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ORIGINAL ARTICLE

The measurable parameters of balance trainings in case of young healthy adults: Improved balance confidence or better postural stability? A pilot study

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ABSTRACT

Purpose: The objective of this pilot study was to compare the effects of two parallel balance trainings on postural sway and balance confidence. The study was performed in different contexts with stable vs. unstable base of support and balance confidence was measured with a scale modified for young adults with higher functional level. *Materials/methods:* Twenty healthy female physiotherapist students volunteered for the study and took part in a six-week balance training intervention. They were randomly assigned to two groups training on different support surfaces. Postural sway was recorded under various conditions: on different surfaces (firm, foam) and with different visual conditions (eyes open (EO), eyes closed (EC)). Modified Activities-specific Balance Confidence (mABC) scale was self-evaluated. *Results:* Both types of training caused a significant improvement in the mABC scores. The sway path increased after the training in the less challenging balance situations. We found a tendency of decreasing sway path only in the more challenging balance situations, that is standing on foam mounted on force plate with EC. *Conclusions:* Considering the improved balance confidence in the case of both groups, we suggest that an increase in sway path after balance training may be the behavioural sign of the higher confidence in the less challenging balance situations.

KEYWORDS

postural control, balance, confidence, perception

INTRODUCTION

Postural control (PC) means controlling the body's position in space to achieve orientation that is a perceptual goal and stability which is a biomechanical goal [1]. In everyday life, these two goals of PC are achieved simultaneously. Postural stability or postural equilibrium, often referred to as balance, is the ability to control the body's centre of mass (CoM) in relation to the base of support (BoS) during quiet standing and movement [2]. Balance and PC during static positions and locomotion is the result of a perceptual-motor process: PC includes the position sense and kinaesthesia derived from the visual, somatosensory, and vestibular systems, by processing sensory information to determine orientation and movement and by selecting the appropriate motor answers to maintain or restore the balance of the body.

In recent decades, the effect of physical activity on body balance has received focused attention, and it is now everyday practice to include balance exercises into neuromusculosceletal prevention and rehabilitation programmes by physiotherapists and other

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rehabilitation team members. The ultimate goal of rehabilitation is to improve functional independence. Improving PC is of utmost importance, since balance is the basis of every function.

One measurable parameter of balance is the postural sway recorded by force plates during posturography. Reviewing the relevant literature, several studies indicated that decreased postural sway would be the indicator of better postural control and balance after participating in a balance training [3, 4]. On the other hand, there is evidence suggesting that increased postural sway after balance training might be also a sign of improvement in postural control as well, as we found in our earlier study with elderly adults, where an increased postural sway could be observed together with improved functional performance after a combined balance training [5].

In case of standing balance, the foot as an internal base of support plays an important role in sensory intake and in mediating motor responses toward the external base of support (BoS), which is the supporting surface, thus the feet are in constant interaction with the environment. Regarding reactive balance, an important milestone is the work by Nashner et al., which is the strategy concept for reacting to perturbations in static positions [6]. The authors described the ankle, hip and stepping strategies by mapping the muscle activation patterns that underlie movement strategies for balance [7]. During single-leg stance, for example, the control of upright posture is accomplished largely through corrective movements at the ankle joint. Activation of gastrocnemius muscle, together with synergistic activation of dorsal muscles in a distal to proximal sequence, leads to plantar flexion torque that slows and reverses forward body sway. In the case of responding to backward instability, the tibialis anterior is the first muscle to act, followed by the synergistic activation of the ventral postural muscles, such as the quadriceps and abdominal muscles [8]. On the other hand, hip strategy is thought to be used to restore equilibrium in response to larger, faster perturbations or when the support surface is compliant [9].

Since the human PC is highly complex, perceptual and cognitive factors must be taken into account when assessing balance. One important feature of these factors is the perceived balance confidence. The Activities-specific Balance Confidence Scale (ABC Scale) is a structured questionnaire that measures an individual's confidence in performing activities without losing balance and was introduced to characterise the fear of falling (FOF) in case of older adults and persons with impaired balance and postural control by Myers et al [10, 11]. The original ABC scale has a limited use in case of healthy young adults due to its ceiling effect.

The objective of this pilot study was to compare the effects of two parallel balance trainings on postural sway and balance confidence. The study was performed in different contexts with stable vs. unstable base of support and balance confidence was measured with a scale modified for young adults with higher functional level.

