Slackline Training for Balance and Strength Promotion

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Key words
- sensorimotor training
- postural sway
- rate of force development
- jumping height

Abstract

The prevalence of sustaining a sport injury is high in adults. Deficits in postural control/muscle strength represent important injury-risk factors. Thus, the purpose of this study was to investigate the impact of a specific type of balance training, i.e. slackline training, followed by detraining on balance and strength performance. Twenty-seven adults participated in this study and were assigned to an intervention (age 22.8 ± 3.3 yrs) or a control group (age 23.9 ± 4.4 yrs). The intervention group participated in 4 weeks of slackline training on nylon webbings. Detraining lasted 4 weeks. Tests included the measurement of *(a)* total centre of pressure displacements during one-legged standing on a balance platform and during the compensation of a perturbation impulse, *(b)* maximal torque and rate of force development (RFD) of the plantar flexors on an isokinetic device, and *(c)* jumping height on a force platform. After training, no significant interaction effects were observed for variables of static/dynamic postural control, maximal torque, and jumping height. Training-induced improvements were found for RFD. After the withdrawal of the training stimulus, RFD slightly decreased. Given that the promotion of balance and strength is important for injury prevention, changes in RFD only might not be sufficient to produce an injury-preventive effect.

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Introduction

The benefits of regular exercise on physical and mental well-being and its potential as a measure to counteract various life style diseases (e.g., obesity, hypertension) have been well-documented in the past [19]. However, sport injuries are unwanted side effects that accompany sports participation and are thus becoming an important public health concern. According to the German National Health Survey, 5.6% of adults engaging in regular recreational physical activity received medical treatment for non-fatal sports injuries during the foregoing year [33]. Notably, the injury incidence rate is highest in the age group 30 years and younger. Dislocations, distorsions, and/or torn ligaments account for 60% of all sports injuries, followed by fractures (18%), contusions, surface wounds, or open wounds (12%) [32]. Further, about 62% of all sports injuries resulted in occupational disability/time off work. Thus, sports injuries lay a high financial burden on the public health care system [30]. The aetiology of sports injuries is multi-factorial comprising extrinsic/environmental risk factors (e.g., weather, sports equipment, etc.) and/or intrinsic/subject-related risk factors [27]. Two important intrinsic risk factors are deficits in postural control [37] and muscle imbalance and/or weakness [39]. Impaired postural control manifests itself for example in prolonged latencies of lower extremity muscles during the compensation of unexpected perturbations [24]. Deficits in muscle strength may cause an imbalance in muscular co-contraction of the ankle or knee joint resulting in reduced joint stiffness during high-load dynamic activities. Thus, the respective joint is susceptible to injury [22]. Therefore, injury-preventive exercise programs should focus on the promotion of balance and strength to effectively reduce sports injury rate. Traditionally, balance training (BT) has been used to rehabilitate lower extremity injuries and postural deficits. Prospective studies have shown preventive effects with respect to ankle and knee joint injuries [2, 6, 28, 38]. Recent studies were able to extend the already existing base of knowledge on the preventive effects of BT by providing

new insights in the impact of BT on static and dynamic postural control as well as on force production of lower extremity muscles in children [14], adolescents [10], adults [20], seniors [12], patients [36], and elite athletes [35]. Notably, BT resulted in an improved ability to rapidly produce force of lower extremity muscles, even though no specific strength enhancing exercises are involved in BT protocols.

A specific type of BT, the so-called slackline training, has recently evolved from a simple climbing activity to a training program which may have great potential to promote balance and strength performance. Slacklining can be described as a balance activity which utilizes tubular nylon webbing stretched tight between 2 objects (trees, poles, etc.) at various heights above the ground. The line is flat (2.5–5 cm wide, 6–20 m long) and its tension can be adjusted for the purpose of increasing or decreasing the difficulty of the balance tasks that are performed while standing or walking on the line. Due to the highly demanding balance tasks involved in slacklining and because of the great popularity it received lately among young people, it seems to be particularly suited as a training regimen for young and healthy adults. However, to the authors' knowledge, there is no study available which investigated the effects of slacklining on intrinsic sports injury-risk factors like deficits in postural control and muscle strength. Given the similarity between BT and slackline training regarding the performance of balance exercises on a reduced base of support, it is suggested that slackline training produces similar improvements in postural control and muscle strength as balance training. Therefore, the objective of this study was to examine the impact of slackline training and detraining on variables of static and dynamic postural control, plantar flexor strength, and jumping height in young healthy adults. Based on the results of studies which investigated the effects of BT on postural control and muscle strength in this age group [10,20], it is expected that slackline training produces significant improvements in balance and strength performance.

