A multi-station proprioceptive exercise program in patients with ankle instability

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ABSTRACT

EILS, E., and D. ROSENBAUM. A multi-station proprioceptive exercise program in patients with ankle instability. *Med. Sci. Sports Exerc.*, Vol. 33, No. 12, 2001, pp. 1991–1998. **Purpose:** The aim of the present study was to investigate the effects of a 6-wk multi-station proprioceptive exercise program that is easy to integrate in normal training programs. **Methods:** Patients with chronic ankle instability were used, and results of three testing procedures before and afterward were compared: joint position sense, postural sway, and muscle reaction times to sudden inversion events on a tilting platform. A total of 30 subjects with 48 unstable feet were evaluated (exercise group: $N = 31$; control group: $N = 17$). **Results:** In the exercise group, the results showed a significant improvement in joint position sense and postural sway as well as significant changes in muscle reaction times. **Conclusion:** Based on the present results, a multi-station proprioceptive exercise program can be recommended for prevention and rehabilitation of recurrent ankle inversion injuries. **Key Words:** ANKLE INSTABILITY, ELECTROMYOGRAPHY, PROPRIOCEPTION, COORDINATION, PERONEAL REACTION TIME

Ankle inversion sprains are frequent injuries in sports and activities of daily living that mostly concern young physically active individuals (1,10). It has been estimated that the incidence is about one ankle inversion per 10,000 people per day (4). Ankle ligament injuries constitute between 15 and 45% of all sports-related injuries and occur in sports with a high level of jumping and cutting activities, especially in ball sports (5,28). Independent of the initial treatment, persistent symptoms or re-injuries remain in 10–30% of individuals (26). Ankle joint instability can be defined as either mechanical or functional instability. Mechanical instability refers to objective measurements of ligament laxity, whereas functional instability is defined as recurrent sprains and/or the feeling of giving way. Causal factors include a proprioceptive deficit, muscular weakness, and/or absent coordination. For rehabilitation after injury or prevention of re-injuries, proprioceptive training has been recommended throughout the literature (6,7,20). The contents of such programs vary, but most of them include some exercises, e.g., on an ankle disk with an exercise frequency of several times per week. There is not much dispute about the actual benefits of such programs, but there is the question of how much it helps and the specific stimulation it generates. It has to be considered that not only strength but also coordination should be addressed in various ways. In addition, there is the question of how to integrate these specific ankle disk procedures of several times per week within a normal training process of a team or group with many participants.

The effects of proprioceptive exercises have been evaluated with test procedures regarding angle reproduction (3,8,13), postural sway (3,7,9,29), or muscle reaction times (12,27). Only a few investigators used more than one test procedure simultaneously, and there is also some controversy about the actual benefit of proprioceptive exercise programs regarding the different testing procedures.

Therefore, the purpose of this project was to investigate the effects of a 6-wk multi-station, low-frequency exercise program that is easy to integrate into normal training routines. The objective parameters were obtained with three different testing procedures for the evaluation of proprioceptive capabilities. Furthermore, it should be shown that such a program addressing strength and coordination in multiple ways but performed only once a week leads to similar results as training on an ankle disk for several times.

METHODS

Subjects. Thirty subjects (18 female, 12 male) with chronic ankle instability participated in the project. Inclusion criteria were repeated ankle inversion sprains and a self-reported subjective feeling of instability or giving way. Talar tilt and anterior drawer sign were not used as an inclusion criterion because of the variability of these parameters across subjects and the reported lack of correlation between mechanical and functional instability (30). Subjects were free of pain at the beginning of the study and were divided into two groups. The exercise group (EG, $N = 20$) participated in a 6-wk physiotherapeutic exercise program; the control group (CG, $N = 10$) only participated in the test procedures before and after the 6-wk period. The anthropometric

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TABLE 1. Anthropometric data of the experimental and the control group.

	Experimental Group		Control Group		
	Mean ± SD	**Range**	**Mean ± SD**	**Range**	***P* Level**
Age (yr)	27.0 ± 7.7	14–47	26.4 ± 4.9	16–34	NS
Weight (kg)	69.6 ± 13.4	50–98	75.7 ± 12.2	64–99	NS
Height (cm)	176.6 ± 10.8	160–198	179.7 ± 9.9	164–194	NS
Sex (m/f)	6/14		6/4		
Sports activity (per week)	5.2 ± 3.1	1–12	4.5 ± 1.5	3–8	NS
Frequency of ankle sprains (per yr)	27.6 ± 26.8	4–104	19.3 ± 18.1	4–52	NS

data revealed no significant differences between the groups (Table 1). Many subjects (55%) revealed a bilateral instability so that 48 feet were evaluated (EG, $N = 31$; CG, $N = 17$). The study was approved by the institution's human ethics committee and before participation, all subjects were informed about the procedures and signed an informed consent form.