MATERIALS AND METHODS

Participants

Twenty healthy female physiotherapist students volunteered for the study and were randomly assigned into two different training groups: one group was performing balance training on stable BoS (SG: mean age: 21.5; SD ± 1.84), while the other group on unstable BoS (UG: mean age 21.3; SD ± 2.36). Unfortunately, the restrictions due to the COVID pandemic situation interfered with completing the study with greater number of participants.

All participants gave their written informed consent prior to participation. The measurements and the training used complied with the current laws of our country, in line with the Helsinki declaration, and the protocol was approved by the National Public Health Center (48590-8/2020/EÜIG).

Training procedure

After the baseline testing, the participants took part in a six-week balance training intervention led by a physiotherapist two times per week, for 50 min each. After 10 min of a warming up period consisting of general mobilising exercises, the balance training components were combinations of lower extremity strength and flexibility exercises, closed kinetic chain weight bearing exercises, as well as static (holding a position) and dynamic (creating perturbations) balance elements. The focus has been put on the proximal stability (trunk and hip control), asymmetric upper and lower extremity exercises, and self-generated trunk perturbations, which exercises are thought to be balance training exercises. Both the SG and IG groups performed the same exercise regime, on stable and unstable base of support respectively. To narrow and specify the perceptual aspects of our program, we focused on excluding visual information throughout the trainings by asking participants to keep their eyes closed for as long as possible [12].

Measurements

Postural stability. We measured static postural stability during standing on a single force platform (Neurocom Basic Balance Master®, Neurocom International Inc, Clackamas, Oregon, USA) in standing position, recording the Centre of Pressure (CoP) displacement. The static balance parameters were measured by the single force platform before and after a six-week balance training module. Sessions were scheduled two times per week and focused on standing balance exercises mainly with eyes closed; in case of the SG (stable surface group) on a firm BOS and in case of the UG (unstable surface group) on an unstable foam surface (Airex balance pad)). The CoP displacement was quantified in quiet standing, with the arms hanging freely on both sides. The participants stood barefoot on the platform with the feet positioned side by side according to the force plate indicator signs, under two visual conditions (eyes open or EO and eyes closed or EC) and two surface conditions (firm and foam). The examiner supervised the closed position of the eyes; opening the eyes during the measurement was an exclusion criterion. We preferred the eyes closed measurements and training instead of being blindfolded considering the different psychological effects of these two situations. Using a blindfold is a type of constraint, which may induce a feeling of uncertainty during balance assessment and may result in a negative compensatory balance strategy, the fixing or stiffening strategy, which we wanted to avoid during testing and training periods [12]. Measurements were repeated three times (with a duration of 10 s) in each condition and the sway path was calculated in both anteroposterior (AP) and mediolateral (ML) directions.

Balance confidence. The ABC score introduced by Myers et al. contains 16 items about the balance confidence in different functional activities and is used widely in the geriatric population [10]. We modified the easiest eight items and replaced them with items thought to be more challenging for our healthy, young participants. Each question was rated between 0 and 100 (0% is no confidence and 100% is completely confident). The modifications are marked in bold in Table 1.

Data analysis

All sway path data were subjected to one way ANOVA (Statistica 13.1 Software) in order to compare the effects of the training on postural sway under various visual conditions and BoSs. The post-hoc test was the Fisher's least significant difference (LSD) multiple comparisons test. The data derived from modified ABC scale were subjected to the Wilcoxon Matched Pairs test to compare the effects of training on balance confidence as a perceptual feature of balance. We adopted $P < 0.05$ as the level of probability for all statistical analyses of the data.

RESULTS

After the training both SG and UG showed a tendency of increased sway path both EO and EC condition, standing on a force plate with firm surface. In ML direction after the training the UG showed significantly bigger postural sway than the SG both with EO ($P = 0.012$) and EC ($P = 0.043$) conditions (Fig. 1, Table 2).

Standing on foam surface, both SG and UG displayed discernible increasing postural sway with visual control, in AP direction; the difference was significant ($P = 0.044$) in case of UG, but not in the ML direction, where only the SG showed a trend of increased sway path after training (Table 2).

