Original Article

The effect of slackline training on balance performance in healthy male children

CARLO FERRI-MARINI[1], FRANCESCO LUCERTINI[1], MANUELA VALENTINI[2], ARIO FEDERICI[1]

[1]*Department of Biomolecular Sciences, Division of Exercise and Health Sciences, University of Urbino Carlo Bo, Urbino, Italy*

[2]*Department of Humanistic Studies, University of Urbino Carlo Bo, Urbino, Italy*

ABSTRACT

Slackline has been proposed as a challenging and motivating tool for balance training. However, the transferability of balance performances among different balance tasks has been questioned. This study aimed to assess if slackline training affects dynamic and static balance performances on stable and unstable surfaces. Eighteen healthy males (8 to 14 years) were randomly assigned to an experimental or control group. For six weeks, both groups performed several supervised sports activities (2-hour sessions, 3 sessions per week). Additionally, the experimental group underwent a slackline-based balance training (1-hour sessions, 3 sessions per week). The dynamic and static balance were tested before and after the interventions using the Bass test (BASS) and the Stork stand test (SST), respectively. Landing ($BASS_{landing}$) and balance ($BASS_{balance}$) components of the dynamic balance were evaluated, while the static balance was assessed with eyes open (SST_{open}) and closed (SST_{closed}) on a stable surface, and with eyes open on an air cushion (SST_{ac}). Two-way mixed-design ANOVAs revealed no interaction effect between time and group allocation in $BASS_{landing}$ (p=0.791), $BASS_{balance}$ (p=0.641), and right leg SST_{open} (p=0.177), SST_{closed} (p=0.076) and SST_{ac} (p=0.039), and left leg SST_{open} (p=0.100) and SST_{closed} (p=0.032). There was a significant interaction on left leg SST_{ac} (p=0.004), showing higher improvements over time in the experimental (mean improvement=4.5 seconds, $p<0.001$) compared to the control group (mean improvement=0.9 seconds, p=0.236). In conclusion, slackline balance training yielded no or negligible improvements on dynamic balance performances, whereas the improvements seemed higher on static balance, especially when measured on an unstable surface. **Keywords:** Tightrope; Exercise program; Transferability; Dynamic balance; Static balance; Children and exercise.

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Corresponding author. *Department of Biomolecular Sciences, Division of Exercise and Health Sciences, University of Urbino Carlo Bo, Urbino, Italy.* https://orcid.org/0000-0003-3134-4511
E-mail: francesco.lucertini@uniurb.it
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INTRODUCTION

Static and dynamic balance or postural stability is the ability to control the centre of mass in relation to the base of support (Donath et al., 2017) and is essential for activities of daily living (Ruhe et al., 2010). Poor postural stability precludes the ability to perform several physical activities along with certain daily activities (Taube et al., 2008), while high levels of postural stability have been positively associated with lower injury rate (McGuine et al., 2000).

Balance training is commonly performed by both people with high levels of fitness, who aim to improve their physical performance and reduce the risk of injuries and their recurrence, and people with poor levels of fitness, who participate in fall prevention programs (Hrysomallis, 2007; Lesinski et al., 2015). Likewise, balance training has been proved to be effective among adolescent and young adult athletes in reducing the incidence of several sports injuries (DiStefano et al., 2009; Hrysomallis, 2007).

To date, several devices and training approaches are used to improve postural stability; however, the efficacy of some have been questioned (Lehman, 2007; Soderman et al., 2000; Wahl and Behm, 2008). In fact, it has been shown that the adaptations of a balance training are highly specific (Giboin et al., 2015) and their transferability to other balance tasks cannot be assumed.

