Acta Balneologica

Published since 1905

ISSN 2082 - 1867

JOURNAL OF THE POLISH BALNEOLOGY AND PHYSICAL MEDICINE ASSOCIATION

2026 MAY-JUNE VOL. LXVIII ISSUE 3 (193)

THERMAL MEDICINE – THERAPY, PREVENTION, REHABILITATION

PHYSICAL THERAPY • BIOKLIMATOLOGY • BALNEOGEOLOGY • BALNEOCHEMISTRY

- Evaluation of rehabilitation outcomes in chronic low back pain
- Medical students' knowledge of biofeedback therapy and their cognitive, emotional, and behavioral attitudes towards its application in treatment
- The impact of a comprehensive cardiorespiratory exercise program on Long COVID survivors
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- Remote forward head posture evaluation using the photogrammetric method

Patronage of Committee of Rehabilitation, Physical Education and Social Integration of the Polish Academy of Sciences

ISSN 2082-1867

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2026 MAY-JUNE VOL. LXVIII ISSUE 3 (193)

Aluna PUBLISHING HOUSE

Acta Balneologica

PROJECT COORDINATOR:
MEDDOM PRESS
tel. +48 604 208 453
barbadom@wp.pl

GRAPHIC DESIGN:
Joanna Gębalska

PUBLISHER:
ALUNA Publishing
29 Z.M. Przesmyckiego St.
05-510 Konstancin Jeziorna, Poland
www.actabalneologica.pl

The journal is indexed in Web of Science – ESCI, Index Copernicus, EBSCO, Ministry of Science and Higher Education and the Polish Medical Bibliography

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ORIGINAL ARTICLE

Evaluation of rehabilitation outcomes in chronic low back pain: fascial therapy versus conventional physiotherapy

Rafał Trąbka[1], Julia Gluza[2], Stanisław Szymanik[3], Małgorzata Szarota[4], Martyna Boba[4]

[1]REHABILITATION CLINIC OF THE DEPARTMENT OF REHABILITATION, FACULTY OF HEALTH SCIENCES, JAGIELLONIAN UNIVERSITY MEDICAL COLLEGE, CRACOW, POLAND

[2]FACULTY OF HEALTH SCIENCES, JAGIELLONIAN UNIVERSITY MEDICAL COLLEGE, CRACOW, POLAND

[3]SURGERY CLINIC OF THE DEPARTMENT OF REHABILITATION, FACULTY OF HEALTH SCIENCES, JAGIELLONIAN UNIVERSITY MEDICAL COLLEGE, CRACOW, POLAND

[4]PHYSIOTHERAPY DEPARTMENT, RST REHABILITACJA, CRACOW, POLAND

ABSTRACT

Aim: The aim of this study was to evaluate and compare two physiotherapeutic treatment models for chronic low back pain: 1. fascial therapy (myofascial release) combined with breathing exercises, and 2. conventional therapy (massage, physical therapy, and kinesiotherapy).

Materials and Methods: Fifty participants were randomly assigned to two groups: fascial therapy (n = 25) and conventional physiotherapy (n = 25). A two-week rehabilitation program comprising ten individual sessions was implemented. Pain intensity was assessed using the Short-Form McGill Pain Questionnaire (SF-MPQ). Disability level was evaluated using the Revised Oswestry Low Back Pain Disability Questionnaire. Trunk flexion range of motion was assessed in both seated and standing positions. Participants completed the questionnaires at three time points: prior to therapy, after five sessions, and after ten sessions.

Results: Fascial therapy resulted in a significantly faster reduction in pain symptoms ($p < 0.05$). However, at the end of the intervention period, both groups achieved a comparable overall improvement in pain. Fascial therapy was associated with a significantly greater reduction in disability levels. No statistically significant differences were found between groups in terms of changes in range of motion.

Conclusions: Fascial therapy combined with breathing exercises enables a more rapid reduction of pain and disability in patients with chronic low back pain. Both treatment strategies are effective in reducing pain and improving functional range of motion. Further research is necessary to determine the optimal protocols for managing chronic low back pain.

KEYWORDS: low back pain, myofascial release, exercise therapy, rehabilitation

Acta Balneol. 2026;68(3): 137-141. doi: 10.36740/ABAL202603101

INTRODUCTION

The prevalence of lumbar spine pain has been steadily increasing in recent years and requires appropriate countermeasures. Conservative management, especially physiotherapy, is an effective method for addressing these symptoms. Such interventions include massage, kinesiotherapy, physical therapy, and manual therapy. Nevertheless, researchers worldwide continue to seek the most effective rehabilitation models for low back pain (LBP) [1-4].

Epidemiological data suggest that approximately 60–90% of the population have experienced, or will experience, at least one episode of low back pain during their lifetime [1-3, 5]. LBP occurs slightly more frequently in women than in men. Regarding age distribution, the number of cases gradually increases from birth until around 40-50 years of age, then progressively decreases. The highest prevalence is among individuals aged 35-64 years, accounting for 50% of all cases [5]. LBP also affects children and adolescents, with prevalence ranging from 12.5% to 76.2%, depending on age, and tends to increase with age [6, 7].

LBP ranks among the leading causes of disability worldwide. The disability-adjusted life years (DALY) index for LBP is 64.9 million annually, with a global prevalence of 577 million cases per year. Projections based on data collected over the past 25 years estimate that these indicators will increase approximately 1.45-fold by 2050 [5].

Manual therapy, broadly defined, is highly popular in LBP rehabilitation. Among its numerous techniques, fascial therapy allows for a holistic view of the body; fascia constitutes an inseparable whole permeating all human tissues [8]. Other widely used physiotherapeutic methods include kinesiotherapy, physical therapy, and massage [4, 5, 9-11].

AIM

The aim of this study was to evaluate and compare two physiotherapy models for the rehabilitation of chronic lumbar spine pain. The first rehabilitation model was based on fascial therapy combined with specific breathing exercises. The second model incorporated elements of conventional physiotherapy, including classical massage, kinesiotherapy, and physical therapy. The study aimed to determine whether one of the proposed interventions would demonstrate greater therapeutic effectiveness in terms of pain reduction, disability level, and lumbar spine range of motion.

MATERIALS AND METHODS

This study was conducted as an experimental study. Approval was obtained from the Bioethics Committee of Jagiellonian University (decision no. 1072.6120.121.2024). The study was conducted at the medical facility RST Rehabilitacja in Biały Kościół from May 6, 2025, to September 1, 2025.

The study group comprised 50 participants (35 women and 15 men). Random allocation was performed using a random number generator, resulting in two groups:

- Group 1 (n = 25; 17 women, 8 men): fascial therapy combined with breathing exercises.
- Group 2 (n = 25; 18 women, 7 men): conventional physiotherapy (physical therapy, kinesiotherapy, and classical massage).

Inclusion criteria

- Age ≥ 18 years (no upper age limit).
- Lumbar spine pain persisting for at least 12 weeks after an acute pain episode.
- ICD-10 diagnosis: M54, M47 (with specification), or M51 (lumbar region).
- Signed informed consent for participation.

Exclusion criteria

- Use of analgesics, antidepressants, anxiolytics, or neuroleptics.
- History of spinal surgery.
- Diagnoses: Ankylosing Spondylitis, Rheumatoid Arthritis, Psoriatic Arthritis.
- Structural spinal changes: spondylolisthesis or spondylolysis.
- Scoliosis grade II or higher.
- Active thromboembolic disease of the lower limbs.
- Coexisting CNS disorders, including post-stroke conditions.
- Active malignancy.
- Respiratory and/or cardiovascular diseases contraindicating physiotherapy.
- Osteoporosis.
- Pregnancy.
- Lack of patient consent.

The research tools included an author-designed informational questionnaire, the Short-Form McGill Pain Questionnaire, the Revised Oswestry Low Back Pain Disability Scale, and two functional tests: the forward trunk flexion in the sitting position test and the finger-to-floor test.

Intervention protocol

Participants from each group attended rehabilitation for two weeks (10 sessions in total) and completed questionnaires and functional assessments at three time points: before therapy, after five sessions, and after ten sessions. Each group was assigned a separate team of physiotherapists, whose composition remained unchanged throughout the study to ensure consistency.

Fascial therapy

Group 1 participants underwent active release techniques and myofascial release. Manual techniques were applied until a "tissue response" was achieved, verified through palpation and the patient's subjective perception of relaxation. Tools included fingertips, interphalangeal joints, fist, forearm, and olecranon. The following body regions were treated: the fascia at the proximal attachment of the gluteus maximus; the anterior and posterior fascia of the gluteus medius along the fan of the peri-trochanteric muscles; the fascia of the tensor fasciae latae and the iliotibial band; the fascia of the back muscles (erector spinae, deep layer of the back muscles, multifidus); quadratus lumborum; fascia in the region of the sacrococcygeal ligament; fascia of the piriformis; fascia of the rectus abdominis; fascia of the suboccipital muscles; the region of the splenius capitis and cervicis; fascia of the lumbrical muscles; the lateral band of the plantar fascia; the region of the calcaneus; the anterior, lateral, posterior, and deep posterior compartments of the lower leg; the knee joint region (peripatellar tissues, pes anserinus area); the fascia of the quadriceps femoris; the fascia of the hamstrings; fascia of the gastrocnemius and popliteus; the anterior and posterior intermuscular septa of the thigh (adductor muscles); and the fascia of the psoas and iliacus muscles. In addition, specific breathing exercises were performed under supervision, based on diaphragmatic activation and pelvic tilt maneuvers, both in supine and quadruped positions:

1. Supine position with feet against the wall, hips and knees flexed to 90°.
2. Upper extremities positioned at 90° shoulder flexion, in maximal protraction.
3. Nasal inhalation; during oral exhalation, the patient performs posterior pelvic tilt, elevating the coccyx from the mat while maintaining the rest of the spine flat.
4. Contraction of the lower limb muscles as if pressing the heels downward.
5. Nasal inhalation followed by exhalation through pursed lips.
6. A 3-second breath hold, followed by repetition of the inhalation-exhalation sequence four times in total.
7. Relaxation and return to the initial position.

Conventional physiotherapy

Group 2 participants underwent physical therapy, kinesiotherapy, and classical back massage. Physical therapy modalities included TENS, electrostimulation, laser therapy, ultrasound, magnetotherapy, and infrared radiation therapy in the IR-A and IR-B ranges. Kinesiotherapy consisted of supervised exercises (e.g., bridges, superman, back extensions, stretching, pelvic rotations, "cat-cow" poses). Classical massage employed techniques such as stroking, rubbing, kneading, compressions, tapping, vibration, and shaking.

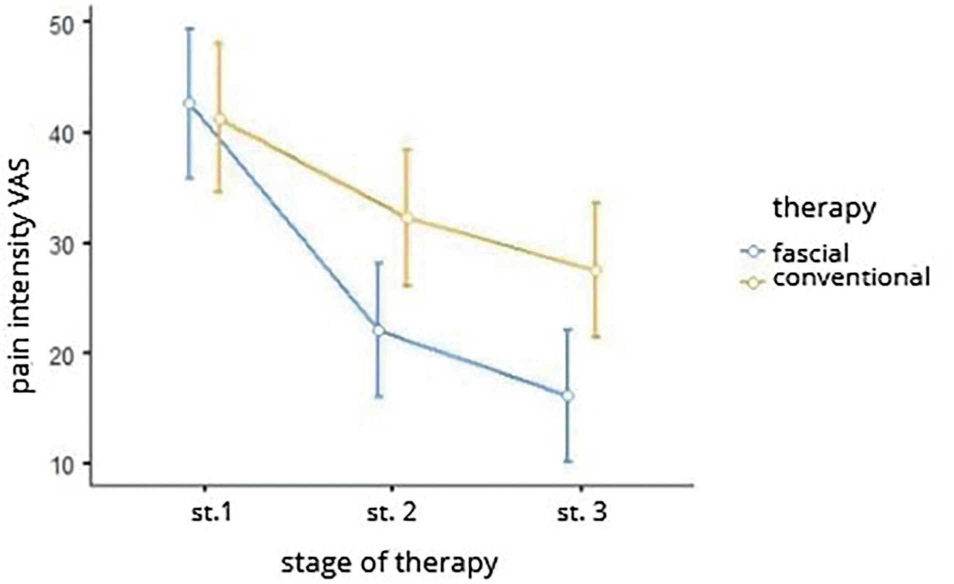

Fig. 1. Changes in pain intensity on the VAS scale during the course of therapy
Source: compiled by the authors of this study

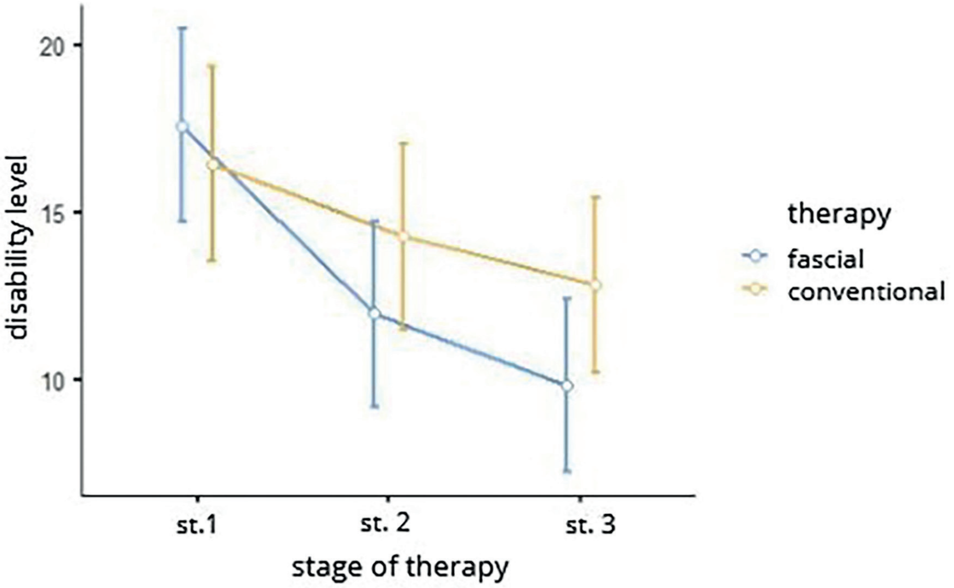

Fig. 2. Change in the disability level during the course of therapy
Source: compiled by the authors of this study

Group characteristics

The total study population included 35 women (70%) and 15 men (30%) with chronic lumbar spine pain. In both groups, women constituted the majority, accounting for 68% in Group 1 and 72% in Group 2. The largest age group was 46-55 years. The fascial therapy group included more participants engaged in physical work (40%) compared to the conventional therapy group, where mixed-type work (standing-sitting) predominated (68%). Most participants reported occasional physical activity. The majority lived in rural areas (92% in Group 1 and 96% in Group 2). The mean BMI was 27.19 in the fascial therapy group and 26.39 in the conventional therapy group.

RESULTS

Statistical analyses were performed using R (version 3.6.0), PSPP, and MS Office 2019. A significance threshold of $p = 0.05$ was applied. Two-factor repeated-measures ANOVA was used.

Pain intensity assessed with the VAS decreased more markedly in the fascial therapy group (M = 42.64 to M = 16.12) compared with the conventional therapy group (M = 41.28 to M = 27.48). No significant between-group differences were observed for pain continuity or sensory and affective dimensions. A significant main effect of time ($p < 0.05$) and a significant interaction effect of therapy type × time ($p < 0.05$) were identified. Post-hoc analysis indicated a greater reduction in VAS scores following fascial therapy at the second measurement; however, after treatment completion, intergroup differences were no longer statistically significant (Fig. 1).

Both groups demonstrated improvement in terms of disability level, but a more pronounced reduction was noted in the fascial therapy group (mean from 17.60 to 9.84) compared with the conventional therapy group (mean from 16.44 to 12.84). A significant decrease in disability was achieved between the first and second measurements in the fascial therapy group. Fascial therapy resulted in a significant reduction in disability level (Fig. 2).

Table 1. Results of ANOVA for within- and between-subject effects of therapy stages and types in relation to changes in range of motion in the standing position

Type of effect	Effect	SS	df	F	p
within-subject effects	stage of therapy	227,43	2	12,90	< 0,001
	stage of therapy*therapy	2,56	2	0,15	0,865
	residual	846,51	96		
between-subject effects	therapy	955,08	1	3,26	0,077
	residual	14071,29	48		

SS - sum of squares; df - degrees of freedom; F - analysis of variance test statistic; p - statistical significance

Source: compiled by the authors of this study

In the finger-to-floor test, the fascial therapy group improved from 14.24 cm to 11.74 cm, compared with a decrease from 9.52 cm to 6.68 cm in the conventional therapy group. In the forward trunk flexion in the sitting position test, the fascial therapy group improved from 1.94 cm to 1.08 cm, whereas the conventional therapy group showed a slight increase (from 1.94 cm to 2.26 cm). No statistically significant intergroup differences were found, although significant improvements over time were observed in both groups ($p < 0.05$) (Table 1).

DISCUSSION

The present study confirmed the effectiveness of both fascial therapy combined with breathing exercises and conventional physiotherapy in treating chronic low back pain. However, fascial therapy resulted in a faster reduction in pain intensity and disability. This may be attributed to its direct influence on the modulation of soft tissue tension and elasticity, thereby decreasing nociceptor irritation. These findings are consistent with previous research by Tamartash & Bahrpeyma [12], which demonstrated comparable effectiveness of fascial therapy and physical therapy for pain reduction and mobility improvement, although intermediate measurements were not performed. Further studies by Tamartash et al. [13] confirmed that fascial techniques applied both locally and remotely can significantly reduce symptoms, supporting the systemic role of the fascial network.

Breathing exercises played an essential role in the present protocol. Jiang et al. [14] demonstrated their efficacy in reducing pain and disability in patients with LBP, likely by improving diaphragmatic activation, postural control, and deep core muscle integration. Conventional therapy outcomes in this study are consistent with the findings of Dal et al. [15] and Er & Yüksel [11], who reported comparable effectiveness of classical and connective tissue massage. Nevertheless, fascial therapy appeared to promote superior functional outcomes, possibly due to its broader systemic impact on musculoskeletal integration. Reports by Li et al. [16], indicating greater effectiveness of combining breathing exercises with deep muscle training than muscle training alone, suggest that incorporating such a protocol could further enhance the efficacy of fascial therapy in patients with LBP.

Strengths of this study include the relatively large sample size (n = 50) and the use of three measurement time points, enabling evaluation of treatment dynamics. Limitations include the short observation period (two weeks) and the absence of a control group, making it difficult to assess treatment effects compared with no intervention. Overall, both therapeutic strategies are effective in managing chronic LBP, although fascial therapy combined with breathing exercises may facilitate faster pain reduction and improved function. Future studies with larger samples and longer follow-up periods are warranted.

CONCLUSIONS

1. Fascial therapy led to a significantly faster reduction in pain symptoms, although post-treatment outcomes were comparable between groups.
2. Fascial therapy resulted in a significantly greater reduction in disability levels than conventional therapy.
3. The type of therapy did not significantly influence changes in range of motion in functional tests.
4. Further studies are necessary to determine the most effective methods for treating chronic lumbar spine pain.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Rafał Trąbka
Rehabilitation Clinic of the Department of Rehabilitation,
Faculty of Health Sciences, Jagiellonian University Medical College,
Kraków, Poland
e-mail: rafal.trabka@uj.edu.pl

ORCID AND CONTRIBUTIONSHIP

Rafał Trąbka - 0000-0002-2663-9617 A E F
Julia Gluza - 0009-0005-3135-2097 B C D
Stanisław Szymanik - 0000-0002-0411-6508 F
Małgorzata Szarota - 0009-0003-2844-7816 A B
Martyna Boba - 0009-0002-0398-7632 B

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 24.09.2025
ACCEPTED: 10.03.2026

ORIGINAL ARTICLE

Medical students' knowledge of biofeedback therapy and their cognitive, emotional, and behavioral attitudes toward biofeedback

Joanna Agnieszka Smolarczyk[1], Paweł Gustaw Dębski[1], Kamil Nikel[2], Aleksandra Lewandowska[3], Piotr Pałczyński[4], Dorota Turska-Czyż[1], Magdalena Justyna Piegza[1], Łukasz Kunert[1], Piotr Gorczyca[1]

[1]DEPARTMENT OF PSYCHIATRY, FACULTY OF MEDICAL SCIENCES IN ZABRZE, MEDICAL UNIVERSITY OF SILESIA, TARNOWSKIE GORY, POLAND

[2]STUDENTS SCIENTIFIC ASSOCIATION, DEPARTMENT OF PSYCHIATRY, FACULTY OF MEDICAL SCIENCES IN ZABRZE, MEDICAL UNIVERSITY OF SILESIA IN KATOWICE, KATOWICE, POLAND

[3]DEPARTMENT OF SPECIAL EDUCATION AND CREATIVE ACTIVITIES, FACULTY OF EDUCATION, UNIVERSITY OF BIALYSTOK, BIALYSTOK, POLAND

[4]INSTITUTE OF PSYCHOLOGY, FACULTY OF PSYCHOLOGY, HUMANITAS UNIVERSITY IN SOSNOWIEC, SOSNOWIEC, POLAND

ABSTRACT

Aim: This study aimed to evaluate medical students' knowledge of biofeedback therapy and to explore their cognitive, emotional, and behavioral attitudes toward this method. The study also examined whether students' year of study influenced their awareness and perceptions of biofeedback.

Materials and Methods: The study was conducted using a diagnostic survey approach. A custom-designed questionnaire developed by a multidisciplinary team was used and distributed between February 10 and March 10, 2025. The questionnaire included demographic questions and items assessing knowledge as well as cognitive, emotional, and behavioral attitudes toward biofeedback therapy. Participation was voluntary and anonymous

Results: The sample consisted of 207 medical students. Only 40% of students correctly defined biofeedback therapy. A majority (71%) were unaware of its recognition as an evidence-based treatment, and more than half of the students (53%) rated their knowledge of the method as poor. Emotional and behavioral attitudes were generally neutral, with 84% expressing no strong feelings toward biofeedback and the majority being unsure about its potential use or recommendation. A higher proportion of fifth-year students reported more favorable views and greater familiarity with the method than second-year students, although positive responses remained a minority in both groups.

Conclusions: Medical students exhibit limited knowledge of biofeedback therapy and its clinical applications. Due to the insufficient level of awareness, their attitudes toward this method remain largely undefined. Integrating biofeedback-related content into medical curricula may support better understanding and informed future use in clinical practice

KEYWORDS: biofeedback; medical students; knowledge; attitudes; medical education

Acta Balneol. 2026;68(3): 142-151. doi: 10.36740/ABAL202603102

INTRODUCTION

Biofeedback therapy is a complementary treatment method used alongside conventional medicine for managing various disorders and diseases [1]. In recent years, there has been a growing interest among both patients and healthcare professionals in alternative treatment and prevention approaches, particularly within the framework of holistic therapies, which include interventions aimed at stress reduction [2-3]. Increasing public knowledge and awareness of health-related issues and the rising use of alternative therapeutic methods by patients may result in more inquiries directed at specialists regarding biofeedback therapy. Physicians' attitudes toward this method may influence the quality of information they provide and their decisions regarding the integration of biofeedback into treatment strategies. Medical professionals' perspectives on specific therapies begin to take shape during their education. This study aims to assess medical students' attitudes toward biofeedback therapy, considering differences between those at the early and final stages of their studies.

Biofeedback is a therapeutic technique aimed at developing self-regulation skills in the context of the body's physiological functions [4]. Various electronic devices are used to monitor specific functions. Electroencephalograms (EEG) are employed to monitor brainwave activity [5]; electromyography (EMG) is used to measure muscle tension; thermal sensors are used to assess skin temperature; electrodermal responses are recorded via sensors collecting data on skin conductance [6]; and devices monitoring cardiac activity are used in heart rate variability (HRV) biofeedback therapy [7]. The equipment provides patients with real-time feedback on their physiological processes, enabling them to engage in voluntary regulation training. The effectiveness of this training is based on the principles of operant conditioning, meaning that the patient receives positive reinforcement when successfully achieving a specific goal.

This technique is used in treating clinical conditions where a prolonged physiological stress response serves as both an etiological factor and a sustaining mechanism. This includes the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic, immune, gastrointestinal, and musculoskeletal systems [8]. It is applied in the management of conditions such as tension and migraine headaches [9-10], hypertension [11], fibromyalgia [12], chronic musculoskeletal pain, and irritable bowel syndrome (IBS). Biofeedback is also utilised in the treatment of psychological disorders, including anxiety and depressive disorders [13], obsessive-compulsive disorder (OCD) [14], post-traumatic stress disorder (PTSD) [15], as well as in relaxation training and exercises designed to enhance cognitive functions [16].

In industrialised countries, the latter half of the 20th century saw what is referred to as an epidemiological transition [17,18], characterised by a shift in the nature of diseases and causes of mortality. This transition involved a decline in the prevalence of infectious and parasitic diseases and an increase in chronic conditions, particularly those related to the cardiovascular system. As a result, psychological and social factors have become increasingly significant in disease development, progression, and treatment [19]. These factors include health habits, coping skills, and self-regulation abilities. Given that biofeedback methods facilitate the development of these essential skills and numerous meta-analyses confirm their effectiveness [20-21], evaluating medical students' attitudes towards such therapeutic techniques becomes highly relevant. In the future, these students will determine the treatment approaches available to patients. Positive attitudes toward biofeedback could lead to greater acceptance and utilisation of innovative complementary medical techniques. In contrast, negative attitudes may create barriers that prevent individuals with somatic and psychological conditions from benefiting from such therapies. Attitudes toward a given subject are shaped by factual knowledge combined with cognitive, emotional, and behavioural components. Attitude formation is a core area of study within social psychology [22]. According to the classical three-component (ABC) model, an individual's attitude toward an object, expressed as approval, disapproval, or specific reactions, comprises cognitive, emotional, and behavioural components. The cognitive component consists of an individual's beliefs about the object, which are descriptive and evaluative judgments based on information, knowledge, and opinions. The emotional component includes feelings and emotions toward the object, which may be positive (e.g., enthusiasm) or negative (e.g., fear). The behavioural component describes tendencies toward specific actions in response to the object, reflecting alignment between beliefs, emotions, and behaviour. Thus, physicians' attitudes toward biofeedback may begin to form during their medical studies. During this period, students acquire knowledge regarding the applications and efficacy of this technique, shaping their individual beliefs. Their level of interest or scepticism will influence their emotional response, which, in turn, will contribute to developing behavioural tendencies that may manifest in their future medical practice.

AIM

This study aimed to evaluate medical students' knowledge of biofeedback therapy and to explore their cognitive, emotional, and behavioral attitudes toward this method. The study also examined whether students' year of study influenced their awareness and perceptions of biofeedback.

MATERIALS AND METHODS

The study was conducted using a diagnostic survey approach. A custom-designed questionnaire was utilised. Data collection occurred between February 10, 2025, and March 10, 2025. Participation in the study was entirely anonymous and voluntary, and participants were informed of this both in the study instructions and by a research team member.

The custom-developed questionnaire comprised three sections: an instructional segment, a socio-demographic module, and the main survey section, which assessed students' knowledge and attitudes toward biofeedback therapy. The socio-demographic section included six items addressing gender, age, place of residence, relationship status, field of study, and year of study. The main section contained questions regarding the use of biofeedback therapy and students' cognitive, emotional, and behavioural attitudes toward this method. A total of nine questions were developed. The questionnaire was designed by a multidisciplinary team of psychiatrists and clinical psychologists, ensuring its content validity and relevance to the study objectives.

RESULTS

The study sample comprised 207 medical students, of whom 56% were female. The most numerous subgroups comprised second-year (n = 100) and fifth-year (n = 101) students. When asked „How would you define biofeedback therapy?", 40% of respondents provided the correct answer, defining it as „a method utilising biological feedback (e.g., via EEG) in therapy". The same proportion (40%) responded, „I don't know" (Fig. 1). Furthermore, 71% of participants indicated they did not know whether biofeedback is a recognised therapeutic method. Only 22% indicated that it is, while 7% stated that, in their opinion, biofeedback is not a recognised therapeutic method (Fig. 2). More than half of the respondents (53%) rated their knowledge of biofeedback therapy as „very poor" (Fig. 3). When asked about factors that would encourage them to consider biofeedback therapy, students most frequently cited stress reduction and enhanced concentration (31%), a recommendation

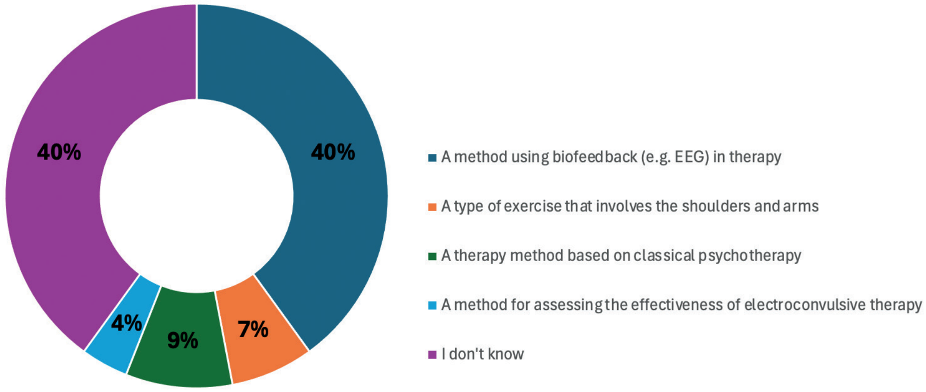

Fig. 1. What do you think biofeedback therapy is?
Source: own materials

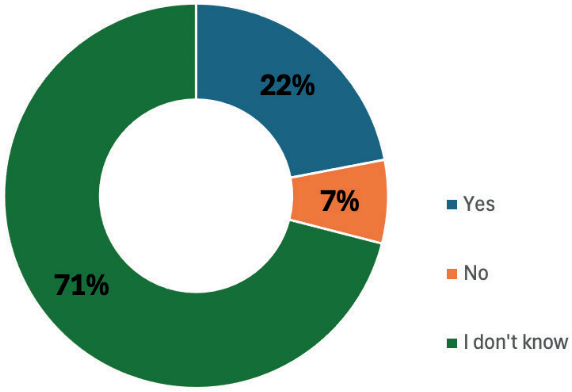

Fig. 2. Is biofeedback a recognised therapeutic method?
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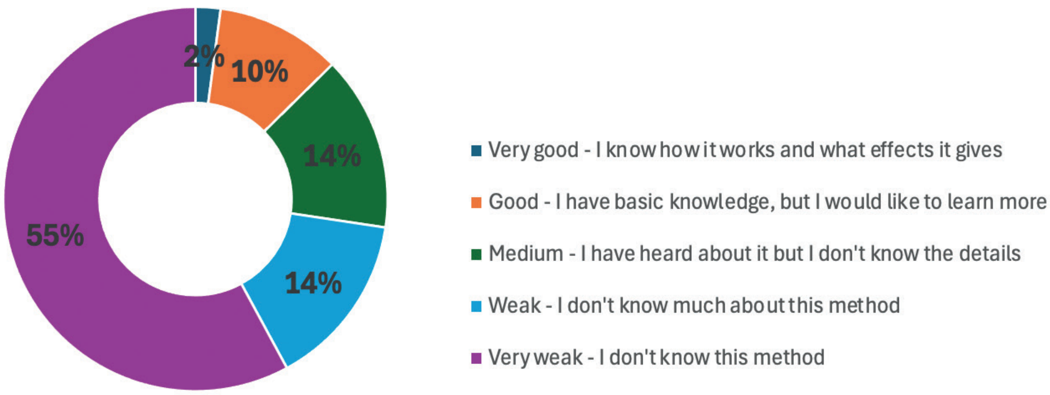

Fig. 3. How would you rate your level of knowledge about biofeedback therapy?
Source: own materials

from a specialist or a trusted individual (24%), and a desire to improve mental health (22%) (Fig. 4).

When asked about their perceptions of biofeedback therapy, the majority of respondents (84%) characterised their attitudes as „neutral" (Fig. 5). Furthermore, most of the surveyed students did not express a positive or negative opinion regarding the effectiveness and safety of this therapeutic method (Figs. 6 and 7).