The only significant decrease ($P = 0.013$) in sway path was in case of SG in AP direction with eyes closed situation after the training. In ML direction, with EC both groups showed a decreased sway path tendency, but the differences were not significant (Fig. 2, Table 2).

As for the modified activity specific balance confidence scores, there were significant improvements in both SG ($P = 0.029$) and UG ($P = 0.019$), that is a statistically discernible increase ($P < 0.05$) after the training in balance confidence (Fig. 3, Table 2).

DISCUSSION

The main finding of the present study is that both types of training caused a significant improvement in the modified activity specific balance confidence score. There were no differences between the groups in this regard, both types of balance trainings were beneficial from the aspect of balance confidence. The ABC scale and also this modified version is a subjective judgement of balance confidence, its scores are not based on clinical observation of performance, and we have to take into consideration other factors such as self-esteem and insight. Since our participants are healthy, young adults with special level of body awareness as physiotherapy students, we can assume that their judgement is reliable.

Above 80% of confidence level measured with the original ABC scale, the person is considered to bear a high level of physical functioning [10]. In case of our participants the original ABC scale would have a ceiling effect and would not be eligible to show any change caused by the balance training. With our modification, that is replacing some easy activities with more challenging activities characteristics for young people, we have obtained a more precise picture about young adults. Using our modified ABC scale, the baseline data of our participants were in the average range with 70%, which means the upper range in the moderate level of physical functioning category (50–80%), if accepting the percentage categorization of the original ABC scale [11]. As the result of different types of balance trainings, both groups' confidence improved significantly and moved from the moderate into the high level of physical functioning category. Therefore, we can conclude that both types of balance trainings (performed on stable and unstable BoS) could influence the balance confidence of our participants.

The other important finding of this present pilot is that the sway path increased after the training in the majority of assessed situations: in case of firm surface measurements in all conditions and in case of foam surface measurements where the visual information was available for the postural control system.

We found a tendency of decreasing sway path as a training effect only in the more challenging balance situation that was standing on unstable BoS force plate with EC.

From the perceptual point of view, the less challenging balance situations are those with EO and stable BoS, while the more challenging situations are those with EC and unstable BoS. The challenges are the highest when the

Table 1. The modified ABC scale for young adults based on Myers et al. [11]

Name: ______________________________ Date: ______________________

ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE

For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady by choosing one of the percentage points on the scale from 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or you hold on to someone, rate your confidence as if you were using these supports. If you have any questions about answering any of these items, please ask the therapist.

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following scale:

No confidence Completely confident

0% 10 20 30 40 50 60 70 80 90 100%

How confident are you that you will not lose your balance or become unsteady when you…

1	**… have to step down from a height?**	%
2	**… bend for your slippers on the ground?**	%
3	… reach for a small can off a shelf at eye level?	%
4	… stand on tiptoes and reach for something above your head?	%
5	… stand on a chair and reach for something?	%
6	… sweep the floor (walking on wet floor)?	%
7	**… must enter a wet tub / shower tray?**	%
8	**… get on and then ride your bike?**	%
9	**… ride a bike on a rainy/slippery road?**	%
10	**… the bus you are traveling on suddenly brakes?**	%
11	**… have to walk on stairs in the dark / in poor visibility conditions?**	%
12	**… trying to pick up your shoes by balancing on one leg?**	%
13	… are bumped into by people as you walk through the mall?	%
14	… step onto or off of an escalator while you are holding onto a railing?	%
15	… step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?	%
16	… walk outside on icy sidewalks?	%
	Total modified ABC score	

