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Postural stability, spinal alignment, mobility, and postural competency in women with unilateral lower extremity lymphedema after radical hysterectomy following gynecologic cancer: A case-control study

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ABSTRACT

Purpose: To compare postural stability, spinal alignment, mobility, and postural competency in women with unilateral lower extremity lymphedema after radical hysterectomy following gynecologic cancer with a matched control group.
Methods: Twenty-seven women with unilateral lower extremity lymphedema (lymphedema group, age: 54.14 ± 5.80 years) and 30 healthy women (control group, age: 51.90 ± 6.54 years) were included. The lymphedema severity was evaluated with circumferential measurements. Postural stability with the Biodex Balance System SD and the spinal alignment, mobility, and postural competency with the Spinal Mouse device were assessed.
Results: In the lymphedema group, it was found that 3.7% of the women had mild lymphedema, 7.4% had moderate lymphedema, and 88.9% had severe lymphedema. Static eyes open (EO) (overall, medio-lateral and antero-posterior) and eyes closed (EC) (antero-posterior) stability scores and dynamic EO and EC stability scores (overall and antero-posterior) were detected to be higher in the lymphedema group than in the controls ($p < 0.05$). Spinal mobility and postural competency scores were lower in the lymphedema group than in the control group ($p < 0.05$). In other parameters, there were no significant differences between the groups ($p > 0.05$).
Conclusion: Decreased postural stability, spinal mobility, and postural competency were detected in women with unilateral lower extremity lymphedema; however, no difference was seen in spinal alignment. These changes should be taken into account in the assessment and the treatment of unilateral lower extremity lymphedema.

1. Introduction

Lymphedema is a progressive and chronic condition that occurs with the accumulation of protein-rich fluid in interstitial tissue spaces due to lymph flow disruption or insufficiency (Kerchner et al., 2008). It can be primary resulting from congenital abnormalities of the lymphatic system or secondary due to injury or dysfunction of the lymphatic system. Lower extremity lymphedema in cancer patients can occur after lymph node resection with surgery or damage of the lymphatic system by radiotherapy (International Society of Lymphology, 2016). It is usually estimated that 20–30% of patients with gynecologic cancer (i.e. cancers affecting the ovaries, uterus, cervix, vulva and vagina) will experience lower extremity lymphedema (van Akkooi et al., 2007).

The most frequent symptoms of lymphedema are asymmetrical swelling, feelings of heaviness, skin changes, altered sensation, and decreased joint range of motion (Cardone et al., 2018; Kerchner et al., 2008). If the condition becomes chronic, muscle weakness and musculoskeletal pain can appear in these patients. Moreover, these symptoms related to lower extremity lymphedema might affect balance and postural stability, spinal alignment and mobility, ability to maintain posture, and daily activity. Physical, psychological, and social well-being, and quality of life may be interrupted (Kim et al., 2015).

Postural stability is the ability to maintain and change the position of the body in space (Woollacott and Shumway-Cook, 2002). Postural

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stability is necessary both to maintain a static position and to assist the body coordination against dynamic position changes. It is related to the central nervous system, proprioceptive system, vestibular system, visual system, musculoskeletal system, and cognitive functions. Lower extremity lymphedema comprises asymmetric weight distribution, altered sensation, and musculoskeletal impairments, which may change postural stability. Although it is stated that postural stability is adversely affected in patients with upper extremity lymphedema (Angin et al., 2014; Altas; Demirdal, 2021; Basar et al., 2012), there are limited studies related to this issue in patients with lower extremity lymphedema, and these studies mainly focus on static postural stability (Doruk Analan and Kaya, 2019; Pehlivan et al., 2022). Postural stability needs a detailed investigation in lower extremity lymphedema in static and dynamic conditions with and without visual inputs.

In addition to the postural stability, spinal alignment, mobility, and postural competency may be important conditions in lower extremity lymphedema. Symptoms occurring with unilateral lower extremity lymphedema may disrupt the load distribution and cause the development of various compensatory mechanisms and affect the spinal structures. Spinal alignment was investigated in patients with upper extremity lymphedema, and it was stated that spinal posture was adversely affected in these patients (Celenay et al., 2020). To the best of knowledge, no study has ever analyzed the changes in spinal alignment, mobility, and postural competency in unilateral lower extremity lymphedema.