Materials and Methods

To test our hypothesis, adaptations following slackline training were evaluated in a controlled longitudinal intervention study. The training period lasted 4 weeks in order to ensure neural modifications (for a review see Taube et al. [34]). Training was followed by a 4 week detraining period to document the stability of the adaptive processes following training. Training-induced improvements were verified by an analysis of static/dynamic postural control and isometric/dynamic muscle strength. Both, gains in balance control and force production developed during training are of vital importance for several sports-related skills as well as for injury prevention purposes [40].

Participants

Twenty-seven young, healthy, and active adults with no significant anthropometrical differences in body mass, body height, body mass index (BMI), and physical activity level participated in the study after experimental procedures were explained (▶ **Table 1**). None had any history of musculoskeletal, neurological or orthopaedic disorder that might have affected their ability to perform a slackline training. The dominant leg was determined according to the lateral preference inventory [4]. The participants were asked to fill in the validated "Freiburg questionnaire of physical activity©" [9] at baseline testing (▶ **Table 1**). Appropriate informed consent was gained from the participants. None of the participants had previously participated in systematic slackline and/or BT. Local ethical permission was given by the EKBB (Ethikkommission beider Basel) and all experiments were conducted according to the latest version of the declaration of Helsinki. Our study meets the ethical standards of the journal [18].

Slackline training

Participants were randomly assigned to either the intervention (INT) or the control group (CON). The intervention group conducted a slackline training for 4 weeks with 3 training sessions per week on non-consecutive days. In general, slackline training comprises balance tasks on nylon tubular webbings which are usually attached between 2 anchor points (e.g., trees, poles). In this study, slackline training was conducted in a gym and the slacklines (Power Slacker, Selzach, Switzerland) were attached to poles which were firmly fixed on the gym floor. To make training safe, the height of the lines was kept close to the floor (i.e., 60 cm) and mats were put right underneath the slacklines (▶ **Fig. 1**). The length of the applied slacklines ranged from 6 to 15 m. The longer the slackline, the more difficult the balancing task. All slacklines were 3.5 cm wide with an elasticity of 4%. Each training session started with a 10 min warm up, followed by 45 min of training on the webbing, and finishing with a 5 min cool down

Table 1 Characteristics of the study participants.

Characteristic	INT-group (n = 13)	CON-group (n = 14)
age (years)	22.8 ± 3.3	23.9 ± 4.4
body height (cm)	168.2 ± 7.0	170.5 ± 8.7
body mass (kg)	63.0 ± 9.3	64.7 ± 10.2
body mass index (kg/m^2)	22.2 ± 1.9	22.1 ± 1.9
everyday and sports-related physical activity level (h/week)	17.3 ± 7.1	15.3 ± 9.9
sex (f/m)	9/4	10/4

Note: Values are mean ± SD. f = female; m = male

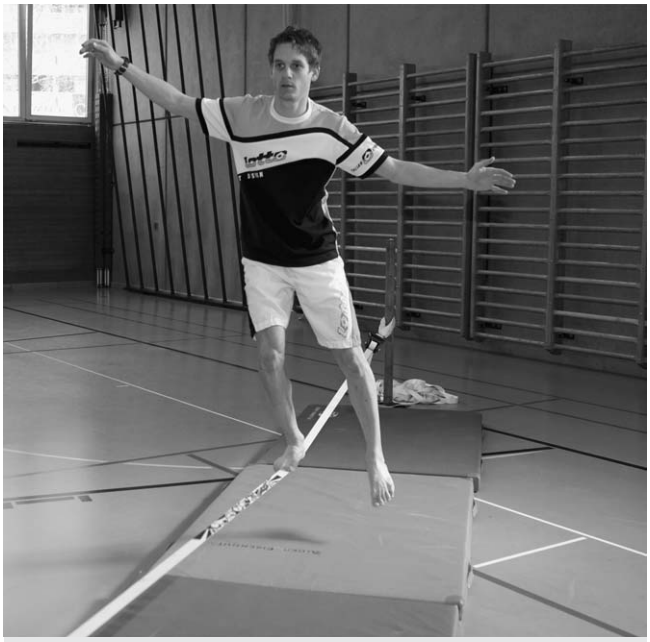

Fig. 1 Study participant on the slackline during training week 2.