Note. Scoring: __________ / 16 = ________% of self-confidence; Total ABC Score

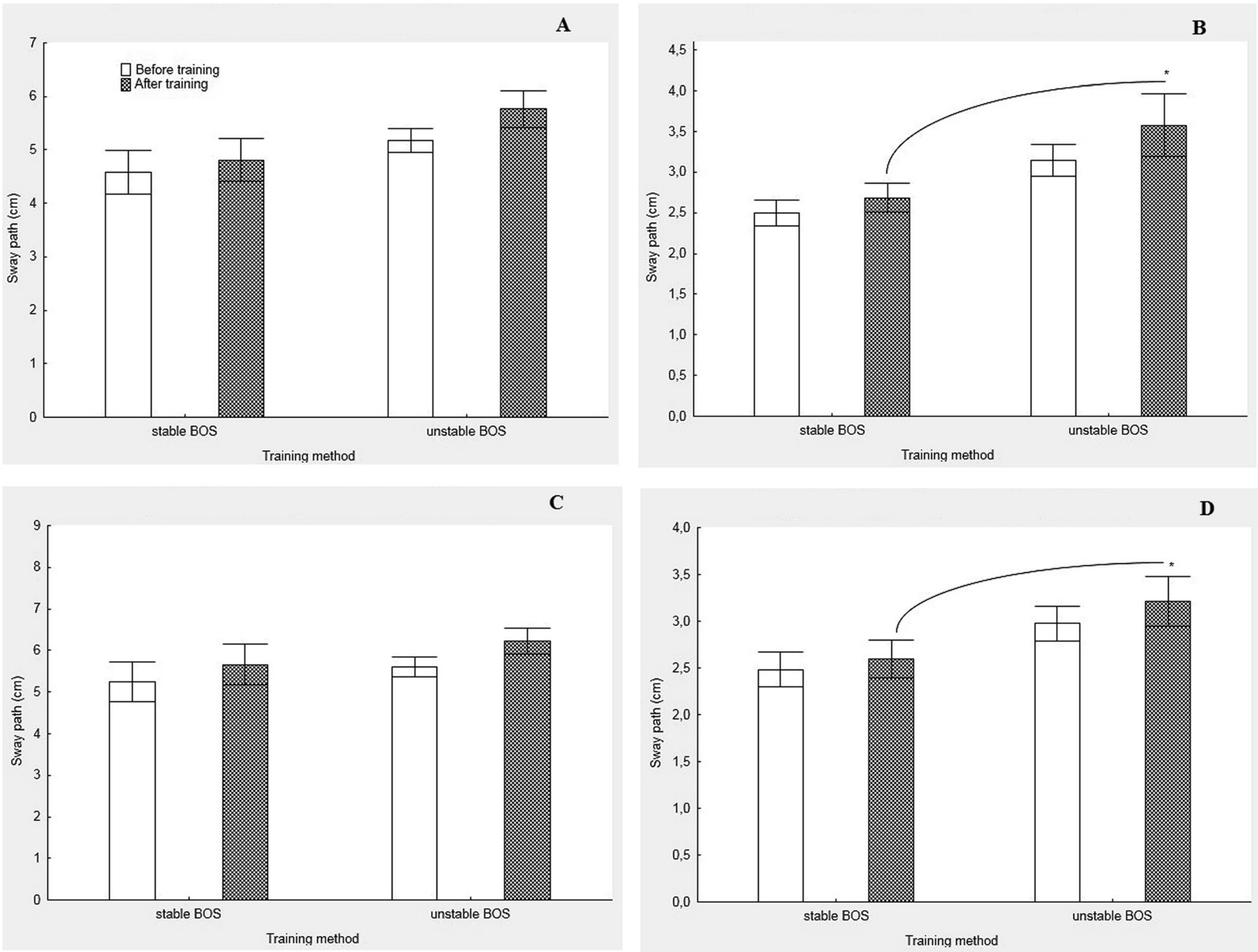

Fig. 1. Sway path data in AP and ML directions, standing on firm surface platform before and after the training with EO (A: in AP direction, B: in ML direction) and EC conditions (C: in AP direction, D: in ML direction).
Note. Asterisks show significant differences ($P < 0.05$). Abbreviations: EO: eyes closed, EC: eyes open, AP: anteroposterior, ML: mediolateral, BOS: base of support

available somatosensory information for postural control is more disturbed with continuous movement information arising from the unstable BoS and when there is no opportunity for the central nervous system (CNS) to replace or complete the disturbed somatosensory and vestibular information with visual information. In these cases, constraint is put on the CNS reweighing the importance of sensory inputs available for PC and perhaps being forced to change strategy in PC.

Considering the improved balance confidence in case of both of our groups, we suggest that an increase in sway path after balance training may be the behavioural sign of the higher confidence in the less challenging balance situations in case of our young participants. We provided evidence for this phenomenon in case of healthy older adults in our earlier study, where the sway path increased significantly after a combined balance training together with improvements in functional dynamic balance parameters [5].

