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THERMAL MEDICINE – THERAPY, PREVENTION, REHABILITATION

PHYSICAL THERAPY • BIOKLIMATOLOGY • BALNEOGEOLOGY • BALNEOCHEMISTRY

- Optimisation of physical therapy in cervical spine pain syndromes
- The impact of somatosensory training with blood flow restriction training on pain and balance in subjects with patellofemoral pain syndrome
- Evaluation of the effectiveness of Buteyko breathing in the comprehensive treatment of bronchial asthma in children
- Use of the Buteyko method in the study of quality of life in asthma patients
- Bright light therapy and combined pectoralis therapy for stress and cyclic mastalgia in primary dysmenorrhea
- Effects of plyometric and Swiss ball training on core stability and dynamic balance in collegiate cricket players
- Exploratory feasibility study of the EUKINES wearable plantar-pressure system for gait analysis

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ORIGINAL ARTICLE

Optimisation of physical therapy in cervical spine pain syndromes

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ABSTRACT

Aim: The aim of the study was to evaluate the effects of physical therapy on symptoms and cervical spine mobility in patients with cervical spine pain syndromes, as well as to assess the influence of selected demographic and clinical factors on treatment outcomes.

Materials and Methods: The study was conducted at the Omega Medical Centre in 40 patients with cervical spine pain associated with degenerative disease who underwent a 2-week outpatient rehabilitation programme. Patients were divided into two groups based on symptom characteristics: Group 1 (predominantly acute pain) and Group 2 (chronic pain of mechanical origin with a pronounced muscular component).

Both groups received TENS currents, massage, and kinesiotherapy; additionally, Group 1 underwent laser therapy, while Group 2 received ultrasound therapy. Treatment outcomes were assessed based on changes in pain intensity and cervical spine mobility before and after therapy.

Results: Physical therapy significantly reduced pain intensity and improved cervical spine mobility in the study patients. Overall clinical improvement was observed after treatment, and a relationship between treatment outcomes and patient age was identified.

Conclusions: Degenerative diseases of the cervical spine constitute an important clinical and social problem. Physical therapy significantly reduces pain and improves cervical spine mobility in affected patients. Associations between treatment outcomes and patient age were observed; however, these relationships should be interpreted with caution. Physical therapy should be tailored to the patient's clinical condition. In particular, patients with paraspinal muscle contractures and neck stiffness may benefit from electrotherapy and ultrasound therapy.

KEYWORDS: cervical spine pain, physical therapy, cervical spine mobility, degenerative disease, multimodal treatment

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INTRODUCTION

Cervical pain syndromes (CPS) constitute a significant clinical and social problem [1-12] and are the second most common musculoskeletal pain condition after lumbosacral pain. Patients with CPS experience pain, upper limb numbness, tingling in the fingers, paraesthesia, and decreased grip strength. Irritation of the vertebral arteries and the nervous system may lead to headaches and dizziness, tinnitus, nystagmus, and sleep disturbances, which considerably hinder normal functioning and reduce quality of life [6-12].

Cervical pain syndromes are common in industrialised countries. It is estimated that up to 71% of the population experience at least one episode of cervical pain during their lifetime. Acute pain has an incidence of approximately 40% and is more common in women. It is also more likely to progress to a chronic phase in women; the chronic form of this disorder occurs in 9.5% of men and 13.5% of women. Recurrent pain is reported in approximately 25% of the population. The incidence of pain syndromes increases with age and stabilises after the age of 50 years. It is estimated that approximately two million adult Poles suffer from spinal pain syndromes.

Based on pain duration, CPS is divided into the acute stage, in which pain is short-term and intense and lasts 4 to 6 weeks; the subacute stage, which begins after 6 weeks and may last up to 3 months and often limits the performance of activities of daily living; and the chronic stage, which develops when appropriate treatment is not introduced and persists for more than 3 months, significantly restricting normal functioning [8-18].

The diagnostic work-up of CPS includes X-ray imaging, magnetic resonance imaging, computed tomography, and ultrasound.

Physical therapy in CPS is aimed at reducing pain, improving spinal joint mobility, and stabilising the spine. Management includes diadynamic currents, interferential currents, ultrasound therapy, laser therapy, and low-frequency variable magnetic fields. Kinesiotherapy is a very important component of physical therapy in these patients [18-25].

AIM

The aim of the study was to evaluate the effects of physical therapy on symptom severity and cervical spine mobility in patients with cervical spine pain syndromes, as well as to assess the influence of selected demographic and clinical factors on treatment outcomes.

MATERIALS AND METHODS

The study was conducted at the Omega Medical Centre in patients with cervical spine pain associated with degenerative disease who underwent outpatient treatment for a period of 2 weeks.

Due to the nature of symptoms and the clinical condition of the patients, participants were divided into two treatment groups: Group 1 included patients with predominantly acute pain, while Group 2 comprised patients with chronic pain of mechanical origin with a pronounced muscular component.

The programme in Group 1 included TENS currents, laser therapy, massage, and kinesiotherapy. The programme in Group 2 included TENS currents, ultrasound therapy, massage, and kinesiotherapy.

The study was based on a diagnostic survey. A questionnaire was used, including questions on demographic and clinical characteristics.

The following mobility parameters were measured to assess cervical spine range of motion: flexion, extension, lateral flexion to the left and right, and rotation to the left and right.

The Laitinen scale was used to assess pain severity. The modified Laitinen pain assessment questionnaire is a subjective scale used to evaluate pain severity and frequency, analgesic use, and limitations in physical activity (score: 0–4 points).

VARIABLES AND PARAMETERS

Absolute and relative outcomes, including improvement in range of motion, reduction, and relative reduction in pain severity, were treated as dependent variables. Data obtained from the survey constituted independent variables.

The study was based on objective parameters, including:

- measurement of range of motion expressed in degrees;
- pain intensity assessed using the Laitinen scale.

STUDY GROUP CHARACTERISTICS

The study included 40 patients treated for cervical spine pain associated with degenerative disease. Two physical therapy programmes were applied: 20 patients were assigned to programme 1 and 20 to programme 2.

Table 1 presents the demographic characteristics of patients in the treatment groups. There were no statistically significant differences between the groups in terms of age, sex, place of residence, education level, type of work, or professional activity. Patients presented with cervical spine pain accompanied by reduced mobility. Radiographic imaging revealed predominantly degenerative and proliferative changes in the spine.

Table 1 also presents data obtained from the patient survey. The mean BMI was 25.9 kg/m^2 in Group 1 and 25.5 kg/m^2 in Group 2. Both groups included 9 patients (45%) with normal BMI values.

Patients in Group 1 predominantly presented with brachial plexus involvement associated with degenerative spinal disease, whereas patients in Group 2 had chronic symptoms related to soft tissue dysfunction in the shoulder girdle.

Before treatment, the groups did not differ in terms of the frequency of individual ranges of motion.

STATISTICAL METHODS

Survey data concerning sociodemographic and clinical factors were analysed using descriptive statistical methods and presented as numbers and frequencies of responses.

The results for cervical spine range of motion and pain assessed with the Laitinen scale before and after therapy were presented using distribution parameters (mean, standard deviation, median, minimum, and maximum).

Treatment outcomes were expressed as improvement, defined as the difference between two subsequent assessments. Treatment efficacy was calculated according to the formula:

$$\text{Treatment efficacy (\%)} = (\text{improvement} / \text{value before treatment}) \times 100$$

Student's t-test for dependent samples was used to compare values before and after treatment. Differences between the two treatment groups were analysed using Student's t-test for independent samples.

Pearson's correlation coefficient, Student's t-test, and one-way analysis of variance (ANOVA) were used to assess the influence of selected factors on treatment outcomes in terms of range of motion and pain. The significance level was set at $p \leq 0.05$. Statistical analysis was performed using STATISTICA 13 software.

RESULTS

In Group 1, the frequency of symptoms after treatment decreased compared with the pre-treatment assessment (Table 2).

In Group 2, the frequency of symptoms after treatment also decreased compared with the pre-treatment assessment (Table 2).

The efficacy of physiotherapy programmes in terms of improvement in cervical spine range of motion

Both Group 1 and Group 2 showed statistically significant ($p < 0.001$) differences between pre- and post-treatment assessments of flexion (Table 3).

Both groups also demonstrated statistically significant ($p < 0.001$) differences in extension (Table 3), lateral flexion to the left and right, and rotation to the left and right (Table 4).

EFFICACY OF PHYSIOTHERAPY PROGRAMMES IN TERMS OF CERVICAL SPINE PAIN REDUCTION

The mean values of the Laitinen parameters, as well as the total score in Group 1, decreased significantly ($p < 0.001$) after treatment. The total Laitinen score decreased from 7.5 points before treatment to 2.2 points after treatment (Table 5).

Similarly, in Group 2, both the mean values of the Laitinen parameters and the total score decreased significantly ($p < 0.001$) after treatment, from 6.9 points to 1.9 points (Table 5).

EFFECTS OF TREATMENT PROGRAMMES ON TREATMENT OUTCOMES

There were no statistically significant differences between the treatment groups in terms of improvement or treatment efficacy for flexion or extension (Table 6).

Table 1. Demographic characteristics of patients in study groups

		Treatment 1		Treatment 2		Significance of differences
		n	%	n	%	
		M + SD Me (min-max)		M + SD Me (min-max)		
Age	**(years)**	**46.7 + 10.7 45 (32-69)**		**49.5 + 10.7 49.5 (31-68)**		**p=0.422**
Age group	up to 40 years	7	35%	4	20%	p=0.594
	41-50 years	7	35%	6	30%	
	51-60 years	3	15%	5	25%	
	Over 60 years	3	15%	5	25%	
Sex	Women	13	65%	9	45%	p=0.204
	Men	7	35%	11	55%	
Place of residence	Town/city	13	65%	7	35%	p=0.058
	Village	7	35%	13	65%	
Education	Primary	2	10%	1	5%	p=0.849
	Vocational	5	25%	6	30%	
	Secondary	1	5%	2	10%	
	Higher	12	60%	11	55%	
Type of work	Manual	8	40%	9	45%	p=0.822
	Intellectual	10	50%	10	50%	
	Farmer	2	10%	1	5%	
Professional activity	Working	17	85%	16	80%	p=0.834
	Pension/disability pension	3	15%	4	20%	
BMI	(kg/m^2)	25.9 + 3.1 26.1 (18.7-32)		25.5 + 3.7 26.1 (18.4-33.5)		p=0.109
BMI assessment	Normal BMI	9	45%	9	45%	p=1.0
	Overweight	10	50%	10	50%	
	Obesity	1	5%	1	5%	
ICD-10 diagnosis	M50	7	35%	7	35%	p=0.023
	G54	10	50%	3	15%	
	M54	3	15%	10	50%	
Disease duration	(years)	6.7 + 4.9 5 (1-17)		6.7 + 5.7 6 (1-20)		p=0.014
Disease duration time group	1-2 years	3	15%	7	35%	p=0.068
	3-5 years	10	50%	3	15%	
	6-10 years	3	15%	7	35%	
	11-20 years	4	20%	3	15%	
Frequency of physiotherapy procedures	1 time a year	10	50%	11	55%	p=0.523
	2 times a year	6	30%	6	30%	
	3 times a year	2	10%	3	15%	
	more often	2	10%	0	0%	

M – arithmetic mean; SD – standard deviation;

Me – median; min – lowest value; max – highest value

Table 2. Effects of physical therapy on symptoms in patients

Group	Symptoms	Before treatment		After treatment		Significance
		number	percentage	number	percentage	
Group 1	Headache	12	60%	4	20%	p=0.024
	Dizziness	7	35%	2	10%	p=0.064
	Arm numbness	11	55%	6	30%	p=0.110
	Shoulder numbness	9	45%	1	5%	p=0.011
	Neck numbness	13	65%	1	5%	p<0.001
	Neck pain radiating to the head	8	40%	0	0%	p=0.002
	Neck pain radiating to the scapula	7	35%	1	5%	p=0.022
Group 2	Headache	7	35%	1	5%	p=0.022
	Dizziness	6	30%	2	10%	p=0.086
	Arm numbness	12	60%	3	15%	p=0.001
	Shoulder numbness	9	45%	1	5%	p=0.011
	Neck numbness	14	70%	4	20%	p=0.004
	Neck pain radiating to the head	6	30%	2	10%	p=0.118
	Neck pain radiating to the scapula	8	40%	2	10%	p=0.029

Table 3. Range of cervical spine mobility in flexion and extension before and after physiotherapy in study groups

Range of motion	Treatment	Assessment	Mean	SD	Me	min	max	Significance
Flexion (cm)	1	before treatment	1.8	0.7	2.0	1.0	3.0	p<0.001
		after treatment	2.5	0.4	2.5	1.5	3.0	
	2	before treatment	1.8	0.7	2.0	1.0	3.0	p<0.001
		after treatment	2.4	0.5	2.5	1.5	3.0	
Extension (cm)	1	before treatment	4.9	1.6	4.8	2.0	8.0	p<0.001
		after treatment	6.7	1.1	7.0	3.5	8.0	
	2	before treatment	5.2	2.0	5.0	2.0	8.5	p<0.001
		after treatment	6.9	1.5	7.0	4.0	9.0	

No significant differences were observed between the groups for lateral flexion to the left or to the right, nor for rotation to the left or to the right (Table 6).

There were also no significant differences between the groups in treatment outcomes expressed as improvement in Laitinen parameters (Table 7) or in overall pain reduction according to the Laitinen scale (Table 8).

EFFECTS OF AGE, SYMPTOM DURATION, AND TYPE OF WORK ON TREATMENT OUTCOMES

Analysis of correlation coefficients showed a statistically significant association between age and improvement in cervical spine mobility for rotation to the left ($r = 0.3813$; $p = 0.015$) and to the right ($r = 0.3172$; $p = 0.046$). Table 9 presents the relationships between age, pain duration, and improvements in cervical spine mobility.

Table 4. Range of cervical spine mobility in lateral flexion and rotation before and after physiotherapy in study groups

Range of motion	Side	Treatment	Assessment	Mean	SD	Me	min	max	Significance
Lateral flexion (cm)	to the left	1	before treatment	3.8	1.5	3.3	2.0	6.5	p<0.001
			after treatment	5.2	0.8	5.0	4.0	6.5	
		2	before treatment	3.9	1.4	4.0	2.0	7.0	p<0.001
			after treatment	4.8	1.1	4.8	3.0	6.5	
	to the right	1	before treatment	3.3	1.4	3.0	1.0	6.5	p<0.001
			after treatment	5.1	1.0	5.0	3.0	7.0	
		2	before treatment	3.7	1.5	4.0	1.0	6.5	p<0.001
			after treatment	5.0	1.2	5.0	2.5	7.0	
Rotation (cm)	to the left	1	before treatment	5.0	2.3	4.5	2.0	8.0	p<0.001
			after treatment	6.8	1.2	7.0	4.0	8.5	
		2	before treatment	5.2	2.1	6.0	2.0	8.0	p<0.001
			after treatment	6.7	1.3	7.0	4.0	8.5	
	to the right	1	before treatment	4.8	1.9	5.0	1.5	8.0	p<0.001
			after treatment	7.1	0.8	7.0	5.0	8.5	
		2	before treatment	5.1	2.1	5.0	2.0	8.0	p<0.001
			after treatment	7.1	1.1	7.5	5.0	8.5	

Table 5. Efficacy of physiotherapy model 1 and model 2 in terms of cervical spine pain reduction

Model	Laitinen parameters	Assessment	Parameter level (Laitinen score)					Significance
			Mean	SD	Me	min	max	
Model 1	Pain severity	before treatment	2.2	0.9	2	1	4	p<0.001
		after treatment	0.5	0.5	0.5	0	1	
	Pain frequency	before treatment	2.1	1.1	2	1	4	p<0.001
		after treatment	0.7	0.5	1	0	1	
	Analgesics use	before treatment	1.5	1.0	1	0	4	p<0.001
		after treatment	0.5	0.7	0	0	2	
	Physical activity limitations	before treatment	1.9	0.9	2	1	4	p<0.001
		after treatment	0.5	0.6	0	0	2	
	Laitinen total score	before treatment	7.5	3.5	7	3	16	p<0.001
		after treatment	2.2	1.9	2	0	6	
Model 2	Pain severity	before treatment	1.8	0.8	2	0	3	p<0.001
		after treatment	0.5	0.6	0	0	2	
	Pain frequency	before treatment	2.1	1.2	2	0	4	p<0.001
		after treatment	0.6	0.5	1	0	1	
	Analgesics use	before treatment	1.3	1.2	1	0	4	p<0.001
		after treatment	0.4	0.6	0	0	2	
	Physical activity limitations	before treatment	1.8	0.8	2	1	3	p<0.001
		after treatment	0.5	0.6	0	0	2	
	Total score	before treatment	6.9	3.5	6.5	1	13	p<0.001
		after treatment	1.9	1.8	2	0	6	

Table 6. Comparison of treatment outcomes for cervical spine mobility in flexion, extension and rotation in treatment groups

Range of motion	Treatment outcome	Treatment model	Mean	SD	Me	min	max	Significance
Flexion	Improvement (cm)	1	0.7	0.6	0.5	0.0	2.0	p=0.547
		2	0.6	0.4	0.5	0.0	1.5	
	Efficacy (%)	1	54.8	58.8	37.5	0.0	200.0	p=0.560
		2	45.1	44.1	25.0	0.0	150.0	
Extension	Improvement (cm)	1	1.8	1.2	1.5	0.0	4.0	p=0.898
		2	1.7	1.3	1.8	0.0	5.0	
	Efficacy (%)	1	48.0	45.5	37.5	0.0	200.0	p=0.988
		2	48.3	57.1	29.3	0.0	250.0	
Lateral flexion to the left	Improvement (cm)	1	1.5	1.1	2.0	0	3	p=0.047
		2	0.8	0.9	1.0	-1.5	2	
	Efficacy (%)	1	54.2	48.2	50.0	0	150	p=0.071
		2	29.8	33.3	25.0	-21.4	100	
Lateral flexion to the right	Improvement (cm)	1	1.8	0.8	2.0	0.5	3	p=0.063
		2	1.3	0.8	1.3	0	2.5	
	Efficacy (%)	1	72.5	58.6	66.7	7.7	250	p=0.229
		2	51.0	52.7	35.4	0	200	
Rotation to the left	Improvement (cm)	1	1.9	1.5	2.0	0	5	p=0.511
		2	1.6	1.3	1.3	0	4	
	Efficacy (%)	1	64.1	70.0	50.0	0	250	p=0.470
		2	49.3	57.6	29.2	0	175	
Rotation to the right	Improvement (cm)	1	2.3	1.4	2.0	0	5	p=0.530
		2	2.0	1.5	2.0	0	5	
	Efficacy (%)	1	74.6	83.0	45.0	0	333	p=0.621
		2	62.5	70.1	40.8	0	250	

Table 7. Comparison of improvement in Laitinen parameters in treatment groups

Laitinen parameters	Assessment	Parameter level (Laitinen score)					Significance
		Mean	SD	Me	min	max	
Pain severity	1	1.7	0.7	1.5	1	3	p=0.165
	2	1.4	0.6	1.0	0	2	
Pain frequency	1	1.4	1.1	1.0	0	3	p=0.779
	2	1.5	1.1	1.0	0	4	
Analgesics use	1	1.0	0.7	1.0	0	2	p=0.692
	2	0.9	0.9	1.0	0	2	
Physical activity limitations	1	1.4	0.7	1.0	0	2	p=0.801
	2	1.3	0.6	1.0	0	2	

Table 8. Comparison of outcomes of pain treatment according to Laitinen scale between treatment groups

Treatment outcome	Treatment model	Mean	SD	Me	min	max	Significance
Improvement (points)	1	5.4	2.7	5.5	1	10	p=0.681
	2	5.0	2.6	5.0	1	10	
Efficacy (%)	1	71.7	23.3	69.6	20	100	p=0.526
	2	76.3	21.4	73.2	33.3	100	

Table 9. Effects of age and pain duration on improvements in ranges of cervical spine motion

Improvement in cervical spine mobility with respect to	age (years)		pain duration (years)	
	r	p	r	p
flexion (cm)	0.1521	p=0.349	0.1246	p=0.444
extension (cm)	0.0431	p=0.792	0.1119	p=0.492
lateral flexion to the left (cm)	0.1505	p=0.354	0.3536	p=0.025
lateral flexion to the right (cm)	0.1616	p=0.319	0.2541	p=0.114
rotation to the left (cm)	0.3813	p=0.015	0.5389	p<0.001
rotation to the right (cm)	0.3172	p=0.046	0.3722	p=0.018

Table 10. Effects of age and pain duration on treatment efficacy with respect to ranges of cervical spine motion

Treatment efficacy for cervical spine mobility with respect to	age (years)		symptom duration (years)	
	r	p	r	p
flexion (%)	0.2156	p=0.181	0.1417	p=0.383
extension (%)	0.1300	p=0.424	0.1567	p=0.334
lateral flexion to the left (%)	0.1453	p=0.371	0.3882	p=0.013
lateral flexion to the right (%)	0.3905	p=0.013	0.3754	p=0.017
rotation to the left (%)	0.5136	p=0.001	0.6028	p<0.001
rotation to the right (%)	0.3740	p=0.017	0.2686	p=0.094

A statistically significant relationship was also observed between age and treatment efficacy for lateral flexion to the right (r = 0.3905; p = 0.013), rotation to the left (r = 0.5136; p = 0.001), and rotation to the right (r = 0.3740; p = 0.017).

A significant positive correlation between pain duration and selected treatment outcomes was observed (Table 10). In particular, longer pain duration was associated with greater improvement in the total Laitinen score (r = 0.3744; p = 0.017) (Fig. 1).

The sex of the study patients had no significant effect on treatment outcomes in terms of pain reduction according to the Laitinen scale.

Place of residence and type of work did not significantly affect improvements in cervical spine mobility.

Treatment efficacy in terms of pain reduction according to the Laitinen scale was higher among working patients compared with non-working patients.

