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SLACKLINE TRAINING ON BALANCE; A SYSTEMATIC REVİEW

Cansu DAL
Department of Physiotherapy and Rehabilitation, Institute of Health Sciences, Mugla Sitki Kocman University, ymcansu@gmail.com
https://orcid.org/ 0000-0001-8407-3394
Banu BAYAR
Prof. Dr. Department of Physiotherapy and Rehabilitation, Institute of Health Sciences, Mugla Sitki Kocman University, bbayar@mu.edu.tr
https://orcid.org/ 0000-0002-8090-5859

ABSRACT

This systematic review assesses slackline training's effects on balance and stability in healthy individuals. Originating from climbing, slackline training has become a popular tool to improve balance and coordination. This review compiles current research to examine its effectiveness across different age groups.

Conducted per PRISMA guidelines, a literature search in PubMed and Web of Science up to January 2024 identified seven randomized controlled trials (RCTs) on balance outcomes in healthy individuals. Study quality was assessed using the PEDro scale.

After applying the inclusion criteria, seven RCTs were selected from an initial screening of 387 records for this systematic review. Slackline training significantly enhanced task-specific balance, especially in dynamic conditions. One study showed improved postural control and reduced H-reflex excitability ($p<0.05$). Another noted gains in static and dynamic balance ($p<0.003$) and increased energy expenditure. Improvements were found in postural control in older adults ($p<0.05$), while other studies showed balance benefits similar to traditional training, with higher enjoyment among slackline users ($p<0.05$). Children improved in static balance on unstable surfaces ($p=0.004$), though one study showed task-specific gains without broader effects ($p<0.001$).

Slackline training effectively enhances balance and stability, providing unique benefits across diverse populations. While it shows limited transfer to unfamiliar tasks, it is a valuable complementary method when integrated with conventional exercises.

Keywords: Slackline Training; Balance; Stability; Postural Control; Physical Therapy

ÖZET

Bu sistematik inceleme, slackline eğitiminin sağlıklı bireylerde denge ve denge üzerindeki etkilerini değerlendirir. Tırmanıştan kaynaklanan slackline eğitimi, denge ve koordinasyonu geliştirmek için popüler bir araç haline gelmiştir. Bu inceleme, farklı yaş grupları arasında etkinliğini incelemek için güncel araştırmaları derler.

PRISMA yönergelerine göre yürütülen, PubMed ve Web of Science'da Ocak 2024'e kadar yapılan bir literatür taraması, sağlıklı bireylerde denge sonuçları üzerine yedi randomize kontrollü çalışma (RCT) belirledi. Çalışma kalitesi PEDro ölçeği kullanılarak değerlendirildi.

Dahil etme kriterleri uygulandıktan sonra, bu sistematik inceleme için 387 kaydın ilk taramasından yedi RCT seçildi. Slackline eğitimi, özellikle dinamik koşullarda göreve özgü dengeyi önemli ölçüde geliştirdi. Bir çalışma, duruş kontrolünün iyileştiğini ve H-refleks uyarılabilirliğinin azaldığını gösterdi ($p<0,05$). Bir diğeri, statik ve dinamik dengede kazanımlar ($p<0,003$) ve artan enerji harcaması kaydetti. Yaşlı yetişkinlerde duruş kontrolünde iyileşmeler bulundu ($p<0,05$), diğer çalışmalar ise denge faydalarının geleneksel eğitime benzer olduğunu, slackline kullanıcıları arasında daha fazla keyif olduğunu gösterdi ($p<0,05$). Çocuklar dengesiz yüzeylerde statik dengede iyileşme gösterdi ($p=0,004$), ancak bir çalışma daha geniş etkiler olmaksızın göreve özgü kazanımlar gösterdi ($p<0,001$).