Test procedures. The order of the three testing procedures was predetermined to minimize the effects between tests and the effect of fatigue. Joint position sense testing was performed first, followed by balance and reflex testing. Both feet were tested in the week before and after the 6-wk exercise period. The tests were repeated in the same manner. One year after the exercise period, the frequency of inversion sprains was reevaluated with a questionnaire that was sent to all subjects.

Joint position sense (JPS). A custom-built device was used for testing the joint position sense in a passive angle reproduction test. It consisted of a footplate in combination with a Penny & Giles goniometer (Biometrics Ltd, Gwent, UK). Subjects sat in front of the measuring device and placed the foot on the horizontal footplate (Fig. 1). The rotation axis of the ankle was aligned with the medial malleolus. The knee joint was placed over the ankle. This position was defined as the neutral position (0°). Subjects were unable to see their feet throughout the examination and had their eyes closed to concentrate on the measurements. For the passive angle reproduction, the foot was brought into one of the four testing positions (10°, 20° dorsiflexion, 15°, and 30° plantarflexion) and was held for 2 s. Then it was brought back in neutral position and back toward the testing position until the subjects indicated that they felt they had reached the same position. The foot was brought back in neutral position, and the next angle was chosen. Angles were given in random order and each angle was tested six times. All joint position tests were performed by the same investigator. The difference of all predefined and reproduced angles was saved for analysis.

Postural sway (PS). A Kistler force plate was used to measure the postural sway in single-limb stance. No information concerning the posture was given to the subjects except to avoid contact of the legs and to focus on a point on the wall directly ahead (Fig. 2). The individual posture was noted by the investigator, and subjects were informed to use the same style as in the pretest when it deviated in the posttest. For each foot six trials of single-limb stance (15 s each) were performed. For analysis, the sway of the center of gravity (CoG) in the xy-plane in medio-lateral and antero-posterior direction as well as the sway distance were averaged over six trials.

Muscle reaction times (MRT). A customized trap door with a 30° tilting angle in the frontal plane was used to simulate lateral ankle sprains (Fig. 3). Subjects stood upright on the platform with one foot on the hinged trapdoor bearing most of the body weight. The axis of rotation of the trapdoor was just medial of the weight-bearing foot, and the other foot was placed only with the toes in contact to the trapdoor to maintain balance. Surface EMG signals were

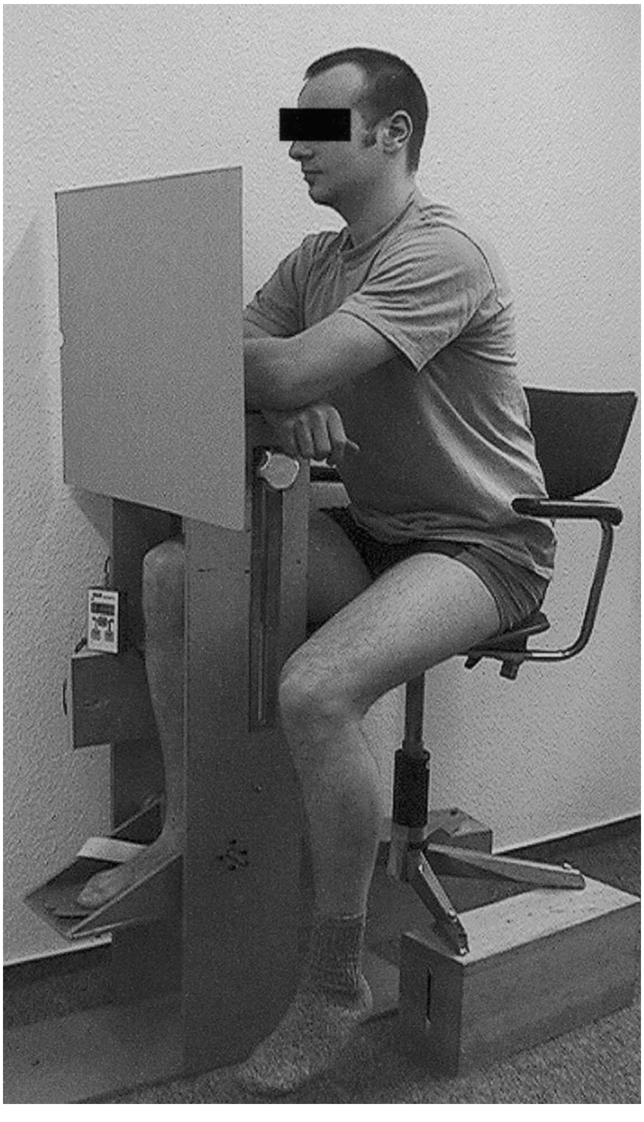

FIGURE 1—Testing of joint position sense.