DISCUSSION

Cervical spine pain is one of the most common reasons for seeking medical attention. It is estimated that cervical pain affects 60–90% of the population at some point in life. Degenerative disease of the spine is one of the main causes of this condition. As a chronic disorder, it requires long-term management, and rehabilitation is aimed at delaying disease progression and alleviating its key manifestations, including pain and reduced mobility [15-24].

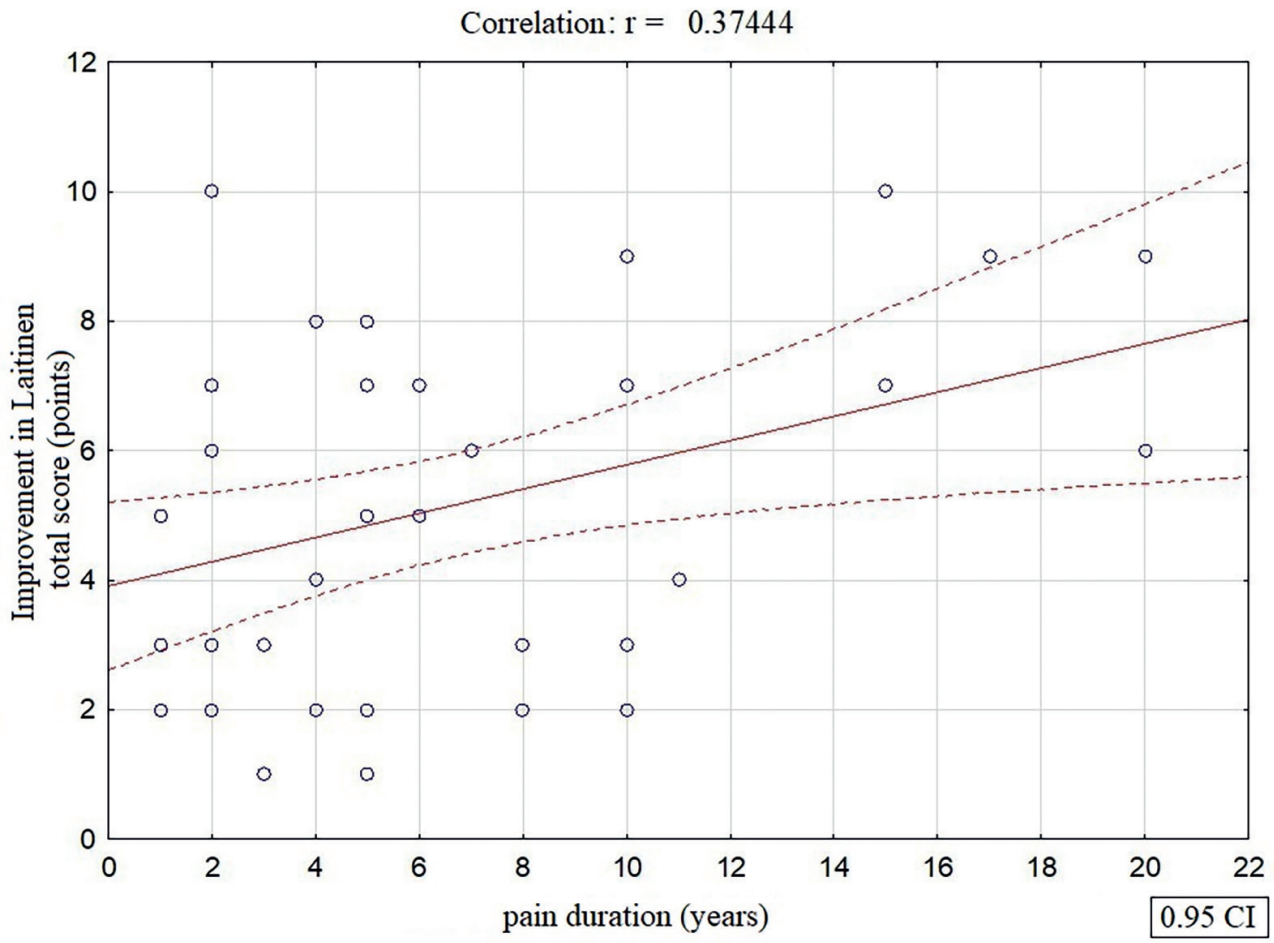

Fig.1. Effects of pain duration on improvement in overall treatment outcome according to Laitinen scale

Source: own materials

Table 11. Treatment outcomes for pain according to Laitinen scale by sex of study patients

Treatment outcome	Sex	n	Mean	SD	Me	min	max	Significance
Improvement (points)	Women	22	5.9	2.5	6.5	1	10	p=0.067
	Men	18	4.3	2.7	3.0	1		10
Efficacy (%)	Women	22	71.2	22.0	71.4	20.0	100	p=0.380
	Men	18	77.5	22.6	73.5	33.3		100

The present study analysed the effects of physical therapy and rehabilitation in patients with cervical spine pain associated with degenerative disease. Both treatment programmes proved effective in improving cervical spine range of motion. In Group 1, where symptoms were predominantly related to nerve root irritation, the applied treatment (TENS, laser therapy, massage, and kinesiotherapy) resulted in a reduction in the frequency of symptoms. Statistically significant improvements were observed for headache ($p = 0.024$), arm numbness ($p = 0.011$), neck numbness ($p < 0.001$), neck pain radiating to the head ($p = 0.002$), and neck pain radiating to the scapula ($p = 0.022$).

In Group 2, where symptoms were mainly related to mechanical factors and muscular dysfunction, treatment including TENS, ultrasound therapy, massage, and kinesiotherapy also led to a significant reduction in symptom frequency. Statistically significant differences were observed for headache ($p = 0.022$), arm numbness ($p = 0.001$), shoulder numbness ($p = 0.011$), neck numbness ($p = 0.004$), and neck pain radiating to the scapula ($p = 0.029$).

After treatment, both groups showed a marked reduction in cervical spine pain (5.3 points in Group 1 and 5 points in Group 2). Improvements were observed across all Laitinen parameters, with statistically significant reductions after treatment ($p < 0.001$). These findings are consistent with recent evidence indicating that multimodal approaches combining physical therapy modalities and exercise lead to significant reductions in pain and disability in patients with neck pain [26, 27].

The effectiveness of the applied interventions supports the use of comprehensive physical therapy in the management of cervical spine pain. In particular, patients with paraspinal muscle contractures and neck stiffness may benefit from the addition of ultrasound therapy to standard treatment. This observation is in line with studies demonstrating the beneficial effects of soft tissue-oriented interventions in patients with chronic neck pain [28].

The results also suggest that age and pain duration may influence treatment outcomes. However, these relationships were observed only for selected parameters and should be interpreted with caution. Similar observations have been reported in the literature, where the response to therapy may depend on both biological and functional factors, including neuromuscular adaptations associated with exercise-based interventions [29].

The present findings confirm that a comprehensive physical therapy approach may significantly reduce cervical spine pain and improve mobility in multiple planes [18-24].

CONCLUSIONS

Degenerative disease of the cervical spine constitutes an important clinical and social problem. Physical therapy was shown to significantly reduce pain and improve cervical spine mobility in the studied patients. Associations between treatment outcomes and patient age were observed; however, these relationships were limited to selected parameters and should be interpreted with caution.

The results indicate that physical therapy should be tailored to the patient's clinical condition. In particular, patients with paraspinal muscle contractures and neck stiffness may benefit from the inclusion of electrotherapy and ultrasound therapy as part of a comprehensive treatment approach.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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ORIGINAL ARTICLE

The impact of somatosensory training with blood flow restriction training on pain and balance in subjects with patellofemoral pain syndrome

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ABSTRACT

Aim: The aim of this study was to investigate the effects of combined somatosensory training with blood flow restriction training (BFRT) on pain intensity and balance function in individuals with patellofemoral pain syndrome (PFPS). PFPS is characterized by pain around or behind the patella, aggravated during weight-bearing activities with knee flexion, and is associated with impaired neuromuscular control and muscle weakness leading to balance deficits. Somatosensory training improves proprioceptive input, while BFRT enhances muscle strength using low loads; however, evidence on their combined effects remains limited.

Materials and Methods: A quasi-experimental study was conducted on 40 subjects with PFPS from a private institution in Kancheepuram, Tamil Nadu. Participants included both males and females with an increased Q-angle, positive Ober's test, and a Kujala scale score of 83/100. Exclusion criteria encompassed prior knee surgeries, lower limb fractures, patellar dislocation/subluxation, muscle tears, degenerative hip or ankle conditions, and systemic disease.

Results: SPSS was used to analyse and interpret all data. The intervention led to significant improvements in pain reduction and balance performance. Participants showed increased reach distances in all directions of the Y Balance Test, with reduced standard deviations, indicating enhanced stability, control, and more consistent performance. These findings highlight the intervention's effectiveness in improving both functional ability and movement reliability.

Conclusions: Combining somatosensory training with blood flow restriction (BFR) therapy significantly improved pain and balance in individuals with patellofemoral pain. This low-risk, joint-friendly approach enhances muscle strength without high-intensity stress, making it suitable for those with instability or discomfort.

KEYWORDS: patellofemoral pain syndrome, blood flow restriction training, somatosensory training, balance, anterior knee pain

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INTRODUCTION

Patellofemoral pain syndrome [PFPS], also known as runner's knee or patellar overload syndrome, is a common musculoskeletal disorder characterized predominantly by anterior knee pain. The condition typically presents initially as mild discomfort localized around or behind the patella, progressively worsening over time. Symptoms are often exacerbated by activities that impose repetitive stress on the knee joint, including squatting, stair climbing, kneeling, and transitioning from a seated to a standing position [1]. With an annual prevalence rate of approximately 22.7%, PFPS represents a significant source of knee pain and functional limitation globally [2]. The etiology of PFPS is multifactorial, involving a complex interaction between local and remote factors that affect the stability and mechanics of the patellofemoral joint. These factors encompass both static elements, such as anatomical alignment, and dynamic contributors such as muscle strength and neuromuscular coordination. The quadriceps muscle group plays a pivotal role in patellar stabilization during knee movement. In particular, the vastus medialis oblique [VMO] muscle is crucial for medial patellar tracking. Weakness or delayed activation of the VMO, coupled with strain on the medial stabilizing structures, may result in lateral patellar tilt or malalignment, thereby increasing joint stress and contributing to pain and dysfunction [3].

In addition to local knee factors, PFPS is influenced by proximal and distal biomechanical contributors. Proximally, deficits in strength or motor control of the hip, pelvis, and trunk can alter lower limb kinematics, increasing patellofemoral joint loading. For example, hip abductor and external rotator weakness can induce excessive femoral internal rotation and adduction, adversely affecting patellar tracking. Distal factors such as foot overpronation or abnormal ankle mechanics also impact tibial rotation, further disrupting patellofemoral alignment and elevating joint stress. Moreover, PFPS is associated with reduced lower limb muscle flexibility, decreased hip extension strength, and diminished knee extension strength, all of which contribute to abnormal joint loading and symptom development [4]. Beyond biomechanical influences, emerging evidence underscores the importance of somatosensory impairments in the pathogenesis and persistence of PFPS symptoms. Somatosensory function – the body's capacity to process sensory inputs including touch, proprioception, pressure, and pain – is critical for coordinated movement and joint stability. Proprioceptive deficits in PFPS patients may impair joint position sense and neuromuscular control, leading to delayed or inap-

propriate muscle activation, decreased coordination, and joint instability.

Blood flow restriction [BFR] training, also known as Kaatsu training, has gained recognition as a novel and promising therapeutic approach for managing musculoskeletal conditions such as PFPS [5]. This modality involves applying controlled external pressure to the proximal portion of a limb via a specialized occlusion cuff or device [6]. The applied pressure partially restricts arterial blood flow while completely occluding venous return, creating localized ischemia within the targeted muscles [7]. During BFR training, a pneumatic cuff is inflated around the upper arm or thigh, depending on the limb targeted. The cuff pressure is carefully titrated to achieve partial arterial occlusion without fully compromising blood supply, alongside complete venous occlusion to trap blood within the musculature. This creates a hypoxic environment in the working muscles, stimulating physiological responses such as increased muscle fibre recruitment, metabolic stress, and enhanced anabolic signalling. These mechanisms collectively promote muscle hypertrophy and strength gains despite the use of low-intensity exercises, typically 20–30% of one-repetition maximum [8].

The key advantage of BFR training lies in its capacity to elicit significant muscular adaptations without the high mechanical loads required by conventional resistance training. This makes it particularly suitable for individuals with PFPS who may be limited by pain or joint instability when performing high-load exercises. By minimizing joint stress while facilitating strength and endurance improvements around the knee, BFR training supports patellar stabilization and pain reduction. Evidence substantiates the effectiveness and safety of BFR training across diverse populations, including healthy individuals, athletes, older adults, and patients undergoing rehabilitation after injury or surgery. Notably, BFR has also been explored in specialized contexts such as spaceflight, where it helps mitigate muscle atrophy induced by microgravity [9]. Although BFRT and somatosensory training have independently shown efficacy in improving muscle function, proprioception, and pain modulation, their combined effect in individuals with PFPS remains largely unknown. Existing research frequently isolates either strengthening or proprioceptive techniques, failing to address the potential synergistic benefits of combining neuromuscular and sensory inputs during blood flow restriction. Furthermore, there is a significant lack of information on how this combined strategy affects pain reduction and balance improvement, despite these being key issues in PFPS management.

AIM

The aim of this study was to investigate the effects of combined somatosensory training with blood flow restriction training (BFRT) on pain intensity and balance function in individuals with patellofemoral pain syndrome (PFPS). Additionally, the study sought to evaluate the potential of this combined intervention as a low-load therapeutic approach for improving functional outcomes in this population.

MATERIALS AND METHODS

This quasi-experimental study examined somatosensory training with BFRT in subjects with patellofemoral pain syndrome. A total of 40 participants were selected as a convenience sample from a private medical university in Kancheepuram district, Tamil Nadu. Both genders aged 20 to 45 years were included; pain aggravated by squatting, jumping, and prolonged sitting; a Kujala scale score of 83 out of 100; individuals with an increased Q-angle and a positive Ober's test were included in this study. Participants were excluded if they had a history of knee surgery, lower limb fracture, patellar dislocation or subluxation, muscle tear, degenerative hip or ankle joint disease, or systemic disease.

Demographic details were recorded before conducting Ober's test. At baseline [pre-test] and following the 6-week treatment period [post-test], the main outcomes, NPRS and the Y Balance Test, were evaluated. Following data collection, SPSS was used to analyse and interpret all data.

The exercise regimen consisted of four sets, four days a week, for six weeks, and each participant was initially assessed for BFR pressure. Three sets of 15 repetitions were performed, with the first set consisting of 30 repetitions. During the study period, all participants were advised to continue their regular daily activities and refrain from physical therapy or other pain treatment methods, and voluntary consent was obtained from all participants.

BFR PRESSURE CALCULATION

BFR devices allow blood to pool in capacitance vessels distal to the cuff, limiting arterial inflow and preventing venous outflow. An experienced physiotherapist (BFRT provider) used a defined technique to create tailored partial vascular occlusion for use in clinical settings. Each participant was instructed to lie in a prone position and rest for 5 minutes. A broad BFR cuff measuring 10 cm in width and 116 cm in length was fastened to the participant's proximal thigh. A vascular Doppler probe was placed over the popliteal artery to record the auscultatory pulse. The cuff pressure was then increased until the pulse disappeared in order to determine the pressure (in mmHg) required for total vascular occlusion. This procedure was repeated every two weeks. Partial vascular occlusion was set at 80% of this pressure based on previous studies, and Doppler confirmation of partial arterial flow was obtained.

Side stepping: The participant was instructed to walk sideways, moving the feet apart and then bringing them back together. Afterward, they were guided to perform a partial squat with the feet together.

Lateral lunge: The participant started with a slight distance between the feet, stepped sideways, and bent the knee into a lunge position. It was important to keep the knees aligned with the toes, allowing the hips to lower. While bending the knees, the participant raised the arms forward for balance.

Standing on one leg: The participant started with a wide stance, flexed both hips and knees to 90 degrees, and held the position for 3 to 5 seconds while maintaining balance.

Standing on one leg with heel raised: The participant stood on one leg, lifted the heel off the ground, and balanced on the toes.

Posterior lunge: The participant began with feet hip-width apart, stepped back with one leg, and bent both knees while keeping the chest upright. The back knee was lowered straight toward the floor, with the thigh parallel to the ground.

Lateral step-up: The participant stepped sideways onto an elevated surface, ensuring both feet were placed on it. They then stepped back down and returned to the starting position.

Air squatting: The participant placed the feet shoulder-width apart, with toes pointing forward or slightly outward. They bent at the hips and knees, lowering the buttocks toward the floor while keeping the back straight. As they squatted, they extended the arms forward and then raised them while returning to standing, keeping the weight on the heels. It was acceptable for the hips to drop below the level of the knees, similar to sitting in a chair.

This study was approved by the institutional board: 296/07/2024/ ISRB /UGSR/SCPT.

STATISTICAL ANALYSIS

Statistical analysis was carried out using IBM SPSS Statistics for Windows (Version 22). The distribution of the data was assessed using the Shapiro–Wilk test, which indicated that the data were normally distributed. Descriptive statistics were computed for all outcome variables and are presented as mean ± standard deviation (SD) at baseline and post-intervention. For within-group comparisons, the paired t-test was applied. A p-value of less than 0.05 was considered statistically significant. Highly significant differences were reported at $p < 0.001$. All tests were two-tailed.

RESULTS

The significant reduction in Mean from pre- to post-test, as shown in Table 1, suggests more consistent NPRS scores, which evaluate pain intensity. The mean score decreased from a pre-test value of 7.84 [SD = 0.7085] to a post-test value of 5.02 [SD = 0.8106], with a t-value of 17.223 and a p-value of < 0.0001, indicating a statistically significant reduction in pain levels.

The significant improvement in SD from pre- to post-test suggests more consistent balance performance among participants following the intervention, indicating both improved balance and reduced variability in performance. In the Y Balance Test, as shown in Table 2, which assessed participants' reach capabilities in multiple directions, notable improvements were observed.

In the anterior reach direction, the pre-test mean reach distance was 31.85 cm [SD = 0.975], which improved significantly to a post-test mean of 42.17 cm [SD = 1.258]. The large increase in reach distance, with a t-value of 37.108 and a p-value of < 0.0001, suggests enhanced forward stability and control. The slight decrease in SD indicates more consistent performance across participants, reflecting improved anterior stability after the intervention.

In the posteromedial direction, one of the most substantial improvements was observed, with the pre-test mean of 29.8 cm [SD = 1.18] increasing to 36.52 cm [SD = 1.131] post-test. The high t-value of 29.337 and p-value of < 0.0001 underscore the significance of this improvement, indicating considerable gains in stability and control when reaching posteromedially. This result is particularly important as it reflects improved balance in a challenging direction that combines lateral and backward reach.

In the posterolateral direction, participants' pre-test mean was 29.8 cm [SD = 1.181], which increased to a post-test mean of 37.65 cm [SD = 1.001]. The corresponding t-value of 30.535 and a p-value of < 0.0001 highlight the statistically significant enhancement in reach distance. The substantial improvement in reach, along with reduced SD, indicates better control and reduced variability in this demanding balance direction, which requires both backward and lateral stability.

Table 1. Comparing pre and post for NPRS

GROUP	TEST	MEAN	SD	T VALUE	P VALUE
Somatosensory training with BFRT	Pre test	7.84	0.7085	17.223	<0.0001
	Post test	5.02	0.8106		

Table 2. Comparing pre and post for Y balance test

TEST	GROUP	MEAN	SD	T VALUE	P VALUE
ANTERIOR REACH TEST	Pre test	31.85	0.975	37.108	<0.0001
	Post test	42.17	1.258		
POSTROMEDIAL TEST	Pre test	29.8	1.18	29.337	<0.0001
	Post test	36.52	1.131		
POSTOLATERAL TEST	Pre test	29.8	1.181	30.535	<0.0001
	Post test	37.65	1.001		

Overall, the statistically significant improvements across all measures demonstrate that the intervention effectively enhanced participants' balance and reach capabilities. The marked increases in post-test values in each dimension, coupled with consistent improvements in SD, indicate both improved balance skills and more reliable performance among participants.

DISCUSSION

The main goal of this study was to determine the efficacy of combining somatosensory training with blood flow restriction [BFR] therapy in reducing pain and improving balance in individuals with patellofemoral pain syndrome [PFPS]. By incorporating BFR into a structured exercise protocol, the study aimed to assess its potential as a low-risk and effective intervention for improving functional outcomes in patients with anterior knee pain, especially those who might not be able to tolerate high--intensity training due to joint instability or discomfort.

This study demonstrates several strengths that support its clinical usefulness and scientific value. First, it introduces a novel approach by combining somatosensory training with blood flow restriction [BFR] therapy, a low-risk intervention particularly suitable for individuals with PFPS who may not tolerate high-load resistance training. The use of validated outcome measures, such as the Y Balance Test and the Numeric Pain Rating Scale [NPRS], ensures objective and reliable assessment of pain and functional balance. The intervention resulted in statistically significant changes, with very low p-values [$p < 0.0001$], and reduced variability in post-intervention performance, indicating both statistically and clinically meaningful improvements.

With a clearly defined and reproducible six-week protocol that included functional, multi-planar exercises designed to improve dynamic stability, the study design was methodologically sound. The accuracy and safety of vascular occlusion were enhanced by individualized BFR pressure calibration using Doppler ultrasound. Additionally, the study adhered to ethical standards, obtaining institutional review board approval and informed consent from all participants. Given the high prevalence of PFPS, the findings support the inclusion of BFR in conventional physiotherapy management and contribute to evidence--based rehabilitation strategies.

This study supports existing evidence that blood flow restriction [BFR] training is effective in improving physical function, in line with a study by Devi et al. [10]. While previous research has demonstrated BFR's ability to enhance strength and muscle growth in healthy individuals, the current study extends its application to a clinical population with patellofemoral pain syndrome [PFPS]. By combining BFR with somatosensory training, the intervention significantly reduced pain and improved balance, highlighting BFR's versatility as a low-risk and effective tool in rehabilitation settings [11, 12].