Slackline eğitimi denge ve dengeyi etkili bir şekilde geliştirerek çeşitli popülasyonlarda benzersiz faydalar sağlar. Alışık olunmayan görevlere sınırlı geçiş gösterse de, geleneksel egzersizlerle entegre edildiğinde değerli bir tamamlayıcı yöntemdir

Anahtar Kelimeler : Slackline Eğitimi; Denge; Denge; Duruş Kontrolü; Fizik Tedavi

INTRODUCTION

Slackline training (SLT), initially developed within the climbing community, has become recognized as an innovative approach to balance training with promising effects on physical function and health. This activity entails balancing on a length of webbing suspended between two anchor points, which, in contrast to stable surfaces like a balance beam, shifts responsively under the user's weight, creating a dynamic environment that intensively challenges balance and stability (Donath et al., 2016; Pfusterschmied et al., 2011). Over time, slackline training has gained popularity as an effective exercise and rehabilitative tool for improving balance, boosting physical capabilities, and enhancing overall well-being. This method has become notable for its capacity to improve balance, coordination, and physical health in a unique way (Pfusterschmied et al., 2011). The slackline's unique, dynamic environment provides substantial benefits across multiple dimensions of balance performance, distinguishing it from traditional balance exercises (Brachman et al., 2017).

A growing body of research on slackline training suggests it leads to significant improvements in critical balance-related aspects, such as postural stability, dynamic balance, and even muscular strength and endurance (Giboin et al., 2018). The slackline's inherent instability demands constant adjustments, intensely engaging the neuromuscular system and helping individuals improve both static (stationary) and dynamic (moving) balance. Studies have reported that participants achieve noticeable gains in postural control, attributed to the high proprioceptive and motor demands of balancing on this unsteady surface (Gabel et al., 2015; Granacher et al., 2015).

Beyond balance, slackline training not only activates core and lower limb stabilizer muscles but also promotes enhanced trunk and limb coordination. With regular practice, individuals can achieve greater joint stability and refined motor control, both of which are essential for maintaining balance in daily life (Paoletti et al., 2012). Additionally, slackline training enhances cognitive abilities related to balance, including focus, reaction time, and rapid decision-making (Donath et al., 2013). Overall, slackline training effectively enhances physical and cognitive balance components, establishing itself as a comprehensive tool for improving stability and control in healthy individuals.

While slackline training shows considerable promise, a thorough review that synthesizes the research on its effects on balance is currently lacking. This absence leaves a gap in our comprehensive understanding of its full benefits and underlying mechanisms.

MATERIALS AND METHODS

This systematic review was conducted following the PRISMA checklist and guidelines, which outline the preferred reporting elements for systematic reviews and meta-analyses (Fig. 1).

Review Issue

The review question was formulated using the PICOS framework (Participants, Intervention, Comparison, Outcome, Study design): "Does slackline training enhance balance and stability in healthy individuals?" Here, P represents healthy individuals; I represents slackline training techniques, C refers to a comparison group (either no training, alternative balance training, or balance training conducted alongside slackline training); O represents improvements in balance and stability; and S indicates that this systematic review includes randomized controlled trials evaluating the effects of slackline training techniques on balance and stability outcomes in healthy individuals.

Search Approach

The review was conducted using the PubMed and Web of Science databases, requiring studies to be in English. The search strategy included specific keywords: “slackline training,” “slackline,” and “balance.” Data collection for the study commenced on October 10, 2024.

Eligibility Criteria

Studies were included based on the following criteria: the population comprised healthy individuals; the intervention involved slackline training; at least one balance-related outcome, such as postural stability or dynamic balance, was assessed; and the study design was a randomized controlled trial (RCT).

Studies were excluded if they did not investigate the effects of slackline training on balance performance or if the population included individuals with neurological disorders or other conditions that could substantially affect balance.

Evaluation of Methodological Accuracy

The Physiotherapy Evidence Database (PEDro) scale, accessible at [https://pedro.org.au] (https://pedro.org.au), was used to assess the methodological quality of the included RCTs. The PEDro scale consists of ten items, each with a binary response (YES for a positive rating, NO for a negative rating) (Table 2). Quality ratings were based on the total scale score: scores below 4 indicate poor quality, scores of 4-5 indicate acceptable quality, scores of 6-8 indicate good quality, and scores of 9-11 indicate exceptional quality (Moseley et al., 2002).