Among balance training devices, the “slackline”, i.e., a narrow flat ribbon tightened between 2 anchor points, has been proposed as a challenging tool to improve balance in different age groups (Donath et al., 2013; Donath et al., 2016). Despite specific performance improvements (e.g., standing and dynamic balancing over the slackline) have been observed in children and seniors (Donath et al., 2013; Donath et al., 2016) after slackline training programs, limited transferability of those improvements to the performance in untrained balance tasks has been found (Donath et al., 2017). Therefore, the authors concluded that balance training should be based on the tasks aimed to improve, and that slackline training should not be used as the sole form of balance training (Donath et al., 2017). However, the effectiveness and the transferability of slackline training interventions on the performance of different balance tasks based upon their similarity remain unclear.

This study aimed to assess the effects of a supervised slackline training on dynamic and static balance tests performed on both stable and unstable surfaces. We hypothesized that the slackline training would have yielded negligible improvements on dynamic and static balance over stable surfaces, whereas the improvements on static balance over unstable surfaces would have been higher.

MATERIALS AND METHODS

Participants

Eighteen healthy male subjects from 8 to 14 years, which took part in a summer school focused on sports activities, volunteered to participate in this study (age 10.8 ± 1.8 years; height 1.47 ± 0.14 m; body mass 38.6 ± 13.0 kg; body mass index 17.5 ± 2.6 kg/m^2).

The study was conducted in accordance with the Helsinki Declaration (2013 revision) and approved by the local Ethics Committee. All participants and their legal guardians were informed of potential risks and discomforts associated with the testing procedures and gave written informed consent to participate in the study.

Experimental design

A randomized parallel-group design was adopted in this study. The participants were randomly assigned to either an experimental (EG) or a control (CG) group. Both groups performed several supervised sports activities for six weeks; additionally, the EG participants underwent a supervised balance training protocol using the "slackline" device (see "Training protocol"). Before (T0) and after (T1) the six weeks, several tests aimed to assess static and dynamic balance were administered to all participants (see "Testing procedures").

Training protocol

Both groups were involved for six weeks, three times a week, in two hours of supervised sports activities, including soccer, ultimate frisbee, flag football, and volleyball. Additionally, the EG participants underwent a supervised balance training, three times a week, one hour per session, performed on a slackline (0.05 m width) in outdoor settings. The extremities of the line were secured on two trees 7.5 m apart, with a distance of 0.2 m from the ground. The relatively short length was chosen to reduce the oscillations and facilitate balance maintenance. After four weeks of training, the length and height of the tapes have been progressively modified to increase the difficulty level, reaching a maximum length of 12.5 m and a height of 0.3 m above the ground.

The training sessions of the first three weeks were structured to allow the participants to maintain a single leg static balance on the slackline for 10 seconds, with both limbs. In the following three weeks, the goal was to increase to 15 seconds the duration of the single leg static balance time in both limbs. Finally, in the last six meetings, after reaching the single leg static balance of 15 seconds with both limbs, the participants started to approach walking on the slackline. The exercises were progressively more difficult, and, in case of need, they were performed with the assistance of the coach, who by providing support to the participants reduced the oscillations of the line and facilitated the maintenance of the balance.

Testing procedures

The static and dynamic balance were assessed using the Stork stand balance tests (SST) and the Bass test of dynamic balance (BASS), respectively.

Stork stand balance tests. The participants performed the SST as described by Makhlouf et al. (2018). Briefly, the participants stood on one leg, with the opposite foot against the inner part of the supporting knee and both hands on the hips, hence they were asked to raise the heel of their supporting foot from the floor and to maintain their balance as long as possible. The trials were stopped when the participants either moved their hands from the hips, the supporting foot from the starting position, or when the heel touched the ground. A stopwatch was used to measure the score (i.e., amount of time in seconds). The SST tests were performed on both legs with eyes open (SST_{open}), closed (SST_{closed}) and on an air cushion (SST_{ac}). The SST_{ac} was performed on an air cushion with a diameter of 65 cm, with eyes open. SST_{ac} differed from SST because the subjects were allowed to maintain the heel of the supporting leg in contact with the air cushion. The SST tests were performed shoeless and repeated three times. The best of the trials of each test was recorded and considered the result of the test.