The Cochrane review on physical activity and exercise for chronic pain in adults highlights that regular, structured physical activity can lead to modest but meaningful reductions in pain and disability across various chronic pain conditions. It emphasizes the importance of tailored exercise programs for pain management and functional improvement. This aligns with the current study, which demonstrates that combining somatosensory training with blood flow restriction [BFR] significantly reduces pain and improves balance in individuals with patellofemoral pain syndrome [PFPS]. Both studies support exercise-based interventions as effective, low-risk strategies to enhance physical function and reduce pain in chronic conditions [13].

Isometric exercises effectively reduce pain in runners with patellofemoral pain syndrome [PFPS] by activating muscles without joint movement, minimizing stress on the knee. This helps restore quadriceps strength and provides pain relief. Somatosensory training improves proprioception and balance by enhancing joint position sense and neuromuscular control, which are often impaired in PFPS. Together, these interventions address pain, proprioceptive deficits, and balance issues, leading to improved knee stability and function. Incorporating both isometric and somatosensory training may improve rehabilitation outcomes in runners with PFPS, although further research is needed to determine optimal protocols [14].

Recent evidence indicates that individuals with patellofemoral pain syndrome present with impaired postural control and balance deficits, supporting the inclusion of sensorimotor and proprioceptive training in rehabilitation programs, which is consistent with the improvements observed in the present study [15].

The study's findings may be limited by several factors. A short intervention duration may not fully capture the long-term effects of combining somatosensory training with blood flow restriction [BFR] on pain relief and balance. The absence of a control group makes it difficult to attribute improvements solely to the intervention, as external factors may have influenced the outcomes. Variability in participant adherence may have affected the consistency of results, while the use of subjective measures such as self-reported questionnaires introduces potential bias related to individual pain perception. Moreover, heterogeneity among participants in terms of PFPS severity, age, gender, and prior rehabilitation experience may have influenced the outcomes and limited generalizability. Finally, these findings may not be applicable to individuals with more severe symptoms, other musculoskeletal conditions, or additional health issues that could alter the effectiveness of somatosensory training and BFR therapy. Future research should include larger randomized controlled trials, long-term follow-up, comparisons with other treatment modalities, personalized protocols, and exploration of combined therapeutic approaches to optimize pain relief and balance in PFPS patients.

CONCLUSIONS

It can be concluded that somatosensory training combined with blood flow restriction training is effective in reducing pain levels and improving balance in subjects with patellofemoral pain. Promising outcomes were ob-

served in a study examining the efficacy of blood flow restriction [BFR] therapy in conjunction with somatosensory training in patients with patellofemoral pain. The combination of these two methods enhanced balance and reduced pain levels. BFR therapy is a safe and effective treatment approach for individuals with patellofemoral pain, as it increases the benefits of low-intensity exercise by promoting muscle hypertrophy and reducing joint stress. This combined intervention shows promise as a low-risk therapeutic approach, particularly for patients who have difficulty performing high-intensity exercise due to joint instability or pain. Future studies should investigate its applicability across different populations and activity levels, as well as its long-term effectiveness.

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CONFLICT OF INTEREST

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ORIGINAL ARTICLE

Evaluation of the effectiveness of Buteyko breathing in the comprehensive treatment of bronchial asthma in children

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ABSTRACT

Aim: To evaluate the effectiveness of Buteyko breathing in the comprehensive treatment of bronchial asthma in school-age children.

Materials and Methods: The study included 48 children with bronchial asthma aged 12 to 18 years. The main group included children who received drug therapy for bronchial asthma in combination with Buteyko breathing (n=24). The comparison group consisted of children who received only drug therapy for bronchial asthma (n=24). The patients were followed up for one year during five scheduled visits at 3-month intervals. At all visits, the dynamics of clinical symptoms and the results of the asthma control test were assessed. At the first and last visits, respiratory function and quality of life were evaluated.

Results: The study demonstrated improvement in quality of life and disease control in patients with bronchial asthma who, in addition to medication, used Buteyko breathing.

Conclusions: In patients with bronchial asthma who used Buteyko breathing along with medical treatment, asthma control improved after 3 months of treatment ($p=0.01$) and continued to increase during the year of observation more than in the comparison group ($p<0.001$). There was also a significant increase in the mean quality of life score in the main group after one year of treatment, in contrast to the comparison group ($p<0.001$). Assessment of respiratory function showed a significant increase in FEV1 in both groups after one year of treatment, without a statistically significant difference between the groups ($p>0.05$).

KEYWORDS: bronchial asthma, asthma control, breathing techniques, Buteyko breathing

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INTRODUCTION

According to the WHO, bronchial asthma (BA) is a disease that affects more than 300 million people worldwide [1, 2]. It has been proven that bronchial asthma can be diagnosed at any age, but most often it debuts in childhood. Among the pediatric population, the incidence is 5–10%, and in some countries it reaches 37.6% [1]. The highest prevalence of asthma is recorded in school age, with urban residents being more likely to be affected (7.1% and 5.7%, respectively) [2].

According to current concepts, bronchial asthma is a heterogeneous disease characterized by a chronic inflammatory process of the airways, and it is this inflammatory nature that determines specific approaches to the diagnosis and treatment of this disease [1, 3, 4].

In recent years, the understanding of the pathogenesis of bronchial asthma has expanded significantly. It has been shown that the disease is based on a chronic inflammatory process that contributes to the development of bronchial hyperreactivity, which is manifested by clinical symptoms (shortness of breath, wheezing, paroxysmal cough) [1]. The onset of pathological symptoms is usually associated with variable airflow limitation, which at least partially resolves spontaneously or with treatment [5].

Currently, the therapeutic options for bronchial asthma are expanding. The Global Initiative for Asthma (GINA – Global Strategy for Asthma Management and Prevention) remains the basic document in the diagnosis and treatment of asthma [1]. The document describes step-by-step algorithms for the treatment of BA and indicates that breathing exercises can be considered as an adjunct to traditional asthma treatment strategies to relieve symptoms and improve quality of life (level of evidence A) [1, 6, 7].

Unfortunately, in practice, non-pharmacological methods of treatment are used much less frequently, as they require separate training in breathing techniques, monitoring of recovery, time, and additional staff engagement [8, 9].

BA significantly reduces patients' quality of life, as it affects the physical, mental, and social aspects of a patient's life and places a significant moral and financial burden on all family members. In children, bronchial asthma remains one of the most common respiratory diseases associated with the risk of disability and mortality [2].

AIM

The aim of the study was to evaluate the effectiveness of Buteyko breathing in the comprehensive treatment of bronchial asthma in school-age children.

MATERIALS AND METHODS

To achieve the study aim, a general clinical assessment, computerized spirometry, and evaluation using the Asth-

ma Control Test (ACT) and quality of life questionnaires were performed.

The study included 48 children with bronchial asthma aged 12 to 18 years. The inclusion criteria were: age 12–18 years, diagnosed bronchial asthma of mild or moderate severity, disease duration of at least 1 year, and no history of allergen-specific immunotherapy. Patients with severe bronchial asthma were excluded from the study. All patients and their parents or legal guardians provided written informed consent to participate.

The Asthma Control Test (ACT) is a patient-completed questionnaire consisting of five items assessing asthma symptoms (daytime and nocturnal), use of rescue medications, and the impact of asthma on daily functioning. Each item includes five response options corresponding to a 5-point Likert-type scale. The total score ranges from 5 (poor asthma control) to 25 (complete asthma control) [9].

The mini version of the Pediatric Asthma Quality of Life Questionnaire (MiniPAQLQ) consists of 13 questions covering the same domains as the full-length questionnaire (symptoms, activity limitation, and emotional function). The questionnaire was validated in the Ukrainian language and used with permission from Elizabeth F. Juniper (Department of Clinical Epidemiology and Biostatistics, McMaster University Faculty of Health Sciences, Hamilton, Ontario, Canada) [10].

A total of 60 children aged 12 to 18 years with suspected or diagnosed bronchial asthma were initially assessed for eligibility. Twelve children were not included in the study: in 5 cases the diagnosis was not confirmed (negative bronchodilation test showing reversibility of less than 12%), 4 patients were diagnosed with severe bronchial asthma, and 3 refused to participate for various reasons. Ultimately, 48 children were included and randomly divided into two groups (Fig. 1). The main group consisted of children receiving standard pharmacological treatment in combination with Buteyko breathing (n=24), while the comparison group included children receiving pharmacological treatment only (n=24).

All patients in both groups were recommended environmental control measures at home, a hypoallergenic diet, and maintenance therapy with inhaled glucocorticosteroids (ICS) and short-acting beta-agonists (salbutamol) as needed.

Patients in the main group, together with their parents, underwent individual training in the Buteyko breathing method during five sessions, each lasting 45 minutes. They were instructed to perform breathing exercises for 15 minutes twice daily.

Patients were followed for one year during five scheduled visits at 3-month intervals. At the first visit, medical history was collected, and clinical examination, computerized spirometry with a bronchodilation test, and asthma control assessment using the ACT were performed. At subsequent visits, clinical symptoms and ACT results were evaluated. Quality of life and respiratory function were assessed at the first and last visits.

The study was conducted in accordance with the principles of the Declaration of Helsinki and the ICH-GCP guidelines. Ethical approval was obtained from the Ethics Committee of Danylo Halytsky Lviv National Medical University (21/12/2020, No. 9) and the Nonprofit Communal Enterprise "City Children's Clinical Hospital of Lviv" (16/11/2018, No. 6).

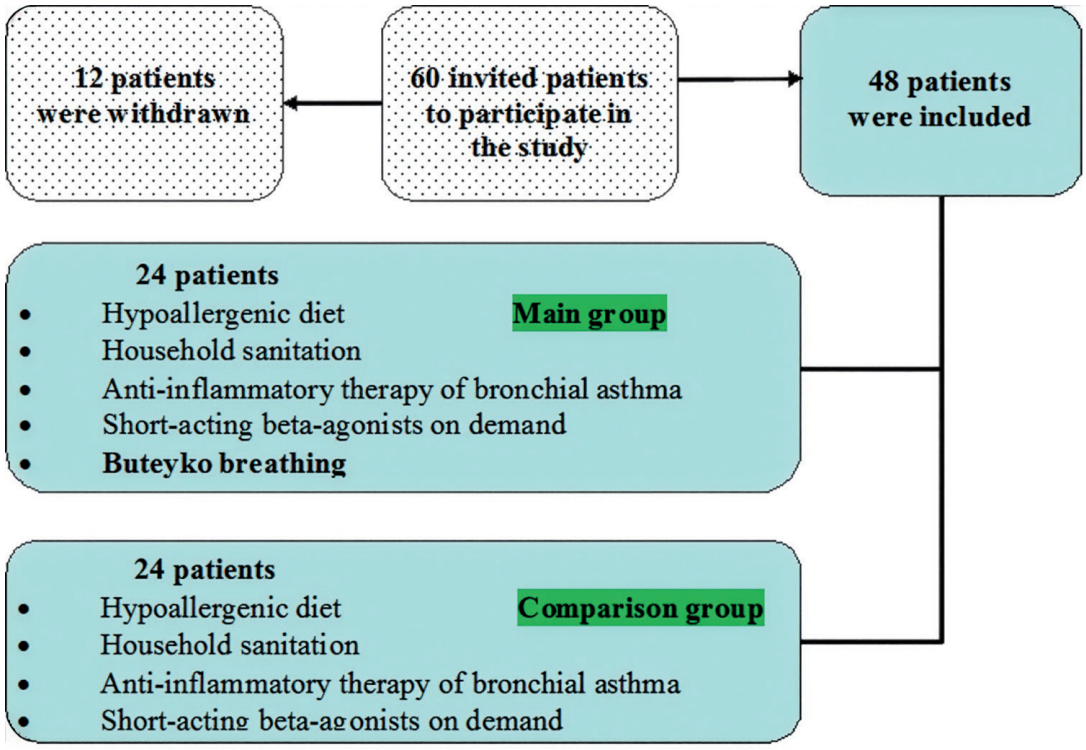

Fig. 1. Research design
Source: own materials

RESULTS

During the one-year follow-up, clinical examinations, spirometry tests, and assessments of asthma control and quality of life were performed.

Among the parameters of computerized spirometry, FEV_1 is of particular importance. Table 1 presents the mean FEV_1 values in patients at the beginning of the study. At baseline, FEV_1 and the mean score of the Asthma Control Test (ACT) (Table 2) in the main and comparison groups did not differ significantly (p=0.228 and p=0.128, respectively).

Evaluation of changes over time showed that FEV_1 did not differ significantly between the groups either at baseline (p=0.228) or during follow-up (p=0.106). It should be noted that comprehensive treatment in both groups resulted in high FEV_1 values (90.8% and 88.73%, respectively).

At baseline, the mean ACT score (Table 2) and the quality of life score (Table 3) did not differ significantly between the groups (p=0.128 and p=0.154, respectively).

Analysis of asthma control showed that the disease was partially controlled at baseline in both groups (Figure 2). During the course of treatment, good disease control was achieved in both groups; however, in the main group this improvement was greater and approached optimal levels. The mean ACT score in the main group increased from 18.96 at visit 1 to 24.08 at visit 5, whereas in the comparison group it increased from 19.79 to 21.21 points.

Another important indicator of treatment effectiveness was the assessment of patients' quality of life. Figure 3 presents the changes in quality of life scores, assessed at the beginning and at the end of the study.

The results show that there were no significant differences between the groups at baseline; however, a significant difference was observed after one year of treatment. In the main group, the mean quality of life score increased from 74.63 to 84.29 points (p<0.001), whereas in the comparison group it increased only from 72.17 to 73.21 points, without statistical significance.

DISCUSSION

Bronchial asthma (BA) is a significant medical and social problem that requires increasing attention not only because of the growing incidence, but also due to the deterioration in patients' quality of life, which affects both patients and their family members. For the vast majority of these patients, not all available therapeutic options are fully utilized [11].

Table 1. Mean values of FEV1 in patients at the beginning of the study

Indicator	Groups		p-value
	Main	Comparison	
FEV1	75,67 %	77,93 %	0,228

Table 2. Mean values of the asthma control test scale in different groups of patients at the beginning of the study

Indicator	Groups		p-level
	Main	Comparison	
Points	17,88	18,83	0,128

Table 3. Mean values of the quality of life assessment poin scale in patients

Indicator	Groups		p-value
	Main	Comparison	
Points	74,63	71,17	0,154

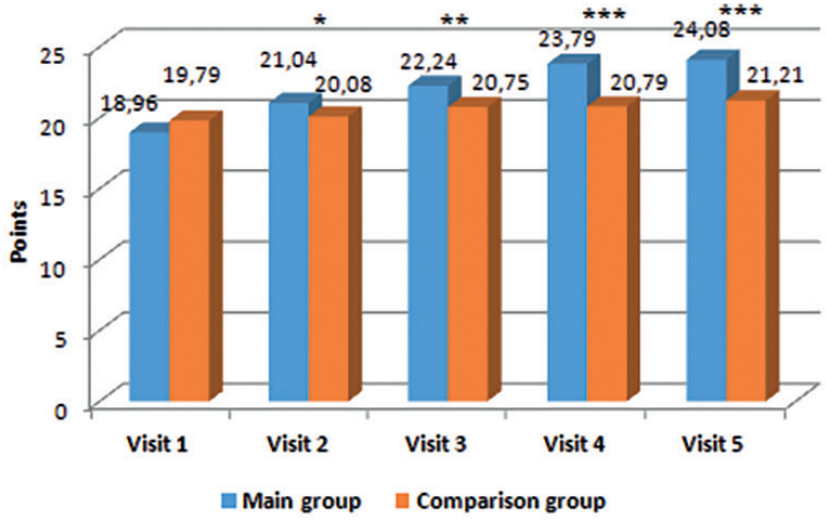

Fig. 2. Dynamics of asthma control test point score

** p=0,01;*

*** p<0,005;*

**** p<0,001*

Source: own materials

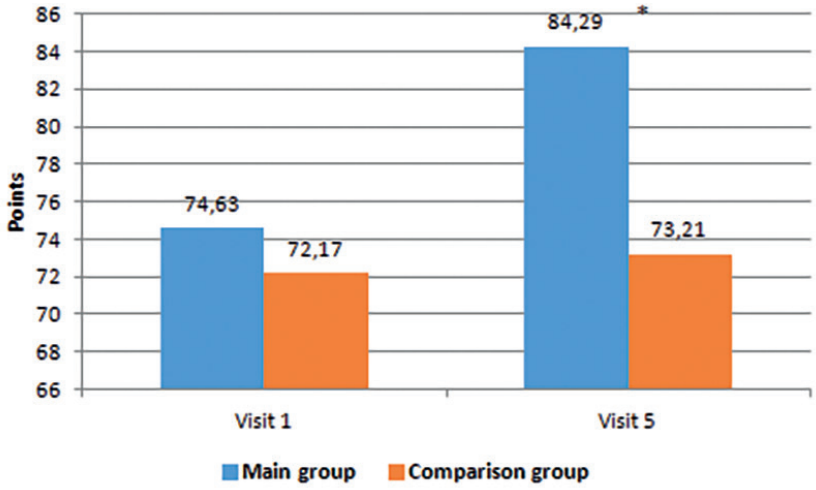

Fig. 3. Dynamics of the quality of life assessment indicator during treatment

** p<0,001*

Source: own materials

The goal of asthma treatment is to achieve disease control, which is associated with improved quality of life. According to international and national guidelines, comprehensive management of asthma includes patient education, elimination of triggering factors, basic and symptomatic pharmacotherapy, biological therapy, allergen-specific immunotherapy (in patients with IgE-dependent disease), as well as the use of non-pharmacological treatment methods [4].

Among non-pharmacological approaches, Buteyko breathing deserves particular attention, as it is considered a method that may help patients control asthma symptoms. However, despite the availability of recommendations in the literature, the use of this method in clinical practice remains limited [12, 13].

The Buteyko breathing method is a breathing technique in which breath control is incorporated into daily life [14]. It includes breathing training and breath-holding techniques, with emphasis on nasal breathing, reduction of breathing depth and frequency, and control of breathing rhythm [15, 16]. Breath control during conversation and physical activity is also an important element of this method. The technique involves control and maximum breath-holding pauses, during which patients gradually increase the duration of breath-holding. In addition, mouth taping may be used to promote nasal breathing during sleep. Overall, the method focuses on reducing chronic hyperventilation [12].

A randomized controlled trial conducted in Germany involving 60 patients demonstrated that, after 3 months, patients using Buteyko breathing in addition to standard therapy showed improvement in several parameters, including increased breath-holding time, improved asthma control (assessed using the ACQ and Nijmegen questionnaires), reduced use of inhaled corticosteroids and short-acting beta-agonists, and favorable changes in capnovolumetry parameters. Interestingly, exhaled nitric oxide (FeNO) levels increased in the Buteyko group, while remaining unchanged in the control group [7, 17].

Other studies have compared different breathing techniques, such as Buteyko and pranayama. A randomized controlled trial involving 69 patients showed that Buteyko breathing reduced the use of bronchodilators; however, no significant differences were observed between groups in terms of FEV_1 or reduction in inhaled corticosteroids. These findings suggest that Buteyko breathing may improve symptoms and reduce medication use without significantly affecting lung function parameters [18, 19].

Similar results were reported in a study conducted among schoolchildren aged 6–12 years, which demonstrated significant improvement in asthma control, reduction in symptom frequency, decreased activity limitation, and improvement in peak expiratory flow rate and heart rate [20, 21].

A case series from New Zealand involving children aged 7–16 years also showed beneficial effects of Buteyko breathing, including reduced medication use, improved quality of life, and alleviation of asthma symptoms [22,23].

Another randomized trial including patients aged 12–70 years showed that, after 12 weeks of Buteyko breathing, hyperventilation decreased, medication use was reduced, and quality of life improved [24].

In the present study, a statistically significant improvement was observed primarily in the quality of life in the main group after one year of treatment, compared with the control group. This may be explained by several factors: (1) patients with severe asthma were not included; (2) baseline ACT scores were relatively high (18.96 in the main group and 19.79 in the comparison group); and (3) the sample size was limited.

Previous studies indicate that Buteyko breathing may improve quality of life, reduce the use of inhaled bronchodilators and corticosteroids, and, to a lesser extent, influence pulmonary function [25–27].

CONCLUSIONS

The treatment of bronchial asthma includes the possibility of using non-pharmacological methods in addition to pharmacological therapy. Buteyko breathing deserves particular attention among these approaches; however, despite recommendations in the literature, its use in clinical practice remains limited, especially in pediatric populations.

The use of the Buteyko method as part of comprehensive asthma treatment demonstrates beneficial effects, particularly in improving asthma control and quality of life. Further studies involving larger groups of patients are required to confirm the therapeutic effectiveness of this method and to support its wider implementation in clinical practice.

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ORIGINAL ARTICLE

Use of the Buteyko method in the study of quality of life in asthma patients

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ABSTRACT

Aim: To evaluate the effectiveness of Buteyko breathing exercises as part of comprehensive asthma therapy.

Materials and Methods: A total of 52 patients with partially controlled moderate asthma were included in the study. Patients were divided into two groups: Group 1 received baseline asthma therapy, while Group 2 received baseline therapy combined with Buteyko breathing exercises. Treatment efficacy was assessed using respiratory function parameters, the SF-36 quality of life questionnaire, and the Asthma Control Questionnaire (ACQ) at baseline and three months after treatment.

Results: Patients receiving baseline therapy combined with Buteyko breathing exercises demonstrated greater improvement in respiratory function parameters compared with patients receiving baseline therapy alone. In Group 2, forced expiratory volume in the first second (FEV_1) increased from 59.31% to 72.11% after treatment ($p<0.05$). Improvements in selected domains of quality of life and asthma control were also observed following treatment.