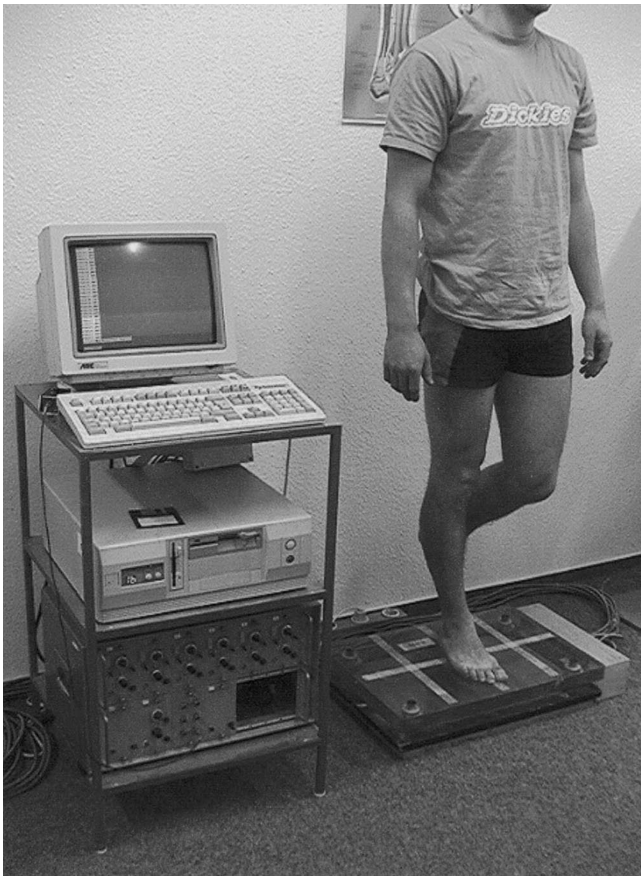

FIGURE 2—Measurement of postural sway in single-limb stance.

FIGURE 3—Measurement of muscle reaction times to simulated sudden ankle inversion (30°).

recorded using bipolar electrodes (Blue sensor (N-50-K), Medicotest GmbH, Andernach, Germany). The skin was prepared with abrasive skin-prepping gel and alcohol to minimized impedance below 10 KΩ. The electrodes were placed 2 cm apart on the muscle bellies of the tibialis anterior, peroneus longus, and peroneus brevis as follows: tibialis anterior approximately 8 cm below tuberositas tibiae and 3 cm lateral of the tibia edge; peroneus longus approximately 8 cm below the head of the fibula close to the connecting line of head of the fibula and the lateral malleolus; and peroneus brevis 5 cm above the lateral malleolus just posterior to the tendon of peroneus longus. All electrode placements were performed by the same investigator, and the correct placements were checked by manual tests and voluntary contractions. The reference electrode was placed over the distal tibia.

The platform was released mechanically when only baseline EMG activity was observed. Each subject underwent at least 10 successful trials. The raw EMG signal was A/D converted and sampled with 1000-Hz and 12-bit resolution, filtered (bandpass 10–1000 Hz), and rectified. EMG onsets were determined manually for each trial when the EMG response showed a steep increase that was higher than maximal baseline noise and followed by enduring activity. The time from the moment of ankle inversion to the first EMG response was defined as the muscle reaction time (MRT) or muscle onset time (Fig. 4). The data for the pre- and posttest of each subject were analyzed simultaneously to take into account individual EMG characteristics. MRT out of 10 trials for each muscle were averaged for analysis. Integrated EMG (IEMG) was evaluated for the first 60 ms after reaction times for different muscles.

For statistical analysis, the nonparametric Mann-Whitney *U*-test and the nonparametric Wilcoxon test were used to determine the differences between the two groups and between pre- and posttests of all 48 chronically unstable feet, respectively. Statistical level of significance was set at $P < 0.05$ (StatView 5.0).