One possible explanation of the increased sway path after training in the less challenging situations could be the theory of freeing versus freezing the degrees of freedom. Bernstein [13] observed that the musculoskeletal system is complex and nonlinear, so synergies between activities in muscle groups can lead to an almost infinite array of motor outcomes. While this perspective provides a great deal of flexibility, there are many potentially redundant degrees of freedom (DoF) within the system that must be controlled by freeing or freezing DoF depending on the type of interaction between the individual's task and environment. We propose that increased sway path after training in less challenging balance situations may be indicative for freeing DoF. Visual information plays an essential role in PC, therefore the trainings without visual inputs are beneficial to promote somatosensory and vestibular information utilisation due to the nature of CNS in reweighing the importance of sensory inputs. The fact that in the less challenging situation with visual control both groups showed an increase in sway path after training is indicating a higher confidence and probably more freeing of the DoF by utilising the available visual information in PC.

Several researchers have suggested that under increased anxiety individuals regress to earlier stages of skill development when being forced to focus attention on the co-

Table 2. Summary of the baseline and outcome values of the sway path and the modified ABC scale

Condition	Baseline (mean ± SE)	Outcome (mean ± SE)
Firm EO AP, SG	4.578 ± 0.415	4.8083 ± 0.404
Firm EO ML, SG	2.493 ± 0.166	**2.6671 ± 0.197**
Firm EC AP, SG	5.249 ± 0.503	5.6631 ± 0.490
Firm EC ML, SG	2.478 ± 0.191	*2.5965 ± 0.204*
Firm EO AP, UG	5.178 ± 0.218	5.7663 ± 0.346
Firm EO ML, UG	3.145 ± 0.200	**3.5767 ± 0.386***
Firm EC AP, UG	5.589 ± 0.237	6.2273 ± 0.297
Firm EC ML, UG	2.972 ± 0.178	*3.209 ± 0.264**
Foam EO AP, SG	6.624 ± 0.362	7.4136 ± 0.362
Foam EO ML, SG	4.191 ± 0.187	4.8533 ± 0.148
Foam EC AP, SG*	13.441 ± 0.760	11.0048 ± 0.559*
Foam EC ML, SG	6.299 ± 0.330	5.8778 ± 0.396
Foam EO AP, UG*	7.331 ± 0.494	8.5492 ± 0.162*
Foam EO ML, UG	5.080 ± 0.336	5.0306 ± 0.356
Foam EC AP, UG	12.520 ± 0.792	12.4879 ± 0.559
Foam EC ML, UG	6.129 ± 0.290	5.7202 ± 0.237
Modified ABC scale SG*	72.946 ± 5.796	86.4644 ± 3.392
Modified ABC scale UG*	72.466 ± 3.136	85.987 ± 3.137

Note. Asterisks show significant differences ($P < 0.05$).
Abbreviations: EO: eyes closed, EC: eyes open, AP: anteroposterior, ML: mediolateral, SG: stable surface group, UG: unstable surface group.

ordination of movement (internal focus) rather than on the performance goal (external focus), compromising automatic motor control processes [14, 15]. The concept of a shift from less to more attention demanding control strategies is nicely illustrated by the phenomenon of 'reinvestment', where individuals re-invest cognitive effort into aspects of performance that had otherwise become subconscious as they become more anxious on a task [14]. In a static standing task, Huffman et al. showed that young adults would self-report higher fear of falling (FoF) and levels of 'reinvestment' (increased attentional demand) under conditions of high, compared to low postural threat (standing on a fixed position at high or low elevation, respectively) [16]. The fear of falling has a profound and largely detrimental effect on balance performance in older adults, providing that the adoption of stiffening strategies leads to inadequate acquisition of the sensory information necessary to plan and execute dynamic and interactive movements [17]. It was consistently shown that behavioural correlates of FoF are indicative of a conservative 'stiffening strategy', which is a negative postural control strategy. When adopting this stiffening strategy, people reduce the range of motion of their centre of mass by reflexively co-contracting their tibialis anterior, soleus, and gastrocnemius muscles, resulting in lower amplitude and higher frequency postural sway [18, 19]. It is generally accepted, that an internal focus of attention (and probably higher level of reinvestment) is leading to freezing the degrees of freedom in the motor system resulting in stiffening strategy. Moreover, it was shown in young adults as well that the internal focus of attention leads to stiffening behaviours and freezing degrees of freedom [14]. Therefore, we suggest that the cases when the SG subjects were tested on a force plate with foam surface and when we could record significant decrease in postural sway after training might have been signs of an internal focus attention and the adoption of the freezing of DoF strategy, and not just signs of improved balance characterised by shorter sway path, especially keeping in mind that this group was not trained in unstable situation only in stable BoS conditions. This balance strategy recorded as decreased sway path occurred in a more challenging situation (EC, unstable BoS), and in AP direction. AP direction is thought to be controlled by ankle and foot muscles, while in ML direction the hip control plays a more important role according to Nashner's strategy concept [7]. Another possible explanation is that the SG practised the ankle strategy during the training; therefore, we postulate that the only significant decrease in sway path exhibited after the training in case of SG in AP and in the more challenging conditions (EC, foam) may be the result of an improved ankle strategy. During the training, the UG group practised on unstable surface that means bigger disturbances, more hip strategy usage, and utilising the vestibular inputs more, since ML direction is under hip joint control. Although we could observe a decreased sway path exhibited by the UG in ML, with EC, on foam condition, this tendency was not statistically discernible in this pilot.

