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Slackline Training: an innovative intervention for improving balance and physical fitness in older adults

Treinamento de Slackline: uma intervenção inovadora para melhorar o equilíbrio e a aptidão física em adultos mais velhos

Entrenamiento Slackline: una intervención innovadora para mejorar el equilibrio y la forma física en adultos mayores

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Abstract

This experimental study investigated the effects of slackline training on the balance and physical fitness of elderly individuals. Participants in a university extension program were divided into two groups: a slackline training group (n = 7, 73.14 ± 6.38 years) and a control balance training group (n = 7, 78.71 ± 5.56 years). The study variables were muscle strength (MS), flexibility (FLEX), static balance (SB), dynamic balance (DB), self-selected walking speed (WS), maximal walking speed (VMAX). Data were analyzed using generalized estimating equations, effect sizes, and Spearman's correlation coefficients. MS, FLEX, DB, WS, and VMAX improved significantly in the slackline group after the intervention. Post-test MS and WS differed significantly between slackline and control balance training groups. There was a strong association between pre-and post-test DB, MS, FLEX, and VMAX. Slackline balance training proved to be a motivating and challenging method for improving the physical fitness of the elderly.

Keywords: Aging; Balance; Physical fitness; Physical exercise.

Resumo

Este estudo experimental investigou os efeitos do treinamento de slackline sobre o equilíbrio e a aptidão física de idosos. Os participantes de um programa de extensão universitária foram divididos em dois grupos: um grupo de treinamento de slackline (n = 7, 73,14 ± 6,38 anos) e um grupo de treinamento de equilíbrio de controle (n = 7, 78,71

± 5,56 anos). As variáveis do estudo foram força muscular (MS), flexibilidade (FLEX), equilíbrio estático (SB), equilíbrio dinâmico (DB), velocidade de caminhada auto-selecionada (WS), velocidade máxima de caminhada (VMAX). Os dados foram analisados usando equações de estimativa generalizadas, tamanhos de efeito e coeficientes de correlação de Spearman. MS, FLEX, DB, WS e VMAX melhoraram significativamente no grupo slackline após a intervenção. Pós-teste MS e WS diferiram significativamente entre slackline e grupos de treinamento de equilíbrio de controle. Houve uma forte associação entre DB, MS, FLEX e VMAX pré e pós-teste. O treino de equilíbrio slackline mostrou-se um método motivador e desafiador para melhorar a aptidão física de idosos.
Palavras-chave: Envelhecimento; Equilíbrio; Aptidão física; Exercício físico.

Resumen
Este estudio experimental investigó los efectos del entrenamiento slackline sobre el equilibrio y la aptitud física de las personas mayores. Los participantes en un programa de extensión universitaria se dividieron en dos grupos: un grupo de entrenamiento slackline (n = 7, 73,14 ± 6,38 años) y un grupo de entrenamiento de equilibrio de control (n = 7, 78,71 ± 5,56 años). Las variables de estudio fueron fuerza muscular (MS), flexibilidad (FLEX), equilibrio estático (SB), equilibrio dinámico (DB), velocidad de marcha autoseleccionada (WS), velocidad máxima de marcha (VMAX). Los datos se analizaron utilizando ecuaciones de estimación generalizadas, tamaños de efecto y coeficientes de correlación de Spearman. MS, FLEX, DB, WS y VMAX mejoraron significativamente en el grupo slackline después de la intervención. Post-test MS y WS difirieron significativamente entre los grupos de entrenamiento de equilibrio slackline y control. Hubo una fuerte asociación entre DB, MS, FLEX y VMAX antes y después de la prueba. El entrenamiento de equilibrio de Slackline demostró ser un método motivador y desafiante para mejorar la condición física de las personas mayores.
Palabras clave: Envejecimiento; Equilibrio; Aptitud física; Ejercicio físico.