Conclusions: The addition of Buteyko breathing exercises to baseline therapy was associated with greater improvement in respiratory function and selected quality-of-life parameters compared with baseline therapy alone. Buteyko breathing exercises may be considered a supportive adjunct to comprehensive asthma management.

KEYWORDS: asthma, Buteyko breathing, quality of life, pulmonary rehabilitation, respiratory function

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INTRODUCTION

Asthma is the most prevalent chronic respiratory disease and remains a significant global health concern, affecting millions of individuals worldwide. The global average prevalence of asthma ranges from 5% to 10% [1]. According to a systematic analysis from the 2021 Global Burden of Disease Study, asthma ranked 23rd among the leading causes of disability-adjusted life years (DALYs) lost [2]. Despite optimistic projections indicating a reduction in the global burden of asthma by 2050, based on age-standardised DALYs decreasing from 257 per 100,000 population in 2022 to 134 per 100,000 in 2050 [3], asthma remains the second leading cause of mortality among chronic respiratory diseases [4]. Current epidemiological data indicate a continuing increase in the prevalence of chronic respiratory diseases, including asthma. A systematic review conducted for the Global Burden of Disease Study reported that, in 2019, asthma affected approximately 262 million people worldwide (an age-standardised rate of 3,416 cases per 100,000 population), with an associated mortality of 455,000 deaths. Forecasting models suggest that by 2025, an additional 100 million individuals may be affected globally [5].

Asthma represents an important challenge not only in allergology and pulmonology but also in primary care practice. Current treatment approaches are primarily based on pharmacotherapy, particularly inhaled corticosteroids (ICS) and bronchodilators (beta-2 agonists) [6]. However, some patients show increasing interest in complementary therapeutic approaches, partly due to concerns regarding long-term steroid use [7]. Breathing exercises are among the most widely recognised complementary approaches used in asthma management and include techniques such as yoga, pranayama, capnometry-guided respiratory training, the Strelnikova method, slow breathing training, and Buteyko breathing exercises (BBE) [8]. These methods combine controlled breathing practices with elements of physical training. Their principal aim is to regulate breathing patterns and reduce hyperventilation. Breathing dysfunction associated with chronic hyperventilation may contribute to hypocapnia and accompanying psychological and physical symptoms, including anxiety and panic disorders. Previous studies have demonstrated that breathing exercises may reduce stress and anxiety, improve behavioural adaptation, enhance respiratory muscle function, and support respiratory rehabilitation in patients with asthma [9].

AIM

The aim of the study was to evaluate the effectiveness of Buteyko breathing exercises as part of comprehensive asthma therapy.

MATERIALS AND METHODS

We examined 52 patients with partially controlled moderate asthma. Patients were under outpatient follow-up and received a standardised baseline therapy consisting of inhaled budesonide/formoterol (160/4.5 μg), administered as two inhalations twice daily throughout the entire treatment period. The therapy was adjusted at the time of presentation, which was defined in the study as the initiation of treatment. No statistically significant differences were observed between the groups at baseline with respect to the studied parameters (Table 1). The age of the examined patients ranged from 21 to 47 years, with a mean age of 35.3±14.3 years (mean ± SD). Among the 52 patients, 42 (80.8%) were male and 10 (19.2%) were female. The duration of asthma ranged from 3 to 12 years, with an average duration of 5 years. The patients were divided into two groups: Group 1 (n=25) received baseline asthma therapy, while Group 2 (n=27) received baseline therapy in combination with Buteyko breathing exercises (BBE). Prior to the start of the study, patients in Group 2 underwent training in the Buteyko breathing technique. The breathing training focused on the regulation and awareness of the patient's breathing process.

The Buteyko breathing technique was implemented according to a standardized breathing retraining protocol described in previous studies [10], aimed at normalising breathing patterns through reduced breathing volume, nasal breathing, and controlled breath-holding exercises to correct hyperventilation.

The clinical efficacy of the treatment was assessed through objective examination and measurements of respiratory function, including forced expiratory volume in the first second (FEV_1) and peak expiratory flow rate (PEFR), as well as the Medical Outcomes Study Short Form-36 (SF-36) quality of life questionnaire and the Asthma Control Questionnaire (ACQ), administered at baseline and three months after treatment.

The study complied with current international and national bioethical standards and was approved by the Ethics and Bioethics Committee of Kharkiv National Medical University. Written informed consent to participate in the study was obtained from each participant.

The distribution of variables was tested for normality using the Shapiro–Wilk test. Variables with a normal distribution are presented as mean and standard deviation (M ± SD). To assess the statistical significance of differences between groups, Levene's test was first performed to evaluate equality of variances, confirming homogeneity between Group 1 and Group 2 ($p \geq 0.05$). For intergroup comparisons (Group 1 vs Group 2), the independent samples t-test was used. For within-group comparisons (before vs after treatment), the paired t-test was applied. Results were considered statistically significant at $p < 0.05$. In Table 1, p1 reflects changes within Group 1, p2 reflects changes within Group 2, and p3 reflects differences between Group 1 and Group 2 after three months of treatment..

RESULTS

The clinical study demonstrated that treatment with basic pharmacotherapy in combination with BBE in patients from Group 2 resulted in greater improvement in respiratory function parameters compared to patients in Group 1. Specifically, FEV_1 in Group 1 increased from 61.3±3.18% before treatment to 65.34±4.32% after treatment, whereas in Group 2 it increased from 59.31±3.32% at baseline to 72.11±4.32% following treatment. Thus, respiratory function parameters in Group 2 were significantly better than those in Group 1 after treatment ($p<0.05$).

Peak flow (PF) values were assessed individually for each patient over a two-week period prior to treatment. At admission, daily PF variability in Group 1 and Group

Table 1. Comparative parameters between the study groups before and after treatment

Parameter	Group 1			Group 2			p_3-value (comparison after treatment between-group)
	Before treatment	After treatment	p_1-value (comparison within-group 1)	Before treatment	After treatment	p_2-value (comparison within-group 2)	
FEV_1 (%)	61.3 ± 3.18	65.34 ± 4.32	p≥0.05	59.31 ± 3.32	72.11 ± 4.32	p<0.05	p<0.05
Physical activity (points)	36.2 ± 6.12	44.40 ± 5.61	p<0.05	35.3± 6.91	71.20 ± 6.23	p<0.05	p<0.05
Vitality (points)	38.70 ± 5.97	48.80 ± 6.51	p<0.05	36.21 ± 4.99	69.70 ± 5.33	p<0.05	p<0.05
Social activity (points)	39.81 ± 5.54	49.8 ± 4.98	p<0.05	41.22 ± 6.33	67.5 ± 4.88	p<0.05	p<0.05
Mental health (points)	43.24 ± 4.96	62.60 ± 5.12	p<0.05	45.33 ± 5.01	81.4 ± 6.11	p<0.05	p<0.05
ACQ score	2.08 ± 1.05	1.00 ± 0.121	p<0.05	2.11 ± 0.99	0.72 ± 0.13	p<0.05	p≥0.05

Group 1 – Basic pharmacotherapy, Group 2 – Basic pharmacotherapy + Buteyko breathing exercises, FEV1 – Forced expiratory volume in the first second, ACQ – Asthma Control Questionnaire, p-value – probability value

Source: compiled by the authors of this study.

2 was comparable, reaching 73±6.5% and 76.4±5.2%, respectively. After treatment, daily PF variability decreased to 32.1% in Group 1 ($p<0.05$) and to 24.5±1.8% in Group 2 ($p<0.05$) compared with pre-treatment values. Normal daily PF variability is considered to be <10%. Three months after treatment, morning PF values improved in both groups; however, greater improvement was observed in patients receiving baseline therapy combined with BBE ($p<0.05$).

The analysis of quality of life (QoL) showed that limitations in daily activities associated with health problems decreased 2.5-fold in Group 2 patients, compared with a 1.2-fold reduction in Group 1. General health status improved in both groups after treatment adjustment, reaching 58.34±1.30 points in Group 1 and 69.3±2.0 points in Group 2 ($p<0.05$). Baseline physical activity scores were 36±7.12 points in Group 1 and 35.3±6.91 points in Group 2. After 3 months, physical activity scores increased to 44.40±5.61 points in Group 1 ($p>0.05$) and to 71.20±6.23 points in Group 2 ($p<0.05$), indicating a statistically significant improvement only in Group 2.

Vitality indicators demonstrated a similar trend. Before treatment, vitality scores were 38.70±5.97 points in Group 1 and 36.21±4.99 points in Group 2. After 3 months, these values increased to 48.80±6.51 points in Group 1 ($p<0.05$) and 69.70±5.33 points in Group 2 ($p<0.05$). Social activity scores at baseline were 39.8±5.54 points in Group 1 and 41.22±6.33 points in Group 2. After 3 months, this parameter improved in both groups, reaching 49.8±4.98 points in Group 1 ($p<0.05$) and 67.5±4.88 points in Group 2 ($p<0.05$).

According to the questionnaire data, mental health indicators at baseline did not differ significantly between the groups and were 43.2±4.96 points in Group 1 and 45.33±5.01 points in Group 2 ($p>0.05$). After 3 months, mental health scores improved in both groups, reaching 62.60±5.12 points in Group 1 ($p<0.05$) and 81.4±6.11 points in Group 2 ($p<0.05$). Intergroup comparison after treatment demonstrated significantly better outcomes in Group 2, with values approximately 1.2-fold higher than those in Group 1 ($p<0.05$).

The level of asthma control assessed using the ACQ was 2.08±1.053 points in Group 1 and 2.11±0.99 points in Group 2 at baseline, indicating uncontrolled asthma. After treatment, symptom control improved in both groups, reaching 1.00±0.121 points in Group 1 ($p<0.05$) and 0.72±0.113 points in Group 2 ($p<0.05$). Patients in Group 1 achieved partial asthma control, whereas patients in Group 2 achieved full asthma control.

DISCUSSION

Studies have shown that timely adjustment of asthma treatment has a positive effect on lung function and reduction of bronchial obstruction. The positive effect of treatment adjustment on the average scores of the SF-36 and ACQ questionnaires highlights the importance of monitoring both the physical and mental health of patients.

Indicators of mental health, vitality, social functioning, and limitations in daily activities due to emotional problems improved in both groups compared to baseline ($p<0.05$). However, patients in Group 2 demonstrated greater improvement in physical activity, emotional status, self-regulation capacity, and social functioning compared to patients in Group 1 ($p<0.05$), supporting the potential role of breathing techniques, particularly Buteyko breathing exercises, as an adjunct to pharmacological treatment and pulmonary rehabilitation.

The findings of this study cannot be extrapolated to all patients with asthma, as not all individuals may be willing to engage in breathing training. Nevertheless, the use of Buteyko breathing exercises was associated with improvement in quality of life and asthma control in the examined patients.

Similar findings regarding the beneficial effects of breathing retraining on asthma control and quality of life in adults with asthma were reported by Bruton et al. [11].

The obtained results are consistent with findings from previous clinical studies, including studies involving children with asthma, which demonstrated beneficial effects of breathing exercises in asthma management and highlighted their role in pulmonary rehabilitation [12, 13].

CONCLUSIONS

Baseline therapy adjusted according to asthma severity was associated with improvement in selected respiratory parameters and quality-of-life measures. The addition of Buteyko breathing exercises was associated with greater improvement in respiratory function and selected domains of quality of life compared with baseline therapy alone. Buteyko breathing exercises may be considered a supportive adjunct to comprehensive asthma management.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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ORIGINAL ARTICLE

Bright light therapy and combined pectoralis therapy for stress and cyclic mastalgia in primary dysmenorrhea

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ABSTRACT

Aim: The aim of the study is to compare the effects of bright light therapy and combined pectoralis therapy with breast massage and relaxation exercise for stress and cyclic mastalgia.

Materials and Methods: This study was conducted at a medical college and hospital in Chennai. 40 subjects were randomly assigned into two groups (n=20). The intervention group received bright light therapy for 30 minutes followed by combined pectoralis therapy for 30 minutes (total 60 minutes per session). The control group received 30 minutes of breast massage followed by 30 minutes of relaxation exercises (total 60 minutes per session). Both groups received interventions 3 times/week for 4 weeks. Outcome measures included daily breast pain charting and perceived stress scale and were measured before and after the intervention.

Results: The participants showed a significant reduction in breast pain for bright light therapy group 28.8 ± 7.8 than for the breast massage group 30.35 ± 5.72. There was a significant reduction in stress in bright light therapy group 15.7 ± 6.05 compared to breast massage group 17.45 ± 7.00.

Conclusions: Bright light therapy and combined pectoralis therapy can be considered as effective treatment method for breast pain and stress during primary dysmenorrhea.

KEYWORDS: primary dysmenorrhea, cyclic mastalgia, bright light therapy, physiotherapy, stress, good health and well-being

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INTRODUCTION

Primary dysmenorrhea (PD) is spasmodic and painful menstruation characterized by crampy, recurrent lower abdominal pain [1]. Cyclic mastalgia is defined as breast pain occurring before the onset of menstruation and subsiding with the onset of the menstrual cycle. It can occur unilaterally or bilaterally and is usually associated with tenderness, heaviness, and swelling [2]. World Health Organization (WHO) assessed the worldwide prevalence of dysmenorrhea in 124,259 non-pregnant women and found that the prevalence increased from 8.8% in women aged 19–41 years to 94% in girls aged 10–20 years [3]. About 40–70% of cases of breast pain (BP) are due to the hormonal cycling of oestrogen, progesterone, and prolactin. In India, the prevalence of dysmenorrhea appears to be similar, with a reported prevalence of 51–54% in the adult urban population [4].

The cause of dysmenorrhea has been identified as increased synthesis and release of prostaglandins, which cause hypercontractility of the myometrium, resulting in increased uterine contractions, uterine muscle ischemia, and hypoxia. When progesterone levels drop prior to menstruation, prostaglandin levels increase, leading to PD with symptoms such as vomiting, nausea, diarrhoea, fatigue, mild fever, and headache [5–8]. PD can also negatively impact daily life activities, ranging from lower educational performance during puberty to poor sleep quality, which also affects mood, resulting in anxiety and stress [9,10]. Chronic stress can lead to hormonal imbalances, heightened sensitivity to pain, and increased inflammation, all of which may contribute to the severity and frequency of menstrual cramps [11]. During menstruation, the production of hormones such as estriol, oxytocin, vasopressin, and estradiol is associated with mastalgia [12].

Despite the availability of pharmacological treatments for dysmenorrhea and cyclic mastalgia, including combined oral contraceptives (COC), progesterone-only contraceptive pills, non-steroidal anti-inflammatory drugs, evening primrose oil, bromocriptine, and danazol, these may have side effects such as deep vein thrombosis, amenorrheic periods, gastrointestinal problems, nephrotoxicity, hematologic abnormalities, and edema. A large placebo effect has been demonstrated for both cyclical and noncyclical mastalgia [13–15].

Studies have shown the effectiveness of structured exercise programmes for cyclic mastalgia, such as thoracic expansion exercises, pectoral stretching, cobra stretch, retractor strengthening, wall push-ups, shoulder shrugging, and bracing, in addition to breast massage (MB) and advice on the use of a supportive brassiere [16]. One study determined the efficacy of physiotherapy modalities and reported that a combination of TENS with thermotherapy had greater efficacy than TENS alone after 20 minutes [17].

The effect of bright light therapy (BLT) seems to be mediated through the eyes, and there is evidence for its efficacy in antepartum depression, premenstrual depression, and chronic depression. Barve et al. (2019) showed that pectoralis stretching and strengthening reduced pain and increased blood flow. A study reported that relaxation exercises stimulate relaxin hormones, which ultimately reduce stress, while breast massage for cyclic mastalgia increases blood flow in the breast region and also reduces pain [18]. Most studies have focused on common physiotherapy approaches for breast pain and stress, but there are fewer studies related to bright light therapy. This study bridges this gap by comparing BLT with commonly used physiotherapy protocols as treatment methods for the same.

AIM

The study aims to compare the efficacy of bright light therapy combined with pectoralis exercises and breast massage combined with relaxation exercises for stress and cyclic mastalgia.

MATERIALS AND METHODS

This was a randomized controlled trial approved by the Institutional Scientific Review Board (007/12/2024/ISRB/PGSR/SCPT), conducted at a leading hospital in Chennai. A breast pain questionnaire was developed and sent to 105 girls for selection of eligible participants; however, only 52 responded. Of these, 4 subjects were not interested in participation and 9 were excluded based on the following selection criteria. The inclusion criteria were individuals diagnosed with primary dysmenorrhea, age 12 to 25 years, stress level more than 30% according to the Depression Anxiety Stress Scale (DASS-21), regular menstrual cycle, and breast pain during menstruation assessed through the breast pain questionnaire. Respondents with severe uncontrolled pain, asthma, breast cancer, history of reproductive or chronic disease, menstrual cycles >35 days apart, and women on oral contraceptive pills were excluded from the study. Finally, 40 female individuals were included. All participants received information about the study objectives and intervention procedures, and informed consent was obtained.

The eligible participants were randomly assigned using computer-generated numbers into two groups: the intervention group (BLT, n=20) and the control group (MB, n=20).

Participants in the BLT group were seated comfortably in an upright position with eyes closed, facing a 10,000-lux light box placed at eye level for passive light exposure for 30 minutes per session, 3 sessions per week, for a total of 4 weeks. This was followed by stretching and strengthening exercises focused on the pectoralis muscle, performed as 10 repetitions for 3 sets. Participants remained standing against a wall to perform low-loaded chest stretches facilitated manually by the therapist. The session concluded with wall-based push-ups and a proper cool-down session.

In the MB group, subjects were placed in a private environment and positioned comfortably in a lying position for breast massage. After providing proper instructions, a gentle circular breast massage was administered using gloved hands, moving from the nipple outward to cover the entire breast area, including the collarbone and upper abdomen, for 30 minutes. This was followed by 30 minutes of deep diaphragmatic breathing exercises performed in the same position, focusing on slow inhalation and exhalation to enhance relaxation and vagal tone. The total duration of each session was 60 minutes, and the intervention was conducted 3 times per week for 4 weeks.

All participants were supervised by a physiotherapist throughout the intervention period. Daily breast pain charting was performed by asking subjects about their overall experience over a one-month period to assess the level of breast pain each day. Stress during menstruation was assessed using Cohen's Perceived Stress Scale [19,20]. Values obtained were recorded before and after the intervention. Blinding of participants and therapists was not feasible; however, statisticians and outcome assessors were blinded to group allocation to minimize bias.

Initially, the distribution of variables was examined. Since the data were not normally distributed, non-parametric tests were used. The level of significance was set at $p<0.001$, and all analyses were performed using IBM SPSS version 30. The Wilcoxon signed-rank test was used to compare within-group results, and the Mann–Whitney U test was used to compare post-test results between groups.

RESULTS

BREAST PAIN CHARTING

Within-group analysis using the Wilcoxon signed-rank test showed a significant reduction in breast pain scores in both groups. In the BLT group, the pre-test score was 33.05 ± 7.20 and the post-test score was 28.8 ± 7.8, with a mean difference of 4.25 ($Z = -3.62$, $p < 0.001$). In the MB group, the pre-test score was 33.50 ± 6.75 and the post-test score was 30.35 ± 5.72, with a mean difference of 3.15 ($Z = -3.78$, $p < 0.001$).

Between-group comparison of post-test scores using the Mann–Whitney U test demonstrated a statistically significant difference between the groups ($p < 0.001$) (Table 1).

Table 1. Breast pain charting for Mann Whitney u test results

COMPARISON	POST TEST VALUE
BLT group	28.8 ± 7.8
MB group	30.35 ± 5.72
Mann- witney u test	168
P value	0.001

Table 2. Perceive stress scale Mann Whitney u test result

COMPARISON	POST TEST VALUE
BLT group	15.7 ± 6.05
MB group	17.45 ± 7.00
Mann- witney u test	179
P value	0.001

PERCEIVED STRESS SCALE

Within-group analysis using the Wilcoxon signed-rank test demonstrated a significant reduction in perceived stress scores in both groups. In the BLT group, the pre--test score was 19.85 ± 5.63 and the post-test score was 15.70 ± 6.05, with a mean difference of 4.15 (Z = -3.62, $p < 0.001$). In the MB group, the pre-test score was 19.85 ± 6.57 and the post-test score was 17.45 ± 7.00, with a mean difference of 2.40 (Z = -3.82, $p < 0.001$).

Between-group analysis using post-test scores with the Mann–Whitney U test revealed a statistically significant difference between the groups ($p < 0.001$) (Table 2).

DISCUSSION

The present study aimed to determine the effect of bright light therapy combined with pectoralis therapy for mastalgia and to analyse the effectiveness of breast massage with breathing exercises for stress in subjects with dysmenorrhea. Both groups were assessed for cyclic mastalgia using daily breast pain charting. After the intervention, a significant reduction in breast pain was observed in the BLT group compared to the MB group. The Perceived Stress Scale was used to assess stress in both groups. After the intervention, a significant reduction in stress levels was observed in the BLT group compared to the MB group.

Babette Bais et al. (2020) reported that when BLT was used in women, median depression scores decreased by 42.6% (Structured Interview Guide for the Hamilton Rating Scale for Depression–Seasonal Affective Disorder version), 40.6% (Edinburgh Postnatal Depression Scale), and 53% (Hamilton Depression Rating Scale) during the intervention period. After the intervention, depression scores decreased by 40.6%–53.1%. Morning light is a device-based treatment that aims to advance circadian timing, improve mood and sleep quality, and may also reduce stress by decreasing reactivity in the amygdala (a part of the brain) [21].

In a systematic review, isometric exercises, yoga techniques, and stretching exercises showed a decrease in pain levels in subjects with primary dysmenorrhea [22]. These findings are consistent with previous evidence indicating that physiotherapy interventions can effectively reduce pain in patients with primary dysmenorrhea. Wahyuni W et al. (2022) stated that deep breathing exercises can make the patient more comfortable by promoting muscle relaxation. The present study found a decrease in breast pain during menstruation in the BLT group, with a mean and standard deviation of 28.8 ± 7.8, compared to 30.35 ± 5.72 in the control group. The present study addresses the gap in the literature by investigating the effects of BLT in combination with other physiotherapy protocols, showing improvement in stress related to dysmenorrhea.