program. During the first week of training, only short slacklines (i.e., 6 m) were used and participants exercised barefoot in pairs of 2 to have one person watch and support the other. Exercises primarily comprised static tasks (e.g., stepping on the line with one foot and subsequently dragging the other foot on the line). After the first 2 training sessions, dynamic tasks were included in terms of taking 1 or 2 steps forward from the anchor point towards the mid of the line. During week 2, participants were able to stand and walk on the line without assistance (▶ **Fig. 1**). Thus, the length of the lines was gradually increased to 10 m. From week 3 on, additional tasks (e.g., kneel down and stand up, place hands on hips during balancing, walk sidewards/backwards, make turns) were included in the training sessions and the length of the lines was extended to 12 m to increase training intensity. During week 4, the length of the slacklines was extended to 15 m and task difficulty was increased by asking participants to juggle a ball, to read a newspaper article, and to close the eyes while balancing on the slackline. During the main part of the training session, subjects continuously exercised for 2 minutes and rested for 2 minutes thereafter. This methodological approach is based on a recently published review on the contents of slackline training [31]. All sessions were documented and supervised by the authors of the study. The CON-group did not receive any intervention.

Testing procedure

Pre, post and follow-up measurements were conducted in our biomechanic laboratory. Test circumstances (e.g., room illumination, temperature, noise) were in accordance with recommendations for posturographic testing [23]. Prior to testing, all subjects underwent a 5 min warm up consisting of bipedal and monopedal balance exercises as well as 5 submaximal plyometrics. Pre, post, and follow-up tests included *(a)* measurements of static and dynamic postural control on a balance platform, *(b)* the analysis of jumping height on a force platform, and *(c)* the assessment of maximal torque and rate of force development (RFD) of the plantar flexors under isometric condition on an isokinetic device. This testing sequence was applied in order to keep the effects of neuromuscular fatigue minimal.

Testing material

Balance platform

Static and dynamic postural control were assessed by means of a balance platform (GKS 1 000®, IMM, Mittweida, Germany). The balance platform consists of 4 uni-axial sensors measuring displacements of the COP in the medio-lateral and anterior-posterior directions. Under static conditions, the balance platform was firmly fixed on the floor. For experimental testing, participants were asked to stand on their dominant leg on the platform with their supporting leg in 30° flexion, hands placed on hips and gaze fixed on a cross on the nearby wall. Subjects were instructed to remain as stable as possible and to refrain from any voluntary movements during the trials. Prior to testing, students performed 2 practice trials on the balance platform. Thereafter, 1 test trial was conducted. Data was acquired for 30 s at a sampling rate of 40 Hz [23]. Total displacement of the COP was computed. Under dynamic conditions, the platform was placed into a cage which is mounted on 4 springs and which is free to move in the transversal, medio-lateral, and anterior-posterior directions. Medio-lateral perturbation impulses were applied in order to investigate dynamic postural control of the participants. Therefore, the platform was moved 2.5 cm from the neutral position in the medio-lateral direction, where it was magnetically fixed. Participants' test position was identical with that during the assessment of static postural control. Several trials helped participants to get accustomed to the measuring device. After investigators visually controlled the position of the subjects, the medio-lateral perturbation impulse was unexpectedly applied by detaching the magnet. The platform suddenly accelerated in the medial direction. The participants' task was to damp the oscillating platform by balancing unilaterally on the platform. Data was acquired for 10 s at a sampling rate of 40 Hz [23]. If participants did not accomplish the whole sampling duration, they were allowed to repeat. Total displacement of the COP was computed. Three trials were performed. The best trial (least COP displacements) was used for further analysis. Intraclass correlation coefficients were calculated for total displacements of the COP under static (ICC = 0.91) and dynamic conditions (ICC = 0.81). This protocol has recently been described in detail elsewhere [10, 12].