Training procedures. The physiotherapeutic program consisted of 12 different exercises (Fig. 5; manufacturer specifications are given in Table 2): exercise mats (Airex®, Gaugler & Lutz oHG, Aalen-Ebnat, Germany), swinging platform (Posturomed®, Haider Bioswing, Pullenreuth, Germany), ankle disk, Pedalo® (Holz-Hortz GmbH, Muensingen, Germany), exercise bands (Thera-Band®, Hadamar, Germany), air squab, wooden inversion-eversion boards (customized), mini trampoline, aerobic step (BodyBench®, Megasport Vertriebs GmbH, Schwetzingen, Germany), uneven walkway (customized), swinging and hanging platform (Haramed®, Original Norsk-MPTT, Erfstadt-Lechenich), Biodex® (Shirley, NY). Most of these devices are of low cost and widely available except for Posturomed®,

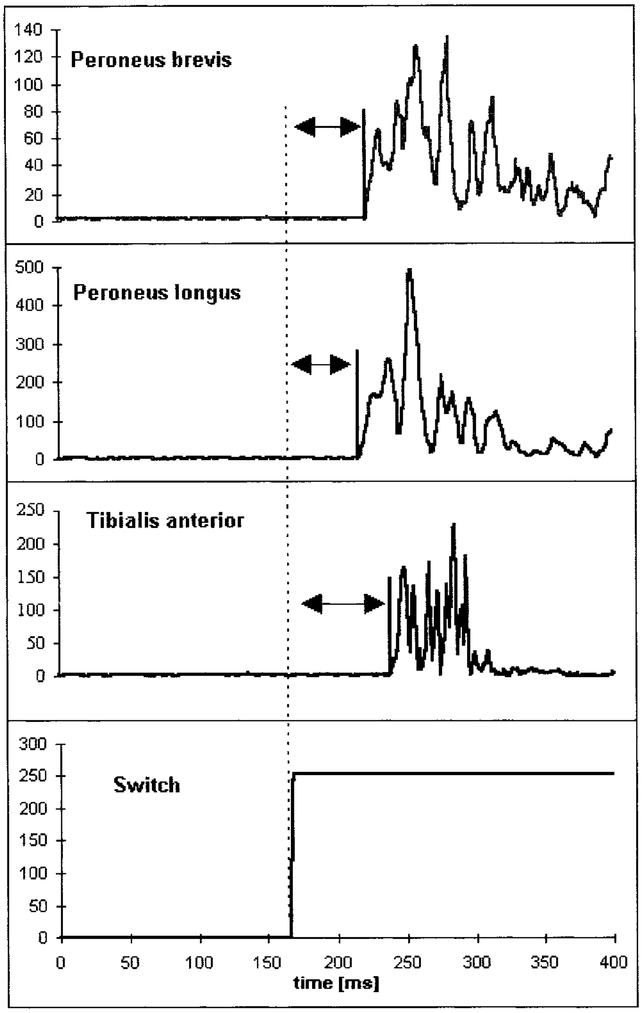

FIGURE 4—Definition of reaction times to simulated sudden ankle inversion for peroneal muscles and tibialis anterior. The *dotted line* indicates the beginning of the tilting movement and the *double arrow* the reaction time for each muscle.

Haramed®, and Biodex®. Alternatively, devices with a comparable stimulation mode can be used.

Subjects started each exercise period with a 5- to 10-min warm-up program. The exercise period took 20 min, and single exercises were performed for 45 s followed by a 30-s break where subjects moved over to the next station. The whole program was performed twice to exercise both feet in the same way. In the first session, the correct posture of the lower leg of the subjects was controlled (slight external rotation of the foot, slightly flexed knee, and the patella over the metatarsophalangeal joint) during the exercise. The intensity of the 6-wk training period was increased by small modifications for each station every 2 wk (Table 2). The main goal of this program was to generate a wide variation of different stimuli for strength and coordination. In addition, many stations were set up to have the possibility to train many persons simultaneously to easily include this program in normal training programs of teams of athletes or groups of patients. A more detailed description of the exercise program is given elsewhere (25).

RESULTS

In the angle reproduction test, an improvement for all testing conditions in the exercise group was found after the exercise period (Table 3). Except for 10° dorsiflexion ($P = 0.057$), all improvements were significant. The greatest changes were seen at 15° and 30° plantarflexion and for the mean of the four testing positions. The control group showed only slightly improved values, but none of the differences were significant.