From this knowledge above we postulated that if the fear of falling is low, one can exhibit and tolerate higher sway by controlling higher degrees of freedom concerning sway movements, but when the postural threat is higher, (in more challenging balance situations) the stiffening strategy and freezing DoF can occur. These shifts between stiffening and freeing degrees of freedom are depending on the actual interaction between the individual, the task, and the environmental situation and are not age specific in postural control.

CONCLUSIONS

We conclude that balance trainings have many beneficial effects on the postural control systems and improve balance confidence. The postural control has a dynamic and adaptive nature, the increase or decrease in sway path is not an absolute determinant how good or bad the function of PC is, especially in case of healthy adults. An increase could be a sign of better confidence, as well as a decrease can indicate better control but also adapting a negative compensation such as freezing the DoF. Therefore, more aspects of PC should be evaluated simultaneously to get a clearer picture.

Trainings on different BoS influence different aspects of postural control and are beneficial in balance, knowing the special effects of different surface trainings; the therapist can choose on purpose which underlying impairment should be targeted in individual cases by which type of interventions.

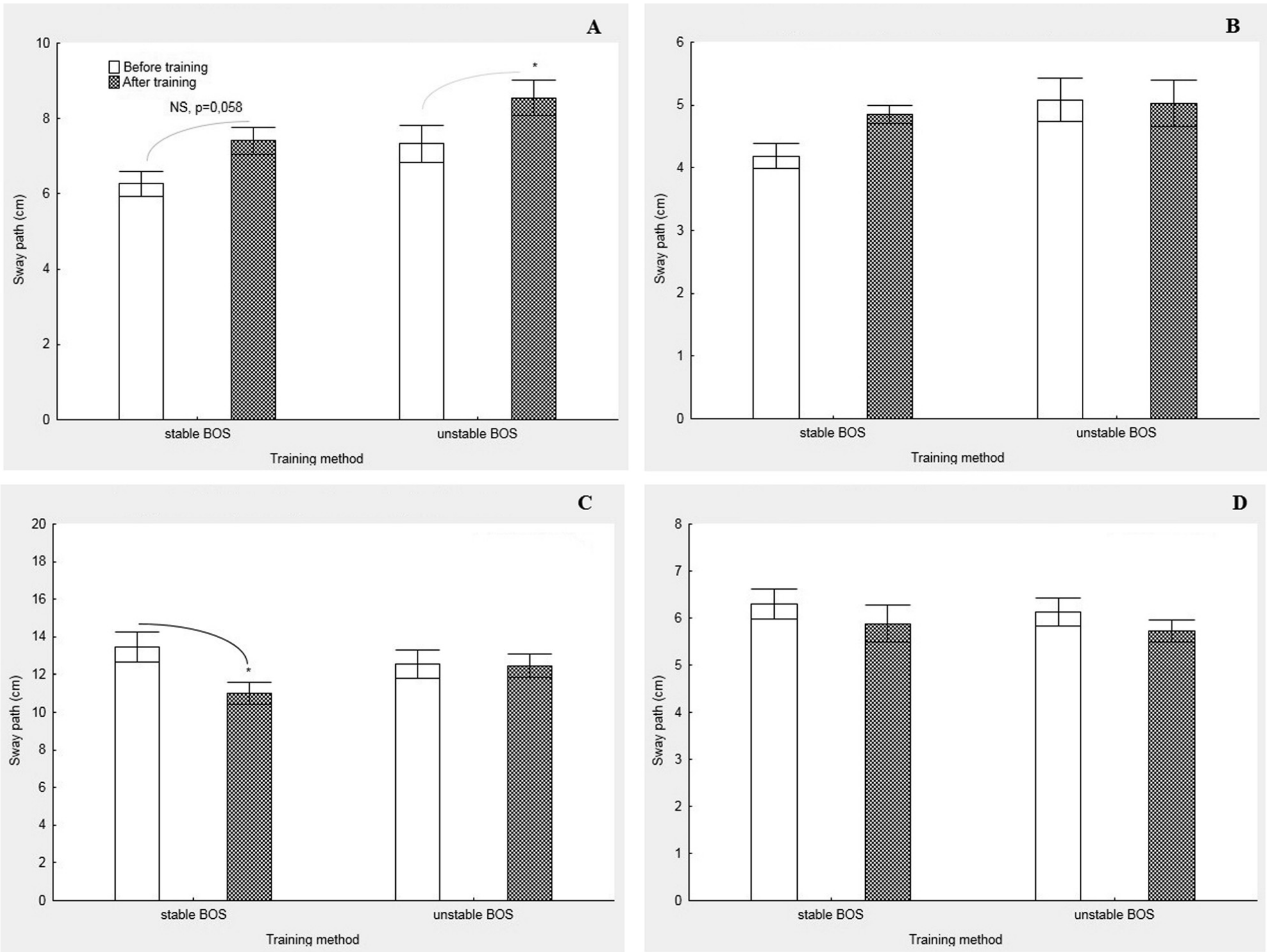