Force platform

Participants performed maximal vertical countermovement jumps (CMJs) while standing on a one dimensional force platform (Kistler® type 9290AD, Winterthur, Switzerland). The vertical ground reaction force was sampled at 500 Hz. During the CMJ, subjects stood in an upright position on the force platform and were instructed to begin the jump with a downward movement, which was immediately followed by a concentric upward movement, resulting in a maximal vertical jump. Subjects performed 3 CMJs with a resting period of 1 min between jumps. The best trial in terms of maximal jumping height was taken for further data analysis. The intraclass correlation coefficient was calculated for CMJ jumping height (ICC = 0.98). This protocol has recently been described in detail elsewhere [13].

Isokinetic device

Maximal isometric torque of the plantar flexors was measured on an isokinetic system (Isomed 2 000®, D & R Ferstl GmbH, Hemau, Germany). The maximum error of the torque sensor was < 0.2 %. Participants lay supine on the seat of the isokinetic device, with hip and knee angles in neutral position (180°) and the ankle angle at 100°. Straps attached to the isokinetic system firmly fixed the shoulders, the waist, the thigh, the shank, and the foot. In addition, participants were asked to cross their arms in front of their chest. Thus, evasive movements of the upper and lower body were not possible. The exact position of each participant was documented and saved so that it was identical in pre, post, and follow-up tests. Testing was performed with the dominant leg. Before the testing started, participants warmed up by doing 3–5 submaximal isometric actions in the isokinetic system to get accustomed to the testing procedure. Thereafter, each subject performed 3 plantar flexor exercises with maximal voluntary effort. For each trial, subjects were thoroughly instructed to act as forcefully and as fast as possible and to avoid forced respiration. The torque signal was sampled at 200 Hz. A digital fourth-order recursive Butterworth low-pass filter, with a cut-off frequency of 50 Hz filtered the torque signal. During offline analysis, the best trial in terms of maximal torque was selected and used for further data analyses. Maximal torque was defined as the maximal voluntary torque value of the torque-time curve, determined under isometric condition. Rate of force development (RFD) was defined as the mean slope of the torque-time curve between 20 % and 80 % of the individual maximal

Table 2 Effects of slackline training and detraining on measures of postural control, plantar flexor strength, and jumping height in young adults.

Parameter	INT-group (n = 13)			CON-group (n = 14)		
	pre	post	follow-up	pre	post	follow-up
total COP displacements under static conditions (mm)	1 005.4 ± 176.7	924.5 ± 124.1	995.7 ± 163.4	998.1 ± 239.8	977.1 ± 232.0	943.8 ± 299.2
total COP displacements under dynamic conditions (mm)	705.3 ± 214.4	489.9 ± 91.8	494.0 ± 95.1	753.7 ± 187.4	549.7 ± 117.8	514.0 ± 143.7
CMJ jumping height (cm)	41.6 ± 6.4	41.3 ± 5.9	41.4 ± 6.1	40.2 ± 7.2	40.2 ± 7.1	39.0 ± 7.0
maximal torque of the plantar flexors under isometric conditions (Nm)	126.1 ± 38.1	141.1 ± 36.3	138.8 ± 34.2	139.4 ± 41.5	150.6 ± 48.3	156.5 ± 50.7
RFD of the plantar flexors under isometric conditions (Nm/s)	466.8 ± 147.1	535.0 ± 149.7	527.6 ± 134.5	517.2 ± 212.0	489.3 ± 148.6	553.6 ± 205.3

Notes: Values are mean ± SD. COP = centre of pressure; CMJ = countermovement jump; RFD = rate of force development

torque. These parameters were chosen in order to gain comparable data to previously conducted studies [16, 17, 35]. The intraclass correlation coefficient was calculated for maximal torque (ICC = 0.97) and RFD (ICC = 0.93) of the plantar flexors. This protocol has recently been described in detail elsewhere [14].