The lack of a clear trend is also reflected in the responses regarding the likelihood of recommending biofeedback therapy to someone close to them (Fig. 8) and whether the students themselves would consider using biofeedback therapy (Fig. 9). A substantial proportion of respondents answered „difficult to say" or „I don't know". Twenty-one percent of participants indicated they would use biofeedback therapy, whereas 8% stated that they would not consider it.

In the analysis of student responses based on their

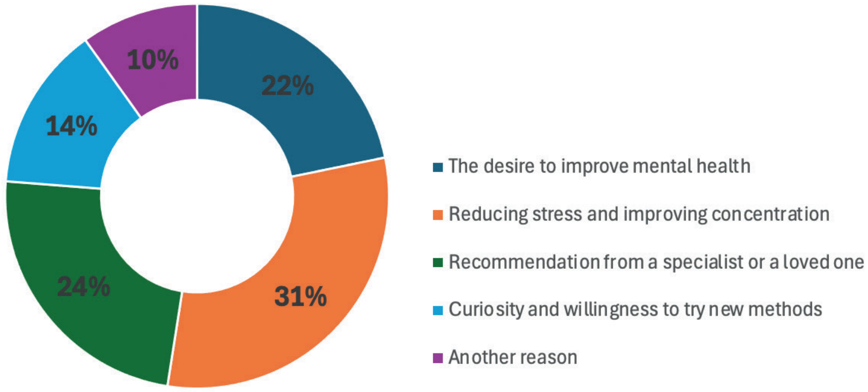

Fig. 4. What would make you consider EEG biofeedback therapy?
Source: own materials

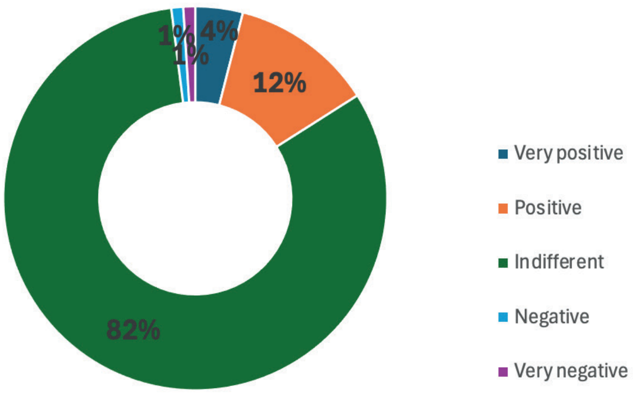

Fig. 5. How do you feel about using biofeedback?
Source: own materials

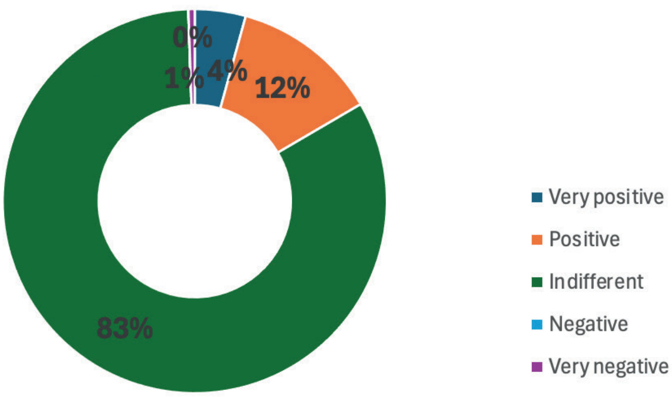

Fig. 6. How do you rate the effectiveness of biofeedback therapy?
Source: own materials

year of study, a higher percentage of fifth-year students compared to second-year students evaluated favourably both the effectiveness (positive: 17.7% vs. 4.7%; very positive: 5.2% vs. 3.5%) and safety (positive: 15.5% vs. 12.9%; very positive: 13.4% vs. 4.7%) of biofeedback therapy. A higher proportion of fifth-year students rated their knowledge of biofeedback more positively than second-year students (Figs. 10 and 11). Furthermore, a greater percentage of fifth-year students correctly recognised biofeedback as an evidence-based therapeutic method (Figs. 14 and 15). Similarly, a larger proportion of fifth-year students expressed a greater willingness to recommend biofeedback to someone close to them (Figs. 12 and 13) and reported more positive feelings toward this treatment modality (Figs. 16 and 17). However, it is important to emphasise that these students still constituted a minority in both groups.

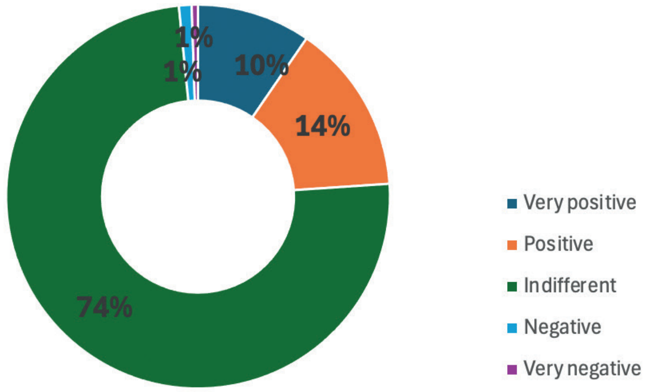

Fig. 7. How do you rate the safety of using biofeedback therapy?
Source: own materials

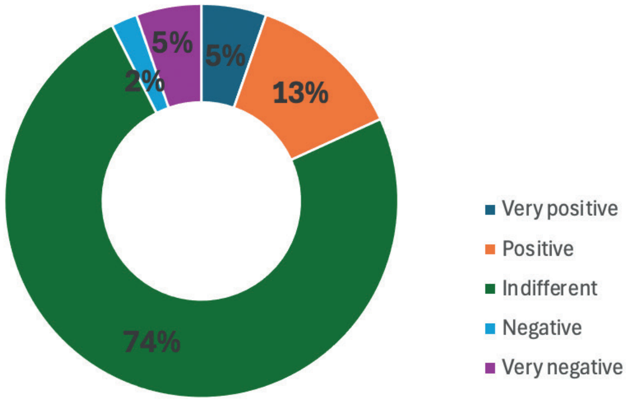

Fig. 8. How likely is it that you would recommend biofeedback to a loved one?
Source: own materials

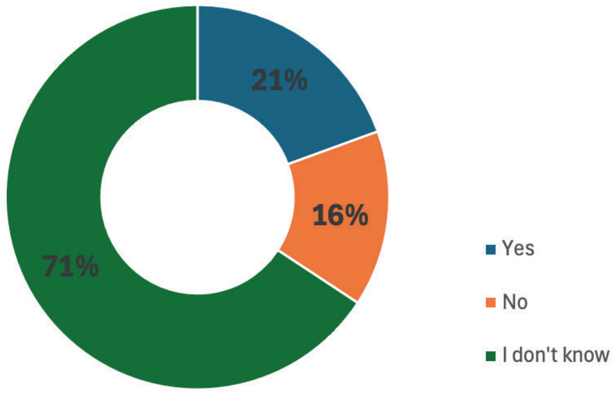

Fig. 9. Would you benefit from biofeedback therapy yourself?
Source: own materials

DISCUSSION

Since the dawn of civilisation, humans have strived for self-understanding. Awareness of one's body, physiological responses to external stimuli, and internal states of tension are not merely a matter of medical inquiry but a fundamental aspect of self-awareness and well-being. Advances in modern psychophysiology, grounded in the principles of biological feedback mechanisms, have led to the development of innovative techniques that go beyond passive observation. Among these, biofeedback emerges as a transformative approach, offering real-time monitoring of physiological processes and the ability to actively modulate and regulate them.

The objective of this study was to assess the level of knowledge among medical students regarding biofeedback therapy and to analyse their attitudes toward this method at different stages of their education. As a technique rooted in physiological self-regulation mechanisms, biofeedback is gaining increasing recognition in medical practice. Its application in stress management, psychosomatic disorders, and cognitive function optimisation opens new possibilities for enhancing human well-being. Patients gain direct insight into their physiological responses through feedback mechanisms, enabling conscious modulation of these processes through thought, intention, and attention. Biofeedback can be

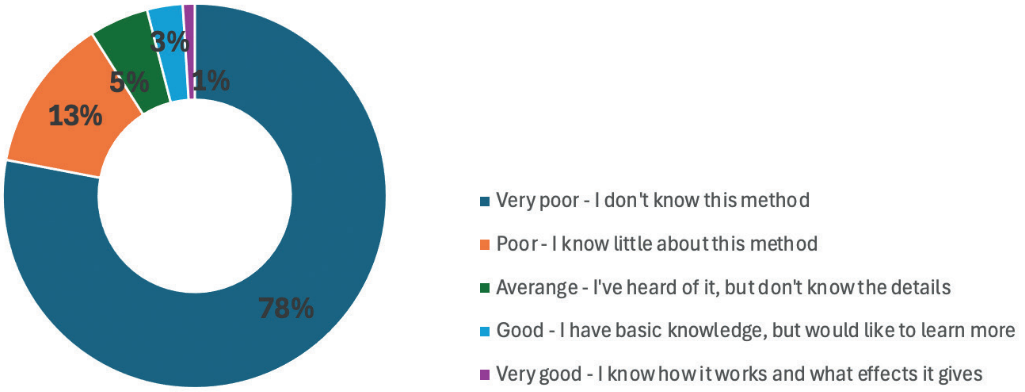

Fig. 10. How do you assess your knowledge about biofeedback? Year: II
Source: own materials

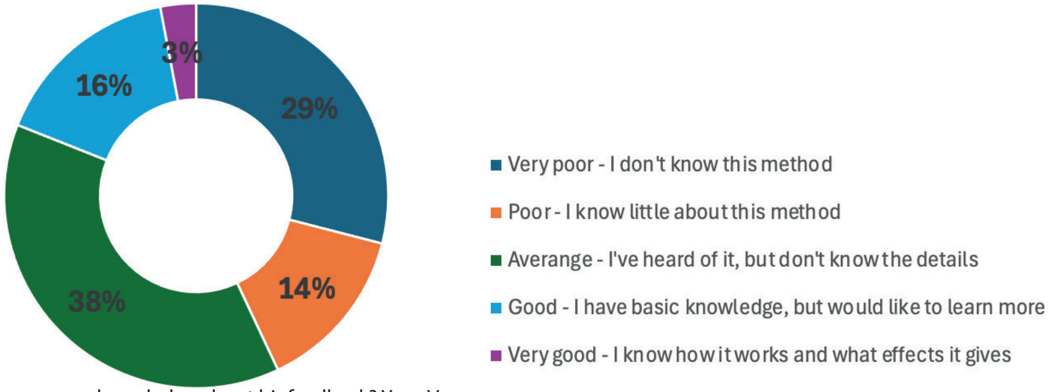

Fig. 11. How do you assess your knowledge about biofeedback? Year: V
Source: own materials

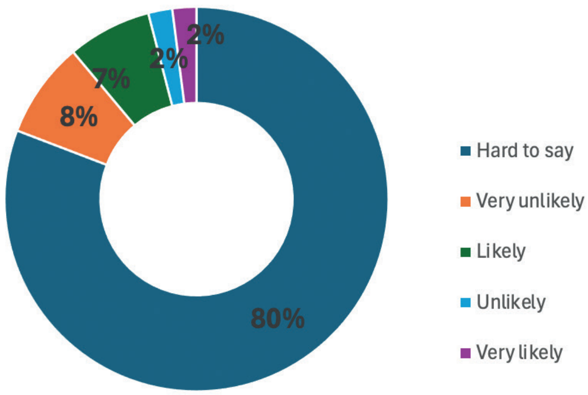

Fig. 12. How likely are you to recommend biofeedback to someone close? Year: II
Source: own materials

understood as a form of learning the language of the body, where the alphabet consists of heart rate patterns, muscle tension, and brainwave activity. This technique facilitates understanding one's arousal state, the capacity for change, the time required for regulation, and the impact of both positive and negative thoughts on physiological activation levels [23].

The findings of this study highlight a significant gap in medical students' knowledge regarding biofeedback therapy. This deficiency is reflected in their responses concerning the definition of the method and their general awareness of its applications and effectiveness. Only 40% of respondents were able to correctly define biofeedback as a therapeutic method based on biological feedback mechanisms, while an equal proportion admitted to having no knowledge of the subject. Even greater uncertainty was observed regarding whether biofeedback is an evidence-based therapeutic approach. Seventy-one percent of students could not determine their stance on this matter, whereas only 22% acknowledged biofeedback as a scientifically validated treatment method.

This substantial lack of knowledge also influences students' emotional and behavioural attitudes toward biofeedback therapy. Most respondents exhibited a neutral stance, with as many as 84% describing their feelings toward biofeedback as indifferent, suggesting an absence of both

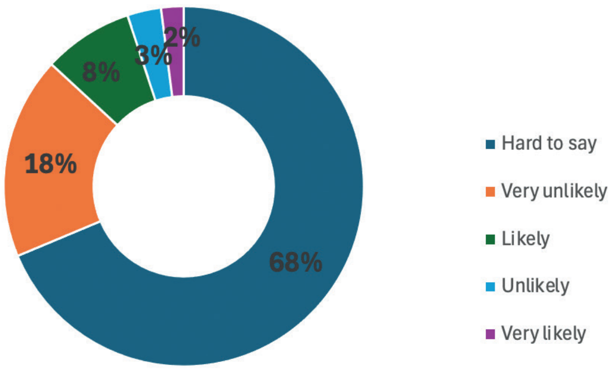

Fig. 13. How likely are you to recommend biofeedback to someone close? Year: V
Source: own materials

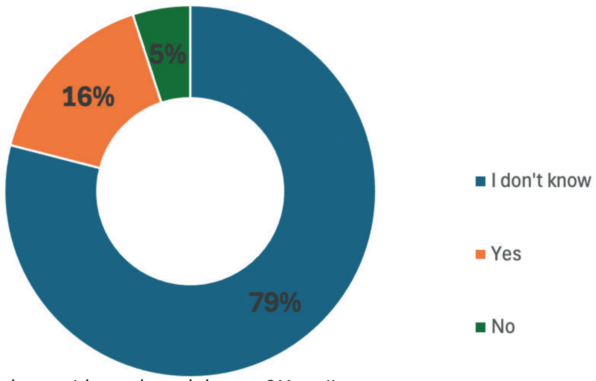

Fig. 14. Is biofeedback an evidence-based therapy? Year: II
Source: own materials

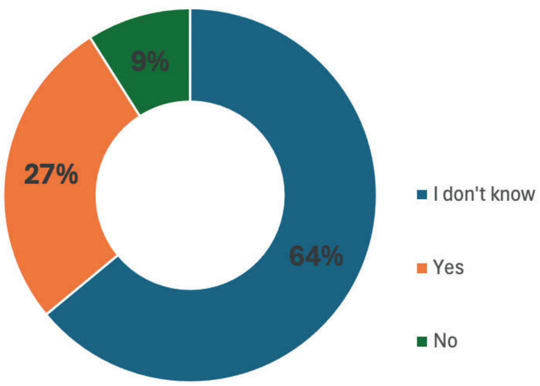

Fig. 15. Is biofeedback an evidence-based therapy? Year: V
Source: own materials

enthusiasm and scepticism regarding this method. Likewise, students demonstrated a lack of clear intent regarding its use, with only 21% expressing a willingness to use biofeedback therapy. At the same time, the vast majority remained undecided, as reflected in responses such as „difficult to say" and „I don't know". This trend is also evident in students' reluctance or uncertainty about recommending biofeedback therapy to someone close to them.

An analysis of the factors that could encourage students to consider biofeedback therapy reveals a predominance of arguments related to mental well-being. The most frequently cited motivators were stress reduction, improved concentration (31% of responses), and recommendations from specialists or trusted individuals (24%). These findings underscore the need to enhance educational efforts regarding biofeedback therapy, particularly within the training of future physicians. Academic knowledge not only shapes students' beliefs but also influences their future medical practice, affecting patient access to modern, complementary therapeutic methods. The absence of clearly defined

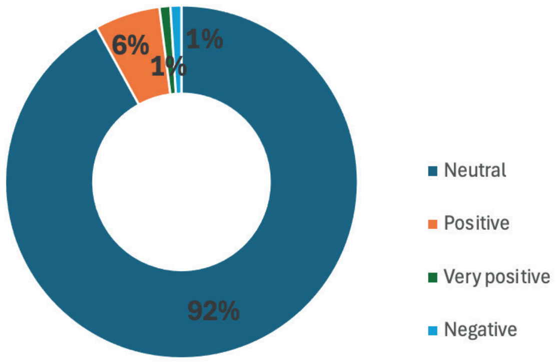

Fig. 16. What are your feelings about using biofeedback? Year: II
Source: own materials

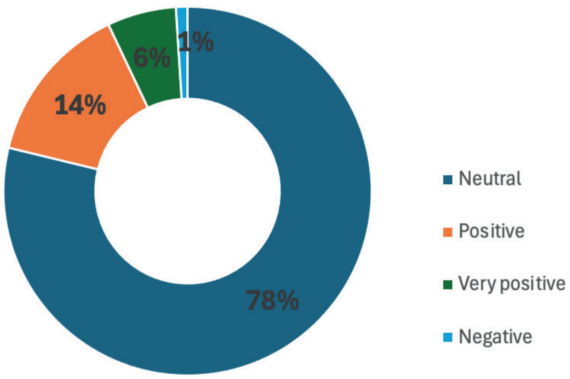

Fig. 17. What are your feelings about using biofeedback? Year: V
Source: own materials

attitudes among participants indicates that biofeedback therapy remains an underrecognised and insufficiently explored method within medical education. The results suggest that integrating education on biofeedback therapy into the medical curriculum could contribute to greater awareness and a more informed approach to complementary and integrative medicine. Ultimately, the attitudes developed during medical training will play a key role in shaping future clinical decisions and determining the accessibility of innovative therapeutic approaches for patients.

It is essential to emphasise that biofeedback therapy offers numerous psychological benefits, enabling patients to enhance their awareness of physiological responses and improve their ability to regulate them. Scientific evidence demonstrates that this technique is effective in reducing stress, anxiety, and depressive symptoms [24]. By learning to consciously modulate physiological functions, patients can experience improved sleep quality, reduced muscle tension [58], and greater resilience to daily stressors. Biofeedback is also widely applied in the treatment of psychosomatic disorders, including migraines, irritable bowel syndrome (IBS), hypertension, and sexual dysfunctions. Furthermore, this method is suitable for individuals across all age groups, including children, adolescents, adults, and older adults [25].

In psychotherapy, biofeedback, as a feedback-based technique, is particularly effective when combined with cognitive-behavioural therapy (CBT) [26]. Within this therapeutic approach, standard behavioural interventions, such as dietary habit modifications and panic disorder coping strategies, are often supplemented with relaxation techniques aimed at reducing excessive physiological arousal. Two such techniques are Jacobson's progressive muscle relaxation and Schultz's autogenic training. However, biofeedback is also frequently employed as a supportive tool in relaxation-based interventions [27-28]. This technique enhances psychotherapy by increasing patient self-awareness, facilitating cognitive restructuring and emotional regulation. Biofeedback is particularly valuable for self-observation, enabling individuals to determine their optimal level of autonomic arousal and acquire skills to regulate physiological activation based on real-time feedback. In CBT, biofeedback is used in the treatment of anxiety disorders (including simple and complex phobias and generalised anxiety disorder), post-traumatic stress disorder (PTSD), and obsessive-compulsive disorder (OCD). Integrating these approaches allows patients to identify and modify maladaptive thought patterns more effectively while enhancing stress management strategies [29]. It is important to note that anxiety disorders differ from everyday anxiety, as they significantly disrupt an individual's functioning due to intense emotional arousal. Individuals suffering from these conditions often experience cognitive and behavioural difficulties that, if left untreated, such as through psychotherapy, may lead to chronic impairment.

The findings of this study underscore the necessity of greater integration of biofeedback therapy into the medical education curriculum, particularly in the context of its potential benefits for mental health prevention and the treatment of stress-related disorders. Incorporating biofeedback into clinical practice could provide substantial support for patient care [30], especially within the fields of psychotherapy and psychosomatic medicine.

CONCLUSIONS

1. The majority of medical students demonstrate a limited understanding of biofeedback therapy and its therapeutic applications.
2. Due to the insufficient knowledge of participants regarding this method, the study did not allow for a definitive assessment of their attitudes toward biofeedback.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Kamil Nikel
Students Scientific Association, Department of Psychiatry
Faculty of Medical Sciences in Zabrze
Medical University of Silesia in Katowice
Katowice, Poland
e-mail: s79826@365.sum.edu.pl

ORCID AND CONTRIBUTIONSHIP
Joanna Agnieszka Smolarczyk - 0000-0003-4297-8974 A B C D F
Paweł Gustaw Dębski - 0000-0001-5904-6407 A C E F
Kamil Nikel - 0009-0007-9851-7129 B D
Aleksandra Lewandowska - 0000-0002-7762-2890 D E
Piotr Pałczyński - 0000-0003-1985-8632 C D F
Dorota Turska-Czyż - 0009-0005-9431-4549 B D
Magdalena Justyna Piegza - 0000-0001-7228-5349 E F
Łukasz Kunert - 0000-0001-7600-9413 B C
Piotr Gorczyca - 0000-0002-9419-7988 F

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 07.05.2025
ACCEPTED: 14.02.2026

ACTA BALNEOLOGICA, VOLUME LXVIII, ISSUE 3, MAY-JUNE 2026

ORIGINAL ARTICLE

The impact of a comprehensive cardiorespiratory exercise program on Long COVID survivors: a randomized controlled trial

Dubba Naga Raju[1], Shenbaga Sundaram Subramanian[2], Ahlam Mazi[3], Maha Bamehrez[3], Saad Suleman Alfawaz[4], Riziq Allah Mustafa Gaowgzeh[4], Baraa Alsulaimani[4]

[1]RESEARCH SCHOLAR, SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES (SIMATS), CHENNAI, TAMIL NADU, INDIA

[2]DEPARTMENT OF MUSCULOSKELETAL SCIENCES, SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES (SIMATS), CHENNAI, TAMIL NADU, INDIA

[3]DEPARTMENT OF PEDIATRICS, FACULTY OF MEDICINE, KING ABDULAZIZ UNIVERSITY, JEDDAH, SAUDI ARABIA

[4]DEPARTMENT OF PHYSICAL THERAPY, FACULTY OF MEDICAL REHABILITATION SCIENCES, KING ABDULAZIZ UNIVERSITY, JEDDAH, SAUDI ARABIA

ABSTRACT

Aim: To assess the effectiveness of a structured cardiorespiratory exercise programme on functional capacity, fatigue, flexibility, and quality of life in non-hospitalised patients with Long COVID.

Materials and Methods: This was an assessor-blinded randomized controlled trial involving 60 non-hospitalised Long COVID survivors aged 18-55 years. Participants were randomly assigned to an intervention group that received an 8-week structured cardiorespiratory exercise program or a control group that received conventional care. The intervention included breathing exercises, low-intensity walking, and stretching, delivered both in supervised sessions and at home. Outcomes were measured at baseline and after 8 weeks based on the Six-Minute Walk Test, Sit-and-Reach Test, Fatigue Severity Scale, and Short Form Health Survey to evaluate quality of life.

Results: After the intervention, the exercise group showed significantly greater improvements than the control group. Walking distance was increased by about 45 meters, flexibility increased by over 4 centimeters, and fatigue severity showed a significant reduction. Both physical and mental aspects of quality of life were significantly improved in the intervention group. Between-group comparisons revealed statistically significant differences across all outcomes, with large effect sizes in favour of the exercise program.

Conclusions: An 8-week structured cardiorespiratory exercise programme improves functional capacity, reduces fatigue, increases flexibility, and improves the quality of life of non-hospitalised long COVID survivors. These findings provide evidence for the inclusion of structured, low-intensity exercise in the treatment of Long Covid, helping individuals develop rehabilitation strategies.

KEYWORDS: long COVID, exercise therapy, rehabilitation, fatigue, quality of life

Acta Balneol. 2026;68(3): 152-158. doi: 10.36740/ABAL202603103

INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has caused the coronavirus disease 2019 (COVID-19) pandemic that has afflicted more than 700 million people worldwide with considerable morbidity and mortality [1,2]. With the decline in acute infections, a large proportion of survivors (530) developed persistent symptoms lasting more than 12 weeks, also known as Long COVID (LC) or post-acute COVID-19 syndrome [3,4]. LC is characterised by a heterogeneous range of symptoms that affect numerous organ systems, including fatigue, exercise intolerance, dyspnea, cognitive impairment (so-called brain fog), myalgia, joint aches, palpitations, sleep disturbances, and post-exertional malaise (PEM) [5]. Among the most debilitating symptoms, significant impairment of activities of daily living (ADL) and quality of life (QoL) are fatigue, or excessive and sustained tiredness that prevents physical activity, and exercise intolerance, which is an abnormally low ability to perform endurance exercise [6,7]. Dermatologic rashes, cardiovascular complications, and musculoskeletal pain are other manifestations that make the recovery more complicated [8].

The aetiology of LC remains poorly understood, and proposed mechanisms include persistent viral replication, immune hyperstimulation, dysregulation of the renin-angiotensin-aldosterone system (RAAS), changes in the microbiome, and endothelial dysfunction [3,9]. These processes could lead to systemic inflammation and tissue destruction, thereby accounting for the varied symptomatology [4]. The clinical course of LC is highly variable, including spontaneous recovery and prolonged disability, decreased QoL, and, in the worst scenario, premature mortality [10,11]. The lack of specific pharmacological interventions for LC highlights the importance of creating effective rehabilitation interventions [9,12]. The existing management is aimed at symptom reduction, and a series of trials is conducted to evaluate the use of antiviral, immunomodulatory, and supportive treatments [5].

The use of pulmonary rehabilitation (PR) in patients who had recently recovered from severe acute COVID-19, especially those who were hospitalised, received high-flow oxygen, intensive care, or mechanical ventilation, has been shown to be an effective intervention [13-15]. Aerobic exercise, breathing methodologies, as well as strength training in PR programs have enhanced anxiety, depression, cognitive, and 6-minute walk distance (6MWD) in the populations [16,17]. Nevertheless, the 6MWD, though a valid index of functional capacity, provides little insight into the physiological processes underlying exercise intolerance or improvement after training [18]. Moreover, most PR research has been conducted on hospitalised patients; there is a knowledge gap regarding non-hospitalised LC survivors, who represent the majority of individuals with Long COVID [11].

Myalgia, muscle weakness, and joint pain are examples of LC symptoms that may lead to long-term complications, including muscle atrophy, contractures, and decreased movement [7,19,20]. Such musculoskeletal symptoms, fatigue, and intolerance to exercise impair ADL and worsen disability [21,22]. Structured exercise programs targeting cardiorespiratory fitness, muscle strength, endurance, and flexibility may counteract the functional consequences of muscle weakness and physical deconditioning, thereby enhancing physical function and quality of life [23-25]. Recent findings indicate that low-intensity exercise, breathing exercises, and stretching are safe and effective in LC patients and may reduce PEM and improve respiratory function [12,26]. Non-hospitalised LC survivors lack well-defined rehabilitation programmes, particularly for the management of musculoskeletal symptoms, and further research is required [26-28].

The proposed research will develop and test a comprehensive cardiorespiratory exercise program for non-hospitalised survivors of LC. The outcomes will be: (1) the effectiveness of the program in improving functional capacity, (2) reducing fatigue, and (3) improving flexibility and quality of life. This study aims to fill these gaps and thereby contribute to the evidence-based rehabilitation of LC.

Most existing studies on LC rehabilitation have employed observational or single-group designs, limiting causal inference. Randomized controlled trials are necessary to distinguish intervention effects from spontaneous recovery. Therefore, this study aimed to evaluate the effectiveness of a structured cardiorespiratory exercise program compared with conventional care in a randomized controlled trial.

AIM

This study aimed to evaluate the effectiveness of an 8-week structured cardiorespiratory exercise programme on the improvement of functional capacity, reduction of fatigue, improvement of flexibility, and improvement of quality of life in non-hospitalised individuals with LC in comparison with conventional care, using validated physical performance measures and patient-reported outcome scales within a randomised controlled trial framework.

MATERIALS AND METHODS

STUDY DESIGN AND PARTICIPANTS

This study was an assessor-blinded, parallel-group randomized controlled trial conducted over 8 weeks at the NIMS Teaching Hospital and Research Centre OPD. The study followed CONSORT guidelines for randomized trials. The institutional ethics committee approved the study protocol, and all participants provided written informed consent before enrolment.

The sample size was calculated using G*Power software based on the following assumptions: 80% statistical power, $\alpha = 0.05$, and a medium effect size (Cohen's $d = 0.5$), according to previous pulmonary rehabilitation studies [14]. Participants were recruited from local health clinics and through a social media campaign targeting COVID-19 survivors.

Inclusion criteria were age 18-55 years, laboratory-confirmed recovery from COVID-19 (negative PCR test within 4 weeks before enrolment), and eligibility according to the American College of Sports Medicine (ACSM) risk stratification.

Exclusion criteria included active COVID-19 infection, no history of COVID-19 infection, high-risk conditions (uncontrolled hypertension, ischemic heart disease, severe pulmonary disease, etc.), and inability to perform low-intensity exercise because of severe disability. Baseline health screening, including resting heart rate, blood pressure, and oxygen saturation measurements, was performed before enrolment.

RANDOMIZATION AND ALLOCATION CONCEALMENT

Participants were randomly assigned in a 1:1 ratio to the intervention or the control group using a computer-generated randomization schedule. Allocation concealment was ensured using sealed, opaque envelopes prepared by an independent researcher who was not involved in recruitment or assessment. The CONSORT flow diagram summarizes participant recruitment, randomization, follow-up, and analysis.

PROCEDURE

Intervention group: structured cardiorespiratory exercise program

The overall 8-week cardiorespiratory exercise program was designed to progressively restore movement, enhance respiratory function, and improve muscle strength and flexibility. The intervention strategy was based on existing data on COVID-19 recovery protocols and was delivered by professional physiotherapists [12,16,18].

The program consisted of three parts:

- Breathing exercises: Participants performed diaphragmatic breathing, pursed-lip breathing, and incentive spirometry using a standard apparatus. Exercises were performed 2-3 times daily for 5-10 minutes to improve respiratory muscle function and oxygenation [12].
- Gentle walking: Walking was performed at a self-selected comfortable pace 3-4 times per week for 10-20 minutes,

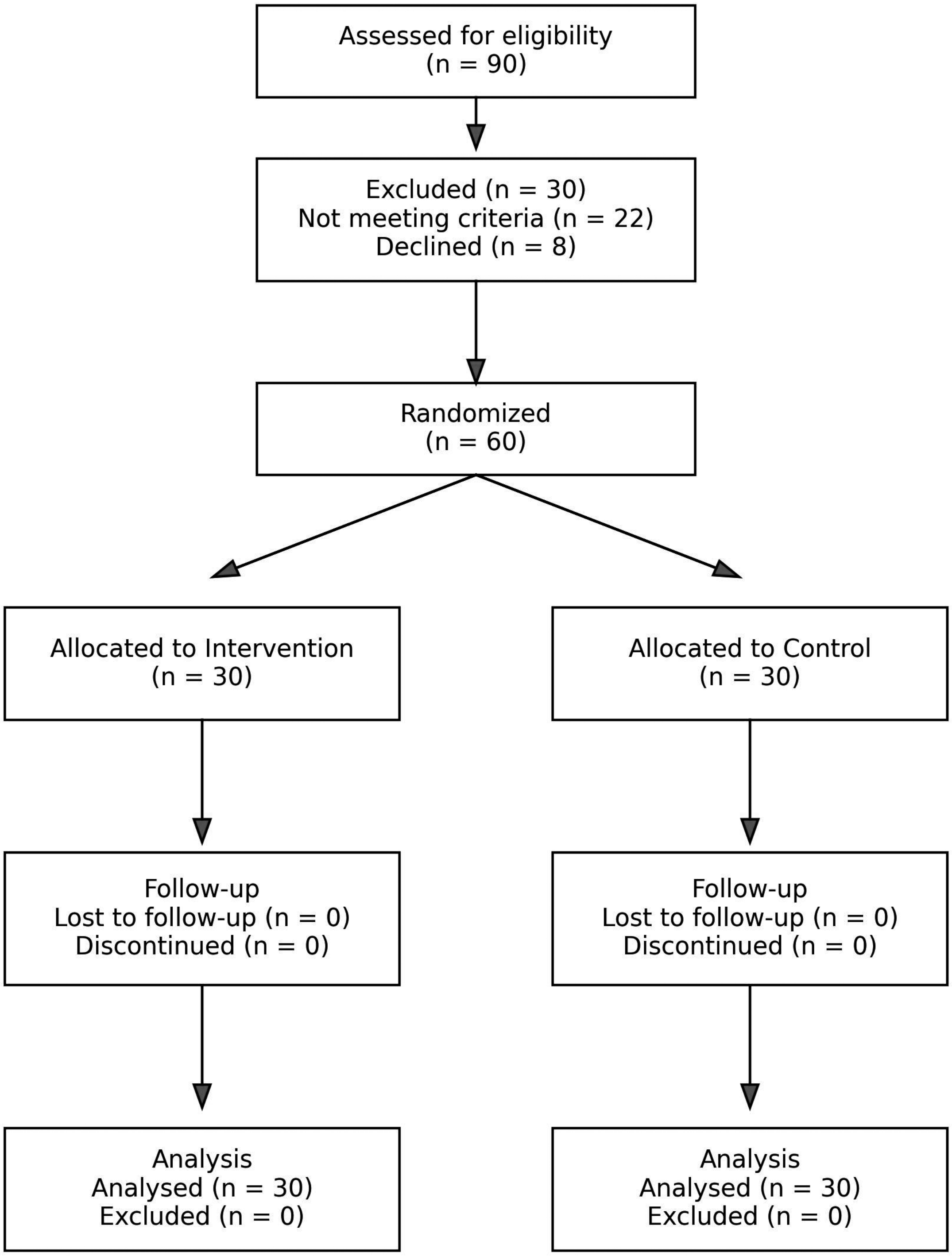

Fig. 1. CONSORT Flowchart

Source: own materials

including a 2-minute warm-up and a 2-minute cool-down to minimize post-exertional malaise (PEM) [27].