Therefore, the current study aimed to compare postural stability, spinal alignment, mobility, and postural competency in women with unilateral lower extremity lymphedema after radical hysterectomy following gynecologic cancer with a matched control group.

2. Methods

2.1. Study design and participants

This study was planned as a case-control study design. It was approved by the ethics committee of Ankara Yildirim Beyazit University (Approval number: 2022-712-03). The Declaration of Helsinki was considered in the study. The study began in April 2022 and ended in February 2023.

Volunteer women with unilateral lower extremity lymphedema who had undergone radical hysterectomy following gynecologic cancer, aged between 18 and 65 years, were included in the lymphedema group. In addition, patients who completed 1 year after surgery were included in the lymphedema group. The patients in the lymphedema group were recruited from the physical therapy and rehabilitation outpatient clinic in Kirsehir Ahi Evran Training and Research Hospital. For the control group, volunteer women without a history of lymphedema or any known diseases, aged between 18 and 65 years, were included. Healthy controls were recruited from the relatives of the patients. Previous spine and abdominal surgery, spinal pain or deformity (scoliosis etc.), osteoporosis, any physical disability that may prevent walking performance, orthopedic problems related to the lower extremities (lower extremity shortness, deformity etc.), neurological and/or rheumatologic diseases, vestibular disorders, morbid obesity, bilateral lower extremity lymphedema, and active cancer treatment were excluded from the study. Written consent forms were obtained.

2.2. Assessments

Physical characteristics and education status were collected. The type of surgery related to cancer history, the treatment process, affected side related to lymphedema, and lymphedema location and duration of all patients were questioned. All assessments were conducted via face-to-face interviews with the same physiotherapists.

The lymphedema-related symptom severity (pain, paresthesia, fatigue and heaviness) was assessed using the Visual Analog Scale (VAS), a 10-cm line. According to this scale, 0 means “no symptom”, and 10 means “the most severe symptom”. Participants were wanted to mark along the line at the intensity of their pain, paresthesia, fatigue, and heaviness symptoms (Tsai et al., 2009). The lymphedema severity was assessed with the circumference measurement during the supine position. The measurement was made bilaterally at 5 cm intervals between the ankle medial malleolus and the proximal thigh. Then, the extremities’ volume was calculated with Frustum Formula using these circumference measurements (Kaulesar et al., 1993). The lymphedema severity was classified according to the volume difference between the two extremities as follows: Mild (<250 ml), moderate (250–500 ml), and severe lymphedema (>500 ml).

Postural stability was evaluated with the Biodex Balance System SD (Biodex Medical Systems, Inc., Shirley, NY, USA) while the eyes were in open (EO) and closed (EC) (bilateral) positions to evaluate visual impacts (Celenay and Kaya, 2019) (Fig. 1). All participants completed static mode (SM) and dynamic mode (DM) on barefoot, respectively. The base was fixed for the static mode. However, the base was set ‘12-1’ for dynamic modes. In this system, the base becomes more unstable while the number decreases. Measurements were repeated three times for each mode. After the measurement, overall stability, anterior–posterior stability, and mediolateral stability scores were recorded. For all these scores, a high value showed low stability.

Spinal alignment, mobility, and postural competency were evaluated with a Spinal Mouse® device (Idiag, Volkerswill, Switzerland), a valid and reliable method (Mannion et al., 2004). First of all, the physical characteristics of all participants were recorded on a computer. The spinal processes of the vertebra from cervical 7 (C7) to sacral 3 (S3) were

Fig. 1. Evaluation of postural stability with the Biodex Balance System SD.

marked and the device was slid along the spine from top to the bottom. The measurements were performed in an upright position for spinal posture and inclination; maximum forward flexion position for spine mobility; and raising her stretched-out arms to shoulder height with weights, designed according to the body weight, in each hand for postural competency (Fig. 2). The spinal posture, mobility, and postural competency scores, as well thoracic, lumbar, and sacral angle, and overall spinal inclination values were calculated with a software program. Moreover, the spinal posture, mobility, and postural competency scores were ranged between 0 (fair) and 100 (excellent).

2.3. Sample size and statistical analysis

The G*Power (Ver. 3.0.10) package program was used for sample size calculation (Faul et al., 2007). First of all, a pilot study was conducted with 10 women with lymphedema and 10 women without lymphedema. The effect size was calculated as 0.920 according to the dynamic eyes-open overall scores of the pilot study. It was calculated that a total of 52 women, with at least 26 in each group, had to be recruited to obtain 90% power with 0.920 effect size, 0.05 type I error, 0.10 type I error.