Bass test of dynamic balance. BASS was executed as proposed by Johnson and Nelson (1986). The subjects were asked to perform ten monopodal jumps and land within rectangular spaces drawn on the floor with an adhesive tape. The test started with the subjects standing on the right foot, facing forward, and hands on the hips. Then, they were asked to perform the first jump, land on the left foot within the delimited area, and maintain their balance for 5 seconds (the time was given by the researcher, which counted aloud up to 5 seconds using a stopwatch). The same action was repeated, alternating the landing legs, up to the last box.

Two types of errors were counted during the BASS test, namely landing errors and balance errors, which yield two study outcomes ($BASS_{landing}$ and $BASS_{balance}$, respectively). A landing error was counted if the participants did not land within the box, stumbled, took their hands off the hips, or if their landing foot was not facing forward. A balance error was counted if during the 5 seconds after landing one of the hands lost contact with the hips, the non-landing leg touched either the ground or the supporting leg, or if the non-landing leg was moved excessively in any direction. $BASS_{landing}$ and $BASS_{balance}$ scores were computed, respectively, as the sum of the landing errors multiplied by 10 and as the sum of the balance errors multiplied by 3.

Before testing, in a separate session, a familiarization phase was carried out, allowing the participants to become accustomed to the testing procedures.

Statistics

Data are presented as means and standard deviations. A two-way factorial mixed-design ANOVA was used to compare each study outcome between interventions (between factor, EG and CG) at the two different time-points (within factor, T0 and T1). When a significant interaction was found, post-hoc pairwise comparisons were performed. Moreover, for each study outcome, Cohen's *d* effect sizes (ES) between and within groups were calculated. For all tests, 2-sided p values with an α level of significance of 0.05 were used. Bonferroni's criterion was used to adjust the overall α level to correct for multiple tests. The analyses were performed using SPSS Statistics (IBM, v.20).

RESULTS

The scores of the balance tests performed before and after the training period, along with the ESs of the differences between group (i.e., EG and CG) at T0 and T1 and within each group (i.e., T1 and T0) are presented in Table 1.

Table 1. Pre-training (T0) and post-training (T1) balance test scores (Mean ± SD), and Cohen's *d* effect sizes (ES) within and between groups

	Control group (CG)			**Experimental group (EG)**			**$ES_{between}$**	
	T0	T1	ES_{within}	T0	T1	ES_{within}	T0	T1
$BASS_{landing}$	40.0 ± 13.2	35.6 ± 12.4	-0.39	37.8 ± 19.9	34.4 ± 18.1	-0.67	0.14	0.08
$BASS_{balance}$	8.7 ± 4.4	7.3 ± 2.6	-0.39	7.7 ± 6.2	7.0 ± 4.5	-0.27	0.2	0.1
SST_{open} R (sec)	3.8 ± 1.2	5.7 ± 1.6	2.24	3.6 ± 1.6	6.9 ± 3.2	1.13	0.17	-0.53
SST_{closed} R (sec)	1.8 ± 0.2	2.1 ± 0.4	0.75	1.9 ± 0.8	2.8 ± 0.8	0.84	-0.08	-1.3
SST_{ac} R (sec)	2.8 ± 2.0	5.0 ± 1.5	1.59	2.8 ± 1.3	8.0 ± 3.8	1.4	0.03	-1.07
SST_{open} L (sec)	3.6 ± 1.8	4.2 ± 1.8	0.61	3.3 ± 1.6	4.8 ± 1.4	1.21	0.18	-0.41
SST_{closed} L (sec)	1.8 ± 0.4	2.1 ± 0.5	0.66	1.7 ± 0.8	3.1 ± 1.0	0.97	0.17	-1.31
SST_{ac} L (sec)	3.5 ± 3.0	4.4 ± 2.3	0.52	2.7 ± 1.3	7.2 ± 3.1	1.71	0.39	-1.08

SD, standard deviation; ES_{within}, ES of the differences between T1 and T0; $ES_{between}$, ES of the differences between CG and EG; $BASS_{landing}$, landing errors performed during Bass test of dynamic balance (BASS); $BASS_{balance}$, balance errors performed during BASS; SST_{open}, Stork stand balance tests (SST) performed with eyes open; SST_{closed}, SST performed with eyes closed; SST_{ac}, SST performed on an air cushion; L, left leg; R, right leg.