- Light stretching: Daily stretching of the hamstrings, quadriceps, shoulders, and back was performed. Each stretch was held for 15-30 seconds and repeated 10-15 times to improve flexibility and reduce muscle stiffness [25].

Participants attended two supervised group sessions per week (approximately 45 minutes each). A home-based exercise program, including an instruction manual and videos, was provided for the remaining sessions. Weekly exercise logs were reviewed during supervised sessions. Participants were instructed to discontinue exercise and report any severe chest discomfort, dyspnea, or dizziness to the researcher.

CONTROL GROUP: CONVENTIONAL EXERCISE PROGRAM

Participants assigned to the control group received an 8-week conventional care program reflecting standard outpatient management of non-hospitalised individuals with LC. The program consisted of one supervised session per week (30-45 minutes) delivered by a qualified physiotherapist to match therapist contact time. Conventional care included health education, low-intensity mobility and range-of-motion exercises, breathing awareness, postural exercises, and symptom self-management rather than structured physical training.

Participants received education regarding LC symptoms, energy conservation, activity pacing, sleep hygiene, hydration, balanced nutrition, stress reduction, and recognition of warning symptoms requiring medical evaluation. They were instructed to maintain their usual level of activity but not to begin any new exercise or rehabilitation program during the study period. Educational handouts were provided, and attendance was recorded.

OUTCOME MEASURES

Evaluations were conducted at baseline (week 0) and after the intervention (week 8) by a trained assessor blinded to group allocation.

The 6-Minute Walk Test (6MWT) assessed functional exercise capacity according to American Thoracic Society guidelines, with continuous monitoring of heart rate and oxygen saturation [13].

The Sit-and-Reach Test assessed hamstring and lower back flexibility using a standardized sit-and-reach box. The best of three attempts was recorded in centimeters [18].

The Fatigue Severity Scale (FSS) assessed fatigue using a validated 9-item questionnaire scored from 1 (no fatigue) to 7 (severe fatigue) [6].

Health-related quality of life was evaluated using the SF-36 Health Survey, in which higher scores indicate better quality of life. Outcome assessors were blinded to group allocation; however, because of the nature of the intervention, participant and therapist blinding was not feasible.

RESULTS

Table 1 presents the baseline demographic and clinical characteristics of participants in the intervention and control groups. There were no statistically significant differences between the groups at baseline in age, sex distribution, functional capacity, flexibility, fatigue severity, or quality-of-life measures (all $p > 0.05$), indicating successful randomization and baseline comparability. Mean baseline values for the 6-minute walk distance, Fatigue Severity Scale, and the physical and mental components of the SF-36 were similar between groups, suggesting that post-intervention differences were attributable to the intervention rather than to pre-existing differences.

As shown in Table 2, both the intervention and control groups demonstrated statistically significant improvements in all outcome measures after the 8-week study period (all $p < 0.001$). However, the magnitude of improvement was consistently greater in the intervention group. The intervention group showed large within-group effect sizes for functional capacity (6MWT: $d = 0.96$), fatigue reduction (FSS: $d = 2.35$), and quality of life (SF-36 physical: $d = 1.55$; SF-36 mental: $d = 1.27$). In contrast, the control group demonstrated small-to-moderate effect sizes across all outcomes (Cohen's d: 0.34-0.76), reflecting modest improvements likely attributable to natural recovery, education, and self-management of symptoms associated with conventional care.

Table 3 summarizes the between-group comparison of change scores, showing significantly greater improvements in the intervention group than in the control group across all measured outcomes (all $p < 0.001$). The intervention group demonstrated significantly greater improvements in functional capacity (47.9 ± 22.1 m vs. 19.7 ± 17.9 m), flexibility (4.3 ± 2.1 cm vs. 1.8 ± 1.6 cm), and fatigue severity (−1.55 ± 0.61 vs. −0.54 ± 0.52). Improvements in both the physical and mental components of quality of life were also significantly greater in the intervention group. Between-group effect sizes were large to very large ($d = 0.92$-1.78), indicating a clinically meaningful advantage of the structured cardiorespiratory exercise program over conventional care.

DISCUSSION

The randomised controlled design strengthens causal inference by demonstrating improvements beyond those observed with conventional care alone. While the control group showed slight improvements, likely due to natu-

Table 1. Baseline characteristics of participants

Variable	Intervention (n = 30)	Control (n = 30)	p-value
Age (years)	35.4 ± 10.1	34.8 ± 10.7	0.81
Sex (Male/Female)	16 / 14	15 / 15	0.79
6MWT (m)	420.8 ± 48.5	418.9 ± 47.6	0.88
Sit-and-Reach (cm)	19.4 ± 5.2	19.2 ± 5.1	0.91
FSS	5.50 ± 0.70	5.46 ± 0.73	0.82
SF-36 Physical	44.9 ± 10.8	45.1 ± 10.5	0.91
SF-36 Mental	49.2 ± 10.6	48.9 ± 10.8	0.93

Source: compiled by the authors of this study

Table 2. Within-group pre–post comparisons

Outcome measures	Group	Pre (Mean ± SD)	Post (Mean ± SD)	p-value	Effect size
6MWT (m)	Intervention	420.8 ± 48.5	468.7 ± 50.2	<0.001	0.96
	Control	418.9 ± 47.6	438.6 ± 48.3	<0.001	0.41
Sit-and-Reach (cm)	Intervention	19.4 ± 5.2	23.7 ± 5.6	<0.001	0.79
	Control	19.2 ± 5.1	21.0 ± 5.3	<0.001	0.34
FSS	Intervention	5.50 ± 0.70	3.95 ± 0.62	<0.001	2.35
	Control	5.46 ± 0.73	4.92 ± 0.68	<0.001	0.76
SF-36 Physical	Intervention	44.9 ± 10.8	61.3 ± 9.9	<0.001	1.55
	Control	45.1 ± 10.5	51.8 ± 10.2	<0.001	0.64
SF-36 Mental	Intervention	49.2 ± 10.6	62.9 ± 11.1	<0.001	1.27
	Control	48.9 ± 10.8	54.6 ± 11.0	<0.001	0.53

Source: compiled by the authors of this study

Table 3. Between-group post-post comparison

Outcome measures	Intervention (Mean ± SD)	Control (Mean ± SD)	p-value	Effect size
6MWT (m)	+47.9 ± 22.1	+19.7 ± 17.9	<0.001	1.38
Sit-and-Reach (cm)	+4.3 ± 2.1	+1.8 ± 1.6	<0.001	1.34
FSS	−1.55 ± 0.61	−0.54 ± 0.52	<0.001	1.78
SF-36 Physical	+16.4 ± 8.9	+6.7 ± 7.3	<0.001	1.19
SF-36 Mental	+13.7 ± 9.2	+5.7 ± 8.1	<0.001	0.92

Source: compiled by the authors of this study

ral recovery and the effects of education, the significantly greater improvements in the intervention group support the effectiveness of structured cardiorespiratory exercise. The positive results observed in this study, including an improvement of 45.3 meters in the 6MWT, a 4.2-cm increase in flexibility, and a 27.6% reduction in fatigue, demonstrate the potential benefits of low-intensity multimodal rehabilitation programs.

This marked improvement in the 6MWT is consistent with the findings of Pouliopoulou et al. (2023), who reported in a meta-analysis that physical rehabilitation is associated with improved exercise capacity and quality of life in post-COVID patients [13]. The moderate aerobic activity included in our protocol may have contributed to cardiovascular reconditioning and improved peripheral oxygenation, thereby supporting recovery of exercise capacity, as reported by Zheng et al. [16]. In addition, the observed improvement in flexibility is consistent with findings from Evcik (2023) and Ciaffi et al. (2023), who reported that musculoskeletal symptoms, such as joint stiffness, are common in LC and can be reduced with physiotherapy interventions [14,15].

Fatigue is also a common symptom of LC, particularly in non-hospitalised patients [30]. The considerable decrease in Fatigue Severity Scale scores observed in this study is supported by previous studies by Minu et al. (2024) and Antony Leo Asser and Soundararajan (2021), who reported reduced fatigue and improved functional independence in post-COVID survivors following structured physical activity [19,21]. The improvements observed in both the physical and mental domains of the SF-36 are also consistent with the findings of Pouliopoulou et al. (2023), who demonstrated improved quality of life after physiotherapy in LC survivors [13].

The favourable results may be attributed to the combined effects of the different exercise modalities. Breathing exercises (diaphragmatic and pursed-lip breathing) have been shown to improve ventilatory efficiency and reduce dyspnea [17]. Self-regulated walking may improve aerobic capacity while minimizing the risk of post-exertional fatigue [16]. Stretching may facilitate musculoskeletal recovery and reduce stiffness, as reported by Khasru et al. (2021) and Omar et al. (2022) [26,27].

The observed functional gains warrant special attention, given the participants' non-hospitalised condition. Compared with patients requiring intensive care, symptoms of LC among community-dwelling individuals are often under-recognised despite being highly prevalent and substantially affecting everyday functioning [30]. Growing evidence suggests that structured rehabilitation may also be effective in patients with milder forms of Long COVID.

Although the intervention in this study consisted of low-intensity exercise, other researchers have suggested the usefulness of resistance-based training. Kaczmarczyk et al. (2024), Lopes et al. (2019), and Kaewmanee et al. (2025) reported improvements in strength and endurance following elastic resistance exercises, together with more favourable metabolic outcomes than low-intensity exercise alone [20,22,23]. These findings suggest that a gradual progression of exercise intensity may be beneficial for long-term recovery.

Myalgia, muscle weakness, and joint pain are common musculoskeletal manifestations of LC reported in several reviews [14,15,27]. Systemic inflammation and disuse atrophy are thought to contribute to these symptoms [28]. These findings support the potential role of gentle physical therapy in preventing contractures, restoring mobility, and improving musculoskeletal health, even in geriatric populations [24].

One of the greatest strengths of this study is its pragmatic, community-based approach and its minimal resource requirements, making the intervention potentially applicable in different healthcare settings. Although the randomized controlled design strengthens causal inference, several limitations remain, including reliance on self-reported adherence and the short intervention period. Self-reported adherence logs may be subject to reporting bias, and long-term sustainability cannot be evaluated after only 8 weeks. Furthermore, the study population was limited to low- to moderate-risk individuals, restricting the generalisability of the findings to older adults and patients with significant comorbidities.

Future studies should employ randomised controlled designs and incorporate objective outcome measures, such as cardiopulmonary exercise testing (CPET), spirometry, or wearable activity monitoring [16]. Additional interventions, including resistance training, nutritional support, and cognitive therapy, may further improve rehabilitation outcomes [20,21]. Longer follow-up periods are also needed to evaluate the durability of treatment effects and the prevention of Long COVID-related complications.

This study demonstrated that an 8-week multimodal cardiorespiratory exercise program produced greater improvements in functional capacity, flexibility, fatigue, and quality of life among non-hospitalised LC survivors than conventional care. The 45.2-meter improvement in the 6MWT exceeded the reported minimal clinically important difference (30-35 meters) for respiratory conditions [8,9]. Similarly, the 4.1-cm improvement in the Sit-and-Reach Test indicates enhanced flexibility, which may be clinically relevant given the frequent occurrence of muscle stiffness and joint pain in LC [14,15]. The observed reductions in fatigue and improvements in SF-36 scores are consistent with previous pulmonary rehabilitation studies, supporting low-intensity exercise as a promising component of rehabilitation for Long COVID.

CONCLUSIONS

This randomised controlled trial shows clinically meaningful effects on functional capacity, fatigue, flexibility, and quality of life in an 8-week structured cardiorespiratory exercise program for non-hospitalised LC survivors, compared with conventional care. These findings provide evidence supporting the integration of low-intensity, structured exercise into LC rehabilitation pathways. Future studies, including longer follow-up periods and objective physiological outcomes, are needed to optimize and maintain recovery.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Shenbaga Sundaram Subramanian
Saveetha College of Physiotherapy
Saveetha Institute of Medical and Technical Sciences (SIMATS)
Chennai, Tamil Nadu, India
e-mail: Subramanian.scpt@saveetha.com

ORCID AND CONTRIBUTIONSHIP
Dubba Naga Raju - 0009-0006-5328-8003 A B
Shenbaga Sundaram Subramanian - 0000-0002-6150-0928 D F
Ahlam Mazi - 0000-0003-3125-5260 E
Maha Bamehrez - 0000-0001-6964-2181 E
Saad Suleman Alfawaz - 0000-0002-1901-5259 C
Riziq Allah Mustafa Gaowgzeh - 0000-0003-4199-2600 C
Baraa Alsulaimani - 0000-0003-0345-3948 E

RECEIVED: 16.01.2026
ACCEPTED: 01.06.2026

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

ORIGINAL ARTICLE

Effect of active neurodynamic sliding versus hamstring stretching with plyometric training on flexibility and agility among collegiate football players

Revanth Manikandan, Vinodhkumar Ramalingam

SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, INDIA

ABSTRACT

Aim: To compare the effectiveness of neurodynamic sliding and static stretching combined with plyometric training in improving flexibility and agility among collegiate football players.

Materials and Methods: A 6-week comparative study included 56 collegiate football players with hamstring tightness recruited from a private university. Participants were randomly assigned to three groups: Group A (n = 18) received standard neurodynamic sliding (SNDS) (5 × 60 s), Group B (n = 18) received modified neurodynamic sliding (MNDS) (3 × 30 s), and Group C (n = 20) received static stretching (SS) (3 × 30 s). All groups also participated in plyometric training to improve agility.

Results: Using SPSS version 29, pre- and post-intervention analyses performed with paired t-tests, one-way ANOVA, and post hoc tests demonstrated significant improvements ($p < 0.05$) across all groups. Group B (MNDS) showed the greatest improvement in agility, while both Group A (SNDS) and Group B demonstrated greater improvements in dominant-leg flexibility than Group C (SS). In addition, Groups A and B showed greater improvements in non-dominant-leg flexibility compared with Group C.

Conclusions: All three intervention groups demonstrated improvements in hamstring flexibility and agility. The MNDS group showed the greatest improvements in hamstring flexibility and agility among collegiate football players. The SNDS group demonstrated similar improvements in dominant-leg flexibility. Future research should further investigate the role of leg dominance in flexibility and explore gender-specific training adaptations to optimize athletic performance.

KEYWORDS: football, hamstring flexibility, neurodynamic sliding, plyometric training, agility

Acta Balneol. 2026;68(3): 159-165. doi: 10.36740/ABAL202603105

INTRODUCTION

Football is a high-performance sport that demands speed, strength, flexibility, agility, and endurance [1]. Athletes and physically active individuals, particularly those involved in competitive sports such as football, rugby, and sprinting, often experience hamstring injuries. These injuries are influenced by several factors, including insufficient warm-up, limited flexibility, muscle imbalances, neural tension, and fatigue [2]. Muscular tightness, which refers to the adaptive shortening of the contractile and non-contractile components of muscles, typically follows a predictable pattern, with biarticular muscles being more susceptible to shortening [3]. Additionally, hamstring tightness can result from increased neural tension in conjunction with musculoskeletal factors [4].

According to De Ridder et al. (2020), the hamstring muscles have a mechanical connection with the sciatic nerve, indicating that neurodynamic techniques can influence their flexibility. Studies suggest that applying a Standard Neurodynamic Sliding (SNDS) technique to the mechanical interactions of the sciatic nerve may result in immediate and temporary improvements in hamstring flexibility among individuals with tightness. This method can be used independently or alongside static stretching [5]. According to D'Souza et al. (2024), neural stretching and sliding techniques are frequently used to improve hamstring flexibility and reduce the mechanosensitivity of the lower limb neural tissues, which can be affected by limited hamstring mobility [6]. These techniques have been shown to improve functional hamstring flexibility and the active knee extension (AKE) angle immediately, particularly in athletes such as soccer players and wrestlers [7].

García-Pinillos et al. (2015) found that hamstring flexibility plays an important role not only in preventing injuries but also in enhancing football-specific abilities such as kicking, agility, jumping, and running. These findings support the inclusion of flexibility training in football conditioning programs from a young age [8]. Moreover, players with greater hamstring flexibility tend to perform better in explosive activities compared to those with reduced flexibility.

AIM

The present study investigated the effects of active neurodynamic sliding and static hamstring stretching, both independently and in combination with plyometric training, on hamstring flexibility and agility in collegiate football players. While previous studies have explored the effects of neurodynamic sliding and static stretching separately, limited research has examined their combined application with plyometric training. Additionally, the impact of varying the duration of neurodynamic techniques on flexibility and agility has not been sufficiently explored. This study compared the effects of static stretching and neurodynamic sliding, as well as the outcomes of combining these techniques with plyometric training, on hamstring flexibility and agility among collegiate football players.

MATERIALS AND METHODS

An experimental study was conducted on a convenience sample of 56 collegiate male football players recruited from a private university in the Kancheepuram district, Tamil Nadu. The study was conducted in compliance with ISRB No. 481/07/2024/ISRB/UGSR/SCPT and was approved by the institution's ethics committee on human experimentation. A power analysis was performed using G*Power 3.1 to estimate the required sample size. With a significance level (α) of 0.05, an effect size of 0.5, and a statistical power of 95%, the analysis indicated that at least 55 participants were required for the study.

Participants aged 18-25 years with a body mass index (BMI) between 18.5 and 24.9 kg/m², a straight leg raise of less than 70°, and at least 2-3 years of collegiate football training and competition were included. Players diagnosed with a hamstring strain or tear within the previous six weeks, those taking muscle relaxants, steroids, or NSAIDs, and athletes engaged in yoga, Pilates, or physiotherapy-based stretching programs were excluded. Additionally, players who had taken a break from football training for more than six consecutive months were excluded to ensure consistency in training levels among participants.

A baseline assessment was conducted before participants were randomly assigned to three groups using simple random sampling by the lottery method. Each participant was assigned a unique number, and a neutral researcher conducted the allocation process to ensure fairness. Because the study used a single-blind design, participants were blinded by not being informed of their group assignments. The flexibility and agility programs for participants in each group were demonstrated by three different research assistants to ensure proper execution. Participants underwent practice sessions to become familiar with the Neurodynamic Sliding (NDS) technique prior to the intervention. Group A (n = 18) received the Stand-

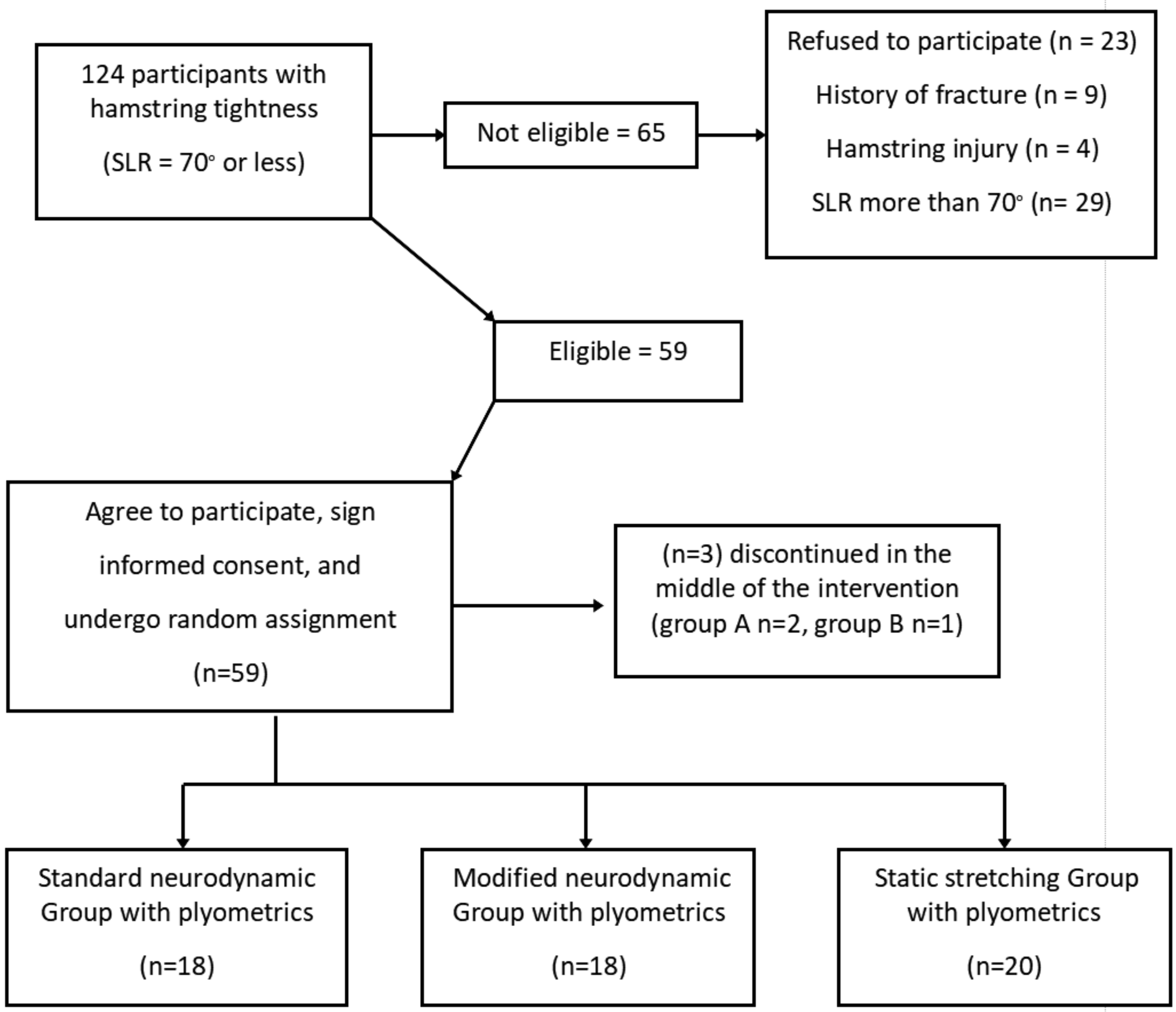

Fig. 1. Consort Flow Chart

Source: compiled by the authors of this study

ard Neurodynamic Sliding (SNDS) technique as described by Castellote-Caballero et al. (2012) [9], Group B (n = 18) underwent the Modified Neurodynamic Sliding (MNDS) technique with a modified duration [10], and Group C (n = 20) received active static stretching (SS), as shown in Figure 1. Additionally, all three groups participated in plyometric exercise training. The groups were trained three days per week for six weeks. A post-treatment outcome assessment was conducted after six weeks of intervention. This duration provided sufficient time for implementing the intervention protocols, ensuring consistent training exposure and allowing a thorough assessment of their effects on participants' flexibility and agility.

Using SPSS version 29, within-group intervention effects were analyzed using paired t-tests, whereas between-group intervention effects were analyzed using one-way ANOVA followed by appropriate post hoc tests to determine differences between interventions. The progression of participants through the various stages of the study is depicted in the CONSORT flow diagram (Fig. 1).

INTERVENTION PROTOCOL

Neurodynamic sliding (NDS) technique

Group A received the SNDS technique following the protocol described by Castellote-Caballero et al. (2012) [9]. Group B received a modified version of the neurodynamic sliding technique with a shorter duration [10], referred to as MNDS. As shown in Figure 2, participants in the SNDS and MNDS groups were instructed to sit in a thoracic flexion posture and alternate between knee extension with ankle dorsiflexion while extending the neck, and knee flexion with ankle plantarflexion while flexing the neck. These NDS techniques facilitate neural mobilization and improve hamstring flexibility [11-13].

Static stretching (SS) technique

Group C participants were instructed to perform a conventional static stretch [14,15] while standing and supporting themselves on a chair with the heel of the dominant leg. They then shifted the pelvis into anteversion while tilting the torso forward until a stretch was felt in the posterior thigh muscles, as shown in Figure 3.

Plyometric training

Plyometric training sessions lasted approximately 35 minutes and consisted of a regular 10-minute warm-up, including 5 minutes of jogging and 5 minutes of stretching, followed by 20 minutes of side jumping, countermovement jumps, and double-bound jumps, and concluded with a 5-minute cool-down. Each exercise consisted of 10 repetitions performed for 4 sets.

Side jumping

Participants performed jumps from side to side while keeping their feet together between cones.

Countermovement jump

Participants fully flexed their knees while swinging their arms backward, then explosively swung their arms forward and upward to jump as high as possible.

Double-bound jump

Participants performed two consecutive forward jumps while keeping both feet close together [16,17].

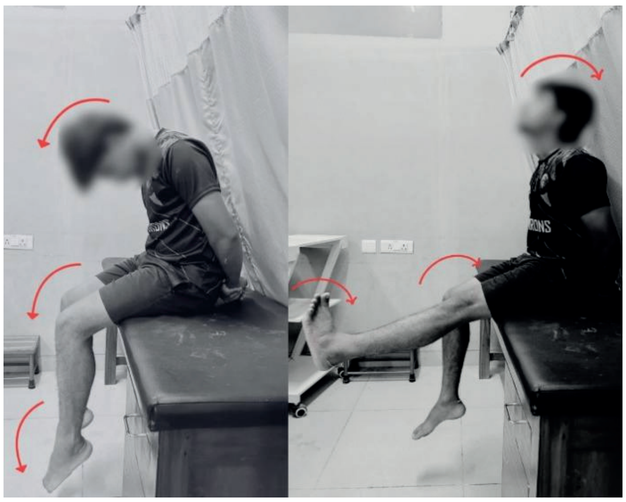

Fig. 2. The neurodynamic sliding technique involved seated thoracic, transitioning between cervical flexion, knee flexion, ankle plantarflexion (Phase A) and cervical extension, knee extension, ankle dorsiflexion (Phase B).

Source: own materials

Fig. 3. Illustrates the static stretching of hamstring muscle in standing by shifting the pelvis into anteversion and forward tilt of the torso.

Source: own materials

Table 1. Intervention study procedure

	Group A (Standard Neurodynamic Sliding)	Group B (Modified Neurodynamic Sliding)	Group C (Static Stretching)
Position	The neurodynamic sliding technique involved seated thoracic, transitioning between cervical flexion, knee flexion, ankle plantarflexion (Phase A) and cervical extension, knee extension, ankle dorsiflexion (Phase B).	The neurodynamic sliding technique involved seated thoracic, transitioning between cervical flexion, knee flexion, ankle plantarflexion (Phase A) and cervical extension, knee extension, ankle dorsiflexion (Phase B).	Participants performed a standing hamstring stretch using a chair for support, tilting the pelvis forward until a stretch was felt.
Repetitions	60 sec and 5 repetitions (14cycles per repetition)	30 sec and 3 repetitions (7 cycles per repetition)	30 sec and 3 repetitions
Duration	6 weeks	6 weeks	6 weeks

Source: compiled by the authors of this study

The intervention strategies and parameters applied to each study group are presented in Table 1.

OUTCOME MEASURES

Active knee extension

Participants lay in a supine position with their hips and knees flexed at 90°. Hamstring tightness was assessed on the right leg first, followed by the left, using a universal goniometer. Anatomical landmarks, including the lateral femoral condyle, greater trochanter, and lateral malleolus, were identified before measurement. The stationary arm was aligned with the femur, whereas the movable arm followed the fibula. Participants extended the knee until a hamstring stretch was perceived, and the popliteal angle was recorded as the average of three consecutive measurements. Based on scientific evidence, men and women have different cut-off values for confirming hamstring tightness: AKE > 33.0° in men and > 23.4° in women represent limited AKE of the tested leg and confirm hamstring tightness. The AKE test demonstrated good inter-rater and intra-rater reliability, with ICC (2,1) and ICC (3,1) values of 0.886 and 0.882, respectively [7].

AGILITY T TEST

Participants' agility was evaluated using the T-test, a four-directional test assessing the ability to change direction rapidly without losing speed or balance. Participants ran 10 m in a straight line, then moved 5 m to the left, shuffled 10 m to the right, shuffled 5 m back to the left, and finally ran backward until crossing the starting line. The therapist measured the completion time using a stopwatch, as shown in Figure 4. The fastest trial was recorded for analysis. Previous studies have reported good to excellent reliability for the T-test, with intraclass correlation coefficients (ICC) ranging from 0.79 to 0.99. Additionally, movement time (ICC = 0.92), decision time (ICC = 0.95), and decision accuracy (ICC = 0.74-0.93) have all demonstrated acceptable reliability [13].

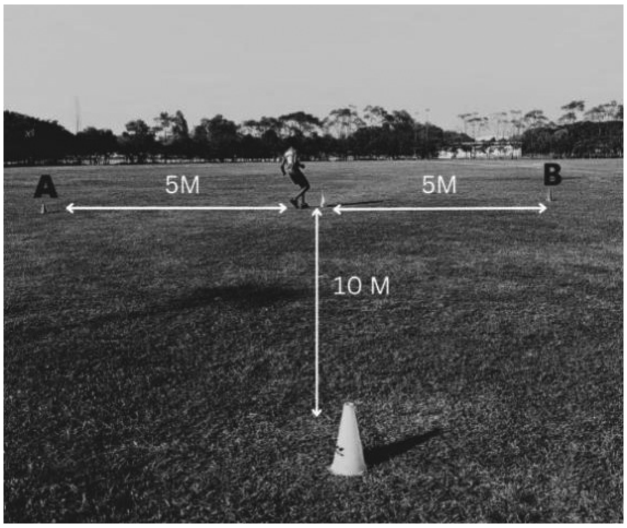

Fig. 4. Illustrates the participants Agility T test testing.

Source: own materials

RESULTS

Table 2 summarizes the baseline characteristics of the study participants and shows that there were no significant differences between the groups before the intervention. These findings indicate good baseline homogeneity.

As shown in Table 3, the Agility T-test results demonstrated significant improvements in agility in all three groups following the intervention ($p < 0.001$). Group A improved from 15.05 ± 1.18 to 13.86 ± 1.17. Group B demonstrated the greatest reduction in completion time, improving from 14.97 ± 1.17 to 12.29 ± 0.65. Group C improved from 15.08 ± 1.17 to 14.006 ± 0.96 ($t = 7.70$). Group B demonstrated the greatest improvement in agility.

For active knee extension (AKE) of the dominant leg (DL), hamstring flexibility improved significantly in all groups ($p < 0.001$), with post-intervention values lower than the normative cut-off values. Group A improved from 34.27 ± 3.62° to 15.16 ± 3.34°. Group B improved from 34.83 ± 3.29° to 15.16 ± 2.52°. Group C improved from 34.95 ± 2.99° to 17.85 ± 3.24°. Group B demonstrated the greatest improvement in dominant-leg flexibility.