The normal distribution of data was evaluated with Shapiro-Wilk test. Descriptive data were presented as mean ± standard deviation, median (minimum-maximum), frequency and percentage. In the comparison of numerical data in the groups, the Independent Samples *t*-test and the Mann Whitney *U* test; in the comparison of categorical data, the Fisher's exact test was used. The IBM SPSS Statistics 21.0 program was used for the analysis. '$p < 0.05$' was determined as the statistical significance level.

3. Results

Sixty-five participants were assessed for eligibility. Twenty-seven women with unilateral lower extremity lymphedema and 30 healthy controls completed the study (Fig. 3). The characteristics of the groups were shown in Table 1 ($p > 0.05$).

The lymphedema group consisted of patients with unilateral lower lymphedema after radical hysterectomy following cervical cancer. The presence of lymphedema was found to be widespread (both distal and proximal) and severe type (88.9%) in the entire lower extremity. It was determined that the left lower extremity was affected in the most of the cases (59.3%). Moreover, it was found that the most disturbing symptom among lymphedema-related symptoms was the feeling of heaviness (6.05 ± 1.50 cm). The characteristics of the lymphedema group were presented in Table 2.

In the lymphedema group, static EO [overall (1.60 (1.10–4.20)), medio-lateral (1.70 (1.00–2.80)) and antero-posterior (1.40 (1.60–3.40))] and EC [overall (1.90 (0.40–3.60)), medio-lateral (1.70 (0.30–3.10)) and antero-posterior (1.80 (0.90–3.40))] stability scores, dynamic EO [overall (4.60 (1.90–7.20)), medio-lateral (2.90 (1.00–4.80)) and antero-posterior (3.60 (1.30–5.70))] and EC [overall (6.90 (4.70–11.90)), medio-lateral (4.30 (1.90–8.00)) and antero-posterior (4.40 (3.60–9.60))] stability scores were detected. In the control group, static EO [overall (1.20 (0.40–3.20)), medio-lateral (0.85 (0.10–3.10)) and antero-posterior (0.90 (0.30–2.40))] and EC [overall (1.70 (0.80–5.70)), medio-lateral (1.05 (0.40–4.50)) and antero-

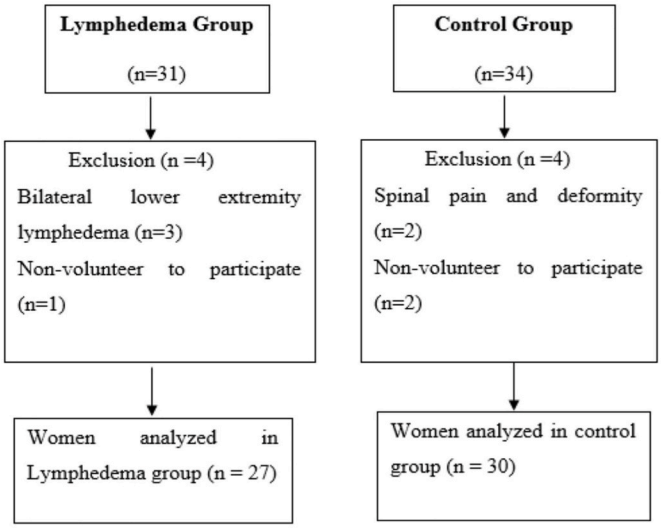

Fig. 3. Flow chart of participants.

Table 1
Comparison of the characteristics of the groups.

	Lymphedema group (n = 27)	Control group (n = 30)	p
Age (year, X±SD)	54.14 ± 5.80	51.90 ± 6.54	0.122[a]
Height (cm, X±SD)	160.85 ± 3.18	161.20 ± 4.42	0.737[a]
Weight (kg, X±SD)	73.81 ± 5.20	72.58 ± 9.38	0.538[a]
BMI (kg/m^2, X±SD)	28.54 ± 2.04	27.95 ± 3.48	0.450[a]
Education status (year, median (min-max))	8 (5–16)	10 (5–18)	0.350[b]

*$p < 0.05$, X: Mean, SD: Standard deviation, min: minimum, max: maximum, cm: centimeter, m: meter, kg: kilogram.
[a] Independent Sample *t*-test.
[b] Mann Whitney *U* test, BMI: Body mass index.