Lack of follow-up can be considered a limitation of the study. Another limitation is that the amount or number of analgesics taken by the subjects was not considered during the intervention. Subjects were not given any interventions during menstruation, considering the impact of the menstrual cycle on exercise performance in primary dysmenorrhea. Further studies are required to evaluate the effects of stress and pain during menstruation. Another limitation is that this study did not include individuals with secondary dysmenorrhea or other comorbid conditions. Future research should expand the selection criteria to include individuals with pelvic pathology.

CONCLUSIONS

The present study suggests that the combination of bright light therapy (BLT) and pectoralis exercises may offer potential benefits in managing cyclic mastalgia and stress associated with primary dysmenorrhea compared to breast massage and breathing exercises. While the findings indicate a positive effect, these results should be interpreted with caution due to methodological limitations, including a small sample size and absence of full blinding. Further large-scale, well-controlled studies are needed to confirm the effectiveness and generalizability of these interventions.

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ORIGINAL ARTICLE

Effects of plyometric and Swiss ball training on core stability and dynamic balance in collegiate cricket players

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ABSTRACT

Aim: To evaluate the effects of plyometric training and Swiss ball training on core stability and dynamic balance in collegiate cricket players.

Materials and Methods: Thirty-eight participants were selected based on inclusion and exclusion criteria and divided into two groups: plyometric training (n = 19) and Swiss ball training (n = 19). Outcomes were assessed using the modified star excursion balance test (MSEBT) and the prone bridge test (PBT).

Results: In the Swiss ball training group, MSEBT scores increased from 83.747 to 91.821 for the left leg and from 84.416 to 92.395 for the right leg ($p < 0.0001$). In the plyometric group, left leg scores increased from 84.279 to 86.105 and right leg scores from 84.884 to 88.642 ($p < 0.0001$). In the prone bridge test, the Swiss ball group improved from 83.68 to 120.11 seconds, while the plyometric group improved from 82.95 to 104.21 seconds ($p < 0.0001$).

Conclusions: Both plyometric and Swiss ball training significantly improved dynamic balance and core stability. Greater improvements were observed in the Swiss ball training group.

KEYWORDS: core stability, dynamic balance, plyometric training, Swiss ball training, cricket players

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INTRODUCTION

Batting, bowling, and fielding are essential skills in the global sport of cricket. Players must perform a variety of movements at different intensities, including running, jumping, twisting, and striding. It has been suggested that increasing muscle strength can improve the effectiveness of cricket-related activities. Fielders require upper body strength for accurate throws, bowlers use upper body and leg strength to enhance deliveries, batters rely on arm and core strength for powerful strokes and balance, and wicket-keepers depend on strong wrists and forearms for catching and stumping [1]. Cricket is a non-contact sport; however, injuries can occur in various ways. The bowling action involves repeated trunk twisting, extension, and rotation while absorbing significant ground reaction forces over a short period. If performed incorrectly or excessively, these movements may lead to overuse injuries, particularly affecting the back in athletes [2].

The concept of core strengthening has increasingly been studied in exercise training, injury prevention, and rehabilitation [3]. A stronger and more stable core enhances the ability of the upper and lower limbs to generate greater power during athletic performance. Core strengthening promotes balance and postural control by effectively preparing the body for movement demands. Core stability serves as the foundation for explosive movements and motor control, including agility, balance, and coordination. Maintaining optimal balance is particularly important during bowling, especially when the movement involves single-limb support and the bowler must preserve equilibrium under high load conditions [4]. Core stability exercises have been shown to improve batting performance, muscle strength, and balance in cricket players. Improvements in throwing accuracy and balance have also been reported in young cricket players following core stability training. Dynamic balance refers to the ability to maintain stability while moving or shifting in different directions while keeping control of the center of gravity. Various factors, including core stability, muscle strength, proprioception, and neuromuscular control, influence dynamic balance [1].

Plyometric training (PT) is one of the most commonly used conditioning methods among athletes participating in high-intensity sports. It is based on the stretch-shortening cycle (SSC), which involves an eccentric contraction of the musculotendinous unit followed immediately by a concentric contraction of the same muscle and connective tissue [4]. Plyometric training includes a variety of jumping exercises and is typically performed using body weight, engaging both the lower and upper limbs [5].

The use of Swiss ball exercises in core stability training has increased considerably in recent years. Proponents of Swiss ball training suggest that it enhances strength, proprioception, and balance by stimulating neuromuscular pathways. Therefore, Swiss balls are frequently used in both athletic training and rehabilitation settings [6].

The Prone Bridge Test (PBT) uses plank-based positions to assess core endurance and stability. These tests are important components of screening for injury risk and for designing exercise programs, as they provide valuable information about trunk muscular endurance [7].

The Modified Star Excursion Balance Test (MSEBT), which uses fewer reach directions, has been proposed to improve practicality and reduce testing time. The anterior, posterolateral, and posteromedial directions are most commonly used in previous research involving the MSEBT [8].

Thus, the present study aimed to investigate whether Swiss ball exercises and plyometric training affect core muscle stability and dynamic balance in collegiate cricket players.

AIM

The aim of this study was to evaluate and compare the effects of plyometric training and Swiss ball training on core stability and dynamic balance in collegiate cricket players.

MATERIALS AND METHODS

STUDY PROCEDURE

This comparative study employed a convenience sampling method and included a total of 38 participants. The subjects were divided into two groups: the plyometric training group and the Swiss ball training group. Pre- and post-tests for core muscle stability were assessed using the prone bridge test (PBT), and dynamic balance was assessed using the modified star excursion balance test (MSEBT). Group 1 (n = 19) and Group 2 (n = 19) participated in three sessions per week over a period of 8 weeks. A rest period of 60 seconds was provided between sets and 15 seconds between repetitions. The study was approved by the Institutional Scientific Review Board (ISRB) (approval number: 061/10/2024/ISRB/UGSR/SCPT) and conducted in accordance with ethical guidelines.

INCLUSION CRITERIA

Amateur cricket players; both male and female; aged 18 to 26 years; willing to participate.

EXCLUSION CRITERIA

Recent sports injury; history of cardiovascular disease; recent surgery; athletes with acute or chronic low back pain.

EXERCISE PROTOCOL

Group 1 – Plyometric training

Warm-up

- Jumping jacks [9]
- Box jump [10]
- Split squat jump
- Overhead slams
- Plyometric push up [11]

Cool down

Group 2 – Swiss ball training

Warm-up

- Swiss-ball alternate arm Lie and leg extension
- Swiss-ball wall squat
- Swiss-ball shoulder bridge
- Swiss-ball back extension
- Swiss-ball leg raises [12]

Cool down

OUTCOME MEASURE

Modified star excursion balance test (MSEBT) [13]

Prone bridge test (PBT) [14].

RESULTS

The plyometric training group showed a significant improvement in the Modified Star Excursion Balance Test (MSEBT) on the right side from pre-test (84.884 ± 2.8332) to post-test (88.642 ± 3.1585), with t = 16.260, and on the left side from 84.279 ± 2.6820 to 86.105 ± 2.6294, with t = 15.049 (p < 0.0001). Similarly, the Swiss ball training group demonstrated significant improvement in the MSEBT on the right side from 84.416 ± 2.5723 to 92.395

Table 1. Pre and Post test values of Plyometric and Swiss ball Training Group

SIDE	GROUP	TEST	MEAN	SD	t value	p value
Right	Plyometric training	Pre test	84.884	2.8332	16.260	<0.0001
		Post test	88.642	3.1585		
	Swiss ball training	Pre test	84.416	2.5723	18.258	
		Post test	92.395	2.2210		
Left	Plyometric training	Pre test	84.279	2.6820	15.049	
		Post test	86.105	2.6294		
	Swiss ball training	Pre test	83.747	2.4910	17.713	
		Post test	91.821	1.7061		

Tabela 2. Post test values of Plyometric and Swiss ball Training Group

SIDE	GROUP	MEAN	SD	t value	p value
Right	Plyometric	88.642	3.1565	4.238	<0.0001
	Swiss ball	92.395	2.2210		
Left	Plyometric	86.105	2.6294	7.949	
	Swiss ball	91.821	1.7061		

Table 3. Pre and Post test values of Plyometric and Swiss ball Training Group

GROUP	TEST	MEAN	SD	t value	p value
Plyometric training	Pre test	82.95	4.983	15.451	< 0.0001
	Post test	104.21	6.451		
Swiss ball training	Pre test	83.68	4.831	21.619	
	Post test	120.11	9.091		

Table 4. Post test values of Plyometric and Swiss ball Training Group

GROUP	MEAN	SD	t value	p value
Plyometric training	104.21	6.451	6.215	< 0.0001
Swiss ball training	120.11	9.091		

± 2.2210 (t = 18.258) and on the left side from 83.747 ± 2.4910 to 91.821 ± 1.7061 (t = 17.713) ($p < 0.0001$). Overall, both groups showed statistically significant improvements, with greater mean changes observed in the Swiss ball training group compared to the plyometric training group, as presented in Table 1.

On the right side of the MSEBT, the Swiss ball training group (92.395 ± 2.2210) demonstrated higher post-test mean values compared to the plyometric training group (88.642 ± 3.1565), with a between-group t-value of 4.238 ($p < 0.0001$). Similarly, on the left side, the Swiss ball group (91.821 ± 1.7061) showed greater improvement than the plyometric group (86.105 ± 2.6294), with a t-value of 7.949 ($p < 0.0001$). Overall, the between-group comparison indicates that the Swiss ball training group achieved significantly better balance outcomes than the plyometric training group, as shown in Table 2.

The plyometric training group showed a significant improvement in the prone bridge test from pre-test (82.95 ± 4.983) to post-test (104.21 ± 6.451), with a t-value of 15.451. Similarly, the Swiss ball training group demonstrated a marked increase in the prone bridge test from pre-test (83.68 ± 4.831) to post-test (120.11 ± 9.091), with a higher t-value of 21.619. Overall, both groups showed statistically significant improvements ($p < 0.0001$), with greater mean changes observed in the Swiss ball training group compared to the plyometric training group, as presented in Table 3.

The plyometric training group showed a post-test mean of 104.21 ± 6.451, while the Swiss ball training group demonstrated a higher mean of 120.11 ± 9.091 in the prone bridge test. The between-group comparison revealed a statistically significant difference, with a t-value of 6.215 ($p < 0.0001$), as shown in Table 4. This indicates that the Swiss ball training group achieved significantly greater improvement compared to the plyometric training group.

DISCUSSION

The study conducted by Manikandan and Kumari in 2024 focused on comparing the impact of Swiss ball exercises with traditional floor exercises on core muscle endurance in athletes. Both exercise methods were found to significantly improve core endurance; however, the Swiss ball group showed a greater level of improvement. This advantage is attributed to the instability introduced by the Swiss ball, which necessitates continuous activation of deep stabilizing muscles such as the transversus abdominis and multifidus. Consequently, these exercises not only enhance endurance but also improve neuromuscular coordination, balance, and control, which are essential for athletic performance and injury prevention.

The results of the present study support the integration of instability-based training, such as Swiss ball exercises, into routine athletic conditioning programs, particularly in sports that require high levels of core stability. The

findings confirm that Swiss ball exercises are effective in improving balance and core stability, as the instability of the surface requires continuous activation of deep core muscles. This leads to improvements in muscular endurance, neuromuscular coordination, and postural control, all of which are essential for both injury prevention and athletic performance [15]. These findings are consistent with recent evidence from a systematic review and meta-analysis demonstrating that core training significantly improves balance and overall athletic performance outcomes in healthy individuals and athletes [16].

The study by Gill SA et al. (2024) investigated the impact of core stability exercises on dynamic balance among novice male cricket players. The findings demonstrated that core stability exercises significantly enhance dynamic balance, which is a critical component of athletic performance and injury prevention. These exercises target deep stabilizing muscles, such as the transversus abdominis and multifidus, which play an important role in maintaining balance and coordination during dynamic movements. Improved dynamic balance supports more effective execution of cricket-specific skills and contributes to overall physical fitness and agility.

The authors emphasized the importance of incorporating core stability exercises into training programs for novice athletes, as these exercises provide a foundation for the development of advanced motor skills and reduction of injury risk. This study highlights the value of targeted training interventions in improving athletic performance. Although core stability and dynamic balance enhance coordination, agility, and control during key activities such as batting, bowling, and fielding, the present findings further support their importance in cricket performance. These components are essential for improving performance and reducing the risk of injury [17].

Similarly, Ashraf N. (2019) explored the effects of a plyometric training program on speed and agility in young Pakistani cricket players. The results indicated that both plyometric and conventional training groups improved speed and agility. These findings are consistent with previous research demonstrating that different training modalities can effectively enhance athletic performance indicators such as speed and agility. While acknowledging the effectiveness of conventional training methods, the study highlights the potential benefits of incorporating plyometric exercises into training programs for young cricket players. These findings further support the role of plyometric training in improving athletic performance [18].

Cuğ M. et al. (2012) examined the effects of Swiss ball training on dynamic balance, core strength, and knee joint reposition sense in sedentary college students. The results demonstrated that Swiss ball exercises significantly improve dynamic balance, which is essential for stability during movement and injury prevention. The instability of the Swiss ball requires continuous activation of deep stabilizing muscles such as the multifidus and transversus abdominis, leading to improved neuromuscular coordination and proprioception. Additionally, enhanced knee joint repositioning awareness contributes to better alignment and control during movement. These findings indicate that Swiss ball exercises are an effective component of training programs, as they improve physical fitness and support the development of more advanced motor skills. The present study further supports the role of Swiss ball training in improving core stability and dynamic balance, as the instability of the training surface challenges the body to maintain control, enhances postural alignment, facilitates functional movement, and reduces the risk of injury [19].

CONSLUSIONS

The present study demonstrated that both Swiss ball and plyometric training had a positive effect on improving core stability and dynamic balance in collegiate cricket players. However, the Swiss ball training group exhibited greater improvements, particularly in core stability.

The unstable nature of the training surface during Swiss ball exercises continuously challenges deep core muscles, enhancing neuromuscular coordination and spinal segmental control. This contributes to improved trunk alignment and postural adjustments during movement, which are essential for athletic performance in sports such as cricket that require agility, rapid transitions, and sustained postural control.

Furthermore, improvements in core stability observed in the Swiss ball training group may support enhanced dynamic balance. A more stable core provides a foundation for controlled limb movements and effective balance responses during activity. As a result, athletes in the Swiss ball group demonstrated greater improvements in balance-related performance tasks.

In conclusion, both training approaches were effective; however, Swiss ball training showed greater benefits in improving core stability and dynamic balance, and may be considered a valuable method for enhancing the physical preparedness of collegiate cricket players.

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ORIGINAL ARTICLE

Exploratory feasibility study of the EUKINES wearable plantar-pressure system for gait analysis

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ABSTRACT

Aim: To assess the early feasibility of the EUKINES prototype plantar-pressure insole system by determining whether stable plantar-pressure data can be acquired during treadmill walking, whether mean foot pressure (MFP) can be derived repeatably, and whether short-duration use is safe and acceptable for adult participants.

Materials and Methods: This preliminary exploratory study was conducted as an early phase of the EUKINES project. Twenty-five adult volunteers were recruited using convenience sampling without restrictive eligibility criteria. Participants completed standardized treadmill walking trials in athletic footwear at 2 km/h for approximately 60 seconds following familiarization. Measurements were collected using prototype EUKINES insoles with printed plantar-pressure sensors and compared with a commercial in-shoe system (Medilogic). The primary analyzed parameter was mean foot pressure, calculated separately for the left and right limbs as the average plantar pressure during stance and expressed as a normalized, dimensionless index. Safety was assessed through observation and participant-reported discomfort, while perceived safety and comfort were evaluated using a 7-item Likert-scale questionnaire.

Results: Technically valid measurements were obtained with a high completion rate and without technical failures requiring session termination. EUKINES and Medilogic showed comparable mean foot pressure values without statistically significant between-system differences. All participants completed the protocol without adverse events; no skin irritation, pain, or gait disturbance was reported. Questionnaire findings indicated high perceived safety and tolerability, with occasional mild discomfort attributed to prototype material and insole folding.

Conclusions: The EUKINES system enabled stable plantar-pressure measurement under controlled walking conditions and was well tolerated during short-term use, supporting progression to preclinical validation and further clinical investigation.

KEYWORDS: insoles, biomechanical phenomena, rehabilitation, total hip arthroplasty, treadmill

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INTRODUCTION

Quantitative gait analysis has become an increasingly important component of modern rehabilitation and orthopaedic practice [1,2]. Objective assessment of spatiotemporal parameters and plantar-pressure distribution provides clinically relevant information on functional performance, load symmetry, and movement efficiency [3,4]. However, access to advanced gait-analysis technologies remains limited in everyday clinical practice [5]. Most high-precision systems are expensive, infrastructure-dependent, and produced by foreign manufacturers, which significantly restricts their availability in many Polish rehabilitation centres and research institutions [6].

The EUKINES project was initiated to address this gap through the development of a Polish, low-cost wearable system for gait analysis based on printable plantar-pressure sensor technology [7]. The long-term objective of the project is to deliver an affordable and clinically deployable tool that may support objective functional assessment and rehabilitation monitoring, particularly in patients undergo-

ing major lower-limb procedures such as total hip arthroplasty (THA). From its inception, the EUKINES programme has been structured as a multi-stage translational pathway, encompassing sensor development, early feasibility testing, preclinical validation, and subsequent hospital-based clinical studies [8,9].

The present article reports the earliest experimental phase of the EUKINES project, conducted prior to formal preclinical validation and in accordance with the staged development framework of the programme. This initial series of measurements was performed in a small group of adult volunteers and was designed to answer fundamental feasibility questions: whether the proposed sensing concept allows stable acquisition of plantar-pressure data, whether basic load-related parameters can be derived in a repeatable manner, and whether the use of the system is safe and acceptable for participants [10,11].

At this exploratory stage, the analyses focused primarily on mean foot pressure (MFP), as a parameter directly reflecting sensor performance and signal stability [12]. In addition, simple safety observations and a brief user-oriented questionnaire were employed to capture early impressions related to comfort and tolerability [13]. These elements were not intended as formal usability validation, but rather as supportive information guiding further technical development and study planning.

By presenting these very early findings, the current publication serves as an introduction to the broader EUKINES research programme and provides Polish clinicians and researchers with insight into the developmental rationale of a domestic wearable gait-analysis system. At the same time, it establishes a transparent starting point for the subsequent stages of the project, which will be reported in separate publications, including a comprehensive preclinical validation study in healthy adults and a hospital-based clinical investigation in patients undergoing THA rehabilitation.

AIM

This study aimed to evaluate the early feasibility of the EUKINES wearable plantar-pressure insole system under standardized walking conditions. The objectives were to determine whether the prototype enables stable acquisition of plantar-pressure data and allows consistent calculation of a basic load-related parameter, mean foot pressure (MFP). Moreover, the study aimed to assess short-term safety and user acceptability, including potential adverse effects, perceived comfort, and overall tolerability during use. The findings were intended to provide preliminary evidence to support further technical development and progression to preclinical and clinical validation.

MATERIALS AND METHODS

The study had a preliminary, exploratory character and was conducted as part of the early phase of the EUKINES project, which aims to develop a domestic, low-cost

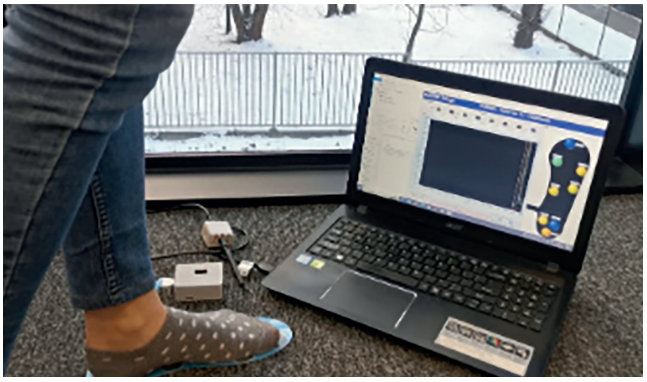

Fig. 1. EUKINES plantar-pressure measurement setup with insole system and real-time data acquisition.

Source: own materials

Fig. 2. External electronic module of the EUKINES system attached to footwear during plantar-pressure measurement.

Source: own materials

plantar-pressure insole system for gait analysis based on printed pressure-sensing technology [8].

The study was conducted in accordance with the Declaration of Helsinki and applicable ethical standards [14]. Ethical approval for the exploratory measurement stages was obtained from the appropriate institutional bioethics committees, in line with the staged structure and requirements of the EUKINES project. All participants provided written informed consent prior to participation.

The results presented here derive from a series of consecutive measurement stages carried out between September and October 2024, preceding formal preclinical validation and subsequent hospital-based clinical studies. The primary purpose of this phase was to confirm the feasibility of further research, to assess the stability of the measurement signal, and to evaluate the safety of system use in a heterogeneous adult population [11].

Adult volunteers (≥18 years of age) were recruited using convenience sampling, without the application of restrictive inclusion or exclusion criteria typical of formal validation studies. This approach was intentional and constituted an important element of the study design, as the main objective at this stage was to evaluate the performance of plantar-pressure sensors under diverse and realistically variable conditions of use, including individuals with different anthropometric characteristics and individual gait patterns [15]. Such a strategy enabled early assessment of the robustness of the measurement system with respect to biomechanical variability, which is critical for further technological development and for the planning of subsequent clinical investigations [16]. In total, 25 individuals participated in the measurements; however, not all participants were involved in every measurement stage. Only recordings that met predefined quality criteria regarding signal completeness and stability were included in the analyses.