Statistical analysis

Data are presented as group mean values ± standard deviations (SD). A multivariate analysis of variance (MANOVA) was used to detect differences between study groups (INT, CON) in all baseline variables. Balance and strength parameters were analyzed in separate 2 (Groups: INT, CON) x 3 (Tests: pre, post, follow-up) ANOVA with repeated measures on test. Post hoc tests with the Bonferroni-adjusted α were conducted to identify the comparisons that were statistically significant. The classification of effect sizes (f) was determined by calculating partial η^2_p. The effect size is a measure of the effectiveness of a treatment and it helps to determine whether a statistically significant difference is a difference of practical concern. f-values = 0.10 indicate small, f-values = 0.25 medium, and f-values = 0.40 large effects [3]. An a priori power analysis [8] with an assumed Type I error of 0.05 and a Type II error rate of 0.10 (90% statistical power) was calculated for postural sway [10] and revealed that 12 participants per group would be sufficient for finding a statistically significant interaction effect. The significance level was set at $p < 0.05$. All analyses were performed using Statistical Package for Social Sciences (SPSS) version 17.0.

Results

Means and standard deviations for all variables are presented in **Table 2**. Thirteen participants completed the slackline training program and none reported any training-related injury. Overall, there were no statistically significant differences in baseline values between the experimental groups.

Static and dynamic postural control

Table 2 indicates slightly reduced COP displacements in both experimental groups from pre to post testing. However, the analysis failed to show main effects of test (F (2, 156) = 1.47, $p > 0.05$, $\eta^2 = 0.05$, $f = 0.23$) and group (F (1, 25) = 0.01, $p > 0.05$, $\eta^2 = 0.01$, $f = 0.10$). In addition, Group x Test interaction for COP displacements did not reach the level of significance (F (2, 156) = 1.52, $p > 0.05$, $\eta^2 = 0.06$, $f = 0.25$).

In terms of dynamic postural control, slightly reduced COP displacements were found for both experimental groups from pre to post testing during the compensation of medio-lateral perturbation impulses (**Table 2**). The statistical analysis detected main effects of test (F (2, 156) = 30.96, $p < 0.01$, $\eta^2 = 0.55$, $f = 1.11$) but not of group (F (1, 25) = 0.95, $p > 0.05$, $\eta^2 = 0.04$, $f = 0.20$). Further, the analysis failed to indicate a Group x Test interaction for COP displacements (F (2, 156) = 0.20, $p > 0.05$, $\eta^2 = 0.01$, $f = 0.10$).

Jumping height

Slackline training resulted in a minor decrease in CMJ jumping height in the INT from pre to post testing. Yet, the analysis did not detect main effects of test (F (2, 156) = 1.92, $p > 0.05$, $\eta^2 = 0.07$, $f = 0.27$), and group (F (1, 25) = 0.42, $p > 0.05$, $\eta^2 = 0.02$, $f = 0.14$). In addition, no significant Group x Test interaction was found for CMJ jumping height F (2, 156) = 1.61, $p > 0.05$, partial $\eta^2 = 0.06$, $f = 0.25$).

Plantar flexor strength

Maximal torque of the plantar flexors increased in both experimental groups from pre to post testing (**Table 2**). The analysis indicated main effects of test (F (2, 156) = 18.10,. $p < 0.01$, $\eta^2 = 0.42$, $f = 0.85$) but not of group (F (1, 25) = 0.71, $p > 0.05$, $\eta^2 = 0.03$, $f = 0.18$). Furthermore, Group x Test interaction for maximal torque of the plantar flexors did not reach the level of significance (F (2, 156) = 1.12, $p > 0.05$, $\eta^2 = 0.04$, $f = 0.20$).

Fig. 2 demonstrates increases in RFD of the plantar flexors in the INT from pre to post-testing. The analysis indicated main effects of test (F (2, 156) = 5.02, $p < 0.01$, $\eta^2 = 0.17$, $f = 0.45$) but not of group (F (1, 25) = 0.03, $p > 0.05$, $\eta^2 = 0.01$, $f = 0.10$). In addition, the analysis detected a Group x Test interaction for RFD of the plantar flexors (F (2, 156) = 5.26, $p < 0.05$, $\eta^2 = 0.17$, $f = 0.45$). Post-hoc analysis revealed that participants in the INT-group significantly increased their RFD from pre to post testing while the participants in the control group showed no significant changes (**Fig. 2**). Further, **Fig. 2** illustrates a minor decrease in RFD of the plantar flexors from post to follow-up testing in the INT-group. Post hoc analysis did not show a significant change. In addition, after detraining, RFD was still significantly higher than the baseline value (**Fig. 2**).