RESULTS

After applying the inclusion criteria, seven RCTs were selected from an initial screening of 387 records for this systematic review. The PRISMA flowchart (Fig. 1) illustrates the selection process. The selected studies

differed in intervention types, duration, sample size, country of recruitment, study methods, and outcome measures (Table 1).

In one study by Keller et al. (2012), a 10-session slackline training program conducted four weeks was used to assess improvements in postural control and changes in spinal reflexes. Key outcome measures included postural control assessments and H-reflex measurements in the soleus muscle. The intervention group demonstrated significant improvements, balancing on a slackline for 20 seconds and reducing sway on a balance board ($p < 0.05$). Additionally, there was a notable decrease in H-reflex excitability ($p<0.05$), indicating that slackline training may reduce spinal reflex responses, contributing to more controlled balance.

In another study, Rutkowski et al. (2022) explored the effects of a short, five-day slackline training program on energy expenditure and balance in healthy young adults aged 21-25. The primary outcomes measured were static and dynamic balance parameters (tested on foam surfaces) and energy expenditure, measured using the SenseWear Armband. The intervention group showed significant improvements in balance on foam surfaces with eyes open ($p<0.003$) and faster tandem walking speeds ($p< 0.05$). Average energy expenditure per session was recorded at 6.0 METs (Metabolic Equivalent of Task), meeting the guidelines for moderate-intensity activity. This study indicates that even short-term slackline training can positively affect static and dynamic balance.

Thomas et al. (2016) evaluated the effects of six weeks of slackline training (twice weekly) on postural control in older adults, with a focus on reducing fall risk by improving balance. Balance improvements were measured trough using various standing positions on a balance platform and recording acceleration during perturbations. The intervention group showed notable improvements in one-leg stance duration without perturbation and reduced platform acceleration in tandem stance (both with and without external disturbances) post-training ($p < 0.05$). These findings suggest that slackline training can enhance both static and dynamic postural control in older adults.

Trecroci et al. (2018) compared 12 weeks of slackline training with traditional balance training (BLT) in young soccer players, using balance (BESS), dynamic balance (SEBT), and physical performance assessments. Key outcomes included balance performance and enjoyment ratings. Both slackline and traditional training groups showed similar improvements in balance on the BESS and SEBT tests; however, the slackline group reported significantly greater enjoyment levels ($p < 0.05$). These findings suggest that slackline training not only provides effective balance improvements but also enhances enjoyment, potentially promoting greater adherence.

Dordevic et al. (2017) implemented an intensive four-week slackline training program, with sessions three times per week, to evaluate improvements in balance and vestibular-dependent spatial orientation in adults. The outcome measures included a clinical balance test (CBT) with eyes closed and a spatial orientation test (OT) in a wheelchair to assess vestibular function. The intervention group showed significant improvements in closed-eye CBT scores ($p = 0.011$) and achieved better on the vestibular OT ($p = 0.049$), suggesting that slackline training may enhance both static balance and vestibular function.

Ferri-Marini et al. (2020) investigated the effects of slackline training on dynamic and static balance in boys aged 8-14 through a six-week program with one-hour sessions three times per week. Key outcomes included the Bass test (for dynamic balance) and the Stork Stand Test (SST) on stable and unstable surfaces. Statistical analysis showed significant improvement in static balance, notably on the left leg when using an air cushion ($p = 0.004$), particularly no significant changes were observed in dynamic balance. These results underscore slackline training's targeted impact on static balance in younger populations, especially on more challenging surfaces.