Measurements were performed using prototype EUKINES insoles equipped with printed plantar-pressure sensors and a dedicated data acquisition system. The insoles were placed in standardized athletic footwear, and walking trials were conducted on a motorized treadmill (Noraxon Zebris) to ensure standardized measurement conditions [17]. Prior to data acquisition, each participant underwent a brief familiarization period with treadmill walking. Measurement trials were performed at a constant, low walking speed of 2 km/h, and data were recorded during trials lasting approximately 60 seconds, with rest periods provided between consecutive measurements.

The primary and sole analyzed parameter was mean foot pressure (MFP), defined as the average plantar pressure recorded during the stance phase of gait [18]. MFP was calculated separately for the left and right limb. At this stage of the project, analyses focused on global MFP values without extended clinical interpretation; however, all raw data were retained to enable more detailed and refined analyses in subsequent phases of the EUKINES research programme. Safety of system use was assessed through continuous observation during the measurement sessions and by monitoring participant-reported discomfort during and after testing.

Fig. 3. Prototype EUKINES plantar-pressure sensing insole with integrated sensor elements.

Source: own materials

The questionnaire was designed to assess perceived safety, comfort, and potential adverse effects associated with the use of the EUKINES insole prototype during gait measurements. It consisted of seven items, each rated on a five-point Likert scale. An open-ended question allowed participants to provide additional comments regarding device safety.

Plantar load distribution was assessed using two in-shoe plantar pressure measurement systems (EUKINES and Medilogic). Both systems acquire raw plantar pressure data using capacitive sensors embedded in flexible insoles [19]. Raw pressure data from the Medilogic system were exported as CSV files and subsequently processed offline.

In the present study, the mean foot pressure (MFP) parameter was computed from the raw plantar pressure data using a custom post-processing procedure. MFP was defined as a normalized, dimensionless index summarizing the average plantar loading over the entire foot during the acquisition period. To ensure comparability between systems, the same normalization concept was applied to the EUKINES data.

During data collection, an iterative assessment of data adequacy was performed, focusing on signal stability, variance estimates, and repeatability of mean foot pressure measurements across consecutive participants [20]. As additional measurements did not result in meaningful changes in variance or signal characteristics, further recruitment was deemed unlikely to provide substantial additional information for the objectives of this exploratory phase. Accordingly, data collection was concluded after 25 participants, consistent with feasibility-oriented study designs in early-stage wearable sensor research [11].

Statistical analysis was planned and conducted to support descriptive assessment of measurement stability and repeatability. Numerical data were presented as means and standard deviations or medians and interquartile ranges, depending on data distribution. Normality was assessed using the Shapiro–Wilk test. For paired comparisons, the paired Student's t-test or the Wilcoxon signed-rank test was applied, as appropriate. Variability of repeated MFP measurements within sessions was evaluated using coefficients of variation and measurement error indices [21]. The level of statistical significance was set at $p < 0.05$. All analyses were performed using dedicated statistical software.

RESULTS

STUDY POPULATION AND DATA COMPLETENESS

Across all exploratory measurement stages, data were collected from 25 adult participants. The proportion of technically valid measurements was high, confirming the feasibility of data acquisition under standardized laboratory conditions. No technical failures requiring premature termination of measurement sessions were observed, and all participants completed the planned walking trials without interruption.

The study population comprised 25 adult participants, including 19 women (76%) and 6 men (24%). Participants' age ranged from 33 to 62 years, with a mean age of 47.8 years, reflecting a heterogeneous adult population representative of typical users encountered in everyday clinical and rehabilitation settings.

Body mass ranged from 57 to 102 kg (mean: 78.3 kg), while body height ranged from 150 to 187 cm (mean: 167.9 cm). The mean body mass index (BMI) was 27.9 kg/m^2, spanning a wide spectrum of nutritional status. Ten participants (40%) had normal body weight (BMI 18.5–24.9 kg/m^2), one participant (4%) was underweight (BMI < 18.5 kg/m^2), five participants (20%) were overweight (BMI 25.0–29.9 kg/m^2), and nine participants (36%) met the criteria for obesity (BMI ≥ 30.0 kg/m^2).

With respect to self-reported medical history potentially affecting gait pattern or study safety, the majority of participants did not report chronic conditions relevant to locomotion. Isolated cases included a history of surgically treated lumbar disc disease and the presence of spinal deformity consistent with scoliosis. No other musculoskeletal, neurological, or systemic conditions that could compromise safe participation in the study were reported.

This heterogeneous sample was selected to allow early assessment of the robustness of the plantar-pressure sensing concept under diverse anthropometric and biomechanical conditions, consistent with the feasibility-oriented objectives of this exploratory study.

MFP MEASUREMENTS

In the analyzed sample, paired MFP measurements were obtained for the left and right foot using the EUKINES and Medilogic systems. For the left foot, the mean MFP value measured with EUKINES was 2.82 (SD = 0.47; range 0.77–3.69), while Medilogic yielded a mean of 2.79 (SD = 0.45; range 1.92–3.70). For the right foot, the mean

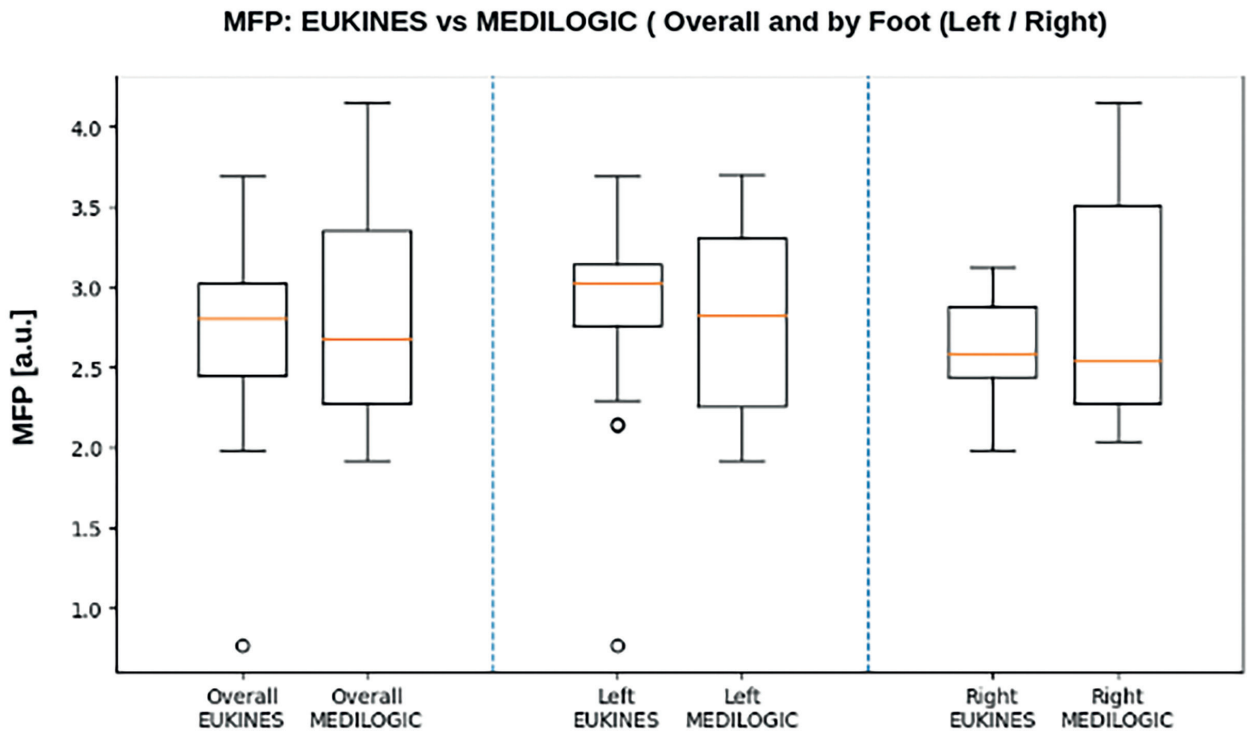

Fig. 4. Comparison of MFP values obtained using the EUKINES and Medilogic plantar pressure systems for the overall dataset and separately for the left and right foot. Boxplots represent the median and interquartile range (IQR), with whiskers extending to 1.5×IQR; dots indicate outliers. MFP is presented as a dimensionless index calculated from raw plantar pressure data.

Source: own materials

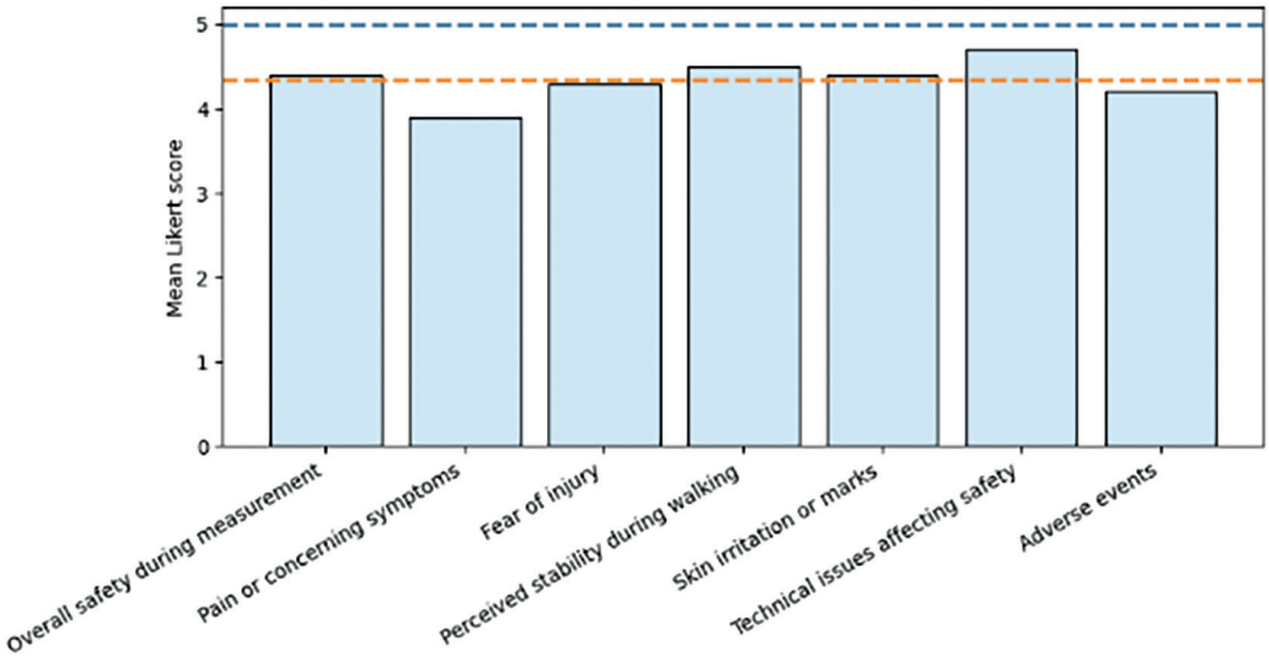

Fig. 5. Mean Likert-scale scores of questionnaire items assessing perceived safety and tolerability of the EUKINES insole prototype. Vertical bars represent mean scores for individual items. The orange dashed line indicates the overall mean score across all items, while the blue dashed line denotes the maximum possible score of 5.

Source: own materials

MFP value obtained with EUKINES was 2.63 (SD = 0.30; range 1.98–3.12), whereas Medilogic recorded a higher mean of 2.92 (SD = 0.60; range 2.04–4.15).

The mean difference between systems for the left foot (EUKINES − Medilogic) was 0.018 (SD = 0.706), indicating comparable absolute measurement levels, with no statistically significant difference observed (paired t-test = 0.12, p = 0.904). For the right foot, the mean difference amounted to −0.238 (SD = 0.657), reflecting a tendency toward lower MFP values recorded by EUKINES compared with Medilogic; however, this difference did not reach statistical significance (paired t-test = −1.77, p = 0.090). These results are illustrated in Figure 4.

SAFETY AND QUESTIONNAIRE-BASED ASSESSMENT

All participants completed the measurement protocol without adverse events. No skin irritation, pain, gait disturbance, or other safety-relevant issues attributable to the use of the EUKINES insole prototype were reported during or immediately after testing. No technical failures requiring interruption or premature termination of the measurement sessions occurred.

Questionnaire-based evaluation corroborated the observations made during the measurement sessions with respect to perceived safety and tolerability of the device. The majority of participants rated the use of the EUKINES insoles as safe or very safe and reported no pain, discomfort, or adverse sensations associated with short-duration gait measurements. The device was generally perceived as stable and safe during walking trials.

A small number of participants reported mild discomfort, which was consistently attributed to the material properties of the prototype insoles and occasional folding or wrinkling of the insole within footwear. Importantly, these sensations were not associated with a subjective feeling of immediate danger or loss of safety during testing. Some respondents expressed concerns regarding potential skin irritation or discomfort during prolonged or repeated use of the insoles, particularly in relation to the prototype material and fixation method.

When quantified using a five-point Likert scale, questionnaire responses yielded a total score of 314 out of 350 possible points (89.7%), indicating a high overall level of perceived safety and tolerability. Mean scores for individual questionnaire items and the overall questionnaire result are summarized in Figure 5.

DISCUSSION

Quantitative gait analysis has become an essential component of contemporary rehabilitation and orthopaedic practice, offering objective insight into functional performance, load distribution, and recovery trajectories following lower-limb interventions [1,2,9]. Despite its recognized clinical value, routine access to advanced gait-analysis technologies remains limited in many healthcare systems, particularly in settings where cost, infrastructure requirements, and dependence on imported solutions restrict widespread implementation [5,6]. This gap is especially evident in everyday rehabilitation practice, where objective functional assessment is often replaced by subjective clinical judgment [3].

The EUKINES project was conceived in response to this challenge, with the aim of developing a domestic, low-cost, and wearable plantar-pressure measurement

system tailored to real-world clinical and research needs. The present study represents the earliest experimental phase of this broader research programme and was intentionally designed as an exploratory investigation rather than a formal validation study. Its primary purpose was to establish whether the proposed sensing concept allows for stable acquisition of plantar-pressure data, whether simple load-related parameters such as mean foot pressure (MFP) can be derived in a repeatable manner, and whether the system can be used safely and acceptably by adult users [11].

The results of this study demonstrate that MFP can be consistently recorded under standardized treadmill walking conditions, with stable signal characteristics and low within-session variability across repeated trials [20]. Importantly, these findings were observed in a heterogeneous group of adult participants with varying anthropometric characteristics and individual gait patterns, suggesting that the sensing concept is sufficiently robust to biomechanical variability encountered in realistic use scenarios [15,16]. At this stage of development, MFP was intentionally treated as a global, dimensionless index reflecting overall plantar loading and signal stability, without extended clinical interpretation [18]. This conservative analytical approach aligns with the exploratory nature of the study and avoids premature conclusions regarding clinical equivalence or diagnostic utility.

Comparative analysis with an established commercial plantar-pressure system further indicated comparable absolute MFP values between systems, without statistically significant systematic differences [19]. While such comparisons cannot be interpreted as validation or interchangeability, they provide contextual support for the technical plausibility of the EUKINES sensing approach and justify its progression to more rigorous validation phases.

Equally important are the findings related to safety, tolerability, and user perception. No adverse events or safety-relevant incidents were observed during the measurement sessions, and questionnaire-based evaluation revealed a high level of perceived safety and tolerability during short-duration gait assessment [13]. Mild discomfort reported by a small number of participants was consistently attributed to the prototypical nature of the insole material and fixation method, rather than to the sensing concept itself, and did not translate into a subjective feeling of immediate danger. These observations are consistent with expectations for early-stage wearable prototypes and provide guidance for subsequent design refinements [8,22].

From a methodological perspective, this study adopts a staged, feasibility-oriented approach that reflects the translational pathway of the EUKINES project [10]. Formal assessments of test–retest reliability, long-term wear comfort, and clinical validity were beyond the scope of the present investigation and are planned as part of subsequent project stages. By explicitly delineating the boundaries of the current study, the present work establishes a transparent baseline against which future preclinical and clinical investigations can be interpreted.

An additional aspect of this publication is its intended role within the domestic scientific and clinical landscape. By presenting early results from a Polish-developed gait-analysis system, this article aims to familiarize clinicians and researchers with the underlying concepts, challenges, and opportunities associated with wearable plantar-pressure technologies [7,8]. Such dissemination fosters informed engagement with ongoing research, supports interdisciplinary collaboration, and provides a contextual framework for interpreting future validation and clinical studies emerging from the EUKINES programme.

In summary, the present exploratory study confirms the feasibility, signal stability, and basic tolerability of the EUKINES plantar-pressure sensing concept in adult users [11,20]. While not intended as a validation study, it provides a necessary and transparent starting point for subsequent stages of technological refinement, preclinical validation, and clinical application. By documenting this early phase, the study contributes both empirically and conceptually to the development of accessible gait-analysis solutions and underscores the importance of incremental, well-documented progress in translational biomedical engineering research [10].

CONCLUSIONS

This exploratory study confirms the feasibility, signal stability, and basic tolerability of the EUKINES plantar-pressure sensing concept in adult users. Stable mean foot pressure measurements were obtained under standardized walking conditions, and no safety-related issues were observed during short-duration use. These findings provide a transparent foundation for further preclinical validation and clinical evaluation of the system within the EUKINES research programme.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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REVIEW ARTICLE

Clinical trials in contemporary medical rehabilitation: role and implications

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ABSTRACT

Clinical trials constitute the foundation of modern medicine and enable the introduction of new therapeutic methods into clinical practice. Their importance is particularly evident in medical rehabilitation, where they allow evaluation of complex therapeutic interventions and their impact on patient functioning and quality of life. This study presents the importance of clinical trials in the development of medical rehabilitation and discusses their role in clinical decision-making and healthcare planning. Literature analysis indicates that rehabilitation interventions evaluated in clinical trials lead to improvements in motor function, independence, and reduction of complications, particularly among older adults. These studies enable comparison of therapeutic strategies and provide a basis for the development of clinical standards and rational use of healthcare resources. Clinical trials play a key role in the advancement of medical rehabilitation and the implementation of evidence-based practice, contributing to improved patient care, optimization of therapeutic approaches, and development of scientific knowledge in this field.

KEYWORDS: clinical trials, medical rehabilitation, evidence-based practice, quality of life, healthcare planning

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INTRODUCTION

Clinical trials constitute the foundation of modern medicine [1,2]. Before new therapies or treatment methods are introduced into clinical practice, they must undergo rigorous evaluation of safety and efficacy, which helps reduce the risk of implementing ineffective or potentially harmful interventions. Clinical trials represent a mandatory stage preceding the authorization of medicinal products or medical interventions and involve studies conducted with human participants to assess therapeutic usefulness under conditions approximating real clinical practice [1,2]. They concern medicinal products, medical devices, diagnostic procedures, and therapeutic methods [2]. According to current European regulations, a clinical trial is defined as any investigation involving human participants intended to confirm clinical or pharmacological effects, identify adverse reactions, or evaluate the safety or efficacy of medicinal products [3].

The results of clinical trials form the basis for the development of clinical guidelines and treatment standards [4]. They are an integral component of evidence-based medicine, enabling therapeutic decisions grounded in reliable data, clinical experience, and patient preferences [4,5]. Conversely, the absence of high-quality scientific evidence may lead to the adoption of ineffective or potentially harmful methods [6]. Clinical trials are conducted by interdisciplinary teams, and their findings are synthesized through systematic reviews and meta-analyses, which enhance the reliability of conclusions and reduce the risk of interpretative bias [5,7].

The importance of clinical trials is particularly evident in medical rehabilitation, where complex and multi-stage therapeutic interventions are applied. Evaluating their effectiveness requires appropriately designed studies capable of analyzing the impact of therapy on patient functioning, level of independence, and quality of life. In the context of an aging population and the increasing prevalence of chronic diseases, the results of clinical trials gain additional relevance, supporting healthcare planning and the rational allocation of available resources [4,8].

Despite their growing importance, clinical trials are still sometimes perceived as risky undertakings; however, in practice, they are subject to strict legal and ethical regulations. Each stage of a trial is overseen by appropriate institutions, and informed consent from participants is a prerequisite for inclusion [9,10]. Ensuring participant safety and procedural transparency constitutes the foundation of the credibility of clinical trials and their social acceptance.

AIM

The aim of this study is to present the importance of clinical trials in the development of medical rehabilitation and to discuss their role in clinical decision-making and healthcare planning.

MATERIALS AND METHODS

This review-based study was conducted through an analysis of contemporary literature on clinical trials, evi-

dence-based practice, and selected studies assessing the effectiveness of rehabilitation interventions.

REVIEW AND DISCUSSION

THE IMPORTANCE OF CLINICAL TRIALS IN REHABILITATION

Clinical trials play a key role in the development of medical rehabilitation. They enable evaluation of the effectiveness of complex therapeutic interventions applied in clinical practice, which often involve the simultaneous use of multiple treatment modalities and rehabilitation techniques [13]. Rehabilitation is not based on a single intervention but on a multidimensional approach that includes physical therapy, patient education, psychological support, and preventive measures. This complexity is reflected in contemporary methodological frameworks for complex interventions, which emphasize the need for structured evaluation of interacting components and outcomes [11]. Treatment outcomes result from collaboration within an interdisciplinary team of specialists, including physicians, physiotherapists, occupational therapists, and nurses. In such settings, clinical trials allow objective assessment of the impact of individual therapeutic components on patient functioning, level of independence, and quality of life, while also enabling comparison of different therapeutic strategies and optimization of clinical management.

The importance of clinical trials in rehabilitation is increasing in the context of population aging and the growing number of patients with chronic diseases and multimorbidity. With advancing age, the prevalence of movement disorders, musculoskeletal diseases, neurological complications, and functional limitations leading to disability increases. Clinical trials make it possible to evaluate the effectiveness of rehabilitation programs in older adults and to tailor therapeutic interventions to their individual functional limitations and needs [1,4]. This facilitates the development of care models that support independence, prevent complications, and improve quality of life in the geriatric population. Evidence-based rehabilitation may play a significant role in slowing functional decline and reducing the burden on healthcare and social support systems. Recent evidence also highlights the role of targeted interventions in preventing or reducing frailty and maintaining functional capacity among older adults [12].