Discussion

The main findings of this study can be summarized as follows. First, 4 weeks of intense slackline training did not result in statistically significant improvements in static and dynamic postural control as well as in maximal torque of the plantar flexors and jumping height. Second, RFD of the plantar flexors was

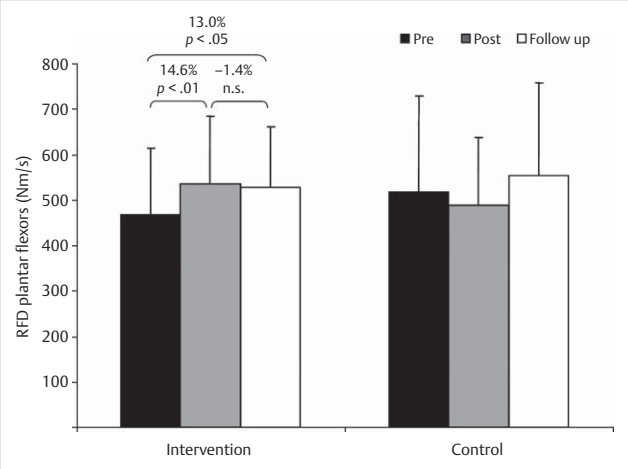

Fig. 2 Performance changes during the training and detraining period in rate of force development of the plantar flexors for the intervention (mean + SD) compared to the control group (mean + SD). Note: RFD means rate of force development; n. s. means a statistically non-significant finding.

significantly enhanced after training, and it remained well above the baseline value following 4 weeks of detraining without showing a significant change from post to follow-up testing. To the authors' knowledge, there are no other studies available which investigated the effects of slackline training on variables of static/dynamic postural control and isometric/dynamic muscle strength in adults. Thus, studies investigating the effects of a similar training regimen, i. e., BT, have to be consulted to discuss the present results.

The findings of this study are not in agreement with results reported in literature regarding the effects of BT on postural control and strength performance in different cohorts. In fact, Granacher et al. [10] found improvements in static postural control during one-legged stance as well as an enhanced jumping height in CMJ after 4 weeks of BT in healthy active adolescents (age 19 ± 2 yrs). In addition, Taube et al. [35] observed a modified reflex activation during stance perturbation as well as a significant increase in jumping height in CMJ following 6 weeks of BT in young elite athletes (age 15 ± 1 yrs). Further, Heitkamp et al. [20] investigated the impact of a 6-week BT program in healthy active adults (age 32 ± 6 yrs) on variables of static postural control and muscle strength and observed that BT significantly improved one-legged stance balance and maximal isometric torque of the knee extensors and flexors. Finally, it was demonstrated that BT was effective in enhancing static/dynamic postural control in subjects with chronic ankle instability [26] as well as in older adults [12]. For the latter, additional improvements in maximal strength and rate of force development of the leg extensors were reported following 13 weeks of BT [11]. Thus, it can be postulated that findings in the literature regarding the impact of BT on measures of postural control and strength performance are consistent for different study populations.

Thus, the question arises why slackline training as compared to BT did not produce significant improvements in measures of postural control? First, it should be noted that the literature base for BT is much broader than that for slackline training. Thus, our results are of preliminary character and should therefore be treated with caution. Further research is needed to provide additional evidence regarding the effects of slackline training on variables of balance and strength. Second, one may argue that the training period was too short to induce adaptive processes in the postural control system of adults. Since no other studies were available which investigated the impact of slackline training on balance and strength performance, we adopted the often applied training period of 4 weeks from BT studies. In a recent systematic review on BT in healthy individuals, it was reported that BT programs performed at least 10 min per day, 3 days per week, for 4 weeks appear to improve balance ability [5]. Nevertheless, future studies should extend the slackline training period to 6–8 weeks with 3 training sessions per week. Third, we relied on a methodological approach for slackline training that is not evidence based [31]. However, there is no scientifically evaluated information available in literature on how to progressively design a slackline training. Gruber et al. [16] and Taube et al. [34] were able to establish such guidelines for BT. These recommendations are also needed for slackline training to make this highly attractive and popular training regimen more effective.