In the postural sway measurements, an improvement after the exercise program was found for all parameters in the experimental group as well as for the control group (Table 4). Sway in the medio-lateral direction was smaller than in the antero-posterior direction for both groups. In the medio-lateral direction, the standard deviation and the maximum sway showed a significant improvement in the exercise group but not in the control group. In the antero-posterior direction, significant improvements were not found in the experimental group but in the control group ($P < 0.05$). The overall sway distance of the center of gravity (CoG) was reduced in both the exercise ($P < 0.01$) and the control group ($P < 0.01$).

Muscle reaction times were in the range of 62–74 ms and were prolonged between pre- and posttest in both groups for all muscles (Table 5). For peroneus longus and peroneus brevis, the difference of approximately 3 ms was significant ($P < 0.001$). No significant differences could be detected for tibialis anterior and for all muscles in the control group.

IEMG showed not consistent results in both groups. In the experimental group, there was a slightly increased muscular response in the peroneal muscles and a slight decrease for the tibialis anterior. In the control group, peroneus longus and tibialis anterior activity increased, whereas peroneus brevis decreased. None of these changes were significant (Table 5).

A total of 90% of the subjects of the exercise group returned the questionnaire 1 yr after training. Evaluation showed a significantly reduced frequency of ankle inversions after the exercise program of almost 60% (from 27.6 to 11.2 times per year, $P < 0.001$). No patient reported an increased frequency of ankle sprains and most subjects reported a better feeling of stability and safety. A total of 10% of the subjects reported to perform proprioceptive exercises at home and did not report any ankle sprains after the exercise program.

DISCUSSION

The aim of the present study was to investigate the effects of a multi-station proprioceptive exercise program obtained with three different testing procedures. We expected that this program would lead to an improvement of proprioceptive capabilities in the exercise group and therefore to improved functional stability and a decrease in the frequency of recurrent ankle sprains.

Based on the positive subjective results of reduced frequency of ankle sprains and a better feeling of stability after the