The results of the two-way factorial mixed-design ANOVAs are presented in Table 2.

Table 2. Two-way factorial mixed-design ANOVAs results

	Group			Time			Group X Time		
DV	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
$BASS_{landing}$	0.051	0.824	0.003	3.564	0.077	0.182	0.073	0.791	0.005
$BASS_{balance}$	0.105	0.75	0.007	2.028	0.174	0.113	0.225	0.641	0.014
SST_{open} R (sec)	0.399	0.537	0.024	26.023	<0.001	0.619	1.996	0.177	0.111
SST_{closed} R (sec)	3.644	0.074	0.186	8.852	0.009	0.356	3.604	0.076	0.184
SST_{ac} R (sec)	2.529	0.131	0.136	31.419	<0.001	0.663	5.035	0.039	0.239
SST_{open} L (sec)	0.049	0.828	0.003	15.919	0.001	0.499	3.052	0.1	0.16
SST_{closed} L (sec)	3.344	0.086	0.173	10.917	0.004	0.406	5.538	0.032	0.257
SST_{ac} L (sec)	0.811	0.381	0.048	26.363	<0.001	0.622	11.502	0.004	0.418

Group, main effect of the independent variable group allocation (i.e., control or experimental group); Time, main effect of the independent variable time (i.e., pre and post training scores); Group X Time, effect of the interaction between Group and Time; DV, dependent variable; F, F value with (1, 16) degrees of freedom; p, probability value associated with F; η_p^2, partial eta-squared; $BASS_{landing}$, landing errors performed during Bass test of dynamic balance (BASS); $BASS_{balance}$, balance errors performed during BASS; SST_{open}, Stork stand balance tests (SST) performed with eyes open; SST_{closed}, SST performed with eyes closed; SST_{ac}, SST performed on an air cushion; L, left leg; R, right leg.

There was no significant main effect of the group allocation (i.e., EG and CG) on any dependent variable. There was also no significant main effect of the time (i.e., T0 and T1) on $BASS_{landing}$, $BASS_{balance}$, and right leg SST_{closed}. In contrast, there was a significant main effect of time on right leg SST_{open} and SST_{ac}, and on left leg SST_{open}, SST_{closed}, SST_{ac}, showing overall significant improvements on the balance scores over time. There was a significant interaction between group and time only on SST_{ac} performed with the left leg, and, the post-hoc pairwise comparison analyses showed that the left leg SST_{ac} scores did not improve over time in CG (mean improvement = 0.9 seconds, p = 0.236), but they improved in EG (mean improvement = 4.5 seconds, p < 0.001). Left leg SST_{ac} scores were not different in EG and CG at T0 (mean difference = -0.8 seconds, p = 0.447), whereas they were higher in EG than CG at T1 (mean difference = 2.7 seconds, p = 0.046).

DISCUSSION

The BASS landing scores (i.e., $BASS_{landing}$ and $BASS_{balance}$) showed that there was no effect of the group, time or, their interaction, which pointed out that dynamic balance did not improve after six weeks and that no intervention was superior to the other.

As expected, there was no main effect of the group variable, which was not significant on any dependent variable. In contrast, the time showed a significant effect on SST tests (SST_{closed} in the right leg excluded), indicating that both groups improved their static balance after the six weeks. The low statistical power might explain the lack of a statistically significant effect of time on SST_{closed} in the right leg, indeed, the p value (p = 0.009) showed a tendency towards statistical significance (α = 0.00625 after Bonferroni correction) and the ESs of the differences between T1 and T0 in CG and EG were medium and large, respectively (see Table 1).