Similarly, active knee extension (AKE) of the non-dominant leg (NDL) improved significantly in all groups ($p < 0.001$). Group A improved from 37.05 ± 3.48° to 16.61 ± 2.76°. Group B improved from 34.88 ± 4.32° to 15.05 ± 2.15°. Group C improved from 34.15 ± 3.31° to 17.10 ± 1.80°. Groups A and B demonstrated significantly greater improvements in non-dominant-leg flexibility than Group C.

Table 4 shows significant between-group differences following the intervention ($p < 0.05$). The mean Agility T-test score differed significantly between the groups ($F(2,53)$

Table 2. Baseline sample characteristics

	Standard Neurodynamic sliding group(n=18)	Modified Neurodynamic sliding group(n=18)	Static Stretching group (n=20)	p value
Age	20.72±2.10	21.88±1.96	21.10±2.16	0.260
BMI	21.95±2.13	21.60±1.33	21.63±1.86	0.812
Leg Dominance (R/L)	18/0	15/3	18/2	-
Pre-Agility T test	15.05±1.18	14.97±1.17	15.08±1.15	0.955
Pre-AKE DL	34.27±3.62	34.83±3.29	34.95±2.99	0.804
Pre-AKE NDL	37.05±3.48	34.88±4.32	34.15±3.31	0.055

Source: compiled by the authors of this study

Table 3. Comparison of agility and hamstring flexibility (AKE) within the groups after Interventions

	GROUP	PRE	POST	df	t value	p value
Agility T test	SNDS	15.05±1.18	13.86±1.17	17	10.543	< 0.001
	MNDS	14.97±1.17	12.29±0.65	17	8.158	< 0.001
	SS	15.08±1.17	14.006±0.96	19	7.70	< 0.001
AKE (DL)	SNDS	24.27±3.62	15.16±3.34	17	22.44	< 0.001
	MNDS	34.83±3.29	15.16±2.52	17	20.48	< 0.001
	SS	34.95±2.99	17.85±3.24	19	24.19	< 0.001
AKE (NDL)	SNDS	37.05±3.48	16.61±2.76	17	18.89	< 0.001
	MNDS	34.88±4.32	15.05±2.15	17	17.51	< 0.001
	SS	34.15±3.31	17.10±1.80	19	18.32	< 0.001

Note: DL - Dominant Leg; NDL - Non-Dominant Leg SNDS - Standard Neurodynamic Sliding group; MNDS - Modified Neurodynamic Sliding group; SS - Static stretching group; AKE – Active knee extension.

Source: compiled by the authors of this study

Table 4. Comparison of agility and hamstring flexibility (AKE) between the groups after Intervention with post hoc results

	GROUPS	MEAN&SD	f	df	p value
PostAgilityT test	SNDS	13.86±1.17	18.15	2	<0.001
	MNDS	12.29±0.65*			
	SS	14.00±0.96			
PostAKE(DL)	SNDS	15.16±3.34*	4.91	2	0.011
	MNDS	15.16±2.52*			
	SS	17.85±3.24			
Post AKE(NDL)	SNDS	16.12±2.72	4.14	2	0.021
	MNDS	15.05±2.15*			
	SS	17.10±1.80			

Note: *denotes the post-hoc significant difference between the groups. SNDS - Standard Neurodynamic Sliding group; MNDS - Modified Neurodynamic Sliding group; SS - Static stretching group; AKE – Active knee extension.

= 18.15, $p < 0.001$). Post hoc analysis demonstrated that the MNDS group (12.29 ± 0.65) achieved significantly better agility performance than the SNDS group (13.86 ± 1.17) and the SS group (14.00 ± 0.96).

For hamstring flexibility, the mean AKE values for the dominant leg differed significantly between the groups ($F(2,53) = 4.911$, $p = 0.011$). Post hoc analysis showed that the MNDS and SNDS groups achieved similar post-intervention AKE values (15.16 ± 2.52° and 15.16 ± 3.34°, respectively), both of which were significantly better than those of the SS group (17.85 ± 3.24°).

The mean AKE values for the non-dominant leg also differed significantly between the groups ($F(2,53) = 4.146$, $p = 0.021$). Post hoc analysis showed that the MNDS group (15.05 ± 2.15°) achieved significantly better post-intervention AKE values than the SNDS group (16.12 ± 2.72°) and the SS group (17.10 ± 1.80°).

DISCUSSION

This study compared the effectiveness of the Standard Neurodynamic Sliding (SNDS) technique, the Modified Neurodynamic Sliding (MNDS) technique, and active static stretching (SS) in improving hamstring flexibility. In addition, it evaluated the influence of plyometric training on agility in collegiate football players. By comparing these interventions, the study sought to identify the most effective approach for improving flexibility and agility and to provide practical implications for training and rehabilitation in athletic populations.

According to Castellote-Caballero et al. (2012) and Park et al. (2014), the SNDS technique is typically performed for 60 seconds with five repetitions [9,10]. The present study introduced a modified protocol consisting of three 30-second sets. This modification was intended to determine whether a shorter intervention could produce comparable improvements in flexibility and agility while offering a more time-efficient approach for athletes.

Previous studies have shown that static stretching (SS) provides immediate improvements in hamstring flexibility, whereas neurodynamic sliding (NDS) may provide more sustained benefits [15]. Consistent with Yogeshwar et al. (2023), the present findings support the effectiveness of both tensioner and neural slider techniques in improving flexibility and postural balance [12]. Similarly, both techniques were found to be effective in football players with short hamstring syndrome. However, the reported findings vary depending on whether short-term or long-term outcomes are evaluated [13]. Furthermore, NDS techniques have been shown to improve soft-tissue flexibility in the lower limbs [18,19]. Previous studies have also reported that static stretching effectively improves hamstring flexibility, whereas dynamic stretching has shown inconsistent effects [20]. Furthermore, ankle mobilization combined with muscle energy techniques has been reported to improve hamstring flexibility in individuals with hamstring tightness more effectively than ultrasound therapy combined with static stretching [17,21,22]. However, this raises the question of whether static stretching alone, without additional interventions, is sufficient to produce optimal improvements in flexibility.

A limitation of this study is that the long-term advantages or disadvantages of the modified neurodynamic sliding technique were not evaluated. In addition, the inclusion of only male athletes limits the generalizability of the findings to female football players. Future studies should further investigate the relationship between leg dominance and hamstring flexibility and explore potential gender-specific adaptations to these interventions.

CONCLUSIONS

This study evaluated the effects of three intervention strategies on hamstring flexibility and agility in collegiate football players. Although all groups demonstrated measurable improvements, the group receiving the Modified Neurodynamic Sliding (MNDS) technique showed the greatest improvements in both hamstring flexibility and agility. These findings suggest that modified neurodynamic sliding combined with plyometric training may provide superior neuromuscular benefits. This approach may contribute to improved athletic performance and could potentially help reduce the risk of lower-limb injuries in collegiate football players.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Vinodhkumar Ramalingam
Saveetha college of Physiotherapy
Saveetha Institute of Medical and Technical Sciences
Saveetha Nagar, Tandalam, Chennai, India
e-mail: vinodhkumar.scpt@saveetha.com

ORCID AND CONTRIBUTIONSHIP

Revanth Manikandan - 0009-0003-0523-7728 A B D
Vinodhkumar Ramalingam - 0000-0002-5269-0520 A C E F

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 22.05.2025
ACCEPTED: 18.06.2026

ORIGINAL ARTICLE

The influence of cardiovascular risk factors and depressive disorders on endothelial function in patients undergoing cardiac rehabilitation

Oksana R. Makar[1], Lukyan V. Andriyuk[1], Oksana M. Hanusych[2], Gennadii P. Siabrenko[3]

[1]REHABILITATION, DANYLO HALYTSKY NATIONAL MEDICAL UNIVERSITY, LVIV, UKRAINE

[2]REHABILITATION, LVIV REGIONAL HOSPITAL FOR WAR VETERANS NAMED BY YURII LYPA, LVIV, UKRAINE

[3]REHABILITATION, KIROVOHRAD REGIONAL CLINICAL HOSPITAL FOR WAR VETERANS, KROPYVNYTSKYI, UKRAINE

ABSTRACT

Aim: To investigate the impact of cardiovascular risk factors and depressive symptoms on endothelial function in patients undergoing ambulatory cardiac rehabilitation.

Materials and Methods: The study included 98 patients (63 men and 35 women, mean age 49±6 years), who were divided into two groups: Group I – patients with stage I–II arterial hypertension (n=53), and Group II – patients without hypertension (n=45). Endothelial function was assessed using flow-mediated dilation (FMD) of the brachial artery via ultrasound (Samsung H-60, 7 MHz linear probe). The presence and severity of depression were assessed using the HADS scale. All patients completed a structured outpatient cardiac rehabilitation program including aerobic training, psychological support, pharmacological therapy, nutritional counseling, and educational sessions.

Results: Patients with hypertension (Group I) demonstrated significantly lower endothelium-dependent and endothelium-independent vasodilation compared to Group II ($p<0.05$). Clinically significant depression was observed in 35% of hypertensive patients at baseline and in 11% of patients in Group II. After rehabilitation, no cases of clinically significant depression were observed in either group, with affected patients shifting to the subclinical depression category. No statistically significant correlation was found between the severity of depressive symptoms and endothelial function parameters.

Conclusions: The presence of hypertension is associated with impaired endothelial function and a higher prevalence of depressive symptoms. A comprehensive outpatient cardiac rehabilitation program, integrating physical, psychological, pharmacological, nutritional, and educational interventions, contributed to a significant reduction in depressive symptoms and improvement in patients' psychoemotional status. These findings support the inclusion of psychosocial interventions in routine cardiovascular care.

KEYWORDS: cardiac rehabilitation; endothelial dysfunction; arterial hypertension; depression; cardiovascular risk factors

Acta Balneol. 2026;68(3): 166-170. doi: 10.36740/ABAL202603106

INTRODUCTION

Despite a significant amount of research devoted to the study of classic risk factors for cardiovascular disease – such as smoking, hypertension, elevated serum cholesterol etc., and despite a significant progress in diagnosis and treatment, cardiovascular disease remains the leading cause of morbidity and mortality in the world [1,2,3]. This makes further study of their etiology, pathogenesis, and modifying factors urgent [4,5,6].

Endothelial dysfunction is a well-recognized early marker of cardiovascular disease. The endothelium, as an active metabolic organ, performs numerous regulatory functions, including the control of vascular tone, permeability, coagulation, and inflammation. Disruption of these mechanisms, known as endothelial dysfunction, plays a leading role in the pathogenesis of atherosclerosis, hypertension, coronary heart disease, and other cardiovascular pathologies [7,8].

One of the key pathogenetic mechanisms of endothelial dysfunction is considered to be a violation of the metabolism of nitric oxide, which is synthesized by endothelial cells. The deterioration of the functional state of the endothelium can be caused by both a decrease in nitric oxide production and its increased degradation due to the activation of oxidative stress [9,10,11].

At the same time, there is growing attention to psychoemotional factors as modifiers of the course of cardiovascular disease [12,13,14]. Depression, one of the most common affective disorders, is associated with an increased risk of cardiovascular mortality, as well as with a worsening prognosis in patients with pre-existing cardiac pathology [15,16]. Chronic psycho-emotional stress and depressive states can exacerbate endothelial dysfunction through effects on the hypothalamic-pituitary-adrenal axis, activation of the sympathetic nervous system, and increased oxidative stress and inflammatory reactions [17,18].

The study of this relationship becomes especially relevant in the rehabilitation period, when the body recovers after an acute cardiovascular event or exacerbation of a chronic process. Rehabilitation is not only physical recovery, but also psycho-emotional stabilization, so taking into account psychosocial factors, such as depressive disorders, is extremely important for achieving a sustainable clinical effect [19].

AIM

The aim of this study is to investigate the impact of cardiovascular risk factors and depressive disorders on the state of endothelial function in patients in rehabilitation settings.

MATERIALS AND METHODS

The study included 98 patients (63 men and 35 women) aged 40 to 60 years, with a mean age of 49±6 years. All patients were undergoing rehabilitation after cardiovascular events or with risk factors for cardiovascular disease. Depending on the presence of arterial hypertension (AH), the participants were divided into two groups: Group I (n=53) - patients with diagnosed AH of stages I-II; Group II (n=45) - patients without clinically verified AH. All patients underwent a comprehensive clinical and instrumental examination, which included assessment of blood pressure, body mass index, laboratory markers of lipid metabolism, and the functional state of the endothelium. The presence or absence of the following risk factors was noted: dyslipidemia, smoking, hereditary predisposition to cardiovascular diseases, low physical activity, and excess body weight.

The functional state of the endothelium was assessed using a cuff test using ultrasound on a Samsung H-60 device with a 7 MHz linear sensor. Endothelium-dependent vasodilation (EDV) and endothelium-independent vasodilation (EIV) of the brachial artery were determined, which allowed assessing both the functional reserve of the endothelium and the reactivity of the vascular wall [20,21].

The assessment of psychoemotional state was carried out using the HADS scale (Hospital Anxiety and Depression Scale), which allowed to identify the presence and severity of depressive and anxiety symptoms in patients with somatic diseases.

Cardiac rehabilitation was performed in an outpatient setting and included a set of measures aimed at improving the functional status of patients and reducing the risk of complications. The basis of the program was aerobic physical activity, which was individually selected according to the functional status of patients, the results of cardiovascular risk stratification, comorbidities, and the level of exercise tolerance.

The program also included: psychological support to reduce stress and correct anxiety and depressive disorders; background drug therapy as part of secondary prevention in accordance with current clinical recommendations; nutritionist consultations on nutritional correction, weight normalization, and improvement of the metabolic profile; educational lectures on healthy lifestyles, behavioral changes, and the role of risk factor modification. This approach provided a multidisciplinary impact on the physical and psycho-emotional health of patients. Indicators were assessed at the beginning and one month after entering the program.

Statistical data processing was performed using Statistica software. Student's t-test and χ^2-test were used to analyze intergroup differences. Correlation analysis was performed using Pearson's coefficient. Results were considered statistically significant at $p<0.05$.

The study protocol was approved by the Local Bioethics Committee. Written informed consent was obtained from all participants prior to enrolment in the study.

RESULTS

In our study, endothelial function indices were compared between two groups of patients: group I (patients with stage I–II arterial hypertension) and group II (patients without arterial hypertension). Ultrasound was used to assess various parameters characterizing the state of the endothelium, in particular, brachial artery diameter and indices of endothelium-dependent and endothelium-independent vasodilation (EDV and EIV) – Table 1.

BRACHIAL ARTERY DIAMETER

Patients in group I had a significantly larger brachial artery diameter (4.68±0.1 mm) compared to patients in group II (4.13±0.1 mm, $p<0.05$). This suggests a more pronounced vascular response to stress, typical of individuals with arterial hypertension.

ENDOTHELIUM-DEPENDENT VASODILATION (EDV)

The cuff test showed that EDV was less pronounced in group I compared to group II:

EDV after 15 seconds was 9.45±1.07% in group I and 13.18±1.2% in group II ($p<0.05$);

EDV after 60 seconds was 12.19±1.16% in group I and 16.5±1.23% in group II ($p<0.05$).

These results indicate impaired endothelial function in patients with hypertension, characterized by a disruption of normal vascular responsiveness.

ENDOTHELIUM-INDEPENDENT VASODILATION (EIV)

EIV also showed a more pronounced response in group II patients:

EIV after 1 minute was 17.28±1.21% in group I and 21.44±1.25% in group II ($p<0.05$);

EIV after 3 minutes was 22.36±1.51% in group I and 28.15±1.47% in group II ($p<0.05$);

EIV after 5 minutes was 24.73±1.5% in group I and 30.18±1.51% in group II ($p<0.05$).

This indicates a higher ability of vessels in group II to recover after cuff application, which may be associated with fewer atherosclerotic changes and better vascular reactivity in patients without arterial hypertension.

PSYCHOEMOTIONAL STATE

All patients underwent an assessment of their psychoemotional state using the HADS scale (Table 2).

The results indicated a pronounced decrease in depressive symptoms in patients from both groups after the rehabilitation program. Clinically pronounced depression disappeared in both groups, with affected patients shifting to the subclinical depression category. Correlation analysis revealed no statistically significant association

Table 1. Comparative characteristics of indicators of endothelium-dependent vasodilatation (EDV) and endothelium-independent vasodilatation (EIV) in patients with AH and without AH

Indicators	I group (n=53), M±m	II group (n=45), M±m	Certainty
Brachial artery diameter, mm	4,68±0,1	4,13±0,1	p<0,05
D 15 s, mm	5,1±0,11	4,63±0,11	p<0,05
D 60 s, mm	5,14±0,11	4,78±0,11	p<0,05
EDV 15 s,%	9,45±1,07	13,18±1,2	p<0,05
EDV 60 s,%	12,19±1,16	16,5±1,23	p<0,05
EIV 1 min,%	17,28±1,21	21,44±1,25	p<0,05
EIV 3 min,%	22,36±1,51	28,15±1,47	p<0,05
EIV 5 min,%	24,73±1,5	30,18±1,51	p<0,05

Source: compiled by the authors of this study

Table 2. Dynamics of changes in depression indicators in both groups during the rehabilitation program

Indicators(HADS-D)	I group (n=53)		II group (n=45)	
	At the beginning of program	At the end of the program	At the beginning of program	At the end of the program
Normal level	0	7 (13%)	7 (15%)	19 (43%)
Subclinical depression	34 (65%)	46 (87%)	33 (74%)	26 (57%)
Clinically pronounced depression	19 (35%)	0	5 (11%)	0

Source: compiled by the authors of this study

between the severity of depressive symptoms and endothelial function parameters (p>0.05).

Discussion. The findings of our study confirm that arterial hypertension is significantly associated with endothelial dysfunction. Patients in group I with arterial hypertension exhibited impaired endothelium-dependent and endothelium-independent vasodilation, which aligns with previous studies showing that elevated blood pressure is a risk factor for endothelial dysfunction [22-24]. The enlarged brachial artery diameter observed in group I may be a result of sustained vascular stress, common in hypertensive patients, and indicative of early-stage atherosclerotic changes.

Endothelial dysfunction, characterized by reduced EDV, is a well-established precursor to cardiovascular events and suggests impaired vascular responsiveness. This finding is consistent with earlier research, which highlights that endothelial dysfunction plays a key role in the development of atherosclerosis and other cardiovascular diseases [7,8]. Moreover, the slower recovery of vascular reactivity in hypertensive patients (as seen in the EIV results) further supports the hypothesis that hypertension impairs endothelial function. It has been widely shown that hypertension leads to increased vascular contractility and impaired endothelial calcium signaling, contributing to long-term cardiovascular risks [22,23].

An interesting finding from our study was the positive effect of the comprehensive cardiac rehabilitation program on the psychoemotional status of patients, which included physical activity, psychological support, and educational interventions. Previous studies have also shown that such multidisciplinary interventions can effectively reduce depressive symptoms and improve endothelial function in patients with cardiovascular disease [19,25]. In our study, depressive symptoms were reduced in both groups, with complete disappearance of clinically pronounced depression and a shift to the subclinical category. These findings underscore the importance of addressing both physical and psychoemotional aspects during cardiac rehabilitation. As demonstrated in several studies, regular physical activity and psychological support positively influence endothelial function and decrease anxiety and depressive symptoms in cardiovascular patients [12,19,25]. However, because endothelial function was assessed only at baseline, the present study cannot confirm improvement in endothelial function following the rehabilitation program.

The slower reduction in depressive symptoms among patients without hypertension (group II) suggests that other psychosocial factors might play a role in the rehabilitation process. This is consistent with research indicating that individual psychological characteristics, such as coping mechanisms and social support, can influence rehabilitation outcomes [13,14]. The relationship between psychological stress, depression, and endothelial dysfunction is well-documented, with oxidative stress and inflammation playing key roles in the pathogenesis of cardiovascular diseases [17,18].

Our findings highlight the critical role of controlling hypertension and addressing depressive disorders in patients with cardiovascular disease. Comprehensive rehabilitation programs targeting both physical and psychological health may contribute to improved psychoemotional status and reduction of depressive symptoms in this population. The observed benefits support the importance of a holistic approach to cardiac rehabilitation [19,25].

CONCLUSIONS

In patients with arterial hypertension, impaired endothelium-dependent and endothelium-independent vasodilation is observed, which indicates the presence of endothelial dysfunction associated with increased cardiovascular risk.

Depressive disorders are found in a significant proportion of patients with and without hypertension, with clinically pronounced depression more common in individuals with hypertension. No statistically significant correlation was found between the severity of depressive symptoms and endothelial function parameters.

The use of a comprehensive outpatient cardiac rehabilitation program, including aerobic exercise, psychological support, drug prophylaxis, nutritionist consultations, and educational activities, contributed to a significant reduction in depressive symptoms and improvement of the psychoemotional status of the patients.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Oksana R. Makar
Rehabilitation, Danylo Halytsky National Medical University
Lviv, Ukraine
e-mail: kseni_kseni@ukr.net

ORCID AND CONTRIBUTIONSHIP
Oksana R. Makar - 0000-0002-1863-1412 A D
Lukyan V. Andriyuk - 0000-0002-8064-8805 E F
Oksana M. Hanusych - 0009-0000-1396-4202 B
Gennadii P. Siabrenko - 0000-0002-2967-0900 C

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 15.04.2025
ACCEPTED: 22.05.2026

ORIGINAL ARTICLE

Effectiveness of Mulligan's two-leg rotation technique versus active release technique on improving hamstring flexibility among college students

Sajitta John, Bharathi Ravichandran, Kamalakannan Mohanan

SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, INDIA

ABSTRACT

Aim: To compare the effect of Mulligan's Two-Leg Rotation (TLR) technique and Active Release Technique (ART) on improving hamstring flexibility among college students.

Materials and Methods: A total of 54 college students with hamstring tightness were randomly allocated into two groups (ART, n = 27; Mulligan's TLR, n = 27) using the chit method (lottery-style random allocation). Each participant picked a sealed chit labeled either 'Group A' (ART) or 'Group B' (TLR). Each treatment session lasted 30 minutes and was administered three times per week for four weeks. Outcome measures were assessed using the Active Knee Extension Test and Sit-and-Reach Test before and after treatment.

Results: Both techniques significantly improved hamstring flexibility and range of motion. However, the Active Release Technique produced significantly greater gains than Mulligan's Two-Leg Rotation technique ($p < 0.001$).

Conclusion: Both ART and Mulligan's TLR techniques are effective in improving hamstring flexibility, with ART showing superior results.

KEYWORDS: hamstring tightness, Active Release Technique, Mulligan's Two-Leg Rotation, flexibility, college students, health and wellbeing

Acta Balneol. 2026;68(3): 171-176. doi: 10.36740/ABAL202603107

INTRODUCTION

The biceps femoris, semitendinosus, and semimembranosus are the three main muscles that make up the hamstrings. They are situated in the posterior compartment of the thigh and function as knee flexors and hip extensors [1]. Fast-twitch muscles, particularly those that traverse more than one joint, are more likely to exhibit decreased muscular flexibility. Moreover, a decrease in hamstring flexibility may cause compensatory adaptations in pelvic motions, posture, and vertebral curves during daily activities [2]. Tightness can occur when muscle tension is raised, whether passively or actively. Passively by postural adaptation, which can promote muscular shortening; actively through muscle spasms or contractions [3]. Rozina Bhimani et al. (2022) conducted a study on "Prevalence and Characteristics of Muscle Tightness in Young Adults" and concluded that muscle tightness is more common in women than in men and is often accompanied by pain [4]. Pratik R. Jaiswal et al. (2022) conducted a study on „Effectiveness of Mulligan's Two-Leg Rotation (TLR) Versus Muscle Energy Technique (MET) in Subjects with Hamstring Tightness" and concluded that Mulligan's TLR showed significantly better results than MET [5]. Maitri Shukla et al. (2021) conducted a study on "Correlation of Hamstring Flexibility with Sitting Hours and Physical Activity among Physiotherapy Students" and concluded that students with longer sitting hours tended to have greater hamstring tightness [6]. Sarfraj Khan et al. (2021) conducted a study on "Immediate Effect of Active Release Technique (ART) Versus Muscle Energy Technique in Subjects with Hamstring Tightness" and found that a single session of ART was more effective than MET in improving hamstring flexibility and range of motion (ROM) [7].

Shraddha Kothawale et al. (2018), in a study entitled "Effectiveness of Positional Release Technique and Active Release Technique on Hamstring Tightness", concluded that ART was more effective than the positional release technique. Pratik A. Phansopkar et al. (2014), in the study "Effects of Mulligan's Two-Leg Rotation Technique in Hamstring Flexibility: A Pre-Post Experimental Study", concluded that Mulligan's TLR technique is effective [8]. A study conducted by Rajalaxmi et al. (2015) examined the impact of Mulligan's Traction Leg Raise (TLR) and Bent Leg Raise (BLR) techniques on individuals experiencing acute non-specific low back pain. The findings indicated that both methods were effective in enhancing hamstring flexibility, as demonstrated by pain relief, an increase in range of motion, and a reduction in functional disability [9]. Similarly, research by Wajida Perveen et al. (2020) compared the effectiveness of Mulligan's Bent Leg Raise Technique with the Traction Straight Leg Raise Technique in improving hamstring flexibility. The results revealed that both approaches were equally beneficial in enhancing flexibility among healthy young adults [10]. George et al. (2006) suggested that the outcomes of ART vary significantly based on the practitioner's proficiency, making it difficult to ensure uniform results across studies [11].

College students frequently experience hamstring tightness due to prolonged periods of sitting, lower levels of physical activity, and insufficient stretching. While several approaches are available to enhance hamstring flexibility, research directly comparing Mulligan's TLR and ART remains scarce. Mulligan's TLR technique is a gentle mobilization method that improves movement range, whereas ART targets soft tissue adhesions to enhance muscle elasticity.

AIM

To compare the effects of Mulligan's TLR and ART on hamstring flexibility among college students.

MATERIALS AND METHODS

Study design: Experimental study

Subjects: College students with reduced hamstring flexibility

SAMPLING TECHNIQUE

The participants were recruited using a convenience sampling technique (easily accessible college students) based on the inclusion and exclusion criteria. Following recruitment, participants were randomly allocated into two groups (ART and Mulligan's TLR) using the chit method (lottery-style random allocation).

SAMPLE SIZE AND BASELINE CHARACTERISTICS

A total of 54 participants were recruited and randomly allocated into two groups (ART: n = 27; TLR: n = 27). Baseline demographic variables, including age, sex distribution, and baseline AKET and SRT values, were recorded prior to intervention. Independent t-test and chi-square test were used to assess baseline comparability between groups.

STUDY PROCEDURE:

This comparative study included 54 participants. The participants were recruited using convenience sampling based on the inclusion and exclusion criteria. Following recruitment, participants were randomly allocated into two groups (ART and Mulligan's TLR) using the chit method. Each participant picked a sealed chit labeled either ‚Group A' (ART) or ‚Group B' (TLR). This method ensured unbiased randomization. After explaining the study procedure to the participants, their informed consent was obtained. Pre-test and post-test assessments were performed using the Active Knee Extension Test (AKET) and Sit-and-Reach Test (SRT). The study procedure is illustrated in Figure 1 as a flow chart. Each treatment session lasted 30 minutes and was administered three times per week for four weeks. The internal validity of AKET and SRT relies on standardized procedures like consistent positioning, warm-up, and controlled movement. Factors such as examiner skill, participant effort, limb length, and measurement tools can affect results. External validity depends on how well these tests apply to various populations. Age, body proportions, and activity levels influence outcomes, but standardization improves reliability and generalization.

Mulligan's TLR technique

In the study, participants were positioned supine, with the therapist standing beside the side exhibiting limited AKE. Participants gripped the side of the plinth with the hand opposite to the side receiving the TLR. Both legs were flexed, lifting the feet off the plinth. While keeping their shoulders on the bed, participants slowly moved their legs toward the side with limited AKE. Upon reaching the limit, the position was sustained for 30 seconds. A one-minute rest was given between each stretch and the procedure was repeated for a set of 10 repetitions. The same procedure was applied to the opposite side.

ART

For the active release technique, participants were positioned prone with their foot hanging off the edge of the treatment table. The therapist then applied longitudinal tension to the tight hamstring muscle bellies while instructing the participant to eccentrically contract these muscles by extending the knee. This was repeated five times, following the ART protocol. The proximal hamstrings were treated with the participants in a supine position, with the hip and knee flexed at 90 degrees, and two treatment passes were applied in this position. The same procedure was performed on the opposite side.

Inclusion criteria

- Age between 18 and 25 years
- AKE greater than 20°
- Both male and female

Exclusion criteria

- Low back pain
- History of lower extremity or hamstring injury
- History of lumbar, hip, or knee surgery
- Any neurological problems

Outcome measures: AKET and SRT

AKET

The Active Knee Extension Test (AKET) gauges hamstring flexibility by measuring the amount of knee extension at 90° hip flexion. The test involves the participant lying supine with one leg extended and one hip flexed to 90°. A goniometer or inclinometer is used to measure the knee angle after the participant is instructed to actively extend the knee as far as possible without moving the thigh. Greater hamstring tightness is indicated by a smaller knee angle. For measuring hamstring flexibility, the AKET exhibits good intra-rater and inter-rater reliability. Extremely good intratester reliability (ICC = 0.99) for both limbs in healthy people was reported by Gajdosik and Lusin. Criterion-related validity was demonstrated by Souza et al., who found that AKET and gold-standard flexibility measures had strong correlations (r = 0.71-0.90).

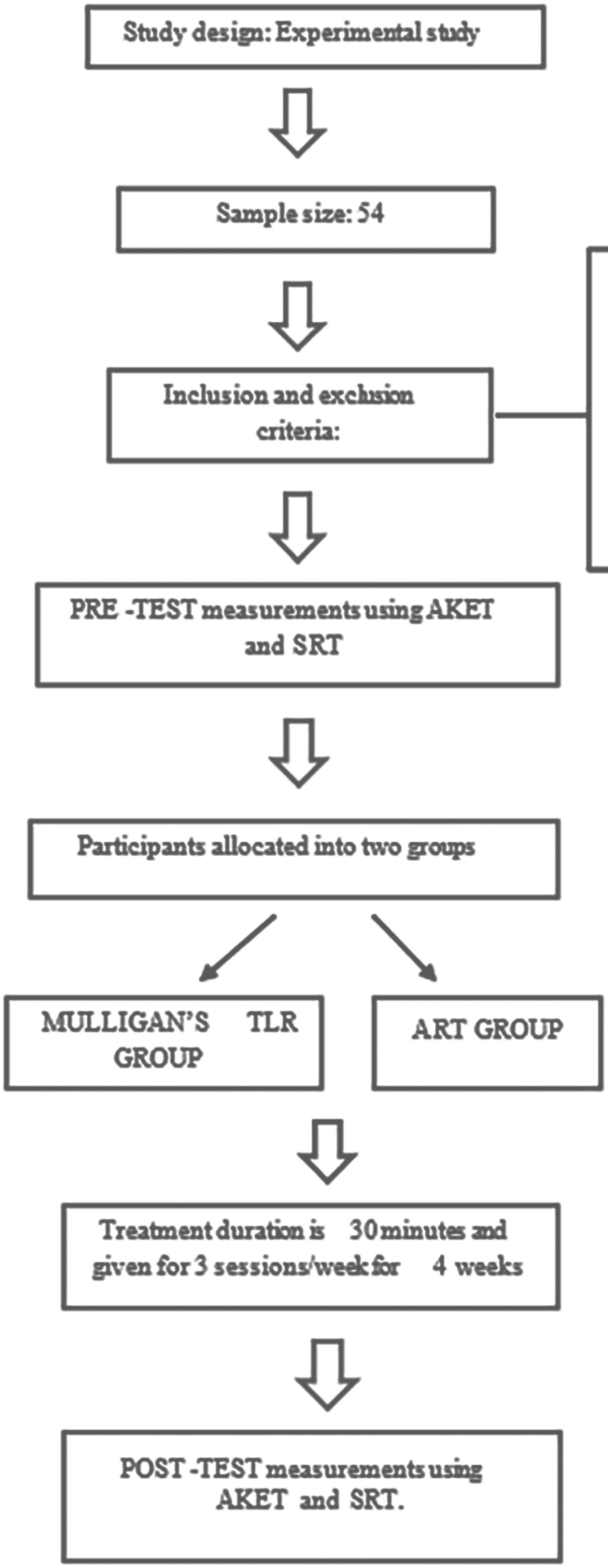

Fig. 1. Methodology – flow chart
Source: own materials

Table 1. Baseline Characteristics of Participants

Variable	ART Group (n = 27)	MTLR Group (n = 27)	P-value
Mean Age (years)	22.1 ± 1.9	22.3 ± 2.1	0.72
Sex (Male/Female)	13 / 14	14 / 13	0.79
Baseline AKET (°)	145.15 ± 3.27	144.37 ± 2.60	0.45
Baseline SRT (cm)	19.07 ± 2.02	19.37 ± 2.18	0.63

Source: compiled by the authors of this study

Table 2. Pre-test and Post-test values of Paired t-test [AKET (°)]

OUTCOME MEASURE	GROUPS	TEST	MEAN (in degrees)	SD	t value	P value
Range of motion	Active release technique (Group A)	Pre test	144.26	3.03	10.21	<0.001
		Post test	153.89	3.71		
	Mulligan's two leg rotation (Group B)	Pre test	145.48	3.23	6.24	<0.001
		Post test	150.63	3.40		

Source: compiled by the authors of this study

Table 3. Pre-test and Post-test values of Paired t-test [SRT (cm)]

OUTCOME MEASURE	GROUPS	TEST	MEAN (in degrees)	SD	t value	P value
Flexibility	Active release technique (Group A)	Pre test	18.19	1.52	8.27	<0.001
		Post test	21.37	1.11		
	Mulligan's two leg rotation (Group B)	Pre test	18.11	1.31	2.89	<0.001
		Post test	19.11	1.09		

Source: compiled by the authors of this study

SRT

When the knees are fully extended and the feet are positioned against a standardized box or bench, the maximum forward flexion of the trunk is measured. The degree of flexibility of the hamstring and lower back muscles is indicated by the distance the fingertips can reach along the measurement scale. Excellent test-retest reliability (ICC = 0.97) in healthy people was reported by Ayala et al. Intraclass correlation values (ICC) ranged from 0.89 to 0.99, showing excellent consistency, according to a meta-analysis by Mayorga-Vega et al. The Sit-and-Reach and Passive Straight Leg Raise (PSLR) tests showed significant criterion-related validity (r = 0.76), according to Baltaci et al.