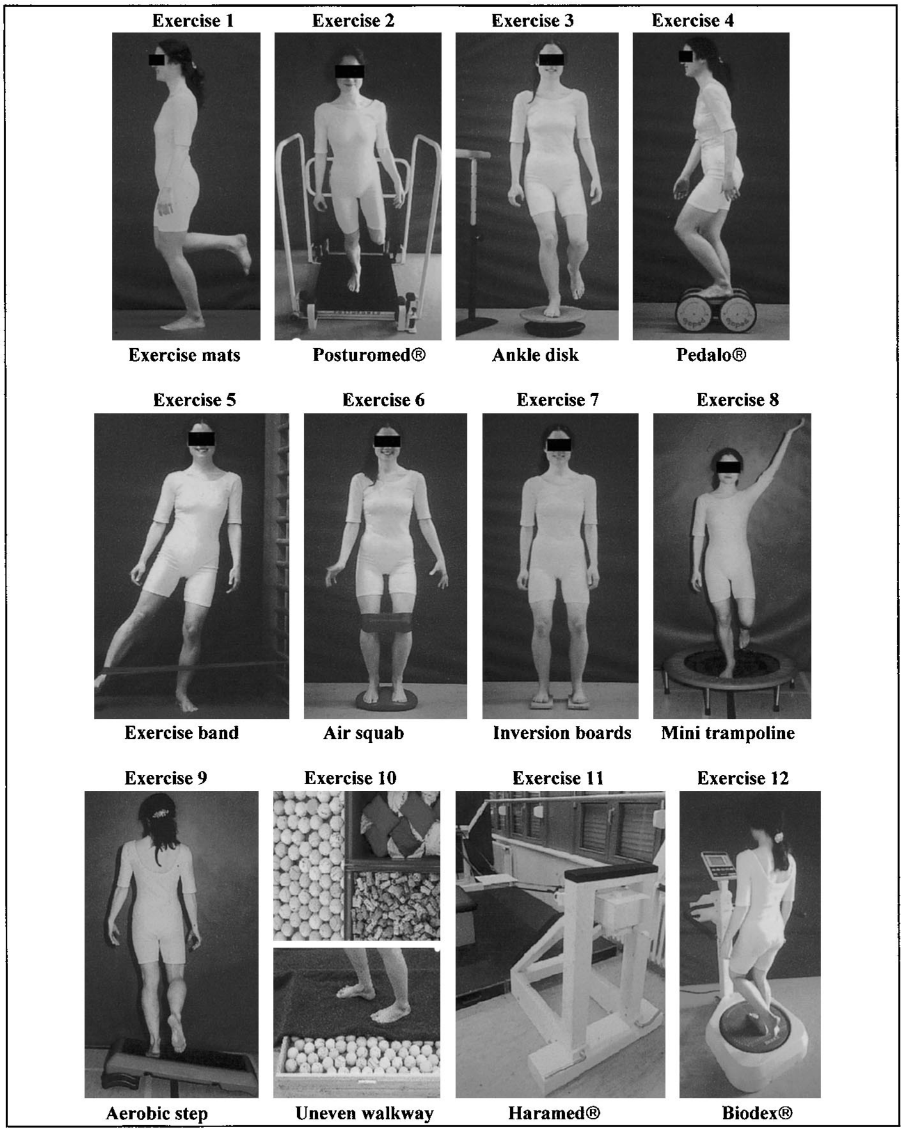

FIGURE 5—The different stations of the proprioceptive exercise program.

exercise period, a proprioceptive multi-station exercise program may be recommended. In addition to these facts, the evaluation of the objective test procedures is of special interest.

Joint position sense. In the present investigation, significant improvements for most testing positions in the experimental group after the training period and none in the control group were found. Most pronounced improvements for angle reproduction were found at 15° and 30° of plantarflexion. This is in accordance with the results of Glencross and Thornton (8). They compared injured and noninjured legs in 24 subjects using an active angle reproduction test and found an increased error on the injured side. Differences between injured and noninjured side became greater as plantarflexion was increased.

Plantarflexion is an important component of the combined movement of supination, and an increased ability to detect the angle of the ankle joint in plantarflexion especially may help the athlete in some circumstances to prevent recurrent injuries.

For evaluation of the joint position sense of the ankle, an angle reproduction test was used in previous studies. Jerosch et al. (13) applied an active test design to distinguish between healthy and unstable subjects. They reported a significantly better joint position sense for inversion in the healthy group compared with the unstable group. Bernier and Perrin (3) measured the active and passive joint position sense for inversion and eversion before and after a 6-wk exercise program. They found no significant improvements after the exercise program in passive and active angle reproduction. For the calculation of mean angles, they only used two trials per subject and that is probably not enough to obtain a representative mean of each subject.

However, it appears that the angle reproduction test is suited to distinguish between healthy and unstable patients, between injured and noninjured legs, and to measure an effect of a proprioceptive exercise program in chronically unstable patients.

In conclusion, the present results indicate that joint position sense for plantar-dorsiflexion improved significantly over a period of 6 wk by a multi-station exercise program.

TABLE 2. Description and modifications of the exercise program.

No.	Stations	Description	Modifications
1	Exercise mats (Airex ®) (Gaugler&Lutz oHG, Aalen-Ebnat, GER)	Single-limb stance on different surfaces	Standing on carpet, exercise mats with different thickness
2	Posturomed ® (Haider Bioswing, Pullenreuth, GER)	Maintain balance in single-limb stance on a mobile platform	Decrease resistance to increase movement of the platform
3	Ankle disk (Hasi GmbH, Munich, GER)	Maintain balance in single-limb stance on an ankle disk	Decrease number of pads under the ankle disk to increase movements of the ankle disk
4	Pedalo ® (Holz-Hortz GmbH, Muensingen, GER)	Movement in different directions	Forward, backward and combined cycling on the Pedalo-device
5	Exercise band (Thera-Band ®) (Thera-Band GmbH, Hadamar, GER)	Maintain balance in single-limb stance with abduction of the contralateral leg against resistance of an exercise band	Standing on carpet, exercise mats with different thickness
6	Air squab (Sissel ®) (Jela GmbH, Bad Duerkheim, GER)	Maintain balance in double- and single-limb stance on an air squab	Double and single-limb stance with and without knee abduction against exercise band
7	Wooden inversion-eversion boards (customized)	Maintain balance in double- and single-limb stance on inversion-eversion boards	Double- and single-limb stance with additional knee flexion-extension and arm movement
8	Mini trampoline (Trimilin ®) (Trimilin ltd, West Sussex, UK)	Maintain balance in single-limb stance on a mini trampoline	Single-limb stance with and without arm movement
9	Aerobic step (BodyBench ®) (Megasport Vertriebs GmbH, Schwetzingen, GER)	Maintain balance with the forefoot on an aerobic step	Single-limb stance with only the forefoot in contact with the aerobic step; plantar-dorsiflexion on level and inclined steps
10	Uneven walkway (customized)	Experience different surfaces in walking	Walking on cork, tennis balls, and sandbags
11	Haramed ® (Original Norsk-MPTT, Erftstadt-Lechenich, GER)	Maintain balance on a horizontally and vertically mobile platform	Double- and single-limb with an additional reduction of the supporting area
12	Biodex ® Balance System (Biodex Medical Systems, Inc, New York, US)	Maintain balance on a computer controlled moveable platform	Increase tilting movement of supporting surface