Clinical trials also provide data necessary for planning healthcare services for older adults and other patient groups requiring long-term rehabilitation. They allow identification of interventions that are effective and safe in long-term use, assessment of cost-effectiveness, and determination of optimal organizational models of care [6]. This is particularly important under conditions of limited healthcare resources, where rational allocation of available funds and implementation of solutions providing the greatest clinical and societal benefits are essential.

EXAMPLES OF CLINICAL TRIALS IN REHABILITATION

To illustrate the practical importance of clinical trials in rehabilitation, examples involving neurological and orthopedic populations are presented. The study "New Technologies in the Rehabilitation of Chronic Stroke" was conducted through collaboration between rehabilitation centers and academic institutions, including Zurich University of Applied Sciences. It was designed as a pilot feasibility clinical trial aimed not only at preliminary assessment of intervention effectiveness but primarily at evaluating the feasibility of implementing an intensive technology-assisted rehabilitation program in clinical practice. The project was carried out between 2018 and 2020, and its results were published in 2022 [13]. Patients in the subacute or chronic phase after stroke with persistent functional deficits limiting independence were included. The study sought to assess feasibility, safety, and potential benefits of intensive technology-supported rehabilitation, including the use of devices facilitating motor training and monitoring therapeutic progress.

The rehabilitation program consisted of a four-week intensive training protocol using rehabilitation technologies, including systems supporting repetitive functional training and tools enabling objective assessment of movement parameters. Participants completed between 28 and 82 therapy sessions, reflecting individualized adjustment of intervention intensity. No serious adverse events were reported, indicating the safety of the proposed approach. Improvements were observed in upper and lower limb function, and rehabilitation efficiency indicators ranged from 10% to 58%, depending on the assessed functional parameters [13]. These findings suggest that technology-supported interventions may increase training intensity and repetition, translating into improved functional outcomes in neurological patients. Systematic reviews of telerehabilitation interventions further support their effectiveness and accessibility in stroke rehabilitation settings [14]. However, the pilot nature of the study highlights the need for further research involving larger populations and longer follow-up periods.

A second example illustrating the significance of clinical trials in rehabilitation is a randomized study published in BMC Musculoskeletal Disorders, concerning rehabilitation following surgical treatment of femoral neck fractures [15]. Conducted between 2020 and 2022, the study included 120 elderly patients randomly assigned either to a rehabilitation program based on individualized exercise prescription or to a control group receiving standard care. The six-month follow-up period enabled assessment of both short- and medium-term therapeutic outcomes.

Patients undergoing the rehabilitation program achieved significantly better hip function scores measured using the Harris Hip Score and demonstrated higher levels of independence in activities of daily living assessed with the Barthel Index. Additionally, a lower incidence of postoperative complications was observed in this group, suggesting a beneficial effect of appropriately planned rehabilitation on recovery and prevention of secondary consequences of immobilization [15]. These findings emphasize the importance of individualized rehabilitation planning and confirm the role of randomized clinical trials in generating high-quality scientific evidence supporting the development of rehabilitation for older adults.

Together, these examples demonstrate that clinical trials represent an essential tool for evaluating the effectiveness of new technologies and therapeutic strategies in medical rehabilitation. They enable not only verification of clinical outcomes but also assessment of safety, organizational feasibility, and potential system-level benefits associated with implementing innovative therapeutic solutions.

CONCLUSIONS

Clinical trials constitute the foundation for the development of modern medicine and medical rehabilitation, enabling evaluation of the safety and effectiveness of therapeutic interventions and the implementation of new standards of care. Conducting such studies in accordance with ethical principles and good clinical practice ensures participant protection and the reliability of the obtained results, ultimately contributing to improved patient care.

In medical rehabilitation, where interventions are often complex and interdisciplinary, clinical trials play a particularly important role in optimizing therapeutic programs and identifying approaches that provide the greatest functional benefits. This is especially relevant in the context of an aging population and the increasing number of patients requiring long-term rehabilitation. Findings from clinical trials support rational healthcare planning and facilitate efficient use of limited system resources.

The development of new rehabilitation technologies and personalized therapeutic strategies further increases the importance of well-designed clinical studies capable of assessing their true clinical and organizational value. Continued research in this field remains essential for advancing scientific knowledge, improving clinical practice, and enhancing patients' quality of life.

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REVIEW ARTICLE

Pressure-sensing technologies in orthopedic telerehabilitation: a review of systems and clinical applications

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ABSTRACT

Gait analysis is an essential tool in orthopedic rehabilitation, enabling objective evaluation of locomotion and recovery after surgical procedures such as total hip and knee arthroplasty, osteotomies, and ligament reconstruction. Traditional observational methods often fail to detect subtle asymmetries and compensatory mechanisms, highlighting the need for objective and repeatable measurement technologies.

Pressure-based systems and wearable solutions, combined with telemedicine and artificial intelligence, increasingly facilitate continuous monitoring and support personalized rehabilitation. This review aims to present pressure-based gait analysis technologies, describe their applications in orthopedic rehabilitation, and evaluate their potential integration with remote monitoring systems. The concept of the EUKINES system, a low-cost wearable solution for home-based rehabilitation, is also introduced.

Pressure measurement systems, including stationary platforms and smart insoles, allow detailed assessment of load distribution, gait symmetry, and biomechanical function. These technologies support monitoring of recovery after arthroplasty, ligament reconstruction, osteotomies, and fractures by identifying compensatory patterns, asymmetry, and abnormal limb loading. Stationary systems provide high precision under controlled conditions, whereas wearable insoles enable continuous monitoring during daily activities and support telerehabilitation.

The EUKINES system combines flexible piezoresistive insoles, wireless data transmission, automated analysis, and real-time biofeedback, offering an accessible and scalable solution for remote rehabilitation.

Pressure-based gait analysis provides objective, clinically relevant information supporting diagnosis, therapy planning, and long-term monitoring in orthopedic rehabilitation. Mobile wearable technologies and systems such as EUKINES expand access to continuous and home-based rehabilitation, enabling more personalized, data-driven care.

KEYWORDS: gait analysis, plantar pressure, wearable devices, orthopedic rehabilitation, remote monitoring

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INTRODUCTION

Gait analysis is a key functional assessment tool in orthopedics and rehabilitation, enabling precise and objective evaluation of a patient's locomotion abilities in both clinical settings and daily activities [1-3]. This plays a particularly important role after surgical procedures such as total knee arthroplasty (TKA), total hip arthroplasty (THA), osteotomies, and ligament reconstruction, where gait quality and symmetry serve as important indicators of therapeutic effectiveness and predictors of recovery [2,3,6]. Normal gait patterns rely on a complex interaction between the musculoskeletal and nervous systems, and their disturbances may lead to chronic symptoms, reduced functionality, and an increased risk of injury [2,3]. Traditional gait assessment methods are based on clinical observation and subjective tests. Although widely used, they often fail to detect subtle asymmetries, compensatory patterns, or delays in healing processes, which creates a risk of underestimating clinically significant deviations [1,2,6].

Instrumental gait analysis, including the measurement of temporo-spatial parameters, kinematics, and kinetics, offers not only biomechanical diagnostics but also supports therapy by identifying asymmetries, functional

deficits, and biomechanical abnormalities that are not detectable in routine examinations [1-3]. Furthermore, studies indicate that improved gait symmetry after surgical procedures, particularly in the context of knee joint surgery, correlates with increased muscle strength and better long-term clinical outcomes [6]. In clinical practice, such data provide valuable support for therapeutic decision-making and the personalization of rehabilitation plans [2,3].

Fig. 1. Conceptual framework of pressure-based gait analysis integrated with telemedicine and remote rehabilitation monitoring

Source: own materials

Therefore, there is a growing need for objective, mobile, and repeatable measurement tools that enable precise and automated monitoring of therapy progress, independent of a therapist's subjective assessment [1,5]. Simultaneously, the development of artificial intelligence (AI) and machine learning (ML) significantly expands the analytical capabilities of these systems [3,4]. ML algorithms enable the processing of large volumes of complex biomechanical data, supporting automated diagnosis and precise modeling of individual gait patterns. This translates into improvements in personalized therapy and prediction of rehabilitation outcomes. AI-based methods, including machine learning and deep learning techniques, also enable the interpretation and visualization of key gait characteristics, supporting clinicians in therapeutic decision-making [3,4].

In recent years, telemedicine and home-based rehabilitation have developed particularly dynamically, highlighting the growing need for tools that enable remote and objective assessment of gait function and therapeutic progress [3,5]. The COVID-19 pandemic, as well as demographic and economic changes, has further emphasized the importance of solutions that allow therapy without the constant presence of a specialist, while increasing accessibility of care and enabling patients to systematically engage in their own rehabilitation [3,5].

AIM

The aim of this article is to review existing pressure-based gait analysis technologies, describe their applications in orthopedic rehabilitation, and assess the prospects for their integration with remote patient monitoring systems (Fig. 1). Additionally, the concept of the EUKINES system is presented as a modern, flexible, and low-cost wearable

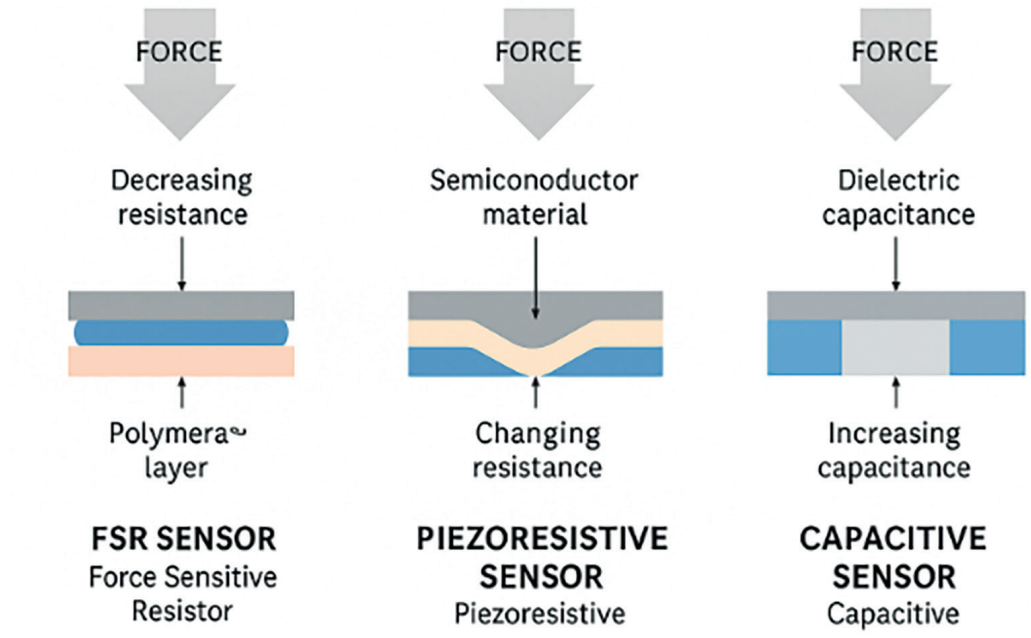

Fig. 2. Representative types of pressure sensors used in gait analysis systems (resistive, piezoresistive, and capacitive)

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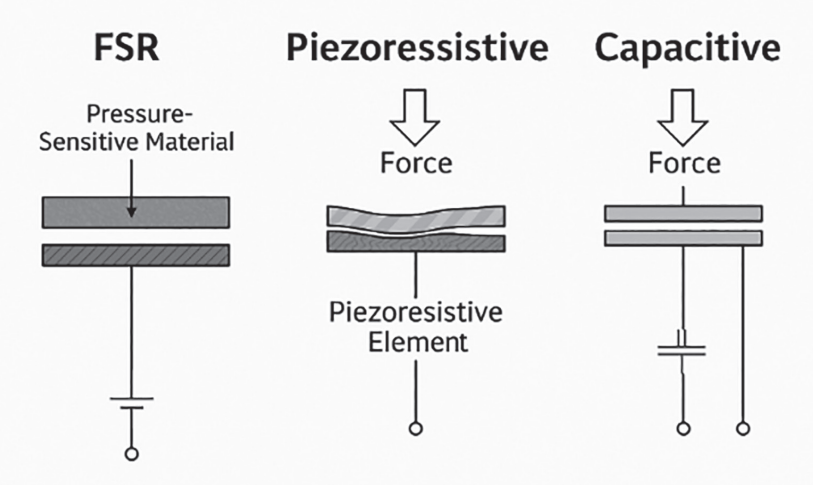

Fig. 3. Operating principles and signal response characteristics of different pressure sensor technologies
Source: own materials

solution designed for widespread use in home and outpatient rehabilitation without the need for the constant presence of a therapist.

REVIEW AND DISCUSSION

PRESSURE SYSTEMS FOR GAIT ANALYSIS

Pressure-based systems are among the most commonly used technologies for biomechanical gait analysis [7-9]. These systems record the force exerted by the foot on the ground or on sensors embedded in specialized insoles, mats, or measuring platforms [7-9]. A key element of these solutions are pressure sensors, which convert mechanical force into an electrical signal for further analysis (Fig. 2) [7,10,11].

Depending on the technology used, several types of pressure sensors can be distinguished. The simplest solution consists of resistive sensors (FSR – Force Sensitive Resistors), in which pressure causes a decrease in electrical resistance [7,10]. Resistive sensors are inexpensive, flexible, and easy to integrate into thin structures; however, they are characterized by limited accuracy and durability [10,11]. Piezoresistive sensors, which utilize the properties of semiconductors that change resistance under strain, offer higher precision and measurement stability, making them suitable for mid-range and professional systems (e.g., Tekscan, Medilogic) [7,10]. The most advanced group of pressure sensors consists of capacitive sensors, where measurements are based on changes in capacitance in response to applied pressure [7,10,11]. This technology provides very high sensitivity and fast response times but is more expensive and complex; therefore, it is mainly used in stationary measuring mats and platforms (e.g., Zebris, GaitRite) (Fig. 3) [7,10,11].

The effectiveness of pressure measurement systems depends on several technical parameters that influence the quality, precision, and clinical utility of the collected data [7-9]. One key parameter is sensor sensitivity, defined as the ability to detect small changes in pressure [7,10]. This is particularly important in assessing subtle gait asymmetries, for example after unilateral total knee replacement, as well as in patients with minor neurological deficits, in whom differences in load distribution are minimal but clinically significant [2,9]. High sensitivity also enables the detection of micro-compensations, which may indicate unconscious pain or early overload changes [7,9].

The measurement range refers to the maximum force the sensor can record without signal distortion [7,10]. This is important not only for obese patients but also for gait analysis in athletes and physically active individuals, where forces can significantly exceed standard values [7,10]. Sensors with a limited range may lead to misinterpretation of data or loss of peak force information [7,10].

Response time determines how rapidly the sensor reacts to changes in force [7,15]. This parameter is crucial for analyzing dynamic gait phases, such as heel strike, foot roll, and toe-off [7,15]. Low sensor inertia allows precise tracking of gait phase transitions, which can be used, for example, to assess fall risk in older individuals or biomechanical performance after ACL reconstruction [7,15].

Repeatability refers to the system's ability to generate a stable and consistent signal after repeated application of the same load [12-14]. High repeatability is essential for monitoring therapy progress over time, particularly in protocols based on quantitative data, such as comparing limb loading after surgery [12-14]. A lack of repeatability may lead to false conclusions regarding improvement or deterioration in the patient's condition [13,14].

The final parameter discussed is spatial resolution, defined as the number of active measurement points per unit area [7,9]. The higher the resolution, the more accurate the representation of pressure distribution across the foot surface [7,9]. This is particularly important in identifying local overloads, such as around the first and fifth metatarsal heads, the heel, or the forefoot [8,9]. This parameter is used, among others, in diabetic foot diagnostics, assessment of orthopedic insole selection, and analysis of compensatory mechanisms after metatarsal fractures or osteotomies [8,9]. In summary, key technical parameters are essential for the design and clinical translation of insole-based systems (Fig. 4).

The market offers both stationary pressure measurement systems (platforms and mats) and mobile solutions

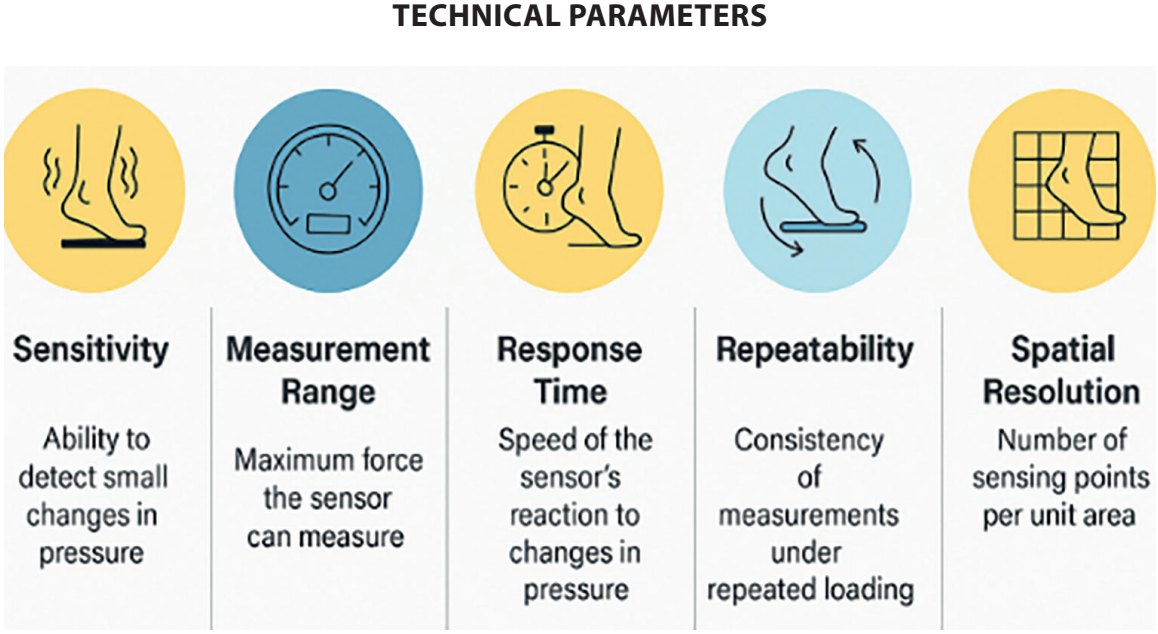

Fig. 4. Key technical parameters determining the performance of pressure-based gait analysis systems, including sensitivity, measurement range, response time, repeatability and spatial resolution

Source: own materials

such as smart insoles, each with distinct performance characteristics [7,16]. Stationary systems enable highly precise measurements under controlled conditions but require laboratory attendance and are often conducted in artificial environments (e.g., barefoot walking or dedicated footwear) [7,8]. Their limited mobility is offset by high resolution and repeatability, making them valuable for clinical diagnostics and research [8,12-14]. Smart insoles, in contrast, allow continuous gait monitoring during everyday activity, offer high user comfort, and are potentially less expensive [16-20]. However, their accuracy depends on the number and placement of sensors, as well as stability in variable environments (e.g., different types of footwear) [17-20].

CLASSIFICATION OF PRESSURE MEASUREMENT SYSTEMS

Contemporary systems for analyzing foot pressure distribution can be divided into two main groups: stationary platforms or mats and smart insoles [7-9]. Both approaches utilize pressure sensors to record foot-ground interactions but differ significantly in design, application, and measurement conditions [7,16].

STATIONARY PLATFORMS AND MATS

Stationary measurement platforms and mats (e.g., Zebris, Tekscan, GaitRite) are considered the gold standard in laboratory-based biomechanical gait analysis [7,8,21,22]. Their operation relies on densely distributed pressure sensors, enabling precise mapping of force distribution under the feet [7,21]. Measurements are performed in strictly controlled environments, most often barefoot or in dedicated footwear [7,8]. These systems offer high spatial resolution, sensitivity, and sampling frequency, making them invaluable for diagnostic and research purposes [7,12,21,22]. However, their limitations include lack of portability, high cost, and the inability to assess gait during daily activities [8,16].

SMART INSOLES

An alternative to stationary systems are mobile, wearable systems in the form of smart insoles [16-20]. Solutions such as Moticon SCIENCE, Medilogic, Loadsol, and OpenGo enable real-time measurements during walking, exercise, and daily activities [16-20].

Smart insoles contain integrated sensors (usually FSR or piezoresistive), whose signals are recorded locally or transmitted to an application via BLE (Bluetooth Low Energy) or Wi-Fi [7,10,11,16-20]. This enables long-term gait monitoring, supports telerehabilitation, and allows patients to independently track therapy progress [16-20,26-28]. A significant advantage is their high comfort, as they can be worn in regular footwear without noticeable changes [18,19,23].

The main limitations of smart insole systems include lower measurement resolution (typically several to a dozen sensors), gradual material wear, the need for data interpretation by a specialist or AI software, and relatively high unit cost, especially in population-scale applications [10,11,17-20,23-25].

To compare the technical capabilities of these two approaches, key parameters of stationary platforms and smart insoles are summarized in Table 1.

APPLICATIONS OF GAIT AND PLANTAR PRESSURE ANALYSIS IN ORTHOPEDIC REHABILITATION

Instrumented and wearable gait analysis systems play a key role in monitoring functional recovery follo-

Table 1. Comparison of stationary pressure measurement platforms and wearable smart insole systems for gait analysis

Technical Parameters	Stationary Platforms & Mats	Smart Insoles
Number of Sensors (Measuring Points)	points/mat	sensors/insert
Sensitivity	Up to N/cm^2	approx. N/cm^2
Measuring Range	Up to N	N (Entire Insole)
Sampling Rate	Hz	Hz
Spatial Resolution	approx. sensors/cm^2	foot sensor/segment
Response Time	< ms	ms
Battery Life	Not Applicable (Network)	hrs (Varies by Model)
System Weight	A Few Kilograms	< g/insert
System Price	EUR	EUR

wing total hip and total knee arthroplasty. These technologies enable objective evaluation of temporo-spatial parameters, joint kinematics, and compensatory movement strategies that may persist despite clinical improvement [2,6,16,17]. Quantitative gait assessment allows early detection of abnormal loading patterns, persistent asymmetry, or reduced joint mobility, which are common after arthroplasty and may influence long-term outcomes [2,6,26]. In addition, plantar pressure measurement and in-shoe sensor systems provide detailed information on weight distribution and limb loading during walking, supporting individualized rehabilitation progression and optimization of gait retraining [3,7,13,18].