Fig. 2. Sway path data in AP and ML directions, standing on foam surface platform before and after the training with EO (A: in AP direction, B: in ML direction) and EC conditions (C: in AP direction, D: in ML direction).
Note. Asterisks show significant differences ($P < 0.05$). Abbreviations: EO: eyes closed, EC: eyes open, AP: anteroposterior, ML: mediolateral, BOS: base of support

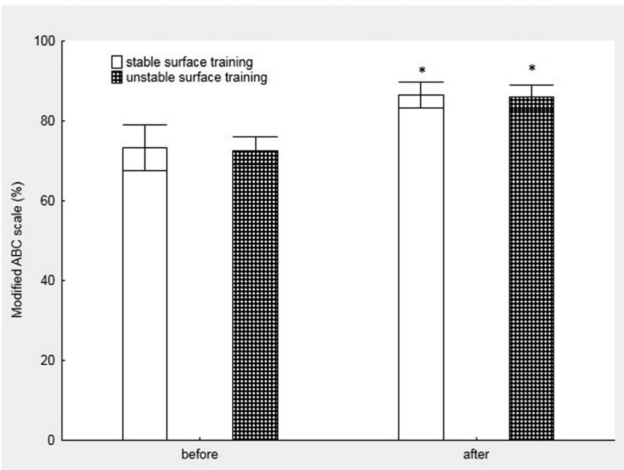

Fig. 3. Modified activities-specific balance confidence scores before and after the two types of balance training.
Note. Asterisks show significant differences ($P < 0.05$). Abbreviations: Modified ABC scale: Modified activities-specific balance confidence scale

Authors' contribution: GP: the conception and design of the study, processing data, drafting the manuscript. DF: training and the acquisition of data; TM: training and the acquisition of data. EN: the conception and design of the study, data analysis drafting and revising the article.

Ethical approval: The study is in compliance with the principles of the Declaration of Helsinki and is approved by National Public Health Center (48590-8/2020/EÜIG).

Conflict of interest/funding: The authors declare no conflict of interest. No financial support was received for this study.

LIST OF ABBREVIATIONS

PC Postural Control
CoM Centre of Mass
CoP Centre of Pressure

BoS	Base of Support
DoF	Degree of Freedom
AP	Antero-Posterior
ML	Medio-Lateral
EO	Eyes Open
EC	Eyes Closed
SG	Stable BoS Group
UG	Unstable BoS Group
CNS	Central Nervous System
ABC	Activity specific Balance Confidence
FoF	Fear of Falling

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