1. Introduction

Aging is a multifactorial, gradual, and irreversible process associated with structural and functional changes. Such modifications affect the systems and structures responsible for maintaining postural control and balance (Halvarsson et al., 2015), such as the vestibular system, the somatosensory system, and visual receptors (Jiam, Agrawal, 2016; Gopinath et al., 2016; Iwasaki & Yamasoba, 2015). Reduced balance control increases the risk of falling and injury, compromises independence, and predisposes the older adult to diseases (McMullan et al., 2018; Iwasaki & Yamasoba, 2015).

Balance is a complex ability to control static and dynamic positions by maintaining the body's center of gravity over the base of support (Granacher et al., 2010). To maintain balance and perform daily activities, the body requires the contribution of neuromuscular, cognitive, and sensory systems (Thomas et al., 2014). In addition to aging, biological, environmental, socioeconomic, and behavioral factors may decrease balance performance (McMullan et al., 2018). Active elderly with good balance performance and muscle strength have lower morbidity and mortality rates (Bembom et al., 2009). Thus, balance is essential for the health and well-being of the older adult.

Reduced balanced, when associated with impairment of other physical abilities, such as agility, alters motor responses during gait and leads to slow movement. These changes are characterized by an increase in the double support phase and base of support as well as a decrease in the swing phase, propulsion, and stride length and width (Cruz-Jimenez, 2017). Balance is also affected by reduced lower limb muscle strength, resulting from loss of muscle mass and function (sarcopenia) (Krause et al., 2012). These modifications affect gait performance, decreasing body stability and foot strength during contact phases and hindering mobility and the ability to perform daily activities (Harkitasari et al., 2018; Gillespie et al., 2012; Pizzigalli et al., 2011).

Different nonpharmacological strategies have been proposed to treat or prevent problems with balance among the older adult, one of the most important of which is regular physical exercise (Conradsson & Halvarsson, 2019). Various studies investigated the effectiveness of interventions, such as Pilates, yoga, and dance, to improve balance (Harkitasari et al., 2018; Halvarsson et al., 2015; Gillespie et al., 2012). Most reports, however, focus on a specific type of exercise or balance (static, dynamic, or postural control), and no consensus has been reached on which form of physical exercise provides the most benefits. According to Gillespie et al. (2012), muscle strength and balance training can be used to reduce the risk of falls. It is important for training exercises to be attractive to stimulate adherence to the program and ensure that neuromuscular improvements are achieved.

Slacklining is the act of balancing or walking on a stretched nylon webbing attached to two anchor points at a certain height from the ground (Pfusterschmied et al., 2013a). The slackline offers a small, non-fixed base of support that moves in the mediolateral direction. To control the body's center of gravity and, therefore, maintain balance on the slackline, the practitioner must counterbalance, with the supporting leg, the lateral movement of the foot, requiring rapid restoration of balance (Pfusterschmied et al., 2013a; Schärli et al., 2013; Keller et al., 2012). This recreational sport is known to improve balance, center of gravity control, and posture (Thomas & Kalicinski, 2016; Pfusterschmied et al., 2013b). Slacklining difficulty can be altered by changing the length, tension, and height of the tape, thereby representing an attractive and stimulating training alternative for the older adult compared with conventional training programs. Few studies have assessed the effects of slacklining on older adults. This study aims to investigate the effects of slackline training on the balance and physical fitness of the older adult.

2. Methodology

Study design

This experimental study was conducted in the real-life settings of a public university in southern Brazil (Pereira et al., 2018; Robitaille, 2012; Koche, 2011). The study protocol was in accordance with the Declaration of Helsinki and Brazilian National Health Council Resolution no. 466/2012 and was approved by the local research ethics committee (protocol no. 32472813.7.0000.5347). All participants signed an informed consent form before participating.

The sample comprised older adults enrolled in an extension program at the Center for Leisure Studies and Physical Activity of the Older people (CELARI), which aims to offer social, cultural, and physical activities through an interdisciplinary approach for the promotion of health and active aging. The sample size was defined on the basis of previous studies with similar instruments and populations (Alfieri et al., 2009). Calculations were performed using G*Power Software considering a significance level of 5%, a statistical power of 80%, and an effect size of 1.21 (Alfieri et al., 2009), which resulted in an estimated sample size of 7 individuals per group.