Following ligament reconstruction, corrective osteotomy, or fracture management, gait analysis provides an objective method to assess restoration of biomechanical function and detect compensatory movement patterns that may increase the risk of reinjury [2,16,17]. Wearable sensors and pressure-monitoring insoles enable continuous monitoring of load transfer, stance time, and symmetry during the return-to-activity process, allowing clinicians to evaluate functional readiness and guide progressive weight-bearing protocols [16-19,26]. Real-time biofeedback derived from these systems can further enhance motor relearning and improve gait retraining outcomes during rehabilitation [23,25].

Modern gait assessment technologies enable precise quantification of interlimb asymmetry, step count, cadence, and dynamic loading characteristics, which are critical indicators of functional recovery after orthopedic interventions [2,16,17]. Instrumented gait analysis and plantar pressure monitoring allow detailed evaluation of limb loading patterns, ground reaction forces, and gait phase distribution, supporting early identification of maladaptive strategies such as off-loading of the operated limb [3,7,13,18]. Continuous monitoring using wearable and insole-based systems facilitates longitudinal tracking of recovery, objective outcome measurement, and personalized rehabilitation planning [18,19,24,26].].

EUKINES – A NEW GENERATION SYSTEM FOR GAIT ASSESSMENT AND TELEREHABILITATION SUPPORT

The EUKINES system was developed in response to the growing demand for low-cost, accessible, and user-friendly solutions supporting remote orthopedic rehabilitation [5,16,18]. The name "EUKINES" derives from the Greek roots eu- ("good," "correct") and kinesis ("movement"), reflecting the system's core concept of supporting effective, safe, and physiologically correct locomotion during rehabilitation.

The goal of its developers was to create technology enabling patients to independently monitor therapy progress at home without frequent visits to medical facilities [5,26]. A key objective was to combine the functionality of laboratory-grade systems with the mobility, affordability, and ease of use of wearable devices [16,18,19].

The system's central element consists of thin, flexible insoles containing piezoresistive pressure sensors manufactured using layer-by-layer printing technology [10,11]. These sensors utilize conductive compounds, including graphene nanoflakes and silver microflakes, ensuring appropriate sensitivity, durability, and scalability of production while maintaining low unit costs [10,11,27]. The device is laminated onto a polymer film less than 150 micrometers thick, making the insoles virtually imperceptible and suitable for everyday footwear [10,11,18].

Each insole is equipped with a compact electronic module with Bluetooth Low Energy (BLE) communication, which collects and wirelessly transmits sensor data to a mobile application or computer [16-19]. The system supports both local (offline) recording and real-time transmission, enabling gait analysis without interrupting patient activity [16,17,26].

The dedicated EUKINES software provides comprehensive support for the therapeutic process. It enables automatic calibration, 2D and 3D pressure visualization, calculation of key gait parameters (such as force distribution, roll time, step count, and stride length), and automated report generation [16,17,24]. Additionally, the

Fig. 5. Architecture and functional components of the EUKINES wearable insole system with wireless data transmission and software interface
Source: own materials

system includes a biofeedback function that allows patients to correct gait patterns in real time according to therapeutic recommendations [23,25].

Compared to existing commercial solutions such as Moticon SCIENCE, Loadsol, and Medilogic, EUKINES stands out due to its lower unit cost, potential for independent home use, and high manufacturing flexibility [18,19,26]. Its printing-based production enables scalability and adaptation to different patient populations [10,11,27]. Furthermore, cloud integration creates opportunities for the development of AI-based algorithms and specialist teleconsultations [4,23,24,26-28].

EUKINES aligns with the modern model of rehabilitation care – proactive, personalized, and patient-centered – offering a solution that combines high functionality with everyday usability [4,5,24,26,28].

CONCLUSIONS

Pressure-based gait analysis provides an objective and practical approach to assessing patient movement during recovery from orthopedic conditions and surgical procedures. Unlike traditional observational assessment, these technologies enable the detection of subtle asymmetries, compensatory strategies, and changes in limb loading that may otherwise go unnoticed. This offers clinicians more reliable data to support treatment decisions and optimize rehabilitation programs.

Stationary pressure platforms and wearable smart insoles serve complementary roles. Laboratory-based systems provide highly precise measurements under controlled conditions, making them valuable for detailed diagnostics and research. In contrast, wearable insoles enable monitoring during daily activities, offering insight into real functional performance and allowing continuous tracking of rehabilitation progress outside the clinical setting. The integration of wearable sensing technologies with telemedicine, automated data analysis, and biofeedback supports a more individualized approach to rehabilitation. Patients can actively participate in their recovery, while clinicians gain access to objective data that facilitates long-term monitoring and decision-making.

The EUKINES system reflects this shift toward accessible and patient-centered rehabilitation. By combining flexible sensorized insoles, wireless data transmission, automated reporting, and real-time feedback within a low-cost and scalable design, it offers a practical solution for home-based monitoring and therapy support. Overall, pressure-based gait analysis technologies contribute to the transition of orthopedic rehabilitation toward more continuous, personalized, and data-driven care.

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CASE STUDY

Effect of postural stability training on cognitive function in a patient with dementia: a case report

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ABSTRACT

Dementia is a progressive neurodegenerative disease characterized by functional disability and cognitive decline. Physical activity, especially activities that improve postural stability, has been shown to support cognitive function in older adults. The aim of this study was to analyze the effect of postural stability exercises on cognitive function in a patient diagnosed with dementia. A 62-year-old male patient with a history of dementia was included in the study. He presented with memory loss, confusion, and a medical history of diabetes and mild osteoarthritis in both knees. The patient underwent balance training, proprioceptive activities, and coordination drills for 30 minutes over three weeks on alternate days. MMSE and MoCA were used to evaluate changes in cognitive function, while the Berg Balance Scale and TUG test were used to assess postural stability before and after the intervention. Following the intervention, an improvement in cognitive function was observed. The study suggests that postural stability exercises may have a positive effect on cognitive function in a patient with dementia.

KEYWORDS: dementia, cognitive function, postural stability, balance training, rehabilitation

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INTRODUCTION

Dementia is a long-term and progressively worsening cognitive disorder that involves memory impairment along with deficits in at least one other cognitive domain, such as language, orientation, reasoning, attention, or executive functioning–the ability to plan and organize tasks. This decline must be significant compared to the individual's previous cognitive abilities and severe enough to disrupt daily activities and independent living [1]. According to a 2023 nationwide survey published in Alzheimer's & Dementia, 7.4% of Indian adults aged 60 years and older–or around 8.8 million people–have dementia. With higher rates observed among women and in rural areas, this prevalence exceeds previous estimates and demonstrates notable differences among states [2]. Postural stability exercises, which focus on balance and coordination, may enhance brain function by improving neural connectivity and reducing fall risk, thereby contributing to better cognitive and functional outcomes [3,4]. For older persons with moderate cognitive impairment (MCI), balance and core resistance training have been linked to gains in both general and specific cognitive domains [5]. Poorer balance in older persons is associated with a faster rate of cognitive decline, according to longitudinal research. This suggests that balance tests could be used as early markers of cognitive impairment [6]. In older adults, even a single session of balance and coordination training can result in measurable improvements in attention and executive function [7]. Apart from physical activity, other interventions have also shown promise in maintaining or improving cognitive function. These include cognitive training programs, pharmacological treatments (such as cholinesterase inhibitors), dietary changes (such as the Mediterranean diet), and social engagement activities [8]. The Montreal Cognitive Assessment (MoCA) is a widely used screening tool designed to evaluate cognitive function across multiple domains, including attention, executive functioning, memory, language, and visuospatial abilities. It is particularly useful in detecting mild cognitive impairment (MCI) and early dementia, providing a more comprehensive assessment compared to other cognitive tests. Research has indicated that physical activity, including balance training and postural stability exercises, may positively influence MoCA scores by promoting neural plasticity and cognitive resilience [9]. The Mini-Mental State Examination (MMSE) is a well-recognized measure for detecting cognitive impairment. Although it is most effective for detecting dementia, low scores may indicate other conditions, such as delirium or depression. It is applicable in many physiotherapy settings, including ambulatory, home, and inpatient care. A score below 24 necessitates further evaluation, including informant history and more comprehensive cognitive assessment. Routine screening with tools such as the MMSE is recommended for detecting cognitive impairment, particularly in higher-risk groups, such as older inpatients [10]. The Timed Up and Go (TUG) test is a widely used clinical tool to assess mobility and fall risk in both hospital and community settings. It measures the time taken for an individual to stand up from a chair, walk three meters, turn, return, and sit down. Shorter completion times indicate better functional per-

formance. A cutoff value of approximately 13.5 seconds is commonly used to identify individuals at increased risk of falls. The test is simple, quick to administer, and requires minimal equipment, making it suitable for routine clinical use. It also allows the use of customary walking aids, ensuring a more functional assessment of mobility [11]. The Berg Balance Scale (BBS) is frequently used in clinical practice to predict falls in older adults. Postural instability has significant consequences, including fear of falling and increased susceptibility to falls. Functional assessment of balance is therefore widely used to identify early abnormalities in postural control and predict fall risk. The BBS is commonly used because it is easy to administer (approximately 15 minutes), requires minimal resources, and includes tasks such as single-leg stance and functional reach [12].

AIM

Hence, the aim of this study was to determine whether a structured postural stability training program can help delay cognitive decline and improve quality of life by assessing its effect on cognitive function, balance, and overall functional performance in a patient with dementia.

CASE DESCRIPTION

A 62-year-old male was referred to the neurophysiotherapy department with complaints of progressive memory loss, confusion, and an inability to perform everyday activities independently. Additional information from the patient's history indicated difficulty walking, emotional instability, and frequent misplacement of household items. According to the patient's medical history, he had mild osteoarthritis in both knees and was diagnosed with diabetes, for which he was on regular medication. He had no history of alcohol use or smoking. Family history revealed that his father had Alzheimer's disease.

The patient's initial cognitive scores were 20 on the Mini-Mental State Examination (MMSE) and 18 on the Montreal Cognitive Assessment (MoCA). Postural stability was assessed using the Berg Balance Scale (BBS), with a score of 38, and the Timed Up and Go (TUG) test, with a time of 18 seconds.

A musculoskeletal examination was performed, focusing on joint range of motion and lower limb strength, particularly in relation to the presence of mild osteoarthritis in both knees. Gait and posture were also evaluated to identify any instability or compensatory movement patterns. Standardized functional scales were used to assess the patient's ability to perform activities of daily living (ADLs). Additionally, peripheral neuropathy and other diabetes-related complications were screened to ensure that these factors were considered in the rehabilitation plan.

Fig. 1a,b. Postural stability exercise performed by the patient in standing

METHODOLOGY

INTERVENTION

The patient underwent a personalized rehabilitation program consisting of 30-minute sessions over 3 weeks, four times per week. The treatment protocol included a combination of static balance training, involving maintenance of stable standing postures, and dynamic balance training with controlled movements to improve stability during motion (Fig 1a,b). Weight-shifting exercises were used to enhance proprioceptive input and postural control. Cognitive tasks were integrated into balance training to promote dual-task performance and improve attention

Table 1. Intervention protocol

Week	Duration per session	Frequency	Cognitive intervention	Physical intervention
Week 1	30 minutes	4 times/ week	3 mins counting backwards during single-leg stance (3–4 reps) Object recall during weight shifting (5–6 reps)	Static balance: Tandem stance & single-leg stance (10–15 sec, 3–4 reps each) Weight-shifting (5 min, 8–10 reps per direction: side-to-side, diagonal, forward–backward)
Week 2	30 minutes	4 times/ week	Naming colours while walking (5 min, 4–5 trials) Answering questions during obstacle navigation (5–6 responses) Word recall on foam surface (3 min, 4–5 reps)	Dynamic balance training (5 min) Gait training – straight-line walking (4–5 trials) Obstacle negotiation (5 min, 4–5 reps) Head turns during walking (5 min, 8–10 reps)
Week 3	30 minutes	4 times/ week	Conversational tasks during walking (5 min) Dual-task ADL training (5 min, 4–5 reps)	Functional task training (5 min) Picking objects from floor (6–8 reps) Folding towels in standing (4–5 reps) Walking with functional tasks (5 min, 3–4 trials)

and executive function. Gait training was also included to support safe and efficient walking patterns (Table 1).

Week 1: The intervention was conducted for 30 minutes per session, four times per week. The focus during this phase was on static balance and basic postural control. Physical training included tandem stance and single-leg stance (10–15 seconds with support), each performed for 3–4 repetitions, along with weight-shifting exercises in multiple directions (side-to-side, diagonal, and forward–backward) for approximately 5 minutes (8–10 repetitions per direction). Cognitive components were integrated through tasks such as counting backwards during single-leg stance (3 minutes) and object recall during weight-shifting activities (5–6 repetitions), targeting attention and memory.

Week 2: Sessions continued for 30 minutes, four times per week, with progression to dynamic balance activities. Physical interventions included gait training with straight-line walking (5 minutes, 4–5 trials), obstacle negotiation (5 minutes, 4–5 repetitions), and head-turn movements during walking for vestibular training (5 minutes, 8–10 repetitions). Cognitive tasks were incorporated, such as naming colours while walking (5 minutes), answering questions during obstacle navigation (5–6 responses per trial), and word recall tasks on a foam surface (3 minutes, 4–5 repetitions), increasing cognitive-motor demand.

Week 3: During the final week, the intervention emphasized functional and task-oriented training, maintaining the same session duration and frequency. Physical activities included picking up objects from the floor (5 minutes, 6–8 repetitions), folding towels in standing, including single-leg stance (5 minutes, 4–5 repetitions), and walking with functional tasks (5 minutes, 3–4 trials). Cognitive engagement was enhanced through conversational tasks during walking (5 minutes) and dual-task ADL training (5 minutes, 4–5 repetitions), promoting real-life cognitive–motor integration.

RESULTS

The study demonstrated an improvement in cognitive function along with improvement in postural stability. Table 2 presents cognitive scores measured using the MoCA and MMSE before and after the intervention. MoCA scores improved from 18 to 21, while MMSE scores improved from 20 to 23, indicating improved cognitive performance. Table 3 presents changes in postural stability before and after treatment. The Berg Balance Scale score improved from 38 to 43. The TUG test time improved from 18 to 16 seconds, indicating improved postural stability.

DISCUSSION

The aim of this study was to determine the effect of a structured postural stability exercise program on cognitive function, postural stability, and functional independence in a patient with dementia. Both cognitive performance and postural stability showed improvement following the intervention. The novelty of this study lies in its integrative rehabilitation approach, targeting both motor and cognitive impairments through structured postural stability training. Unlike traditional rehabilitation methods that often address cognitive and motor deficits separately, this case study emphasizes a combined strategy involving both domains. The findings suggest that improving postural control may positively influence cognitive function. These improvements may reflect enhanced cognitive–motor interaction, with better proprioceptive input and postural control potentially supporting neural integration.

Previous research indicates that postural control during activities such as turning and transitioning to sitting requires considerable cognitive engagement in everyday life, highlighting the close interaction between cognitive and motor functions. Consequently, in balance and motor rehabilitation, the evaluation of cognitive function should be considered an important component rather than being overlooked. Supporting this relationship, previous studies have reported that even a single session of coordination and balance-based intervention can lead to measurable improvements in attention and executive function among older adults [7,13].

According to existing literature, exercises focused on postural stability can enhance balance and physical performance in older adults with cognitive impairment; however, their impact on fall reduction is inconsistent when implemented as a single intervention. In contrast, multidimensional approaches that combine physical activity with cognitive involvement appear to yield greater impro-

Table 2. Cognitive function assessment

TOOL	PRE TEST SCORE	POST TEST SCORE	RANGE BETWEEN PRE AND POST TEST SCORE
MMSE	20	23	+3
MoCA	18	21	+3

Table 3. Balance and functional mobility assessment

TOOL	PRE TEST SCORE	POST TEST SCORE	RANGE BETWEEN PRE AND POST TEST SCORE
BBS	38	43	+5
TUG	18	16	-2

vements in mobility and functional capacity. Additionally, integrating cognitive stimulation into balance training may further optimize postural control [14,15].

Evidence suggests that exercise interventions produce limited and variable improvements in cognitive function in individuals with dementia, with outcomes differing across studies. Additionally, no specific exercise parameters, such as type, intensity, or duration, have been consistently identified as key determinants of cognitive change. These findings highlight the importance of structured and targeted interventions addressing both motor and cognitive aspects, which may contribute to improved functional outcomes [16–18].

Exercise training has been shown to reduce the dependence on prefrontal cognitive resources involved in executive function and attention during complex motor tasks, potentially allowing more efficient use of cognitive capacity in everyday activities and reducing fall risk [19]. In addition, resistance training has been associated with improvements in executive function and physical performance. Although these findings are based on different exercise approaches, they are consistent with the present study and suggest that postural stability exercises may contribute to improvements in both cognitive and motor function through cognitive–motor integration [20,21].

This study is limited by its single-case design, absence of a control group, short intervention duration, and lack of long-term follow-up, which restrict generalizability and causal interpretation. Additionally, possible assessor bias, limited sensitivity of screening tools to detect subtle cognitive changes, and the influence of comorbid conditions may affect the reliability of the findings. Future research should include larger samples, randomized controlled designs, standardized protocols, longer follow-up periods, and more comprehensive outcome measures to strengthen the evidence and improve clinical applicability.

CONCLUSIONS

Structured postural stability training may have a positive impact on cognitive performance, potentially through improved sensorimotor integration, cerebral perfusion, and reduced fall risk. The observed improvements in balance and coordination may contribute to increased functional independence, which can indirectly support cognitive functions such as attention, executive function, and memory. Improved balance and postural control may also contribute to better spatial awareness and overall quality of life. These findings suggest a potential role for postural stability training in multimodal dementia rehabilitation programs.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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29th Balneology Course, April 2026

Irena Ponikowska

CIECHOCINEK, POLAND

From 13 to 24 April 2026, the 29th Balneology Course for Physicians took place in Ciechocinek. The course focused on "Balneology and Physical Medicine – Therapeutic Methods and Selected Issues in Thermal Medicine".

The programme spanned 82 hours of instruction, including 78 hours of lectures and 4 hours of hands-on workshops held in two groups at St. George Balneology Centre.

Sixty-one physicians from across Poland participated, most of them holding clinical specialisations in various fields.

As in previous editions, the course covered the core topics of thermal geology, climatology, balneochemistry, indications and contraindications for thermal therapy, and health-resort infrastructure. All major balneotherapy and physiotherapy methods were discussed, with the final section of the programme devoted to selected clinical issues viewed through the lens of thermal medicine.

During the course, the participants also had the opportunity to meet with the National Consultant in Balneology and Physical Medicine, Dr Aleksandra Sędziak, which enabled them to learn about organisational aspects and future development prospects of Polish thermal therapy centres. The course concluded with a meeting with Professor Joanna Głogowska-Szeląg, President of the Polish Association of Balneology and Thermal Medicine. Participants thus had the chance to meet some of the most prominent figures in the fields of balneology and physical medicine.

On the final day of the course, participants were required to take a written test covering the topics addressed throughout the programme. The test consisted of 40 single-choice questions and was by no means straightforward – yet every participant passed, achieving either a good or very good result. Correct answers ranged from 83% to 97%, reflecting a strong overall performance across the group. Upon passing the test, participants received certificates of course completion along with the relevant professional credentials during a formal ceremony.

Throughout the course, participants showed keen interest in the subject matter, engaged actively in all sessions, and took part in lively discussions following the lectures. They also had the opportunity to purchase publications directly from the publisher, including the two-volume handbook "The Great Book of Balneology, Physical and Thermal Medicine" as well as a newly released title by Professor Irena Ponikowska, "On Longevity and Good Quality of Life". Also available was the newly reissued „Encyclopedia of Balneology and Physical Medicine", reprinted this year. These resources will allow participants to consolidate and expand the knowledge gained throughout the course.

According to participant feedback, the course was of an exceptionally high standard, with a distinctly interdisciplinary and holistic character. The presentation format was particularly praised for making the subject matter engaging

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and accessible. A significant number of participants also expressed their intention to join the Polish Association of Balneology and Physical Medicine.

The course was held in excellent facilities at St. George Family & Senior Spa in Ciechocinek, located in the very heart of the health resort. I would like to extend my sincere thanks to the owners and staff of the venue for their commitment and for creating such a welcoming atmosphere. My gratitude also goes to everyone involved in organising the course, including Ms Anita Gawrońska, Ms K. Golis, Ms Diana Nowosad, and others. A special word of thanks is due to Dr Katarzyna Placek, whose support was invaluable both in coordinating the course and in leading the practical workshops and lectures.

The course was conducted in a spirit of friendliness and teamwork. The Social Coordinator chosen by the physicians cooperated excellently and worked hard to integrate the entire group. An important added value of the course was the opportunity for face-to-face – rather than virtual – interaction, which enabled networking and the exchange of expertise across various medical fields. On Saturday, mid-way through the course, an additional group of balneology enthusiasts from previous editions gathered in Ciechocinek. This reunion was initiated by Dr Monika Donderska, the Social Coordinator of the 27th balneology course.

The course concluded with a "family" group photo and several smaller group sessions. A selection of these photos is attached.

We also thank the participants for their enthusiasm and for fostering a collegial, friendly atmosphere, with special appreciation to the Social Coordinator, Dr Mateusz Stolarski.

Scientific Director of the Course
Prof. Irena Ponikowska, MD, PhD

Source: author's archive