Giboin et al. (2018) conducted a three-month slackline training program to evaluate balance improvements in both trained and untrained tasks. Using static and dynamic balance tasks on the slackline and other untrained balance tests, findings showed significant improvements only in slackline-specific tasks ($p<0.001$), with limited transfer to other balance tasks. This suggests that extended slackline training may result in highly task-specific adaptations, which may not generalize to unrelated balance activities.

Overall, the methodological approaches and outcome measures in each study demonstrate slackline training's effectiveness for various balance aspects, though the transferability of these gains to untrained tasks varies across interventions. These findings provide valuable insights into task-specific adaptations and potential applications targeting balance needs in specific populations.

Table1.Characteristics of Included Studies

Study	Sample Sizes	Target Group	Interventions	Outcome Measures	Study Groups	Results	P Values
Keller et al. (2012)	24	Healthy adults, no prior slackline experience	10 sessions of slackline training over 4 weeks	Postural control, spinal reflex excitability (H-reflex)	Training group, Control group	Improved postural control, reduced H-reflex excitability (p<0.05)	p<0.05
Rutkowski et al. (2022)	28	Healthy young adults aged 21-25	5-day program, 15 minutes per day on slackline	Static and dynamic balance, energy expenditure	Experimental group, Passive control group	Improved static and dynamic balance (p<0.003); increased MET	p<0.003
Thomas et al. (2016)	24	Older adults aged 60-67	6-week slackline training, 2 times per week	Postural control in different standing positions	Intervention group, Control group	Significant improvement in postural control (p<0.05)	p<0.05
Trecroci et al. (2018)	42	Young soccer players aged 11-12	12-week slackline and traditional balance training	Balance, physical performance, enjoyment	Slackline training, Traditional balance, Control group	Both SLT and BLT improved balance; SLT higher enjoyment (p<0.05)	p<0.05
Dordevic et al. (2017)	50	Young adults aged 18-30	1 month of intensive slackline training, 3 times per week	Balance on CBT, spatial orientation (OT)	Training group, Control group	Better performance in closed-eye CBT, OT improvement (p<0.05)	p=0.011
Ferri-Marini et al. (2020)	18	Healthy male children aged 8-14	6 weeks of slackline training, 1 hour per session	Static and dynamic balance on stable and unstable surfaces	Experimental group, Control group	Higher improvement in static balance on unstable surface (p=0.004)	p=0.004
Giboin et al. (2018)	26	Young adults aged 18-28	3 months of slackline training, 2 sessions per week	Balance performance on slackline and untrained tasks	Training group, Control group	Improved slackline task performance, no transfer to other tasks.	p<0.001

MET: Metabolic Equivalent of Task, SLT: Slackline Training, BLT: Balance Training (Traditional Balance Training), CBT: Clinical Balance Test.