Postural sway. The assessment of postural sway in single-limb stance with open eyes on a force plate is a well-established procedure used in the literature. In the present study, an improvement in all parameters for postural sway was found and that is in accordance to the results of Hoffmann and Payne (9), Tropp and Askling (29), and Gauffin et al. (7). They all showed that postural sway in medio-lateral as well as in antero-posterior direction was significantly reduced after an 8 or 10-wk exercise program on an ankle disk with a training frequency of 3–5 times per week. A reduction of sway in antero-posterior direction was also found in the present investigation, but this was not significant. Furthermore, the reduction of sway of the control group was significant in that direction. It appears that the control group who only participated in the pre- and posttest decreased postural sway in single-limb stance more effectively in antero-posterior direction, whereas subjects of the exercise group reduced sway more effectively in the medio-lateral direction. The movement in latter direction is mainly controlled in the subtalar joint, whereas the movement in antero-posterior direction is more regulated in the tibiotalar joint. From that point of view, the results may be interpreted as short-term adaptation by a learning process in the control group and long-term adaptation as a result of the exercise program. During the exercises, the position of a slight external rotation of the foot, slightly flexed knee, and the patella over the metatarsophalangeal joint in single-limb stance was controlled to force subjects to regulate sway mainly in the subtalar joint. This regulation and correction of posture was not given to the subjects in the control group. Bernier and Perrin (3) also reported the influence of a learning effect in their results. However, the posture correction in the present investigation is not reported in the studies mentioned above and is therefore a possible reason for the slightly different results in antero-posterior direction between the studies. In addition, the specific training on the ankle disk probably generates a different stimulation than a complex multistation program once a week.

TABLE 3. Errors and deviations in the joint position test from predetermined angles.

	Exercise Group			Control Group		
	Pretest	Posttest		Pretest	Posttest	
Degrees of Error [°]	Mean ± SD	Mean ± SD	*P* Level	Mean ± SD	Mean ± SD	*P* Level
10° dorsiflexion	1.6 ± 0.7	1.3 ± 0.6	NS	1.4 ± 0.6	1.3 ± 0.6	NS
20° dorsiflexion	1.7 ± 0.9	1.2 ± 0.4	<0.05	1.2 ± 0.6	1.3 ± 0.4	NS
15° plantarflexion	2.3 ± 1.1	1.5 ± 0.6	<0.01	1.5 ± 0.6	1.4 ± 0.5	NS
30° plantarflexion	2.5 ± 0.9	1.8 ± 0.7	<0.01	2.0 ± 0.9	1.5 ± 0.8	NS
Mean error	2.0 ± 0.6	1.5 ± 0.4	<0.01	1.5 ± 0.5	1.4 ± 0.3	NS

TABLE 4. Means and deviations for parameters of postural sway.

	Exercise Group			Control Group		
	Pretest	Posttest		Pretest	Posttest	
Postural Sway [mm]	Mean ± SD	Mean ± SD	*P* Level	Mean ± SD	Mean ± SD	*P* Level
Standard deviation medio-lateral	4.5 ± 0.8	4.3 ± 0.7	<0.05	4.5 ± 0.9	4.4 ± 1.1	NS
Standard deviation antero-posterior	6.5 ± 1.5	6.1 ± 1.5	NS	6.6 ± 1.8	5.9 ± 1.6	<0.05
Maximum sway medio-lateral	22.3 ± 4.8	20.4 ± 2.8	<0.01	21.6 ± 4.1	20.7 ± 4.1	NS
Maximum sway antero-posterior	30.5 ± 7.2	28.4 ± 6.2	NS	30.3 ± 7.9	27.8 ± 7.8	<0.05
Total sway distance	483.5 ± 111.0	438.8 ± 103.0	<0.01	446.6 ± 68.3	406.2 ± 77.2	<0.01

The significant reduction of the overall sway distance is due to the fact that this parameter combines the sway in medio-lateral and in antero-posterior direction and also reflects the influence of the observed learning effect. Therefore, it is recommended that an additional test before the pretest should be performed to minimize habituation effects.

In conclusion, the results of the analysis of postural sway show that the multi-exercise program has a positive but slightly different effect on proprioception compared with training on an ankle disk.