Fig. 2. Evaluation of spinal alignment, mobility, and postural competency with the Spinal Mouse® device: a. upright position, b. maximum flexion position, c. standing position while carrying weights in each hand.

Table 2
Characteristics of the lymphedema group.

	Lymphedema group (n = 27)
Type of surgery, n (%)	
Radical hysterectomy	27 (100.0)
Chemotherapy, n (%)	
Yes	26 (96.3)
No	1 (3.7)
Radiotherapy, n (%)	
Yes	16 (59.3)
No	11 (40.7)
Affected lower extremity, n (%)	
Right	11 (40.7)
Left	16 (59.3)
Duration of lymphedema (year), X±SD	4.40 ± 2.22
Severity of lymphedema, n (%)	
Mild	1 (3.7)
Moderate	2 (7.4)
Severe	24 (88.9)
Location of lymphedema, n (%)	
Overall extremity (proximal and distal)	27 (100.0)
Severity of the lymphedema-related symptoms	
Pain (VAS, cm), median (min-max)	1 (0–6.5)
Paresthesia, (VAS, cm), X±SD	3.09 ± 1.20
Fatigue, (VAS, cm), X±SD	5.85 ± 1.45
Heaviness (VAS, cm), X±SD	6.05 ± 1.50

VAS: Visual Analog Scale.

posterior (1.10 (0.30–5.50))] stability scores, dynamic EO [overall (3.45 (1.80–6.40)), medio-lateral (2.20 (1.00–5.20)) and antero-posterior (2.30 (1.30–5.70))] and EC [overall (4.40 (3.10–9.20)), medio-lateral (3.40 (1.50–8.20)) and antero-posterior (3.10 (1.30–7.30))] stability scores were also found. When the postural stability scores of the groups were examined; static EO (overall, medio-lateral and antero-posterior) and EC (antero-posterior) stability scores, dynamic EO (overal and antero-posterior) and EC (overall and antero-posterior) stability scores were detected to be higher in the lymphedema group than in the control group ($p < 0.05$, Table 3). There was no significant difference in the stability scores of static EC (overall, medio-lateral), dynamic EO (medio-lateral) and EC (medio-lateral) between the groups ($p > 0.05$, Table 3).

In the lymphedema group, thoracic, lumbar, sacral, and inclination angles, posture, mobility, and postural competency scores were calculated as 43.40 ± 7.88 degree, 20.88 ± 7.72 degree, 8.00 (2.00–27.00) degree, 4.00 (2.00–16.00) degree, 22.00 (2.00–58.00), 15.07 ± 9.13 and 10.00 (2.00–37.00), respectively. In the control group, thoracic, lumbar, sacral, and inclination angles, posture, mobility, and postural competency scores were seen as 40.70 ± 11.95 degree, 20.13 ± 8.16 degree, 7.00 (2.00–23.00) degree, 4.00 (0–14.00) degree, 25.00 (2.00–57.00), 21.93 ± 10.83 and 16.50 (2.00–57.00), respectively. When the scores of the groups related to the spinal alignment, mobility, and postural competency were examined; it was found that the control group had higher mobility and postural competency scores compared to the lymphedema group ($p < 0.05$, Table 3). However, there were no significant differences in posture score, thoracic, lumbar, sacral and inclination angles between the groups ($p > 0.05$, Table 3).

4. Discussion

This study showed that women with unilateral lower extremity lymphedema after radical hysterectomy following gynecologic cancer had lower postural stability, spinal mobility, and postural competency in comparison to controls. However, no difference was observed in spinal alignment between women with and without unilateral lower extremity lymphedema.