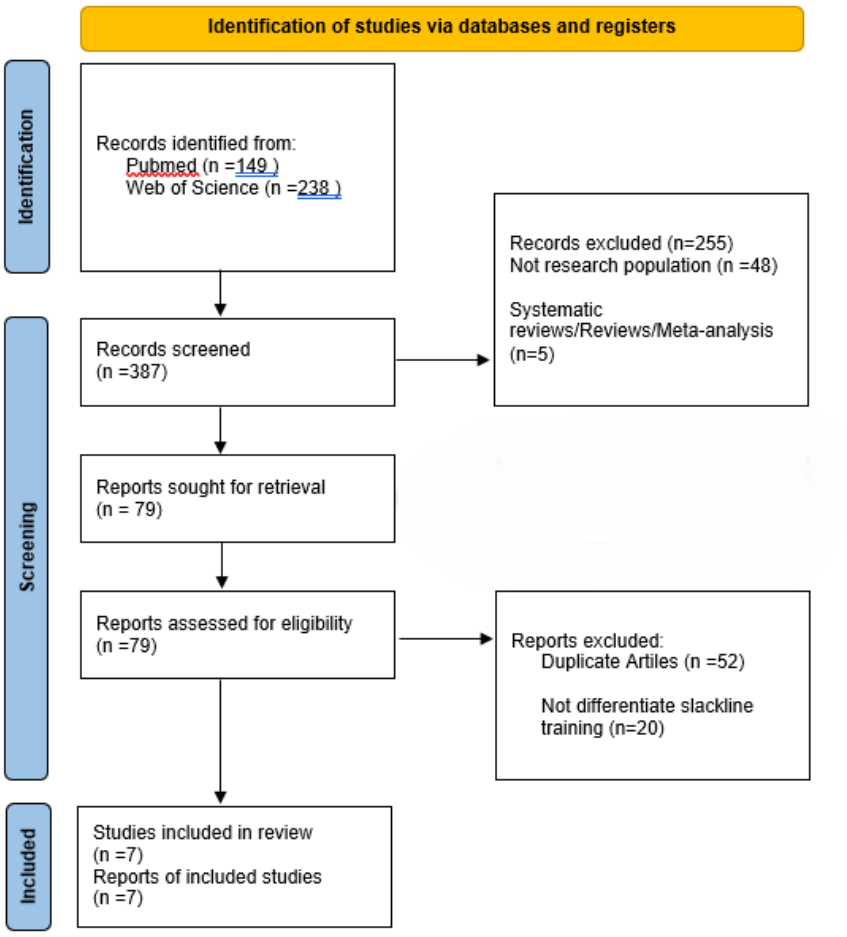

Fig. 1. The Study's PRISMA Flowchart Diagram.

Table 2. Methodological Evaluation of The Studies' Quality

Author, Year	1	2	3	4	5	6	7	8	9	10	11	Total
Keller et al. (2012)	**YES**	**YES**	NO	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	8
Rutkowski et al. (2022)	**YES**	**YES**	**YES**	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	9
Thomas et al. (2016)	**YES**	**YES**	**YES**	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	9
Trecroci et al. (2018)	**YES**	**YES**	**YES**	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	9
Dordevic et al. (2017)	**YES**	**YES**	**YES**	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	9
Ferri-Marini et al. (2020)	**YES**	**YES**	NO	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	8
Giboin et al. (2018)	**YES**	**YES**	**YES**	**YES**	NO	NO	**YES**	**YES**	**YES**	**YES**	**YES**	9

Note that the presence of each item is marked by "YES," while "NO" indicates the item is absent.

1. Eligibility criteria were specified.
2. Participants were randomly assigned to groups (in crossover trials, subjects were randomly assigned to treatment sequences).
3. Allocation information was concealed.
4. Baseline measurements showed similar key prognostic factors across groups.
5. All participants were blinded.
6. All therapists delivering the intervention were blinded.
7. Blinding was applied to all assessors measuring at least one key outcome.
8. Measurements were obtained for more than 85% of key outcomes after initial group assignment.
9. Data for all subjects with outcome measures were analyzed according to their assigned treatment or control group, or, if not, an "intention to treat" approach was used for at least one key outcome.
10. Statistical comparisons between groups are reported for at least one key outcome.
11. The study includes both point estimates and variability measurements for at least one key outcome.

DISCUSSION

The seven studies reviewed collectively highlight the diverse benefits of slackline training across different demographic groups, each demonstrating specific improvements in balance, postural control, and task-specific adaptation. Variations in study design, participants, and intervention duration highlight the distinct outcomes and targeted potential of slackline training.

Slackline training consistently enhances postural stability across ages and various baseline fitness levels. Studies involving younger adults, older adults, and children generally showed improved balance under dynamic and challenging conditions (Keller et al., 2012; Rutkowski et al., 2022; Thomas et al., 2016). These improvements in postural control are frequently linked to the continuous fine motor adjustments required for slackline stabilization, which engage both core and lower limb muscles. Notably, studies with shorter intervention durations often reported generalized balance improvements, suggesting that even brief exposure to slackline training can produce significant balance gains as a short-term intervention (Rutkowski et al., 2022; Thomas et al., 2016).