STATISTICAL ANALYSIS

The collected data were compiled and subjected to both descriptive and inferential statistical analyses. Results are presented as mean values with their corresponding standard deviations (mean ± SD). Within-group differences between pre- and post-intervention measurements were evaluated using paired t-tests, while independent t-tests were applied for comparisons between groups. Statistical significance was established at a p-value of less than 0.05. All analyses were performed using SPSS software, and the accuracy of the statistical outputs, including the calculated t-values, was verified against the original study dataset. The data analysis was clearly explained in Tables 2, 3, and 4.

Statistical software

SPSS software was used for statistical analysis.

RESULTS

Baseline demographic and clinical variables, including age, gender distribution, baseline AKET, and baseline Sit-and-Reach Test (SRT) values, were comparable between the two groups. Statistical analysis revealed no significant between-group differences at baseline ($p > 0.05$), indicating that the groups were homogeneous prior to intervention (Table 1).

Within-Group Changes in Hamstring Flexibility: Both intervention groups demonstrated statistically significant improvements in hamstring flexibility following the treatment period. Paired t-test analysis showed significant increases in AKET values from pre-test to post-test in both the ART and Mulligan's TLR groups ($p < 0.001$). Similarly, significant improvements were observed in Sit-and-Reach Test scores within both groups after intervention ($p < 0.001$). These findings indicate that both treatment techniques were effective in enhancing hamstring flexibility (Tables 2 and 3).

Between-Group Comparison of AKET Outcomes: Although both groups improved significantly, the magnitude of improvement in AKET values was greater in the ART group compared with the Mulligan's TLR group. Following the intervention period, the ART group recorded a mean AKET value of 153.89° ± 3.71°, whereas the MTLR group attained a mean value of 150.63° ± 3.40°. Statistical evaluation using an independent t-test demonstrated a significant difference between the two treatment approaches ($t = 3.36$, $p < 0.001$). These findings suggest that ART was more effective in enhancing hamstring range of motion compared with the MTLR technique (Table 4).

Between-Group Comparison of Sit-and-Reach Test Outcomes: A similar trend was observed for Sit-and-Reach Test outcomes. The mean post-test SRT score in the ART group was 21.37 ± 1.11 cm, while the MTLR group achieved a mean score of 19.11 ± 1.09 cm. Statistical comparison showed a highly significant difference between the groups ($t = 7.54$, $p < 0.001$). The greater post-treatment flexibility observed in the ART group indicates that this intervention provided greater improvements in hamstring flexibility than the MTLR technique (Table 4).

Overall, both ART and Mulligan's TLR techniques were effective in improving hamstring flexibility among college students. However, participants treated with ART demonstrated significantly greater improvements in both AKET and Sit-and-Reach outcomes compared to those receiving Mulligan's TLR intervention.

DISCUSSION

The present study demonstrated that ART (Group A) had a greater effect on increasing ROM and flexibility than Mulligan's TLR (Group B) among college students with reduced hamstring flexibility.

According to Nayee and Vaghasiya (2024), hamstring flexibility was considerably increased by both ART and foam rolling, but ART had a stronger impact [12]. Conversely, Joshi et al. (2022) discovered hamstring flexibility was successfully increased by applying foam rolling and ART [13]. The benefits of Mulligan Bent Leg Raise (BLR) and ART on hamstring flexibility were examined by ul Abideen et al. (2024), who discovered that both treatments increased flexibility, but the impact of ART was greater [14]. Similar to that, Kage and Ratnam (2012) found that ART improved football players' hamstring ROM and flexibility more than BLR did [15].

Tikhile et al. (2024) found that in a person with LBP and hamstring tightness, combining PNF and TLR approaches greatly reduced pain severity and improved lumbar mobility, function, SLR, and core muscle strength [16]. Phansopkar and Kage (2013) discovered that Mulligan's TLR was more successful than BLR [17]. According to the literature, LBP along with concurrent hamstring tightness can be effectively managed by integrating PNF and Mulligan's TLR technique. ART may successfully result in an immediate increase in hamstring extensibility, according to a systematic study by Barnes and Rivera (2023) [18]. On the other hand, Maghade and Rao (2018) found no discernible difference between ART and Dynamic Soft Tissue Mobilization (DSTM) treatments [19].

Razzaq et al. (2022) examined the effects of MET and Mulligan's TLR technique on hamstring flexibility and showed that MET produced more notable improvements [20]. Ahmed (2014) discovered that both dynamic stretching and MET helped healthy people become more flexible [21]. Therefore, the needs of each patient and the therapist's clinical judgment should guide the technique selection. Liyanage et al. (2024) found neurodynamic exercises more effective than stretching alone for improving hamstring flexibility in university students, aligning with Castellote-Caballero et al. (2014) [22,23]. However, Medeiros et al. (2016) supported static stretching as still effective in healthy adults [24]. Overall, research supports a variety of methods for improving hamstring flexibility, with neurodynamic workouts demonstrating beneficial results.

The study had a few key limitations: a small, college-only sample restricts broader relevance, and without a control group, it's hard to isolate the true effects of the interventions. Short-term testing also doesn't show if results last over time [25,26]. The sit-and-reach test's accuracy can vary, and therapist technique differences may affect consistency. Additionally, the lack of follow-up leaves long-term benefits unclear. Future research should involve more diverse participants, include long-term follow-ups, and use tools like EMG and functional outcome measures. Gender analysis and combining methods with strength or mobility training could boost effectiveness [27].

CONCLUSIONS

According to the study's conclusion, ART has demonstrated promising efficacy in controlling hamstring tightness by increasing flexibility and ROM. This study used the AKE and Sit-and-Reach tests to compare Mulligan's TLR and ART for improving hamstring flexibility in college students. Flexibility was improved by both methods, although ART demonstrated greater improvements than Mulligan's TLR. However, the generalizability of the findings is constrained by a small sample size, brief study duration, and population-specific focus. Furthermore, it's challenging to verify whether the improvements were entirely attributable to the interventions in the absence of a control group. Longer follow-ups and larger, more diverse groups should be used in future studies to evaluate long-term efficacy..

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Bharathi Ravichandran
Saveetha College of Physiotherapy,
Saveetha Institute of Medical and Technical Sciences, Chennai, India
e-mail: rathisri2707@gmail.com

ORCID AND CONTRIBUTIONSHIP

Sajitta John - 0009-0004-2782-5245 B D
Bharathi Ravichandran - 0009-0004-0624-6535 A C E
Kamalakannan Mohanan - 0000-0003-2056-3137 F

RECEIVED: 23.05.2025
ACCEPTED: 06.12.2026

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

ORIGINAL ARTICLE

Effects of FIFA 11+ upper limb injury prevention protocol on dynamic balance in amateur badminton players

Surya Vishnuram[1], Jai Ganesh[2], Senthilkumar Natarajan[3], Pavithra Aravind[2]

[1]SCHOOL OF PHYSIOTHERAPY, SBV CHENNAI, SRI BALAJI VIDYAPEETH (DEEMED-TO-BE UNIVERSITY), PONDICHERRY, INDIA

[2]SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES (SIMATS), CHENNAI, TAMILNADU, INDIA

[3]KRUPANIDHI COLLEGE OF PHYSIOTHERAPY, BANGALORE, KARNATAKA, INDIA

ABSTRACT

Aim: This study aimed to compare a general warm-up with the FIFA 11+ upper limb injury prevention protocol in amateur badminton players, addressing the sport's unique demands for comprehensive injury prevention. Dynamic balance is an important predictor of injury risk.

Materials and Methods: Ninety-three participants were screened for eligibility, of whom 60 were enrolled and allocated into two groups: Group A ($n = 30$) followed the FIFA 11+ upper limb injury prevention protocol, while Group B ($n = 30$) performed traditional warm-up exercises. Both groups completed their respective protocols three times per week for four weeks. Dynamic balance was assessed using the Y Balance Test.

Results: Group A (FIFA 11+ protocol) demonstrated significant improvements in dynamic balance, with anterior reach increasing from 73.30 to 90.27 cm, posteromedial reach from 91.20 to 93.50 cm, and posterolateral reach from 89.75 to 90.99 cm. Composite balance scores also improved significantly. Group B (traditional warm-up) showed smaller but significant improvements. Overall, participants in Group A demonstrated greater improvements in dynamic balance than those in Group B.

Conclusions: The FIFA 11+ upper limb injury prevention protocol significantly improved dynamic balance in amateur badminton players compared with a traditional warm-up program, supporting its use as an effective injury prevention strategy.

KEYWORDS: FIFA 11+; badminton; dynamic balance; Y Balance Test; injury prevention

Acta Balneol. 2026;68(3): 177-181. doi: 10.36740/ABAL202603109

INTRODUCTION

Badminton is a dynamic and high-intensity racket sport that places significant physical demands on both the upper and lower extremities, making players susceptible to a variety of musculoskeletal injuries [1, 2]. The combination of rapid footwork, repetitive arm movements, lunges, and swift directional changes contributes to a heightened risk for overuse and acute injuries, particularly in the shoulders, knees, and ankles [3, 4]. Despite its non-contact nature, badminton has a reported injury incidence rate of 4.1%, with many players neglecting proper warm-up routines, especially those over the age of 30 [5].

The FIFA 11+ injury prevention program, originally designed to reduce lower extremity injuries in soccer, consists of structured neuromuscular exercises targeting strength, balance, and core stability [6]. Recent adaptations of this protocol, such as the FIFA 11+ upper limb program, have shown promise in addressing shoulder injuries, particularly in goalkeepers and throwing athletes [7, 8]. However, its application in badminton, where overhead strokes and wrist activity are dominant, remains underexplored.

Proper warm-up and preventive exercise routines are vital in mitigating injury risks in badminton. Training programs that focus on muscle strength, proprioception, and dynamic control can address common biomechanical vulnerabilities, such as eccentric overloading of the wrist extensors and the impact from lunge landings [9–11]. Moreover, lower limb strength and balance, essential for agility and movement efficiency, play a crucial role in injury prevention and performance [12–14]. The Y Balance Test (YBT) is widely used to assess dynamic postural control, which is a key predictor of lower limb injury risk [15]. There is growing evidence linking neuromuscular training with reduced injury incidence and improved athletic performance [15, 16].

AIM

This study investigates the effects of the FIFA 11+ upper limb injury prevention protocol on balance among amateur badminton players.

This experimental study included amateur badminton players recruited from various badminton academies in and around Chennai. A convenient sampling technique was employed to recruit participants. Among the 93 players assessed for eligibility, 60 met the inclusion criteria and were enrolled, while 33 were excluded due to not fulfilling the selection criteria. Eligible participants were males and females aged between 18 and 30 years who played at least one match or attended a minimum of two practice sessions per week. Players with a history of car-

Fig. 1. The patient performing a side bench strengthens core stability.
Source: own materials

Fig. 2. The patient performing lunges improves lower-limb strength and balance.
Source: own materials

Fig. 3. The patient performing a broad jump exhibits explosive lower-limb power.
Source: own materials

Fig. 4. Participant performing the Y Balance Test for assessment of dynamic balance.
Source: own materials

diovascular or neurological conditions, or fractures, as well as those already following the FIFA 11+ upper limb injury prevention protocol, were excluded.

After enrolment, the participants were divided into two groups. Group A (n = 30) followed the FIFA 11+ Upper Limb Injury Prevention Protocol, while Group B (n = 30) followed traditional warm-up exercises. Both groups adhered to their respective warm-up routines three times per week over a period of four weeks. The FIFA 11+ protocol consisted of 25 structured exercises divided into general warm-ups, upper limb strengthening, core stability [6-8], and neuromuscular control drills [15, 16]. The exercises included dynamic activities such as straight-ahead runs, hip mobility drills, lateral shuffles, zigzag footwork, and plyometric jumps. Strength and stability exercises targeted the shoulders, elbows, wrists, core muscles, and hamstrings using bodyweight, resistance bands, and light weights (Figs. 1-3).

Balance was assessed using the Y Balance Test (YBT), which involved reaching in anterior, posteromedial, and posterolateral directions while standing on one leg (Fig. 4). Distances reached in each direction were recorded, and a composite score was calculated. The test also evaluated inter-limb asymmetry, which provided insights into neuromuscular control and dynamic balance [17, 18].

STATISTICAL ANALYSIS

Statistical analysis was performed using paired sample t-tests to compare pre- and post-intervention scores within and between groups in PSPP software version 2.0.1. Mean and standard deviation were computed for all outcome measures. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 60 amateur badminton players completed the study, with 30 participants allocated to Group A (FIFA 11+ Upper Limb Injury Prevention Protocol) and 30 participants allocated to Group B (Traditional Warm-Up Group).

In Group A, anterior reach distance increased from 73.30 ± 1.76 cm to 90.27 ± 1.73 cm. Posteromedial reach improved from 91.20 ± 0.64 cm to 93.50 ± 0.67 cm, while posterolateral reach increased from 89.75 ± 4.40 cm to 90.99 ± 4.39 cm. The composite balance score increased from 254.25 ± 4.78 cm to 274.76 ± 4.77 cm. Statistically

Table 1. Pre- and Post-Test Balance Values in Group A (FIFA 11+ Protocol)

Balance Measure	Test	Mean (cm)	SD	t-value	p-value	Significance
Anterior	Pre-test	73.30	1.761	−1.485	0.1483	Not significant
	Post-test	90.27	1.734			
Posteromedial	Pre-test	91.20	0.643	−3.945	0.00046	Significant
	Post-test	93.50	0.667			
Posterolateral	Pre-test	89.75	4.402	−13.034	< 0.001	Highly significant
	Post-test	90.99	4.390			
Composite	Pre-test	254.25	4.78	−10.299	< 0.001	Highly significant
	Post-test	274.76	4.77			

Source: compiled by the authors of this study

Table 2. Pre- and Post-Test Balance Values in Group B (Traditional Warm-Up Group)

Balance Measure	Test	Mean (cm)	SD	t-value	p-value	Significance
Anterior	Pre-test	77.20	0.687	−0.851	0.4017	Not significant
	Post-test	90.26	2.520			
Posteromedial	Pre-test	88.56	1.967	−4.465	< 0.001	Significant
	Post-test	88.88	2.130			
Posterolateral	Pre-test	92.25	4.402	−5.511	< 0.001	Highly significant
	Post-test	92.90	4.706			
Composite	Pre-test	258.01	4.87	−7.752	< 0.001	Highly significant
	Post-test	272.04	5.75			

Source: compiled by the authors of this study

significant improvements were observed in the posteromedial, posterolateral, and composite balance scores following the intervention ($p < 0.05$). No statistically significant difference was observed in the anterior reach distance ($p = 0.1483$) (Table 1).

In Group B, anterior reach distance increased from 77.20 ± 0.69 cm to 90.26 ± 2.52 cm. Posteromedial reach improved from 88.56 ± 1.97 cm to 88.88 ± 2.13 cm, while posterolateral reach increased from 92.25 ± 4.40 cm to 92.90 ± 4.71 cm. The composite balance score increased from 258.01 ± 4.87 cm to 272.04 ± 5.75 cm. Significant improvements were observed in the posteromedial, posterolateral, and composite balance scores ($p < 0.001$), whereas the improvement in anterior reach distance was not statistically significant ($p = 0.4017$) (Table 2).

Comparison of the pre- and post-intervention values demonstrated improvements in dynamic balance in both groups. However, participants who underwent the FIFA 11+ Upper Limb Injury Prevention Protocol exhibited greater improvements in posteromedial reach and composite balance scores than those performing traditional warm-up exercises, suggesting enhanced dynamic postural control and balance performance following the FIFA 11+ intervention.

DISCUSSION

This study is among the first to apply the FIFA 11+ upper limb injury prevention protocol to amateur badminton players, with a specific focus on its effects on lower limb balance. While previous research has demonstrated the protocol's effectiveness in reducing upper extremity injuries in football players, particularly goalkeepers, its impact on badminton athletes, who rely heavily on rapid directional changes, lateral footwork, and upper limb dynamics, has not been extensively explored [6-8].

The findings revealed significant improvements in balance among participants who followed the FIFA 11+ protocol compared to those who performed traditional warm-up routines [9, 10]. These results suggest that the FIFA 11+ program, with its emphasis on proprioceptive training, neuromuscular control, and functional strength, effectively addresses the physical demands of badminton [11].

These findings support the use of a comprehensive, multi-joint approach to injury prevention that extends beyond upper limb conditioning to include lower limb function and dynamic balance enhancement. For athletes, coaches, and clinicians, this evidence offers a practical, structured intervention that can be easily incorporated into regular training routines.

Badminton demands rapid footwork, multidirectional movement, and frequent deceleration and landing tasks, all of which require strong postural control and lower limb stability. The protocol's inclusion of exercises targeting joint alignment, muscular coactivation, and dynamic control likely contributed to the observed improvements [1, 2].

Specifically, the posteromedial reach, a direction closely associated with functional movement and injury risk in the lower extremities, showed greater enhancement in Group A compared to Group B [3-5]. This supports the hypothesis that structured, progressive training that targets proprioception and muscle control is more effective than generic warm-ups in preparing athletes for sport-specific demands [7, 9, 10].

Moreover, previous trials have demonstrated that the FIFA 11+ protocol can significantly reduce both contact and non-contact injuries [6-8, 11]. Although the present study was limited to short-term outcomes, the improvements in balance recorded within just four weeks suggest the protocol may offer protective effects even over brief durations. Future studies should examine the long-term adherence and impact of this program in racquet sports.

CONCLUSIONS

This study demonstrated that the FIFA 11+ upper limb injury prevention protocol can significantly enhance lower extremity balance among amateur badminton players when compared to traditional warm-up routines. Although the improvements were modest, they were statistically significant, indicating meaningful gains in neuromuscular control, postural stability, and dynamic postural control, attributes essential for optimal performance and injury prevention in badminton.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Surya Vishnuram
School of Physiotherapy, SBV Chennai
Sri Balaji Vidyapeeth (Deemed-to-be University)
Pondicherry, India
e-mail: suryavishnuram@gmail.com

ORCID AND CONTRIBUTIONSHIP

Surya Vishnuram - 0000-0002-7381-967X A D E F
Jai Ganesh - 0009-0000-2987-5634 A B C
Senthilkumar Natarajan - 0000-0001-6130-9077 A E F
Pavithra Aravind - 0000-0001-9574-8270 C D

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 28.05.2025
ACCEPTED: 01.12.2025

ORIGINAL ARTICLE

Remote forward head posture evaluation using the photogrammetric method: a feasibility study

Vinodhkumar Ramalingam[1], Callie Tan Kai Lin[2], Vinosh Kumar Purushothaman[2], Vikram Mohan[3], Viswanath Sundar[4]

[1]SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, INDIA

[2]FACULTY OF HEALTH AND LIFE SCIENCES, INTI INTERNATIONAL UNIVERSITY, NILAI, MALAYSIA

[3]DEPARTMENT OF REHABILITATION AND SPORTS SCIENCES, FACULTY OF HEALTH AND SOCIAL SCIENCES, BOURNEMOUTH UNIVERSITY, BOURNEMOUTH, UNITED KINGDOM

[4]DEPARTMENT OF PHYSICAL EDUCATION & SPORT SCIENCE, VISVA-BHARATI UNIVERSITY - A CENTRAL UNIVERSITY AND AN INSTITUTE OF NATIONAL IMPORTANCE, SANTINIKETAN, INDIA

ABSTRACT

Aim: This study aimed to evaluate the feasibility of using photogrammetry to remotely assess forward head posture (FHP).

Materials and Methods: A total of 107 eligible participants were assigned to three groups (G1 = 32, G2 = 36, and G3 = 39). Each group included both health science and non-health science students. Special instructions were provided as follows: G1, written instructions and graphics; G2, video illustration; and G3, written instructions, graphics, and video illustration for palpating the C7 spinous process and capturing photographs for remote evaluation. The principal investigator screened the images and measured the craniovertebral angle (CVA) and tragus-shoulder gap using WebPlotDigitizer. Thirteen photographs were excluded because of unclear anatomical landmarks, leaving 94 participants for the final analysis. The intraclass correlation coefficient (ICC) was used to assess measurement consistency, while two-way ANOVA and the Kruskal-Wallis test were used to evaluate procedural and technical feasibility.

Results: The intraclass correlation coefficient (ICC = 0.98) demonstrated excellent intra-rater reliability of the image analysis. The findings indicate that assessing the craniovertebral angle (CVA) and the tragus-shoulder gap using different instructional methods is feasible and applicable to both health science and non-health science students. The video-based instruction method appeared to result in better participant understanding; however, CVA and tragus-shoulder gap outcomes did not differ significantly between the instructional groups.

Conclusions: Remote assessment of FHP using photogrammetric methods is feasible when clear instructions are provided. Furthermore, the video-based instruction approach may facilitate remote assessments in telehealth, particularly among individuals with diverse educational backgrounds.

KEYWORDS: assessment, audiovisual demonstration, health, posture, photogrammetry, telerehabilitation

Acta Balneol. 2026;68(3): 182-190. doi: 10.36740/ABAL202603110

INTRODUCTION

Global adoption of mobile technologies has increased dramatically. Today, more than half of the communication devices owned by the estimated 5 billion people worldwide are smartphones. Researchers have observed that young adults increasingly own and use electronic devices, as these technologies play a crucial role in modern life because of the wide range of services they provide [1]. Consequently, university students are becoming increasingly reliant on cellphones, computers, and other electronic devices [2]. However, long-term use of these devices can lead to poor posture, which may result in musculoskeletal problems and a wide range of related disorders [3]. Research indicates that forward head posture (FHP) and increased neck flexion during electronic device use are risk factors for musculoskeletal pain [4]. According to a recent study by Purushothaman et al., severe forward head posture (FHP) was detected in 73.3% of laptop users compared with tablet users. According to their study, the majority of respondents preferred tablets and laptops [5]. Previous studies have also found a correlation between the frequency of musculoskeletal pain and the time spent using smartphones during learning, as well as poor sitting posture [3,6]. Ramalingam et al. [7] and Ashok et al. [8] demonstrated a high prevalence of improper forward head posture (FHP) among university students and electronic gamers in Malaysia prior to the introduction of remote learning, owing to the increasing use of smartphones and computers. FHP is characterized by anterior displacement of the head and is commonly assessed using the craniovertebral angle (CVA), with values below 50° generally indicating forward head posture

[7]. The tragus-shoulder gap is the horizontal distance between the tragus of the ear and the posterior angle of the acromion and is considered abnormal when it is ≥ 5 cm [7,9,10].

Numerous non-invasive techniques, such as goniometry, imaging, and three-dimensional (3D) motion analysis systems, have been adopted for clinical use [11]. The two standard methods for assessing FHP are visual observation and photogrammetry. In visual observation, clinicians assess the position of the external auditory meatus relative to the vertical postural line to identify FHP [12]. In the photogrammetric method, WebPlotDigitizer software is used to measure neck angles [13]. These methods also reduce radiation exposure compared with radiographic techniques, such as X-ray imaging used for CVA assessment [14]. However, inaccurate palpation of the C7 spinous process may affect the accuracy of CVA measurements [15]. Studies on FHP assessment typically involve health science students, particularly physiotherapy students, who are familiar with palpating the C7 spinous process [16,17]. Recently, there has been a significant increase in the development of digital health solutions and a notable improvement in the availability of digital health services [18,19]. Digital physiotherapy is defined as health care services, support, and information delivered remotely via digital communication or devices [20-22]. Two previous systematic reviews have focused on physiotherapy assessments for musculoskeletal conditions using real-time digital technologies. Although reliability and validity varied considerably, both reviews indicated that certain aspects of physiotherapy assessment using telehealth video solutions may be valid and reliable for musculoskeletal conditions [23]. Digital physiotherapy has already been evaluated, and previous studies have demonstrated good concurrent validity and reliability of teleassessment [24]. Previous studies have also investigated the prevalence of musculoskeletal disorders among university students following two years of remote learning. Because non-health science students are generally unfamiliar with anatomical terminology, there is limited evidence regarding the accuracy of C7 spinous process palpation in this population. In contrast, health science students, who are familiar with anatomical terminology, have been studied in this regard. Introducing alternative methods for assessing forward head posture (FHP) using written instructions, graphics, video illustrations, and digital support may facilitate remote assessment among non-health science individuals [25,26]. With growing concerns regarding sedentary lifestyles and their associated musculoskeletal impairments, remote assessment methods are becoming increasingly important. Photogrammetry offers a non-invasive, cost-effective approach that could improve accessibility to FHP evaluation and intervention. However, before such methods can be widely adopted, it is essential to evaluate their feasibility in real-world remote settings, particularly among non-health science individuals. In the present study, feasibility is specifically defined as technical and procedural feasibility. Technical feasibility refers to the ability to obtain clear, analyzable images suitable for photogrammetric assessment, whereas procedural feasibility refers to participants' ability to independently follow standardized instructions to capture appropriate postural images. These criteria were considered essential for determining the applicability of remote FHP assessment among non-health science individuals.

AIM

The present study aimed to evaluate the procedural and technical feasibility of remote photogrammetric assessment of forward head posture using different instructional methods among health science and non-health science university students.

MATERIALS AND METHODS

PARTICIPANTS

A cross-sectional study was conducted online from March 30, 2022, to May 31, 2022, by distributing Google Forms to university students in Malaysia through social media platforms such as Facebook and Instagram. The required sample size was estimated at n = 106, assuming a 5% dropout rate and an alpha level of 0.05. One hundred thirty individuals (n = 130) aged between 19 and 29 years responded (Fig. 1). Twenty-three volunteers were excluded based on the following exclusion criteria: presence of kyphosis, scoliosis, history of cervical spine surgery, and injuries to the shoulder and cervical spine [7].

Initially, snowball sampling was used to identify and recruit interested participants through peer referrals on social media. After screening for the inclusion and exclusion criteria, eligible participants were categorized into health science (physiotherapy) and non-health science (engineering, mass communication, and business) groups. Participants who met the eligibility criteria (n = 107) were first categorized into health science and non-health science groups. These participants were then pooled into a single database, and allocation into three intervention groups (G1, G2, and G3) was performed using a computer-based randomization tool (https://www.randomizer.org/), thereby minimizing selection bias.

Within each group, participants represented both health science and non-health science categories. The primary investigator provided three distinct sets of instructions: G1 (written instructions and graphics), G2 (video illustration only), and G3 (written instructions, graphics, and video illustration). The prevalence of musculoskeletal symptoms was assessed using the Modified Nordic Questionnaire (MNQ) [27,28].

The primary investigator provided standardized guidance virtually to all participants on palpating the C7 spinous process, ensuring visibility of the tragus, preparing for photo capture, and uploading images via the provided link. Among the 107 submitted photographs, 13 were excluded (Table 1) because of poor visibility of key anatomical landmarks (tragus and C7 spinous process). In addition, intra-rater reliability was assessed using a subset of

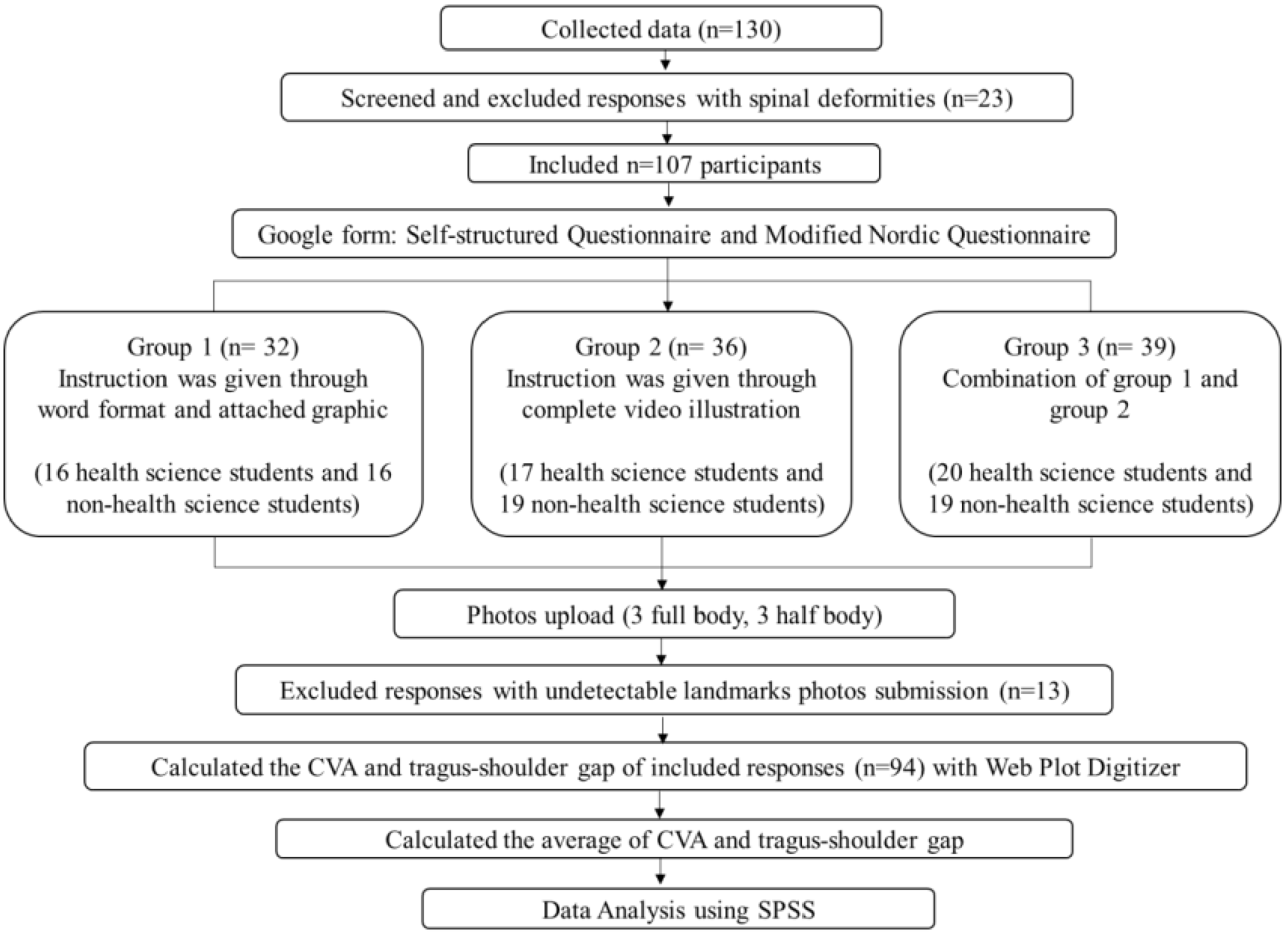


Fig. 1. Flow chart showing the participant's recruitment

Source: compiled by the authors of this study

Table 1. Demographic Characteristics of study participants

	Health Science	Non-health Science	Total	Mean ± SD	
				Age (years)	BMI (kg/m^2)
G1	15	16	31		
G2	15	17	32	22.14±1.66	21.62±3.36
G3	15	16	31		

Note: G1: Instructions/graphics; G2: video illustration and G3: Instructions/graphics and video illustration; SD: standard deviation; BMI: Body Mass Index

Source: compiled by the authors of this study

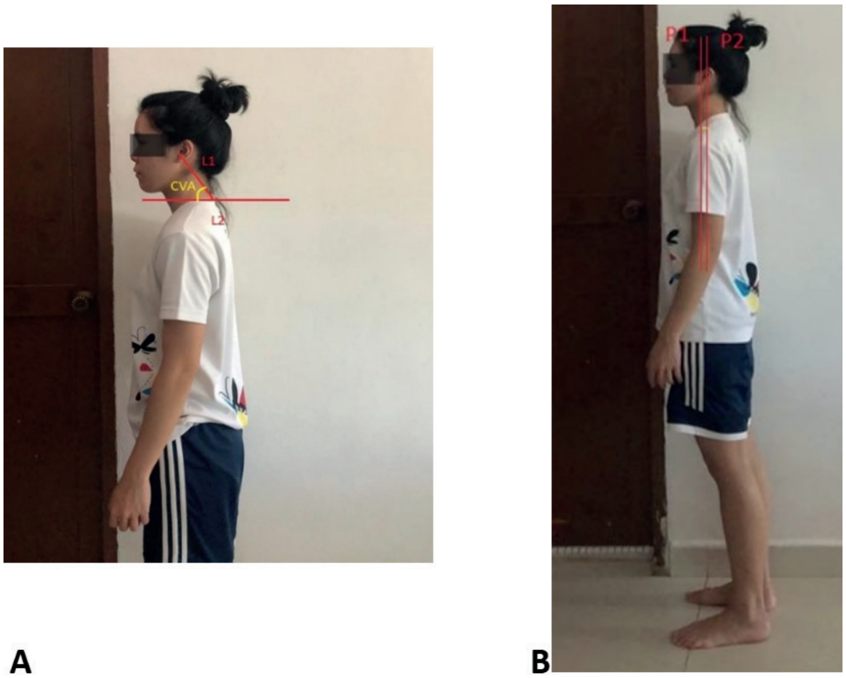
15 images. The intraclass correlation coefficient (ICC) was used to evaluate the consistency of the remote forward head posture assessment.