Postural stability plays an important role in the performance of daily activities and locomotor system function. Many factors such as impairments in the sensory-motor system and weight asymmetry such as amputation or unilateral volume change in the body may play a certain role in the degradation of postural stability (Doruk Analan and Kaya, 2019; Greitemann et al., 1996; Ruhe et al., 2011). Ku et al. reported that weight distribution might be associated with an increase in postural sway (Ku et al., 2012). The disturbances in postural stability indicate impaired balance, and increased falling and musculoskeletal injury (Merlo et al., 2012). Identifying conditions that may adversely affect postural stability, may reduce the risk of fall and injury. Therefore, the investigation of postural stability in lower extremity lymphedema, associated with the functional, cosmetic, and emotional problems, is important. Doruk and Kaya examined the static postural stability of patients with lower extremity lymphedema and healthy individuals with the Tetrax Interactive Balance System. They found that the postural stability scores increased and fall risk did not change in the lymphedema group (69.44% of patients had mild lymphedema) compared with the healthy group (Doruk Analan and Kaya, 2019). Pehlivan et al. also investigated the static balance of patients with lower extremity lymphedema and healthy individuals with one leg balance test. They reported that static balance was lower in these patients than in healthy individuals. Furthermore, in this study of Pehlivan et al., it was reported that patients had mild (22.5%), moderate (22.5%), and severe lymphedema (55.0%) (Pehlivan et al., 2022). In our study, women with unilateral lower extremity lymphedema, 88.9% of whom had severe

Table 3
Comparison of postural stability, spinal alignment, mobility, and postural competency of the groups.

	Lymphedema group Median (min-max) X±SD (n = 27)	Control group Median (min-max) X±SD (n = 30)	p
Postural stability scores			
Static overall stability _EO	1.60 (1.10–4.20)	1.20 (0.40–3.20)	0.008[a]*
Static medio-lateral stability_ EO	1.70 (1.00–2.80)	0.85 (0.10–3.10)	<0.001[a]*
Static antero-posterior stability_EO	1.40 (0.60–3.40)	0.90 (0.30–2.40)	<0.001[a]*
Static overall stability _EC	1.90 (0.40–3.60)	1.70 (0.80–5.70)	0.730[a]
Static medio-lateral stability_ EC	1.70 (0.30–3.10)	1.05 (0.40–4.50)	0.247[a]
Static antero-posterior stability_EC	1.80 (0.90–3.40)	1.10 (0.30–5.50)	0.001[a]*
Dynamic overall stability_ EO	4.60 (1.90–7.20)	3.45 (1.80–6.40)	0.049[a]*
Dynamic medio-lateral stability_ EO	2.90 (1.00–4.80)	2.20 (1.00–5.20)	0.239[a]
Dynamic antero-posterior stability_ EO	3.60 (1.30–5.70)	2.30 (1.30–5.70)	0.023[a]*
Dynamic overall stability_ EC	6.90 (4.70–11.90)	4.70 (3.10–9.20)	0.001[a]*
Dynamic medio-lateral stability_ EC	4.30 (1.90–8.00)	3.40 (1.50–8.20)	0.148[a]
Dynamic antero-posterior stability_ EC	4.40 (3.60–9.60)	3.10 (1.30–7.30)	0.001[a]*
Spinal alignment, mobility and postural competency			
Thoracic angle (degree)	43.40 ± 7.88	40.70 ± 11.95	0.323[b]
Lumbar angle (degree)	20.88 ± 7.72	20.13 ± 8.16	0.722[b]
Sacral angle (degree)	8.00 (2.00–27.00)	7.00 (2.00–23.00)	0.248[a]
Inclination angle (degree)	4.00 (2.00–16.00)	4.00 (0–14.00)	0.284[a]
Posture score	22.00 (2.00–58.00)	25.00 (2.00–57.00)	0.554[a]
Mobility score	15.07 ± 9.13	21.93 ± 10.83	0.013[b]*
Postural competency score	10.00 (2.00–37.00)	16.50 (2.00–57.00)	0.030[a]*

*$p < 0.05$, a: Mann Whitney *U* test, b: Independent Sample *t*-test, EO: eyes open, EC: eyes closed.

lymphedema, had a lower static and dynamic postural stability compared with healthy women. These findings may be due to lymphedema severity and its accompanying problems (Cardone et al., 2018; Kerchner et al., 2008; Kim et al., 2015). According to these results, weight distribution changes and balance disorders should be considered for the rehabilitation processes in patients with lower extremity lymphedema.