A consistent finding across studies is that slackline training tends to result in task-specific balance improvements. For example, studies focusing specifically on slackline skills reported clear gains in participants' ability to balance on similar slackline setups (Keller et al., 2012; Ferri-Marini et al., 2020; Giboin, 2018). However, when assessing balance on non-slackline untrained tasks, such as static balance or reactive balance on stable surfaces, the effects were less marked (Dordevic, Giboin). This task-specific characteristic of slackline training suggests that while it effectively enhances balance in conditions similar to those practiced, its benefits may not fully extend to unrelated balance tasks. This insight is especially relevant for programs aiming to improve overall balance across a variety of everyday activities, such as fall prevention for older adults, where slackline training may need to be complemented with more generalized balance exercises (Thomas et al., 2016).

Furthermore, the studies indicate that slackline training's effects may vary based on participants' age and initial abilities. For example, older adults demonstrated notable improvements in functional balance tasks related to fall prevention (Thomas et al., 2016), suggesting that slackline training can be an effective intervention to increase safety and confidence in situations with a high risk of falls. Conversely, children showed selective improvements, mainly in static balance on unstable surfaces, highlighting developmental factors that may influence how younger individuals benefit from slackline training (Ferri-Marini et al., 2020). This finding suggests that slackline training may require adjustments based on age and developmental stage, as younger individuals may respond differently to balance challenges than adults.

While the motivational appeal of slackline training was not a variable directly investigated in this study, its engaging nature, as highlighted in previous research, represents a notable advantage. Studies such as Trecroci et al. (2018) have demonstrated that younger individuals, including adolescents and athletes, often find slackline training more enjoyable than traditional balance exercises. This increased enjoyment could indirectly support adherence and sustained participation, ultimately enhancing the effectiveness of balance and postural control interventions. For athletic training programs, incorporating slackline exercises may provide comparable improvements in dynamic balance while simultaneously fostering greater engagement and motivation among athletes (Trecroci et al., 2018).

In summary, slackline training shows considerable potential for improving balance and postural control, particularly in task-specific settings. However, the variation in outcomes across different tasks and participant demographics suggests that slackline training may be most beneficial when tailored to specific needs and supplemented with other exercises for broader balance improvement. This underscores the importance of individualizing slackline interventions to optimize benefits for various groups, from young athletes aiming to improve dynamic stability to older adults prioritizing fall prevention and functional balance in daily activities.

LIMITATIONS

The systematic review included only seven studies that met the inclusion criteria, highlighting a limited amount of research on the topic. This limitation could impact the generalizability and reliability of the findings. Differences in study designs, sample sizes, interventions, treatment durations, and outcome measures were observed across the included studies. This variability may contribute to inconsistent results, making it challenging to draw firm conclusions. The inclusion of only English-language studies leads to possible language bias. Limiting the literature search to PubMed and Web of Science may have contributed to publication bias and reduced the scope of the review. The lack of a meta-analysis limits the ability to quantitatively synthesize results of the different studies. While a narrative synthesis is acceptable in the presence of heterogeneity, a rationale for not conducting a meta-analysis should be explicitly stated.

CONCLUSION

In conclusion, this systematic review highlights the distinct and varied benefits of slackline training for

improving balance and postural control across different age groups and fitness levels. The findings underscore the importance of task-specific adaptations, demonstrating that while slackline training yields significant gains in dynamic balance, its effects are often limited to conditions closely resembling those practiced. This specificity suggests that slackline training may be most effective when incorporated into tailored interventions, particularly for populations like athletes and older adults, where targeted improvements are prioritized. However, to enhance overall balance across a broader range of activities, slackline training may need to be supplemented with additional, generalized balance exercises. Furthermore, the motivational appeal of slackline training—especially among younger individuals—highlights its potential to improve adherence and engagement in balance-focused exercise routines. Future research should focus on optimizing intervention parameters and exploring the long-term impacts of slackline training across diverse populations to maximize its applicability in both preventive and rehabilitative contexts.

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