Participants were selected by non-random convenience sampling. Subjects were instructed to maintain their usual level of physical activity (uncontrolled data) during the study period. Inclusion criteria were (i) participation in the extension program for at least 6 months and attendance of balance training classes and (ii) age over 60 years. Exclusion criteria were (i) use of prosthetic and/or mobility devices, (ii) vision or hearing impairment, (iii) incomplete physical assessment, and (iv) less than 75% class attendance. Initially, the total sample consisted of 24 older adults individuals. After application of the exclusion criteria, the overall sample was reduced to 14 individuals divided into groups, a slackline balance training group (7 women, 73.14 ± 6.38 years) and a control balance training group (6 women and 1 man, 78.71 ± 5.56 years).

Assessment instruments

Physical and functional fitness tests were performed using assessment instruments validated with the older adults population. Muscle strength and flexibility were assessed by two tests from the Senior Fitness Test battery (Rikli & Jones, 1999): 30-second chair stands (muscle strength) and chair sit and reach (flexibility). Static balance was evaluated by the Unipedal Stance test (Gustavsson et al., 2000), and dynamic balance by the Timed Up and Go test (Podsiadlo & Richardson, 1991). Walking speed was measured in terms of self-selected speed along a 10 m walkway and maximal speed (Novaes et al., 2011).

Balance training interventions

Participants were assigned to a slackline balance training or a control balance training group. Classes were provided separately for each group as two weekly sessions of 45 min each during 12 weeks, totaling 24 sessions. Table 1 describes the training program used in each intervention.

Table 1. Description of balance training interventions for slackline and control groups.

Item	Slackline group	Control group
Routine	Warm-up (5–10 min): joint mobility, dynamic warm-up, and walking exercises	Warm-up (5–10 min): joint mobility, dynamic warm-up, and walking exercises
	Six-station circuit (25 min) aimed at improving: - Lower limb strength (2 exercises) - Static balance (1 exercise) - Slackline balance (2 exercises) - Lower limb flexibility (1 exercise)	Six-station circuit (25 min) aimed at improving: - Lower limb strength (2 exercises) - Static or dynamic balance (3 exercises) - Lower limb flexibility (1 exercise)
	Cooldown (5–10 min): stretching and relaxation exercises	Cooldown (5–10 min): stretching and relaxation exercises
Load	Each station lasted 90 s, followed by a resting time of 30 s. The circuit was completed twice at each session.	Each station lasted 90 s, followed by a resting time of 30 s. The circuit was completed twice at each session.
Intensity	Progression was gradual (every 3 weeks). Exercise complexity and intensity were increased by reducing sensory stimuli, shifting the body's center of gravity, increasing execution speed, and requiring greater movement coordination. In the slackline group, progression followed four phases related to intensity, balance, and support. - Phase I: proprioception, adaptation, basic techniques (how to get up and down the slackline). Use of a support device is mandatory. - Phase II: posture, balance, breathing. Use of support is optional, assistance by a trained individual is mandatory. - Phase III: balance and walking. Use of support or assistance is optional. - Phase IV: walking without support. Assistance is optional.	Progression was gradual (every 3 weeks). Exercise complexity and intensity were increased by reducing sensory stimuli, shifting the body's center of gravity, increasing execution speed, and requiring greater movement coordination.

Source: Authors (2021).

Slackline training is an innovative proposal for improving balance in older individuals. The following safety measures were adopted: (i) the slackline was set at a height of 35 cm from the floor, (ii) anchoring points were 1.7 m apart (optimal distance), (iii) routines progressed gradually from basic techniques to functional exercises and slackline walking (Pfusterschmied et al., 2013B).

Statistical analysis

Generalized estimating equations (GEE) (Zeger & Liang, 1986) were used to assess the effects of slackline training in older adults. GEE analysis is a type of longitudinal regression based on generalized linear models that accounts for within-subject variations over time. Here, the time factor refers to pre- and post-test results, and the group factor to slackline and control groups. Main and interaction effects of group and time factors on balance and physical fitness variables were investigated by analysis of variance (GEE). Multiple comparisons were performed using Bonferroni's post-hoc test to identify differences revealed by the GEE.