The asymmetric weight distribution and symptoms related to unilateral lower extremity lymphedema may load extra stress on the body, especially on the spine. To the best of our knowledge, this study is the first to investigate the spine alignment, mobility, and postural competency in unilateral lower extremity lymphedema. It was found that no difference was observed for spinal alignment in the sagittal plane (in thoracic, lumbar, sacral, inclination) between women with and without unilateral lower extremity lymphedema. However, Celenay et al. reported that thoracic kyphosis and frontal inclination angle were negatively affected in women with unilateral upper extremity lymphedema (Celenay et al., 2020). Surmeli et al. explained that spinal posture was more affected due to upper extremity lymphedema the following breast cancer surgery (Surmeli and Cinar Ozdemir, 2022). Surgical excision of breast tissue, especially due to breast cancer, and asymmetric upper extremity lymphedema may have changed biomechanical structures and affected spinal alignment. According to these studies, it can be thought that upper extremity lymphedema may affect spinal alignment more than lower extremity lymphedema. Further research in detail on lower extremity lymphedema and spine posture is needed.

In contrast to postural alignment, spinal mobility and postural competency were found to be decreased in the lymphedema group. Physical inactivity and sedentary behavior might be the reasons that might lead to adaptive changes in tissue stiffness or osseous restriction (Wisdom et al., 2015). Physical inactivity alters the muscle fiber composition and decreases muscular endurance (Ng et al., 1998). We did not questioned the level of physical activity of these patients. However, in the literature, it was reported that physical performance decreased by about 30% in individuals with lower extremity lymphedema (Katz et al., 2010). The decrease in physical performance of these patients is related to the decrease in physical activity and walking, and deterioration in the clinical course of lymphedema (Brown et al., 2014). Spinal functions should be taken into account as much as physical functions in patients with unilateral lower extremity lymphedema. Early identification of these patients may be necessary to commence rehabilitation.

There were some limitations in the study. Firstly, we did not compare postural stability, spinal alignment, mobility, and postural competency of patients according to their lymphedema severity. In our study, it was observed severe lymphedema in overall extremity in most cases. However, there were a few mild or moderate lymphedemas. We did not exclude them. Secondly, the severity of the lymphedema-related symptoms (pain, etc.), the lymphedema duration, and the treatments such as radiotherapy or chemotherapy might affect the results. Further studies may focus on these conditions and relationships. Lastly, the results should not be generalized because the study was conducted in a single center. Multicenter studies are needed in the future.

5. Conclusion

In this study, decreased postural stability, spinal mobility, and postural competency were detected in women with unilateral lower extremity lymphedema after radical hysterectomy following gynecologic cancer; however, no difference was observed for spinal alignment. The changes of postural stability, spinal mobility, and postural competency should be taken into account in the assessment of patients with unilateral lower extremity lymphedema. Moreover, in these patients, balance and spine rehabilitation should also be given importance in addition to edema treatment.