STANDARD INSTRUCTIONS FOR PHOTO

Participants were provided with standardized instructions for taking the photographs as part of the study procedure. They were instructed to find a clean, brightly illuminated wall. They were asked to position themselves with their left side facing the camera, keeping their hands at their sides and their feet hip-width apart [16]. To capture the half-body image, participants were instructed to position the camera 1.5 meters away, and 3 meters away for the full-body image [29]. Additionally, participants were instructed to position the camera parallel to their shoulders. Camera grid lines were enabled to ensure that the participant was precisely centered in the image and that the camera was not tilted. Participants were also instructed to ensure that the camera captured their head, neck, tragus, and entire body.

INSTRUCTIONS TO PALPATE C7 SPINOUS PROCESS

Participants were instructed to locate the C7 spinous process by placing their index and middle fingers over the most prominent bone at the back of the neck while flexing and extending the neck. Subsequently, they were instructed to place a marker or sticker over the C7 spinous



A

B

Fig. 2A. CVA measurement using half body photogrammetry; **2B.** Horizontal distance between vertical line of tragus of ear to vertical line of centre of shoulder.
Source: own materials

Table 2. Two-Way ANOVA of CVA Half Body Image

	CVA Half Body Image Mean ± SD (°)			Group		Background		Group Background	
	Health Science	Non health Science	Effect size	F	Sig.	F	Sig.	F	Sig.
G1	54.45±7.88	54.32±4.78	0.019						
G2	54.96±3.82	54.46±8.24	0.077	.713	.493	.790	.376	.417	.660
G3	57.54±5.02	54.76±5.91	0.50						

Note: G1: Instructions/graphics; G2: video illustration and G3: Instructions/graphics and video illustration

Source: compiled by the authors of this study

process. Similar palpation instructions were used in previous studies involving health science students [16,26,30,31].

REMOTE FHP ASSESSMENT

Three half-body and three full-body images were requested from each participant to reduce bias caused by physical and emotional tension during photography and to minimize measurement differences resulting from postural sway [32]. The principal investigator downloaded the completed participant responses to verify the visibility of anatomical landmarks before using WebPlotDigitizer (WPD) to measure the craniovertebral angle (CVA) and tragus-shoulder gap.

Half-body images were used to measure the CVA by plotting three landmarks: the tragus of the ear, the marker placed on the C7 spinous process, and a point horizontally aligned with the C7 spinous process using WPD (Figure 2a). Full-body images were used to assess the tragus-shoulder gap by marking the tragus and drawing a vertical line through the center of the shoulder (Figure 2b).

DATA ANALYSIS

SPSS (Statistical Package for the Social Sciences), Version 28.0, was used to analyze the data collected in this study. Descriptive statistics were used to summarize participants' age and body mass index (BMI). The Shapiro-Wilk test was used to assess data normality ($p > 0.05$). In addition, Levene's Test of Equality of Error Variances was used to verify the assumption of homogeneity of variances. Two-way analysis of variance (ANOVA) was used to compare mean values between groups. The Kruskal-Wallis test and the Mann-Whitney U test were used to analyze variables that were not normally distributed.

RESULTS

The mean age (22.14 ± 1.66 years) and BMI (21.62 ± 3.36 kg/m^2) of the participants are presented in Table 1. To assess intra-rater reliability, a subset of 15 images was re-analyzed by the same investigator after a time interval. The intraclass correlation coefficient (ICC) demonstrated excellent reliability (ICC = 0.98), and the standard error of measurement (SEM = 0.15) indicated high consistency with minimal measurement error. Given this high consistency and minimal measurement error, participant data from the three groups were included in the subsequent analyses.

As shown in Table 2, the mean CVA values in G1 were 54.45° ± 7.88° and 54.32° ± 4.78° for health science and non-health science students, respectively. In G2, the corresponding values were 54.96° ± 3.82° and 54.46° ± 8.24°. The mean CVA in G3 was higher than that of the non-health science students (57.54° ± 5.02° vs. 54.76° ± 5.91°). However, no statistically significant difference was observed among the three groups (G1, G2, and G3) ($F = 0.713$, $p = 0.493$). Likewise, the half-body image results showed no statistically significant difference between participants with health science and non-health science backgrounds ($F = 0.790$, $p = 0.376$). Furthermore, no significant interaction between educational background and instructional method was observed for remote half-body CVA assessment ($F = 0.417$, $p = 0.660$). These findings indicate that the instructions for remote half-body CVA assessment were understandable regardless of participants' educational background.

The tragus-shoulder gap measurements obtained from the full-body images were not normally distributed. The Kruskal-Wallis H test showed that there was no statistically significant difference among the three groups (G1, G2, and G3) ($H = 0.519$, $p = 0.771$) (Table 3).

Similarly, the Mann-Whitney U test showed no statistically significant difference in tragus-shoulder gap measurements between health science students (mean rank = 41.86, n = 45) and non-health science students (mean rank = 52.68, n = 49) (Mann-Whitney U = 848.500, $p = 0.055$) (Table 4).

Based on participants' responses to the MNQ, the most common musculoskeletal disorders reported during the past 12 months and the past 7 days involved the neck (22.2% and 18.2%, respectively), followed by the shoulders (16.7% and 15.2%) and lower back (16.7% and 12.1%). Moreover, most participants (68.2%) indicated that musculoskeletal problems did not affect their daily activities during the previous year (Table 5).

In terms of understanding the instructions, health science students generally demonstrated better comprehension than non-health science students (Table 6). Among non-health science students, the written instructions and graphics method appeared to be the most challenging, with 31.3% of respondents selecting „maybe," whereas the video illustration method appeared to provide the highest level of participant understanding regardless of educational background (Table 6).

The video-based instruction method appeared to result in better participant understanding; however, CVA and tragus-shoulder gap outcomes did not differ significantly between the instructional groups.

DISCUSSION

This study sought to determine the procedural and technical feasibility of remotely assessing forward head posture (FHP) using a photogrammetric method among health science and non-health science students in Malaysia. The findings indicate that participants from both educational backgrounds were able to understand the procedures and technical instructions provided. The acquisition of digital half-body and full-body images using the photogrammetric method proved to be feasible, as no significant differences in the outcome measures were observed between the study groups. These findings suggest that remote physiotherapy assessment of FHP may be feasible among non-health science university students. Cote et al. [16] used cloud-based video communication technology to quantify CVA and reported accurate results. However, assistance from an examiner was required

Table 3. Kruskal-Wallis H Test of Tragus-shoulder Gap (Full Body Image) in Different Groups

Group	N	Mean Rank of Tragus-shoulder Gap (Full Body Image)
G1	31	46.21
G2	32	45.95
G3	31	50.39
Kruskal- Wallis test:	H (2) = 0.519	p=0.771*

Note: N- number of subjects; Mean Rank- average of rank; H- values of Kruskal-Wallis test; p- coefficient of significant of differences of mean ranks;
*-statistically significant level of differences; G1: Instructions/graphics; G2: video illustration and G3: Instructions/graphics and video illustration
Source: compiled by the authors of this study

Table 4. Tragus-shoulder gap between health science (n=45) and non-health science (n=49) students (mean rank)

	Health science	Non-health science	U	Z	p
Tragus-shoulder gap	41.86	52.68	848.500	-1.922	0.055

Note: U- Mann-Whitney U; Z- z-score; p- significant level
Source: compiled by the authors of this study

during the remote assessment. Similarly, pre-recorded videos and graphic illustrations have been used to assess the elbow and knee joints during videoconferencing [25]. Nevertheless, Truter et al. [33] reported that virtual lumbar spine posture assessment demonstrated lower concurrent validity because of difficulties in identifying anatomical landmarks in low-resolution images and because exposure of the lower back was more challenging, particularly in female participants.

The present study demonstrated that self-palpation and following standardized instructions without real-time therapist guidance can be used for remote FHP assessment among university students. The results showed high consistency across instructional groups and educational backgrounds for both half-body and full-body images. Compared with synchronous video-based teleassessment, this approach may reduce the demand for healthcare personnel. Furthermore, the findings may be applicable beyond health science students, facilitating remote identification of forward head posture across a broader university population.

The present study found that participants' CVA values ranged from 54° to 57°, which are generally considered to represent normal head posture because values above 50°

Table 5. Participant's musculoskeletal pain report for the past 12 Months and past 7 days

	MSK Troubles in the Past 12 Months		MSK Troubles Have Prevented from Carry Out Normal Activities During Last 12 Months		MSK Troubles in The Past 7 Days	
Location	N	%	N	%	N	%
Neck	45	22.7	8	7.3	24	18.2
Shoulders	33	16.7	7	6.4	20	15.2
Upper Back	14	7.1	4	3.6	10	7.6
Elbows	3	1.5	0	0.0	0	0.0
Wrists/Hands	9	4.5	1	0.9	4	3.0
Lower Back	33	16.7	9	8.2	16	12.1
Hips/Thighs	10	5.1	1	0.9	4	3.0
Knees	18	9.1	3	2.7	3	2.3
Ankles/Feet	11	5.6	2	1.8	2	1.5
None	22	11.1	75	68.2	49	37.1
Total	198	100	110	100	132	100

Source: compiled by the authors of this study

Table 6. The understanding of respondents to the instructions given in three different groups

Background	Group	Yes		No		Maybe	
		N	%	N	%	N	%
Health Science	written instructions and graphics	14	93.3%	0	0.0%	1	6.7%
	video illustration only	13	86.7%	0	0.0%	2	13.3%
	written instructions, graphics, and video illustration	15	100.0%	0	0.0%	0	0.0%
Non-health Science	written instructions and graphics	11	68.8%	0	0.0%	5	31.3%
	video illustration only	14	82.4%	0	0.0%	3	17.6%
	written instructions, graphics, and video illustration	13	81.3%	0	0.0%	3	18.8%

Source: compiled by the authors of this study

are regarded as normal [7]. Similarly, Cote et al. [16] reported mean CVA values between 50° and 55° in healthy individuals. In contrast, Youssef et al. [32] reported mean CVA values of 46.4° ± 5.1° and 46.6° ± 5.3° in healthy adults, indicating forward head posture, possibly owing to reduced physical activity. Moreover, Mani et al. [34] reported a mean CVA of 47.43° ± 7.97° among individuals with excessive electronic device use, whereas Alonazi et al. [35] found a mean CVA of 49.4° ± 6.7° in a similar population. In the present study, participants demonstrated normal CVA values. Furthermore, no significant differences in CVA measurements obtained from half-body images were observed among instructional groups, educational backgrounds, or their interaction, indicating that half-body photogrammetry is a feasible method for FHP assessment when clear instructions and standardized procedures are provided.

According to participants' responses, unfamiliar anatomical terminology appeared to make the written instructions more difficult for non-health science students to understand. In contrast, both health science and non-health science students appeared to better understand the video illustration approach, which allowed them to visualize the entire preparation procedure, palpation of the C7 spinous process, and photograph acquisition. Therefore, the video instruction method appeared to be the most understandable among participants from both educational backgrounds. Similarly, Sobierajska-Rek et al. [36] reported that video illustrations were better accepted by caregivers when delivering exercise instructions.

Exposure to online learning during the two years of the Movement Control Order (MCO) was associated with a high prevalence of musculoskeletal complaints, with 88.9% of participants reporting symptoms during the previous 12 months and 62.9% during the previous seven days. These values were higher than those reported among students exposed to conventional classroom learning (65.1% and 45.7%, respectively) [37]. In the present study, musculoskeletal complaints most frequently involved the neck, followed by the shoulders and lower back. Similar findings were reported by Salameh et al. [6]. Reduced physical activity and poor ergonomic posture during online learning may have contributed to these complaints [38]. Despite the high prevalence of musculoskeletal symptoms, they did not appear to have a substantial impact on forward head posture, as indicated by the mean CVA values greater than 50°.

One limitation of this study is that all images and measurements were obtained at a single time point, which may have introduced variability and limited the generalizability of the findings. In addition, the validity of C7 spinous process palpation was not compared with the radiographic gold standard, which would have provided a more comprehensive assessment of its accuracy. Although this study provides preliminary evidence supporting the feasibility of this method, its diagnostic accuracy requires further investigation. Future studies should compare photogrammetric assessment with established reference methods to further evaluate the consistency, validity, and reliability of this approach.

CONCLUSIONS

Remote evaluation of forward head posture using photogrammetric methods with clear instructions is feasible. Based on participants' responses, the video illustration group produced the fewest invalid photographs among both health science and non-health science students, suggesting that video-based instructions may facilitate successful image acquisition. Considering the diverse educational backgrounds of potential users, the video instruction approach may further improve remote assessments in telehealth. Because the craniovertebral angle and tragus-shoulder gap are clinically relevant measures of head and neck alignment, they provide objective parameters for digital assessment of forward head posture. Wider implementation of this approach may support healthcare professionals in remotely assessing and monitoring FHP, thereby facilitating appropriate clinical decision-making in telehealth.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Vinodhkumar Ramalingam
Saveetha College of Physiotherapy
Saveetha Institute of Medical and Technical Sciences,
Chennai, India
e-mail: vinodhkumar.scpt@saveetha.com

ORCID AND CONTRIBUTIONSHIP
Vinodhkumar Ramalingam - 0000-0002-5269-0520 A C E F
Callie Tan Kai Lin - 0009-0003-4053-8307 A B D
Vinosh Kumar Purushothaman - 0000-0001-5213-3065 E
Vikram Mohan - 0000-0002-9067-2817 E F
Viswanath Sundar - 0000-0003-2234-718X A E

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 28.05.2025
ACCEPTED: 25.03.2026

REVIEW ARTICLE

Phototherapy in modern medicine: mechanisms and clinical applications

Włodzisław Kuliński

DEPARTMENT OF REHABILITATION, MILITARY INSTITUTE OF MEDICINE, NATIONAL RESEARCH INSTITUTE, WARSAW, POLAND

ABSTRACT

The aim of this paper is to present the mechanisms of action, clinical applications, and therapeutic potential of phototherapy in modern medicine. This review presents the biological effects of phototherapy, including its influence on the immune properties of the skin, skin phototypes, principles of treatment dosing, types of phototherapy devices, and current clinical indications. Particular attention is paid to the mechanisms underlying therapeutic effects and to selected applications in dermatology, rehabilitation, and wound management. The available evidence indicates that phototherapy is an effective adjunctive therapeutic modality in the management of numerous dermatological, musculoskeletal, and chronic wound conditions. Clinical examples, including a case of successful treatment of a pressure ulcer with polarized light therapy, illustrate its potential to enhance tissue regeneration, accelerate wound healing, and improve functional recovery. Phototherapy is a versatile therapeutic modality that supports regenerative processes, reduces pain and inflammation, and improves patients' quality of life. Its beneficial effects are associated with improved microcirculation, enhanced tissue oxygenation, modulation of inflammatory responses, and stimulation of cellular repair processes. Owing to its broad spectrum of clinical applications, phototherapy remains an important component of contemporary rehabilitation and multidisciplinary patient care.

KEYWORDS: phototherapy, photobiomodulation, wound healing, ultraviolet radiation, rehabilitation

Acta Balneol. 2026;68(3): 191-197. doi: 10.36740/ABAL202603111

INTRODUCTION

Phototherapy is a therapeutic modality that uses natural (heliotherapy) or artificial (actinotherapy) light sources for the treatment of various diseases. Depending on the clinical indication, it employs infrared radiation (e.g. Sollux lamps), ultraviolet radiation (e.g. quartz lamps), or combinations of different wavelengths to achieve therapeutic effects [1-16].

The skin, which serves as both a physical barrier and an essential component of the immune system, plays a central role in mediating the biological effects of phototherapy. Light exposure influences cutaneous immune responses and modulates the activity of skin-associated lymphoid tissue, thereby contributing to local and systemic biological processes.

Figure 1 illustrates the penetration depth of different wavelengths of light into the skin.

The skin is the largest organ of the human body, with a total surface area of approximately 1.6-2.0 m^2. It provides protection against external environmental factors, maintains homeostasis, and receives and processes numerous physical and chemical stimuli. Structurally, the

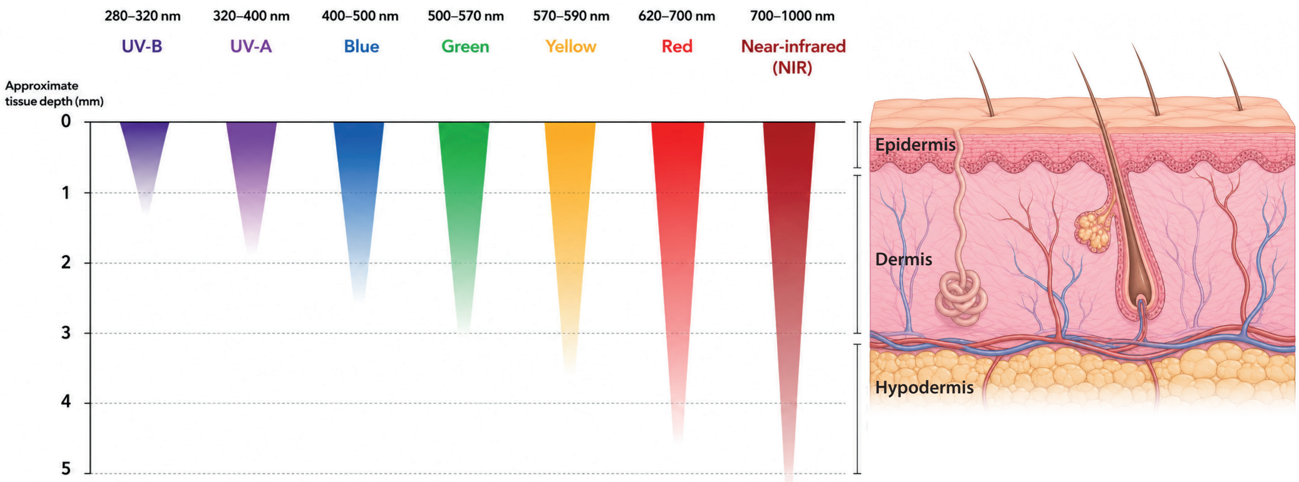

Fig. 1. Schematic representation of the approximate penetration depth of different optical wavelength ranges within the anatomical layers of human skin.

Source: compiled by the authors of this study

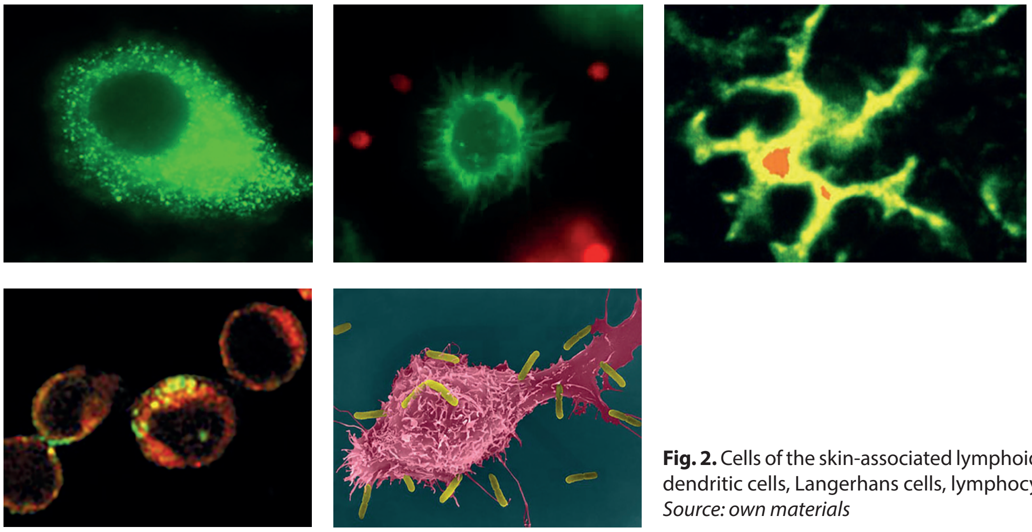

Fig. 2. Cells of the skin-associated lymphoid tissue (SALT): keratinocytes dendritic cells, Langerhans cells, lymphocytes, macrophages
Source: own materials

skin consists of three layers: the epidermis, dermis, and subcutaneous tissue.

In addition, the skin contains numerous appendages, including sebaceous glands, sweat glands, and hair follicles, as well as an extensive network of blood vessels, lymphatic vessels, and sensory nerves.

SKIN IMMUNE SYSTEM

The skin immune system comprises a variety of epidermal and dermal cells collectively referred to as skin-associated lymphoid tissue (SALT). These cells play a key role in immune surveillance and regulation of inflammatory responses.

SKIN-ASSOCIATED LYMPHOID TISSUE (SALT)

Keratinocytes actively participate in cutaneous immune responses through the production of cytokines, chemokines, and other mediators involved in immune regulation (Fig. 2).

AIM

The aim of this paper is to present the mechanisms of action, clinical applications, and therapeutic potential of phototherapy in modern medicine.

BIOLOGICAL EFFECTS OF ULTRAVIOLET RADIATION

PHOTOCHEMICAL ERYTHEMA

Photochemical erythema is induced most effectively by UVB radiation (297 and 250 nm), less effectively by UVA radiation, and only minimally by UVC radiation.

It is characterised by transient erythema resulting from vasodilation, followed by increased skin pigmentation.

The reaction consists of three consecutive phases:

- latent phase (time from irradiation to the onset of symptoms), lasting 1-6 hours;
- erythema intensification phase (time from symptom onset to maximum erythema), lasting approximately 6-24 hours;
- erythema resolution phase, extending from several hours to several days after irradiation.

The severity of photochemical erythema depends on several factors, including the wavelength of ultraviolet radiation, duration of exposure, distance from the radiation source, radiation intensity, anatomical location of the irradiated area (the trunk being the most sensitive and the feet, hands, and scalp the least sensitive), as well as individual skin sensitivity.

The main consequences of photochemical erythema include:

- thickening of the epidermis;
- epidermal desquamation;
- dark brown skin pigmentation.

EFFECTS ON THE SKIN IMMUNE SYSTEM

Epidermal cells, including Langerhans cells, keratinocytes, and T lymphocytes, play an important role in regulating immune responses within the skin.

Exposure to UVB and UVC radiation results in a marked reduction in both the number and activity of Langerhans cells, leading to temporary suppression of local immune responses. Following discontinuation of irradiation, their number and function gradually return to baseline. However, repeated and intensive ultraviolet exposure may result in excessive immunosuppression.

The immunosuppressive properties of ultraviolet radiation constitute one of the mechanisms underlying its therapeutic efficacy in the treatment of psoriasis.

PHOTOSENSITIVITY REACTIONS

Administration of substances capable of absorbing photons and transferring light energy to tissues increases sensitivity to ultraviolet radiation, a phenomenon known as photosensitization.

Such substances, referred to as photosensitizers, include coumarin derivatives present in certain plants, tar derivatives (e.g. wood tar preparations used in psoriasis), dyes, natural essential oils (e.g. sandalwood and cedar oils), compounds of selected metals (iron, gold, silver, arsenic, and bismuth), and several medications, including tetracyclines, diazepam, and salicylamides.

The therapeutic effects of photosensitization are utilized in PUVA therapy.

PHOTOTHERAPY DOSING

The minimum ultraviolet dose should be determined individually before initiating a course of phototherapy using:

- biological testing;
- determination of the patient's skin phototype.

For individuals with Fitzpatrick skin phototype III, the minimal erythema dose generally corresponds to:

- 0.038-0.053 J/cm² for UVB and UVB-SUP;
- 0.5-0.6 J/cm² for narrowband UVB (311 nm);
- 20-50 J/cm² for UVA.

Biological testing provides a more objective assessment of skin sensitivity than evaluation based solely on skin complexion.

Whole-body irradiation is usually initiated with 50-70% of the minimal erythema dose (MED). The irradiation dose is subsequently increased by approximately 50% of the MED during the second treatment session, depending on the patient's clinical response.

During treatment, erythema more severe than first-degree erythema (E I°) should be avoided, with threshold erythema being considered the desired response. Doses producing second- or third-degree erythema (E II° and E III°) may be used only during local irradiation, whereas children should receive doses producing first-degree erythema only.

Patients should wear appropriate protective eyewear throughout the irradiation procedure.

Phototherapy sessions are typically performed three to five times per week, with a complete course consisting of 10-30 treatment sessions, depending on the clinical response.

TYPES OF ULTRAVIOLET PHOTOTHERAPY

The following ultraviolet radiation modalities are currently used in dermatological practice:

1. broadband UVB (BB-UVB; 280-320 nm);
2. selective UVB phototherapy (SUP; multiple emission peaks at 305 and 325 nm);
3. narrowband UVB (NB-UVB; 311 nm);
4. PUVA therapy, combining UVA radiation (320-400 nm) with psoralens:
    - oral 5-methoxypsoralen (5-MOP) or 8-methoxypsoralen (8-MOP),
    - topical trimethylpsoralen (TMP) administered as a bath solution;
5. UVA1 (340-400 nm) (Fig. 3).

High-pressure mercury lamps with halogen additives mounted in vertical cabinets are commonly used for whole-body irradiation.

These devices are employed in both SUP and PUVA therapy. The therapeutic UVA spectrum used in PUVA treatment is obtained by applying appropriate optical filters.

PUVA combines UVA irradiation with psoralens, which are photosensitizing agents administered to enhance skin sensitivity to UVA radiation. The effective activation spectrum of psoralens ranges from 320 to 400 nm, with peak activity occurring at approximately 365 nm.

UVB radiation exerts antiproliferative, anti-inflammatory, and immunomodulatory effects.

Fig. 3. Devices used in UVA and UVB phototherapy
Source: own materials

Fig. 4. Clinical examples of patients undergoing treatment
Source: own materials

COMBINATION THERAPY

UVB phototherapy is frequently combined with other therapeutic modalities in the management of psoriasis, including:

- UVB combined with retinoids (Re-UVB 311 nm; Re-SUP);
- UVB combined with wood tar baths (Goeckerman method);
- UVB combined with wood tar baths and topical dithranol (Ingram method);
- UVB combined with corticosteroids;
- UVB combined with vitamin D derivatives;
- UVB combined with tazarotene;
- UVB combined with therapeutic baths, including brine and sulphide/hydrogen sulphide baths.

HELIOTHERAPY

Heliotherapy is one of the oldest forms of phototherapy and utilizes natural solar radiation for therapeutic purposes.

Sunlight consists of approximately:

- 59-65% infrared radiation;
- 33-40% visible light;
- 1-2% ultraviolet radiation.

Only ultraviolet wavelengths exceeding 290 nm reach the Earth's surface.

In temperate climate zones, the therapeutic use of natural sunlight is limited by seasonal variations in ultraviolet radiation. The intensity of ultraviolet radiation is generally sufficient only during the summer months, whereas exposure during late autumn and winter is considerably lower.

Particularly favourable conditions for heliotherapy occur in the Dead Sea region, where the intensity of short-wave UVB radiation is reduced, allowing longer and safer sun exposure. In addition, bathing in highly saline Dead Sea water provides an important complementary therapeutic effect.

Optimal clinical outcomes are generally achieved after 4-6 weeks of treatment. Under these conditions, additional therapeutic interventions are often unnecessary.

In temperate climates, heliotherapy may be initiated with 15-20 minutes of sun exposure per body side, increasing the duration by 10-15 minutes daily until approximately 2 hours of daily exposure is reached after two weeks.

Following heliotherapy, patients should not experience significant adverse reactions and should maintain good general wellbeing. Intense photochemical erythema, headache, weakness, excessive nervous excitability, or fever may indicate excessive ultraviolet exposure.

Excessive sunlight exposure should be avoided because it may exacerbate psoriatic lesions or contribute to the development of new lesions [16-24].

CLINICAL APPLICATIONS OF PHOTOTHERAPY IN VARIOUS FIELDS OF MEDICINE

Indications for UV therapy

- Throat and nose conditions, chronic bronchitis, bronchial asthma
- Rickets, soft tissue rheumatism, osteoarthritis
- Acne vulgaris, furunculosis, soft tissue inflammation, alopecia areata
- Trophic ulcers, poorly-healing wounds, psoriasis, impaired bone union, convalescence, hypothyroidism, ovarian failure.

