<0.001$). We found no differences in pain intensity and duration between the CLBP high-fear and low-fear groups (NRS: $U=213.0$, $p=0.37$, duration: $U=235.0$, $p=0.69$).

Maximum lumbar range of motion and velocity data during lumbar bending and extension movement

The Kruskal–Wallis test revealed that there were no significant main effects among the three groups in terms of the maximum ROM during lumbar bending ($K=0.45$, $p=0.79$: HC: mean 44.7 ± 11.1 SD, CLBP low-fear 44.3 ± 17.6, CLBP high-fear 46.0 ± 11.9). There were also no significant main effects of peak velocity among the groups during lumbar bending ($K=1.33$, $p=0.51$: HC 323.7 ± 162.1, CLBP low-fear 311.4 ± 155.7, CLBP high-fear 342.9 ± 124.3) or extension ($K=3.64$, $p=0.16$: HC −281.3 ± 135.5, CLBP low-fear −256.1 ± 131.5, CLBP high-fear −297.5 ± 98.8). Post hoc tests did not find any significant differences among the groups ($p>0.017$).

Time data in each phase during the lumbar movement task

Figure 2 shows the time data for each divided phase during the lumbar movement task. Among the three groups, the Kruskal–Wallis test revealed significant main effects of the durations of phase 1 ($K=9.13$, $p=0.01$) and phase 3 ($K=7.11$, $p=0.02$). The time data of phase 2 ($K=3.96$, $p=0.13$) and phase 4 ($K=0.23$, $p=0.89$) were comparable. Post hoc tests revealed that the duration of phase 1 in the CLBP high-fear group was longer than that in other groups (CLBP low-fear: $U=141.0$, $p=0.006$; HC: $U=108.5$, $p=0.004$). The duration of phase 3 in the CLBP high-fear group was significantly longer than that in the HC group ($U=122.0$, $p=0.011$) and CLBP low-fear group ($U=156.0$, $p=0.014$).

When the data for all participant groups were combined, the durations of phase 1 and phase 3 were significantly correlated with the TSK total score ($p<0.05$) and TSK avoidance of activity subscore ($p<0.05$), but not with the TSK somatic focus subscore ($p>0.05$). The results of these correlation analyses are shown in Fig. 3.

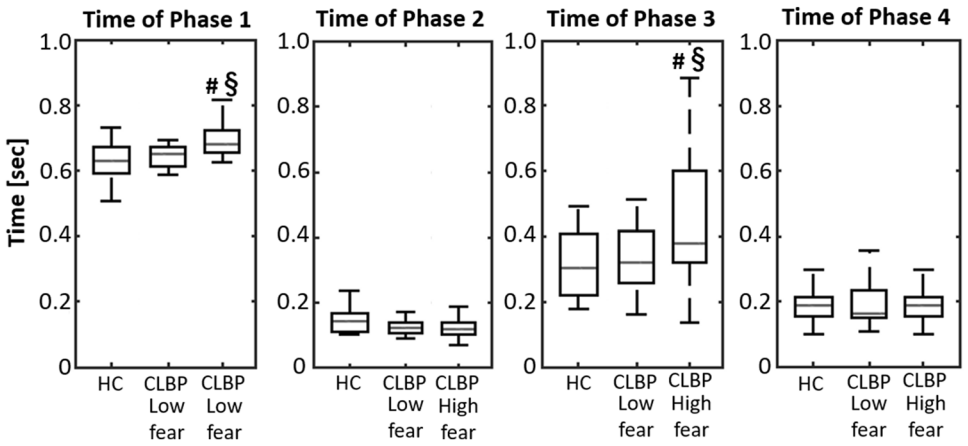

Fig. 2 Comparison of phase duration among groups.[#]Significant difference between CLBP high-fear and HC group ($p < 0.017$). [§]Significant difference between CLBP high-fear and CLBP low-fear groups ($p < 0.017$)

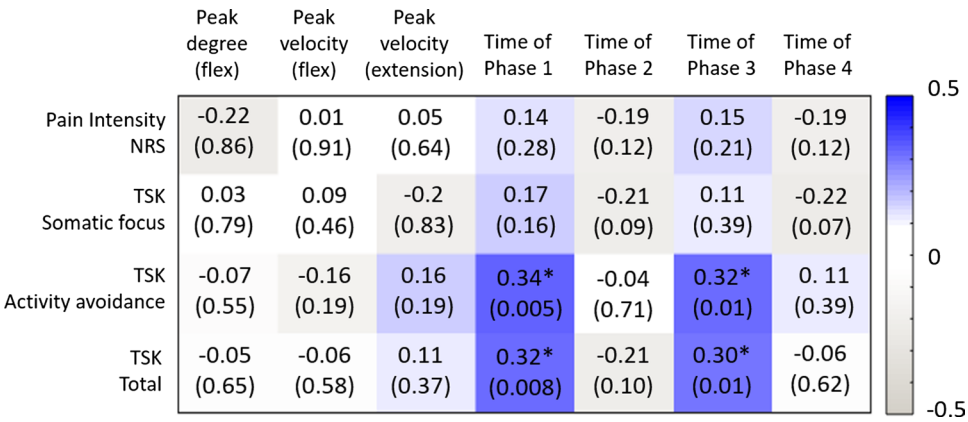

Fig. 3 Correlation between kinematic data, kinesiophobia, and pain intensity. The r values denote the effect size of the correlation, and p values indicate significance. *Significant correlation ($p < 0.05$)