Cohen's d was used as a measure of effect size, calculated from the mean score changes and standard deviations of pre- and post-test results by group (Cohen, 1992). Effect size was interpreted as insignificant ($d \leq 0.19$), small ($0.20 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), or large ($d \geq 0.80$) (Cohen, 1992).

Correlations between study variables were assessed by Spearman's correlation (r) test. Correlations were categorized as strong ($r > 0.60$), moderate ($0.30 \leq r \leq 0.60$), or weak ($r < 0.30$) (Hernandez-Nieto, 2002). Statistical analyses were performed using SPSS software. The level of significance adopted for all analyses was $p \leq 0.05$.

3. Results

Table 2 shows the physical fitness variables of slackline and control groups.

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Table 2. Pre- and post-training assessment of physical fitness in older adults who participated in slackline and control balance training interventions.

Variable	**Time**	**Slackline group**		**Control group**		**Analysis of variance (*p*)**		
		Mean ± SD	**Effect size**	**Mean ± SD**	**Effect size**	**Group (G)**	Time (T)	**G × T**
Muscle strength (repetitions)	Pre-training	18.00 ± 4.93*	0.64	15.43 ± 2.64	0.38	0.053	0.001	0.139
	Post-training	20.86 ± 3.90*†		16.57 ± 3.21†				
Flexibility (cm)	Pre-training	−9.71 ± 8.02*	0.40	−4.29 ± 8.14	0.25	0.234	0.003	0.491
	Post-training	−6.29 ± 8.67*		−2.14 ± 8.55				
Static balance (s)	Pre-training	23.00 ± 9.29	0.13	18.18 ± 10.11	0.09	0.339	0.482	0.867
	Post-training	24.29 ± 10.36		19.18 ± 11.60				
Dynamic balance (s)	Pre-training	6.46 ± 0.84*	1.47	6.31 ± 0.94	0.39	0.823	0.000	0.136
	Post-training	5.51 ± 0.36*		5.85 ± 1.36				
Self-selected walking speed (m/s)	Pre-training	1.44 ± 0.16*	0.37	1.33 ± 0.14	0.00	0.074	0.148	0.190
	Post-training	1.50 ± 0.16*†		1.33 ± 0.15†				
Maximal walking speed (m/s)	Pre-training	0.56 ± 0.07*	0.70	0.57 ± 0.05	0.00	0.259	0.130	0.082
	Post-training	0.52 ± 0.04*		0.57 ± 0.06				

An asterisk (*) indicates a significant difference ($p < 0.05$) between pre- and post-test results within groups. A dagger (†) indicates a significant ($p < 0.05$) difference between groups in the post-test. Source: Authors (2021).

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GEE analysis indicated that some parameters varied with time (Table 2). The factors group and group × time had no significant influence on fitness variables. Time had a significant effect on muscle strength (p = 0.001), flexibility (p = 0.003), and dynamic balance (p = 0.000).

Post-hoc analysis using Bonferroni correction indicated differences between pre- and post-tests. In the slackline group, training improved muscle strength (p = 0.004, medium effect), flexibility (p = 0.012, small effect), and dynamic balance (p = 0.000, large effect). In the post-test, the mean values of flexibility and dynamic balance were lower, indicating better performance. Post-hoc analysis showed a significant improvement in self-selected walking speed (p = 0.025, small effect) and maximal walking speed (p = 0.020, medium effect), although initial analysis indicated that the effect of time on these parameters was nonsignificant (p = 0.148, p = 0.130 respectively).

Post-hoc comparisons between slackline and control groups indicated a significant difference in muscle strength (p = 0.015) and self-selected walking speed (p = 0.042) in the post-test. However, as per the GEE analysis, group effects on muscle strength (p = 0.053) and self-selected walking speed (p = 0.074) were not significant, and differences were observed between pre- and post-training.