CRediT authorship contribution statement

Seyda Toprak Celenay: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Esra Bayramoglu Demirdogen:** Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Funding acquisition. **Ozge Barut:** Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Funding acquisition. **Basak Cigdem Karacay:** Resources, Writing – review & editing, Supervision, Funding acquisition. **Derya Ozer Kaya:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Altas, E.U., Demirdal, U.S., 2021. The effects of post-mastectomy lymphedema on balance, Kinesiophobia and fear of falling. J. Community Health Nurs. 38 (2), 130–138.
Angin, S., Karadibak, D., Yavuzşen, T., Demirbuken, I., 2014. Unilateral upper extremity lymphedema deteriorates the postural stability in breast cancer survivors. Contemp. Oncol. 18 (4), 279–284.
Basar, S., Bakar, Y., Keser, I., Kaba, H., Guzel, N.A., Ozdemir, O.C., et al., 2012. Does lymphedema affect the postural stability in women after breast cancer? Top. Geriatr. Rehabil. 28, 287–294.
Brown, J.C., Lin, L.L., Segal, S., 2014. Physical activity, daily walking, and lower limb lymphedema associate with physical function among uterine cancer survivors. Support. Care Cancer 22 (11), 3017–3025.
Cardone, M., Cappellino, F., Vincenzo, S., Moneta, G., Failla, A., Losa, M., et al., 2018. Proprioception sense in lymphedema affected upper limb. Lymphology 51 (2), 66–72.
Celenay, S.T., Kaya, D.O., 2019. Immediate effects of kinesio taping on pain and postural stability in patients with chronic low back pain. J. Bodyw. Mov. Ther. 23 (1), 206–210.
Celenay, S.T., Ucurum, S.G., Kaya, D.O., 2020. Comparison of spinal alignment and mobility in women with and without post modified radical mastectomy unilateral lymphoedema. Clin. Breast Cancer 20 (3), e295–e300.
Doruk Analan, P., Kaya, E., 2019. Postural stability in patients with lower limb lymphedema. Lymphatic Res. Biol. 17 (6), 647–650.
Faul, F., Erdfelder, E., Lang, A.G., Buchner, A., 2007. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39 (2), 175–191.
Greitemann, B., Guth, V., Baumgartner, R., 1996. Asymmetry of posture and truncal musculature following unilateral arm amputation–a clinical, electromyographic, posture analytical and photogrammetric study. Z. Orthop. Ihre Grenzgeb. 134 (6), 498–510.
International Society of Lymphology, 2016. The diagnosis and treatment of peripheral lymphedema: 2016 consensus document of the international society of Lymphology. Lymphology 49 (4), 170–184.
Katz, E., Dugan, N.L., Cohn, J.C., Chu, C., Smith, R.G., Schmitz, K.H., 2010. Weight lifting in patients with lower-extremity lymphedema secondary to cancer: a pilot and feasibility study. Arch. Phys. Med. Rehabil. 91 (7), 1070–1076.
Kaulesar Sukul, D.M., den Hoed, P.T., Johannes, J.E., van Dolder, R., Benda, E., 1993. Direct and indirect methods for the quantification of leg volume: comparison between water displacement volumetry, the disk model method and the frustum sign model method, using the correlation coefficient and the limits of agreement. J. Biomed. Eng. 15 (6), 477–480.
Kerchner, K., Fleischer, A., Yosipovitch, G., 2008. Lower extremity lymphedema. J. Am. Acad. Dermatol. 59 (2), 324–331.
Kim, S.I., Lim, M.C., Lee, J.S., Lee, Y., Park, K., Joo, J., et al., 2015. Impact of lower limb lymphedema on quality of life in gynecologic cancer survivors after pelvic lymph node dissection. Eur. J. Obstet. Gynecol. Reprod. Biol. 192, 31–36.
Ku, P.X., Abu Osman, N.A., Yusof, A., Wan Abas, W.A., 2012. Biomechanical evaluation of the relationship between postural control and body mass index. J. Biomech. 45 (9), 1638–1642.
Mannion, A.F., Knecht, K., Balaban, G., Dvorak, J., Grob, D., 2004. A new skin surface device for measuring the curvature, and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. Eur. Spine J. 13 (2), 122–136.
Merlo, A., Zemp, D., Zanda, E., Rocchi, S., Meroni, F., Tettamanti, M., et al., 2012. Postural stability and history of falls in cognitively able older adults: the canton ticino study. Gait Posture 36 (4), 662–666.

Ng, J.K., Richardson, C.A., Kippers, V., Parnianpour, M., 1998. Relationship between muscle fiber composition and functional capacity of back muscles in healthy subjects and patients with back pain. J. Orthop. Sports Phys. Ther. 27 (6), 389–402.
Pehlivan, B., Erdoganoglu, Y., Of, N.S., Tuzun, S., 2022. The relationship between kinesiophobia, physical performance and balance in lower extremity lymphedema patients. Turk J Physiother Rehabil 33 (1), 39–47.
Ruhe, A., Fejer, R., Walker, B., 2011. Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: a systematic review of the literature. Eur. Spine J. 20 (3), 358–368.
Surmeli, M., Cinar Ozdemir, O., 2022. The effect of upper limb lymphedema in posture of patients after breast cancer surgery. J. Back Musculoskelet. Rehabil. 35 (4), 829–837.
Tsai, H.J., Hung, H.C., Yang, J.L., Huang, C.S., Tsauo, J.Y., 2009. Could kinesio tape replace the bandage in decongestive lymphatic therapy for breast-cancerrelated lymphedema? A pilot study. Support. Care Cancer 17 (11), 1353–1360.
van Akkooi, A.C., Bouwhuis, M.G., van Geel, A.N., Hoedemaker, R., Verhoef, C., Grunhagen, D.J., et al., 2007. Morbidity and prognosis after therapeutic lymph node dissections for malignant melanoma. Eur. J. Surg. Oncol. 33 (1), 102–108.
Wisdom, K.M., Delp, S.L., Kuhl, E., 2015. Use it or lose it: multiscale skeletal muscle adaptation to mechanical stimuli. Biomech. Model. Mechanobiol. 14 (2), 195–215.
Woollacott, M., Shumway-Cook, A., 2002. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture 16 (1), 1–14.