Discussion

We compared kinematic data collected during a lumbar movement task among participants in CLBP low-fear and high-fear groups, as well as healthy controls. We found no group differences in the maximum ROM during lumbar bending or peak velocities during lumbar bending and extension, for which kinematic outputs simply reflect lumbar motor function. These results were inconsistent with previous studies [24] that found significantly impaired lumbar ROM and velocity in CLBP patients at medical facilities. One possible reason for this inconsistency may be differences in the instructions given to participants. In a previous study [24], participants with CLBP were instructed to bend their lumbar spine at a "comfortable" speed. Conversely, in the present study, participants were instructed to bend their lumbar spine as fast as possible. Thus, our instructions might have fulfilled the forced movement function of individuals with CLBP, such that there were no differences in the maximum ROM and peak velocities during lumbar bending. Alternatively, the practice trials completed before the lumbar movement task may have influenced the data. Particularly, the practice might have stretched stiff lumbar muscles resulting in increased ROM and velocities in participants with CLBP. Here, we found that the lengths of phase 1 and 3 were significantly longer in the CLBP high-fear group compared with the other two groups. That is, the lengths of phase 1 and 3 were significantly and positively correlated with the TSK avoidance of activity subscore, suggesting that the time data in phases 1 and 3 for the CLBP high-fear group were affected by kinesiophobia, and particularly by avoidance beliefs.

From the standpoint of protection of the lumbar structure, mechanical load in the lumbar spine reaches a maximum point during phase 3 when lumbar movement switches direction from forward to backward motion [25]. Therefore, the strategy of switching the direction of lumbar movement at a slower speed is likely to reduce mechanical load in the lumbar spine [26]. Apart from mechanical load in the lumbar spine, the extent time of lumbar movement switching was identified as a form of excessive protective behavior in individuals with movement-related pain and subsequent kinesiophobia. Further, unlike in phase 3, participants had just begun to initiate lumbar movements during phase 1 in the present study. Hence, there was not likely to be an increase in mechanical load in the lumbar

spine because no lumbar movements had been initiated. Like the excessive protective behavior observed in phase 3, pain-related fear can lead to hesitation at movement onset [27]. Fear of movement can affect central processing from motor programming to motor outputs, as reflected in movement hesitation at movement onset [28]. Considering that we found no differences in the causes of low back pain between the high- and low-fear participants with CLBP, our present kinematic findings suggest that our participants were affected by kinesiophobia rather than lumbar structural problems. The longer phase 1 and 3 durations could be, respectively, interpreted as "initial hesitation" and "freezing-like behavior," both of which indicate excessive protection of the lumbar structure and/or a pain experience [29, 30].

We detected a particular movement pattern in individuals with CLBP who experienced fear regarding lumbar movements. That is, when either initiating or switching lumbar movements, individuals with CLBP may hesitate or freeze on the basis of their fear avoidance belief. In clinical practice, kinesiophobia has been usually estimated using the Tampa Scale for Kinesiophobia (TSK). However, such self-reported questionnaires often do not represent direct measurements because psychological factors, such as kinesiophobia, depression, and anxiety, are influenced reciprocally. The present kinematic analysis could quantify not only the degree of disability associated with CLBP but also the influence of kinesiophobia in individuals with lumbar movement disorder. Particularly, a focus on straightforward excessive protective behavior (i.e., hesitating and freezing lumbar movements) might help clinicians to detect lumbar movement disorder associated with kinesiophobia.

Limitations

We did not obtain X-rays, CT scans, MRIs, or bone scans in the present analysis. Future studies may benefit from the inclusion of a greater amount of demographic and medical information that may relate to impaired lumbar movements. Finally, the present study did not have a sufficient sample size to fully examine the relationship between psychosocial factors and kinematic data. Thus, future studies should include larger sample sizes.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare.

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Affiliations

Michihiro Osumi[1] · Masahiko Sumitani[2] · Yuko Otake[2] · Tomohiko Nishigami[3] · Akira Mibu[3] · Yuki Nishi[1] · Ryota Imai[1] · Gosuke Sato[1] · Yusuke Nagakura[1] · Shu Morioka[1]

✉ Michihiro Osumi
m.ohsumi@kio.ac.jp

[1] Graduate School of Health Science, Kio University, 4-2-2 Umaminaka, Koryo-cho, Kitakatsuragi-gun, Nara 635-0832, Japan

[2] Department of Pain and Palliative Medicine, The University of Tokyo Hospital, Tokyo, Japan

[3] Department of Nursing and Physical Therapy, Konan Woman's University, Kobe, Hyogo, Japan