In both groups, a trend of improvement on the balance performance was noticeable in each dependent variable. Indeed, the ESs of the differences between T1 and T0 were negative on BASS scores and positive on SST scores, indicating that the participants committed fewer errors and were able to maintain their static balance longer.

The improvement on the static balance of both groups over time can be imputable to both the older age of the participants and the positive effect of the supervised sports activities. However, we surmised that the improvements over time should be attributed to the supervised sports activities because the effect of having older subjects in T1 compared to T0 should be negligible since T0 and T1 were relatively close (i.e., six weeks apart).

When the interaction between group and time was considered, the only significant effect was detected on the left leg SST_{ac}, showing higher improvements over time in the EG compared to the CG. Noteworthy, the interaction effect on SST_{ac} in the opposite leg showed a tendency towards statistical significance ($p = 0.039$) and, the lack of statistical significance might be caused by the low statistical power, which is due to the Bonferroni correction for multiple testing and the small sample size.

The magnitude of the interaction effect was the highest on SST_{ac} in both limbs, which suggests that despite the slackline training had a relatively small transfer to dynamic balance and ground-based static balance, the transfer effect of the balance training was higher on the balance performances on an unstable surface (i.e., air cushion). This might be attributable to the fact that balance training induces highly task-specific adaptations (Donath et al., 2017; Giboin et al., 2015) and, since air cushions and slacklines offer both unstable surfaces, the similarity of the two balance tasks might be higher compared to the similarity between slackline and ground-based balance tasks.

The ES of the differences between CG and EG ($ES_{between}$) on BASS scores were negligible ($BASS_{landing}$) and small ($BASS_{balance}$) at T0, whereas at T1 the $ES_{between}$ were negligible on both BASS scores, suggesting no effects of the slackline training on dynamic balance (see Table 1). Likewise, the $ES_{between}$ of the SST scores at T0 were either negligible or small, however, at T1, each $ES_{between}$ decrease in its numerical value, showing a negative sign, while increasing in its magnitude (see Table 1). Hence, the static balance performances of the two groups were similar at T0 with a tendency to be higher in EG compared to CG at T1, suggesting a beneficial effect of slackline training on static balance performances.

The present study is in line with the findings of Donath et al. (2017), which highlight the task-specific training effect of slack line training and that the transfer to dynamic and static balance is limited. However, in contrast to Donath et al. (2017), who found a moderate (standardized mean difference = 0.52) and significant ($p = 0.02$) transfer effect of slackline training on dynamic balance, and a small (standardized mean difference = 0.30) and not statistically significant ($p = 0.07$) transfer effect on static balance, in the present study the improvement in balance performance seemed higher in the static compared to the dynamic balance.

Notwithstanding the presence of a control group (i.e., CG), a limitation of the present study is the lack of an additional control group performing a standard balance training program (matched for characteristics to the slackline training). Hence, the present study cannot infer on the superiority or inferiority of slackline training compared to other balance training programs.

CONCLUSIONS

The slackline balance training proposed in this study yielded no or negligible improvements on dynamic balance performances, whereas the improvements seemed to be higher on static balance performances, especially when the static balance was measured on an unstable surface. The higher improvements of the static balance performance on unstable surfaces (i.e., air cushion) could be due to the high task-specificity of balance training, indeed, both slacklines and air cushions do not offer stable surfaces, hence the tasks performed on slacklines might be more similar to those performed on air cushions compared to those ground-based.

Therefore, slackline training might yield some improvements in the performance of other balance tasks. However, the improvements seemed limited and correlated to the similarity between the tasks. Hence, even though slackline training provides a challenging exercise mode, it should not be used as the principal and unique modality to improve the subjects' balance, but the balance training should be chosen based upon the specific task needed to improve. Future researches are needed to assess the similarity and the transferability of slackline training to different balance tasks and athletic performances, especially in those athletic tasks that require high levels of balance and are performed on unstable surfaces.

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