Muscle reaction times. The measurement of peroneal reaction times to sudden inversion is a widely used procedure for the assessment of proprioceptive capabilities (2,12,14–19,21,22,24,27). In comparison between healthy and chronically unstable patients, a significantly prolonged reaction time of peroneus longus for the unstable group was reported (12,15,16,21,24). On the other hand, Johnson and Johnson (14) as well as Isakov et al. (11) did not find significant differences between these two groups. It is also reported that peroneal reaction time is dependent on different factors like amount of plantarflexion or posture (2,18,23).

No effect on peroneal reaction times was reported from Sheth et al. (27) in healthy subjects after an 8-wk training program on an ankle disk, whereas Javed et al. found a significantly reduced reaction time in chronically unstable patients after a 6-wk exercise program on a wobble board (12). However, the authors did not report anything about duration, intensity, and frequency of the training program, and it has to be considered that a decrease in reaction times is also dependent on the results in the pretest. Prolonged reaction times in the pretest probably lead to a decrease in the posttest. Javed et al. (12) reported a mean reaction time of peroneus longus in the posttest of 63 ms, which is close to the values of the pretest in the present investigation.

The mean reaction times in the present study for peroneus longus, peroneus brevis, and tibialis anterior after simulated sudden ankle inversion are in accordance with the results of other studies (2,12,21). The longer reaction time of tibialis anterior as compared with peroneal muscles is due to the fact that the tibialis anterior is not directly involved in the inversion movement.

The comparison of reaction times between pre- and posttraining showed a significant prolongation in the experimental group of 3 ms for peroneus longus and brevis but not in the control group. These prolonged reaction times for peroneal muscles also reflect the specific stimulation of the multi-station exercise program when including the reaction times of tibialis anterior. A shorter reaction time for peroneus longus and brevis after an intensive exercise program on an ankle disk probably describes one strategy of neuromuscular response to very specific training stimulation. However, other strategies to prevent from recurrent injuries are also possible: e.g., a more synchronized reaction of peroneus longus and tibialis anterior in stabilizing the ankle joint after sudden inversion. We found a decrease in time between these two muscles in 65% of all cases, and although this difference is statistically not significant, it underlines the improvement of coordination.

Differences between pre- and posttests for the IEMG were small and not significant for all muscles, i.e., the training program probably did not increase muscular strength directly after sudden inversion. This fact also reflects that the specific stimuli of the training program not only address muscular strength but also coordination.

In conclusion, the evaluation of EMG showed that the multi-station exercise program has a significant influence on proprioceptive capabilities resulting in a more synchronized reaction of peroneus longus and tibialis anterior to sudden inversions.

CONCLUSION

The multi-station proprioceptive exercise program led to significant improvements of proprioceptive capabili-

TABLE 5. Muscle reaction times and IEMG of peroneus longus, peroneus brevis, and tibialis anterior after sudden ankle inversion.

	Exercise Group			Control Group		
	Pretest	Posttest		Pretest	Posttest	
Muscle Reaction	Mean ± SD	Mean ± SD	*P* Level	Mean ± SD	Mean ± SD	*P* Level
Reaction time peroneus longus (ms)	61.6 ± 6.5	64.8 ± 6.2	<0.001	64.9 ± 6.5	65.4 ± 5.4	NS
Reaction time peroneus brevis (ms)	66.9 ± 6.8	70.4 ± 6.0	<0.001	70.4 ± 4.2	72.6 ± 3.4	NS
Reaction time tibialis anterior (ms)	70.2 ± 8.0	72.6 ± 6.7	NS	71.1 ± 9.9	74.6 ± 5.5	NS
IEMG peroneus longus (μV·s)	11.6 ± 5.1	13.0 ± 5.2	NS	10.4 ± 3.9	11.6 ± 4.7	NS
IEMG peroneus brevis (μV·s)	7.2 ± 2.9	7.5 ± 4.1	NS	8.9 ± 2.7	8.4 ± 2.5	NS
IEMG tibialis anterior (μV·s)	5.2 ± 3.5	4.8 ± 3.5	NS	5.1 ± 2.8	5.6 ± 3.4	NS

ties in chronically unstable patients. The main advantage compared with other programs is the relatively low training frequency of once per week, the possibility to perform this training in a bigger group, and to include it in normal training procedures. The evaluation of objective parameters and the subjective feedback of the patients allows the recommendation of such a proprioceptive exercise program in the treatment of recurrent inversion injuries.

This newly developed exercise program appears applicable also for untrained or older patient populations. In this context, it has to be considered that some exercises for strength have to be modified to take into account reduced physical fitness in the elderly or in untrained patients.

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