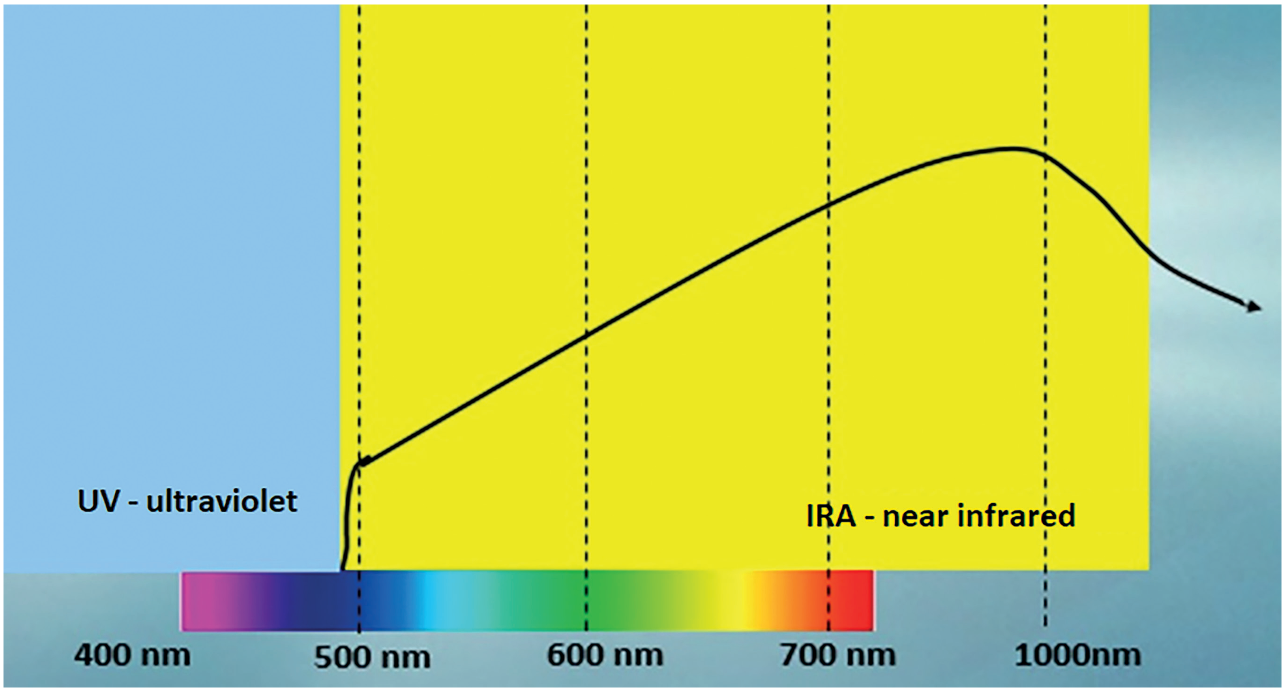

Fig 5. Polarised visible light (before and after treatment)
Source: own materials

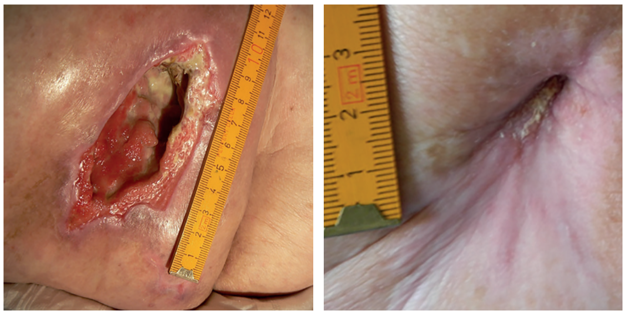

Fig. 6. Bedsore: before and after treatment
Source: own materials

Clinical examples of patients undergoing treatment (Fig. 4):

- Chronic venous insufficiency
- Lower leg ulcers
- Keloids
- Psoriasis
- Acne vulgaris
- Atopic dermatitis

BEDSORES

Bedsores (decubitus ulcers) are areas of tissue necrosis of a three-dimensional nature. Necrosis is the local death of an organ, tissues, or cells in a living organism.

Healing process: it is a complicated, dynamic system that allows for effective repair of damaged tissues.

If the repair process is delayed, it should be stimulated in order to get back on the right track. External stimulation increases electrical activity and the rate of repair. The better the blood supply, the faster the healing.

Physiotherapy factors that support bedsore treatment [17-30]: electrical stimulation (microcurrents, HVS, high tone power therapy, TENS currents, IF currents), laser biostimulation, ultrasound therapy, magnetic field therapy, magnetic stimulation, LED therapy, polarised light therapy.

CASE DESCRIPTION: THERAPEUTIC EFFECTS IN THE TREATMENT OF PRESSURE SORES

TT was an 86-year-old female patient with a body mass of approximately 80 kg and a height of 160 cm.

The patient underwent surgery due to pertrochanteric fracture of the left femur (she stayed in hospital for 7 days before surgery and was discharged on the 7th day after surgery with a bedsore on the left buttock). The surgical wound and bedsore were treated in an outpatient setting for 2 months without any effects. Polarised light therapy was used (3 times a day) for 6 weeks (Fig. 5).

The wound was completely closed. The patient ambulated with a walking frame. The rehabilitation was focused on increasing the motor function.

DISCUSSION

Phototherapy is a form of physiotherapy that has been developing since antiquity. Patients are treated with ultraviolet, visible, and infrared light. Ultraviolet light, commonly known as UV, is responsible for the synthesis of vitamin D3 in the body. It speeds up metabolism and bone mineralisation, lowers blood pressure, and stimulates oxygen metabolism. It is used to treat different types of skin, respiratory, ear, nose and throat, and rheumatological conditions and endocrine gland insufficiency.

Visible light has a positive effect on haematopoietic system function, metabolism, endocrine gland function, and mental wellbeing.

Infrared light overlaps with sunlight in over 60% and penetrates deep into tissues, which is used to treat pain by raising the pain threshold.

The biological effects include improved blood supply to the skin, dilation of capillaries, and increased arterial blood flow through tissues. The radiation also causes reactions in deeper vessels according to the Dastre-Morat law, stimulates metabolic processes, and reduces muscle tone [4-16].

CONCLUSIONS

Phototherapy is a versatile method of treatment that considerably improves the quality of life in patients with different conditions. By using appropriate wavelengths of light, this therapy supports regenerative processes in the body, reduces pain and inflammation, and has a positive effect on mental wellbeing.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Włodzisław Kuliński
e-mail: wkulinski52@hotmail.com.pl

ORCID AND CONTRIBUTIONSHIP

0000-0002-6419-4030-Włodzisław Kuliński A B D E F

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 30.12.2025
ACCEPTED: 29.03.2026

REVIEW ARTICLE

Biological markers of stress response and systemic cellular adaptation to environmental and therapeutic stimuli in balneotherapy

Izabela Woźny-Rasała[1,2]

[1] KORLAB LABORATORIA MEDYCZNE SP. Z O.O. SP. KOMANDYTOWA, RUDA SLASKA, POLAND

[2]UNIWERSYTET IM. JANA DŁUGOSZA W CZĘSTOCHOWIE, CZESTOCHOWA, POLAND

ABSTRACT
Balneotherapy and health resort medicine are based on controlled exposure to natural therapeutic stimuli that induce systemic adaptive responses. Mineral waters, peloids, therapeutic gases, hydrotherapy, and climatic factors act as mild biological stressors, activating regulatory mechanisms that enhance physiological resilience. These responses involve coordinated neuroendocrine, immunological, and oxidative pathways at both systemic and cellular levels. Balneotherapeutic stimuli influence the hypothalamic–pituitary–adrenal (HPA) axis, autonomic nervous system balance, and inflammatory mediator activity, contributing to restoration of homeostasis. At the cellular level, adaptation includes modulation of redox signaling, mitochondrial function, endoplasmic reticulum stress responses, and proteostasis regulation. These mechanisms are consistent with the concept of hormesis, where low-intensity stress promotes adaptive and cytoprotective effects. Biological markers relevant in balneological research include heat shock proteins, pro- and anti-inflammatory cytokines, oxidative stress parameters, antioxidant enzymes, nitric oxide metabolites, and molecular chaperones. Monitoring these biomarkers may provide objective tools for evaluating treatment efficacy, assessing systemic adaptation, and optimizing individualized spa therapy programs. Understanding molecular indicators of stress response strengthens the evidence-based foundation of balneotherapy and supports its integration into modern physical and rehabilitative medicine

KEYWORDS: balneotherapy; biomarkers; oxidative stress; hormesis; cellular adaptation

Acta Balneol. 2026;68(3): 198-204. doi: 10.36740/ABAL202603112

INTRODUCTION

The biological response to stress represents a complex and highly coordinated process that enables organisms to maintain homeostasis in the face of environmental and psychological challenges. Stress exposure activates a wide spectrum of adaptive mechanisms involving the nervous, endocrine, immune, and metabolic systems. At the cellular level, these processes are reflected by dynamic changes in gene expression, protein synthesis, redox balance, and intracellular signaling pathways. Although acute stress responses may promote survival and physiological adaptation, prolonged or excessive activation of stress pathways can lead to maladaptive changes associated with the development of neuropsychiatric, cardiovascular, and metabolic disorders [1, 2].

Central to the regulation of stress adaptation is the hypothalamic–pituitary–adrenal axis (HPA axis), which coordinates hormonal responses through the release of glucocorticoids. These hormones influence immune activity, neuronal plasticity, and energy metabolism, thereby linking psychological stress with systemic biological effects. Simultaneously, activation of the autonomic nervous system alters cardiovascular function and inflammatory signaling, further shaping cellular responses to stress stimuli. Emerging research indicates that intracellular stress mechanisms, including oxidative stress, mitochondrial dysfunction, and endoplasmic reticulum stress (ER stress), play an essential role in determining whether cells adapt successfully or undergo pathological changes [3, 4].

In addition to psychosocial stressors, controlled environmental and therapeutic stimuli – such as physical, climatic, or hydrothermal factors – may also induce regulated adaptive stress responses. In this context, the concept of hormesis becomes particularly relevant, as moderate activation of stress pathways can enhance cytoprotective mechanisms and improve systemic resilience. Understanding the molecular basis of such adaptive processes is increasingly important in fields integrating biological sciences with clinical and rehabilitative medicine.

Biological markers of stress response have therefore become an important area of investigation in modern medicine. Molecules such as cytokines, heat shock proteins, reactive oxygen species, and molecular chaperones may serve as indicators of cellular resilience or vulnerability. Identifying reliable biomarkers may improve early diagnosis, risk assessment, and monitoring of therapeutic interventions in stress-related conditions. Moreover, integrating molecular biology with clinical research provides new opportunities for developing personalized strategies aimed at enhancing adaptive capacity and preventing disease progression. This review presents current knowledge on biological markers involved in cellular adaptation to stress, with particular emphasis on molecular mechanisms, adaptive responses to environmental stimuli, and their potential clinical relevance [5, 6].

AIM

The aim of this review is to summarize current knowledge on biological markers of stress response involved in cellular adaptation to stress, with particular emphasis on molecular mechanisms, adaptive responses to environmental and therapeutic stimuli, and their clinical relevance.

REVIEW AND DISCUSSION

NEUROBIOLOGY OF STRESS AND CELLULAR ADAPTATION

The neurobiology of stress involves a complex interaction between central nervous system structures, neuroendocrine pathways, and autonomic regulation that together determine the organism's ability to adapt to environmental challenges. A key component of this regulatory network is the hypothalamic–pituitary–adrenal axis (HPA axis), which coordinates hormonal responses through sequential activation of the hypothalamus, pituitary gland, and adrenal cortex. In response to stress exposure, corticotropin-releasing hormone released from the hypothalamus stimulates adrenocorticotropic hormone secretion, leading to increased glucocorticoid production.

These hormones regulate immune function, metabolism, and neuronal activity, thereby supporting adaptive responses during acute stress. However, chronic activation of the HPA axis may disrupt feedback mechanisms and contribute to neuroendocrine imbalance, which has been associated with impaired cellular resilience and increased vulnerability to disease [7, 8].

Within this regulatory framework, the autonomic nervous system represents another essential element of stress adaptation. Sympathetic activation prepares the organism for immediate action by increasing heart rate, blood pressure, and metabolic demand, whereas parasympathetic activity promotes recovery and restoration of physiological balance. Persistent sympathetic dominance may lead to oxidative stress, inflammatory activation, and alterations in cellular signaling pathways, underscoring the importance of autonomic balance in maintaining homeostasis. The interaction between autonomic regulation and immune responses further illustrates how psychological stress can translate into measurable biological changes at the cellular level [9].

In the context of balneotherapy and health resort medicine, controlled exposure to natural therapeutic stimuli – such as mineral baths, hydrotherapy, peloid applications, and climatic factors – may induce a regulated activation of both the HPA axis and autonomic pathways. Unlike chronic psychosocial stress, these mild environmental stimuli can trigger adaptive neuroendocrine responses consistent with the concept of hormesis, promoting improved stress tolerance and restoration of homeostatic balance. Modulation of glucocorticoid signaling and autonomic tone may contribute to the anti-inflammatory and immunoregulatory effects observed during spa treatment.

At the central level, brain structures such as the amygdala, hippocampus, and prefrontal cortex play a pivotal role in interpreting stress signals and shaping adaptive behavior. The amygdala is involved in emotional processing and threat detection, the hippocampus contributes to contextual memory integration, and the prefrontal cortex regulates executive control and emotional inhibition. These regions influence both HPA axis activity and autonomic output. Dysregulation within these neural circuits may impair adaptive cellular responses, linking neurobiological stress mechanisms with molecular alterations such as oxidative imbalance and intracellular stress signaling. Understanding these interconnected processes provides a foundation for identifying biological markers that reflect adaptive or maladaptive responses to stress [10, 11].

Emerging evidence further suggests that spa-based environmental modulation may influence central stress-processing circuits through neuroplastic mechanisms, potentially enhancing emotional regulation and resilience. Such neurobiological effects may be reflected at the molecular level by changes in oxidative stress parameters, cytokine profiles, and cellular stress markers, thereby supporting the integration of neurobiological and balneological perspectives in contemporary rehabilitative medicine.

MOLECULAR MECHANISMS OF CELLULAR STRESS RESPONSE

Cellular adaptation to stress is mediated by molecular mechanisms that preserve homeostasis and protect against environmental and psychological challenges. A key component of this response is proteostasis, which ensures proper protein folding and degradation. Accumulation of misfolded proteins activates the unfolded protein response (UPR), triggered by endoplasmic reticulum stress (ER stress). The UPR reduces protein synthesis, enhances molecular chaperone activity, and promotes cellular survival during transient stress [1, 4, 6, 12, 13].

In balneotherapy, controlled exposure to thermal and mineral factors may induce mild activation of proteostatic pathways, supporting adaptive UPR signaling without triggering pathological ER stress. This effect may enhance cellular resilience and restore homeostatic balance.

Heat shock proteins (HSPs) are critical molecular chaperones that stabilize proteins under metabolic or oxidative stress. Concurrently, antioxidant systems neutralize reactive oxygen species (ROS), which function as signaling molecules at moderate levels but may cause mitochondrial dysfunction when excessive [14, 15]. Balneotherapeutic procedures, particularly thermal and sulphide-rich baths, may stimulate endogenous antioxidant defenses and reduce lipid peroxidation, promoting adaptive mitochondrial responses in line with hormetic principles.

Redox signaling interacts with inflammatory mediators, influencing cytokine production and gene expression. Modulation of oxidative and inflammatory pathways during spa therapy may contribute to systemic immunoregulation. Evaluation of these molecular indicators may therefore support objective assessment of spa treatment outcomes and strengthen the integration of molecular biology with evidence-based rehabilitative medicine [16, 17].

ENDOPLASMIC RETICULUM STRESS AS A CENTRAL ADAPTIVE MECHANISM

Endoplasmic reticulum stress is a fundamental component of cellular adaptation and plays a central role in maintaining protein quality control and intracellular homeostasis. The endoplasmic reticulum regulates protein folding, lipid synthesis, and calcium balance, making it highly sensitive to metabolic and inflammatory disturbances. Accumulation of misfolded proteins activates the unfolded protein response, a conserved signaling network that restores cellular equilibrium by reducing protein synthesis, increasing molecular chaperone expression, and promoting degradation of damaged proteins [18, 19].

The UPR is mediated by three principal signaling pathways: protein kinase RNA-like endoplasmic reticulum kinase (PERK), inositol-requiring enzyme 1 alpha (IRE1α), and activating transcription factor 6 (ATF6). Activation of PERK reduces global protein translation through phosphorylation of eukaryotic initiation factor 2 alpha (eIF2α), while inositol-requiring enzyme 1 alpha (IRE1α) modulates messenger RNA (mRNA) processing and inflammatory signaling. ATF6 enhances expression of genes involved in protein folding and cellular recovery. Together, these pathways promote adaptive responses and increase cellular resilience under transient stress conditions [20, 21].

In balneotherapy, controlled exposure to thermal and mineral stimuli may induce mild activation of ER-associated adaptive pathways, supporting proteostatic balance without triggering chronic ER stress. This effect aligns with the hormetic model observed in health resort medicine, where moderate environmental stressors enhance cytoprotective signaling.

However, sustained ER stress may contribute to oxidative imbalance, mitochondrial dysfunction, and activation of apoptotic pathways. ER stress interacts closely with immune and redox signaling, forming an integrated network that determines the direction of cellular adaptation [22].

Balneological interventions, through modulation of oxidative and inflammatory mediators, may influence ER–mitochondrial crosstalk and improve cellular bioenergetics. Monitoring ER stress–related biomarkers may therefore provide objective indicators of adaptive responses and therapeutic effectiveness in spa therapy. Identification of ER stress markers may also support improved diagnostic strategies and the development of targeted interventions aimed at restoring cellular homeostasis [23, 24].

OXIDATIVE STRESS AND MITOCHONDRIAL ADAPTATION

Oxidative stress is a key molecular mechanism involved in cellular responses to environmental and psychological stressors. Mitochondria play a central role in energy production through oxidative phosphorylation while generating ROS as metabolic by-products. At physiological levels, ROS act as signaling molecules regulating gene expression and adaptive pathways. However, excessive or prolonged stress may disturb the balance between oxidant production and antioxidant defenses, leading to lipid, protein, and DNA damage [15, 25, 26].

In balneotherapy, controlled exposure to thermal and mineral factors – particularly sulphide-rich waters and radon baths – may transiently modulate redox balance. Mild oxidative stimulation can activate endogenous antioxidant systems in accordance with hormetic principles, enhancing cellular resilience rather than promoting damage.

Mitochondrial adaptation, including regulation of energy metabolism and antioxidant enzyme activity such as superoxide dismutase and glutathione peroxidase, is essential for maintaining redox homeostasis. When compensatory mechanisms fail, oxidative imbalance may impair mitochondrial membrane integrity and reduce ATP production, contributing to cellular dysfunction [4, 27, 28].

Oxidative stress closely interacts with inflammatory pathways and endoplasmic reticulum stress, forming an integrated network that influences cellular adaptation [1, 29]. From a balneological perspective, modulation of the oxidative stress–inflammation axis represents an important therapeutic mechanism. Monitoring biomarkers such as malondialdehyde and antioxidant enzyme activity may provide objective indicators of systemic adaptation during spa therapy. Integration of redox biomarkers into balneological research may strengthen the evidence-based foundation of health resort medicine and support personalized rehabilitative strategies. The major balneotherapeutic factors and their potential molecular targets are summarized in Table 1.

Table 1. Balneotherapeutic factors and their potential molecular targets

Balneological intervention	Primary stimulus	Molecular targets	Expected adaptive response
Sulphide mineral baths	Chemical (H_2S), thermal	Redox pathways, cytokines	Increased antioxidant capacity
Radon therapy	Low-dose radiation	Hormetic stress pathways	Activation of cytoprotective signaling
Hydrotherapy	Hydrostatic pressure	Autonomic regulation	Improved parasympathetic activity
Peloid therapy	Thermal + mineral	Inflammatory mediators	Reduced proinflammatory cytokines
Climatic therapy	Temperature, UV, altitude	Neuroendocrine modulation	Improved stress resilience

Source: compiled by the authors of this study

INFLAMMATORY AND IMMUNE BIOMARKERS OF STRESS

The immune system plays a central role in the biological response to stress, linking psychological experiences with measurable molecular changes. While acute stress may transiently enhance immune activity, chronic exposure often leads to persistent low-grade inflammation characterized by increased production of proinflammatory cytokines and acute-phase proteins [30].

Stress-related immune activation is mediated through neuroendocrine pathways, particularly the HPA axis and the autonomic nervous system. Although glucocorticoids initially exert anti-inflammatory effects, prolonged exposure may promote glucocorticoid resistance and increased inflammatory signaling. Elevated levels of interleukin-6 and tumor necrosis factor alpha have been associated with maladaptive stress responses [31].

In balneotherapy, natural therapeutic factors such as sulphide-rich mineral waters and peloid applications may modulate cytokine profiles, reducing proinflammatory mediators and enhancing anti-inflammatory responses. These effects may be linked to improved autonomic balance and neuroendocrine regulation.

Inflammatory processes closely interact with oxidative stress and endoplasmic reticulum stress, forming an integrated network influencing cellular adaptation. From a balneological perspective, modulation of the oxidative–inflammatory axis represents a key therapeutic mechanism. Monitoring biomarkers such as C-reactive protein and selected cytokines may provide objective indicators of systemic adaptation and treatment efficacy in health resort medicine [32].

EPIGENETIC REGULATION AND MICRORNA IN STRESS ADAPTATION

Epigenetic mechanisms play an essential role in cellular adaptation to stress by regulating gene expression without altering DNA sequence. Among them, microRNAs (miRNAs) are important modulators of stress-related molecular pathways. These short non-coding RNAs regulate mRNA stability and translation, influencing proteins involved in inflammatory signaling, oxidative balance, and intracellular stress responses. Altered miRNA expression has been observed in both acute and chronic stress, suggesting a role in individual variability in stress resilience [33].

Stress-induced epigenetic changes affect neurotransmission, immune regulation, and metabolic processes. Specific miRNAs modulate pathways related to ER stress, the UPR, mitochondrial function, and inflammatory signaling, acting as molecular links between environmental stimuli and cellular adaptation [7, 10, 34].

In balneotherapy, controlled exposure to mineral waters, thermal factors, and climatic stimuli may influence epigenetic regulation through modulation of oxidative and inflammatory pathways. Emerging evidence indicates that environmental interventions can induce potentially reversible epigenetic modifications, contributing to sustained adaptive effects observed after spa treatment.

Epigenetic regulation also interacts with HPA axis activity, as stress hormones influence transcriptional patterns. The reversibility of epigenetic modifications makes them attractive therapeutic targets. Monitoring selected miRNA profiles before and after spa interventions may provide innovative tools for assessing systemic adaptation and personalizing rehabilitative strategies [35]. Integration of epigenetic biomarkers into balneological research may further strengthen the evidence-based foundation of health resort medicine.

SYSTEMIC CONSEQUENCES OF CHRONIC STRESS

Chronic exposure to stress produces systemic effects extending beyond the central nervous system and influencing cardiovascular, metabolic, and immune regulation. Persistent activation of the HPA axis and the autonomic nervous system may promote insulin resistance, dyslipidemia, and increased cardiovascular risk [36].

A key consequence of chronic stress is endothelial dysfunction. Prolonged inflammatory activation and oxidative stress reduce nitric oxide bioavailability and impair vascular integrity, contributing to hypertension and atherosclerosis. Endoplasmic reticulum stress has also been implicated in endothelial impairment, linking intracellular stress mechanisms with systemic disease progression [7, 37].

In balneological practice, many patients present with stress-related cardiometabolic disturbances. Balneotherapeutic procedures, including immersion in mineral-rich waters and hydrostatic stimulation, have been associated with improved endothelial function, enhanced nitric oxide availability, and reduced vascular stiffness. Modulation of oxidative and inflammatory pathways during spa therapy may therefore support cardiovascular adaptation and autonomic balance [A].

Chronic stress additionally promotes low-grade inflammation and mitochondrial dysfunction, further disrupting metabolic and immune homeostasis. Comprehensive spa treatment combining hydrotherapy, physical activity, and climatic exposure may exert multimodal regulatory effects, attenuating inflammation and oxidative imbalance.

Assessment of biomarkers reflecting endothelial function, inflammatory status, and redox balance may help identify individuals at risk and objectively evaluate spa therapy outcomes, strengthening the evidence-based foundation of health resort medicine [39].

CLINICAL IMPLICATIONS AND PERSONALIZED APPROACHES

Understanding biological markers of stress response has important clinical implications for diagnosis, prevention, and treatment of stress-related disorders. Molecular indicators reflecting adaptive or maladaptive cellular responses may enable early detection of physiological imbalance before overt clinical symptoms appear. Biomarkers associated with oxidative stress, inflammatory signaling, and ER stress provide objective information about the biological burden of chronic stress and may complement traditional psychometric assessment [40].

Selected clinical applications of stress-related biomarkers in health resort medicine are presented in Table 2.

Table 2. Clinical applications of stress biomarkers in health resort medicine

Clinical domain	Relevant biomarkers	Application in spa medicine	Expected adaptive response
Cardiovascular risk	CRP, endothelial markers, NO metabolites	Monitoring vascular adaptation	Increased antioxidant capacity
Metabolic disorders	Cortisol, oxidative stress markers	Assessing metabolic resilience	Activation of cytoprotective signaling
Chronic inflammation	IL-6, TNF-α	Evaluating anti-inflammatory effects	Improved parasympathetic activity
Stress-related disorders	Cortisol, miRNAs, HSPs	Personalizing spa therapy	Reduced proinflammatory cytokines
Rehabilitation monitoring	MDA, antioxidant enzymes	Measuring treatment response	Improved stress resilience

Source: compiled by the authors of this study

Integration of molecular biology with clinical practice supports more individualized therapeutic strategies. Personalized approaches aim to tailor interventions according to the patient's neuroendocrine, immune, and metabolic profile. Patients with inflammatory activation may benefit from immunomodulatory strategies, whereas those with oxidative imbalance or mitochondrial dysfunction may respond better to antioxidant-based or lifestyle interventions. Monitoring dynamic biomarker changes may also help evaluate treatment efficacy.

In balneotherapy and health resort medicine, assessment of stress-related biomarkers may guide individualized spa treatment programs. Selection of mineral baths, hydrotherapy, peloid applications, or climatic interventions could be adapted to the patient's inflammatory and redox status [41]. Spa therapy, as an integrative non-pharmacological intervention, may beneficially modulate neuroendocrine and inflammatory pathways, supporting systemic adaptation [42].

Further research is needed to standardize biomarker assessment and validate clinical utility. Incorporating molecular diagnostics into balneological practice may strengthen the evidence-based foundation of health resort medicine and facilitate personalized rehabilitative strategies [43].

CONCLUSIONS

Biological markers of stress response offer important insight into the molecular mechanisms underlying cellular and systemic adaptation to environmental challenges. Activation of neuroendocrine pathways, inflammatory signaling, oxidative balance, mitochondrial function, and endoplasmic reticulum stress constitutes an integrated network that determines whether stress exposure results in adaptive resilience or maladaptive pathology. Dysregulation of these mechanisms contributes to the development of neuropsychiatric, cardiovascular, and metabolic disorders.

Advances in molecular diagnostics highlight the clinical value of biomarkers related to inflammation, redox status, proteostasis, and epigenetic regulation. Their assessment may support early identification of stress-related dysregulation and enable more precise monitoring of therapeutic outcomes.

In balneotherapy and health resort medicine, controlled exposure to natural therapeutic stimuli may beneficially modulate stress-responsive pathways in accordance with hormetic principles. Integration of biomarker evaluation into spa practice may strengthen the evidence-based foundation of balneological treatment and facilitate personalized rehabilitative strategies aimed at enhancing systemic resilience and long-term health.

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FUNDING SOURCE
This study was supported by the National Center for Research and Development, a Polish executive agency as defined by the Act of 27 August 2009, on Public Finance (Journal of Laws of 2022, item 1634, as amended). The agency is responsible for implementing tasks related to the state's scientific, technical, and innovation policy. Funding was provided through the ERA-Net Neuron International Grant No. 20/2019.

CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Izabela Woźny-Rasała
KORLAB Laboratoria Medyczne Sp. z o.o. Sp. Komandytowa
Ruda Śląska, Poland
e-mail: izarasala@wp.pl

ORCID AND CONTRIBUTIONSHIP
Izabela Woźny-Rasała – 0009-0005-7051-3092 A B D E F

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 03.05.2026
ACCEPTED: 11.06.2026

CASE REPORT

A holistic physiotherapy approach to stress urinary incontinence and infertility-related distress: a case report

Pavithra Sakthivel[1], Jeslin G N[1], Praveenkumar Rajendran[2]

[1]UROLOGY AND OBSTETRICS GYNECOLOGICAL SCIENCES, SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, TAMIL NADU, INDIA

[2]DEPARTMENT OF SPORTS SCIENCES, SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, TAMIL NADU, INDIA

ABSTRACT

Aim: To present a rare case of female infertility coexisting with coital urinary incontinence and evaluate the outcomes of a comprehensive physiotherapy-based intervention aimed at enhancing pelvic floor function, reducing psychological stress, and improving sexual well-being in both partners.

Case report: A 29-year-old woman with a two-year history of primary infertility and urinary incontinence during intercourse was referred for physiotherapy. She also reported decreased sexual satisfaction. Her 27-year-old husband described heightened psychological stress associated with fertility-focused sexual activity. A structured, holistic physiotherapy protocol was administered, incorporating pelvic floor muscle training (PFMT) using mirror biofeedback, the Knack technique, Jacobson's progressive muscle relaxation, diaphragmatic breathing, aerobic exercise, yoga, and supportive counselling. Outcome measures included pelvic floor muscle (PFM) strength assessed using the PERFECT scheme, self-reported frequency of urinary incontinence, perceived stress using the Perceived Stress Scale (PSS), and fertility-related quality of life using the FertiQoL questionnaire.

Initial evaluation revealed weak PFMs and elevated stress levels in the female patient, with psychosocial strain affecting both partners. Over a six-week intervention period, marked improvements were noted in PFM strength, cessation of coital incontinence, and enhanced sexual satisfaction. Both partners demonstrated reductions in stress and improvements in FertiQoL scores.

Conclusions: This case underscores the clinical relevance of an integrative physiotherapy approach that addresses both physical dysfunction and emotional stress in couples experiencing infertility. A multidisciplinary, partner-focused rehabilitation program may contribute to improvements in pelvic floor function, psychological well-being, and relationship-related outcomes in couples experiencing infertility.

KEYWORDS: pelvic floor disorders, infertility, biofeedback, stress urinary incontinence, pelvic floor muscle training

Acta Balneol. 2026;68(3): 205-209. doi: 10.36740/ABAL202603113

INTRODUCTION

Infertility is defined as the inability to conceive after one year of regular, unprotected sexual intercourse for couples where the woman is under 35 years of age [1]. For women aged 35 or older, infertility is defined as the inability to conceive after six months of regular, unprotected intercourse. The cause of the condition can come from either the male or female partner, both partners simultaneously, or causes that are not yet identified, which is known as unexplained infertility [2].

This definition encompasses both primary infertility-no prior pregnancies and secondary infertility-difficulty conceiving after previous pregnancies [3]. The prevalence of infertility is equal among men and women, with 30%-40% of cases attributed to male factors, 30% to female factors, and 20% due to combined or unexplained causes [4]. Fertility can be significantly affected by alcohol and smoking by disrupting hormonal balance, reducing sperm quality, and increasing the risk of conditions such as early menopause and erectile dysfunction [5].

Conservative infertility management includes lifestyle changes, hormonal therapies, and pharmacological treatments like clomiphene, metformin, and gonadotropins [6]. Male infertility treatments involve gonadotropins, clomiphene, antioxidants, bromocriptine, and antibiotics to address hormonal imbalances and improve sperm quality [7]. The psychological approach to infertility involves counseling, cognitive behavioral therapy (CBT), stress reduction techniques, and support groups to enhance emotional well-being and coping strategies [8].

Pelvic floor muscle training, myofascial release, visceral manipulation, and relaxation techniques are all physiotherapy interventions that can help with infertility [9]. Enhancing pelvic circulation, reducing musculoskeletal restrictions, and lowering stress are all benefits of these approaches, which contribute to improved reproductive health [10]. Mirror biofeedback is a physiotherapy technique that enhances muscle awareness, coordination, and strength, and provides visual feedback to help treat conditions like urinary incontinence and pelvic dysfunction [11]. Preventing urine leakage and enhancing pelvic support [12] can be achieved by voluntarily contracting the pelvic floor muscles before and during activities that increase intra-abdominal pressure with the Knack technique. By reducing stress, improving blood flow to the reproductive organs, balancing hormones, and promoting relaxation, yoga, specifically pranayama, can enhance fertility [13,14]. Jacobson's relaxation technique, along with breathing exercises, aids in relaxation. Aerobic exercise is effective in improving blood flow to pelvic organs, balancing hormones, and reducing stress, which can be beneficial for infertility [15]. The body's calming response is increased by controlled breathing, which reduces muscle tension and stress. When combined, these techniques can decrease heart rate and cortisol levels, leading to relaxation. This makes them effective in managing stress-related issues like urinary incontinence and pelvic floor dysfunction.

AIM

The aim of this case report was to present the outcomes of a multidisciplinary physiotherapy approach for improving pelvic floor muscle function and managing stress urinary incontinence in a woman with infertility, while addressing psychological well-being in both partners.