Our finding of an improved RFD following slackline training is in accordance with a study that investigated the effects of 4 weeks of BT with 2 training sessions per week on RFD of the leg extensors during maximal isometric contraction in young healthy adults (age 28 ± 6 yrs) [15]. Following training, the authors did not detect an increase in maximal isometric leg extensor strength. Yet, RFD was significantly enhanced by 33 % which was accompanied by a higher activation level of the m. vastus medialis after training. Since it is not possible to increase muscle mass during 4 weeks of training, Gruber and Gollhofer [15] suggested that the increase in RFD of the leg extensors following BT may arise from enhanced reflex contributions acting on a spinal level. The authors speculated that withdrawal of presynaptic inhibition of Ia terminals, belonging to the motoneurons of the acting muscles, could account for the enhanced RFD. This neural mechanism could also be responsible for the observed improvement in RFD of the plantar flexors following slackline training. However, due to methodological limitations of this study, we cannot directly infer on the underlying neuromuscular mechanisms responsible for the investigated results.

In the present study, 4 weeks of detraining resulted in a slight decrease in RFD from post to follow-up tests which amounted to 1.4 %. However, the observed RFD-value after detraining was still significantly higher (13.0 %) than the baseline value. This indicates that the training effect was at least in part present after detraining. Mechanisms responsible for the effect of detraining on RFD of the plantar flexors have yet to be elucidated. Preliminary evidence regarding detraining effects following resistance training indicate that reduced motor unit activation and losses in motor coordination may account for the reported slight decreases [1]. However, to the authors' knowledge, there is no study available which investigated balance/slackline training and detraining effects on variables of postural control and muscle strength in young adults.

The question remains open whether slackline training has a preventive effect on sports injury rate of lower extremities. Given that we were only able to find significant improvements in RFD of the plantar flexors and not in measures of static/dynamic postural control, it is argued that changes in RFD only are not sufficient enough to have an injury-preventive effect. However, owing to the small sample size and the short duration of this study, it was not feasible to investigate possible injury rates of our participants. Thus, until there is evidence of an injury-preventive effect of slackline training, it is recommended to

conduct BT for prevention purposes because reduced injury rates were observed in basketball players [7,25], soccer players [25], and European handball players [28,29,38] following BT.

We acknowledge that this study has some limitations that warrant discussion. First, the sample size applied in this study is relatively small. However, the a priori power analysis revealed that 12 participants per group are sufficient to obtain a statistically significant interaction effect for an investigated balance parameter. In addition, other researchers used even smaller sample sizes and found significant interaction effects in terms of the impact of BT on measures of balance and strength in adolescents [10] and young elite athletes [35]. Second, we only reported results regarding total COP displacements as a global parameter for static/dynamic postural control. Our initial analysis included velocity, range, root mean square, and the coefficient of variation for total COP displacements as well as for COP displacements in medio-lateral and anterior-posterior direction. Since the statistical analysis revealed no additional information through the integration of the above mentioned parameters, we decided to focus on the global parameter COP displacements only. Third, the applied testing methodology known from BT studies might not have been adequate to capture adaptive processes in the postural control system following slackline training because slacklining is a highly dynamic task including the lower and the upper body for balance control, whereas balance enhancing exercises primarily focus on the lower body. Thus, future studies should incorporate more dynamic tests for the assessment of balance control to elucidate whether slacklining has an effect on postural control or not. Further, exercises on the slackline may primarily produce large balance threats which are, in accordance with the theory of hip strategy [21], compensated for by muscles encompassing the hip joint. Therefore, it is suggested that instead of investigating muscle strength of the ankle joint, the hip joint should be tested.

In summary, the results of this study illustrate that slackline training is a safe training modality that produces marked improvements in RFD of the plantar flexors in young adults. The observed gains were transient. They began to slightly deteriorate after the withdrawal of the training stimulus. Unfortunately, slackline training did not result in significant improvements of static/dynamic postural control variables. Given that the promotion of balance and strength is important for injury prevention [40], training-induced changes in RFD alone might not be sufficient to produce an injury-preventive effect.

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