Because the interventions were aimed at physical balance training, we investigated the correlation between balance variables (dynamic and static) and other physical fitness variables (Table 3). Correlation analysis revealed a significant, strong, and inverse correlation between dynamic balance and muscle strength (p = 0.008) in the pre-test of the slackline group and a significant and direct correlation between static balance and flexibility (p = 0.025) in the post-test. For the control group, post-test dynamic balance was significantly and directly proportional to maximal walking speed (p = 0.050).

Table 3. Correlations between pre- and post-training balance and physical fitness variables.

Variable	**Time**	**Static balance**				**Dynamic balance**			
		Slackline group		**Control group**		**Slackline group**		**Control group**	
		r	***p***	***r***	***p***	***r***	***p***	***r***	***p***
Muscle strength	Pre	−0.883	0.008	−0.643	0.119	−0.173	0.711	0.512	0.240
	Post	−0.667	0.102	−0.655	0.111	0.636	0.125	0.202	0.664
Flexibility	Pre	−0.607	0.148	−0.643	0.119	0.144	0.758	0.591	0.162
	Post	−0.571	0.180	20.45	0.596	0.815	0.025	0.202	0.664
Self-selected walking speed	Pre	−0.357	0.432	−0.643	0.119	−0.631	0.129	0.355	0.435
	Post	−0.571	0.180	−0.595	0.159	−0.037	0.937	0.089	0.849
Maximal walking speed	Pre	0.523	0.229	0.667	0.102	0.055	0.908	−0.447	0.314
	Post	0.214	0.645	0.755	0.050	0.000	10.00	−0.449	0.312

r, Spearman's correlation coefficient. Source: Authors (2021).

4. Discussion

A recent systematic review and meta-analysis reported that most interventions aimed at balance improvement exert small or moderate effects on the balance performance of the elderly (Farlie et al., 2019). Here, we showed that slackline training for 12 weeks, performed twice a week, provided significant positive improvements in muscle strength, flexibility, dynamic balance, and self-selected and maximal walking speed in older adults. Effect sizes varied from medium, for muscle strength and maximal speed, to large, for dynamic balance. For the slackline group, dynamic balance was inversely associated with muscle strength in the pre-test, and static balance was positively associated with flexibility in the post-test.

Slackline training is an innovative, attractive, and physically demanding technique that has been used as an alternative for balance training (Pfusterschmied et al., 2013a,b; Santos et al., 2016). The main difference between slackline training and conventional balance training is that a mobile rather than a fixed support base is used, requiring high balance ability so as not to fall off the tape. Thus, the positive effects of slackline training can be transferred to the practitioner's stability and postural control in other situations (Santos et al., 2016).

There are few studies on the application of slackline training to improve balance in the older adult. Thomas and Kalicinski (2016) assessed the use of slacklining twice a week for six weeks on postural control in older adults. The time of different standing positions on a balance platform with and without an external disturbance and the acceleration of the balance platform were measured pre- and post-intervention. The results showed improvements in one-leg and tandem stance with and without external disturbances, indicating that slackline training had a positive impact on postural control. Postural control on the balance platform improved after four weeks of slackline training, as evidenced by better compensation of unstable conditions with and without external disturbance and prolonged times in the one-leg stance position. Therefore, the results of the referenced study, whose study population was similar to ours, corroborate those obtained here for balance variables. Many factors can influence postural control in the older adult, such as biomechanical constraints, movement strategies, sensory strategies, dynamic balance control, spatial orientation, and cognitive processing, which may vary across individuals.

Donath et al. (2016) conducted a randomized study with older adults distributed in intervention (n = 16) and control (n = 16) groups. Their objective was to investigate the effects of a structured and progressive six-week slackline training intervention on balance performance, muscle strength, and muscle activity of the lower limbs and trunk. Slackline training had a significant effect on standing balance and moderate to large effects on ankle strength and muscle activity. According to the authors, slacklining may induce task-specific improvements of balance performance and explosive power of the ankle accompanied by reductions in muscle activity of the lower limbs and trunk. Our results differ in that we found significant improvements in muscle strength and dynamic balance with slackline training.