CASE DESCRIPTION

A 29-year-old woman and her 27-year-old husband visited a leading fertility center at a multispecialty hospital in Chennai, India, on 2 December 2024 with concerns about infertility after two years of unsuccessful attempts to conceive despite regular unprotected intercourse. The woman had a six-year history of hypothyroidism treated with Thyronorm but had no other medical conditions, such as diabetes or hypertension. The husband occasionally consumed alcohol in social settings. Due to his demanding work schedule and the couple's ongoing fertility struggles, both partners reported experiencing high levels of stress. Neither partner had previously undergone physiotherapy.

Their relationship had become strained because sexual activity had become goal-oriented and lacked intimacy, as revealed during detailed history taking. The woman reported embarrassment related to urinary leakage during intercourse, which negatively affected her self-confidence and intimacy with her husband.

She underwent a comprehensive assessment of her pelvic floor muscles, posture, and breathing pattern. The assessment suggested that her urinary incontinence was associated with pelvic floor muscle weakness. The couple's difficulties were considered to be associated with work-related stress and lifestyle factors.

CLINICAL FINDINGS

She presented with normal beta-human chorionic gonadotropin (β-hCG) levels (< 2.39). Ultrasound follicular assessment demonstrated dominant follicles in both ovaries with a normal profile. Laboratory investigations showed normal metabolic parameters, including fasting blood sugar (FBS) of 97 mg/dL, postprandial blood sugar (PPBS) of 149 mg/dL, and HbA1c of 6%. However, thyroid function tests indicated elevated values, with free triiodothyronine (FT3) of 3.54, free thyroxine (FT4) of 1.54, and thyroid-stimulating hormone (TSH) of 6.007. Hormonal assessment revealed normal luteinizing hormone (LH) (1.79), follicle-stimulating hormone (FSH) (4.77), and prolactin (17.8) levels. Her complete blood count (CBC) was within normal limits. Meanwhile, semen analysis confirmed normozoospermia in the husband. Collectively, these findings provided a comprehensive overview of both partners' reproductive health.

During the initial assessment, the woman reported urinary incontinence occurring predominantly during intercourse in the missionary position. Posture was assessed using the REEDCO Posture Score, and breathing pattern was evaluated using the Breathing Pattern Assessment Tool (BPAT). Both assessments indicated normal posture and a balanced breathing pattern. Functional assessment using the PERFECT scheme [16] revealed mild pelvic floor muscle weakness, with a pelvic floor muscle (PFM) power grade of 3 on the Modified Oxford Scale. The ICIQ-UI SF score [17] was 14, indicating moderate stress urinary incontinence.

For the husband, the assessment focused on stress-related factors and lifestyle habits. He displayed moderate to high stress levels on the Perceived Stress Scale (PSS) [18], with scores between 20 and 35, mainly attributed to work-related pressure. Both partners were assessed using the FertiQoL questionnaire [19]. The woman reported lower emotional and social scores, whereas the husband reported greater difficulties in the relational domain due to stress and societal expectations. Semen analysis confirmed normozoospermia. Both partners expressed a willingness to improve their overall lifestyle and reproductive health.

Treatment focused on pelvic floor rehabilitation in the woman using mirror biofeedback, the Knack technique, and targeted exercises. Both partners participated in stress-management interventions, including Jacobson's progressive muscle relaxation, breathing exercises, pranayama, aerobic exercise, and counselling to improve overall well-being. Outcome assessment included pelvic floor muscle strength (PERFECT scheme), urinary incontinence severity (ICIQ-UI SF), and psychological well-being (Perceived Stress Scale).

INTERVENTIONS FOR HER

A multidisciplinary physiotherapy approach was implemented to strengthen pelvic floor muscles and manage stress urinary incontinence. The following interventions were planned with a mix of supervised and home-based exercises which are also explained in Table 1.

Monday, Wednesday, Friday (Supervised by Physiotherapist)

Knack Technique Training: Under physiotherapist supervision, engage pelvic floor muscles before activities (3 sets of 10 reps/session).

Breathing Exercises: Diaphragmatic and 4-7-8 techniques; inhale for 4 seconds, hold for 7 seconds, exhale for 8 seconds, 10 rounds, 3 times/day.

Mirror Biofeedback Training: Guided by a physiotherapist for real-time feedback on pelvic floor activation (3 sets of 10 reps/session).

Tuesday, Thursday, Saturday (Home-Based Exercises)

Knack Technique Training: Independent practice before activities triggering urinary incontinence.

Mirror Biofeedback Training: Use a mirror at home to reinforce proprioception, gradually transitioning to exercises without visual feedback.

Breathing Exercises: Diaphragmatic and 4-7-8 techniques; inhale for 4 seconds, hold for 7 seconds, exhale for 8 seconds, 10 rounds, 3 times/day.

INTERVENTIONS COMMON FOR BOTH

Both partners participated in stress relief targeted interventions to reduce stress and improve overall well-being.

Monday, Wednesday, Friday (Supervised by Physiotherapist)

Jacobson's Progressive Muscle Relaxation (JPMR) – Conducted under physiotherapist supervision to ensure proper progression and technique. (20–30 minutes per session)

Mindfulness & Guided Imagery – Included in JPMR sessions, focusing on positive visualization for 10–15 minutes daily.

Aerobic exercise (Brisk walking) 30-40 minutes per day together as a couple.

Tuesday, Thursday, Saturday (Home-Based Exercises)

Pranayama (Nadi Shodhana & Bhramari) – Nadi Shodhana (alternate nostril breathing) for 5–7 minutes per session, 10 breath cycles in 2 sets. Bhramari (humming bee breathing) for 5 minutes per session, 6–8 breath cycles in 2 sets.

Table 1 presents the intervention timeline and treatment protocol.

OUTCOME MEASURE

Using PERFECT/ICIQ captures objective and subjective pelvic floor function and symptom changes, while PSS/FertiQoL provides critical insight into emotional and quality-of-life outcomes. Together, these measures justify a thorough evaluation of the holistic intervention involving supervised pelvic floor exercises, breathing practices, mindfulness, and physical activity, enabling evidence-based assessment of efficacy in a woman-specific context over a clearly defined timeline.

Table 2 presents the pre- and post-intervention results of the PERFECT scheme, demonstrating improvements in pelvic floor muscle function following the intervention. The Perceived Stress Scale (PSS) indicated a reduction in stress levels, suggesting the effectiveness of the intervention in managing infertility-related distress. Table 3 presents the baseline FertiQoL scores, while the post-intervention assessment demonstrated improvements across several quality-of-life domains in both participants. The PSS score for the male participant decreased from 35 (high stress) before the intervention to 20 (low stress) after the intervention. The man scored 50 in the emotional domain, reflecting improved emotional regulation, whereas the woman scored 45. In the mind-body domain, the man scored 55, indicating reduced tension, while the woman scored 50, suggesting improved overall well-being. In the relational domain, the man scored 50,

Table 1. Timeline and Interventions

Period	Woman-Specific	Both Partners
Baseline (Dec 2, 2024)	PERFECT/ICIQ baseline	PSS/FertiQoL baseline
Wks 1-6 Mon/Wed/Fri (supervised)	Knack (3x10), Mirror biofeedback (3x10), Diaphragmatic/4-7-8 breathing (10 rounds x3/day)	JPMR (20-30min), Mindfulness (10-15min), Brisk walking (30-40min)
Wks 1-6 Tue/Thu/Sat (home)	Knack/mirror/breathing continued	Pranayama: Nadi Shodhana (10 cycles x2), Bhramari (6-8 x2)
Wk 6 Post	PERFECT improved, ICIQ=0 (self-report)	PSS/FertiQoL improved

Rationale: Biofeedback/ Knack enhances PFM for SUI/fertility circulation; relaxation/pranayama reduces stress/hormonal disruption.

Source: compiled by the authors of this study.

Table 2. PERFECT Scheme (Woman)

Parameter	Pre	Post
Power	3	4
Endurance	5s	8s
Repetitions	5	12
Fast contractions	5	10
Timed/Execution	Lost	Proper

Source: compiled by the authors of this study.

Table 3. FertiQoL Pre (Mean/100)

Domain	Man	Woman
Emotional	50	45
Mind-body	55	50
Relational	50	55
Social	60	50
Tolerability	50	50
QoL	60	50

Post-FertiQoL: Man QoL 60-75, woman 55-70 across domains. SUI resolved; no statistics (single case). No adverse events.

Source: compiled by the authors of this study.

whereas the woman scored 55, indicating greater relationship satisfaction. Overall, the man's quality-of-life scores ranged from 60 to 75, while the woman's ranged from 55 to 70, demonstrating improvements across multiple domains following the intervention.

DISCUSSION

One of the key strengths of this study is its unique holistic approach, integrating pelvic floor muscle rehabilitation with various stress management strategies. This comprehensive approach considers both the physical and psychological aspects of infertility, acknowledging the importance of addressing the concerns of both partners. Such an approach ensures that treatment is not limited to one partner, which aligns with emerging trends in holistic fertility management [20,21].

However, this study has several limitations. A longer follow-up period is needed to assess the sustained effects of the intervention, as infertility is influenced by multiple factors over time. Extended follow-up would provide a better understanding of the long-term impact of pelvic floor rehabilitation and stress management on fertility-related outcomes [22]. Furthermore, the findings should be interpreted with caution because this report describes a single case, includes a relatively short follow-up period of six weeks, and does not evaluate pregnancy outcomes.

When compared with the existing literature, the approach used in this study is consistent with previous reports in the field of infertility management. For instance, [23] demonstrated that combining pelvic floor rehabilitation with psychological support significantly improved reproductive outcomes in couples with unexplained infertility.

The present case suggests that a holistic physiotherapy approach may improve pelvic floor muscle function, reduce stress, and enhance quality of life in couples experiencing infertility-related distress. These findings support the rationale for integrating both physical and psychological interventions into fertility care. Nevertheless, further studies with larger sample sizes and longer follow-up periods are required to confirm these observations.

CONCLUSIONS

This case report suggests that a multidisciplinary physiotherapy programme may improve pelvic floor muscle function, resolve stress urinary incontinence, and enhance quality of life in couples experiencing infertility-related distress. Further studies are warranted to confirm these findings in larger patient populations.

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ETHICAL CONSIDERATIONS

Approval: 02/053/2024/ISRB/PGSR/SCPT. Written informed consent was obtained, and confidentiality was maintained.

ACKNOWLEDGEMENTS

The authors would like to thank the department and the institution for their support. They also sincerely thank the participating couple for their trust, cooperation, and willingness to participate in this study.

CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Pavithra Sakthivel
Urology and Obstetrics Gynecological Sciences
Saveetha College of Physiotherapy
Saveetha Institute of Medical and Technical Sciences
Thandalam, Chennai, Tamil Nadu, India
e-mail: pavithrasakthi11@gmail.com

ORCID AND CONTRIBUTIONSHIP

Pavithra Sakthivel - 0009-0006-7635-0893 A B D F
Jeslin G N - 0000-0001-5045-9221 A C E F
Praveenkumar Rajendran - 0009-0001-0181-1724 C D F

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 16.07.2025
ACCEPTED: 31.01.2026

CASE REPORT

Sustained effects of orthoptic exercises for convergence insufficiency in a post-stroke patient: a follow-up single-case study

A Fayaz[1], Sathya Siva[1], Sukumar Ramaswami[2], Prathap Suganthirababu[1], V Madhubala[1], J Shahil[1], S Vimal Ajay[1], J Kingsley[1]

[1]SAVEETHA COLLEGE OF PHYSIOTHERAPY, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, INDIA

[2]SAVEETHA MEDICAL COLLEGE AND HOSPITAL,SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, CHENNAI, INDIA

ABSTRACT

Aim: The purpose of this follow-up case study was to evaluate the sustainability of clinical improvements achieved following a structured orthoptic exercise programme in a post-stroke patient with convergence insufficiency and to further strengthen the evidence supporting the effectiveness of the intervention.

Case report: This follow-up single-case study was carried out in a private hospital. A post-stroke patient with symptomatic convergence insufficiency underwent a structured orthoptic exercise programme consisting of stereogram training and pen convergence exercises. Sessions lasted 15 minutes and were conducted three times per week for three weeks. Outcome measures included the Near Point of Convergence, Convergence Insufficiency Symptom Survey, stereopsis, diplopia severity, and reading endurance. Baseline (pre-intervention), immediate post-intervention (3 weeks), and follow-up assessments (6 weeks after baseline) were performed to evaluate the durability of treatment effects.

This follow-up single-case study involved a 51-year-old male post-stroke patient presenting with symptomatic convergence insufficiency. A structured orthoptic exercise programme, including stereogram fusion tasks and pen convergence exercises, was administered for 15 minutes, three times per week, over three weeks.

Conclusions: This follow-up study demonstrated beneficial effects of orthoptic exercises for convergence insufficiency in a post-stroke patient and showed that these improvements were maintained at the 6-week follow-up. These findings support the inclusion of targeted orthoptic rehabilitation in multidisciplinary post-stroke care for patients with binocular vision disorders.

KEYWORDS: convergence insufficiency, diplopia, health, post-stroke, World Health Organization

Acta Balneol. 2026;68(3):210-214. doi: 10.36740/ABAL202603114

INTRODUCTION

Convergence Insufficiency (CI) is a common binocular vision dysfunction in which the eyes struggle to maintain alignment during near viewing. Individuals with CI frequently report visual discomfort, including headaches, blurred or double vision, eye fatigue and difficulty sustaining near work [1]. These symptoms can impair reading efficiency, concentration, and overall performance in daily tasks. Stroke, being a major contributor to long-term neurological disability, may disrupt neural pathways responsible for coordinating ocular movements and thereby result in secondary binocular vision disorders such as CI. When present after stroke, CI can impede rehabilitation progress, participation in functional activities, and reintegration into work or domestic routines [2].

Reports suggest that CI affects a small percentage of the general population but may be more frequently observed in individuals with neurological injury, including stroke survivors. Damage to structures involved in vergence control can lead to impaired convergence responses, making previously manageable visual tasks significantly challenging. Although orthoptic interventions are well-established as the primary treatment for symptomatic CI in non-neurological populations, research evaluating their therapeutic value in stroke patients is still evolving [3,4]. Orthoptic rehabilitation typically includes structured exercises that aim to strengthen convergence ability and improve visual comfort. Activities such as near-focus training, vergence jumps and stereogram-based therapy help in enhancing the coordination between both eyes. However, stroke survivors may present unique barriers related to cognition, motor skills or sensory processing, which can influence therapy engagement and effectiveness. Therefore, further studies are needed to establish tailored protocols and better understand treatment outcomes in this specific population [5,6,7]

The present follow-up single-case study investigates the effectiveness of a targeted orthoptic exercise programme, including pen convergence and stereogram training, administered over a three-week period in a post-stroke patient with convergence insufficiency (CI) [8,9]. By evaluating the sustainability of treatment outcomes through a six-week follow-up assessment, this study seeks to add to the limited body of evidence supporting the role of visual rehabilitation in post-stroke convergence insufficiency management. Enhanced understanding in this domain may assist clinicians in integrating vision therapy more systematically into neuro-rehabilitation to support recovery and improve quality of life.

AIM

The aim of this follow-up single-case study was to evaluate the sustainability of clinical improvements achieved following a structured orthoptic exercise programme in a post-stroke patient with convergence insufficiency and to provide additional evidence supporting the effectiveness of this intervention.

CASE DESCRIPTION

A 51-year-old male attended orthoptic services six weeks following an ischemic stroke involving the right parietal region. Since the cerebrovascular event, he had experienced visual symptoms including intermittent diplopia, eye fatigue, and difficulty maintaining clear focus during near activities. These symptoms became particularly noticeable during prolonged reading and were initially accompanied by headaches in the first few days after the stroke.

Before the neurological event, the patient reported no history of binocular vision problems, ocular trauma, or neurological disease, apart from age-related presbyopia. His post-stroke status included mild cognitive fatigue but no significant speech, sensory, or major motor impairments. He remained independent in activities of daily living but experienced difficulty with near-vision tasks such as reading and computer use.

At the time of referral, the patient was participating in a multidisciplinary stroke rehabilitation programme that included physiotherapy and cognitive retraining. No other vision-specific interventions or changes in spectacle correction were introduced during the orthoptic intervention or the subsequent follow-up period to ensure the integrity of treatment outcome assessment.

CLINICAL FINDING

Clinical examination confirmed the presence of convergence insufficiency. Initial assessments recorded a receded near point of convergence (NPC) of 18 cm, a Convergence Insufficiency Symptom Survey (CISS) score of 36, reduced stereoacuity of 200 arc-seconds, and a Diplopia Questionnaire (DQ) score of 70. Eye movements were full and coordinated in all directions. Cover testing demonstrated exophoria at near fixation, indicating instability in binocular fusion. A slightly reduced accommodative response was also noted and considered a contributing factor to the patient's near-vision discomfort.

Together, these assessment findings supported a diagnosis of symptomatic convergence insufficiency associated with the recent stroke [Table 1].

REHABILITATION INTERVENTION

A structured visual therapy programme was introduced to improve convergence ability and minimise functional diplopia. Two key exercise approaches were utilised: stereogram-based fusion tasks and pen convergence exercises.

The orthoptic exercise programme was administered by a licensed physical therapist experienced in neurological rehabilitation and trained in the delivery of vision rehabilitation exercises. The intervention consisted of 15-minute sessions conducted three times per week over a three-week period. Exercise progression was individualized according to the patient's performance and tolerance [10,11].

STEREOGRAM TRAINING

The stereogram was positioned at arm's length, with a pen held midway between the card and the patient.

The patient focused on the pen while slowly bringing it closer, keeping the stereogram images in peripheral awareness.

When double vision of the stereogram occurred, the patient was encouraged to achieve fusion until the central figures combined into a single image.

At later stages, fusion was attempted without the pen to strengthen voluntary convergence control.

PEN CONVERGENCE TRAINING

A pen was held at arm's length and slowly advanced toward the nose while the patient maintained focus on its tip.

Training emphasized maintaining a single image for as long as possible.

Breaks were provided as needed to minimise fatigue while promoting convergence adaptation.

All therapy sessions were supervised to ensure proper technique, monitor compliance, and adjust the level of difficulty according to the patient's performance.

OUTCOME MEASURES

A combination of standardized clinical assessments and patient-reported outcome measures was used to evaluate binocular visual function and symptom changes before and after the intervention. All assessments were completed by an orthoptist at baseline, immediately after the three-week intervention, and at the six-week follow-up assessment. All outcome assessments were independently performed by a certified orthoptist who was not involved in the delivery of the intervention. This approach was adopted to ensure consistency of measurement and reduce potential assessor bias.

Near Point of Convergence

NPC was assessed using a standard accommodative near target moved gradually along the patient's midline toward the nose. The break point (distance at which diplopia first occurred) was measured in centimetres. A reduced NPC distance indicates improved convergence ability and binocular efficiency [3].

Convergence Insufficiency Symptom Survey

The CISS was used to quantify subjective symptoms associated with convergence insufficiency, including eye strain, blurred vision, difficulty maintaining focus, and headaches during near work. Scores range from 0 to 60, with higher scores indicating a greater symptom burden [3].

Table 1. Baseline, post-intervention, and follow-up outcome scores

Outcome Measure	Baseline	Post-Intervention (3 Weeks)	Follow-up (6 Weeks)
Near Point of Convergence (NPC)	18 cm	7 cm	5 cm
Convergence Insufficiency Symptom Survey (CISS)	36	14	10
Stereopsis (Randot Test)	200 arc-seconds	60 arc-seconds	40 arc-seconds
Diplopia Questionnaire (DQ)	70	20	10
Reading Endurance	8 minutes	22 minutes	30 minutes

Source: compiled by the authors of this study

Stereopsis

Stereoacuity was assessed using the Randot stereotest, and results were recorded in arc-seconds. Lower scores represent improved depth perception and more efficient binocular sensory fusion [3].

Diplopia Questionnaire

Diplopia severity and frequency were assessed using the Diplopia Questionnaire (DQ), a validated tool used to evaluate diplopia in various gaze positions during functional activities. The questionnaire categorises diplopia as never, rarely, sometimes, often, or always across different gaze directions (straight-ahead distance, straight-ahead near, reading position, up gaze, down gaze, right gaze, and left gaze). Responses were used to detect changes in both the frequency and functional impact of diplopia following the intervention [3].

Reading Endurance

Functional near-vision tolerance was assessed by recording the time (in minutes) the patient could read standard printed text before experiencing discomfort or symptom onset. This measure was included to evaluate functional relevance and real-world visual performance [3].

Follow-up Period

Following completion of the three-week orthoptic exercise programme, the patient did not participate in any additional orthoptic exercises, vision therapy programmes, or other vision-specific rehabilitation interventions. Furthermore, no changes were made to spectacle correction or ocular management during the follow-up period. A follow-up assessment was conducted six weeks after baseline to evaluate the sustainability of treatment outcomes.

Follow-up assessment conducted 6 weeks after baseline demonstrated further clinically meaningful improvement across all outcome measures. Near Point of Convergence improved from 18 cm at baseline to 7 cm immediately after intervention and further to 5 cm at follow-up. The CISS score decreased from 36 at baseline to 14 post-intervention and 10 at follow-up. Stereoacuity improved from 200 arc-seconds at baseline to 60 arc-seconds post-intervention and 40 arc-seconds at follow-up. Diplopia severity measured using the Diplopia Questionnaire decreased from 70 to 20 following treatment and further to 10 at follow-up. Reading endurance progressively increased from 8 minutes at baseline to 22 minutes post-intervention and 30 minutes at follow-up. These findings indicate sustained and progressive clinical improvement following the orthoptic exercise programme.

No adverse effects such as headache, excessive fatigue, or worsening of symptoms were reported during or after the intervention period.

Overall, the results indicate that the structured orthoptic programme led to meaningful improvements in convergence function, symptom burden, stereopsis and functional reading endurance. These findings support the clinical value of targeted orthoptic exercises in addressing post-stroke convergence insufficiency.

DISCUSSION

The effective management of diplopia requires precise identification of the underlying binocular dysfunction and individualized treatment planning, highlighting the significance of comprehensive assessment and coordinated rehabilitation efforts [10]. Orthoptic therapy has been consistently shown to improve CI by reducing visual fatigue and discomfort during near tasks, making it a well-supported non-invasive treatment option [11,12].

CI and other binocular vision disorders are commonly observed among stroke survivors due to impairment of neural pathways controlling coordinated ocular movements [13]. These visual deficits can hinder participation in rehabilitation and adversely affect independence in daily living. Therefore, early visual screening is recommended in stroke rehabilitation protocols to support optimal functional recovery [14,15]. Research further indicates that structured orthoptic programmes are effective in treating convergence and fusion deficits in neurological populations, reinforcing the value of integrating vision therapy into standard stroke care [16].

Comparable improvements have been reported in traumatic brain injury (TBI), where eye-movement–based therapy enhances gaze stability, reduces diplopia, and improves overall visual performance [17,18]. Evidence underscores that successful management of diplopia in TBI and stroke requires a patient-specific, multidisciplinary approach designed to restore efficient binocular control [19].

In the current case, significant improvements were observed in convergence ability, symptom severity, binocular sensory fusion, and functional reading endurance following the three-week orthoptic intervention, with these improvements maintained and further enhanced at the six-week follow-up. These findings are consistent with prior studies supporting the benefit of visual rehabilitation in neurological populations with CI [20]. Continued research with larger sample sizes and extended follow-up periods is necessary to establish standardized treatment protocols and evaluate long-term outcomes.

CONCLUSIONS

This follow-up single-case study supports the effectiveness of orthoptic exercises as a rehabilitative intervention for post-stroke convergence insufficiency. The patient demonstrated clinically relevant improvements in convergence ability, stereopsis, diplopia severity, and functional near-work tolerance after a structured three-week orthoptic exercise programme. These findings are consistent with outcomes reported in previous research, reinforcing the role of targeted visual rehabilitation in promoting neuro-visual recovery following stroke.

Importantly, the improvements observed at follow-up were maintained despite the absence of additional vision-specific rehabilitation, orthoptic exercises, or changes in ocular management during the follow-up period. This finding suggests that the benefits achieved through the structured orthoptic exercise programme were sustained over the short term. Orthoptic exercises may therefore serve as a feasible, low-cost, and non-invasive stand-alone intervention for selected post-stroke patients presenting with binocular vision dysfunction. While the results are promising, the single-case design limits generalizability. Future research involving larger controlled samples and long-term follow-up is warranted to validate these findings, explore optimal dosing and timing within the post-stroke therapeutic window, and determine the sustainability of visual gains over time.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

CORRESPONDING AUTHOR
Sathya Siva
Saveetha College of Physiotherapy
Saveetha Institute of Medical and Technical Sciences
Saveetha Nagar, Thandalam, 602105, Chennai, India
e-mail: sathyasivakannan@gmail.com

ORCID AND CONTRIBUTIONSHIP
A Fayaz - 0009-0009-7488-5554 A B D
Sathya Siva - 0000-0002-4253-4030 A B C E F
Sukumar Ramaswami - 0000-0002-3193-3845 D F
Prathap Suganthirababu - 0000-0002-1419-266X D F
V Madhubala - 0009-0003-1514-9027 A D E
J Shahil - 0009-0004-3303-0094 D E
S Vimal Ajay - 0009-0001-2576-2058 B D
J Kingsley - 0009-0002-2545-9654 D

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

RECEIVED: 31.05.2025
ACCEPTED: 30.01.2026

Professor Gerard Straburzyński (1930-2015). A tribute on the 10th anniversary of his death

Marcin Straburzyński-Lupa[1], Anna Straburzyńska-Lupa[2], Mariusz Migała[3], Patrycja Rąglewska[2]

[1]DEPARTMENT OF UROLOGY, HOSPITAL IN PUSZCZYKOWO, PUSZCZYKOWO, POLAND

[2]DEPARTMENT OF PHYSICAL THERAPY AND SPORT RECOVERY, POZNAN UNIVERSITY OF PHYSICAL EDUCATION, POZNAN, POLAND

[3]DEPARTMENT OF PHYSIOTHERAPY, FACULTY OF PHYSICAL EDUCATION AND PHYSIOTHERAPY, OPOLE UNIVERSITY OF TECHNOLOGY, OPOLE, POLAND

Acta Balneol. 2026;68(3):215-216. doi: 10.36740/ABAL202603115

IN MEMORIAM

In March 2025, it will be ten years since the passing of Professor Gerard Straburzyński, MD, PhD, a physician, balneologist, and Chair of the National Specialists Board and the National Specialist for Health Resort Treatment and Physical Medicine, as well as the long-serving director of the Institute of Health Resort Medicine in Poznań. He was a respected expert in the fields of balneology, health resort treatment, and physical medicine, and the author of the first physical therapy and massage therapy curricula at the faculty of physical rehabilitation (later physiotherapy) at the University of Physical Education in Poznań. To commemorate the achievements of Professor Straburzyński, this tribute has been prepared.

Gerard Straburzyński was born on October 16, 1930, in Ostrów Wielkopolski. During the war, as a child, he was sent by the occupiers to forced labour. After the war, he continued his education in his hometown, first at the First State Gymnasium, and then at the High School for Boys, where he graduated with distinction from the humanities track.

He completed his medical studies at the Medical Academy in Poznań in 1955. During his third year of studies, he was employed at the Department of Human Physiology (headed by Professor Edward Czarnecki). He progressed through all the academic ranks at the Medical Academy in Poznań, from assistant to professor. He conducted lectures in human physiology for medical and dental students, as well as anatomy and physiology for pharmacy students. He also conducted lectures for physical rehabilitation students at the Poznań Univeristy of Physical Education. Between 1957 and 1962, he also worked as an assistant at the Balneoclimatic Institute in Poznań (headed by Professor Józef Jankowiak).

In 1963, he obtained the degree of Doctor of Medicine, with his dissertation supervised by Professor Edward Czarnecki, and in 1970, he became an associate professor in medical sciences. He was awarded the title of Full Professor in Medical Sciences in 1983.

He completed his specialization internship at the Third Department of Internal Medicine at the Poznan Medical Academy, initially headed by Professor Franciszek Labedzinski and later by Professor Kazimierz Wysocki, and obtained his first degree specialization in internal medicine in 1971. He completed a first-degree specialization in physiotherapy in 1960 and second-level specialization in physical medicine and balneotherapy in 1962 at the Balneoclimatic Institute in Poznań, headed by Professor Józef Jankowiak. In 1974, he obtained his second-degree specialisation in clinical physiology at the Department of Human Physiology at the Poznań Medical Academy, first headed by Professor Edward Czarnecki, later by Professor Jan Kiersz.

In 1975, after Prof. Jozef Jankowiak retired, he became director of the Institute of Balneology and Climatology in Poznań. The Institute was the only unit in Poland established by the Minister of Health to supervise health resort treatment in the country. From 1986 until its dissolution in 1992, the Institute operated under the name Institute of Health Resort Medicine. The Institute's tasks included scientific research, training physicians in physical and health resort medicine, coordinating work in spa physiotherapy, and supervising health resort treatment and physical medicine in Poland in cooperation with the National Specialist and the National Team of Specialists for Health Resort Treatment and Physical Medicine. From 1975 to 1991, he served as chairman of the National Team of Specialists and held the position of national specialist in health resort medicine and physical medicine.

During this period, he was the editor of Balneologia Polska and a member of the Scientific Committee of Zeitschrift für Physiotherapie, among other roles. He also served as president of the Polish Society of Balneology, Bioclimatology and Physical Medicine, and as vice-president of the World Federation of Hydrotherapy and Climatotherapy (FEMTEC) with its headquarters in Paris. He was a member of the International Society of Medical Hydrology (ISMH) with its headquarters in Munich and a member of several other international scientific societies. He also supervised training of 41 physicians from all over Poland in balneology and physical medicine.

From 1991 to 2001, he worked as a professor at the University of Physical Education in Poznań, where he headed the Chair of Physiotherapy and Health Resort Rehabilitation within the Institute of Rehabilitation, which he had established. He was the author of the first educational programmes in physiotherapy and massage therapy for the Faculty of Physical Rehabilitation (later the Faculty of Physiotherapy) at University of Physical Education in Poznań, and the postgraduate courses in recovery and wellness that he developed and led within the Centre for Postgraduate Education for many years in Poznań and Szczecin. From 2002 until his death, he worked at the President Stanisław Wojciechowski Higher Vocational State School in Kalisz, where, thanks to his efforts, a physiotherapy degree programme was established. He held various positions, including Director of the Institute of Physiotherapy and Emergency Medical Care, the Dean of the Faculty of Rehabilitation, and the Director of the Chair of Physiotherapy and Sports Recovery. Since 2002, he also worked as a professor at the University of Education and Therapy in Poznań.

Professor Straburzyński's scientific work focused on various issues in experimental and clinical physiology, physical medicine and rehabilitation. His scientific output includes approximately 500 publications, including original research papers and review articles, congress reports, numerous book chapters, and several academic textbooks. He was the author and co-author of textbooks on physiotherapy, including Fizjoterapia (1986, 2003), Medycyna fizykalna (1997), Księga przyrodolecznictwa (1997), and Fizjoterapia z elementami klinicznymi (2008). He actively participated in over 80 national and international scientific conferences. A significant portion of his research on physiotherapy and health resort treatment was applied in daily spa medical practice.

Since 1950, he was an active member of the Polish Association for Adult Education (TWP) and one of the outstanding promoters of various fields of medical knowledge and health education. Over more than 65 years as a lecturer, he delivered countless public lectures and speeches. He also held numerous leadership positions within TWP, including President of the Regional Chair of TWP and Director of the Regional Department of TWP in Poznań.

Over the years, he received many honours, distinctions, and awards for his work. Even in the final years of his life, the Hipolit Cegielski Society honoured him with the Hipolit Cegielski Gold Trophy and recognized him as an Outstanding Personality of Organic Work. His international recognition was reflected in his appointment as a correspondent and honorary member of several renowned foreign scientific societies.

Professor Gerard Straburzyński passed away on March 27, 2015, in Poznań. He will be remembered as a dedicated educator, mentor, and teacher to many generations of young doctors and physiotherapists, and as an undisputed scientific authority in the fields of balneology, health resort medicine, and physical medicine.

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CORRESPONDING AUTHOR
Mariusz Migała
Opole University of Technology
Opole, Poland
e-mail: m.migala@po.edu.pl

RECEIVED: 30.05.2026
ACCEPTED: 28.06.2026