Unlike our study, Magon et al. (2016) sought to investigate morphological and functional changes in the brain of older individuals after slackline training. Participants were subjected to balance assessment (static and dynamic) and magnetic resonance imaging (MRI). Static balance was determined by slackline standing performance, and dynamic balance by slackline tandem stance time. The intervention lasted six weeks, comprising three weekly sessions of 90 min. The intervention group had a significant improvement in static and dynamic balance compared with the control group. MRI revealed no morphological or functional connectivity differences. The effects of slackline training on balance were similar to those observed in the current study. It should be noted that tandem stance time may be associated with speed, a variable that improved in our intervention.

Studies on slackline training with other study populations, albeit rare, showed that the activity promotes similar effects on balance to those observed here. Santos et al. (2016) used slackline as an additional balance training for basketball athletes. The results indicated greater activation of the main muscles of the lower limbs, quadriceps, soleus, and gastrocnemius. Another study compared the ability of children and young adults to perform a single-legged stance on a slackline (Schärli et al., 2013). Children were found to have greater head-in-space rotation and translation and greater gaze variability around a visual anchor point. Pfusterschmied et al. (2013b) reported that slacklining improved postural control, counteracted deficits in proprioception, and stabilized leg joints but seemed to be demanding in terms of hip and knee movements. Overall, although these studies were not conducted with older adults, they are evidence of the benefits of slackline training, which can be emphasized during training planning.

Slackline training is an interesting alternative for promoting physical fitness in the older adult. According to Donath et al. (2016), aging-induced reduction in postural control may be enhanced by improvements in balance promoted by slacklining. However, it should be noted that some positions can be very demanding, particularly for the older adult, which is why, in many cases, only trends are observed in the improvement of fitness and balance variables. Compared with younger populations, older adults generally take more time to perform tasks on the slackline, probably because of the decline in motor learning and adaptive capacity. Slackline balance training is believed to generate specific neuromuscular adaptations in the older adult. Thomas and Kalicinski (2016) stated that balance operates reactively, in response to unexpected destabilization during slipping or stumbling, or proactively, by pre-activation of muscles to expected destabilization, such as a change of direction during walking. The ability to control body positions, both static and dynamic, is required regularly in everyday life situations and is important for autonomy and functional independence.

The results of our study showed improvement in muscle strength, flexibility, dynamic balance, and speed with slackline training. One of the advantages of slacklining for dynamic balance is the improvement in the capacity to align the body's center of gravity resulting from a decrease in muscle activity (Donath et al., 2016). Slackline training should be introduced into traditional exercise programs to diversify and expand neuromuscular adaptations in the older adult. Improvement in dynamic balance was not accompanied by an improvement in static balance. This finding can be explained by the fact that, because of the highly dynamic movements in slacklining, the need to regain balance is much greater than the need to maintain balance (Pfusterschmied et al., 2013B).

Balance involves the ability to control multiple functions (Granacher et al., 2010). A strength of our study was the use of slacklining as part of balance training rather than as a single intervention strategy, in line with the recommendation of a review study on the effects of slackline training in different populations, including the older adult (Donath et al., 2017). One of the limitations was the lack of control over participant medication use, motivational aspects, and physical exercise in parallel or previous to the intervention. Inclusion of slacklining in training routines seems to have promoted greater benefits than conventional balance training alone. More studies with larger samples are needed to confirm these incipient results.

5. Conclusion

This study assessed the effects of balance training with slackline on the physical fitness of older adults. Muscle strength, flexibility, dynamic balance, self-selected walking speed, and maximal walking speed improved significantly after the slackline intervention. Balance training with slackline proved to be a viable, innovative, challenging, and potentially effective alternative to enhancing physical fitness in the older people.

Further studies on the older adults population and their physical needs are essential for the development of new methods to improve autonomy, functional independence, and quality of life in this age group. New studies involving the practice of Slackline with a larger sample of older people and with a longer duration of time are suggested.

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Declaration of Conflicting Interests

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